Matthew Lombard · Frank Biocca
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Rachel J. Schaevitz *Editors*

Immersed in Media

Telepresence Theory, Measurement & Technology

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Chapter 1
Lighting a Path While Immersed in Presence: A Wayward Introduction

Frank Biocca

Abstract The sense of presence in simulated environments, be it fragile and fleeting or sometimes deep and traumatizing, is the construct used to describe, measure, and sometimes evaluate and design and optimize systems that provide that ability. We spend more and more time in simulated realities provided by the systems that occupy our walls as screens or projections, fill our hands with messages from other places, or increasingly attach to our bodies and senses augmenting our physical reality with virtual objects, places, and beings.

Within the work on presence there is an interdisciplinary community of researchers, who bring different theoretical and methodological approaches to the study of presence. The community of presence researchers include: psychology, philosophy, medicine, engineering, communication, and various other areas.

This book represents some of the work from experienced researchers on presence with a weight on definitional and psychological issues and less on the engineering and technical aspects of specific interfaces.

Keywords Media technologies • Simulation • Sense • Reality systems • Presence

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1.1 Introduction

Media technologies are simulators for the mind. They are Plato's cave, casting shadows of things outside by pressing on our senses and firing up our imagination for the forms out of reach. In this press of imagery our bodies have the illusion of being transported to place beyond the cave, a sense of things and others just outside our reach. But we might feel as if we can see, hear, and touch them.

Sometimes the sense of presence is faint, like the sense of hearing the voice of friend when reading their text. Sometime the illusion is intense vivid as when we are being chased by some predator on some virtual savanna or human battleground.

The simulations may work because our minds automatically simulate places and other beings in the process of perceiving and modeling the space. To paraphrase the perceptual psychologist Richard Gregory, "Virtual reality seems so real, because reality is so virtual." We conjure (distal attribution) spaces and things based on patterns of energy that press on our senses (Loomis 1992). We understand the emotions and intentions of other people by simulating them with our own bodies, activating the same neurons we use to act and be. All media, Marshall McLuhan long ago reminded us, are extensions of our bodies, most of our senses. Through them our bodies adapt and extend their range, neurons magically adapt and respond to touches on the end of stick extending our hands beyond our bodies, even when it is our virtual hands on a computer screen (Maravita and Iriki 2004; Shokur et al. 2013). In a phrase we are capable of feeling present in a space other the one we are in. We feel present and respond emotionally to virtual others in computer game, pixelated faces on teleconferencing systems, humanoid forms in a computer, or an empty spirit inhabiting a robot shell. Spaces and beings appear present and available to us to act. We are inside. We feel present in the environment.

The sense of presence in simulated environments, be it fragile and fleeting or sometimes deep and traumatizing, is the construct used to describe, measure, and sometimes evaluate and design and optimize systems that provide that ability. We spend more and more time in simulated realities provided by the systems that occupy our walls as screens or projections, fill our hands with messages from other places, or increasing attach to our bodies and senses augmenting our physical reality with virtual objects, places, and beings.

I encountered the concept of presence while doing research on virtual reality systems (Biocca 1992a, b), body tracking systems (Meyer et al. 1992), and simulation sickness (Biocca 1992c) with colleagues at NASA. As a student of Marshall McLuhan, it struck me that the concept presence attempted to describe a fundamental property of media, how we use and experience media, and how the psychological process is independent of the technology used to achieve presence. The very word "tele" in tele-vision, tele-phone, had in its root the idea of transporting the senses to a different place. In its incarnation within tele-operation and tele-robotics, that a focus on tele-presence came again to the foregrounded and a journal bearing the destination of Presence (Held and Durlach 1992).

As an editor contributing several articles already to a special issue of virtual reality, I convinced Jonathan Steuer at a San Francisco coffee shop, then an open-minded, young researcher at Stanford to describe and array media in terms of presence, in an article now cited thousands of times (Steuer 1992, 1995). I dug into the topic treating it in a psychological version in my own work on embodiment and presence immersive systems (Biocca 1997).

The path to presence has continued. This book before you and most of the articles were partly stimulated by a generous program within the European Union, Future and Emerging Technologies. Whereby a €20 million initiative sought explore presence, to understand how it works psychologically, and to design better presence interfaces to stimulate the construction of virtual environments. The articles in this book were recruited by three of the editors (Biocca, Freeman, IJsselsteijn) under the umbrella of a project called OmniPres, a title suggesting a certain omniscience, if not omnipresence.

Some of the work related from several projects remains in this book, others were scattered elsewhere. Matt Lombard, a tireless supporter, researcher, and organizer of presence research, helped the distracted and, therefore, not omniscient, original editors to finally bring these fine articles to press in this form.

The book represents some of the work from experienced researchers on presence with a weight on definitional and psychological issues and less on the engineering and technical aspects of specific interfaces.

1.2 Telepresence: Defining and Operationalizing a Construct

As one of the articles reminds us, the sensation of being present in a virtual environment is not synonymous with consciousness, but like consciousness it is a global percept cohering from engagement and action of the sensorimotor system with stimuli, motor action, or intention. Presence has from the beginning seen as multidimensional (Biocca 1997; Heeter 1992; Held and Durlach 1992) dealing with a broad, integrated nature of spatial experience of virtual environments and of social experience (social presence) of other apparently intelligent entities mediated humans or agents. Because it deals with a broad, sweeping aspect of experience, there is an issue with specifying conceptually and operationally what psychologically defines presence experience, how the experience can be validated and measured, and how technological form and content can be designed or engineered to increase the sense of presence. Within the work on presence there is an interdisciplinary community of researchers, who bring different theoretical and methodological approaches to the study of presence. The community of presence researchers include: psychology, philosophy, medicine, engineering, communication, and various other areas.

Several articles in this book deal specifying with the construct, how it can be refined or extended, and how it might be used effectively in empirical and design oriented research.

In Chap. 2 the Lombard and Jones' review wades into and organizes the diverse literature that has evolved over the definition of the broad construct of presence. They lay out the key cleavage points on which the broad construct divided or slightly shifts. The end with very practical recommendations the help cleave to practical structures identifying the exact locus of definitions along several fault points: presence or telepresence, objective or subjective presence, spatial or social presence; remote, virtual, or medium telepresence; mediated or unmediated; real/imaginary and realistic/unrealistic.

In Chap. 3 Waterworth and colleagues seek to integrate presence within a larger setting of "conscious mental life." The goal is to connect up the presence experience to the larger continuum of a sense of presence in the world linking this to evolutionary perspectives and to work of Damasio (1994) on consciousness.

The article provides some conceptual support for limiting the scope of presence experiences. Presence experiences have been structured to give primacy to the experience of the physical environment and to delimit the experience of internal mental imagery. For Waterworth and colleagues presence is a perceptual phenomenon that can be enhanced by reflection and by links to personal history and goals (extended presence, "self-presence" in other areas). Following Damasio, they introduce related concepts of proto-presence, core presence, and extended presence dealing with different levels of engagement with perception and the reflective self.

Presence for Waterworth and colleagues is largely influenced by perceptions not by internal imagery. Presence is presence with a stimulus, not imagination. Retreat into mental imagery [the "third pole" for Biocca (Biocca, May 2003)] is absence. In this way the cut the knot of the "book problem" by declaring imagery based absorption as "absence" from the perceptual world, and less primal and present that action and engagement with perceptual works be they real or virtual. "Presence is what it feels like to be embodied and consciously attending to an external, perceptible." Absence is preoccupation with internal world. We cannot share imaginal worlds and the normal brain does not confuse the imaginal world with the world of perceptual action. This has implication on how to measure presence and for therapeutic applications.

In Chap. 4 Turner and colleague wade into the discussion of presence conceptualizing attempting to bridge some psychological and philosophical aspects. For Turner the sense of presence is in part based on the primacy of affective response to stimuli, mediated or otherwise. The affective response is immediate and directed towards quickly modelling corporeal response. In some ways Gibsonian focus (Gibson, 1966, 1979) on the link perception and action is tied to research and philosophy on in which emotions and immediate possibilities for action cohere around environments (spatial presence) and agents in these environments (social presence).

In Chap. 5 Riva and colleagues position their perspective on presence in psychological and neuroscientific terms. The see presence as a mechanism related to evolutionary processes. The resulting argument and theoretical frame is multilayered and cannot be readily summarized here.

The sense of presence emerges from basic psychological processes related to the process of embodiment. Presence is related to the body and emerges out of the embodiment process. In mediated environment a second-order mediation of the interface becomes the center of action. Riva and colleagues also focus on enabled action in the environment viewed from the different levels of proto, core, and extended presence (see Chap. 2). Presence is related to human action and its organization directed with intention to the environment. They argue based on neuro-scientific evidence that action and perception are fundamentally linked. Motor functions (motor neurons) not only control action and also represent the action. The link between perception and action, especially at the lower sensorimotor levels helps enable a sense of presence with mediated tools and environment. Intention is a property of all mental states, directed at some state of affordances in the world. Differentiating different forms of intention they argue presence provides feedback as the status of actions and goals, based on perceptions of one's actions upon the environment. Higher quality of presence is achieved through the quality of intention, action, and experience. Media that support lower sensorimotor levels activity help induce optimal presence. Activity theory shows that action is linked to physical and social tools. Cognition, including presence, occurs in specific environment with specific end. Therefore presence is causal emergence of a user engaged with the physical world and social environment.

Riva and colleagues also discuss social presence in this content. Motor intention models others actions, whereby we infer the mental state of the other. Social presence results from prediction of other's actions and intentions. Sensorimotor integration "…establish a direct link between one's being and other beings, in that both are mapped in a neutral fashion: the observer uses her/his own resources to directly experience the world of the other by means of an unconscious process of motor resonance." Recommendations for design are made which focus on the specificity of support for actions at the different levels of presence.

In Chap. 6 Gamberini and colleagues use activity theory to take an action theoretic approach to presence experiences. They see presence as part of the hybrid connection between a user, a tool, and a set of enabled actions within a system. They focus on the constructs of space/place, action, and mediation to characterize behaviors that are shaped by the tool and the spatial context.

Using a more behavioral and descriptive approach, they seek to describe and document actions and only to lesser degree psychological processes. In this way they claim to describe presence in digital and non-digital environments through behaviors, using driving a car or motorcycle as an example action-place-tool framework. Through this approach they may make the construct independent of the psychological state of the user.

In Chap. 7 Hartman and colleagues focus on spatial presence and very much on the spatial element of the experience and perception of physical location. They examine spatial presence as a psychological construct, common among different media, and one that provides for a potential interaction of medium and user.

Hartman et al. link spatial presence to empirical studies of presence, showing that components of the experience. Spatial situation model is created and in second level support the primary egocentric reference frame which places the user in relation to objects and the environment. They also look into attention to the stimulus, its role that is critical for the onset and sustaining presence. Sensory components, vividness, and presence are analyzed. They review issues of whether presence is binary or continuous, the role of attention, and the implications for measurement.

1.3 Telepresence: Research and Design

Research on presence has focused on how media form or content influence presence or how presence affects human performance in mediated environments. This section of the book covers some of this research; some of the threads also extend into the following section on applications.

Building on previous reviews of measures and methods, Chap. 8 by Laarni and colleagues provides a thorough review of the different ways in which the construct of presence has been measured. As presence deals often with unconscious, global judgments of the location of the actors' perceived location, spatial location relative to objects and intelligent others, it is widely accepted that there are several dimensions to the sense of presence. Laarni and colleagues detail the various subjective and so- called objective measures of presence that try to assess the contract as whole or its sub dimensions.

They detail various ways to capture the judgments of spatial location, perceived realism, and potential actions typically mined in retrospective self-report. They also review various ways in which interactants reveal that they are present with shifts in their natural behaviors (behavioral indicators) or by behavioral probes such as secondary-reaction time. As the sense of presence is a continuous process some have also sought to measure shifts in presence, sense of space, and ones location within a space via continuous measures such as physiological indicators that may correlate with onset or intensity of presence.

In Chap. 9 Smyth and colleagues address and very specific attempt to design a telepresence experience of particular places via image based rendering technology. How can the interactive experience of place be as realistic as possible? In this HCI design oriented chapter they look at how observations and measures play a role in the design of telepresence within place reproducing environments. They focus on embodiment in a very particular "somewhere."

They support the design with the use of place probes to capture users' experience of particular places to assess how well the qualities of the physical spaces could be reproduced in the virtual place in all its specificity. The design process included different "patterns" for spatial characteristics, technology, meaning, affect, and others. In this way they sought high levels of presence by successful mapping real experience to virtual experience hopefully rendering the mediating technology more transparent.

Presence research often explores the effect of stimuli on visual displacement towards the represented environment and away from the physical environment. This is accompanied by sense of genuine physical displacement. In Chap. 10 Riecke and Schult-Pelkum integrate the well-studied phenomena of "vection" in the context of emerging presence.

Explored for more than 100 years, the experience of vection is the illusion that one's body is moving when one is stationary, something that can be induced by purely abstract moving visual field such as rotating stripes or even acoustic stimuli. This process is automatic and widely exploited in simulators and virtual environments to create the illusion of self-motion. Riecke show that this phenomenon is related to physical or spatial presence. Like presence it is influence by visual technical features such as field of view and perceptual realism (spatial frequency) and multimodal consistency.

Reicke and Schult-Pelkum provide evidence of very strong relationship between vection effects and self-report measures of spatial presence. They also provide evidence that spatial presence may be related to successful training and learning in virtual environments.

1.4 Telepresence: Applications

While presence issues may be related to psychological states, ultimately the study of presence is motivated and directed to understanding and extending mediated telepresence experiences.

In Chap. 11 Steed and Schroeder focus on collaborative virtual environments, specifically how social, 3D, and largely immersive technologies can be characterized by spatial extent that is shared and different degrees of user modelling. Both dimensions of an interface or environment can be seen as supporting different levels of other awareness and coordinated action, termed co-presence. The article embeds the discussion in the context of specific design issues and existing collaborative systems. The article considered different levels of user representations and avatar interaction, different avatar interaction approaches which they term "puppeteered, tracked, and reconstructed." Illustrating with specific systems, they point how affordances provided by different avatar types enable different levels of communication and co-presence, and where the interface allows co-presence to break down. Steed and Schroeder also examine how modality, realism and context affect the sense of presence and co-presence. They end by looking at different blends of collaborative environments between captured environments and simulated.

Probably one of the areas where presence inducing technologies are systematically applied is in the area of mental health applications. Among these, virtual reality is often used to support compelling therapeutic experiences.

In Chap. 12 Riva and colleagues review the application of "presence inducing systems," specifically virtual reality technologies in mental health interventions. Presence inducing technologies allow patients to elicit optimal experiences in the support of psychological change. Riva and colleagues show the application of presence within a range of clinical issues including the treatment of phobias (e.g., flying claustrophobia, etc.) panic disorders, eating disorders, post-traumatic stress, pain treatment, and other areas.

More immersive experiences such as VR are associated with more optimal experiences than other media or the past use of doctor-patient driven imagined reconstructions. Riva and colleagues demonstrate the presence systems, that afford interaction with more intuitive, perceptual, bottom up sensorimotor interfaces, elicit stronger effects for some problems as compared to more rational operations on internal representations or classic patient-therapist talk. While presence is not a guarantee of successful outcomes it is related, and especially when linked to meaningful, relevant, emotional experiences.

Riva and colleagues point out that user-patients can confront a perceptual representation of his or her problem in controlled yet safe settings. The vivid perceptual experience, the sense of the real embedding within meaningful experience, can help induce changes in behavioral routines and responses to stimuli in the physical environment. Riva and colleagues review the relationship between presence and therapeutic changes in this application area.

In summary the book represents an interesting range of research and theory on presence technologies and experience.

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Part I
Telepresence Concepts and Theories

Chapter 2
Defining Presence

Matthew Lombard and Matthew T. Jones

We define presence as the feeling of being located in a perceptible external world around the self.

Waterworth et al. (2015)

Presence is the experience of being engaged by the representations of a virtual world.

Jacobson (2002)

Presence [is defined formally as t]he perceptual illusion of nonmediation.

Lombard and Ditton (1997)

Presence is tantamount to successfully supported action in the environment.

Zahorik and Jenison (1998)

The sense of presence considered here is… a numinous [i.e., supernatural, sacred, holy] sense of otherness.

Cheyne (2001)

Abstract The concept of presence has become the focus of an increasing amount of attention in both academic and public forums, but scholars have developed divergent and overlapping definitions of the concept, which threatens to inhibit our progress in understanding presence phenomena. In this chapter we present a framework for untangling the conceptualizations and promote a standardized terminology for discussing and defining presence. A brief consideration of the benefits and dangers of the endeavor is followed by an overview of the origins and evolution of presence terminology, presentation of the definitional framework, and recommendations for its use.

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In the definitions above, presence is alternately defined as "feeling," "engagement," "perception," "action," and "sensation." Aside from the issue of what is being felt, engaged with, perceived, acted upon, or sensed, this makes it abundantly clear that the question of how we conceive of presence phenomena has many possible answers. As a consequence of this and as the definitions above and elsewhere further demonstrate, scholars have developed divergent and overlapping definitions of presence. When they examine dimensions or types of presence – with labels including telepresence, co-presence and spatial, social, virtual, immersive, perceived, subjective, environmental, and corporeal presence – the conceptual confusion multiplies. As Waterworth et al. (2015, p. 36) note, "Terminological and other confusions about what comprises presence, and what does not, have impeded progress in the field. At the current time, no unifying theory of presence is possible, because the word 'presence' is being used differently by different researchers." The Waterworths' observation over a decade earlier (and echoed by many presence scholars) remains true: "researchers in the area agree that there is something important conveyed by the term, but differ widely on exactly what that something is" (Waterworth and Waterworth 2003, Conclusions).

In this chapter we present a framework for untangling the many conceptualizations of presence. The goal is not to critique or advance certain definitions but to sort and categorize the definitions and promote a standardized terminology for discussing the phenomena of 'presence' that fascinate so many theorists, researchers, creators and consumers.

While presence phenomena date back to the earliest representational art (IJsselsteijn 2004, 2005), and arguably the beginning of humanity, the academic consideration, and labeling, of these phenomena began relatively recently. The diversity of definitions is the result of necessary conceptual 'brainstorming,' but if scholars are to constructively collaborate and ultimately better understand presence, we need a common framework and terminology.

After a brief consideration of the benefits and dangers of this endeavor and overview of the origins and evolution of presence terminology, we present the definitional framework and offer recommendations regarding its use.

2.1 Benefits and Dangers of Standardizing Presence Definitions and Terminology

To build knowledge in any area and about any phenomena, researchers and theorists must have a common understanding of the meanings of the words they use. White et al. (1998) note that "It is essential to the process of communication that all individuals and groups concerned either use the same term for a particular object or concept, or at least have the ability to translate between different terms," and Heilbron (2002), echoing Francis Bacon (1889), observes that "Among the obstacles to the steady advance of science are the words invented to denote its conquests" (p. 585). Adopting a common framework for definitions and terminology of presence will allow us to communicate and collaborate more effectively, compare theoretical propositions and empirical results within and across disciplines, and ultimately build knowledge in this area. The availability of common and generally accepted definitions means that scholars don't have to continually construct new definitions that are similar or identical to those already in use. Although they don't insure more consistent and comparable measurements of presence, standardized definitions are a prerequisite for standardized measurements. And such a framework will eventually allow us to more accurately characterize acquired knowledge about presence phenomena via meta-analysis.

Despite the need for such a framework, there are reasons to be cautious. An inflexible, prescribed set of definitions and labels could constrain creativity and limit the development of innovative approaches and, therefore, academic progress.

What is needed is a categorization of the important definitional work that has been done in a format that won't restrict, and will even encourage, the evolution of that work in the future.

2.2 Historical Overview of Presence Definitions and Terminology

Film theorist André Bazin is (apparently) the first to define the common term presence in a scholarly context. In a 1951 article in *Esprit* (later translated to English in *What is Cinema?* (1967)) a section titled "The concept of Presence" defines the term with regard to "time and space," noting that for an individual to be present, they must "come within the actual range of our senses" (p. 96). Applying the concept to media, Bazin further notes that "[i]t is false to say that the screen is incapable of putting us 'in the presence of' the actor" since it reflects the actor's image as a mirror and "relays the presence of the person reflected in it" (p. 97).

The sociologist Irving Goffman defined a variant of the term presence in his 1959 book, *The Presentation of Self in Everyday Life*. He wrote that co-presence is a situation in which humans are co-located, i.e., together, face to face, and "accessible, available and subject to one another" (p. 22). For full co-presence, "persons must sense that they are close enough to be perceived in whatever they are doing, including their experiencing of others, and close enough to be perceived in this sensing of being perceived" (p. 17).

In 1976 Short, Williams and Christie theorized about presence phenomena involving communication mediated by technology (e.g., a closed-circuit television, a speakerphone, a letter). After defining social presence "as a quality of the medium itself" they clarify that it is a "subjective" quality that is "dependent on the medium's objective qualities" – the perceived "degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships" (p. 65).

The best known variant of the term presence is telepresence, as defined by Marvin Minsky in 1980 in the context of teleoperation:

> "Each motion of your arm, hand, and fingers is reproduced at another place by mobile, mechanical hands. Light, dexterous and strong, these hands have their own sensors through which you see and feel what is happening. Using this instrument, you can 'work' in another room, in another city, in another country, or on another planet." (p. 45) … "Telepresence emphasizes the importance of high-quality sensory feedback and suggests future instruments that will feel and work so much like our own hands that we won't notice any significant difference." (p. 47) … "The biggest challenge to developing telepresence is achieving that sense of 'being there.'" (p. 45)

In 1992 this phenomenon was termed presence in the title of the MIT Press journal *Presence: Teleoperators and Virtual Environments.*

Five years later Lombard and Ditton (1997) identified six dimensions of presence from diverse literatures and defined the generalized concept as "the perceptual illusion of nonmediation" which occurs "when a person fails to perceive or acknowledge the existence of a [human-made] medium in his/her communication environment and responds as he/she would if the medium were not there. … [It] can occur in two distinct ways: (a) the medium can appear to be invisible or transparent and function as would a large open window, with the medium user and the medium content (objects and entities) sharing the same physical environment; and (b) the medium can appear to be transformed into something other than a medium, a social entity" (Presence Explicated).

During the spring of 2000 members of a growing interdisciplinary community of presence scholars developed a comprehensive explication of the concept through an electronic discussion on the presence-l listserv (International Society for Presence Research 2000). The lengthy explication, available on the web site of the International Society for Presence Research (ispr.info), begins with this overview:

> Presence (a shortened version of the term "telepresence") is a psychological state or subjective perception in which even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience. Except in the most extreme cases, the individual can indicate correctly that s/he is using the technology, but at *some level* and to *some degree*, her/his perceptions overlook that knowledge and objects, events, entities, and environments are perceived as if the technology was not involved in the experience. Experience is defined as a person's observation of and/or interaction with objects, entities, and/or events in her/his environment; perception, the result of perceiving, is defined as a meaningful interpretation of experience. *(The Concept of Presence: Explication Statement)*

In the last half century, and especially during and since the 1990s, these and many other scholars have advanced a wide variety of unidimensional and multidimensional conceptualizations, and corresponding terminology, for presence. While individually useful, many of the definitions overlap, conflict with, and contradict one another. And while it's a sign of the growing sophistication in presence scholarship, the identification of many new dimensions of presence has led to a glut of composite terms (e.g., spatial, social, mediated, virtual, immersive, perceived, objective, subjective, physical, environmental, inverse, backward, forward, physical, self and corporeal presence).

2.3 A Framework for Presence Definitions

In Fig. 2.1 we present a framework that organizes most scholarly definitions of presence and variants of presence in the literatures of diverse disciplines. A more detailed, interactive version of Fig. 2.1 can be found online at matthewlombard.com/presence-definitions. No such effort can likely be, much less stay, complete, but the framework is designed to characterize and organize existing definitions and guide the development of new conceptualizations.

The left-most column in the figure contains questions that organize the definitions based on their fundamental characteristics. The definitions at the top of the figure are the most general or broad, and those at the bottom are the most specific or narrow. Definitions and distinctions based on each of the organizing questions are discussed below. In some cases we modified terminology to draw distinctions but whenever possible we used authors' original terminology.

2.3.1 Is Technology Involved in the Phenomenon?

The first and most basic distinction among definitions of presence concerns the issue of technology. Some definitions focus on properties of communication that explicitly exclude technology. An example is Zhao's (2003) definition of corporeal copresence: "the most primitive mode of human togetherness. To interact with someone in corporeal copresence is to interact with that person face to face or body to body" (p. 447). Other definitions explicitly involve the use of technology, "a machine, device, or other application of human industrial arts including television, radio, film, the telephone, computers, virtual reality, and simulation rides; traditional print media such as newspapers, books, and magazines; and traditional arts such as painting and sculpture" (International Society for Presence Research 2000). Minsky's oft cited definition of telepresence in the context of teleoperation (see above) is one of many in this category. And some definitions can apply in either context, when technology is involved or not. For example, Heeter (1992) writes that "presence is reacting to the external world or what seems like the external world, as it happens" (p. 343).

2.3.2 What Is the Phenomenon a Property Of?

A second key distinction concerns whether the phenomenon being defined is an objective property of a mode of communication, technology, person, object or entity, or a subjective property of a person. Zhao's (2003) definition (above) is of an objective mode of communication – corporeal copresence occurs when people interact "face to face or body to body" (p. 447), regardless of how they perceive the experience. Similarly, corporeal telecopresence is "a form of human co-location in

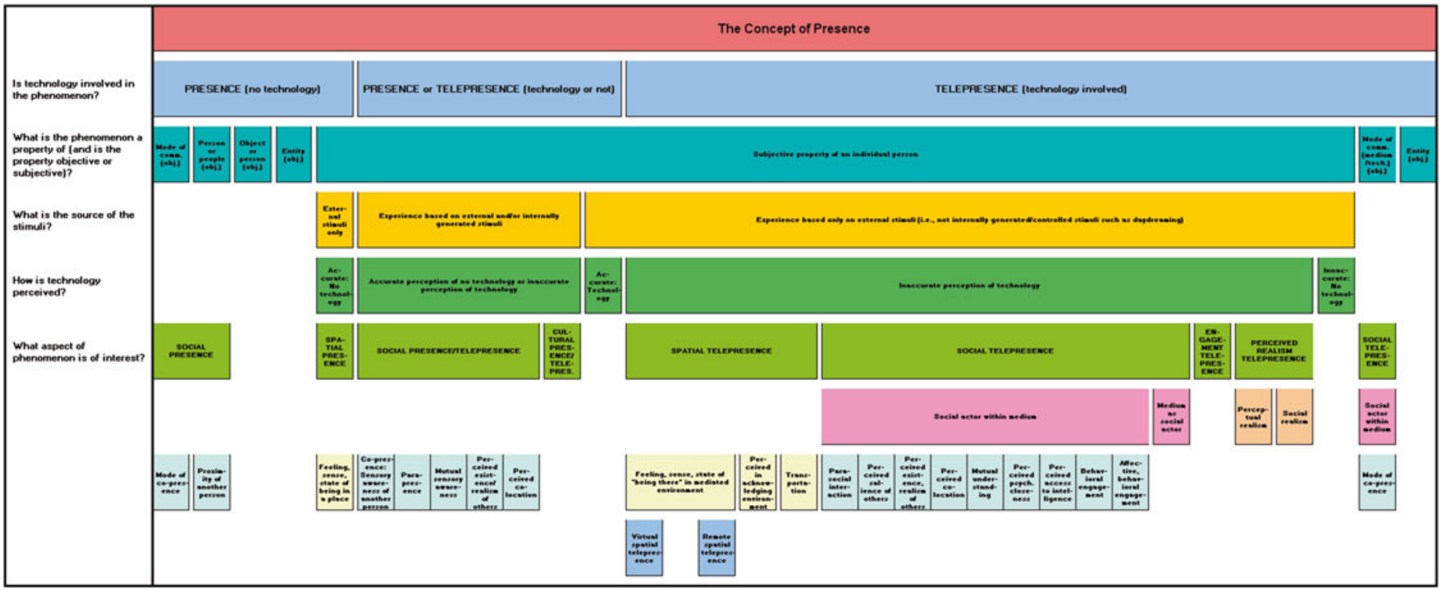

Fig. 2.1 This framework organizes most scholarly definitions and variants of presence within a diverse set of literatures. An interactive version of this figure can be found at http://matthewlombard.com/presence-definitions

which both individuals are present in person at their local sites, but they are located in each other's electronic proximity rather than physical proximity" (Zhao 2003, p. 447). To the emerging telepresence conferencing industry, "[t]elepresence is a conferencing technology where participants feel as if they are in the same physical space even if they are actually separated by thousands of miles" (Lichtman 2006); note that telepresence here is the technology, not the feeling of its users.

In other cases presence is the objective property of a person: "In [studies] of unmediated interactions, social presence is treated as self-evident: the other simply is or is not present" (Biocca et al. 2003, p. 462). Schloerb (1995) defines physical presence as "the existence of an object in some particular region of space and time. For example, this text (in some form) is physically present in front of you now" (p. 68); he also notes that people can be present in this sense. Floridi (2005) proposes a model of presence based on "successful observability": "an external and objective evaluation" of whether human and nonhuman entities (e.g., "teleagents and telepatients") can be successfully observed, at various "levels of abstraction," as being in local and/or remote spaces.

But the phenomenon described in most definitions of presence is a subjective quality – usually a perception or experience – of an individual person. It is variously defined as "a psychological phenomenon" (Sas and O'Hare 2003), an "experience" (Steuer 1992), a "subjective feeling or mental state" (Sheridan 1992), a "perceptual illusion" (Lombard and Ditton 1997), and "a psychological state" (Lee 2004). Some animals may experience presence too. Humans share "core consciousness" (which is the domain of presence) with all creatures (Waterworth and Waterworth 2003).

2.3.3 What Is the Source of the Stimuli?

For those definitions of presence that involve a subjective property of an individual, the source of the experience or perception can be external – i.e., outside the body, in the 'real' world, or it can be internal – i.e., inside the body (specifically the brain). External sources are basically all impingements on our senses from the physical world around us, while internal sources are controlled or automatic mental processes that result in remembering a vivid experience, dreaming, daydreaming, or any other experience that depends exclusively on imagination.

Some definitions explicitly or implicitly apply only to our experiences of the external world (via technology or not). Examples include definitions by Waterworth et al. (2015, p. XX) ("the feeling of being located in a perceptible external world around the self"), Steuer (1992) ("the experience of one's physical environment" (p. 75) and Lombard and Ditton (1997) ("a phenomenon that involves continuous (real time) responses of the human sensory, cognitive, and affective processing systems to objects and entities in a person's environment" (Presence Explicated)). Other definitions are more inclusive, with either external or internal stimuli generating presence. Specifically, Biocca (2003) describes a three-pole model in which presence shifts between the real world, the virtual world and the internal mental world depending upon the quality of external sensory cues. But the distinction between external and internal can be difficult. Heeter (2003) writes that "[p]resence occurs during periods when cognition is closely tied to current perceptual stimuli" (p. 342) and includes hallucinations because "the hallucinator believes that the stimuli are currently present" but does not include daydreams because "nothing about the daydream sensory stimuli is external; they are under our control" (p. 343). This definition stipulates that the source of a presence experience need not be external if it is *perceived as external*, while those above would seem to exclude hallucinations because they do not, in fact, originate externally. And in definitions related to religion and spirituality, there is little consensus regarding whether the source of a sense of the presence of the sacred or holy (e.g., the "presence of God") (see Cheyne 2001) is external or internal.

Most presence scholars acknowledge that subjectively experienced presence cannot occur without internal mental processing, which takes external and/or internal stimuli and translates them into experience. The distinction here is between experiences that can only occur in response to objects and events in the external, physical world and those that have no external source. See Jones (2007) and Waterworth et al. (2015) for detailed discussions.

2.3.4 How Is Technology Perceived?

The fourth distinction in presence definitions concerns the perception of technology in an experience. There are four logical possibilities: When technology is not involved in an experience, as in 'face to face, body to body' communication (Zhao 2003), the fact that the technology plays no role can be accurately or inaccurately perceived; but even when technology is involved, as when a person uses virtual reality or other media, the role of technology can be accurately or inaccurately perceived as well. The following diagram clarifies these distinctions (Table 2.1):

Table 2.1 The four logical possibilities for defining the perception of technology in an experience

	Technology	No Technology
Accurate perception	Conscious of technology	Presence
Inaccurate perception	Telepresence	Inverse presence (see below)

The two most common types of definitions describe the accurate perception that there is no technology involved and the inaccurate perception that technology is not involved when it is. In the first of these scenarios, a 'natural' or 'direct' or 'non-technology-based' experience is accurately perceived as such, and in the second, a person unconsciously or willfully overlooks the 'artificial' or 'indirect' or 'technology-based' nature of an experience created or modified by technology. Steuer (1992) provides an example of both of these when he defines presence as "the experience of one's physical environment… the sense of being in an environment" (p. 75), while "[t]elepresence is defined as the experience of presence in an environment by means of a communication medium" (p. 76).

The most common definitions involve the kind of misperception of technology that Steuer implies. As noted above, Lombard and Ditton (1997) formally label it “the perceptual illusion of nonmediation,” while the International Society for Presence Research (2000) explication identifies “a psychological state or subjective perception in which even though part or all of an individual’s current experience is generated by and/or filtered through human-made technology, part or all of the individual’s perception fails to accurately acknowledge the role of the technology in the experience” (The Concept of Presence: Explication Statement). Minsky (1980) notes the misperception of technology in his description of “future instruments that will feel and work so much like our own hands that we won’t notice any significant difference” (p. 47). Lee (2004) reviews other definitions and advances this one: “a psychological state in which virtual (para-authentic or artificial) objects are experienced as actual objects in either sensory or nonsensory ways” (p. 37). Stevens and Jerrams-Smith (2001) identify “the subjective experience that a particular object exists in a user’s environment, even when that object does not” as object-presence.

Some definitions of presence can logically fall into either of the two categories here. For example, Heeter (2003) writes that “[p]resence is reacting to the external world or what seems like the external world, as it happens” (p. 343) and “What does presence have to do with technology? Nothing” (p. 344). Here, whether one reacts to the world experienced through technology or not, they have experienced presence.

A few scholars have focused on the other two logical possibilities regarding how technology is perceived, the inaccurate perception that there is technology involved when it is not and the accurate perception that technology is involved when it is. Timmins and Lombard (2005) write that “[i]f telepresence is the illusion of nonmediation, then inverse presence is the illusion of mediation” (p. 496). They cite cases where people “experience natural beauty and perceive it as a picture, nature documentary or other mediated experience … [or] are involved in a disaster, crime or other tragedy and [say] their experience seemed ‘like a movie’,” and define inverse presence as a “psychological state or subjective perception in which even though an individual’s current experience is not generated by and/or filtered through human made technology, part or all of the individual’s perception fails to accurately acknowledge this” (p. 496).

Numerous scholars (e.g., Biocca 2002; Schubert and Crusius 2002; Gysbers et al. 2004) have struggled with what Biocca (2002) identified as “the book problem,” which is the idea that, despite higher levels of immersion in other media, “people can also experience presence in narratives presented in books, that is, [a medium] with a seemingly very low [level of] immersion” (Schubert and Crusius 2002, p. 1). While some resolve the paradox with the argument that, regardless of the medium, our experience is based on cognitive representations of what we see, hear, read, etc., others question whether there is even a “problem”:

> When I say I can smell the sea and feel the wind when I read Moby Dick, I do not mean that literally. I do not perceive the sea or the wind, through any sense modality. The text is so engaging, the expression so vivid, that it is almost as if I do. My intellect and my emotions are engaged as if I were perceiving it, as if I were present, but I am not present and I do not feel presence. (Waterworth and Waterworth 2003, Introduction; see also Waterworth et al. 2015).

The Waterworths are describing a case in which a technology user accurately perceives the role of technology in her experience; while she is present in a room with a book, she is not present in the space and with the people in the text of the book.

The distinctions regarding how technology is perceived in presence have also been described in (sometimes confusing) ways using the concept of mediation. To mediate, in this context, means "to effect or convey as an intermediate agent or mechanism" (The American Heritage Dictionary of the English Language, Fourth Edition, 2000). Humans rarely consider the fact that all of our experiences of the outside world are mediated by our biology. Although it nearly always seems like it, we do not interact directly with our environment – we perceive it through our perceptual apparatus, including our sense organs and central nervous system, notably the brain. Those of us who wear glasses or a hearing aid are regularly reminded of this fact – the objective reality of our environment doesn't change when we remove these technological aids, only our perception of it changes. This mediation by biology is often termed "first order mediation." Our own thoughts and what we see in our mind's eye when we contemplate or daydream are also only possible via this first order mediation; in fact there is no such thing as experience that is not mediated by at least these mechanisms. "Second order" mediation refers to experience mediated not only by biology but also by human technology. So an accurate perception that there is no technology involved can also be identified as "first order mediation perceived as first order mediation," the inaccurate perception that technology is not involved when it is can be identified as "second order mediation perceived as first order mediation," etc. Floridi (2005), IJsselsteijn (2004), and Pinchbeck and Stevens (2005) note that a potential problem with this terminology is that it assumes an "I think, therefore I am" Cartesian dualism that views the mind as separate from the body: if biology comes between "the world" and "us" then it is unclear what difference there is between "biology" and "us."

2.3.5 What Aspect of the Phenomenon Is of Interest?

The fifth and last distinction among presence definitions in the framework concerns the different aspects of the phenomenon. These definitions typically denote distinct but overlapping dimensions or types of presence, including spatial presence, social presence, self presence, engagement, realism, cultural presence and parapresence. These are briefly discussed below.

2.3.5.1 Spatial Presence

The most common type of presence identified in the definitions is spatial presence, that is, presence related to spaces and environments. Of these definitions those that describe the feeling, sense or state of "being there" in a mediated environment are most common. Witmer and Singer (1998) define presence as “the subjective experience of being in one place or environment, even when one is physically situated in another” (p. 225). Biocca et al. (2003) identify “telepresence (also known as spatial presence or physical presence) [as] the phenomenal sense of ‘being there’ including automatic responses to spatial cues and the mental models of mediated spaces that create the illusion of place” (p. 459). Sas and O’Hare (2003) write that:

> [p]resence is a psychological phenomenon, through which one’s cognitive processes are oriented toward another world, either technologically-mediated or imaginary, to such an extent that he or she experiences mentally the state of being (there), similar to one in the physical reality, together with an imperceptible sliding of focus of consciousness to the proximal stimulus located in that other world. (p. 523)

And there are many other variations (e.g., Freeman 2004; Saari et al. 2004; Wirth et al. 2007).

In some cases a distinction is made between “being there” in a virtual, computer-generated, not “real” environment (e.g., Saari et al. (2004): “Virtual presence means that the person feels present in a computer-mediated world”) and “being there” in a remote, actual location (e.g., Minsky (1980) and Sheridan (1992): telepresence is the “sense of being physically present with virtual object(s) at [a] remote teleoperator site” (p. 120).

Others limit this kind of presence to the sense of being there in an environment that acknowledges that the person is there. For example, Zahorik and Jenison (1998) write that “presence is tantamount to successfully supported action in the environment” (p. 87) and Heeter (1992) writes that “environmental presence refers to the extent to which the environment itself appears to know that you are there and to react to you” (p. 263).

A last subtype of spatial presence concerns transportation. Kim and Biocca (1997) discuss Gerrig’s (1993) claim that “a reader of a book can be phenomenally transported to the narrative environment created by the medium” (The Idea of Telepresence as Transportation: Departure, Arrival, and Return from a Mediated Place or Space), and propose “two [presence] factors: ‘arrival,’ for the feeling of being there in the virtual environment, and ‘departure,’ for the feeling of not being there in the physical environment” (Abstract). Lombard and Ditton (1997) describe transportation as including “‘You are there,’ in which the user is transported to another place [and] ‘It is here,’ in which another place and the objects within it are transported to the user” (Presence as transportation).

2.3.5.2 Social Presence

The second dimension or type of presence highlighted in definitions is social presence, or presence related to social entities (human, electronic and otherwise). Biocca et al. (2003) review a large set of definitions of social presence and divide them into nine categories; the framework in Fig. 2.1 contains an adapted and expanded categorization of social presence definitions. Zhao’s (2003) definitions above represent social presence as an objective property of a mode of communication. Biocca et al.'s (2003) "binary formulations of social presence… [in which] the other simply is or is not present" represent social presence as an objective property of a person or people. In the context of technology, Lombard and Ditton (1997) note that Horton and Wohl's (1956) observations about (now) old media represent a kind of social presence:

> One of the striking characteristics of the new mass media--radio, television, and the movies--is that they give the illusion of face-to-face relationship with the performer. The conditions of response to the performer are analogous to those in a primary group. … We propose to call this seeming face-to-face relationship between spectator and performer a para-social relationship. (abstract)
>
> The more the performer seems to adjust his performance to the supposed response of the audience, the more the audience tends to make the response anticipated. This simulacrum of conversational give and take may be called para-social interaction (p. 215)

Other types of social presence involve a medium user's perception of the salience of other people and their relationships with them (Lee 2004; Short et al. 1976), the perceived existence or realism of others (Gunawardena 1995; Spante et al. 2004), perceived co-location (or shared space or "we are together") (Lombard and Ditton 1997; Sallnas, Rassmus-grohn et al. 2000), mutual understanding (Savicki and Kelley 2000), perceived psychological closeness (Palmer 1995), perceived access to another intelligence (Biocca 1997; Huang 1999), behavioral engagement (Huang 1999; Palmer 1995), and affective and behavioral engagement (Harms and Biocca 2004). These definitions generally involve people and/or electronic representations of people, but many of the phenomena they delineate logically apply to nonhuman animals (e.g., pets) as well.

A somewhat different type of social presence concerns social responses not to entities within a medium but to the medium itself. Nass and his colleagues (see Nass and Moon 2000) studied many examples of human users responding to computers as if they were people (e.g., they follow politeness etiquette and gender-based rules as they do in human-human interaction). They identify this work as the "Computers Are Social Actors" (CASA) paradigm. Evidence has been found for social responses to television sets (Lemish 1982; Nass et al. 1996) and web sites (Kumar and Benbasat 2002) as well. Self-driving cars may be the next generation of CASA technology (Waytza et al. 2014). Nass and Steuer (1993) argue that "interactions with technologies that possess social characteristics may best be thought of as phenomena in the domain of interpersonal communication" (p. 522). Reeves and Nass (1996) conclude that "individuals' interactions with computers, television, and new media are fundamentally *social* and *natural*, just like interactions in real life" (p. 5). The same logic applies in the context of interactive toys and robots (e.g., see Heerink et al. 2008; Leite et al. 2009; Shin and Choo 2011). Lombard and Ditton (1997) identify these social responses explicitly as a type of presence, presence as medium as social actor, in which users "ignore, in a counter-logical way, the mediated nature of a communication experience" (Presence as medium as social actor).

2.3.5.3 Self Presence

Focusing on how technology users experience mediated representations of themselves (e.g., avatars), Ratan (2013) built on definitions by Biocca (1997) and Lee (2004), along with Riva et al. (2004) application of Damasio's (1999) framework of self to presence, to explicate the concept of self presence. He defines self presence as:

> "the extent to which some aspect of a person's *proto* (body-schema) self, *core* (emotion-driven) self, and/or *extended* (identity-relevant) self is relevant during media use" (p. 325). Essentially, self presence occurs when we perceive the body, emotions and/or identity of a technology-based version of us as our own. This type of presence, and extensions of it, should be increasingly important as technology provides new opportunities to be embodied in diverse representations (see Blascovich and Bailenson 2011; Slater et al. 2010).

2.3.5.4 Engagement

The third dimension or type of presence that can be identified in presence definitions focuses on psychological engagement. Often related to distinct but closely related concepts such as attention, involvement (Palmer 1995), flow (Csikszentmihalyi 1990), absorption (Quarrick 1989), and (perceived) immersion (Schubert et al. 2001; Witmer and Singer 1998), this type of presence involves a strong connection with the content and/or form of an experience. Jacobson (2002) writes that "[p]resence is the experience of being engaged by the representations of a virtual world," Palmer (1995) defines it as "the degree to which users of a virtual environment feel involved with, absorbed in, and engrossed by stimuli from the virtual environment," and Lombard and Ditton (1997) note that "[w]hen users feel immersive presence they are involved, absorbed, engaged, engrossed" (Presence as Immersion). Freeman (2004) identifies "engagement/involvement/attention" as one of three key dimensions of presence based on a review of several presence measures (which logically stem from definitions) and the results of their use.

2.3.5.5 Realism

Another aspect of presence phenomena emphasized in presence definitions concerns their realism. Although it has many meanings, "realism" in this context generally refers to the perceived correspondence between a technology-mediated experience and a similar experience not mediated by technology (often confusingly termed "real" or "real life"). Slater (2003) writes that:

> Presence is the response to a given level of immersion (and it only really makes sense when there are two competing systems – one typically the real world, and the other the technology delivering a given immersive system). There are many signs of presence – behaviours (in the widest sense) that match being in a similar situation in reality. (Summary; see also Slater 2007)

A further distinction is often made between perceptual realism and social realism. Lee's (2004) definition – "a psychological state in which virtual (para-authentic or artificial) objects are experienced as actual objects in either sensory or nonsensory ways" (p. 37) emphasizes the perceptual correspondence, as does this definition from Zahorik and Jenison (1998):

> Presence is tantamount to successfully supported action in the environment… When actions are made in an environment, the environment reacts, in some fashion, to the action made. When the environmental response is perceived as lawful, that is, commensurate with the response that would be made by the real-world environment in which our perceptual systems have evolved, then the action is said to successfully support our expectations. (p. 87)

In contrast to these primarily perceptual types of realism, Lombard and Ditton (1997) define presence as social realism as "the extent to which a media portrayal is [perceived as being] plausible or "true to life" in that it reflects events that do or could occur in the nonmediated world" (Presence as realism) and point out that an experience can be high in perceptual realism and low in social realism, and vice versa.

Freeman (2004) identifies "naturalness/realness/consistency with real world" as the second of three key dimensions of presence based on a review of presence measures and the results of their use.

2.3.5.6 Cultural Presence

Mantovani and Riva (1999) reject the underlying premise of presence as realism and draw on cultural psychology to advance a cultural definition of presence. They write:

> [We] reject the basic assumption of the ingenuous realism, the idea that 'real' objects exist outside social actors' minds and ideas and that 'virtual' objects exist only in people's heads. This dualistic view has no real foundation because the whole human experience of being in an environment is bioculturally mediated so that there is no 'outside' (things, objects) as independent from and opposed to an 'inside' (mind, knowledge, perception, and so on). (p. 543)

This view of reality as culturally and socially constructed leads them to their definition of presence:

> In our perspective, presence in an environment, real or simulated, means that individuals can perceive themselves, objects, and other people not only as situated in an external space but also as immersed in a sociocultural web connecting objects, people, and their interactions. (p. 540)
>
> For more on this approach to presence, including its implications for measurement, see Spagnolli et al. (2003) and Spagnolli and Gamberini (2005).

2.3.5.7 Parapresence

A final type of presence, likely unfamiliar to many presence scholars, is termed here parapresence. The focus of the parapresence phenomena is the perception that a person or entity is physically present in one's environment when they are not, and could not logically be, present. Brugger (n.d.; see also Brugger 2006; Cook and Persinger 1997 and Koehler and Sauer 1984) discusses four "autoscopic phenomena," which involve "the illusory reduplication of one's own body," including the phantom double:

> The phantom double which is only felt, but not seen, is the autoscopic phenomenon most similar to the phantom limb (which is also only represented in the somesthetic modality). As a phantom limb, also the "felt" being can be localized very precisely in near extrapersonal space. The phenomenon is commonly labelled "feeling of a presence" (Brugger et al. 1996), but is also known as "Anwesenheit" (Thompson 1982), "concrete awareness" ("leibhafte Bewusstheit", Jaspers 1913) and "false proximate awareness" (Koehler and Sauer 1984). … [E]xhausted mountaineers frequently overcome hopeless situations by caring for 'the other' who climbs with them, and whose presence is felt compellingly enough to be offered food (e.g., Smythe 1934). These observations suggest that the feeling of a presence rests on postural and kinesthetic representations of one's own body that are falsely localized in extrapersonal space. (*The somesthetic phantom double*)

Related types of experiences include "widows' ongoing attachments to their deceased husbands and a sense of their presence" (Conant 1993, 1996), "[t]he sense of 'a presence' or of a sentient being… during partial sensory deprivation and exposure to very weak, complex magnetic fields across the cerebral hemispheres" (Persinger, 2003), and "sensed presence during sleep paralysis" (Cheyne 2001). About the last of these Cheyne (2001) writes:

> Qualitative descriptions of the sensed presence during sleep paralysis are consistent with the experience of a monitoring, stalking predator. … The sense of presence considered here is an 'other' that is radically different from, and hence more than a mere projection of, the self. Such a numinous sense of otherness may constitute a primordial core consciousness of the animate and sentient in the world around us. (p. 133)

This group of presence phenomena may also include the sensed presence of religious entities (see Cheyne 2001; Landtblom 2006).

Observe how these aspects of presence are not mutually exclusive and can, in some contexts, be organized hierarchically. Depending on the circumstances, spatial and social presence may or may not be interrelated. Though we commonly experience social presence in a physical space, we can also be alone in a physical space or interact without sharing any specific space (e.g. via telephone). Similarly, one may or may not experience engagement or realism in social or spatial encounters, however, engagement and realism are both relevant only within spatial or social contexts. Self-presence and parapresence are arguably particular variations of social presence.

It is noteworthy that Mantovani and Riva's (1999) conception of cultural presence seems to form a foundation for all other aspects since it's difficult to imagine any presence encounter that is not shaped by language and culture.

2.4 Recommendations

The framework of current presence definitions presented in Fig. 2.1 and reviewed in the previous section confirms that the concept is multi-faceted and complex. The term presence, and its many variants, is used to refer to a very diverse set of phenomena. Some will argue that the phenomena identified by these definitions are so diverse that they represent distinct concepts; others will see important common characteristics in many or all of the definitions. Either way, it is clear that a single, one-word term – presence – is insufficient to characterize the many aspects of this concept. For presence scholarship to advance, those who study it need to all be "on the same page" and because there are so many subtle and not-so-subtle distinctions among the definitions, and because it's often not clear which definition scholars have in mind, "when people talk about *presence* they are often not talking about the same underlying concept at all" (Slater 2003, Introduction).

Based on the definitions reviewed and the framework developed above, we offer the following recommendations to those who study and write about presence:

2.4.1 Explicitly Identify the Conceptual Definition of Presence You Are Using

We believe the best way to encourage advances in presence theory and research is not to propose or attempt to build consensus around a single, ideal definition of presence, but for scholars to make very explicit the definition(s) that they are using in their work. A logical way to do this is to answer for readers and listeners the five key questions that organize the framework presented here (i.e., locate the definition being used in the framework of definitions).

2.4.2 Resist the Temptation to Create New Presence Definitions and Terms

Our collective work will also advance more quickly if we use existing definitions (and terms) whenever possible (assuming they represent our views well) and only construct new ones when they represent truly new and distinct forms of presence. As presence scholarship evolves and those definitions are developed (and redundant terminology fades), we plan to update the framework in the more detailed, online version of Fig. 2.1 at matthewlombard.com/presence-definitions to accommodate them.

2.4.3 Use Presence Terminology as Precisely and Consistently as Possible

Although any terminology must be explicitly defined to be useful, the inconsistent use of many presence terms is also problematic. Even if it could be developed, a standardized set of terms to capture all of the distinctions in the definitional framework in Fig. 2.1 would be unwieldy and difficult for a community of scholars to learn and adopt (Zhao (2003) developed an impressive taxonomy just for 'co-presence,' but it is complex and hasn't been widely adopted). But we believe four key distinctions can and should be captured by our terminology:

(a) Presence and telepresence

Scholars use the term presence both to refer to phenomena in which technology is not involved (e.g., a face-to-face encounter), and as a shortened version of the term telepresence, which refers to phenomena in which technology is specifically involved. This situation creates considerable confusion. We suggest that the longer term telepresence be used at least initially (e.g., "Telepresence (hereafter, presence)...") in any presentation referring to a presence phenomenon in which technology is specifically involved. If the phenomenon of interest occurs in contexts both with and without technology, this should be explained and both terms should be used.

(b) Objective and subjective

Objective forms of presence or telepresence involve characteristics of the world that can be easily observed and confirmed such as modes and technologies of communication, while subjective forms – which are more typically the interest of presence scholars – involve the experiences (perceptions, feelings, senses, states) of individuals. The terms "objective" and "subjective" should be used when there is any chance of confusion (e.g., in discussions of telepresence technologies vs. the experiences they evoke in users).

(c) Spatial and social

Spatial presence phenomena involve wholly or primarily the use or experience of physical space (e.g., teleoperation), while social presence phenomena involve wholly or primarily entities that are or seem to be alive (e.g., collaborative communication technologies). Of course many phenomena of interest involve both spatial and social presence, but the distinction is important; a study of spatial presence should not be identified simply as a study of presence.

(d) Remote, virtual, and medium telepresence

One large group of telepresence phenomena involves interactions among people and/or objects over distance (e.g., video conferencing). These can be identified as remote telepresence. In contrast, another group of telepresence phenomena involves our interactions with people and objects that are generated by technology itself (e.g., in simulation software). These can be labeled virtual telepresence. A final group of telepresence phenomena involves interactions not with people or objects experienced via or created by technology but with technologies themselves (e.g., androids, robots, toys and computers that seem to be 'alive'). These phenomena can usefully be identified as medium telepresence. Again, many phenomena of interest involve more than one of these types of telepresence (e.g., interactions with avatars that represent other users in the Second Life virtual environment constitute both remote and virtual telepresence). Whether they use this terminology or not, authors should make distinctions between and among these types of telepresence to avoid reader confusion.

Two other important distinctions are worth noting:

- ***Mediated and nonmediated*** – Mediated and nonmediated are ambiguous terms because they don't distinguish between types of mediation. While mediated can usually be assumed to refer to technological mediation (e.g., experiences via virtual reality, film, books, etc.), it can also refer to biological mediation (i.e., experiences of the world, involving technology or not, as filtered through our perceptual apparatus). Scholars should explicitly specify their intended use of these terms, distinguishing, wherever appropriate, between first and second-order mediation.
- ***Real/imaginary and realistic/unrealistic*** – While the term real is used in a variety of confusing ways (including as 'not mediated by technology' and 'nonfiction'), it is used appropriately to refer to something that exists (or is said to exist) in our physical world, as opposed to something that exists only in the imagination (i.e., a computer generated environment still exists in the world and is therefore real). But technology-mediated presentations or experiences (in part or whole), and responses to them, can be said to be realistic to the extent that they correspond to the equivalent objects, entities, experiences and responses in the non-technology-mediated physical world. In sum, clarity is essential when distinguishing between "real" and "unreal" phenomena.

We recognize the challenge in asking our colleagues and others to follow suggestions such as these in their written and presented work. To illustrate the ease of their use, consider an example of a definitional statement: "Telepresence (hereafter, presence) refers to subjective perceptions of a person as they use technology. Presence occurs when the person's perceptions about the role of technology in their experience are inaccurate in some way; specifically, we're interested in a kind of spatial presence – the person's sense or feeling that they are in the remote environment presented by the technology." Even simpler but still in complete accordance with our call for explicitness and clarity would be reference to an existing detailed explication of presence.

2.5 Conclusion

A review and categorization of definitions of presence has demonstrated that it is an unusually rich and diverse concept. Technology is bringing an ever-richer variety of mediated experiences to nearly every aspect of our lives, including architecture and real estate, arts and entertainment, business, engineering, health and medicine, sexuality, space and undersea exploration, war and peace, and many others. And our experiences not mediated by technology are arguably more important and precious amid these changes. Presence, and definitions of presence, touch on profound issues involving the nature of reality and existence; human cognition, affect and perception; the characteristics, uses and impacts of primitive, advanced and futuristic technologies; and the subtleties of interpersonal communication and human-technology interaction. This richness is valuable for a relatively young area of scholarship, especially one closely linked to quickly evolving technologies. As presence scholarship moves forward we expect confusion among definitions and terms to slowly resolve, which will help us to better understand the fascinating and important phenomena of interest to presence scholars, creators and the broader public.

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Chapter 3
Presence: Form, Content and Consciousness

John A. Waterworth, Eva Lindh Waterworth, Giuseppe Riva, and Fabrizia Mantovani

Abstract In this chapter we present a rather wide-ranging perspective on presence as a central, characterizing feature of conscious mental life. After clarifying what we mean by presence in the first section, Sect. 3.2 discusses the implications of this for measurement. In Sect. 3.3, we consider the importance of media form for the sense of presence, before moving on in Sect. 3.4 to the relationship between presence and the sense of self considered in evolutionary terms. Section 3.5 deals specifically with attention, viewing presence as a reflection of attentional focus. Our aim is to convey the big picture about presence: what it is, what it's for, how it evolved, what it is determined by and the effects it can have.

Keywords Evolution • Consciousness • Embodiment • Self • Psychology • Psychotherapy • Synesthesia • Measurement • Action • Brain • Imagination • Imagery • Form • Content • Attention

3.1 Introduction

In this chapter we present a rather wide-ranging perspective on presence as a central, characterizing feature of conscious mental life. After clarifying what we mean by presence in this section, Sect. 3.2 discusses the implications of this for measurement. In Sect. 3.3, we consider the importance of media form for the sense of presence, before moving on in Sect. 3.4 to the relationship between presence and the sense of

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self considered in evolutionary terms. Section 3.5 deals specifically on attention, viewing presence as a reflection of attentional focus. Our aim is to convey the big picture about presence: what it is, what it's for, how it evolved, what it is determined by and the effects it can have. In attempting that, we first need to be clear about what we mean by the term presence.

Terminological and other confusions about what comprises presence, and what does not, have impeded progress in the field. At the current time, no unifying theory of presence is possible, because the word "presence" is being used differently by different researchers. Perhaps we need different words for these different meanings, as Slater has suggested (Slater 2003). According to his presentation, what he means by presence could, perhaps more accurately, be labeled *pretence*. According to Websters online dictionary, this means "An artful or simulated semblance". This is consistent with his earlier (Slater 2002) definition of presence as:

> the total response to being in a place, and to being in a place with other people. The 'sense of being there' is just one of many signs of presence – and to use it as a definition or a starting point is a category error: somewhat like defining humor in terms of a smile (p. 7).

The problem with this is that it begs the questions: which place, and what response? If presence (in a virtual environment) is the total response to a simulation, as compared to the response to the physical environment being simulated, then what about virtual environments that convey fictional realities? Can we not measure presence in them? And if no comparison with reality is involved, how can something as unspecific as "total response" be quantified? This view seems to boil down to the most common everyday meaning of presence, of being physically present somewhere. But in this case, one can be present while mentally elsewhere or nowhere – say, on the phone, solving a difficult cross-word puzzle, asleep, in a coma, or even dead! This view seems to imply that presence is simply the degree of similarity with physical reality, not a thing that can be experienced in itself (*feeling* more or less present).

Some researchers (e.g. Biocca 1992, 2003) maintain that high levels of presence can be evoked by imagining a world as well as by directly perceiving and acting in a world (sometimes referred to as the "book problem"). From our perspective, they are really talking about a more general psychological concept, *salience*, or "the tendency of something to thrust itself into attention". Their definition of presence would seem to be something like "the feeling of being engaged by something whether imagined or perceived". For us, the most relevant schism in views of presence is between those theorists who suggest that presence is evoked both by internal imagery and perceptions, and those theorists (including ourselves) who suggest that presence is evoked only in the latter case. By our account, presence is literally "the perception that something is present" and we define presence as *the feeling of being located in a perceptible external world around the self*. We agree with Heeter (2003) that "Presence occurs during periods of time when cognition (processes such as perception, attention, learning, thought and affect ....) is closely tied to current perceptual stimuli.".

Of course, any useful definition must exclude things, and a useful definition of presence must have implications for what is not presence (Floridi 2004). We have termed this "*absence*", a state of absorption in an internal world (Waterworth and Waterworth 2001, 2003a, b) detached from the current perceptual flow. By introducing the concept of "absence", presence can be distinguished from other concepts with which it is sometimes confused, including engagement, attention, and even consciousness itself. A useful definition should also afford measurement, ultimately of physical changes associated with the psychological experience of presence. In this chapter we discuss the measurement of both presence and absence, since we do not see the latter as merely a lack of the former, but – like presence – as a distinct psychological state, contrary to many other interpretations (e.g. Jones 2007). On the other hand, given the limited capacity of conscious attention, we suggest that less presence makes possible more absence, and *vice versa*.

This is not to say that individual differences in imaginative skill may not predict the tendency to feel presence, to some extent, as Sas and O'Hare (2003) suggested. But while they suggest that presence can arise in response to imagined worlds, they also conclude that "the more users think, feel and act in the remote world [……] the greater the sense of presence they will experience" (p. 535). But, clearly, we do not act in imagined worlds! Indeed, the point of imagination can be seen as the testing of possible actions without carrying them out (Damasio 1999). There is also evidence that in a mediated environment designed for mood change (around a relaxing island theme, with verbal narrative), imagery ability only correlated with effective change in narrative-only conditions (Freeman et al. 2004). In this study, there was no correlation when visual displays of the virtual island were also presented – that is, in conditions in which visual imagery was not needed. Perhaps we can understand Sas and O'Hare (2003) as referring to the more general concept of absorption: a characteristic of the individual that involves an openness to experience emotional and cognitive alterations across a variety of situations (Roche and McConkey 1990). Presence and absence can both be seen as absorption states, the former based around the current perceptual flow, the latter around imagined events and situations.

For us, presence is about the present, the here and now in the physical or a virtual world. The feeling one gets from absorption in an internal world (a novel, a fantasy, or whatever) is quite different, which is why healthy people almost never confuse the two (see Waterworth and Waterworth 2003b; Riva and Waterworth 2003). Imagined worlds are often not related to real time; a book can be put down, a line of thought can be suspended until later. As we put it earlier (Waterworth and Waterworth 2001) "The root of the problem with many existing models of presence is perhaps confusion between presence and suspension of disbelief". Our view is that suspension of disbelief, as when reading an engaging novel, does not result in "the illusion of nonmediation" that, as Lombard and Ditton (1997) aptly suggest, characterizes presence. Rather, suspension of disbelief results in imagined presence, which can be highly engaging. We suggest that *presence* must be tied to the *present*, to the *here and now*, real time world – that is, the perceived world of the body and its surroundings – or else we had better stop calling it presence!

A counter argument is sometimes made (e.g. Biocca 2003), that we may experience high presence when dreaming, when we are not perceiving or acting in the external world (the "dream state problem"). We suggest that dreaming while asleep is a special case ("*dream presence*"), in that our motor systems are immobilized while we dream to prevent damage to ourselves and those around us. In the rare cases that this defense fails, the results are shocking: we may wake up in a state of paralysis (failure to turn the defense mechanism off), or we may act out deeds totally against our normal waking nature (failure to turn the defense mechanism on); see for example, Ohayon et al. (1999). This is not the case when we imagine a situation, whether while reading a book or not. When awake, we do not confuse what we conceive in imagination with what we perceive as the external world. It is our sense of presence that allows us to make this distinction. When dreaming we do – by definition – confuse the two because, we would argue, the presence mechanism is suspended when dreaming, along with gross motor responses. In other words, we have the experience of being and acting in an external world when dreaming, even though the world is entirely internally-generated, and our bodies do not act out what we dream them to be doing.

Both of these so-called problems for a unified view of presence (book reading and dreaming), and their solution, relate to the evolutionary role of presence. Looking to evolution is a key step in making further progress in the field, as we discuss in Section 3.4 (see also; Riva and Waterworth 2003; Riva et al. 2015; Waterworth and Waterworth 2003b). In the next section, we consider the implications of our view of what presence is for how it can be measured.

3.2 Formal Requirements for Presence

Slater (2003) suggested that presence is about form, not content. It should not be confused with degree of interest in, nor emotional engagement with, the contents of an environment. We agree that it is important to distinguish presence from emotional engagement, otherwise the concept of presence will lose any distinctive meaning but, as later sections will make clear, emotional engagement will have an impact on presence, through its effect on attentional selection.

Following many earlier researchers, we have been suggesting that presence is a function of form for several years now (e.g. Waterworth 1996; Waterworth and Waterworth 2000a, b, 2001; 2003a, b). Waterworth and Waterworth (2003a) presented evidence that different versions of a media production elicited different levels of presence, depending on the degree of abstraction of the information presentation. In summary, we found that when the abstraction level of an experience increases, the feeling of presence decreases, and vice versa, and that the sense of presence is highly subjective and varies widely across individuals. Most researchers would presumably agree that more immersive media tend to evoke higher levels of presence, other things being equal. But few writers have commented on why this might be the case. Why do more immersive media tend to elicit higher levels of presence than less immersive media?

Our argument is that people, as thinking organisms, routinely deal with two kinds of information, the concrete and the abstract. Concrete information is of a form that can be dealt with directly via the perceptual-motor systems; it includes information coming from the world around us, and it gives rise to the sense of presence. The information is realized as the world or, through technology as *a* world that exists outside our minds. Abstract information must be realized mentally or through technology for it be understood. For example, reading an interesting novel results in the creation of an imaginary world from the information provided by the abstract, alphabetic text. Such imagined worlds may be very vivid and emotionally engaging, but they are only realized mentally. As already mentioned, we refer to engagement with an internally-realized world as "absence", the inverse of presence. For example, Waterworth and Waterworth (2000a) claim that: "Presence arises when we mostly attend to the currently present environment within and around the body. The capacity we have for such attention depends on the amount of conceptual processing the situation demands. As we process more in an abstract way, we can consciously sample fewer concrete aspects of the present situation, and so our sense of presence diminishes; we become absent".

We need to understand the presence-absence distinction if we are to understand the role of form in eliciting presence, and perhaps also to understand consciousness in general. As Max Velmans puts it: "What we normally call the 'physical world' just is what we experience. There is no additional experience of the world 'in the mind or brain'", physical things are experienced as outside the body, in the external world, a process Velmans calls "perceptual projection". But, as Velmans points out "We also have 'inner' experiences such as verbal thoughts, images, feelings of knowing, experienced desires, and so on." and "In so far as these processes are experienced, they are reflexively experienced to be roughly where they are (in the head or brain)" (Velmans 2000, p. 110).

Perceptual projection[1] occurs in response to both physical reality and virtual reality. As Velmans states: "Virtual reality systems in which one *appears* to interact with a (virtual) three-dimensional world in the absence of an *actual* (corresponding) world provide one of the best demonstrations of perceptual projection in action – and the investigation of virtual realities will no doubt provide useful information about what the necessary and sufficient conditions for perceptual projection might be" (Velmans 2000, p. 231). Perceptual projection underlies our definition of presence as the feeling of being located in a perceptible external world around the self; a "perceptible external world" is the result of perceptual projection. It is necessary but not sufficient for high levels of presence.

The distinction between internally- and externally-generated worlds (and the importance of form) is clear if we consider the difference between reading a gripping novel and acting in a convincing virtual reality. The world of the novel is depicted in an abstract form – the symbols of textual language. We must do conceptual

[1] *Distal attribution* is a related term. Loomis suggested in the very first issue of Presence journal (Loomis 1992) that distal attribution results when afference is lawfully related to efference (after White 1970) and that attribution to self occurs when they are unrelated.

work to realize it mentally. A VR is depicted in a concrete form, and can be experienced in the ideal case without extra work – by the same perceptual processes by which we interact with the physical world. The virtual world is the same for everyone who acts in it, just as the physical world is (though, of course, our overall experiences and reactions differ). But the world I realize in my head when I read a novel is not the same as the one you realize, though it will have some similarities. Put even more simply, we can share external worlds, but we cannot share imagined worlds. Media form determines the extent to which information is realized externally or internally. It also determines whether we feel the world to be around us, or in our heads (the key distinction in the contents of consciousness pointed out by Velmans 2000). Presence is what it feels like to be embodied and consciously attending to an external, perceptible world. The key formal requirement for presence to occur is that information is presented in a form that an observer can make sense of intuitively, in a bodily way, rather than having to think about it (see also Sect. 3.5.3). The result is the feeling of being in an external world – presence.

We have earlier suggested that degree of presence versus absence is orthogonal to both the real-virtual distinction, and the level of attentional arousal of the experiencer (Waterworth and Waterworth 2001). By this view, we can be highly present in a virtual world, highly absent in the real world (and vice versa), the level of attention can be high when we feel present, but also when we feel absent, and presence can be high even when attention level is low. Since emotional content is one of the factors that can be expected to affect attention level, this is compatible with Slater's (2003) statement that "Presence is orthogonal to emotional content", insofar as emotional content determines level of attention.

However, presence and emotion cannot really be treated as independent. Presence is a function of form, but not only of form, and it is not possible to alter the form in which information is experienced without – to some extent – changing content. When the content of an environment is engaging people will tend to experience higher levels of presence. And even the most sophisticated simulation will not elicit high presence if it is very boring, which would seem to be contrary to Slater's position (2003). More interestingly, it may be that presence – as a reaction to being immersed in a world – is intrinsically tied to emotional engagement as well as the formal requirements for perceptual projection. It has been suggested that we cannot act or make decisions without emotion (Damasio 1994, 1999). If this is true, to feel present is also to have emotions. But this is also true of absence! To make sense of this, and clarify why presence cannot be the same as emotional engagement but is affected by it, it is necessary to consider what biological purpose presence might have.

3.3 Presence and the Conscious Self

In this section, we relate the experience of presence to the evolution of a conscious sense of self, suggesting that three levels of self which have emerged over the course of human evolution correspond quite directly to three layers of presence.

The overall sense of presence in a situation depends, we suggest, on the extent to which these three layers are integrated or *focused* on the same external situation. Here, we consider the development of self from the perspective of the individual organism, whereas Riva et al. (2015) present the same underlying model of presence from a more cultural perspective and with a focus on intentionality.

3.3.1 The Evolutionary Levels of Selfhood

Damasio proposes conceptual distinctions between a preconscious antecedent of self and two distinct notions of selfhood (Damasio 1999; Dolan 1999):

- *the proto self*: a coherent collection of neural patterns that map, moment by moment, the physical state of the organism;
- the *core self*: a transient entity which is continuously generated through encounters with objects;
- the *extended self* [2]: a systematic record of the more invariant properties that the organism has discovered about itself.

The basis for a conscious self is a feeling state that arises when organisms represent a non-conscious proto-self in the process of being modified by objects. In essence, the core sense of self depends on the creation of a second-order mapping, in certain brain regions (brainstem nuclei, hypothalamus, medial forebrain and insular and somatosensory cortices), of how the proto-self has been altered (Dolan 1999). This gives the feeling, not just that something is happening, but that something is happening *to me*. However, it is only the extended self that generates the subjective experience of possessing a transtemporal identity. The extended self centers the flow of our interactions with perceptual objects on itself, thereby making them our own experiences (see Fig. 3.1). In summary, the presence of *you* is the feeling of what happens when your being is modified by the acts of apprehending something (Metzinger 1999).

Core consciousness is what we presumably share with many nonhuman animals – a simple biological phenomenon, the scope of which is the Here and Now. This basic, integrated representation of one moment and one place is independent of language, reasoning and memory (Metzinger 1999). When we imagine, think, plan and generally deal with information that does not only constitute our experience of things and events in the currently present external situation we are exercising extended consciousness: "Extended consciousness has to do with making the organism aware of the largest possible compass of knowledge." (p. 198). It is extended consciousness that allows us to create an internal world in which we may suspend disbelief, as compared to a perceptual world experienced as outside the self.

[2] Damasio refers to this as the "autobiographical self". But because of its intrinsic dependence on extended consciousness, and because it consists of more than autobiographical memories and the self-conscious *idea* of self, we prefer to call this third layer the "extended self".

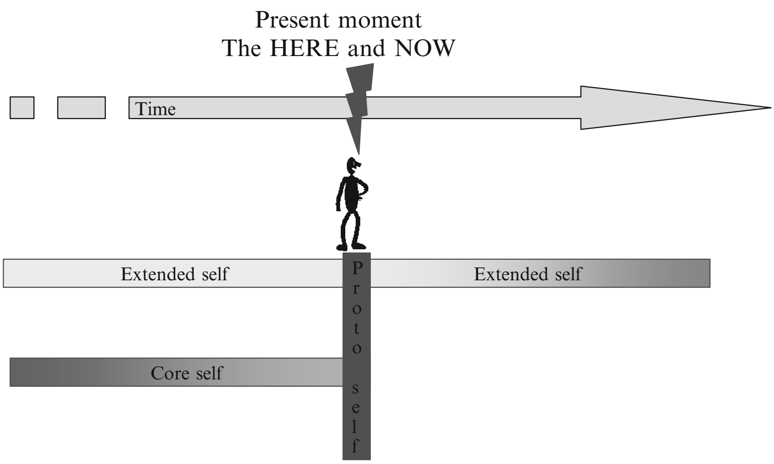

Fig. 3.1 The three levels of the self (Reprinted from Riva et al. 2004)

Extended consciousness relies on working memory (Damasio 1999), which can be seen as the "active scratchpad" of mental life (Baars 1988). It is in working memory that the internal world we are currently experiencing is largely created. Its main function is to allow us to consider possibilities not present in the current external situation. In contrast, core consciousness is directed exclusively to the here and now – the present.

Extended consciousness gives us obvious advantages over organisms without it, such as the ability to imagine and evaluate possible scenarios of the future, as well as to increase the sophistication of learning from the past. Language depends on it, because we must retain linear sequences of symbols in working memory if we are to understand utterances, whether spoken or written, and then build an internal model of their content. But the advantages of extended consciousness depend on the fact that we can distinguish between the experience of the external world and the experience of internal worlds, both remembered and imagined. Confusions of the two indicate serious psychological problems, problems which, until recent times, would have prevented survival and the passing on of this condition.

As noted by Waterworth and Waterworth (2003b): "if we react as if the external world is only imaginary we will not survive long (think of this the next time you cross a busy street). And if we think that what we are merely imagining is actually happening, we may omit to carry out basic activities on which our survival depends" (p. 2). How then do we distinguish perceptions of the external world (perceptions which are themselves largely hypothetical mental predictions) from the purely mental constructions that constitute imagined situations and events? How do we separate the internally from the external? We are suggesting that presence is the feeling that evolution has given us to make this vital distinction – this is the biological purpose of presence.

3.3.2 The Three Layers of Presence

We suggest that it is possible to associate a specific layer of presence with each of the three levels of self identified by Damasio. Since each layer of presence solves a particular facet of the internal/external world separation problem (which is the purpose of presence), it is characterized by specific properties. Our suggestions are compatible with the claims of at least some representatives of the "embodied cognition" community (e.g. Clark 1997). In the following parts of this section, we outline the characteristics of each layer in more detail, by focusing on its particular characteristics.

3.3.2.1 The First Layer: Proto Presence

The main activity of the proto self is a largely non-conscious mapping of the physical state of the organism. What is the evolutionary goal of the proto self? To predict the characteristics of the external world as it is experienced through sensory inputs.

In this process movement plays a key role (see Fig. 3.2). On the one side, an adaptive movement is the evolutionary goal of the proto self. On the other side, it is only through motility that it can embed the properties of the external world in its sensorimotor representation. These properties are the constraints generated by the coordinate systems that describe the body: in an evolutionary process that required millions of years, the proto self experienced, through movement, these constraints and used them to model the external world. In this vision how can we define the sense of presence possessed by the proto self ("proto presence")? Tentatively we can say that the more the proto self is located in the body, the more it is different from the external world. More precisely we can define *proto presence* as an *embodied presence related to the level of perception-action coupling (self vs. non-self)*. The more the organism is able to couple correctly perceptions and movements, the more it differentiates itself from the external world, thus increasing its probability of survival.

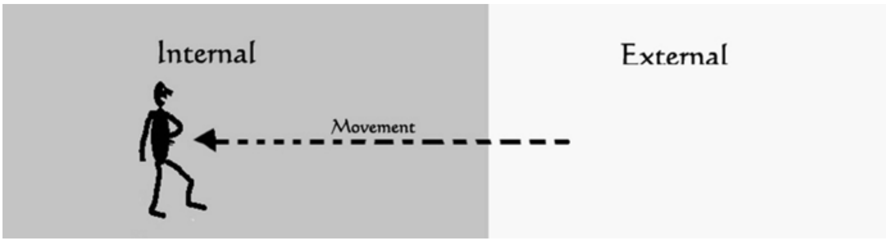

Fig. 3.2 Proto presence (Reprinted from Riva et al. 2004)

3.3.2.2 The Second Layer: Core Presence

The core self is a transient but conscious entity, ceaselessly re-created for each and every object with which the brain interacts. What is the evolutionary goal of the core self? It is the integration of specific sensory occurrences into single percepts. According to Gregory (Gregory 1998) this is done through a coherent world-model that evolves in real time according to its own internal logic. In such a vision, perception depends very largely on knowledge derived from past experiences of the individual and from evolutionary history.

What is the role of core presence in this? The model only works if the nervous system can differentiate between internal (imagined) and external (perceived) states of affairs. As we have indicated, distinguishing the *present* from the *imaginary* is essential for survival in the here and now. Core presence is *the activity of selective attention made by the self on perceptions (self vs. present external world)*: the more the organism is able to focus on its sensory experience by leaving in the background the remaining neural processes, the more it is able to identify the present moment and its current tasks, increasing its probability of survival (see Fig. 3.3).

Core presence is needed mainly when the core self tracks a significant change in the level of core affect. When this happens, it is critical for the core self to focus on its sensory experience by leaving in the background the remaining neural processes. In this sense, a shift in the level of core affect activates the possibility for a high level of core presence. Core affect is not dependent on any reality judgment: it responds to the contents of consciousness whether based on reality or imagination. Core presence was evolved to make this essential distinction between the imagined and the actual.

3.3.2.3 The Third Layer: Extended Presence

The result of the activity of the extended self is extended consciousness. But what is the role of extended presence? The goal hierarchy model of personality and motivation (Cropanzano et al. 1994) can provide the theoretical underpinning for

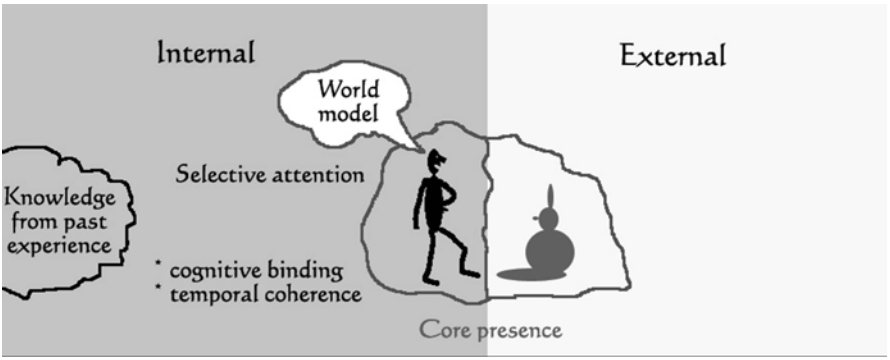

Fig. 3.3 Core presence (Reprinted from Riva et al. 2004)

answering this question. Cropanzano and colleagues described personality as an interrelated series of goals that direct and organize an individual's behavior. In their model, which has many similarities with the description of the extended self of Damasio, goals are arranged hierarchically from abstract orientations (analogous to traits) at the top, through values, self-identities, and ultimately down to concrete, behavioral goals. Abstract goal orientations, such as a tendency to approach positive stimuli or avoid negative stimuli, are mapped onto distinct response styles that serve as directional orientations. As noted by Brett and eWalle (1999), response styles do not offer the specificity to make behavioral predictions, but instead determine the types of goals that individuals will set. These lower level goals regulate the specific behaviors selected for performance.

The possibility of defining internal goals and tracking their achievement is the element that allows the final shift in the evolution of the self: from meaning-as-comprehensibility to meaning-as-significance. Meaning-as-comprehensibility refers to the extent to which the event fits with our view of the world (for example, as just, controllable, and nonrandom) whereas meaning-as-significance refers to the value or worth of the event for us (Janoff-Bulman and Frantz 1997). In this vision, the role of *extended presence* is to *verify the significance to the self of experienced events in the external world (self relative to the present external world)*. The more the self is present in significant experiences, the more it will be able to reach its goals, increasing the possibility of survival (see Fig. 3.4).

In summary, we suggest that the overall sense of presence in a situation depends on the extent to which the three layers described above are integrated or *focused* on the same external situation, when attention is not focused internally, on imagined situations. This implies that the upper and lower layers have the same focus as core (perceptual) presence. This is in marked contrast to Biocca's (2003) three-pole model of presence, which suggests that when attention is focused on a perceived world, or on imagined mental contents, as when reading an engrossing book, a high level of presence will be experienced (this is the "book problem" discussed earlier). Baños et al. (2005) tested these views by comparing the reported sense of presence in virtual versus imagined spaces. They found that participants in "imagery spaces" indicated a decrease in their sense of presence, whereas the opposite occurred for participants in virtual spaces.

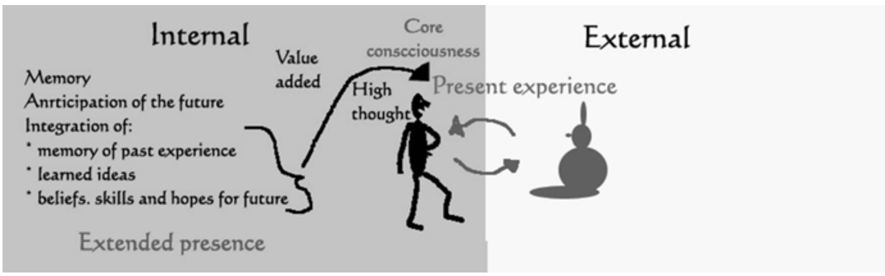

Fig. 3.4 Extended presence (Reprinted from Riva et al. 2004)

3.4 Presence and Psychotherapy

We have suggested that presence is how it feels to be engaged with an external world, and that this can be distinguished from how it feels to be engaged with an internal world (absence). Both kinds of world, the external one eliciting presence and the internal one producing what we call absence, require attention, and both evoke emotion. We feel embarrassment when we are publicly humiliated, and we feel it again when we imagine ourselves in that situation. But normally, and naturally, the external world in which we feel ourselves to be present is given priority. When driving, we must act to avoid the traffic hazard before we continue our absent-minded daydreaming about the weekend – even if what we were imagining was much more exciting than the present situation. In other words, we move our attentional focus from our internal world to the external world, and in so doing we experience a sudden increase in the sense of presence. All at once, we are highly aware of where we are and what we are doing in relation to the external world around us. This is a move from absence to presence, not from one kind of presence to another. In other words, it is a shift of attention from a world we experience as being in our head, to a world we experience as being outside.

In our view, it is because of the biological priority given to what is perceptually present that VR has such potential as a powerful psychotherapeutic tool. The aim of much psychotherapy is to change the linking between life events and emotional responses to those events. We will not attempt here to review the many, often successful, attempts to apply VR to a variety of psychological maladjustments (see, for example, Riva et al. 1999). However, we do suggest that presence may provide a "royal road" to the evocation of emotion and change, just because it has a psychological precedence based on its biological and evolutionary importance. As Damasio (1999) suggests on the basis of neurological findings, "the 'body-loop' mechanism of emotion and feeling is of greater importance for real experience of feelings than the 'as if body-loop' mechanism [of the imagination]" (p. 294).

Most psychotherapies take the internal world (or 'as if body-loop') route to emotion. Ideation of a situation might, for example, be used to provoke an emotional response that can then be discussed and addressed, perhaps in conjunction with relaxation techniques. VR is most often seen as an adjunct to ideation, a way to strengthen this approach to change. But the basic approach remains the same and rests on the idea that meaning resides primarily in internal worlds, and that change should arise first and foremost in those internal worlds. The result is that psychotherapy, although successfully exploiting VR technologies, does so within a framework that may sometimes fail to capitalize on the biological priority of what evokes presence.

The conventional framework could be described as "imagining evokes emotions and the meaning of the associated feelings can be changed through reflection and relaxation". We would suggest as an alternative that "experience evokes emotions that result in meaningful new feelings which can be reflected upon". The conventional framework is limited by the secondary nature of the feelings evoked, based on the internal world route (the 'as if body-loop'). We speculate that the alternative approach may be more effective, because by using VR it can take the external world (actual ‘body-loop’) route. We suggest that meaning derives ultimately from bodily experiences of being in an external world. If this is true, it seems reasonable to predict that the meanings of feelings can be more effectively changed when they are addressed at source. Our view of meaning rests on recent trends in philosophy, such as Lakoff and Johnson’s “experiential realism” (Lakoff and Johnson 1999), and this approach has been successfully applied to the design of navigable information landscapes (Waterworth et al. 2003a). By this view, meaning derives ultimately from embodied experience, in core consciousness – from presence. Presence comes first, both in evolutionary terms and in epistemological terms. Presence provides the grounding for meaningful reflections in extended consciousness.

We speculate that many common psychological problems, such as phobias, depression, anxiety, debilitating shyness and so on, arise from an imbalance in the relative levels of presence and absence. Specifically, we suggest that most of these problems arise as the result of too little presence, sometimes in specific situations, sometimes more generally. The sufferer focuses too exclusively on their idea of what is happening and their own place in it (their internal model of the situation or world), at the expense of experiencing their own, relatively unreflective, presence in the external situation or world. To lose the sense of presence is to lose one’s sense of being in the world, and is both an unnatural and a distressing condition. Other conditions are characterized by too much presence, when attention is distracted towards the external world at inappropriate times or to an excessive degree. In other words, psychological problems may be the result of an inappropriate focusing of attention, on the external world (too much presence) or the internal world of thought and imagination (too little presence).

Different psychological problems are associated with different kinds of emotional reactions that are related to the sense of presence vs. absence. For instance when a person experiences a panic attack, at first she becomes aware of the situation she is in (high degree of presence), and this evokes a feeling of anxiety. She starts to reflect on the feeling and so the attention is directed from the external world to the internal world e.g. to abstract thinking about the specific feeling, and this in turn creates a high degree of absence. Often the person experiencing the panic attack is not much aware of what is happening around her, mostly only of her own feeling of panic. For example, according to dialectic behavior therapy (Kåver and Nilsonne 2002), one way to deal with a panic attack is for the person to direct more attention to the external world. In other words, they are trained to direct their attention from the internal world to the external world, and this in turn will give rise to an increase in the sense of presence at the cost of decreasing the sense of absence. If appropriately designed, a virtual environment can be used to train the tendency to experience increased levels of presence (see e.g. Waterworth et al. 2003b). It may also be possible to design for higher levels of presence than are ever normally experienced in relation to the physical world (see Riva et al. 2015).

If presence has an evolutionary rationale, as we are suggesting, we would expect a strong relationship between presence and emotion, and especially arousing emotional states. As Pinker (1997, p. 374) puts it: “Each human emotion mobilizes the mind and body to meet one of the challenges of living and reproducing in the cognitive niche." Freeman et al. (2005) present evidence for their view that only arousing emotions elicit higher presence, and this is compatible with the evolutionary account of presence presented here.

Since presence is, for us, a reflection of the extent to which an individual is engaged with (and feels able to act in) an external world rather than with an internal world of the imagination, we would expect personality factors that are known to affect this relation to also affect experienced presence. For example, we might expect that extrovert personalities in general experience lower presence in the same situation than introvert personalities. This would be compatible with extraverts seeking out high levels of stimulation, and thus presence, while introverts easily "overdose" on the external world and try to withdraw more into absence. Similarly, elderly people might be expected to experience less presence in common situations than the young. Although not much work has been carried out in this area, there is some evidence to support our conjectures.

Laarni et al. (2004) present evidence of a positive relationship between experienced presence and extraversion, impulsivity and self-transcendence. Since Eysenck's (1967) characterization of the extravert was of a person who was predominantly engaged with events in the external world, rather than the internal world of thoughts and imaginings, this is to be expected from our own view of presence as a focus on action in the present, external environment. The same is true of impulsivity, since according to Laarni et al. (2004) impulsive individuals are better able to shift their attention in external space. And it has been previously suggested that the highest levels of presence are associated with self-transcendence, with a loss of self-consciousness (Waterworth et al. 2002; Riva et al. 2004).

3.5 Presence and Absence

We have already described the overall feeling of presence as arising from the combined influence of three specific layers: the extent to which these layers are all focused on the same attended situation in the external world. We have also described how we see another mental state – that of absence – as arising from a predominant focus on thoughts, dreams, plans and other internally realized events. In this section we attempt to clarify the relationship between presence and absence, first by considering the relevant phenomena, and then through a discussion of possible and actual ways of measuring them.

3.5.1 The Phenomenology of Presence and Absence

Following Waterworth et al. (2010), we start with presence and its first layer, proto presence. Imagine yourself trying to walk along a rather narrow log to cross a small river. To succeed, you must not be much concerned with the rest of the world around you, the broader surrounding environment, nor with your internal thoughts, plans and reflections. Rather your attention will be focused externally, and especially on the orientation and movement of your body in relation to the very immediate world outside. As an example of a situation where core presence would have a relatively large role, imagine that you have been walking along an undemanding footpath, passing through unexceptional, rather barren, scenery for quite some time. Suddenly, you find yourself on a large, flat, grassy promontory, providing a wide open view of a beautiful valley, hills and a river ahead, with a wonderful sunset in progress. Your attention shifts almost exclusively to the perceptual aspects of the scene before you, and for a while you experience a relatively high degree of core presence. To clarify the phenomenology of extended presence, imagine yourself about to take the final penalty kick in a football match, the outcome of which will determine not only the match, but a major international championship. This is the most important kick of your entire career as a footballer, one that will affect your future and that of your club for years to come. If you succeed in not being distracted by *thinking about* these aspects, the significance of the event will result in an enhanced degree of extended presence while actually taking the kick, adding extra meaning to the perceptual and bodily experiences involved in carrying out the necessary actions successfully.

Presence is maximized when all three layers are integrated around the same external situation. In an awake, healthy animal in the physical world, proto-presence and core presence will rarely if ever be in conflict. This is an aspect of presence in the physical world that is impossible to duplicate with interactive media, since there is always some degree of conflict between these two layers. And there will also almost always be some conflict in an interactive media situation between core presence and extended presence, resulting in less than maximal presence. Because the three layers of presence were added progressively over the course of evolutionary development, all three layers of presence may be engaged by the external but not by the internal world (to which only extended presence applies).

According to our model, absence only exists for organisms possessing the capacity for extended presence, and the combinations of factors are therefore not just the converse of those for absence. We experience maximum presence in a situation where the three layers are integrated around the same content and conscious attention is focused. This situation might occur, for example, when an expert sportsperson performs at her peak. We experience maximum absence when conscious attention is focused but the layers are *not* integrated. An example of this might be when someone is fully engaged in day-dreaming, or in solving a difficult logical problem, while walking along an undemanding footpath. When the layers are integrated but attention is unfocused, less than maximal presence results. An example might be a novice learning a new physical skill. When attention is focused but the layers are not integrated, we would experience less than maximal absence. This could be the case when we are driving a car while simultaneously having a conversation.

3.5.2 On the Measurement of Presence

Viewing presence as a primarily perceptual phenomenon has implications for measurement, which we suggest should focus on three main responses to a mediated experience. Firstly, is there a successful perceptual illusion of being located in the virtual environment? Secondly, do physical measures of brain activity confirm the experience of presence and distinguish presence from other psychological phenomena? And thirdly, does the participant respond appropriately to events in the virtual world?

How do we measure presence conceived as a perceptual illusion? It is not adequate merely to ask a participant in a virtual reality whether she experienced the illusion of being there. Rather, we should look for a way of testing whether features of the display materials were reported in a way that is consistent with actually perceiving the illusion, not just imagining it ("as if"). Familiar examples from perceptual psychology include reports that indicate that equal stimuli are seen as unequal, that motion is perceived in stationary displays, that ever-rising pitch is heard in continuous patterns of sound, or that objectively straight lines are really seen as bent (these and numerous others are discussed in Gregory 1998). It is not that the observer can imagine these things, but that she actually perceives things that way. In other words, we should not ask for an opinion or judgment about whether an illusion is experienced, but rather for a report and/or for behavior that depends on the illusion being experienced.

3.5.2.1 Lessons from Synesthesia

Along with the sense of presence, artificial synesthesia (or sensory cross-over) is often a feature of experiences in virtual reality and other interactive environments, usually as an accidental byproduct, but sometimes by design (Biocca et al. 2001; Waterworth 1997; Waterworth and Fällman 2003). There are other suggestive parallels between presence and the psychological phenomenon of synesthesia, where a stimulus in one modality produces a consistent sensation in that and another modality. Everyone can probably carry out a thought experiment, where they imagine the days of the week, say on a calendar, each having its own color or smell. Or, we could all do the same with a few numbers. For example, you might imagine 1 as yellow, 2 as red, 3 as brown, 4 as blue, 5 as green, and so on, and you might do this fairly consistently on different occasions (if you have a good memory). If you were shown a number by an experimenter, you could name a color, and if you were asked if you experienced the color, you might say that you do (in a sense, you do, because imagining color is an experience). But, of course, unless you really are a natural synesthete of the right variety, you do not really perceive the number as colored! This is an analogous distinction to the one between an imagined scene and a (real or virtual) perceived scene. A true synesthete does not imagine colors in letters or the days of the week, she really perceives them. So it is with all perceptual illusions and so, we suggest, it is with presence. Imagined presence is not presence.

The problem with questionnaires becomes clearer if we consider questioning people about synesthetic experiences. It is well known that many people who are not true synesthetes claim to have such experiences (Cytowic 1989). When asked if they associate the days of the week (or musical notes, or whatever) with colors, they will claim, not entirely falsely, that they do. But this association is not perceptual, it is imaginary or metaphorical. Such questions cannot distinguish between synesthesia and metaphorical thinking. To report such experiences of mental imagery is simply to report "the literary mind" in operation. In the same way, questions about presence cannot distinguish between metaphor and perception, a distinction we believe to be crucial to progress in the field.

The analogy between presence and synesthesia can be taken further, to suggest objective tests of presence. Ramachandran and Hubbard (2001) devised several procedures to distinguish true synesthesia from imagined (metaphorical) number coloring. In one example, a visual display showed a screen-filling array of many small black "5"s on a white background, with a large shape (say, a triangle) made of equal-sized black "2"s embedded in it. If you are not synesthetic it will take you a long time to identify what and where the shape is. For a number-color synesthete, the shape perception is instantaneous, because a triangle (formed by the "2"s, seen as, say, red) will "pop out" against a background of "5"s (seen as, say, green). It is not possible to fake synesthesia with this test, and there is no danger of its being confused with the results of a vivid imagination!

A similar test for presence as perceptual illusion might go like this. An identical room, as far as possible, might be described in text and created in a virtual reality. When the items in the room were "viewed", in imagination or in the VR, from a certain perspective they would form a "hidden" shape of some kind. In the case of the written text, finding the hidden shape would be a slow and mentally demanding process (if possible at all, which is doubtful). In the VR, the shape would "pop out" automatically if the observer is attending to the environment. This test would seem to depend on the difference between conceiving in the imagination and perceiving the environment, between being there and imagining you are there. This is an extreme contrast to bring out the idea. In practice and with different media, time taken to find the hidden shape could potentially serve as a measure of presence.

If presence is, as we suggest, the feeling of involvement with the here and now of the present environment, then an obvious problem with questionnaire administration is its retrospective nature. Observers may not remember the ongoing experience accurately. By their nature and the time of administration, the questions must tap the contents of extended consciousness, what is recalled from the experience, not the core experience itself. We know that memory is affected by emotion in complex ways; remembered experiences may not be accurate reflections of the experience at the time it occurred. As far as possible, we should measure experiences through behaviour as it occurs, which is what we are trying to achieve with some sort of "perceptual pop-out" test.

3.5.2.2 Brain Measures and Action

Several different indicators can be used to measure presence as we define it. It is well established in cognitive neuroscience that there exist two pathways in the brain dealing with the visual perception of the world, as first discovered by Ungerleider and Mishkin (1982). Following Goodale and Milner (1992), Ramachandran and Blakeslee (1998) name these the "how" (or "where") and the "what" pathways – leading from the visual cortex to the posterior parietal cortex and the inferior temporal cortex respectively – and provide many examples of their influence on how the immediately present world is perceived, based on studies in neuropathology. As the names suggest, the "what" pathway tells us only what an object is, while the "where" pathway tells us only where it is. The "where" pathway is centrally concerned with guiding current actions, but to select an appropriate action information from the two pathways must be integrated; a process known as perceptual integration (Allport 1987). We suggest that rapid perceptual integration will be associated with periods of high presence.

Lee et al. (2004) report a study that investigated the importance of these two pathways to the formation of a sense of spatial presence, using functional magnetic resonance imaging (fMRI). Their results support the suggestion that presence can be distinguished from attention per se, and that spatial presence is determined by relatively low level factors, unlike what they term "conceptual presence". They conclude that "Our position on how spatial presence is formed is that it is a product of basically a bottom up perceptual process that gathers spatial cues to actively place and register the user in the seemingly surrounding environment [……..] As for the content factors, we believe that they must be spatial in nature to create synergistic effect with the form factors." (p. 26). Mikropoulos et al. (2004) recorded brain activity by EEG of participants navigating in virtual environments varying in richness of textures and objects. Their main finding was that a decrease in alpha wave[3] activity resulted from increased richness, and corresponded to greater attentional activity and visual awareness. They suggest that "scene realism and information consistent with the real world that are involved in the environment richness and selective attention cause the observed alpha wave decrease in the frontal, parietal and occipital lobes." (p. 264). Similar results were reported earlier by Schier (2000) with a simulated driving task.

We do not believe that such indicators can distinguish between perceiving and acting in virtual worlds and perceiving and acting in the physical world. VR fools the presence mechanism. But it is possible to detect the difference between imagining a world and attending to a perceived external world, whether this is real or virtual. Until recently, it has been common to stress the similarity in brain activity sampled during imagining versus during perceiving. In recent years, however, as brain activity measurements of various kinds have become more sensitive, the differences between the two are increasingly recognized. Bartolomeo (2002) provides a good review of this topic.

[3] Alpha waves indicate activity of the visual cortex in an idle state.

Action is a simpler indicator to interpret: as we have already pointed out, we carry out bodily acts in both real and virtual external worlds, but not in imagined worlds. The extent to which people move their bodies in relation to portrayed events would thus appear to be a remarkably simple measure of presence, and appropriate postural changes have been used in several published studies as corroboration that participants are experiencing presence. Examples include Regenbrecht et al. (1998), Usoh et al. (1999) and Freeman et al. (2000). Neither the fact that some of the same brain areas are activated when imagining an act as when carrying it out, nor even that we may "covertly" carry out some small motor actions when imagining, mean that we do not sense the difference between physically-executed actions and imagined ones.

What of the distinction between mediated presence and non-mediated presence? At the highest levels of presence we would suggest that there is no difference in lived experience between the two. In line with our understanding of Lombard and Ditton's (1997) definition ("the illusion of nonmediation"), we suggest that the more presence we feel in a mediated environment the more we succumb to the illusion that it is not mediated. At the highest levels, we may know, if asked, that our surroundings are not physical, but our lived experience and responses are that they are. This relates to the biological purpose of presence, which we addressed in Sect. 3.4, from which comes the power of mediated presence in psychotherapy, which we considered in Sect. 3.5. In essence, we are suggesting that presence is an evolved mechanism for distinguishing between the physical and the imagined, and that we have no such mechanism for distinguishing between physical and mediated presence. Even if we know conceptually that there is an illusion taking place, our embodied experience is otherwise and is not different in the two cases.

3.5.3 Measuring Absence

We suggest that while the relationship between presence and the judged duration of a test interval is a contentious one (see Waterworth and Waterworth 2006) that of absence and experienced time-in-passing should be more straightforward. Because absence is defined as the processing of internal events, it should be inversely related to the extent of experienced time-in-passing of a given interval. Time seems to pass relatively quickly for us when working memory is heavily loaded, so that attending to information that requires significant conceptual work will tend to result in shorter duration estimates than when the ongoing memory load is lighter, other things being equal, and if the estimates are taken during or immediately after the test interval (Waterworth 1984; see also Flaherty 1999). In future studies, we intent to attempt to corroborate the predictions of our 3-layer model of presence by supplementing various measures of presence, as outlined above, with duration estimates taken as a measure of absence. As already stated, we would predict maximum presence in a situation where the three layers are integrated around the same content and conscious attention is focused. We predict maximum absence when conscious attention is focused but the layers are *not* integrated. When the layers are integrated but attention is unfocused, we predict less than maximal presence. And when attention is focused but the layers are not integrated, we would experience less than maximal absence. See Sect. 3.5.1 (above) for more details.

3.6 Conclusions

In this chapter, we have reprised and clarified our earlier arguments for an evolutionary rationale of the sense of presence (e.g. Riva and Waterworth 2003; Waterworth and Waterworth 2003b) based on the ability to distinguish the internal from the external. As far as we are aware, these were the first explicit attempts to explain the sense of presence from an evolutionary psychological perspective, although many other researchers had pointed to the fact that humans have evolved to perceive three-dimensional space (e.g. Steuer 1992).

From an evolutionary perspective, there are often obvious biological reasons for many of the feelings we experience. We feel hungry so that we will not allow ourselves to starve. We feel the need for sex so that we will perpetuate our genetic heritage. We feel pain when we have been damaged, perhaps so that we won't damage ourselves that way again, and also to ensure that we attend to our own repair. We feel fear when we are in a dangerous situation. We feel presence when we are attending to an externally present world, because we need this information to act adaptively in the world.

For organisms in a natural environment, it is vital to pay attention and respond rapidly to present threats and opportunities. Our emotional life is built on this evolutionary substrate. But as extended consciousness evolved, imagined situations became increasingly important to survival and biological success. Because of this, these imagined situations evoke the same mechanisms of interest and emotion but they do not elicit presence. Presence is the feeling of being bodily in a perceptible, externally-existing world. It was designed by evolution to ensure that organisms attend to the things in their here and now that might affect their survival, even though they use much of the same mental machinery to generate internal worlds and experiences of them. Or rather, they need to feel presence when attending to external worlds *because* they use much of the same mental machinery to generate internal worlds and experiences.

Extended consciousness allows us to imagine almost anything. We often imagine presence in imaginary or fictional situations and, when we do, some of the same psychological processes are activated that allow us to experience an actually present world, including emotional responses. This is sometimes called suspension of disbelief, as when we read a gripping, highly descriptive novel. We have called this mental absence. We may be moved to tears when we read a story, but we do not try to comfort the protagonists because we do not feel their presence in our world, nor our presence in theirs. To be truly present in a world is to feel and act accordingly.

Because of the evolutionary development of the mind, current events from the surrounding external environment are only confused with mentally constructed events in exceptional cases of psychological disturbance. This is true no matter how vivid or emotionally engaging the mentally created world may be. Suspension of disbelief (in a mentally constructed world) is only confused with presence (in an externally surrounding world) when the organism's sensory systems are seriously impaired or artificially "turned off" (see Humphrey 1992; Ramachandran and Blakeslee 1998, Chapter 5). What we are experiencing when we interpret the imagined as the real is hallucination, and is usually indicative of a serious problem for the organism concerned. It is from the experienced distinction between imagined and real presence that the therapeutic potential of presence derives.

In general, organisms must be attentive to relevant perceptions of the current external world in order to carry out successful actions in that world. Action requires information that is not available from imagination. We can see several common psychological problems, for example PTSD, depression, phobia, panic attacks, as examples of a maladjustment of the normal presence mechanism. The power of presence – as we define it – in psychotherapy stems from the ability to override and reset this faulty mechanism. Technologies such as VR that evoke presence in a virtual, but still external, perceived world, have great power to evoke emotional experiences that can lead to psychotherapeutically valuable changes in the individual. The important point is that they appear to be more effective than techniques that rely only on imagination. We suggest that this reflects the power of presence – seen as the feeling of being located in a perceived, external world – in developing and affecting psychological wellbeing. This makes little sense if presence also arises when we focus on imagined worlds and events.

Presence is a result of the necessary combination of form (concrete), content (attracting attention), and consciousness (a feeling, experiencing organism). We see meaning as residing ultimately at the lowest level of concrete embodied experiences of external worlds – in presence – and not in the more abstract, higher level thoughts, reflections and imaginings that constitute our internal world and underlie absence. Our internal worlds and their meanings are built on the foundation of what it feels like to be consciously in a concrete external world, on what it means to be present.

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Chapter 4
Affect, Availability and Presence

Phil Turner

Abstract This chapter is intended to be both theoretical and a little speculative. It draws upon psychological, neuro-dynamic and philosophical sources to create an account of what happens when we experience presence, that is, when we become aware that we are present. This chapter also offers an alternate treatment of the work of Riva and his colleagues with respect to their bio-cultural approach to presence.

Rather than appealing to evolution, biology or technology, this account starts like this: affect precedes cognition. We feel before we think. These feelings (or affective responses) are primarily evaluative and effectively prime our cognition for the world (real or digital) we find ourselves in. All of the apparatus of sense making, reasoning and so forth follow fairly quickly but they are not the first responders. Our affective response is very fast – much faster than our cognition.

In answering the question, how do we find the world, that is, just what is this affective response in response to, we must switch from psychology to philosophy.

Heidegger tells us that we encounter the world as available. Psychology and sense making follow this. We connect with this available world by what Merleau-Ponty calls an intentional arc or intentional threads which "anchor us" to it. This is not simply philosophical discourse as Freeman is able to explain the neuro-dynamics of this arc by invoking the operation of the limbic system – that is, those parts of the brain responsible for our emotional response to the world.

Keywords Affect • Response • Cognition • Intentional impressions • Intentions • Consciousness

4.1 Introduction

Unless we are victims of alien abduction or have taken a powerful psychotropic drug we are not the free-floating, disembodied minds which philosophers have often characterised as a "brain in a vat" – instead we are embodied, situated individuals

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whose mental faculties and bodies are oriented towards dealing effectively with being present in the world. As such this is a good starting point to consider the following two closely related issues. Firstly, the question of whether the *initial* experience of presence is something which we primarily “think” or something we “feel”. By “think”, we mean something which is a product of our cognition (alone). Whereas by “feel” we mean it is an embodied affective response to the world. (*After this initial phase we can assume that presence is a whole body or whole being experience*.) Although thinking and feeling are now regarded as closely related phenomena, presence as the *product* of cognition is quite a different proposition to presence as the *response* of our embedded affective systems.

Secondly, presence is not a synonym for consciousness. Thus while we can happily discuss consciousness *per se*, in that it does not necessarily take a predicate (as in “the patient is now conscious”), the same is not true of presence. When we are present, we are present somewhere in particular, that is to say, presence has content. So the second issue is one of how do we acquire this content. Again, our focus is on the initial acquisition.

Our proposed answer to both questions is that our initial experience of presence is an affective response to the world. Further, this response connects us to the world by what Merleau-Ponty (1945/1962) calls an *intentional arc*. This is not mere philosophical speculation as Freeman (1995) has proposed a neuro-dynamic model of this arc based on the operation of the brain’s limbic system. The limbic system being the seat of our emotional response to the world.

So, that experience of the world we describe as presence is, in the first instance, an affective response which, we shall argue, offers an evaluative priming of our cognition which then goes on to make sense of where we are and what we are doing. This affective response may act as a “bootstrapping” mechanism and is offered as alternate to Riva et al. (2004) proto self/proto-presence proposal. (As we noted in the abstract, this chapter deals with a number of issues which overlap with the Riva bio-cultural account of presence, particularly what they describe as proto-presence. Our intention is not to offer a critique of their work per se, but to highlight evidence and mechanisms which might reasonably contribute in their account.)

4.2 Thinking and Feeling

Many of the definitions and measurements of presence are predicated on what people *feel*, and not what they *think*, about their state or situation. This is not simply an empty convention but an unrecognised reflection of how we encounter and imagine we encounter the world. By *feel*, of course, we can mean quite a variety of things including the nature of our emotional or affective response (to where we are and what we are doing). Feel might also refer to our mood which is a more diffuse affective state but one which is able to colour, for good or ill, any number of other psychological states. Feel can also refer to our beliefs and impressions upon which we rely to make an evaluation, such as, whether or not this is a dangerous place to be.

Finally (at least for the moment) these feelings might also refer to the range of sensations we are experiencing, just as I am having as I *feel* my way around this slippery concept.

For Goldie (2002) emotions involve two kinds of feeling: "bodily feeling and feeling towards. Both are intentional, in the sense of being directed towards an object". Bodily feelings are directed towards the condition of one's body, although they can reveal details about the world beyond one's body. He also notes that *"Feelings are directed towards the object of the emotion – a thing or a person, a state of affairs, an action or an event; such emotional feelings involve a special way of thinking of the object of the emotion"*. In other words, affect is intentional, that is, it is directed at or is in response to something in the world.

Further, this emotional invocation ("how we feel") stands in sharp contrast to the many, complex and elaborate treatments of presence which adopt an essentially cognitive stance. Indeed this is more generally true in that "the cognitive revolution" (of the last 50 or so years), according to Damasio (1999, 2010) has neglected the role of emotions in human and animal behaviour, on the basis of the following assumptions: (i) emotions cannot be trusted; (ii) they are too subjective; and (iii) they are elusive and vague. He continues that because of this, neuroscientists and cognitive scientists have been much more interested in cognitive aspects (i.e. those which can be mapped onto computational accounts) of the mind than in these untrustworthy, elusive and vague processes.

However, our interest here is not concerned with how, why or what we think about the experience of presence but how we feel about it – specifically, our initial impressions or feelings. Just as we greet each other with a "How are you?", that is, an enquiry concerning the state of one's being, we invite the reply "I'm fine / good" which is an affective response. This is another example of the ontological eliciting the affective. With this in mind is it not the case that when we discuss being present we are simply asking, at least in part, a response as to how we feel?

If it is, then we should not be surprised as our affective response to virtual environments is often cited as evidence for the experience of presence itself. For example, there are numerous studies have shown that phobias and stress related disorders can be both induced and treated by way of especially designed virtual environments. There is clear evidence of our affective response and engagement with virtual aircraft, spiders, recreations of terrorist attacks, travelling on tube trains, public speaking, the analgesic effects of snow-filled landscapes, and so forth (e.g. Rothbaum et al. 1996; Carlin et al. 1997; Garcia-Palacios et al. 1998; Bouchard et al. 2005).

4.3 So, to What Is This Affective Response, a Response?

It is our response to the world (real or digital) but by responding to it in this way means that it is not susceptible to a rationalistic answer, that is, we cannot sit back and reflect on it as it is, by this very definition, pre-reflective. Heidegger offers a solution to this, that is, we first encounter the world as *available*. He regards availability as being more *primordial* than any act of perception or act reflecting our embodiment.

Instead, his insight is consistent with the neuro-physiological evidence which supports the position that emotional responses can occur pre-attentively, that is, before the organism has had a chance to analyse or evaluate the incoming stimulus or stimuli (cognitively). LeDoux (1996) has demonstrated that affective reactions cannot be voluntarily controlled, and occur within a matter of a few milliseconds. Further, he argues that the mechanism underpinning this is controlled by a small bundle of neurons that lead directly from the thalamus to the amygdala across a single layer of synapse, allowing the amygdala to receive direct inputs from the sensory organs and initiate a response *before* the stimuli have been interpreted by the neocortex. This has been described as the amygdala "shortcut". In the next section we have a little more to say about affect.

4.4 The Primacy of Affect

Wundt, one of the founding fathers of modern psychology, wrote about the primacy of affect like this:

> When any physical process rises above the threshold of consciousness, it is the affective elements which as soon as they are strong enough, first become noticeable. They begin to force themselves energetically into the fixation point of consciousness before anything is perceived of the ideational elements. … They are sometimes states of pleasurable or unpleasurable character, sometimes they are predominantly states of strained expectation. … the clear apperception of ideas in acts of cognition and the recognition is always preceded by feelings. (Wundt 1897, pp. 243–244, my underlining).

So for Wundt, affect appears before the apperceptive (which we would now describe as *cognitive*) and there is abundant evidence for this. As we shall see many of these are from the study of first impressions.

4.5 First Impression as Intentions in Action

Of the many studies of first impressions, most, though not all, have been concerned with what we make of each other. The first impressions we form of other people allow us to determine accurately and reliably another's: sexual attractiveness (e.g. Berry 2000); sexual orientation (Rule and Ambady 2008); and physical attractiveness (Cunningham 1986). And it's not just about sex – well, it is actually in one way or another, as we also form impressions of people's: trustworthiness (e.g. Basso et al. 2001), political affiliations (Ballew and Todorov 2007), personality (Borkenau et al. 2009), and competence (Cuddy et al. 2008). In short, we form first impressions of those we encounter, finding them attractive, trustworthy, threatening and so forth.

These emotional responses may reflect what Searle (1983) calls *intentions in action*. Interestingly, these responses are not simple like/dislike judgments but are more complex. They can reasonably be interpreted as a means of readying the organism to deal with the world.

First impressions are formed quickly. Zajonc (1980) has demonstrated that stimulus preferences can be elicited with exposure times as low as 1–5 ms. However most first impressions studies have focussed on the 50–500 ms range. Lindegaard and her colleagues (2006), for example, have demonstrated that we are easily able to decide on the aesthetics of webpages in as little as 50 ms – one twentieth of a second. First impressions have also been shown to be reliable and accurate in a variety of test/re-test situations (e.g. Willis and Todorov 2006; Zajonc 1980; Bornstein 1992).

LeDoux (1996) has also suggested that emotional "logic" is at work, concluding that "objects in the world may not necessarily be defined by their objective identity: what matters is how they are perceived" p. 116. Norman (2004) has made similar observations in his account of emotional design (and user experience) the foundational level of which is the visceral. He also describes the visceral level as being pre-reflective and independent of culture (and learning).

Finally, first impressions become lasting impressions (e.g. Gawronski et al. 2010) because, it is thought, that we store expectancy-violating experiences as exceptions-to-the-rule, such that the rule is treated as valid except for the specific context in which it has been violated. Together we seem to be able to form rapid, accurate and reliable impressions of each other in a fraction of a second and well before we before we become consciously aware of these judgments.

4.6 The Evaluative Power of Affect

Having argued that first impressions serve to ready the organism, we can observe that a key purpose of affect – more generally – is to provide an evaluation of the situation or current behaviour to the organism.

Oatley (1992) tells us, "Each goal and plan has a monitoring mechanism that evaluates events relevant to it. When a substantial change of probability occurs of achieving an important goal or subgoal, the monitoring mechanism broadcasts to the whole cognitive system a signal that can set it into readiness to respond to this change. Humans experience these signals and the states of readiness they induce as emotions." (p. 50). A similar case has been made by Damasio (1999) who has argued that emotions offer a means by which the brain monitors the body's past and hypothetical responses, both in the autonomic and the voluntary systems, in terms of "somatic markers". The association of characteristic bodily states with past and hypothetical experiences and responses establishes a connection between the emotion and the world (that was or might have been). Oatley and Johnson-Laird (1987) develop this further by regarding affect as primarily being a means of communication, in that our emotions guide our actions in situations of bounded rationality (in situations of imperfect knowledge and multiple conflicting goals). Our emotions offer this guidance by making available a repertoire of actions which have been previously useful in similar situations, thus emotions effectively guide our actions and decision making (consciously and unconsciously). In conclusion, Schachter and Singer (1962) write that, "The emotional response is hypothesised to prepare and mobilise the person to cope with the particular appraised harm or benefit in an adaptive manner …" (p. 95). They also describe:

> appraisal is an evaluation of what one's relationship to the environment implies for personal well being.

All in all, affect is a credible candidate for evaluating where we find ourselves and "bootstrapping" our sense of presence thereafter. In the next section we move from psychology to philosophy and from affect to availability.

4.7 Availability

Heidegger's (1927/1962) ontology requires us to regard all things in the world as beings – e.g. *book*-beings, *pen*-beings, *cup-of-tea*-beings, *tablet-computers*-being. While this is a little unfamiliar it does remove the fundamental Cartesian assumption of subject and object. Instead, we *encounter* other beings but this is not to suggest that these beings have intelligence or sentience but that an everyday ontological examination of chairs would be into their chair-ness for me. The everydayness of a chair is its availability for sitting on, or standing on, or smashing to pieces in despair over falling academic standards and so on.

Dreyfus describes this interaction as "skilful engagement" (Dreyfus 1991). Dreyfus and Wrathall (2005, p. 4) write, "we first encounter worldly things as available. Something is available when (1) it is defined in terms of its place in a context of equipment, typical activities in which it is used, and typical purposes and goals for which it is used, and (2) it lends itself to such use readily and easily without need for reflection. The core case of availability is an item of equipment that we know how to use and that transparently lends itself to use". For Heidegger, all human activity is located in vast, inter-related array of tools and equipment. For example, I am writing this at my desk, in my study at home. On the desk is my laptop computer, all around me are my academic papers and books, to my right is a coffee cup and to my left are some of my fossils (including a mammoth tusk from the North Sea). By the above definition, all of these items are available to me, as they are proximal and ready-to-hand and comprise one of my preferred working environments. However, in addition to these physically proximal entities, I have a wireless Internet link which connects me to a range of services and the rest of the world. So, readiness-to-hand is a matter of experience, or of how I encounter the world rather than location in physical space. Indeed readiness-to-hand is also a very good description of the affordances available to Dasein (Gibson 1986). And as has been suggested, this initial encounter with the World as available may be affective in character.

4.8 Affordance

This Heideggerian perspective moves us away from thinking in terms of listing the discrete properties of things, to how we encounter these things as tool-beings (Harman 2002). Re-casting this slightly, we can say that we encounter the world as a network of inter-connected affordances. Gibson describes an affordance in a similar kind of way, for example, when he writes “An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behaviour. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer” (Gibson 1986, p. 129). Thus affordance is not a property of a tool but how we encounter that tool. While this all appears rather functional, and rather confined to manual labour, tools for enjoying ourselves and for having fun are no different. However, since Gibson first introduced the concept, it has been developed in a variety of ways particularly by ecological psychology (e.g. Warren 1984; Turvey 1992) and human-computer interaction communities (e.g. Norman 1988, among very many).

Finally, there is also substantial evidence from studies of the neural basis of perception and action, for example, positron emission tomography has shown that those parts of the brain responsible for motor representation are activated in response to the perception of the affordances of objects. Grèzes and Decety (2002, p. 212) concluding that “perception of objects automatically affords actions that can be made towards them”. It may be that availability has its origins with the ways in which we first encounter the world. Although Heidegger does not directly address the issue of our corporeality or embodiment, it is evident that we first encounter the limits of the scope of what is available to our bodies. This progresses from encountering our own hands (through, for example, sucking our thumbs) and the body of our mother to all manner of external objects (beings) to the internalisation of these actions to form what we experience as cognition (e.g. Piaget and Inhelder 1956; Piaget 1963, 1973).

In summary, our initial affective response to the world is to recognise its affordances and from this the experience of being present follows (cf. Zahorik and Jenison 1998). However we still need to say a little more about the intentionality itself.

4.9 The Neuro-dynamics of Intentionality

It is Brentano (1874) who is usually credited with reviving interest in intentionality. He recognised that very many of our mental states (including attitudes, affective states and so forth) are directed towards things in the world. Brentano defining intentionality as the main characteristic of mental phenomena and the means by which they could be distinguished from physical phenomena.

Before embarking on a discussion of intentionality proper, we should begin by distinguishing it from intending, or from having intentions. Intentionality is derived from the Latin *intentio*, from *intendere*, meaning being directed towards some goal or thing. In a widely quoted passage, Brentano writing that, “Every mental phenomenon is characterized by what the Scholastics (Medieval Christian philosophers) of the Middle Ages called the intentional (or mental) inexistence of an object, and what we might call, though not wholly unambiguously, reference to a content, direction towards an object (which is not to be understood here as meaning a thing), or immanent objectivity. In presentation something is presented, in judgement something is affirmed or denied, in love loved, in hate hated, in desire desired, and so on” (1995, p. 88). The obscure expression “the intentional (or mental) inexistence of an object” simply refers to the mental state of being ‘in’ the mind.

4.10 The Intentional Arc

More recently, Merleau-Ponty in his *Phenomenology of Perception* (1945) has further revived interest in intentionality by applying it to include what we would now describe as embodiment. He argued that it is only though our lived bodies that we have access to what he describes as the *primary world*. Without our bodies there could be no world (for us). The lived body is central to his account of *corporeal intentionality*. Merleau-Ponty rejects the standard Cartesian mind-body distinction wherein we have intentional mental states about things “out there”, instead he argues that the world and the lived body together form what he calls an *intentional arc* which binds the body to the world. This intentional arc ultimately comprises the knowledge of how to act in a way that “coheres” with one’s environment bringing body and world together. This arc anchors us in and to the world. He writes, “the life of consciousness – cognitive life, the life of desire or perceptual life – is subtended by an ‘intentional arc’ which projects round about us our past, our future, our human setting, our physical, ideological and moral situation” (ibid, 352). A description which resonates with our introductory description of being present.

However, Merleau-Ponty also recognised the role of the world (environment) when he wrote, “*To move one’s body is to aim at things through it; it is to allow oneself to respond to their call*” (*ibid*, 139). Specifically the movement of the lived body creates (produces) existential space. In essence he envisaged a reciprocal relationship between the embodied self and the world. The world can only be accessed by way of the body. This kinaesthetic feedback is the means by which we both objectify the world and orient ourselves within it. To orientate ourselves is to adopt an external point or frame of reference. Thus we need bodies to both actively create the world and to orientate and “prehend” ourselves within it.

At this point we consider Freeman’s neurological account of this intentional arc which involves the operation of the limbic system. While our affective response to the world involves the entire nervous system, it is the limbic system which is of primary significance. The limbic system is a complex set of structures which includes the hypothalamus, the hippocampus, the amygdala, the entorhinal cortex and so forth. It addition to being responsible for our emotional response to the world it is strongly implicated in memory formation and wayfinding (i.e. making sense of being in the world). We have, of course, already discussed a role of a key element of the limbic system, namely, the amygdala in the creation of first impression but Freeman's account of the neuro-dynamics of intentionality is significantly more detailed and substantial.

Figure 4.1 is Freeman's architecture of the limbic system and the proposed neurological basis of intentionality. Freeman (1999) tells us that input from the visual, auditory, somaesthetic and olfactory cortices converge, via the entorhinal cortex, on the limbic system, where they are integrated. He goes on to cite work which indicates that the same forms of neural activity as those found in these sensory cortices are found in various parts of the limbic system. From this he hypothesizes that the limbic system has the capacity to create its own spatio-temporal patterns of activity. These are embedded in past experience and a variety of sensorial input, but they are self-organized. Thus the limbic system is able to provide a continuous pattern of neural activity that form goals and direct behaviour toward them. This then is the (hypothesized) neural basis of intentionality.

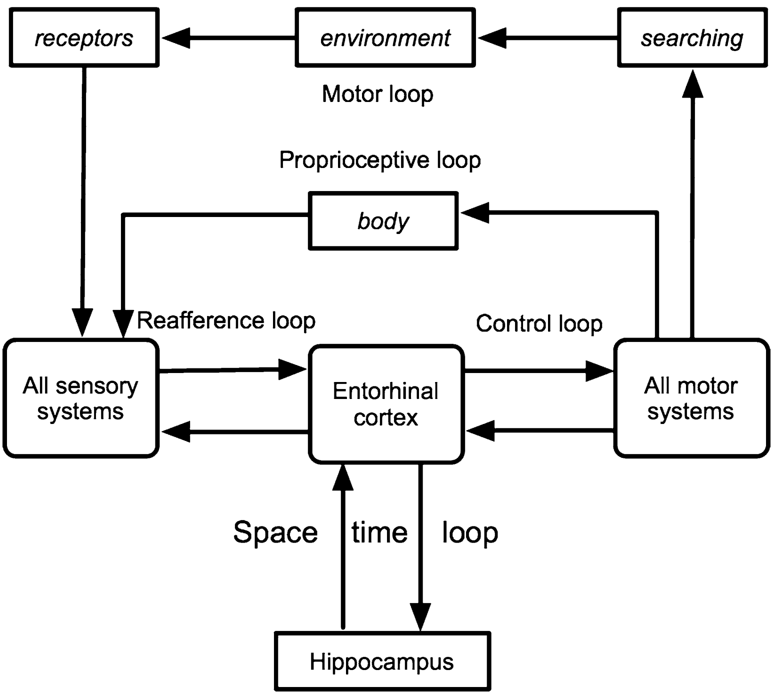

Fig. 4.1 The dynamic architecture of the limbic system (Redrawn after Freeman 1999, p. 150)

He argues that the dynamics of the limbic system operate by means of the multiple loops (as illustrated above). Freeman proposes that intentional action is created by the anti-clockwise flow of activity around the loops into the body and the world, comprising "implicit cognition, and that awareness and consciousness are engendered by clockwise flow within the brain, comprising explicit cognition" (p. 150). This pattern of interaction is transmitted to the brain constitutes a control loop. A complementary patterns of activation created by our bodily engagement with the environment – the motor loop. This interplay of inward and outward flowing loops prompting us to recall Merleau-Ponty's remarks about the body creating and orienting itself within the world. This account, while the language is a somewhat different, is congruent with Riva et al.'s (2004) proto presence/proto self proposal but differs in that it foregrounds the roles of environment and affect.

4.11 Discussion

When Riva and his colleagues posed the question, "What is the purpose of presence?", they sought to answer this from an evolutionary perspective and with reference to the work of Damasio. They began by noting that "*the human psyche has evolved as a device for dealing with individual and social problems in the ancient environment …*" and "*the appearance of the sense of presence allows the nervous system to solve a key problem for its survival: how to differentiate between internal and external states*". Either presence is merely an emergent property of the particular configurations of our nervous systems, that is, it has evolved for no particular purpose or it has some evolutionary advantage. They concluded quite reasonable, that there is an advantage to it – not least it has kept academics (usefully) employed for decades.

They went on to propose that though presence is a unitary experience that it has a tripartite structure reflecting the proposed three-part structure of the self as proposed by Damasio. These comprise proto-, core and extended layers of selfhood and presence.[1] The simplest, oldest and most fundamental aspect of self and presence being described as "proto self"/"proto presence". They define "*proto presence as an embodied presence related to the level of perception-action coupling (self vs. non-*

[1] It should be noted that in their more recent treatments of presence, Riva and Waterworth have modified and significantly extended their position. For example, they treat extended presence as, "*related to the emergence of the extended self: the intuitive perception of successfully acting in the external world towards a possible object*" (Riva and Waterworth 2013, p. 207).

From this short quotation we can see that they propose that presence is intuitive and is concerned with goal-directed behaviour. By *intuitive*, they mean that the experience of presence, as a product of our cognition, does not require conscious deliberation while the term *object* carrying with it the suggestion of objective, motivation and, possibly, intentionality. Here presence is seen to have an evaluative role, providing the organism with feedback on how it is doing with regard to achieving its object or goals. Riva and Waterworth have also suggested a neurological mechanism for this involving a particular form of simulation theory (cf. Blackemore and Decety 2001).

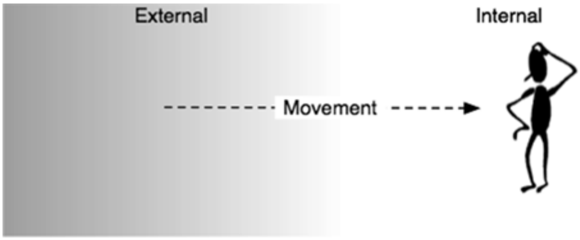

Fig. 4.2 Proto presence (Reproduced with kind permission from Riva et al. 2004, p. 409)

self). The more the organism is able to couple correctly perceptions and movements, the more it differentiates itself from the external world …" (p. 409–410). While fully agreeing with their position, it does seem a little under-described. For example, we have argued that we initially experience the world not just pre-reflectively but specifically affectively.

Secondly, as can be seen from Fig. 4.2, which has been reproduced from their account, and in common with much of presence research, they have reduced the richness of the real or virtual environment to a grey mist labelled "external".

In contrast, this chapter has presented a case for the role of "external" as providing the of-*ness* or about-*ness* of presence. Presence is about being present somewhere engaged in something or other. This, importantly, defines presence an *intentional* state.

Further, an argument has also been made that the "movement" in the above figure should be recognised as bi-directional and comprising complementary loops of sensory input and motor control – not just "movement". We have presented a brief overview of Freeman's account of the operation of the limbic system/intentionality as a potential candidate for this bi-directionality.

Finally, if it is recognised that presence is indeed intentional,[2] that is, it is about something then we need an account of this something. Thus there is a need for significant, affordance-rich detail to be added to both treatment of the external and virtual worlds.

In closing we note that cognition – in whatever form – whether it is "traditional", embodied, extended, distributed or external, involves representation – that is, something standing for something else. This necessarily requires us to consider the nature of this representation and how it is created, manipulated and interacted with (by our cognition). Affect, in contrast, makes no attempt to represent reality instead it is our <u>response</u> to it and as such offers quite a different and more direct perspective to presence than cognition can.

[2] To illustrate the importance of recognizing presence as intentional it is worth contrasting it with a non-intentional state. One such non-intentional state is *anxiety*. Anxiety is, by definition, a sense or state of nervousness or unease about something uncertain or ill-defined, for example, "I am anxious about the state of the world". Presence is about feeling one is somewhere or engaged with something in particular.

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Chapter 5
Intention, Action, Self and Other: An Evolutionary Model of Presence

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Abstract The term "presence" entered in the wide scientific debate in 1992 when Sheridan and Furness used it in the title of a new journal dedicated to the study of virtual reality systems and teleoperations: Presence, Teleoperators and Virtual Environments. Following this approach, the term "presence" has been used to describe a widely re-ported sensation experienced during the use of virtual reality. The main limitation of this vision is what is not said. What is presence for? Is it a specific cognitive process? To answer to these questions, a second group of researchers considers presence as a broad psychological phenomenon, not necessarily linked to the experience of a medium, whose goal is the control of the individual and social activity. In this chapter we support this second vision, starting from the following broad statements: (a) the psychology of presence is related to human action and its organization in the environment; (b) the psychology of presence is related to the body and to the embodiment process; (c) presence is an evolved process related to the understanding and management of the causal texture of both the physical and social worlds. In the following paragraphs we will justify these claims and underline their relevance for the design and usage of interactive technologies.

Keywords Evolutionary psychology • Activity theory • Presence • Action • Intentionality • Self • Consciousness

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5.1 Introduction

The term "*presence*" entered in the wide scientific debate in 1992 when Sheridan and Furness used it in the title of a new journal dedicated to the study of virtual reality systems and teleoperations (Coelho et al. 2006): *Presence, Teleoperators and Virtual Environments.* In the first issue of the journal, Sheridan (1992): describes presence as "the effect felt when controlling real world objects remotely" as well as "the effect people feel when they interact with and immerse themselves in virtual environments" (pp. 123–124).

Following this approach, the term "presence" has been used to describe a widely reported sensation experienced during the use of virtual reality. However, as commented by Biocca (1997), and agreed by most researchers in the area, "while the design of virtual reality technology has brought the theoretical issue of presence to the fore, few theorists argue that the experience of presence suddenly emerged with the arrival of virtual reality." Rather, as suggested by Loomis (Loomis 1992), presence may be described as a basic state of consciousness: the attribution of sensation to some distal stimulus, or more broadly to some environment.

Due to the complexity of the topic, and the interest in this concept, different attempts to define presence and to explain its role are available in the literature. In general, as underlined by Lombard and Jones (2006): "the first and most basic distinction among definitions of presence concerns the issue of technology." (p. 25).

One group of researchers describe the sense of presence as "Media Presence", a function of our experience of a given medium (IJsselsteijn et al. 2000; Lombard and Ditton 1997; Loomis 1992; Marsh et al. 2001; Sadowski and Stanney 2002; Schloerb 1995; Sheridan 1992, 1996). The main result of this approach are the definitions of presence such as the "*perceptual illusion of non-mediation*" (Lombard and Ditton 1997) produced by means of the disappearance of the medium from the conscious attention of the subject. The main advantage of this approach is its predictive value: the level of presence is reduced by the experience of mediation during the action. The main limitation of this vision is what is not said (Waterworth et al. 2012). What is presence for? Is it a specific cognitive process? What is its role in our daily experience? It is important to note that these questions are unanswered even for the relationship between presence and media. As underlined by Lee (2004b) "Presence scholars, may find it surprising and even disturbing that there have been limited attempts to explain the fundamental reason *why* human beings can feel presence when they use media and/or simulation technologies." (p. 496).

To answer to these questions, a second group of researchers considers presence as "Inner Presence", a broad psychological phenomenon, not necessarily linked to the experience of a medium, whose goal is the control of the individual and social activity (Baños et al. 1999, 2000; Lee 2004a, b; Mantovani and Riva 1999; Marsh et al. 2001; Moore et al. 2002; Riva 2011; Riva and Davide 2001; Riva et al. 2003a, b, 2014; Riva and Mantovani 2012a, b; Riva and Waterworth 2014; Schubert et al. 2001; Spagnolli and Gamberini 2002; Spagnolli et al. 2003; Waterworth and Waterworth 2001, 2003; Waterworth and Waterworth et al. 2012; Zahoric and Jenison 1998). In this chapter we support this second vision, starting from the following broad statements:

- *The psychology of presence is related to human action and its organization in the environment* (Mantovani and Riva 1999; Marsh 2003; Riva et al. 2003a). As suggested by Zahoric and Jenison (1998), "Presence is tantamount to successfully supported action in the environment… Successfully supported action in the environment is a necessary and sufficient condition for presence." (pp. 79–80).
- *The psychology of presence is related to the body and to the embodiment process* (Biocca 1997; Biocca and Nowak 2001; Riva 2006; Riva et al. 2014). As expressed by Biocca (1997) "before paper, wires, and silicon, the primordial communication medium is the body. At the center of all communication rests the body, the fleshy gateway to the mind… Thinking of the body as an information channel, a display device, or a communication device, we emerge with the metaphor of the body as a kind of simulator for the mind." (Online: http://onlinelibrary.wiley.com/doi/10.1111/j.1083-6101.1997.tb00070.x/full).
- *presence is an evolved process related to the understanding and management of the causal texture of both the physical and social worlds* (Lee 2004a, b; Riva and Waterworth 2014). As underlined by Lee "the knowledge of the causal texture of both the physical and social worlds should be innate, or at least developed very rapidly after birth (probably within the first 3 or 4 years). The lack of innate or very rapidly acquired knowledge of the causal structure of both the physical and social worlds poses an enormous survival threat to humans" (p. 498).

In this chapter we attempt to provide a more elaborate – and probably controversial – account of the fundamental presence-enabling mechanisms. Recent research in neuroscience has tried to understand human action from two different but converging perspectives: the cognitive and the volitional. On one side, cognitive studies analyze how action is planned and controlled in response to environmental conditions. On the other side, volitional studies analyze how action is planned and controlled by the subject's needs, motives and goals. In this chapter we suggest that presence is the missing link between these two approaches. Specifically, we consider presence as a neuropsychological phenomenon, evolved from the interplay of our biological and cultural inheritance, whose goal is the control of agency and social interaction through the unconscious separation of both "internal" and "external", and "self" and "other" (Inghilleri et al. 2015; Riva 2007, 2009; Riva et al. 2014).

5.2 The Theoretical Background

5.2.1 Evolution and Presence

Several recent authors, perhaps most influentially the neurologist Antonio Damasio, the philosopher Daniel Dennett, and the cognitive psychologist Steven Pinker, discuss in detail how human psychological characteristics, including emotional responses to various situations, have come to be shaped by evolutionary forces. An integral part of this contemporary psychological stance is to assume that the mind is not (in most respects) a computer-like disembodied processor of information.

Rather, the modern mind reflects the evolutionary history of humankind, of long heritage of embodied organisms striving to survive in competitive physical environments.

According to Bereczkei (2000), the evolutionary approach to psychological phenomena entails recognizing certain features of human behavior that have been designed by natural selection to be useful for survival and reproduction in the environments and situations in which humankind evolved. Using this approach, we can explain a wide variety of seemingly different behaviors and support a new kind of understanding of human nature. Within this vision, an evolved psychological mechanism can be described (Buss 1995) as a set of processes inside an organism that:

- Exists in the form it does because it (or other mechanisms that reliably produce it) solved a specific problem of individual survival or reproduction recurrently over human evolutionary history.
- Takes only certain classes of information or input, where input can be (a) either external or internal, or (b) actively extracted from the environment or passively received from the environment, and (c) where the input specifies to the organism the particular adaptive problem it is facing
- Transforms that information into output through a procedure (e.g., a decision rule) in which output (a) regulates physiological activity, provides information to other psychological mechanisms, or produces manifest action and (b) solves a particular adaptive problem.

If many researchers have no problem in accepting that some key psychological features are the result of some evolutionary process, most are less ready to accept the application of the same approach to presence (Biocca 1992; Lee 2004b). As suggested by Crook (1980), humans evolved specific psychic processes, defined as awareness of the external world and awareness of one's own internal state. The symbolic representations of the external world and of individuals themselves were formalized by means of descriptions and behavioral rules stored in the individual's central nervous system (intrasomatic level) and in material tools, books, and artistic and religious artifacts (extrasomatic level).

Within this vision, we suggest that the ability to feel "present" in a virtual reality system – an artifact – basically does not differ from the ability to feel "present" in the real world. One of the main ideas expressed in this chapter is the link between presence and its evolutionary role. In more detail, we suppose that presence is an evolved psychological mechanism, created by the evolution of the central nervous system, whose goal is the *enaction* of the volition of the subject.

Varela and colleagues (1991) define "*enaction*" in terms of two intertwined and reciprocal factors: first, the historical transformations which generate emergent regularities in the actor's embodiment; second, the influence of an actor's embodiment in determining the trajectory of behaviors. As suggested by Whitaker (1995) these two aspects reflect two different usages of the English verb "enact". On one side is "to enact" in the sense of "to specify, to legislate, to bring forth something new and determining of the future", as in a government enacting a new law. On the other side is "to enact" in the sense of "to portray, to bring forth something already given and determinant of the present", as in a stage actor enacting a role (online: http://www.enolagaia.com/RW-ACM95-Main.html).

In line with these two meanings, presence has a dual role:

- First, presence "locates" the self in an external physical and/or cultural space: the Self is "present" in a space if he/she can act in it
- Second, presence provides feedback to the Self about the status of its activity: the Self perceives the variations in presence and tunes its activity accordingly.

In the following paragraphs we will flesh out these claims.

5.2.2 Embodied Cognition: Linking Action and Perception

The *Embodied Cognition* paradigm takes as its starting point the idea that cognition occurs in specific environments, and for specific ends (Clark 1997, 2001; Haugeland 1998). Moreover, the *Embodied Cognition* approach underlines the central role of the body in shaping the mind (Clark 2001, 2003; Gallagher 2005; Gallese and Lakoff 2005; Garbarini and Adenzato 2004; Lakoff and Johnson 1980; Ziemke 2003). Specifically, the mind has to be understood in the context of its relationship to a physical body that interacts with the world. Hence human cognition, rather than being centralized, abstract, and sharply distinct from peripheral input and output modules, has instead deep roots in sensorimotor processing. This approach has been applied to the design of interactive systems in recent years, under the rubric of *Experiential Design* (e.g. Waterworth et al. 2003).

An emerging trend within embodied cognition is the *analysis of the link between action and perception*. According to this approach, action and perception are more closely linked than has traditionally been assumed: *perception is a means to action and action is a means to perception.* Specifically, for the *Common Coding Theory* (Hommel et al. 2001), the cognitive representations for perceived events (perception) and intended or to-be generated events (action) are formed by a common representational domain: actions are coded in terms of the perceivable effects they should generate. For this reason, when an effect is intended (*intention*), the movement that produces this effect as perceptual input is automatically activated, because actions and their effects are stored in a common representational domain.

This theory has received strong empirical support from neurological data. Different researches have shown that cortical premotor areas contain neurons that respond to visual, somatosensory, and auditory stimuli (Gallese 2000a, 2005; Rizzolatti et al. 1997). Further, the pre-motor and parietal areas, rather than having separate and independent functions, are neurally integrated not only to control action, but also to serve the function of building an integrated representation. In particular, as underlined by Gallese (2000b) "the so-called 'motor functions' of the nervous system not only provide the means to control and execute action but also to represent it." (p. 23).

This conclusion – that is very close to the claims of *Common Coding Theory* – is the outcome of a long series of experiments of single-neuron recordings in the premotor cortex of behaving monkeys (Rizzolatti et al. 1996, 1998). In particular, Rizzolatti and colleagues discovered that a functional cluster of premotor neurons (F5ab-AIP) contains "*canonical neurons*", a class of neurons that are selectively activated by the presentation of an object as a function of its shape, size, and spatial orientation (Gallese 2000a, 2005; Rizzolatti et al. 1997). Specifically, these neurons fire during the observation of objects whose features – such as size and shape – are strictly related to the type of action that the very same neurons motorically code. Further, the *canonical neurons* are activated not only by observing the same object, but also by observing a group of objects that have the same characteristics, in terms of the type of interaction they allow. Two aspects of these neurons are important (Gallese and Lakoff 2005; Rizzolatti et al. 2000). On one side, what correlates with their discharge is not simply a movement (e.g. opening the mouth), but an action, that is, a movement executed to achieve a purpose (e.g. tear apart an object, bring it to the mouth). Second, a critical feature for the discharge is the purpose of the action, and not some dynamic details defining it, like force, or movement direction.

In a different cluster (F4-VIP) Rizzolatti and colleagues (Fogassi et al. 1996; Rizzolatti et al. 1997) identified a class of neurons that are selectively activated when a monkey heard or saw stimuli being moved in their peri-personal space. The same neurons discharge when the monkey turns its head toward a given location in peri-personal space. A possible explanation of this dual activation is that these neurons simulate the action (head-turning) in the presence of a possible target of action seen or heard at the same location (Gallese and Lakoff 2005). The existence of these functional clusters of neurons suggests that a constitutive part of the representation of an object is the type of interaction that is established with the object itself. In other words, different objects can be represented as a function of the same type of interaction allowed by them.

These experimental data match well with the *Converged Zone Theory* proposed by Damasio (1989), which has two main claims. First, when any physical entity is experienced, it activates feature detectors in the relevant sensory-motor areas. During visual processing of an apple, for example, some neurons fire for edges and planar surfaces, whereas others fire for color, configural properties, and movement. Similar patterns of activation in feature maps for other modalities represent how the entity might sound and feel, and also the actions performed on it. Second, when a pattern becomes active in a feature system, clusters of conjunctive neurons (*convergence zones*) in association areas capture the pattern for later cognitive use. As shown also by the data collected by Rizzolatti, a cluster of conjunctive neurons codes the pattern, with each individual neuron participating in the coding of many different patterns.

Another consequence of the link between perception and action is that *observing actions or action effects produced by another individual may also activate a representation of one's own actions*. This assumption, too, has recently been confirmed from the outcome of experiments of single-neuron recordings in the premotor cortex of behaving monkeys (Rizzolatti et al. 1996, 1998). Specifically, Rizzolatti and colleagues discovered that a functional cluster of premotor neurons (F5c-PF) contains "*mirror neurons*", a class of neurons that are activated both during the execution of purposeful, goal-related hand actions, and during the observation of similar actions performed by another individual (Gallese et al. 1996; Rizzolatti and Arbib 1998; Rizzolatti et al. 1996). Different brain-imaging experiments demonstrated in humans the existence of a mirror system in the premotor and parietal areas – similar to that observed in monkeys – matching action observation and execution (Buccino et al. 2001; Decety and Grèzes 1999; Iacoboni et al. 1999). Further, a recent study showed that a similar process happens with emotions: observing an emotion activates the neural representation of that emotion (Wickham 1994). In the experiment, a group of male subjects observed video clips showing the emotional facial expression of disgust. Both observing such faces, and feeling disgust, activated the same sites in the anterior insula and to a lesser extent in the anterior cingulate cortex. Finally, the results of three studies by Keyser and colleagues (2004) showed that the first-person subjective experience of being touched on one's body activates the same neural networks in the secondary somatosensory cortices activated by observing the body of someone else being touched.

The general framework, outlined by the above results, suggests the sensory-motor integration supported by the mirror matching system instantiates neural activations utilized not only to generate and control goal-related behaviors, but also to map the goals and purposes of others' actions (Barsalou 2003; Gallese 2004, 2005; Gallese and Lakoff 2005). This process establishes a direct link between one's being and other beings, in that both are mapped in a neutral fashion: the observer uses her/his own resources to directly experience the world of the other by means of an unconscious process of motor resonance.

5.2.3 From Cognitive to Volitional: The Activity Theory Perspective

As we have suggested earlier, cognitive studies analyze how action is planned and controlled in response to environmental conditions, whereas volitional studies analyze how action is planned and controlled by subject's needs, motives and goals. How can the two be integrated?

One of the most interesting answers to this question comes from the work of the Russian psychologists Vygotsky and Leontjev. According to these authors – usually labeled as *Activity* theorists – consciousness is not a set of discrete disembodied cognitive acts (decision making, classification, remembering…) and certainly it is not the brain; rather consciousness is located in everyday practice: you are what you do (Nardi 1996). Within this framework, any action is strictly related to the general and specific goals of the subject (intentionality). As underlined by Ryder (1998): "In its simplest terms, an *activity* is defined as the engagement of a subject toward a certain goal or objective. In nature, an activity is typically unmediated. Picking a berry from a bush and eating it is a simple, unmediated activity that involves direct action between the subject and object. In most human contexts our activities are mediated through the use of culturally established instruments, including language, artifacts, and established procedures. Picking mushrooms in the forest and eating them is an activity that is ill-advised without some form of mediation. Our subject would prudently appropriate some prior knowledge – a field guide, prior education in mycology, the direct advice of an experienced mushroom forager, or some other embodiment of human experience with mushrooms. Some means is necessary to bring the prior experience of history into the current activity. Animals have only one world, the world of direct objects and situations, mediated only through instinct. Humans have the vicarious worlds of other humans that they can invoke into the present through the use of language and artifacts" (http://carbon.cudenver.edu/~mryder/iscrat_99.html).

According to this view, any activity is undertaken by a subject (actor) – who is oriented towards a specific intention (object) – and it is always mediated by physical and social tools (artifacts). Activity Theory goes further in analyzing the action process. In particular, Leontjev (1981) distinguished, within the general activity of the subject, three different levels.

Activity is the highest level: the direct answers to a specific objective of the subject. The activity of the subject moves toward the object of a specific need and terminates when it is satisfied. Specifically, an objective is a process characterizing the activity as a whole. For example, in reference to Fig. 5.1, the activity is to obtain a Ph.D. in Psychology. Any objective is closely related to a need/motive – e.g. helping others to solve their problems – and both have to be considered in the analysis of activity.

Each activity is then translated into reality through a specific or a set of *actions*. Each action is a process performed with conscious thought and effort, planned and directed towards achieving a *goal*. In reference to Fig. 5.1, the activity – obtain a Ph.D. – is translated into a set of actions: going to the library to search for the

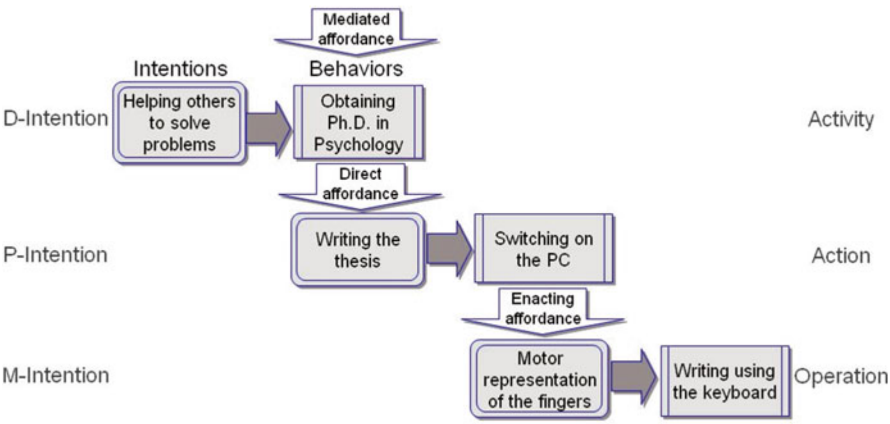

Fig. 5.1 The three activity levels and their link with the intentional chain

sources, preparing an index, discussing it with the tutor, etc. Each action can be then split in sub-activities, each related to a sub-goal: searching for the books about psychology of media, writing the structure of the first chapter, etc..

Actions and sub-actions are developed through *operations*: if actions are connected to conscious goals, operations are related to behaviors performed automatically. In reference to Fig. 5.1, the operation of typing when preparing the index of the dissertation is done automatically, without a conscious focus on the movement of the fingers. All the operations, however, are oriented by some *conditions*: specific constrains and affordances related to the characteristics of a given tool – such as the position of the keys on the keyboard – that influence the outcome of the operation.

The consciousness of the conditions of a given tool is what distinguishes actions and operations. When we learn how to use a new tool, its conditions are addressed with deliberate and conscious attention: they require actions. For instance, the first time one types, one has to consciously check the position of the letters on the keyboard. When the activity becomes well practiced and experienced, actions do not need to be planned but are performed without conscious thought or effort: actions become operations. The opposite process is also possible: operations become actions when the original conditions are violated. For instance, if something breaks down – pressing the key does not visualize the given letter on the screen – and/or impedes execution, the subject has to consciously address (goal) the new situation using an action.

The next step of the analysis offered by *Activity Theory* is related to the link between the user and the tool. Mastering a tool has two effects for the user (Kaptelinin 1996). First, the tool becomes transparent to the activity of the user: its conditions are handled automatically by the operations. Second, the tool is experienced as a property of the user: it complements or supports the user's abilities improving the efficacy of the activity. Marsh (2003) provides the following example to clarify this point: "For example, a builder uses a saw to cut wood, a hammer fixes nails and joins wood, etc. In normal use, the saw and hammer become an extension of the builder rather than belonging to the external world. Consequently, the builder is able to focus on cutting the wood or driving the nail and not on the operations of (or reflect on) the saw and hammer in use." (p. 88). The main limitation of the *Activity Theory* is in its descriptive focus. As noted by Nardi (1996): "Activity theory is a powerful and clarifying descriptive tool rather than a strongly predictive theory" (p. 6).

5.2.4 From Volitional to Cognitive: The Dynamic Theory of Intentions

Both the *Embodied Cognition* approach and *Activity Theory* include intentional states in their models. But what is an intention? What is it to do something intentionally? How we can read the intentions underlying the behaviour of others?

If we check the literature on this topic we can find two different definitions of intention (Malle et al. 2001):

- intention as a *property of all mental state*s. In such a perspective any subjective, conscious experience – no matter how minimal – is an experience *of* something.
- intention as an *act concerning and directed at some state of affairs in the world*. In this sense, individuals deliberately perform an action in order to reach a goal.

The link between these two definitions is the idea that a mental representation has been formed to accomplish a task or direct behavior to achieve some desired state in the world (Sebanz and Prinz 2006). This view corresponds to the folk psychology definition of intention: given an agent performing an action, the intention is his/her specific purpose in doing so. However, the latest cognitive studies clearly show that any action is the result of a complex intentional chain that cannot be analyzed at a single level (Pacherie 2006, 2008; Searle 1983).

The *Dynamic Theory of Intentions* presented by Pacherie (2006, 2008; Castelfranchi 2014) identifies three different "levels" or "forms" of intentions, characterized by different roles and contents: distal intentions (D-intentions), proximal intentions (P-intentions) and motor intentions (M-intentions):

- *D-intentions (Future-directed intentions)*. These high-level intentions act both as intra- and interpersonal coordinators, and as prompters of practical reasoning about means and plans: in the activity "obtaining a Ph.D. in psychology" described in Fig. 5.1, "helping anorexic girls" is a D-intention, the object that drives the activity of the subject.
- *P-intentions (Present-directed intentions)*. These intentions are responsible for high-level (conscious) forms of guidance and monitoring. They have to ensure that the imagined actions become current through situational control of their unfolding: in the activity described in Fig. 5.1, "preparing the dissertation" is a P-intention.
- *M-intentions (Motor intentions)*. These intentions are responsible for low-level (unconscious) forms of guidance and monitoring: we may not be aware of them and have only partial access to their content. Further, their contents are not propositional: in the activity described in Fig. 5.1, the motor representations required to move the pen are M-intentions.

Any intentional level has its own role: *the rational (D-intentions), situational (P-Intention) and motor (M-Intention) guidance and control of action*. They form an intentional cascade (Pacherie 2006, 2008) in which *higher intentions generate lower intentions.*

More, recent cognitive studies on our representation of external space demonstrated that tool-mediated actions modify the multisensory coding of near peripersonal space (the space within reach of any limb of an individual): the active use of a tool to physically and effectively interact with objects in the distant space appears to produce a spatial extension of the multisensory peri-hand space corresponding to the whole length of the tool (Farné et al. 2007; Gamberini et al. 2008; Riva and Mantovani 2012b). In other words, through the successful enaction of his/her intentions using the tool, the subject becomes physically present in the tool (Riva and Mantovani 2012b; Riva et al. 2014).

5.3 Our Theoretical Stance

5.3.1 From Intentions to Presence

If we compare our short description of the volitional (paragraph 2.4) and cognitive (paragraph 2.5) approaches to action and intentions, we can find some interesting similarities. Both analyze agency through a three-level chain of objects/intentions in which higher levels generate lower ones (see Fig. 5.1). Both evaluate an action as successful through the comparison of the objects/intentions driving the action with its outcome. And both consider the mastering of a tool as the way to make it transparent (directly present) to the subject. However, neither of them identifies a specific cognitive process addressing the complex task of comparing in real time and unconsciously the objects/intentions driving the action with its outcomes.

Nevertheless, recent research by Haggard and Clark (2003, 2002), on voluntary and involuntary movements, provides direct support for the existence of a specific cognitive process binding intentions with actions. In their words (Haggard et al. 2002): *"Taken as a whole, these results suggest that the brain contains a specific cognitive module that binds intentional actions to their effects to construct a coherent conscious experience of our own agency."* (p. 385).

According to the view proposed in this chapter, this role is played by presence. As indicated earlier, we consider presence as a neuropsychological phenomenon, evolved from the interplay of our biological and cultural inheritance, whose goal is to produce a sense of agency and control: subjects are "present" if they are able to enact in an external world their intentions (Riva 2007, 2009). As suggested by Zahoric and Jenison (1998): "*presence is tantamount to successfully supported action in the environment"* (p. 87, italics in the original).

In other words, presence can be described as a sophisticated but unconscious form of monitoring of action and experience, transparent to the self but critical for its existence (Riva et al. 2008). The main experiential outcome of this process is the sense of agency: we feel that we are both the author and the owner of our own action. For this reason, the feeling of presence is not separated by the experience of the subject but it is related to the quality of our agency. It corresponds to what Heidegger (1959) defined as "the interrupted moment of our habitual standard, comfortable *being-in-the-world*". In fact, a higher level of presence is experienced by the self as a better quality of action and experience: the more the subject is able to enact his/her intentions in a successful action, the more he/she is present.

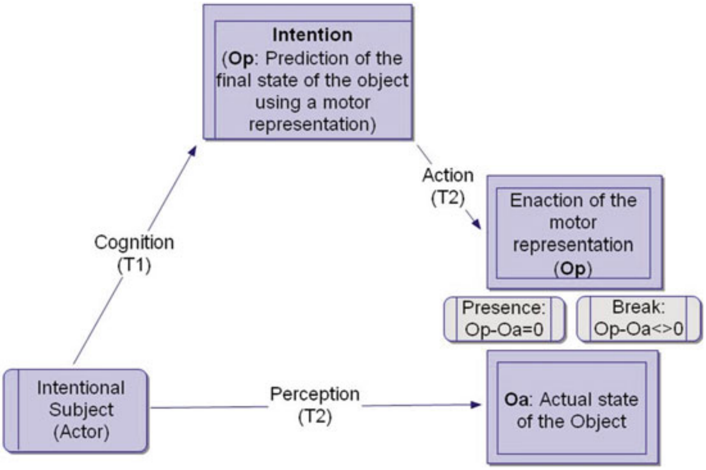

Fig. 5.2 The forward-inverse model of presence

Here we also argue that it is the *feeling of presence that provides to the self feedback about the status of its activity*: the self perceives the variations in the feeling of presence and tunes its activity accordingly.

From a computational viewpoint, the experience of Presence is achieved through a forward-inverse model (Fig. 5.2):

1. First, the agent produces the motor command for achieving a desired state given the current state of the system and the current state of the environment;
2. Second, an efference copy of the motor command is fed to a forward dynamic model that generates a prediction of the consequences of performing this motor command;
3. Third, the predicted state is compared with the actual sensory feedback. Errors derived from the difference between the desired state and the actual state can be used to update the model and improve performance.

In sum, *presence provides to the agent a feedback about the status of its activity*: the agent perceives the variations in presence and tunes its activity accordingly.

Why do we consciously track presence variations? Our hypothesis is that they are a sophisticated evolutionary tool used to control the quality of behaviour. Specifically, the subject tries to overcome any breakdown in its activity and searches for engaging and rewarding activities (optimal experiences). It provides both the motivation and the guiding principle for successful action. According to Csikszentmihalyi (1975, 1990), individuals preferentially engage in opportunities for action associated with a positive, complex and rewarding state of consciousness, defined by him as “optimal experience” or “flow”. There are exceptional situations in which the activity of the subject is characterized by a higher level of presence than in most others. In these situations the subject experiences a full sense of control and experiential immersion. When this experience is associated with a positive emotional state, it constitutes a flow state. An example of flow is the case where a professional athlete is playing exceptionally well (positive emotion) and achieves a state of mind where nothing else is attended to but the game (high level of presence). A corollary of the proposed vision is important for our goals: it is possible to design mediated situations that elicit a state of flow by activating a high level of presence (maximal presence) (Morganti and Riva 2004; Riva 2004; Waterworth et al. 2003).

5.3.2 The Layers of Presence

Even if presence is a unitary feeling, recent neuropsychological research has shown that, on the process side, it can be divided into three different layers/subprocesses (for a broader and more in-depth description see (Riva and Waterworth 2014; Riva et al. 2004)), which are described in Table 5.1, phylogenetically different, and strictly related to the evolution of Self (Damasio 1999). Here, we consider the development of Self in relation both to its intentional abilities and to the Other, whereas Waterworth, Waterworth, Riva, and Mantovani (Chap. 3, this volume) present this same basic model of presence from the perspective of the individual organism.

More precisely we can define "proto presence" as the process of internal/external separation *related to the level of perception-action coupling (self vs. non-self)*. The more the organism is able to couple correctly perceptions and movements, the more it differentiates itself from the external world, thus increasing its probability of surviving. Proto presence is based on proprioception and other ways of knowing bodily orientation in the world. In a virtual world this is sometimes known as "spatial presence" and requires the tracking of body parts and appropriate updating of displays.

"Core presence" can be described as *the activity of selective attention made by the self on perceptions (self vs. present external world)*: the more the organism is able to focus on its sensorial experience by leaving in the background the remaining

Table 5.1 The layers of presence

Layers	Relation with the self	Consciousness	Intentions	Activity	Media
Proto presence	Self vs. non self (Other)	Mostly unconscious (breakdowns)	Motor intentions (conditions)	Operation	Proprioceptive
Core presence	Self vs. present external world	Conscious of here and now	Present intentions (goal)	Action	Perceptual
Extended presence	Self relative to present external world	Conscious of self in relation of the world	Future intentions (objects)	Activity	Conceptual

Adapted with permission from Riva et al. (2004)

neural processes, the more it is able to identify the present moment and its current tasks, increasing its probability of surviving. Core presence in media is based largely on vividness of perceptible displays. This is equivalent to "sensory presence" (e.g. in non-immersive VR) and requires good quality, preferably stereographic, graphics and other displays.

The role of "extended presence" is to *verify the significance to the self of experienced events in the external world (self relative to the present external world)*. The more the self is present in significant experiences, the more it will be able to reach its goals, increasing the possibility of surviving. Extended presence requires intellectually and/or emotionally significant content. So, reality judgment influences the level of extended presence – a real event is more relevant than a fictitious one – and then the level of presence-as-feeling.

It is interesting to note that these three levels of presence correspond to the three levels of intentions identified by Pacherie in her *Dynamic Theory of Intentions* (Pacherie 2006): Motor Intentions (M-Intentions), Present Intentions (P-Intentions) and Future Intentions (F-Intentions). These three levels also correspond to the different levels of activity identified by *Activity Theory*: operation, action and activity. This suggests that the more complex is the level of activity, the more are all three layers of presence are required. We discuss this point further below.

5.3.3 From Presence to Social Presence

The previous section connected action and intentions to Presence. Recent studies suggest that a similar link exists in Social Presence, the ability of recognizing others in an external environment (Biocca et al. 2003). Specifically, it is through the recognition of the Other's intentions that he/she becomes present to us (Riva 2006).

There is a large body of evidence suggesting that infants, even in the first months of life, show a special sensitivity to communication and participate in emotional sharing with their caregivers (Legerstee 2005). Trevarthen (2001) and Trevarthen and Aitken 2001) argues that an infant is conscious, from birth, of others' subjectivity: he/she is conscious of other's mental states and reacts in communicative, emotional ways so to link each other's subjectivity. Meltzoff goes further (Meltzoff 1999; Meltzoff and Decety 2003; Meltzoff and Moore 1977; Meltzoff et al. 2002) proposing the existence of a *biological mechanism allowing infants to perceive others "like them" at birth*.

This ability can be defined as *"Social Presence": the non mediated (prereflexive) perception of an enacting other within an external world* (Riva 2008).

How does a subject learn to recognize and explain the full intentional chain of the other? Following Csibra and Gergely (2006), this processes can be considered a *predictive* one: it emulates the action needed to achieve a hypothesized goal. From the computational viewpoint, it follows the same approach used by Presence (Fig. 5.3):

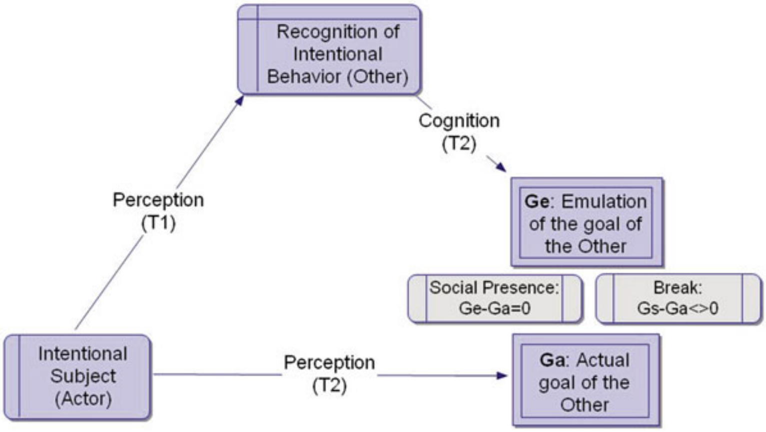

Fig. 5.3 The forward-inverse model of social presence (adapted with permission from Riva 2008)

1. First, the agent recognizes a motor intention, and identifies the actor as another intentional self (Other);
2. Second, an efference copy of the motor commands (intentional chain) is fed to a forward dynamic model that generates a prediction of the consequences of performing it;
3. Third, the predicted state is compared with the actual sensory feedback. Errors derived from the difference between the predicted state and the actual state (break) can be used to update the model and improve performance.

Supporting this vision, Oztop et al. (2005) showed that the motor modules of the observer can be used in a "predictive mode" to infer the mental state of the actor. According to their model, mirror neurons (Rizzolatti et al. 1998, 2000) can be involved in the sensory forward prediction of goal-directed movements, which are activated *both* for motor prediction during action observation and for feedback-delay compensation during movement.

From an evolutive viewpoint this approach has two strengths. First, it can be seen as the brain's attempt to minimize the free energy induced by a stimulus by encoding its most likely cause (Kilner et al. 2007). More, the recognition of others' intentions using a forward model allows interpretation without prior experience since, as long as an intentional movement or behavior is in the repertoire of the Self, it will be interpretable without any training.

If Social Presence is the result of predicting Other's intentions through an internal simulation, it is not separated by the experience of the subject but it is related to the quality of his/her social interactions. In fact the subject experiences reflexively the feeling of Social Presence only when the quality of his experience is modified during a social interaction: according to the level of Social Presence experienced by the subjects, they will experience *intentional opacity* on one side (break in Social

Table 5.2 The layers of social presence

Layers	Relation with the other	Recognized intentions	Activity	Media	Social experience
Proto social presence	There is another self (Other)	Motor intentions (conditions)	Operation	Proprioceptive	Imitation
Interactive Social Presence	The Other is directed to the Self	Present Intentions (goal)	Action	Perceptual	Communication
Shared Social Presence	The Other is like the Self	Distal Intentions (objects)	Activity	Conceptual	Empathy

Adapted with permission from Riva (2008)

Presence), and *communicative attuning and synchrony* (optimal social experiences) on the other side (Anolli et al. 2002).

5.3.4 The Layers of Social Presence

It is important to note, however, that social presence evolves in time and it is related to the intentional skills of the subject: a subject can recognize only the intentions that he/she is able to enact. As underlined by Meltzoff and Brooks (2001): "Evidently, infants construe human acts in goal-directed ways. But when does it start? We favor the hypothesis that it begins at birth… The hypothesis is not that neonates represent goal directedness in the same way as adults do. In fact, neonates probably begin by coding the goals of pure body acts and only later enrich the notion of goals to encompass object directed acts" (p. 188).

Specifically, the study of infants and the analysis of their ability of understanding and interacting with people suggest that also *social presence*, on the process side, includes three different layers/subprocesses (see Table 5.2) phylogenetically different, but mutually inclusive (Riva 2008):

- Proto Social Presence (there is an Other);
- Interactive Social Presence (the intention of the Other is toward the Self);
- Shared Social Presence (the Self and the Other share the same intention).

More precisely we can define *"Proto Social Presence"* the process allowing the identification of other intentional selves in the phenomenological world (there is an other intentional Self). In fact, newborns are able to detect *intentionality* (there is an Other) – they recognize that a M-intention is being enacted by another self – but they cannot detect higher level intentions – they do not recognize D-intentions and P-intentions – nor identify the *motives* of motor behaviors – they do not recognize why the specific M-intention is being enacted. However, this simple ability has a critical role for the newborn: the more he/she is able to identify other selves, the more the possibility of starting an interaction, thus increasing his/her probability of surviving. Proto Social Presence allows the recognition of M-Intentions only.

The next step in the development of social presence is *the "Interactive Social Presence",* allowing the identification of communicative intentions in other selves (the intention of the Other is toward the Self). The more the infant is able to identify a communicative intention in other selves, the more the possibility of starting an interaction, thus increasing its probability of surviving. This skill requires the ability of enacting P-intentions and usually appears after 4–9 months from birth. Interactive Social Presence allows the recognition of M-Intentions and P Intentions only.

The highest level of Social Presence is *"Shared Social Presence",* the identification of intentional congruence and attunement in other selves (the Self and the other share the same D-intention). The more the self is able to identify intentional attunement in other selves, the more the possibility of conducting an interaction, thus increasing its probability of surviving.

5.3.5 Intentions, Presence and Self

A key assumption of the model we just presented is a strict link between intentions, Self and Presence. Here we try to add a final claim (Riva 2008): *Presence and Social Presence evolve in time, and their evolution is strictly related to the evolution*

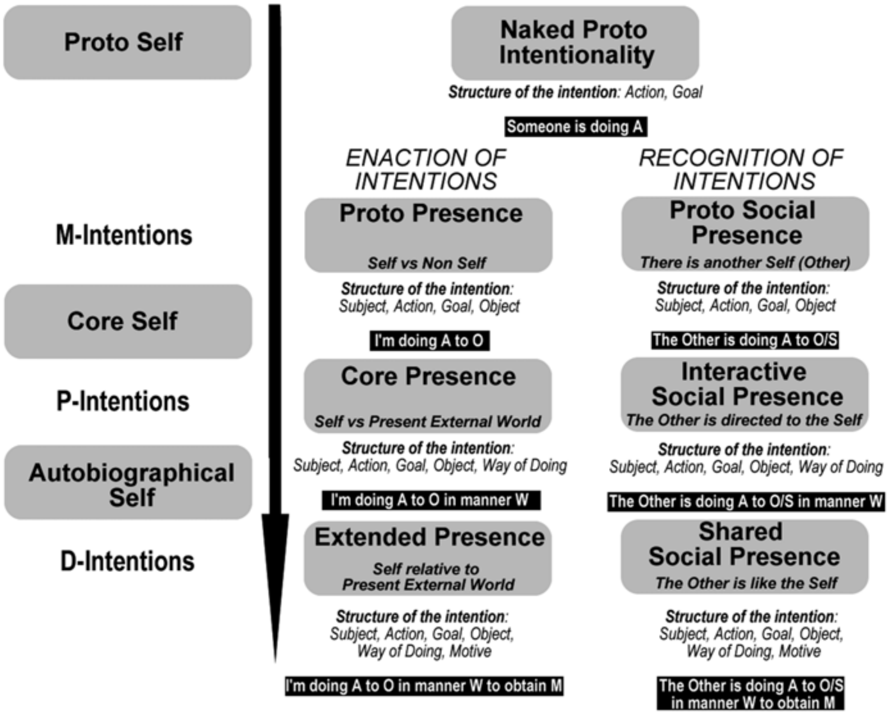

Fig. 5.4 The evolution of self, presence and social presence (Reprinted with permission from Riva 2008)

of Self. Specifically, following the three-stage model of the ontogenesis of Self (Proto-Self, Core Self, Autobiographical Self) proposed by Damasio (1999), we can identify higher levels of Presence and Social Presence associated with higher levels of intentional granularity (Riva 2008).

As shown in Fig. 5.4, the higher is the complexity of the enacted and recognized intentions, the higher is the level of Presence and Social Presence experienced by the Self. In *proto naked intentionality* the structure of the intention includes action and goal only. When the Self experiences the highest level of Presence and Social Presence he is able to express, enact and recognize complex intentions including Subject, Action, Goal, Object, Way of Doing and Motive. In sum, the enaction and recognition of high-level intentions − D-Intentions − requires higher levels of Presence and Social Presence.

5.4 Designing Optimal Presence

In our model, optimal presence in a mediated experience arises from an optimal combination of form and content, able to support the activity of the user. This picture provides us the first two guidelines for developing optimal presence in a mediated experience:

1. *To induce optimal presence, the developer of a mediated experience has to include recognition of the specific purpose of the user*. If the developer is not able to identify the specific objective of the user it will fail in supporting his/her action, reducing the level of presence.
2. *To induce optimal presence, the developer of a mediated experience has to identify and support the specific tools that mediate the activity of the user*. Most of the activity of the user is mediated by physical and social artifacts. The developer has to identify and embed in the virtual reality system features to support the action of the user effectively.

In general, we suggest that proto presence is determined only by form, core presence by both form and content, and extended presence only by content. Media form must provide the means for a convincing perceptual illusion, but the content should be integrated with (and so attract attention to) the form for the presence illusion to happen convincingly. Further, both have to support the activity of the user in reaching his/her specific objective.

We also claim that the role of the different layers is related to the complexity of the activity done in the mediated experience: the more the activity is complex, the more are the layers needed to produce a high level of presence. At the lower level – operations – proto presence is enough to induce a satisfying feeling of presence. At the higher level – activity – the media experience has to support all three levels. As suggested by Juarrero (1999), high level intentions (Future Intentions/Objects) channel future deliberation by narrowing the scope of alternatives to be subsequently considered (cognitive reparsing). In practice, once the person forms an intention, not every logical or physically possible alternative remains open, and those that do are countered differently: once I decide to do A, non-A is no longer a viable alternative and should it happen I will consider non-A as a breakdown (Bratman 1992).

What we have just seen provides two other guidelines for developing optimal presence in a mediated experience (Riva et al. 2011; Waterworth et al. 2010):

1. *To induce optimal presence, the developer of a mediated experience has to decompose the activity of the user into its different components*: the virtual reality system has to identify the start and the end of each level and sublevel of the activity of the subject to support them. Further, each level and sublevel has its specific motive. The developer has to identify all the driving motives to effectively support the activity of the person. If I want to develop a VR surgical simulator, I have to identify all the levels and sublevels of activity used by the surgeons in their standard practice and verify that the developed environment is able to effectively support them (Riva et al. 2007).
2. *The lower is the level of activity, the easier it is to induce optimal presence:* The object of an activity is wider and less targeted than the goal of an action. So, its identification and support is more difficult for the designer of a VR system. Further, the easiest level to support is the operation. In fact, its conditions are more "objective" and predictable, being related to the characteristics (constraints and affordances) of the artifact used: it is easier to automatically open a door in a virtual environment than to help the user in finding the right path for the exit. At the lower level – operations – proto presence is enough to induce a satisfying feeling of presence. At the higher level – activity – the media experience has to support all the three levels.

At the higher level of activity, optimal presence arises when the contents of extended consciousness are aligned with the other layers of the self, and attention is directed to a currently present external world (J. A. Waterworth and Waterworth 2006). However, this is a difficult task to achieve for a VR developer. He/She has to provide as much immersion as possible, integrating proto (spatial) and core (sensory) presence. To integrate extended presence, the events and entities experienced in the virtual environment must have significance for the participant. The form must provide the means for a convincing bodily and perceptual illusion, but the content should be integrated with (and so attract attention to) the form for the illusion of mediated presence to happen convincingly.

Often, an interaction designer's aim is to design for as much presence as possible. In previous work, we have identified three ways of approaching the design of maximal mediated presence (Riva 1997; Riva and Gamberini 2000; Riva et al. 2004; Waterworth and Waterworth 2012; Waterworth et al. 2010): digital participation, mediated flow, and embodied immersion. In these situations, the organism responds as if what happens in a mediated environment is real, in the fullest sense, and of immediate significance. Digital participation can arise if we design a role for the participant as a performer in an interactive drama (Nath 2001) seen from a first person perspective. If the performer becomes emotionally and intellectually engaged by the events in an appropriately immersive environment, extremely high levels of presence can be achieved (Waterworth et al. 2002). A feature of this state of participation is a corresponding loss of self-consciousness. Not that the self is not present – it is maximally so – but an internal model of the self is not the focus of extended consciousness. In this respect, digital participation resembles the flow state. According to Trevino and Webster (1992) *mediated flow* corresponds to the extent to which (a) the user perceives a sense of control over the interaction, (b) the user perceives that his or her attention is focused on the interaction, (c) the user's curiosity is aroused during the interaction, and (d) the user finds the interaction intrinsically interesting. As with digital participation, events are experienced from a first person perspective.

Finally, embodied immersion, is the outcome of *second-order mediated actions* (Riva and Mantovani 2012b): the subject use the body to control a proximal tool that controls a different distal one (a tool present and visible in the extrapersonal space, either real or virtual) to exert an action upon an external object. An example of second-order mediated action is the one of the videogame player using a joystick (proximal tool) to move an avatar (distal tool in a virtual space) to pick up a sword (external virtual object). A possible, simpler variant of second-order mediated action is the direct use of the body to control a distal tool that exerts an action upon an external object. An example of this variant is the interaction with the Microsoft Kinect system: I move my body to move an avatar (distal tool) to pick up virtual objects. This specific mediated action produces two different effects on our spatial experience (Riva and Mantovani 2012a; Riva et al. 2014; Slater et al. 2009, 2010):

- a successfully learned *second-order* mediated action produces *incarnation:* a second peripersonal space centered on the distal tool (the subject is present in the extrapersonal space – telepresence);
- a successfully learned *second-order* mediated action associated to a spatio-temporal correspondence between multisensory feedbacks experienced by the user and the visual data related to the distal virtual body (avatar) produces *embodiment:* the user experiences a new body in the avatar (the subject is present in a different body – body ownership illusion).

5.5 Conclusions

There is a consensus that the experience of presence is a complex, multidimensional perception formed through an interplay of raw (multi-) sensory data and various cognitive processes (IJsselsteijn and Riva 2003). Starting from this broad statement, in this chapter we attempted to provide an elaborate – and probably controversial – account of the fundamental presence enabling mechanisms based on the interaction between intentions and actions.

Recent research in neuroscience has tried to understand human action from two different but converging perspectives: the cognitive and the volitional. On one side, cognitive studies analyze how action is planned and controlled in response to environmental conditions. On the other side, volitional studies analyze how action is planned and controlled by subject's needs, motives and goals. Here we suggested that presence is the missing link between these two approaches.

Specifically, we described presence as a neuropsychological phenomenon, evolved from the interplay of our biological and cultural inheritance, whose goal is the enaction (to transform in actions) of the volition (intentions) of the Self: subjects are "present" if they are able to enact their intentions in an external world.

The link between intention and action is also the key to recognizing and distinguishing between Self and Other. Through presence, the Self *prereflexively* controls his/her action through a forward-inverse model: the prediction of the action is compared with perceptual inputs to verify its enaction. Through Social Presence – *the non mediated perception of an enacting Other within an external world* – the agent *prereflexively* recognizes and evaluates the action of Others using the same forward-inverse model: the prediction of the action is compared with perceptual inputs to verify its enaction.

We have described social presence as a defining feature of self, allowing the detection of the content and motives of others' intentions. Without the emergence of the sense of social presence it is impossible for the self to develop a theory of mind allowing the comprehension, explanation, and prediction of behavior and, in general, the management of the social interactions.

Both Presence and Social Presence evolve in time, and their evolution is strictly related to the evolution of Self. Through an evolutionary process allowed by the interaction between presence and social presence, the sensory-motor information embedded in Motor Intentions is transformed in the perceptual and indexical content of proximal intentions and finally in the descriptive, conceptual content of distal intentions, as suggested by Pacherie in her *Dynamic Theory of Intentions* (Pacherie 2006). Following Damasio's three-level model of Self (Proto-Self, Core Self, Autobiographical Self) we can identify higher levels of Presence and Social Presence associated with higher levels of intentional granularity.

The above vision applies also to mediated action. When we experience strong mediated presence, our experience is that the technology has become part of the self, and the mediated reality to which we are attending has become an integrated part of the other. When this happens, there is no additional conscious *effort of access* to information, nor *effort of action* to overt responses in the mediated environment. We perceive and act directly, as if unmediated: we do not need any effort to check if were able to transform our intentions in actions. The extent to which we experience presence through a medium thus provides a measure of the extent to which that technology has become an integrated part of the self. Maximal presence in a mediated experience arises from an optimal combination of form and content, able to support the intentions of the user.

In conclusion, we believe that our model makes sense in terms of evolutionary psychology and is beginning to be supported by evidence of the neural and other physical correlates of action, imitation and self-monitoring. It also provides testable predictions about how to improve the experience of presence in interactive media.

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Chapter 6
An Action-Based Approach to Presence: Foundations and Methods

Luciano Gamberini and Anna Spagnolli

Abstract This chapter presents an action-based approach to presence. It starts by briefly describing the theoretical and empirical foundations of this approach, formalized into three key notions of place/space, action and mediation. In the light of these notions, some common assumptions about presence are then questioned: assuming a neat distinction between virtual and real environments, taking for granted the contours of the mediated environment and considering presence as a purely personal state. Some possible research topics opened up by adopting action as a unit of analysis are illustrated. Finally, a case study on driving as a form of mediated presence is discussed, to provocatively illustrate the flexibility of this approach as a unified framework for presence in digital and physical environments.

Keywords Action • Affordances • Space • Place • Hybridity • Positionality • Mediation

6.1 Introduction

The need to reflect on the nature of presence appeared to us during a study with a virtual environment reproducing the library of our department. We started to notice participants dealing with occasional technical anomalies, such as the entanglement of a wire, or, less frequently, the freezing of the whole program (Spagnolli and Gamberini 2002, 2006). Problems like these (also found in Garau et al. 2004) are believed to orient the participant's attention towards the technology (Dreyfus 1991, p. 65; Winograd and Flores call this circumstance a breakdown, 1986, p. 36) and -since the epistemic failure to recognize the technology generating the virtual environment is considered as a precondition to the sense of presence (Floridi 2005) – they are supposed to dramatically decrease the sense of presence. Nonetheless, participants kept wearing the helmet and handling the joystick,

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sometimes still in action in the virtual library or quickly able to resume such action as the technical problem was about to be solved. Thus, we started wondering where the participants' presence could possibly be located during those episodes. In the virtual environment or in the real one? Or suspended between worlds? And could "real reality" be neatly distinguished from "virtual reality" if to move in the virtual environment the participant had to operate on a joystick and rotate the head?

We felt the need to go deeper into the theoretical foundations of presence, as did several other colleagues, searching within disciplines that devoted special attention to the notion of human place, to the nature of action and to the role of technological mediation. The approach illustrated in these pages collects the input from various disciplines with a tradition of addressing those themes (e.g., Human Geography, Philosophy and Cultural Psychology) and results in an *action-based* framework according to which presence is dynamically achieved and maintained by acting in that environment. The merit of this approach in our view is to enrich the toolkit for the study of presence and to provide a unified approach to presence in virtual, real and mixed environments. Regarding the former, an action-based approach allows to investigate both the intensity of the sense of presence and the qualitative configuration of the presence experience. Regarding the latter, this approach can take advantage of current theoretical reflections on the study of human environments, acknowledging the commonalities between environments that only for historical reasons and disciplinary traditions appear as different. At the same time, the framework is able to identify the specificities of the presence in each different environment, tracking them back to the different affordances and the practice characterizing the tools mediating presence.

The chapter is organized in this way. Section 6.2 briefly describes the theoretical and empirical foundations of this approach, formalized into three key notions of place/space, action and mediation. Section 6.3 addresses some common assumptions in the study of presence with methodological implications. Section 6.4 illustrates possible research topics that emerge when using action as a unit of analysis. Section 6.5 reports a case study on driving as a form of mediated presence, which provocatively illustrates the suitability for this approach to account for presence in mediated environments supported by any kind of medium.

6.2 Foundations

6.2.1 Space: The "There" in "Being There"

By defining a person as present, one implies that person's connection with a certain place. This is partially acknowledged by the conventional characterization of presence as 'the sense of being there' (Lombard and Ditton 1997; Biocca and Levy 1995), where the deictic 'there' points directly to the environment within which presence can be both detected and defined – not only by third parties, but also by the present person herself. What is the nature of this relation with the environment?

Recently, this question has been dealt with under the rubric of spatial presence (as 'the consistent feeling of being in a specific spatial context, and intuitively knowing where one is with respect to the immediate surround' (Riecke and Von der Heyde 2002, p. 1; also, Vorderer et al. 2004) or mediated space (O'Neill et al. 2005; Turner and Turner 2004; Wimelius 2004; Nova 2005). Environmental psychologists have investigated the relationship between human behavior and the socio-physical space (Bonnes and Secchiaroli 1992), sometimes in collaboration with architects and engineers (Canter and Lee 1974). Paul Dourish (2001) in the field of Human-Computer Interaction mentions a sociological tradition of place studies and identifies some landmark contributions in this sense, mainly Anthony Gidden's concept of locale and Anselm Strauss's idea of social worlds. In contrast to a tradition that has separated the individual experience from the experience of specific objects, these approaches emphasizes the essentially relational nature of the individual experience of place.

The notion of Place (Casey 1997) is used in Philosophy to capture the idea of a human environment reconfigured by the relation with its inhabitants and interdependent from them. Similarly, it is adopted in human geography to 'challenge empiricist and positivist approaches' to the study of human environments (Adams et al. 2001, p. xvi). In this domain, place was firstly articulated from a phenomenological perspective. Tuan, for instance, depicted the experience of place as a stance, determined by perception, memory and imagination and unfolding on an aesthetic, symbolic and sensorial dimension (Tuan 1990). Subsequently, a phenomenological perspective seemed too much at risk of remaining trapped within the idiosyncrasies of the individual world, so action was identified instead as the source of the involvement with the environment (Harvey 1973). In Bourdieu's words, the 'active presence in the world through which the world imposes its presence, with its urgencies, its things to be done or said, things "made" to be said and said 'to be done', which directly command words and deeds without ever deploying themselves as a spectacle'(1977, p. 96). 'It is because we act, going to places and reaching for things to use, that we can understand farness and nearness, and on that basis develop a representation of world-space at all. It does not identify a point A in a neutral, container-like space, but rather, our spatial activities determine a "here" with respect to the things we deal with and the way we move. Regions are inherently organized by activities which emanate from a center of action.' (Arisaka 1995 pp. 4–6).

On these bases, presence is attributed to an actor who inhabits an environment by acting in it.

6.2.2 *Action: Presence as a Practical Achievement*

In the previous paragraph we have located the distinctiveness of presence in the relation between the human experience and the specific environment in which it takes place, and have considered action as the vehicle through which this relation is established. In fact, several theories posit action at the basis of cognition (Clancey 1997;

Lakoff and Johnson 1999), consciousness (Hurley 1998) and other psychological processes or states, including presence (from a phenomenological-ecologic perspective: Zahorik and Jenison 1998; from a constructionist-cultural psychological perspective: Mantovani and Riva 2001). It might be worth clarifying how action is conceived in this perspective. The practical engagement with the local environment has priority over any symbolic or representational process: there is never a cognitive plan to do something that is not already an embodied activity itself (Suchman 1987). Action is not the mere physical execution of a plan or of a decision already made in the individual mind (as is maintained by other theories, e.g. Fishbein and Ajzen 1975): it is the very locus in which plans are made and resources exploited. 'Our names for things and what they mean, our theories, and our conceptions *develop in our behavior* as we interact with and perceive what we and others have previously said and done' (Clancey 1997, pp. 3–4). These theoretical arguments can count on a great amount of empirical evidence; psychological research confirms that humans build their relationships with the environment by acting in it. A vivid piece of evidence is that far objects, including digital objects, can be re-coded by our brain as collocated within the peripersonal space if the user is able to act upon them with a tool (Gamberini et al. 2008, 2013).

This has several implications, but one of the most prominent is that, contrary to the Cartesian separation between mind and matter, the material and physical resources are put at the same level of more symbolic ones, since they are all crucial resources in shaping action. Presence is actively achieved and maintained by exploiting these resources, so reliance on material resources such as a joystick cannot *per se* be a possible impediment in the achievement of a genuine sense of presence (see below 'hybridity') (Spagnolli et al. 2003).

6.2.3 Mediation: Tools and Their Specificities

The status we confer to technologically-mediated presence with respect to presence in natural environments depends first of all on the role we attribute to technology in the human experience. The positions taken in the scientific community or in the media towards technology, as it is typical at the first appearance of an innovations (for instance, the reactions to the bicycle or the automobile, Kern 1983, pp. 141–158), have been very extreme – alternating fears and fantasies (for instance, Heim 1999 or Hillis 1999 for the former; Negroponte 1995 or Turkle 1996, for the latter). However, technologically mediated environments do not represent a discontinuity in the human landscape, but rather a further instance of a familiar phenomenon. Amin and Thrift (2002) mention several kinds of innovations: commuting, information transmission/storage, growth of reliable means to support everyday actions (such as gas or electric networks) and, growth of means of mass representation. All these innovations have represented 'a wave of re-mediation of everyday life, in which the very fabric of presence and absence, departure and return is reworked (…)' (Amin and Thrift 2002, p. 98). Current technical innovations join previous innovations and extend the set of possible mediations available (Munt 2001; Couldry and McCarthy 2004).

Indeed, the use of tools has been a hallmark of human culture (Cole 1996) and a condition for cognitive development long before digitalization (Vygotski 1978). Most resources on which human cognition relies are located outside the human body, from material tools such as a calculator to abstract tools such as language or mathematics (Cole 1996). Scholars pinpoint that it represents a way in which agents delegate part of their cognitive efforts to resources that are external to their individual mind and call this phenomenon 'mediation' (Hollan et al. 2000; Scaife and Rogers 1996; Norman 1988; Pea 1993; Salomon 1993; Lave 1988; Lave and Wenger 1991). According to the Vygotskian Activity Theory, mediation is the way through which human cognition becomes more and more complex (Nardi 1996; Engestroem et al. 1999). Also scholars such as Murray and Sixsmith (1999), Harrè (1991) or Clark and Chalmers (1998) have questioned the idea that the individual is delimited by the confines of the body, interfaced to the surrounding yet separated from it. They emphasize the strong dependence of human faculties on external tools, prostheses allowing to move and to operate in the digital environment. These tools overcome the bodily limitations in manipulating, cleaning and constructing and inevitably influence the modes of being present. Furthermore, the actor-network theory has embraced the idea of a thorough and intimate human connection with technologies with its notion of the *hybrid* – namely, the union of an actor and a tool operating as a whole (Latour 1993). A similar idea is the postmodern notion of the *cyborg*, in which tools are prostheses that become part of the person's functionality (Haraway 1991), and which is well captured by the famous example of the blind man's cane (Dreyfus 1991): 'We hand the blind man a cane and ask him to tell us what properties it has. After hefting and feeling it, he tells us that it is light, smooth, about three feet long, and so on; it is occurrent for him. But when the man starts to manipulate the cane, he looses his awareness of the cane itself; he is aware only of the curb (or whatever object the cane touches); or, if all is going well, he is not even aware of that, but of his freedom to walk (p. 75).'.

But then, if mediation is so widespread, what justifies the study of computer-mediated presence as a domain on its own? Presence in a computer-mediated environment is different from presence in other environments, and it is legitimate to study it as a distinct type of phenomenon. The reason is that any mediating tool shapes the contours of presence so if the tool changes, also the presence affordances are supposed to change. Studying presence in a computer-mediated environment means then studying the way in which the specificities of such environment affect that experience, either qualitatively or quantitatively.

6.3 Implications

The approach described in this chapter dissolves the bases of several presuppositions in the study of presence. We will consider in details three of them, the separation between digital and virtual presence, the objective definition of the mediated environment and presence as a personal phenomenon.

6.3.1 Beyond the Separation Between Real and Digital

The first image of telepresence that comes to mind is perhaps a virtual environment that offers the user a robust, credible world, alternative to the 'real' one. This representation assumes that being present means to approximate a state of exclusive and stable engagement with the virtual environment. This representation, although tempting in its simplicity, is imprecise for at least two reasons. First, it does not consider forms of mediated presence that are not immersive, for instance videoconferencing systems. Second, it does not include material resources that are necessary in order to produce whatever kind of digital experience we are designing, for instance the body. The arguments presented in the previous paragraphs make evident that presence is not exclusively made of resources found in the mediated environment; for instance, a person acting in a virtual environment is simultaneously operating the joystick, listening to the instructor, and enduring sickness or fatigue.

6.3.2 Beyond a Neutral, Objective Treatment of the Mediated Environment

It is a common assumption in this field to consider that the digital tool that a person is using defines the environment in which his/her mediated presence is located. Studies usually offer a pre-defined definition of this environment, simply consisting of the name of the technical tool being used. Instead, the environment in which one is present is defined moment by moment by the actions undertaken, and is a collage of hybrid resources not matching the confines of the digital space generated by the medium; the resulting the environment must be a matter of investigation, instead of being presupposed a priori. The episode of the digital library mentioned at the beginning of the chapter is pertinent in this respect. The users temporarily interrupted their action in the virtual environment, and started an instrumental course of action to resolve a physical problem with joystick and wire. During these moments, the active involvement with the physical environment became more relevant but part of their body was still oriented to the interrupted movement in the virtual space.

6.3.3 Beyond Presence as an Intimate State

Most studies of presence use self-reported data because they address the feeling of presence as a personal phenomenon (e.g., Spagnolli et al. 2014); but if we are interested in acts of presence, the nature of our phenomenon is public. First, it is recognizable because it relies on common conventions and recurrent practices. Second, presence is consequential: the practices through which presence is established in a certain environment have implications to the actor and to other people. Third, presence is accessible to the subject performing the action, as well as to the researchers observing it. This opens up the way to new methods based on collecting actions, which are discussed in the next section.

6.4 Studying Presence by Collecting Actions

There are several ways of using action as the unit of analysis for studying presence.[1] A first way is quantitative and tries to measure the intensity of presence by identifying categories of actions that reveal an engagement with the environment or with other users in the environment, and by measuring their occurrence. The current standard today is to collect these actions (or better, behaviors) automatically, by logging the user's operations on the interface (Hilbert and Redmiles 2000), but is can also been done manually. For instance, in a study we carried out, participants were asked to navigate in the virtual environment; at a certain point, unexpectedly, an alarm rang and virtual flames invaded the virtual aisles (Gamberini et al. 2003). Participants' movements in the virtual library were analyzed and showed a clear change in the interaction style after the fire: backwards movements started to be used, and collisions with the walls increased. This shows that the engagement with the virtual environment changes before and after the fire, and so the way of being present there. Another example is provided by a study on social presence, assessing how it changes if social feedback is provided to users (Martino et al. 2009). Social presence was operationalized as reciprocal behavioral engagement and then it was measured by studying the number and direction of communication exchanges between users.

A second approach is qualitative and aims at understanding the configuration of presence more than its intensity. It consists of observing the relation between an action performed in a certain way and the environment in which it takes place to identify the practices through which users construct their spatio-temporal presence in a certain environment or the way in which the environment itself is configured as an arena for action (e.g. Arminen 2008; Licoppe and Inada 2008; Spagnolli and Gamberini 2007; Spagnolli et al. 2008).

6.5 Driving as Mediated Presence

To offer a provoking demonstration of an action-based approach to presence, we will consider the case of driving/riding a vehicle. After all, the car and the motorbike are prosthetic tools (Dant 2004): they are controlled by the human body and add capabilities to it. We will use some examples from a collection of video-recordings

[1] This might remind the reader of the idea of using behavioral measures as indices of presence (e.g., Freeman et al. 2000; Lepecq et al. 2009; Sheridan 1992); but while those behavioral measures are considered as 'symptoms' of a phenomenon that is hidden to an observer, here action is considered as the exact the locus in which presence is achieved.

of eight experienced drivers aged 20–58 driving in a city in North-East Italy (Belluno). We had four people driving their motorbike, and four people driving their car. The vehicles were equipped with a camera (Fig. 6.1) that recorded the scene in front of the driver, fixed steadily on the top of the passenger seat or of the motorbike tank. Cars also had an additional camera shooting the driver from the rear seats, held by a member of the research team. Participants were asked to drive along an easy and intuitive route following the main streets in their city; the route included intersections with and without traffic lights, roundabouts, pedestrian crossings and other elements requiring the coordination with other vehicles. The observations occurred preferably during heavy traffic hours.

Lets' first consider what it means to be present on the street in a car. Figure 6.2 shows two sets of pictures aligned on a timeline, taken from the camera attached to the motorbike front. In the first raw, the motorbike is approaching a traffic light. The street is not divided into different lanes yet, but starting from the second picture, the motorbike moves to the left side of the street, preparing to turn left after the intersection. The automobile preceding the motorbike is closer to the traffic light, but from neither the position on the street nor the direction lights is it apparent what direction the car will take until the fourth picture. At that point, its position projects the trajectory along which the car is moving and the motorbike reduces the distance from the car (11/00 and 12/00) and surpasses it, in this way showing its confidence that the car will no longer threaten to occupy the left lane.

Fig. 6.1 A participant driving on the street. The inserted picture is produced by the camera shooting the driver, the main picture is produced by the camera positioned on the passenger seat

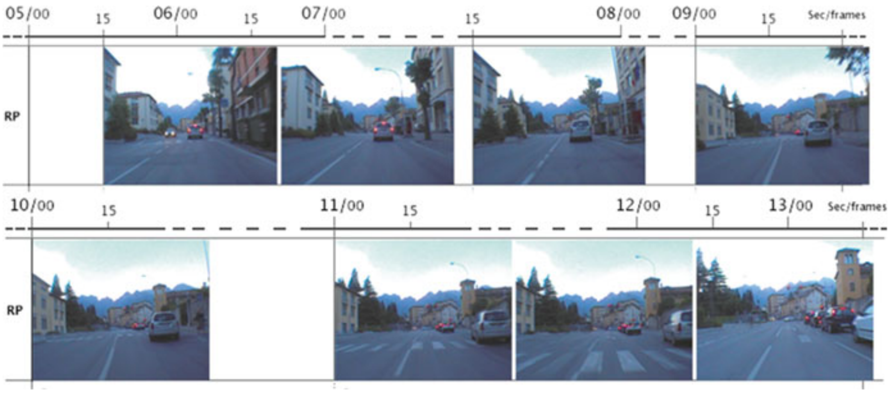

Fig. 6.2 A motorbike driving on the street. The timeline above the pictures shows the time at which the events represents in the images occur, 30 frames per second

This example illustrates the relevance of the pragmatic dimension of presence out of a laboratory setting. The presence of a vehicle on the street and the way it is managed has first of all a strong pragmatic import for all other vehicles. The position and appearance of the car is a richer source of cues on the driver's plans and projected actions than the limited set of dedicated communication devices available to the driver (e.g., direction lights). The drivers' presence on the street is a then not just an objective state or a feeling, but something that takes shape by acting on the street with the car and that – deliberately or not – provide cues to the other drivers to manage their own presence.

In this context, it then becomes very important to analyze not just the feeling of the driver as part of a car-driver hybrid, but the specific affordances of the vehicle and how they allow to mediate presence and co-presence. We can notice for instance that the difference between an automobile and a motorbike are dramatic; the former occupies more space, and lanes are drawn in such a way that automobiles proceed one after the other; on the contrary, motorbikes are slim, do not need to follow the previous vehicle and can easily occupy interstitial spaces that are not usable to the automobiles. The movement possibilities for a motorbike are richer and more versatile: space leftovers for the cars represent a precious escape route for the motorbike (Fig. 6.3).

In addition, motorbikes can accelerate faster than cars. As a result, the former are more agile and – at least in the Italian street in which they have been observed – they change position very rapidly, against a traffic background that is usually slower and more predictable. In our data, motorbikes remain in the car stream 77.24 % of the time they spend in the traffic (defined as the time in which there are other vehicles in front of them). During the remaining time, amounting to 36 s per person on average, they manage to engage in 15 maneuvers in which they move between vehicle streams of different nature: parallel to the automobiles, between the automobiles or constituted of other motorbikes.

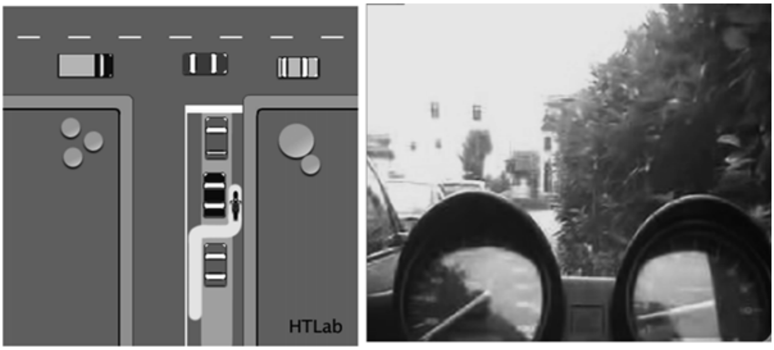

Fig. 6.3 The interstitial room available to a motorbike seen from above (*left*) and from the riders' camera (*right*)

The mediated-presence of automobiles and motorbikes on the street space is then asymmetric, suggesting that studying the way in which co-presence is managed by drivers and riders and the specific practices and affordances used to do so would help to understand some potential coordination issues on the street. More generally, this example was meant to show that there is space to understand mediated presence even outside the virtual reality laboratory and that being present in a mediated environment – whatever mediates this presence – has pragmatic implications that an action-based model can help identify.

6.6 Conclusions

This chapter describes an action-based approach to presence, reminding that presence is enacted in addition of being felt. The interest is then not in the *sensation* of being present as such, but in the *acts* of being present and in the practices through which presence is achieved, manifested and recognized. Action becomes the unit of analysis and allows us to address questions such as: what does it mean to be present in a certain environment? What is the configuration of the environment in which the user is present at a certain moment? What are the pragmatic implications of being present in that environment for the individual and the other co-present individuals?

This framework offers an additional option to presence scholars who have to deal with the complexity of this phenomenon. First, it is inclusive: it is applicable to presence in real and virtual environments alike. Second, this model describes the users' practices and does not abide to an objective depiction of the mediated environment, but it does not resort to subjectivism either. Presence is approached as an inter-subjective phenomenon, because it derives from cultural practices and is exposed to the ratification of the external events and social interaction.

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Chapter 7
Spatial Presence Theory: State of the Art and Challenges Ahead

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Abstract Throughout the last decades, research has generated a substantial body of theory about Spatial Presence experiences. This chapter reviews some of the most important existing theoretical explications. First, building on notions offered in literature, the core of the construct will be explicated: what exactly is meant by the term "Spatial Presence"? Second, theoretical views on the "feeling of being there" provided by different Presence researchers are introduced. Important aspects and determinants of Spatial Presence have been highlighted in the past, such as attentional processes and embodied cognition. However, coherent theoretical frameworks are rare and more empirical research seems necessary to advance the theoretical understanding of Spatial Presence. The chapter concludes with an overview about recent controversies and future trends in Spatial Presence research.

Keywords Spatial presence • Telepresence • Attention • Embodiment • Embodied cognition

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7.1 Introduction

With research on Presence maturing over the years, the original concept (Minski 1980) became more complex and multi-faceted, which inevitably caused a differentiation into sub-concepts. Lee (2004a) distinguishes physical, social, and self-presence. Other scholars distinguish between Spatial Presence, Social Presence, and Co-Presence (Ijsselstein et al. 2000). Spatial Presence is probably the subtype that has received most attention from researchers, which may be due to its close relationship with Minski's (1980) foundational considerations on machine-mediated tele-operations that function effectively if the human users feel located at the place of operation. Spatial Presence thus refers to the perception or illusion to be located in an environment that is conveyed by some sort of media technology (Biocca 1997; Sheridan 1992a, b; Riva et al. 2003; Lee 2004a). Another reason for the concept's prominence is certainly the wide range of media applications that benefit from the capacity to induce Spatial Presence. For instance, Spatial Presence has been proposed as a precondition for effective telemedical services (e.g., Westwood et al. 1999). Spatial Presence is also a driving component of media enjoyment, for instance, in players of video games (Tamborini and Skalski 2006). Many e-learning approaches also rely on students' experience of Spatial Presence in a mediated educational environment (Regian et al. 1992; Psotka 1995). Numerous further examples will come to the readers' mind immediately, because Spatial Presence is important in any kind of simulation application (e.g., Biocca and Levy 1995), and there is a virtually infinite number of domains in which effective simulation is desirable.

The history of the concept of Spatial Presence is driven by the remarkable advances in audiovisual and multimodal display technologies that have occurred in the past 20 years. With better graphics and sound, meaningful interactivity and almost full coverage of the user's perceptional system ("virtual reality"), advanced media technology has demonstrated its power to deliver experiences of Spatial Presence. The causal relationship between increased media capacities and higher probabilities and intensities of Spatial Presence is obvious, yet in demand of theoretical explanation. For instance, one alternative determinant of Spatial Presence is the individual processing and imagination of the users, which probably interacts with the media technology to form experiential states. Thus, powerful and convincing media technology may not always be the only way to establish Spatial Presence (e.g., Gysbers et al. 2004; Schubert and Crusius 2002). The interplay between medium and user (and potentially additional situation characteristics) in the formation and endurance of Spatial Presence has therefore been construed in various theories and models. Based on lessons from technology development and empirical inquiries, these theories represent the conceptual state of the art in the field. Reviewing and synthesizing the theoretical advances on Spatial Presence promises to be a fruitful endeavor, but is also difficult, because Presence research is highly interdisciplinary. Great diversity exists in contemporary Spatial Presence theory, which refers to both (meta)theoretical foundations and conceptual focus of the construct explication.

Engineers, for example, will necessarily give their models of Spatial Presence a specific shape that differs from the general approach of philosophers or psychologists.

The purpose of this chapter is to introduce those models of Spatial Presence that in our view represent the most prominent and advanced approaches (see for existing excellent reviews Nunez 2007; Draper et al. 1998; Barfield et al. 1995; Riva et al. 2003; Lee 2004a; Schuemie et al. 2001; Sanchez-Vives and Slater 2005). In line with our own background, we will primarily focus on models that highlight the *psychological* underpinnings of Spatial Presence. From this walkthrough of the state of the art in the conceptualization of Spatial Presence, we proceed to discuss some of the unresolved and emerging challenges. Before we review Spatial Presence theory and draw our conclusions, however, we first try to offer a comprehensive introduction to the term Spatial Presence and its common understanding.

7.2 Conceptualizations of Spatial Presence – A Review

7.2.1 What Is the Phenomenon of "Spatial Presence" About?

Spatial Presence is a genuine experience. People may feel spatially present in non-mediated natural environments ("natural Presence", Steuer 1992; "proximal Presence", Zhao 2002, p. 264). However, Spatial Presence is usually referring to an experience that is generated by human-made technologies, namely media systems ("mediated presence", Lee 2004a, p. 29; Sheridan 1992b; Zhao 2002). A closer look at nonmediation phenomena therefore provides a good starting point to derive a definition of Spatial Presence (ISPR 2001; Lombard and Ditton 1997; Lee 2004a). The experience of nonmediation has been conceptualized as "a psychological state or subjective perception in which even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience" (ISPR 2001). The definition implies that an individual perceives and experiences media stimuli almost in such a way as if they were real, even though they are not. If spatially present, users feel located in a mediated space, even though they are not. Instead of maintaining a critical distance to the media (Cupchik 2002), users start feeling surrounded by the media environment (Sheridan 1992b; "mediated sense of Presence", Steuer; 1992) and being temporarily less aware of the technological source of their experience. Consequently, if spatially present, "the medium […] appears to be […] transparent […] as a large open window, with the user and the medium content (objects and entities) sharing the same physical environment" (Lombard and Ditton 1997).

Accordingly, Spatial Presence can be defined as the subjective experience of a user or onlooker to be *physically* located in a mediated space, although it is just an illusion. Originally, Spatial Presence experiences have been discussed in the context of interactive tele-working, with a focus on the teleoperator's capability to perform a task while feeling more or less spatially present in a remote space (Minsky 1980; Draper et al. 1998). These roots are still reflected in early definitions of Spatial Presence, for example in Sheridan's (1992a) explication of telepresence as a "feeling like you are actually there at the remote site of operation." (p. 120). Also, early definitions referred heavily to technological aspects as defining elements of Spatial Presence (for example Zeltzer 1992: "the degree to which input and output channels of the machine and the human participant(s) are matched"; p. 129; see also Schloerb 1995). However, with researchers from other perspectives becoming aware of the concept, the common notion of the term changed from technological-oriented definitions and conceptualizations restricted to teleoperation systems to a broader psychological understanding (see for example Lee 2004a: "a psychological state in which virtual (para-authentic or artificial) objects are experienced as actual objects in either sensory or nonsensory ways", p. 37; see also Schubert et al. 1999; Ijsselstein 2002; Slater and Wilbur 1997). With the power of the user's mind to create vivid spatial illusions acknowledged, also other media than immersive teleoperating systems were regarded as being capable to evoke experiences of Spatial Presence (Lee 2004a), for example video-games (Tamborini and Skalski 2006), television (Lombard et al. 2000) or books (Schubert and Crusius 2002; Gysbers et al. 2004).

With the advent of psychological conceptualizations, the underlying cognitive, affective and bodily processes become relevant when defining the phenomenon of Spatial Presence. Recent explications draw strongly on models of (cognitive) psychology. For example, one basic idea that has been incorporated is the assumption of mental models as the core of Spatial Presence experiences (Biocca 1997; Schubert et al. 1999; Wirth et al. 2007). Linked to the concept of mental models is an acknowledgement of the close relationship between actions (either carried out or just imagined) and perception or the construction of meaning ("ecological theory of perception", Schuemi et al. 2001, p. 3; Biocca 1997; Haans and IJsselsteijn 2012; Regenbrecht and Schubert 2002; Schubert et al. 1999; Slater and Usoh 1994). Some researchers, like Zahorik and Jenison (1998), even regard the perception of actions as the heart of Spatial Presence: "Presence is tantamount to successfully supported action in the environment" (p. 87). The importance of perceived or imagined actions is also reflected in a recent definition of Spatial Presence suggested by Wirth et al. (2007, p. 497), who argue that "Spatial Presence is a binary experience, during which perceived self-location and, in most cases, perceived action possibilities are connected to a mediated spatial environment, and mental capacities are bound by the mediated environment instead of reality."

In sum, most researchers understood Spatial Presence as a subjective experience, conviction or state of consciousness, when perceivers feel bodily or physically situated in a mediated environment. Beyond this common ground, the understanding of Spatial Presence varied, however. The next section will therefore review a number of selected theoretical elaborations of Spatial Presence in order to provide a more detailed overview of how the construct has been explicated in the past (see for an excellent review also Nunez 2007). The overview also implies a discussion of the determinants that have been set forth in the different conceptualizations. First, Draper et al.'s (1998) attention-based model of Spatial Presence will be reviewed.

Second, Steuer's (1992) explication of telepresence will be discussed. The conceptualization argues that sensory stimulation is a key mechanism of Spatial Presence. Third, the work of Slater and colleagues will be reviewed. They argue that "feeling there" depends on "doing there" and that sensory information is integrated in a mental model or cognitive Gestalt, which forms the basis of Spatial Presence. This approach is similar to Schubert et al.'s (2001) embodied cognition framework of Spatial Presence, which will be discussed in a fourth step. Fifth, the work by Wirth et al. (2007) will be explicated; they sought to develop an integrative two-level model of Spatial Presence formation. The model also stresses cognitive mechanisms underlying Spatial Presence, namely the role of a spatial situation model and perceptual hypotheses. The review closes with a follow-up contribution by Schubert (2009) that conceptualizes Spatial Presence as a cognitive feeling.

7.2.2 Draper and Colleagues: Attention as a Key Determinant of Spatial Presence

If a user encounters a mediated environment, the depicted spatial scenery may challenge the actual reference system of the user (Slater 2002; Wirth et al. 2007). It might be argued that the media system competes with the actual environment of the user for controlling his or her senses – in order to induce their "spatial logic" and to override the existing spatial reference system of the user. Accordingly, attention seems to play a major role in the development of Spatial Presence. Building on these assumptions, Draper et al. (1998) proposed an *attentional* model of Spatial Presence. "In the context of the attentional model, telepresence can be interpreted as a state arising from commitment of attentional resources to the computer-mediated environment. The more attentional resources that a user devotes to stimuli presented by the displays, the greater the identification with the computer-mediated environment and the stronger the sense of telepresence" (p. 366). According to Draper et al., attention is a key component of Spatial Presence formation, as it may direct users' sensory perception to mediated stimuli and away from cues provided by the real environment. Draper et al. are not specific about the information that needs to be processed by the user, but consider attention to be sufficient to evoke Spatial Presence: "When attentional resources are totally committed to the computer-mediated environment, the user will report a strong sense of telepresence" (p. 368).

Similar to Draper et al., many Presence researchers highlighted the importance of attention in the formation of Spatial Presence (Kim and Biocca 1997; Bystrom et al. 1999; Wirth et al. 2007). However, whereas most acknowledged that attention is important in the formation of Spatial Presence, less clarity exists about *what* spatial information users need to perceive in order to foster Spatial Presence. Clearly, attentional resources can be absorbed even by stimuli that are not capable to evoke a spatial sensation at all (e.g., a "Ganzfeld", Zeltzer 1992, p. 128). In sum, attention appears to be a necessary condition for Spatial Presence experience. But it does not seem sufficient to construe the "feeling of being there" as a mere function of attentional action.

7.2.3 *Steuer: Mapping the Sensory Stimuli Impinging on Our Senses*

"We are immersed in a very high bandwidth stream of sensory input, organized by our perceiving systems, and out of this 'bath' of sensation emerges our sense of being in the world" (Zeltzer 1992, p. 128). Like Zeltzer, many researchers have stressed the notion that the very building blocks of Spatial Presence are the sensory inputs generated by a media system (for example Sheridan 1992a; Biocca 1997). One of the first and probably most influential works to put this notion forward was Steuer's (1992) article on the dimensions of Telepresence (i.e. Spatial Presence). According to Steuer, Spatial Presence mainly builds on two properties of a media system, vividness and interactivity (see for a similar notion Sheridan 1992a, b). Steuer understands vividness as "the representational richness of a mediated environment as defined by its formal features, that is, *the way in which an environment presents information to the senses*" (p. 2, highlighted by the authors). In general, the more different senses a media system addresses (visual, auditive, haptical senses, etc.…), the higher the breadth of its vividness. The more each sensory channel is occupied by stimuli generated by the media system as opposed to the physical environment, the stronger is the "saturation of the sensory channels engaged" (p. 5), and the more intense is the vividness provided by a media system. A media system's vividness may be further improved, if sensory channels that are not stimulated by the media are actually suppressed (i.e., "dampen[ed], eliminate[d], or minimize[d]", p. 5). The reason is that unsupported sensory channels may be occupied by real-world stimuli, which may distract the user and diminish the illusive power of the media environment.

But a high breadth and intensity of sensory channels stimulated by a media environment is not necessarily sufficient to foster Spatial Presence. According to Steuer, the decisive characteristics of media system's vividness eventually is the "sensory fidelity […] within each sensory channel" (p. 5). The more "the energy array produced by a mediated display matches the energy array of an unmediated stimulus" (p. 5), the more accurate is the information provided by a media system. In sum, Steuer suggests that a media system is capable to evoke Spatial Presence, if it stimulates selected sensory channels of the user in a profound and natural way, and suppresses sensory stimulation on any of the unstimulated channels.

The second property of a media system that Steuer (1992) regards as a determinant of Spatial Presence is interactivity. Interactivity is defined "as the extent to which users can participate in modifying the form and content of a mediated environment in real time" (p. 4). According to Steuer, the interactive capabilities of a media system vary by "the rate at which [a user's] input can be assimilated in the mediated environment" ("speed", p. 4), by "the number of possibilities for action at any given time" ("range", p. 4), and, probably most importantly, by the ability of the system to map the user's input in a natural manner ("mapping", p. 4).

Mapping actually connects both of Steuer's suggested determinants of Spatial Presence, vividness and interactivity. Put simply, mapping implies that a media system responds in a natural time and with a natural sensory stimulation onto users' inputs. Touching a seemingly wooden table in a virtual environment, for example, should immediately result in a haptic sensation of wood. Mapping therefore helps to solve the difficult question about what a natural or adequate sensory stimulation is that fosters Spatial Presence. The importance of "mapping" has been highlighted by many Spatial Presence researchers (e.g. Loomis 1992; Zeltzer 1992; DiZio and Lackner 1992; Biocca and Delaney 1995; Slater et al. 1995; Biocca 1997; Wirth et al. 2007). In general it is assumed that Spatial Presence is a function of the degree "to which input and output channels of the machine and the human participant(s) are matched" (Zeltzer 1992, p. 129; Sheridan 1992a). More specifically, it is argued that each action undertaken by the user that involves the motor system causes an inner stimulation, called the "efference copy", which is memorized in the user's central nervous system ("afferent-efferent-loop", von Holst and Mittelstaedt 1950). Simply put, this efference copy, in turn, generates an automatic expectation what the sensory stimulation evoked by the action (the so-called "afference"; Loomis 1992; Sheridan 1992a) will be like. The better the afferent information conceived on an input matches the expectation based on the efference copy, the better the mapping. Spatial Presence might therefore result as the stable sensation of the user to be physically located in the depicted environment, if every action leads to the naturally expected feedback. However, if the incoming sensory stimulation fails to match the expectations based on the efference copy, users need to adapt their perception system in order to retain a balanced and concise experience (see Welch et al. 1996; DiZio and Lackner 1992). Due to limitations of the media system, the users' strivings to adapt can also fail, which in turn may result in imbalanced, unstable perceptions and experiences (e.g., cyber sickness; DiZio and Lackner 1992) and eventually the diminishing of Spatial Presence.

7.2.4 Slater and Colleagues: Spatial Presence as a Gestalt and Binary State

The idea that mapping is a crucial mechanism in the formation of Spatial Presence is also visible in the important work of Slater and colleagues (Sanchez-Vives and Slater 2005; Slater et al. 1996; Slater and Steed 2000; Slater and Usoh 1993, 1994; Slater et al. 1994; Slater and Wilbur 1997). "The key to this approach is that the sense of 'being there' in a VE is grounded on the ability to 'do' there" (Sanchez-Vives and Slater 2005, p. 333).

Like other presence researchers (e.g., Lombard and Ditton 1997; Lee 2004a), Slater and colleagues act on the assumption that Spatial Presence entails "a state of consciousness, the (psychological) sense of being in the virtual environment, and corresponding modes of behaviour" (Slater et al. 1996, p. 9). This psychological state is considered to be the corollary of an *immersive* virtual environment. An environment is considered immersive, if it provides an optimal match between the displayed sensory data and the user's proprioception (see for empirical insights, Sanchez-Vives and Slater 2005). Whether a virtual environment is immersive is therefore determined by its inherent objective features and the fidelity of its equipment (e.g., visual field of view, degree of interactivity; "external factors"), but also by user characteristics.

An optimal match between user's actions and the provided sensory feedback is supposed to induce a sense of a "virtual body", i.e. the representation of the user in the virtual environment (Slater and Usoh 1994; see also "self-presence"; Lee 2004a; Haans and Ijsselstijn 2012). Users immersed in the virtual environment are likely to identify with their virtual body, as they can engage in an egocentric frame of reference so that their self-representation in the media scenery coincides with the viewpoint from which the virtual world is experienced (Slater et al. 1994). That implies that the immersive potential of a medium is high, if the application allows for a successful implementation of the user's egocentric reference frame into the mediated scenery. This assumption is empirically well backed by investigations conducted by Slater et al. (1996; see also Jordan et al. 2004) and Havranek et al. (2012). Havranek et al. manipulated the degree of immersiveness of a video game environment by applying either an egocentric or an exocentric user perspective; effects on the extent to which users felt spatially present were examined. No matter if users played or observed the video game environment, they felt more spatially present if they experienced it from an egocentric perspective (i.e., first-person view) than if they experienced it from an exocentric perspective (i.e., third-person view). Obviously, the potential of a media environment's sensory stimulation to evoke Spatial Presence increases if users perceive the environment from an egocentric point of view. An egocentric perspective seems to support a more natural mapping, and seems to improve the chances that users perceive their virtual body as their actual body. "Presence occurs when there is successful substitution of real sensory data by computer-generated sensory data, and when people can engage in normal motor actions to carry out tasks and to exercise some degree of control over their environment"(Sanchez-Vives and Slater 2005, p. 338).

According to Slater and colleagues, next to features of the media environment, user characteristics play an important role in the formation of Spatial Presence experiences as well. This notion is in line with a series of other authors who also argue for the relevance of user factors in the formation of presence experiences (e.g., IJsselsteijn 2002; Draper et al. 1998; Lombard and Ditton 1997; Schubert et al. 2001; Wirth et al. 2007). Building on the Neuro-Linguistic-Programming model (NLP model), Slater and colleagues argue that users' mental models and representation systems structure their subjective experience of Spatial Presence (Slater and Usoh 1993, 1994). According to the model, all experience is encoded in terms of three different representation systems, i.e. visual, auditory, and kinesthetic. The predominant representation system of users influences the experiences they will have when navigating through virtual environments and in turn also their Spatial Presence experiences. For example, users holding a predominant auditory representation system will primarily construe spatiality by processing auditive spatial cues provided by the environment, whereas more visual-oriented users will rely on the graphical details of the depicted scenery (Slater and Usoh 1993, 1994; Slater et al. 1994). This implies that the right sensory stimulation to evoke Spatial Presence also depends on individual characteristics of the user. An adequate mapping seems particularly important among those sensory channels that are of primary importance to a user. In sum, the work by Slater and colleagues stresses the importance of a natural mapping for the formation of Spatial Presence. An egocentric perspective as well as a match between users' primary representational systems and the sensory channels stimulated by a media environment are identified as factors of a natural mapping.

Next to their ideas about the determinants of Spatial Presence, the work by Slater and colleagues also contributed to a better understanding of Spatial Presence itself. In trying to find an alternative way of measuring presence experiences, Slater and Steed (2000; see also Brogni et al. 2003; Garau et al. 2008; Slater et al. 2003; Slater 2002) introduced the concept of "breaks in presence". The suggested methodological approach also has important implications for theory on Spatial Presence. The main idea of the approach is that media users receive spatial signals from different and often competing environments – the real environment and the media environment – which they have to assemble in a consistent cognitive Gestalt. Users may continuously shift their attentional resources towards the specific signals belonging to the virtual or real world. Depending on which of the data streams they primarily rely on to interpret a situation in a given moment, their referring spatial Gestalt may correspond more to the world portrayed by the media environment or to the real world. For the sake of consistency, "sensory data corresponding to the non-favored interpretation may be ignored, or incorporated into the prevailing Gestalt" (Brogni et al. 2003). Slater (2002) links this aspect to psychological theories on perceptual hypotheses testing: Users have to hold a "working assumption" about the world (i.e., the construed spatial Gestalt), which implies that they have to decide for a consistent interpretation of the situation even in the light of competing signals. If users primarily rely on data from the virtual environment to build their spatial "Gestalt", they may experience Spatial Presence. However, if they rely on the data stream from the real world, the feeling of being in the virtual world may be lost.

With the users' attentional focus permanently switching between the real and the virtual world, a constant transition between feeling spatially present in the one or the other environment might occur. Slater and colleagues termed this transition "breaks in presence": "A break in presence (BIP) is the moment of switch between responding to signals with source in environment X to those with source in environment Y. It is equivalent to the aha! Moment in gestalt psychology: the switch between seeing the duck and the rabbit, for example [in a multistable figure]" (Slater 2002, p. 437). Consequently, Spatial Presence is considered a binary state: The user either feels present in the virtual environment or not (Slater and Steed 2000). Brogni et al. (2003) show that the users' overall feeling of being present in the virtual environment correlated negatively with the number of breaks in presence reported during exposure. Similarly, results by Slater and Steed (2000) indicate that breaks in presence are associated to the overall feeling of Spatial Presence assessed after the exposure to a virtual environment.

7.2.5 *Schubert and Colleagues: Spatial Presence as Embodied Cognition*

Schubert et al. (1999) conceptualize Spatial Presence as a result of embodied cognition, i.e., the mental representation of actions or possibilities of actions in the virtual environment. Dwelling on Glenberg's framework of embodied cognition (1997), they state "that a virtual environment, like every other environment, is perceived and understood by mentally combining potential patterns of actions" (p. 267). Actions can be triggered from objects in the virtual environment that follow bodily constraints (Gibson 1979), for example, opening a door before being able to leave a room ('projectable properties'). Or they can be affected by memory (Glenberg 1997), for example, not to open the door because something frightening is probably behind it ('nonprojectable properties').

According to Schubert et al., users of virtual environments mentally model the action possibilities they perceive in a virtual environment. In contrast to mere spatial models or a spatial Gestalt, those representations may be addressed as *embodied* mental models that build on perceptions of the own body, its position in the room, and related possible actions. "They are spatial-functional models, not purely spatial models" (p. 268). Following the conceptualization, the more stimuli from the real world are suppressed, and the more natural the feedback of a virtual environment that follows onto any conducted action, the easier the construction of an embodied mental model is supposed to be. An embodied mental model, once constructed, is supposed to immediately trigger a feeling of Spatial Presence. Accordingly, Schubert et al.'s central idea is that "[Spatial] presence develops from the cognitive representation of possible actions that can be performed in the virtual world" (Regenbrecht and Schubert 2002, p. 426).

In a couple of empirical studies, Schubert and colleagues (Schubert et al. 1999; Regenbrecht and Schubert 2002) show that mental representations of possible actions indeed enhance Spatial Presence. For example, Spatial Presence increased the more users were able to predict what would happen next in the media environment and the greater users' possibility to explore and actively search the virtual environment (Schubert et al. 1999; Regenbrecht and Schubert 2002). A third study by Regenbrecht and Schubert (2002) shows that Spatial Presence could even be increased my merely suggesting action possibilities. In the study, participants reported a more intense Spatial Presence experience if they expected to be able to interact with avatars in a virtual environment than participants that could not expect such an interaction possibility.

In sum, in their approach of Spatial Presence as embodied cognition, Schubert et al. (1999, 2001) merged ideas about mental models that already circulated in presence research (Biocca 1997) with theories about the importance of body actions and motor processes for perception and lived cognition (Gibson 1979; Varela et al. 1991). Their idea of an embodied mental model that underlies the sensation of Spatial Presence corresponds with recent theorizing about Spatial Presence (Haans and IJsselstijn 2012). It also shares many similarities with the notion of Slater

(2002) that Spatial Presence is the result of a consistent spatial Gestalt. Both approaches stress the importance that the media system needs to naturally map users' sensory channels. In both approaches, the body of the user emerges as the central object that needs to be appropriately represented in the media environment for Spatial Presence to occur. Schubert et al.'s approach also converges with Steuer's ideas (1992) in that they both stress the role of actions within the media environment. For Steuer (1992), user actions must lead to a natural response of the media environment in order to induce Spatial Presence (mapping). In addition, they provide convincing evidence that even *anticipated* actions may already trigger Spatial Presence.

7.2.6 Wirth and Colleagues: Spatial Presence Resulting From a Confirmed Perceptual Hypothesis

Wirth et al. (2007) developed a Two-Level-Model of Spatial Presence that aims to explain the formation of Spatial Presence on the basis of several perceptual and cognitive processes, as well as media and users factors. They claim that the model is adaptable to all kind of media, i.e., not only to virtual reality but also to low-immersive media like films and books. In the model, Spatial Presence is reduced to its core experience consisting of two dimensions: the feeling of being physically present in a mediated environment ("self location"), and the perception of having possibilities to act in this environment ("possible action"; Wirth et al. 2007; see also "interactions" in the embodied presence framework of Schubert et al. 1999). Further, like in previous approaches (e.g., Draper et al. 1998), the model sketches the media exposure situation as a conflict or struggle between the spatial environment of the "apparent reality" and the one of the media environment. Similar to the notion of Slater (2002), Spatial Presence is thought to be the result of a user accepting the spatial logic provided by a media environment.

The Two-Level Model argues that the formation of Spatial Presence basically entails two crucial steps. According to the *first level* of the model, users – after allocating their attention to the media stimulus – construct a *spatial situation model* of the media environment (McNamara 1986). The spatial situation model is simply understood as a cognitive representation of the spatial scenery depicted by an environment, similar to Slater's (2002) notion of a spatial Gestalt. Its formation involves processes of subjective construction and interpretation (Oostendorp 1994; Rinck et al. 1997). The spatial situation model may be continuously adapted during a media exposure episode, but just like a mental Gestalt it tends to be complete and consistent (Schnotz 1988; Slater 2002).

According to the Two-Level Model, the spatial situation model is expected to be more detailed and comprehensive, the more spatial cues the medium offers and the more attentive and motivated users are (Lee et al. 2004). In addition, cognitive abilities of users like their spatial visual imagery skills are thought to support the formation of a spatial situation model. Spatial visual imagery skills belong to the broader construct of spatial ability (Hegarty et al. 2002). They imply that an individual is capable to produce vivid spatial imaginations. Individuals with higher spatial visual imagery skills find it easier to fill in missing space-related information from their memory. Accordingly, spatial visual imagery skills may allow for a rich and stable spatial situation model even if the spatial data provided by the media product is poor (Bestgen and Dupont 2003; Dean and Morris 2003).

According to the Two-Level Model by Wirth et al. (2007), a spatial situation model is a mere mental representation of the spatial logic provided by an environment. A photo or a postcard may already evoke a spatial situation model. Such a model is not equivalent to the way users understand their actual spatial surrounding; it only provides an alternative interpretation of what the actual surrounding may be. However, a spatial situation model may challenge users' momentarily activated understanding of their spatial surrounding. If convincing, it may urge them to adapt their prevalent interpretation of the situation. The *second level* of the Two-Level Model by Wirth et al. (2007) conceptualizes this "struggle" between users' prevalent interpretation of their spatial surrounding and the new and competing information provided by the media-bound spatial situation model.

According to the Two-Level Model, users' prevalent understanding of their actual surrounding can be addressed as their "Primary Egocentric Reference Frame" (Riecke and von der Heyde 2002). A Primary Egocentric Reference Frame defines which space surrounds the own body and accordingly, how incoming spatial information is ordered. All perceived objects, including one's own body, are positioned with reference to the spatial logic inherent to the Primary Egocentric Reference Frame. A picture on a postcard may provide an alternative spatial scenery to the real world (e.g., the living room), for example, but as long as the spatial logic of the postcard is not accepted as the Primary Egocentric Reference Frame, the spatial scenery of the picture will be interpreted as secondary and the postcard (and the depicted space) itself will be located according to the spatial order of the Primary Egocentric Reference Frame.

According to the Two-Level Model, on the second level of Spatial Presence formation, users unconsciously choose a Primary Egocentric Reference Frame, i.e., they start to either believe in the spatial surrounding of the real or the mediated environment, depending on if they follow the logic of the spatial situation model of the real world or the one of the media environment. Similar to Slater's approach (2002), the Two-Level Model refers to the theory of perceptual hypotheses (Bruner and Postman 1949) to illustrate this choice. The model argues that acceptance of a reference frame is identical to the confirmation of a perceptual hypothesis. If the spatial information of the media environment is accepted as the Primary Egocentric Reference Frame, the feeling of being in the environment – or Spatial Presence – should emerge.

Media factors, user activities, and user characteristics are thought to affect the outcome of the perceptual hypothesis testing. A lack of user motivation to experience Spatial Presence may be overruled by pervasive and convincing media characteristics (for example highly immersive virtual reality applications). In turn, insufficient spatial cues of the media environment (for example a book scenario) may be counteracted by users' traits and actions. Specifically, user's absorption, involvement, and suspension of disbelief are considered to be relevant with regard to the test of perceptual hypotheses (Böcking et al. 2005). Trait absorption refers to an individual's motivation and skill in dealing with an object in an elaborate manner (Wild et al. 1995). Involvement is regarded as a form of intensive cognitive elaboration of the media environment (Wirth 2006). A highly involved user is willing to keep his or her attention onto the media stimulus and to deeply process the incoming information. According to the model, users can also actively suspend any upcoming disbelief (Bystrom et al. 1999). The concept of suspension of disbelief originated in literature theory (Coleridge 1817/1973). Suspension of disbelief can be defined as the intentional elimination of external stimuli and internal cognitions that might contradict the (spatial) illusion provided by a medium.

In sum, the proposed Two-Level Model of Spatial Presence aimed to integrate many of the ideas and thoughts that already existed in the Spatial Presence literature. Key ingredients of Spatial Presence formation, like attentional processes, mental spatial models, and the struggle of competing spatial scenarios play an important role in the suggested model, as well. Empirical support for the model is growing (Havranek et al. 2012; Hofer et al. 2012; Wirth et al. 2012). However, the model tells less about how a media environment should map users' senses in order to evoke Spatial Presence, even though "mapping" has been stressed as an important mechanism in many previous conceptualizations (e.g., Sanchez-Vives and Slater 2005). Similar to other existing approaches, the Two-Level Model also stresses primarily cognitive mechanisms that may underlay the formation of Spatial Presence. This raises the question of whether the model conceptualizes the phenomenon sufficiently or if emotions or "hot mechanisms" like arousal also play an important role in the formation of Spatial Presence.

7.2.7 Schubert: A new Conception of Spatial Presence – Once Again, With a Feeling

In a recent theoretical contribution, Schubert (2009) suggests that we understand Spatial Presence as a cognitive feeling. It should be noted that Schubert's approach does not intend to explain to what extent users' emotions (e.g., feelings of sadness) influence the Spatial Presence experience. However, his conceptualization helps to combine previous approaches from Schubert et al. (1999), Slater (2002) or Wirth et al. (2007) in a parsimonious way. "Feelings are immediate, given, and not consciously inferred in a deliberate process" (p. 8). Previous models failed to fully explain how Spatial Presence as a subjective experience should result from unconscious processes. But if Spatial Presence is understood as a cognitive feeling, it can be entirely based on unconscious processes, even though users consciously experience the sensation. The general function of feelings is to inform the conscious mind about the status of unconscious processes. Cognitive feelings "report about" unconscious cognitive processes, for example, in the context of feelings of knowing or tip-of-the-tongue states (Burton 2009). Accordingly, Schubert (2009) suggests that "Spatial Presence is a feedback of unconscious processes of spatial perception that try to locate the human body in relation to its environment, and to determine possible interactions with it. If the spatial cognition processes are successfully able to locate the body in relation to the perceived environment, and construct possible actions in it, the feeling of spatial presence is fed back and becomes available for conscious processes" (p. 15). Thus, Schubert's notion of Spatial Presence as a feeling helps to combine several important "ingredients" previously mentioned in the literature, including the perception of possible actions, the role of a spatial mental model or Gestalt, and the testing of perceptual hypotheses. In sum, Schubert's notion provides a parsimonious and illuminating conceptualization of Spatial Presence as an outcome of automatic processing, which is compatible with many of the previous approaches.

7.3 A Brief Conclusion and Four Challenges Ahead

Theory development has continued to expand in the field of Spatial Presence. Early works on Spatial Presence were quite diverse as they departed from different scientific disciplines, but now there seems to be a trend towards a more psychological understanding of the phenomenon. Accordingly, theoretical models of Spatial Presence start to converge. There is now a widespread consensus that Spatial Presence is a subjective experience or (cognitive) feeling of the user of being physically located within the space depicted by a medium. Agreement on the determinants of this "feeling of being there" seems to be growing, too. For example, most researchers seem to agree that in highly immersive media environments, such as CAVE systems, automatic processes of spatial cognition are apparently the drivers of Spatial Presence (see Lee 2004b). Spatial Presence may thus occur in highly immersive virtual environments even if people do not want it, do not expect it, or are fully aware that they experience just an illusion. This is because immersive virtual environments guide users' attention (Draper et al. 1998; Wirth et al. 2007; Regenbrecht and Schubert 2002), provide natural feedback on users' inputs, and may convincingly stimulate users' senses in a similar way as real-world objects would do (e.g., Sheridan 1992a, b; Steuer 1992; Slater 2002). Various conceptualizations consider the body of a user as the pivotal object that needs to be appropriately embedded in the mediated world (e.g., Schubert 2009; Sanchez-Vives and Slater 2005). "Presence is enhanced when body movements in interaction effects are not just arbitrarily coupled (a mouse-click moves the virtual body forward), but coupled in a way that fits the experiences one has with one's body" (Schubert 2009, p. 16). Most approaches share the assumption that the bodily interaction with a virtual environment enhances the sense of Spatial Presence if this interaction is intuitive, meaningful, well-timed (e.g., no delay in the computer system's response to a movement), and, most importantly, consistent and error-free (e.g., Haans and IJsselstijn 2012; Sheridan 1992a, b).

7.3.1 Can Users Feel Spatially Present in Non-interactive Settings?

More variance in the conceptualizations emerges, however, when it comes to the sensation of Spatial Presence in users of less immersive media environments, especially non-interactive media like television or books. There is some empirical evidence for Spatial Presence experiences in such environments (e.g., Schubert and Crusius 2002; Gysbers et al. 2004), but the explanations for these phenomena are somewhat different between the reviewed models. Some models do not cover Spatial Presence experiences that may occur outside of virtual environments (e.g., Steuer 1992). Other approaches (which often are rooted in a psychological perspective), like the notion of Spatial Presence as a cognitive feeling (Schubert 2009) or the Two-Level Model (Wirth et al. 2007), suggest that Spatial Presence in virtual environments is only a special case of a more general phenomenon. Draper et al. (1998) base their model solely on attentional processes which can theoretically refer to any kind of (mediated) environment. Those approaches attempt to explain any experience of Spatial Presence independently of the medium.

The question therefore remains if Spatial Presence is bound to immersive virtual environments (which would require different notions and models for comparable experiences in users of television, books, etc.) or if Spatial Presence is a general type of media experience that is only most salient and intuitively expectable in users of virtual environments, but can also occur in non-immersive communication settings. In our view, this question is one of the most critical challenges for the progress of Spatial Presence theory, as it implies the need for clarifications of the relationship between Spatial Presence and other media experiences, such as transportation (Green and Brock 2000); suspense (Vorderer et al. 1996), involvement (Wirth 2006), and flow (Sherry 2004).

7.3.2 Spatial Presence: A Binary or Continuous Experience?

Some of the reviewed models argue that Spatial Presence is a binary sensation that is either "on" or "off" (e.g., Slater 2002; Wirth et al. 2007). As media users may experience Spatial Presence to be "on" for longer or shorter periods during exposure, their subjective perceptions may converge into a resulting experience of specific intensity of Spatial Presence. However, a fine temporal resolution of measurement would actually identify time portions in which Spatial Presence is either "on" or "off". This view implies a critical-incident notion of the formation of Spatial Presence, which means that if certain circumstances are given, the experience switches abruptly from "off" to "on": Within a moment, users (subjectively) enter the media space (and leave the real space).

An alternative view would consider Spatial Presence as a continuous experience, which means that users can actually perceive different intensities of Spatial Presence on a scale between "not at all" to "maximum possible" (see ISPR 2001). A medium value of Spatial Presence would then mean that users feel half present in the mediated environment and half present in the real environment. For example, findings reported by Kim and Biocca (1997) suggest such a mixed-experience structure ("departure" from the real world and "arrival" in the mediated world). But further empirical inquiry is required to resolve this theoretical question. Maybe the construal of Spatial Presence as a binary state (on/off) is just a consequence of conceptual oversimplification, or maybe the notion of a continuous intensity of Presence is just an artifact of measurement mainly produced by questionnaire tools that allow media users to produce a (metric) rating value of their experience (Slater 2002).

7.3.3 Is There a "Hot Route" to Spatial Presence Experiences?

The number of studies that have reported a link between affect and Spatial Presence continues to grow (e.g., Baumgartner et al. 2006; Västfjäll 2003; Banos et al. 2004), but the causal direction of this link seems to be unclear and unifying theoretical explications are still rare. Schubert's conceptualization (2009) of Spatial Presence as a cognitive feeling helps to move the concept closer to affective mechanisms, but does not aim to conceptualize the role of emotions in the formation of Spatial Presence. Furthermore, all other reviewed models of Spatial Presence rely heavily on perceptual and cognitive processes to explicate the formation of Presence experience, for example, the attention-oriented approach by Draper et al. (1998) and the Two-Level Model by Wirth et al. (2007) that conceptualizes the emergence of a spatial situation model of the media environment as the link between mere attention and actual Presence experience. This orientation towards cognition is justified by the fact that Spatial Presence is about spatial cognition and space-related experience, of course. Yet, these models may overlook a potential role of affective processes (i.e., arousal, positive and negative affect, behavioral tendencies triggered by concrete emotions like fear or joy) in the formation of Spatial Presence. Another challenge for Spatial Presence theory therefore is to clarify the role of emotion and forms of affective processing in the formation of Spatial Presence.

7.3.4 Dual Systems: Is Spatial Presence Affected by Reflective Processing?

In many studies on Spatial Presence scholars report the paradoxical observation that users felt like being in the mediated environment despite being fully aware that they actually were not (e.g., Slater 2011). This observation appears paradoxical, because users simultaneously experience a feeling opposite to their beliefs. However, users' belief about their actual location may conceptually differ from their intuitive feeling of "being there". In line with this idea, Hartmann (2012, 2011) suggests explaining the paradoxical experience underlying most media illusions, including the experience of Spatial Presence, from the perspective of recent psychological dual process models (Evans and Stanovich 2013). Related approaches argue that human beings process information in two different brain systems. In the evolutionary older System 1, the intuitive processing system, (sensory) information is processed quickly, effortlessly, and unconsciously in an associative manner. The system gives rise to feelings – of which the feeling of "being there" may be one. In contrast, the evolutionary younger System 2, the reflective processing system, performs slower, more effortful, and deliberate analytical operations. This system gives rise to beliefs. Because both systems operate in parallel, users may simultaneously feel spatially present in a mediated environment while knowing they are not.

However, merging Spatial Presence and dual process theories leads to a number of yet unsolved but important questions. For example, past research seems to view Spatial Presence primarily as an outcome of automatic System 1 processing, but little is known to date about the way System 1 and 2 processing mutually affect each other in the formation of Spatial Presence. Research on users' suspension of disbelief (a process that may be considered a reflective, intentional suppression of information considered unlikely or implausible), for instance, suggests that users' System 2 processing may effectively influence their System 1 processing in the formation of Spatial Presence (Hofer et al. 2012). Clarifying the complex interactions between users' automatic and reflective processing while encountering media environments promises to further enhance our understanding of Spatial Presence.

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Part II
Telepresence Research and Design

Chapter 8
Ways to Measure Spatial Presence: Review and Future Directions

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Abstract The chapter focuses on the measurement of spatial presence. Our aim is review existing measures of spatial presence and provide evaluative classifications of the quality and appropriateness of these measurement methods. In addition to existing methods, we also shortly discuss the appropriateness of measures that have not been extensively used so far, such as "think aloud"-method, dual-task measures, eye-related measures and psychophysiological measures.

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We discuss the pros and cons of the different measures of spatial presence by using a range of indicators that are typically used to evaluate empirical methods. Both subjective and objective measures are evaluated in detail according to seven criteria, reliability, validity, sensitivity, applicability, diagnosticity, obtrusiveness and implementation requirements. A special emphasis is put on assessing whether a particular measurement method measures what it is aimed to measure (validity); to what degree it is able to discriminate different levels of effects (sensitivity); to what degree it provides information of the causes of differences (diagnosticity); and what its possible application domains are (applicability).

Our central conclusion is that we need both objective and subjective indicators of spatial presence, and they should be combined in a single study in a way that makes sense for the specific research question. We also need more comprehensive and better-validated questionnaires that are theoretically derived and tap the multi-dimensional nature of the phenomenon. Also, objective indicators of spatial presence should be selected on the basis of the specific dimensions of presence being assessed.

Keywords Special presence • Methods • Reliability • Validity • Sensitivity • Diagnosticity • Obtrusiveness • Applicability • Implementation requirements

8.1 Introduction

In this paper we will discuss the pros and cons of the different measures of spatial presence by using a range of indicators such as validity, reliability and sensitivity. We provide short descriptions of existing measures of presence and provide evaluative classifications of the quality and appropriateness of these methods. Another aim is to provide suggestions of how to improve existing methods and how to develop better new ones.

8.1.1 Characteristics of Spatial Presence

People's assumption on what presence is has implications on the measurement of presence. Some of these assumptions are discussed here. For example, a quite general view is that presence is a multidimensional construct, similar to workload or situation awareness. Different authors have listed different explications of presence (see, e.g., Murray et al. 2000; Zhao 2002). Zhao, for example, have provided a fruitful classification by making a distinction between the mode of presence and the sense of presence. The first distinction reflects the physical relationship between the perceiver and the environment. Zhao differentiates three different modes of presence, proximal presence, remote presence and virtual presence. Sense of presence is the subjective experience of being present in the mediated environment. It can be differentiated to physical presence, co-presence and social presence. At the next lower level there are the different psychological dimensions of presence experience such as spatial presence and involvement.

When talking about the measurement of presence, we should also ask which levels of analysis are relevant. Psychological investigation of the presence phenomenon can take place at many levels of analysis. So far, most of the studies have operated at levels between interpersonal interaction and physiological, but other levels such as the social networks and groups, on the one hand, and neurological, on the other hand, are also possible. Since presence may have effects on different levels (e.g., sociological, psychological and physiological) we need methods that tap these different levels of presence. The methods that are used depend on whether spatial presence is a conscious phenomenon. If presence is a conscious phenomenon (e.g., Waterworth and Waterworth 2001), it can be measured by subjective reports. However, it is also possible that people are conscious of only some aspects of it. In the latter case, self-reports, perhaps, cannot give us a full picture of the phenomenon, but they have to be complemented by objective methods.

By which way we should measure presence depends also on in which media environments presence can occur. There is some controversy on this issue, but a quite common view is that presence can only be experienced in virtual environments (VEs). Proponents of this view claim that experiences of presence should be differentiated from emotional/intellectual engagement that can be experienced in other media environments (Waterworth and Waterworth 2001, 2003). Another view is that, since similar cognitive processes operate in all media environments, also the psychological phenomenon is the same in all contexts (e.g., Schubert and Crusius 2002).

8.1.2 Which Kind of Measures Are Needed?

Research methods and techniques can be evaluated by several criteria. Seven criteria are used in this paper, reliability, validity, sensitivity, diagnosticity, applicability, obtrusiveness and implementation requirements (e.g., ANSI/AIAA 1992; Rehmann 1995).

Reliability has, at least, two meanings: First, it means the consistency of a measure, that is, the degree with which the same information is obtained by a measurement across different times. Second, reliability refers to internal consistency. Internal consistency means to what degree the test items measure aspects of the same phenomenon. Internal consistency is typically expressed by calculating the average correlation among items within a test (e.g., Nunnally and Bernstein 1978).

Generally, validity is an indication of whether a particular measure measures what it is aimed to measure. Several types of validity can be differentiated, face and content validity, criterion validity (predictive and concurrent validity), and construct validity (convergent and discriminant validity). Content validity is an indication of the representativeness of scale items. Criterion validity is a measure of the relationship between a particular performance and some criterion behaviour, and construct validity means to what degree a measure is measuring a theoretical construct.

Sensitivity is an index of whether a particular measure is able to discriminate levels of effects (e.g., Rehmann 1995). Diagnosticity is a characteristic of a measure to provide information of the underlying causes of differences in test results (e.g., ANSI/AIAA 1992; Rehmann 1995). Applicability indicates to what degree a measure can be used in different conditions and environments (Jex 1988). Obtrusiveness refers to what degree a particular measure disrupts the task performance and distract attention away from the media world (Jex 1988). The implementation requirements deal with such issues as overall cost/benefit of a measure, its administration requirements and acceptance (Jex 1988).

8.1.3 Classification of Presence Measures

We can categorize the presence measures in different ways. The classification can be based on the ways we gather the data. Alternatively, we could classify the methods in according to the ways we analyze it. Here we provide a classification that is based on the different ways of gathering the data: measurement methods are here categorized as to subjective measures and objective measures. This does not, however, mean that there is a clear distinction between subjective and objective measures. Since subjective and objective measures should be seen as positioning along a continuum going from subjective to objective ones, measures are more or less subjective or objective (van Baren and IJsselsteijn 2004). Subjective and objective measures can be further classified in different ways. In the following part of the paper, subjective (Sect. 8.2), and objective (Sect. 8.3) measures of presence are discussed and evaluated with the criteria introduced in Sect. 8.1.2.

Another distinction can be made between quantitative and qualitative measures. All objective measures are quantitative in nature, but subjective measures can be both qualitative and quantitative. Quantitative methods involve manipulation and analysis of numerical data by using statistical procedures. Qualitative techniques are subjective methods that focus on the meanings of the information which has been acquired. The emphasis on qualitative measures is based on the belief that the attempts to quantify human experiences are, more or less, misguided and will fail (see, e.g., Denzin and Lincoln 2000).

8.2 Subjective Methods

When subjective measures are used, participants have to consciously and introspectively judge and describe their experience. It is assumed that feelings of presence are something that people can be consciously aware of, and people are able to express these feelings using verbal statements. It is also assumed that feelings of presence are something universal, common to most of people, and nearly all people experience presence when suitable conditions are provided. There also must be something common in these experiences across individuals. That is, in order to be meaningful, people should associate the term 'presence' to same types of mental phenomena.

There is evidence that presence is a meaningful concept in this respect, but it is not guaranteed that all people use the term in the same way and relate it to same types of experiences. People tend to see things differently from one another, and there are differences in people's ability to put their feelings into words.

8.2.1 Post-test Rating Scales/Questionnaires

Post-test rating scales are typically paper-and-pencil questionnaires. They have been widely used in assessment of state of presence, and there are several questionnaires that have been developed to assess users' sense of presence in different types of media environments (e.g., Baños et al. 2000; Biocca et al. 2001; Hartmann et al. in press; Hendrix and Barfield 1996; Kim and Biocca 1997; Kizony et al. 2005; Lessiter et al. 2001; Lombard et al. 2009; Sas and O'Hare 2001; Schubert et al. 2001; Slater et al. 1994, 1995; Witmer and Singer 1998; Witmer et al. 2005; Vorderer et al. 2004).

Van Baren and IJsselsteijn (2004) mentioned 28 questionnaires that have been used to measure spatial presence; 16 of them measure spatial presence alone, four of them measure both spatial and social presence. Many of these questionnaires are based on an original approach, but their reliability, validity and sensitivity are not extensively assessed. Most of them are also very short, and in many studies presence has even been assessed by a single question that directly ask to what degree the person experienced feelings of presence in the mediated environment.

8.2.1.1 Early Efforts to Measure Presence by Questionnaires

SUS (Slater et al. 1994, 1995)

One of the most widely used of the short questionnaires is SUS. This questionnaire asks six questions which deal with the sense of 'being there' in the computer-generated world; the extent to which there were times when the experience of the computer-generated world became the dominant reality for the users, so that they forgot the outside world; and whether users remembered the computer-generated world as 'something they had seen' or 'as somewhere they had visited earlier'. The questions are asked on a 1–7 scale each, and the number of 6 and 7 responses is counted to produce the score for the SUS (e.g., Usoh et al. 1999).

There is some evidence for the content and construct validity of the SUS, but its sensitivity is moderate, at best. For example, there was a significant difference between the real condition and the three media conditions in Mania and Chalmers' (2001) study, but there were no differences between the three media environments. Additionally, the SUS could differentiate the graphics and text conditions in Nunez and Blake (2003), but it was not able to differentiate the low-and high-quality graphics conditions. Neither could it differentiate stereoscopic and monoscopic presentation conditions in Baňos et al.'s (2008) study. Recently, Slater et al. (2009) presented a 11-item pit room questionnaire for assessing participants' experiences in a virtual pit room. In a study in which the visual quality of the pit room environment was modified, it was found that the level of presence was considered higher in a more realistic environment.

Nichols et al.'s (2000) scale is an extension of Slater's questionnaire. Presence items deal such questions as awareness, flatness of the media context, enjoyment, lag and attention. This brief questionnaire deals with some novel themes, but its reliability and validity are not yet evaluated.

Kim and Biocca's (1997) Questionnaire

The questionnaire is based on their idea of telepresence as transportation, that is, the user is first transported, then he/she arrives a particular place and finally he/she returns to the environment of origin (Kim and Biocca 1997). The questionnaire consists of eight Likert scale items. Two factors were found in Kim and Biocca's (1997) study. The first factor is called 'arrival'. It means the sensation of being there in the mediated environment. This factor was found to have a positive effect on confidence in brand preference, which, in turn, has a positive effect on buying intention (Kim and Biocca 1997). The second factor is called 'departure'. It means that the user is not being in the physical environment. Departure was shown to affect both factual memory and recognition memory, and it had a direct positive effect on buying intention (Kim and Biocca 1997).

Kim and Biocca's (1997) questionnaire is based on an original approach. However, since the number of items is small, its reliability is apparently limited. It has not been carefully validated, but there is some evidence that its validity is moderate, at best. For example, Kim and Biocca (1997) found that the presence of unmediated visual stimuli and the visual angle of the TV set had no effect on presence ratings. Its sensitivity and diagnosticity seems to be moderate, and it is mainly applicable to virtual environments only. Because of small number of items, it is easy to administer and score.

Barfield et al. (1998) Presence Questionnaire; PRQ (The Presence & Realism Questionnaire)

Based on their earlier questionnaires (e.g., Hendrix and Barfield 1996), Barfield et al. (1998) presented a 18-item questionnaire which consists of three topic areas, sense of presence, engagement of senses, perceived fidelity of the interaction between the user and the VE. It consists of a 10-item presence and realism checklist, as well as overall rate of realism and presence. Barfield et al. found significant differences between input device lag and presence scores. The questionnaire is mainly applicable to virtual environments only. There are other questionnaires that are partly based on Barfield et al.'s questionnaire (Kim and Biocca 1997; Parent 1998; SUS).

8.2.1.2 Multidimensional Presence Questionnaires

Since it became clear that short questionnaires could not tap the multidimensional nature of the phenomenon, more extensive questionnaires were going to replace them. Several detailed and extensive questionnaires, such as the PRQ, PQ, IPQ, ITC-SOPI, and MEC-SPQ and TPI, are now available. They are based on studies in which quite similar constituents of presence have been found. Thus, it can be argued that they have quite well allowed for a differentiation of the main aspects of presence.

Presence Questionnaire (PQ), Witmer and Singer (1998)

One of the first of the multi-item questionnaires is Witmer and Singer's (1998) Presence Questionnaire (PQ). The PQ is mainly measuring people's perceptions of different features that may have an influence on the sense of presence. Witmer and Singer's (1998) Immersion Tendency Questionnaire (ITQ), in turn, examines individual differences in the ability to experience presence. According to them, two psychological states, involvement and immersion, are necessary for experiencing presence. A valid measure of presence should address factors that influence both of these states. They suggested that four factors (control, sensory, distraction and realism factors) have an effect on involvement and immersion which, in turn, determine the state of presence. The presence score is the sum of the control, sensory, distraction and realism scales.

Witmer and Singer (1998) tested the PQ in four experiments which revealed three subscales: involved/control, natural and interface quality, which do not perfectly match the original four factors. More recently, Witmer et al. (2005) carried out principal-component analyses of the PQ data from 325 participants and found that a four factor model provided the best fit to their data. The factors were labelled involvement, adaptation/immersion, sensory fidelity and interaction quality. The three first mentioned correspond to those found in Witmer and Singer's (1998) study; the adaptation/immersion factor is the only addition to the original questionnaire.

Several studies have provided some evidence for the criterion/construct validity of the original PQ and/or the ITQ. For example, Casanueva and Blake (2000) found a significant positive correlation between Witmer and Singer's ITQ and the presence questionnaire developed by Slater, and there was a significant difference between the PQ scores between desktop screen users and semi-immersive screen users in Tichon and Banks' study (2006). However, negative evidence has also been reported: For example, Youngblut and Huie (2003) did not find a correlation between the PQ scores and task performance.

If the ITQ scores reflect an individual's ability and tendency to experience presence, there should be a correlation between the PQ and ITQ items, that is, people who get higher scores on the ITQ should report more presence on the PQ. The evidence is, however, somewhat mixed. Witmer and Singer (1998) found a positive correlation between the PQ and ITQ scores, but Johns et al. (2000) showed that the ITQ scores did not predict the PQ scores. Vora et al. (2002), in turn, found that ITQ involvement and PQ involvement significantly correlated.

There is some support for the sensitivity of the PQ (Nunez and Blake 2003). Since the PQ includes three subscales that measure different aspects of the causes of presence, it may also have some diagnostic value. As the PQ has been developed to measure presence in VR, it is not, without modifications, applicable to low-level media environments.

Baňos et al.'s (2000) questionnaire is based on Witmer and Singer's (1998) presence questionnaire and Baños et al.'s (1999) reality judgment questionnaire. The final questionnaire includes 18 items of which five are reality judgment items, and another five are presence items. The rest of items are measuring realism, interaction and attention. The internal consistency reliability was shown to be high, but there is little evidence of the validity of the questionnaire.

Stevens et al. (2002) adapted the Witmer and Singer PQ to measure object presence. Object presence was defined as the subjective experience that a particular object exists in the user's environment even when it does not really exist there. The internal consistency of the questionnaire was shown to be high, but there is negative evidence for its validity, since no correlation was found between their Object Presence Questionnaire and the ITQ.

Sas and O'Hare's (2001) Presence Questionnaire

Sas and O'Hare developed a questionnaire which measure three dimensions and variables. In agreement with Kim and Biocca (1997) they thought that the two key elements in presence experience are 'being there' and 'not being here'. Their third key element is reflexive consciousness (awareness of being there). A particular set of variables is associated with each of these dimensions. They provided evidence for the reliability and concurrent validity of their questionnaire.

Biocca et al. (2001)

Biocca et al. (2001) developed an 18-item presence questionnaire based on Lombard and Ditton's (1999) unpublished scales. The questionnaire measures spatial presence, tactile engagement and sensory presence in different kind of VEs. Data from 80 participants showed that the reliabilities for the three presence scales were quite high (0.51-0.87). No evidence of construct validity of the measure was provided.

Igroup Presence Questionnaire (IPQ) (Schubert et al. 2001)

Schubert and his colleagues (Schubert et al. 2001) developed a presence questionnaire (Igroup Presence Questionnaire, IPQ) that is based on the embodied cognition framework (e.g., Glenberg 1997; Lakoff 1987). According to Schubert et al., presence includes two components: the sense that we are located in the VE and act from within it, and the sense that we have focused our attention to the mediated environment and ignored the real world.

Eight factors were found in Schubert et al.'s (2001) study of which three factors were concerned with presence. The presence factors were related to spatial presence, involvement, and judgment of reality.

The reliability of the scales was shown to be quite high. The factor analytic structure closely resembled the dimensions Schubert et al. had theoretically assumed, which provides some support for the construct validity of the IPQ. A confirmatory factor analysis gave additional support that the subscales reflect the intended constructs.

There is also preliminary evidence for the sensitivity and diagnosticity of the IPQ. Schubert et al. (2001) compared two video games and found significant differences for spatial presence and immersion. An exploratory path analysis also showed that the immersion factors can predict the presence factors.

The IPQ measures presence in a VE, but may also be applicable to other types of media environments. Since the questionnaire has only 14 presence items, the filling of the questionnaire is not time-consuming and laborious.

ITC Sense of Presence Inventory (ITC-SOPI) (Lessiter et al. 2001)

Lessiter and her colleagues (2001) developed a presence questionnaire with the purpose that it should be applicable to all kind of media environments. The ITC-SOPI consists of four factors. Sense of physical space is related to the sense of physical placement in the media world, and interaction and control over different aspects of the environment; engagement means a tendency to feel psychologically involved in the media world and ability to enjoy the content; ecological validity is related to a tendency to perceive the mediated environment as real; and negative effects is a tendency to have adverse physiological reactions (Lessiter et al. 2001).

The reliability of the four scales was quite high in Lessiter et al.'s (2001) study. There is also support for the construct validity of the measure. Lessiter et al. found that the ITC-SOPI and Slater et al.'s (1994) SUS loaded on the same factors, and the ITC-SOPI could discriminate between different media.

Lessiter et al. (2001) found that the scores increased with the enhancement of the immersiveness of a media form suggesting that the ITC-SOPI should be a quite sensitive measure. The results, for example, showed that ratings on sense of physical presence, engagement and ecological validity were significantly higher for three-dimensional media environments than for two-dimensional environments. Suh and Chang (2006) found that presence measured by the ITC-SOPI was higher for VE interfaces than for video-clip and multiple-picture interfaces in a study in which the effect of presence on consumer behaviour was investigated. Some recent studies have provided negative evidence of the ITC-SOPI's sensitivity to differences in perceived realism of media (Baňos et al. 2008; de Kort et al. 2006).

As mentioned above, the ITC-SOPI should be applicable to all kinds of media environments. It is also quite easy to administer and score. The ITC-SOPI has been used in over 400 laboratories worldwide under a free academic license, and has been cited in more than 500 studies on presence.

MEC-SPQ (Böcking et al. 2004; Vorderer et al. 2004; Wirth et al. 2007)

The MEC Spatial Presence Questionnaire (MEC-SPQ) is based on a two-level model of the formation of spatial presence which proposes that people first generate a mental representation of the physical space that is presented, and after that, they activate and test perceptual hypotheses that concern the acceptance of the mediated space as the primary frame of reference (Wirth et al. 2007). The questionnaire includes process factors such as attention allocation, spatial situation model, spatial presence and two factors that are directly related to spatial presence: self-location and possible actions (Wirth et al. 2007). It also includes two factors that refer to states and actions: higher cognitive involvement and suspension of disbelief and three factors that address enduring user-related variables: domain specific interest, visual spatial imagery and absorption. The preliminary questionnaire consisted of 103 items.

An English-version of this questionnaire was administered to 290 participants in three different countries (Finland, Portugal and USA; Wirth et al. 2007). The questionnaire was tested with four types of media (text, film, hypertext and virtual environment). A dual-task paradigm was used: half of the participants were distracted several times during the presentation of the media stimulus and they had to perform a secondary task, the other half of the participants was not distracted.

Item analysis was carried out, and full, medium and short versions of all scales were computed. Internal consistency of the questionnaire is high (Wirth et al. 2007).

There is some preliminary support for the validity of the MEC-SPQ (Wirth et al. 2007). Factor analysis provided support for two separate subscales of spatial presence (i.e., self-location and possible actions). A one-factor solution for involvement was also supported. All the three presence-related scales (cognitive involvement, self-location, possible actions) were sensitive to the manipulation of attentional distraction. Additionally, inter-scale correlations provide support for the validity of the scales. The involvement scale correlated positively with the self-location scale and the possible actions scale.

Overall, empirical studies (e.g., Gysbers et al. 2004; Baumgartner et al. 2006) provide some support for the reliability, validity and sensitivity of some of the MEC-SPQ presence scales. More evidence is, however, needed to provide support for the validity of all six scales.

Hartmann et al. (in press) has recently developed a short eight-item Spatial Experience Scale (SPES) based on the MEC-SPQ that measure people's self-location and perceived possible actions in media environments. Two studies have conducted that provide preliminary support for the reliability and validity of the SPES.

TPI (The Temple Presence Inventory; e.g., Lombard et al. 2000, 2009, 2011)

Lombard and his colleagues (2000) have developed a 42-item questionnaire. It contains items that are selected from a comprehensive literature review of presence theory and research. It includes eight factors, spatial presence, parasocial interaction, passive interpersonal presence, active interpersonal presence, engagement (mental immersion), social richness, social realism and perceptual realism. Spatial presence, engagement and perceptual realism scales are the most relevant for spatial presence.

Bracken (2006) found some evidence for the validity and sensitivity of the TPI in a study in which the impact of television form on presence was investigated. Lombard et al. (2009) demonstrated TPI's reliability, validity and sensitivity across media type, format and content. Lombard et al. (2011) also showed that subscales of the TPI are correlated with the corresponding subscales of some other presence questionnaires (SUS, PQ, IPQ, MEC-SPQ and ITC-SOPI) which provides support for the convergent validity of the TPI.

8.2.1.3 Evaluation of the Presence Questionnaires

Most of the questionnaires (e.g., the PQ, IPQ, ITC-SOPI, and MEC-SPQ and TPI) have shown to be internally-consistent, but the consistency of participants' responses over time has not been so far evaluated. In fact, it can be argued that some of the scales might have problems with test-retest reliability.

Because of the quite short history of measurement of presence, the above-mentioned questionnaires are typically not extensively examined, and there is quite little published evidence of their validity. What is promising is that the multi-item questionnaires are based on studies in which quite similar constituents of presence have been found. Thus, it can be argued that they have enabled a differentiation of the main aspects of presence. However, since some of the questionnaires show a high overlap of exactly the same items, it is not very surprising if factor analyses reveal the same structure for the construct. It can also be questioned whether the questionnaires have tapped all the relevant contents of the presence experience.

Some questionnaires have been critisized for their scales being derived deductively (e.g. Hartmann et al. in press). However, overall, it is not at all clear whether factor analyses should be used to identify the components of presence, or whether we should use established theory-derived components of presence to determine the questions to be included in a questionnaire (Wilson and Nichols 2002). Typically, it is preferred that we proceed 'backwards', that is, the development of the questionnaire should be based on a well-established theory. At least, the fact that there is still no generally accepted theory of presence and the whole concept is rather vague, has an effect on the validity of the questionnaires. It is quite common that some essential aspects of presence are easily underrepresented and some irrelevant aspects are overrepresented in the questionnaires (cf. Strube 2000). Overall, the construct validation process of the presence questionnaires is only just in the beginning.

Statistical analyses of questionnaire data face special challenges if it is based on Likert-scales. Gardner and Martin (2007) has noted that Likert scaled data from presence questionnaires cannot be treated as if it were interval scaled, and therefore it has to be analyzed by using rank-based statistical methodologies. According to them, it is also questionable to average Likert scores of several questionnaire items into aggregated constructs.

There is evidence that, at least, the IPQ, ITC-SOPI, MEC-SPQ/SPES and TPI can discriminate between different types of media, and they also have sensitivity to different levels of presence. Multidimensional questionnaires should also be quite diagnostic.

One important question is the application domain of a questionnaire. Many of the above-mentioned questionnaires are mainly aimed to measure presence in virtual environments. Since the ITC-SOPI, MEC-SPQ/SPES and TPI make little reference to physical properties of the system, they are proper cross-media questionnaires applicable to most types of media environments

Overall, since presence is a subjective mental state, it is then quite natural to try to measure it by questionnaires. Questionnaires should be quite diagnostic providing information of the multiple factors determining the phenomenon, and they can be applied for all kinds of media environments. Also, since they are administered after exposure to media stimuli, they do not interfere with the users' experience. Even though questionnaires may have problems with their validity and sensitivity, a good quess is that the questionnaire will be the basic tool in the measurement of presence also in the future.

Questionnaires rely on users' ability to recollect afterwards their experiences. Since people may have problems to recall from memory relevant information, it may sometimes be better to ask them to make an online judgment of their experiences.

8.2.2 Continuous Subjective Presence Assessment Techniques

It is a reasonable assumption that during media exposure people's experiences of presence varies from moment to moment either by a continuously manner or by abruptly changing from 'not-present' state to a 'present' state. For example, it may vary over time depending on the displayed content and the extent of sensory information available in the stimulus material. Therefore, it would be useful to try to measure temporal variations in presence. There are different possibilities to carry out an online assessment of presence. For example, it can be asked people verbally express their evaluation of sense of presence with verbal or pictorial scales (Wissmath et al. 2010). Another possibility is to ask people to make an online judgment of presence by adjusting a hand-held slider (Freeman et al. 1997; IJsselsteijn et al. 1998; IJsselsteijn and de Ridder 1998).

8.2.2.1 Continuous Presence Assessment by a Slider

In this method people have to continuously indicate the subjective level of presence experience by adjusting the position of a hand-held slider along a graphical scale, while the computer constantly samples the position of the slider (IJsselsteijn et al. 1998; Wissmath et al. 2011).

IJsselsteijn et al. (1998) have provided evidence for the reliability, validity and sensitivity of the method. They have, for example, shown that there is a link between perceived three-dimensional depth and feeling of presence measured by the counter. It may also be a diagnostic tool providing information of the causes of changes in presence, if changes in adjustments are, for example, compared to video recordings of the media stimuli.

Even though IJsselsteijn et al. (1998) have shown that the measurement device requires little attention or effort, online assessment necessarily to some degree disturbs the presence experience. Moreover, since the need to continuously adjust the slider makes it difficult at the same time to interact with the environment, the method can only be applied to non-interactive media.

8.2.2.2 Continuous Presence Assessment by a Counter

Slater and Steed (2000) have proposed another continuous assessment method in which the aim is to count the transitions from presence in the mediated environment to presence in the real world. They assume that presence is a binary state, and the need to continuously reflect on the transitions of presence does not itself influence the participants' ability to report these experiences.

There is little evidence of the reliability and validity of the method, but preliminary results suggest that the presence counter-method may be quite sensitive (Slater and Steed 2000). In principle, the method is applicable only to highly immersive virtual environments which surround the user and isolate her from the reality. It may be quite intrusive, but it should disturb the media experience in a lesser degree than other continuous subjective assessment methods. Overall, this technique is quite easy to administer and score, and no special equipment is needed.

Sometimes, more direct information of users' sense of presence is needed than can be provided by using the above-mentioned methods. The next section highlights the possibility of using psychophysical methods for scaling of presence experiences.

8.2.3 Psychophysical Measures

Since the feeling of presence is a subjective mental state, it is possible that presence could be investigated by psychophysical methods. There is considerable consistency in psychophysical scaling, and it is considered one of the most powerful ways to gather human data. Since psychophysical methods can produce interval-scaled data, they can provide information of the magnitude of differences in presence experiences between mediated environments (O'Donnell and Eggemeier 1986).

8.2.3.1 Magnitude Estimation

A free-modulus magnitude estimation can be used in investigating the effects of media on presence. Users have to assign numeric labels for each stimulus such that these labels correspond to the strength of their sense of presence. In cross-modality matching the users have to express a judgment of a subjective sensation in one modality by responding through adjusting a parameter in a different modality.

Kuschel et al. (2007) introduced a new method for presence based on the perception of bimodal information within a visual-haptic virtual reality system. In their study, participants performed the magnitude estimation of the conflict perceived. It was found that the rating of presence decreased monotonically as a function of the amount of perceived conflict between visual and haptic information.

Magnitude estimation is useful for scaling of presence (Stanney et al. 1998), and magnitude estimation has shown to be a very reliable and valid method (Meister 1985). However, since we do not know the physical manipulations of media stimuli that are needed for the manipulation of presence, it is hard to estimate possible range effects when applying magnitude estimation. A second difficulty with magnitude estimation is anchor effects, that is, the value assigned to a given condition may depend on the conditions to which it is compared. Participants should also have a clear idea what is meant by the term 'presence', since vague understandings may reduce the reliability and validity of this method.

8.2.3.2 Method of Paired Comparisons

When the method of paired comparison is used, the presence is measured in terms of the amount of noise needed to make a real scene indistinguishable from a virtual scene, and the participant is asked: "Which of these two media stimuli produces the greater amount of presence for you?" (Stanney et al. 1998). There are several stimuli that have to be compared, and all the possible pairings that have to be scaled are presented. Since the participant has to distinguish between a virtual and a real environment, this method can be thought as some kind of 'virtual reality Turing test' (Schloerb 1995; Welch 1997).

Since the method of paired comparisons is very direct, it should be sensitive and an ideal alternative for the measurement of the realism of virtual environments. The method may be quite diagnostic, since studying the effect of systematic manipulations of specific features of the media stimulus on paired comparisons provides useful information of the causes of differences in states of presence. On the other hand, since only highly immersive environments can be confused with a real environment, the applicability of the method is very limited.

8.2.4 Qualitative Measures

Qualitative research methods such as the focus group method and ethnographic techniques, have also been proposed as possible methods to investigate experiences of presence. Qualitative research methods provide information which is not based on quantitative data. Qualitative techniques providing information that is not based on quantitative data afford us a means to identify subtle aspects of presence experience, highlight these experiences and stimulate quantitative research.

Qualitative research is aimed to understand how people experience and interpret events (e.g., Denzin and Lincoln 2000). It involves the use of different types of interpretative practices in order to get a better understanding of people's experiences. Those who use these methods typically study the matters in their natural settings, so that they could better understand the meanings people bring to them. It also uses a diverse set of methods in analysing data, such as content and discourse analysis.

8.2.4.1 Interviews

One possibility to gather qualitative data is to interview participants after the experimental session (e.g., Garau et al. 2008; Murray et al. 2000; Rétaux 2002; Slater and Usoh 1993; Turner et al. 2003). Open-structured interviews are the most suitable for presence research. It could be, for example, asked users to tell in their own words about feelings of presence. Additionally, they could be asked about possible reasons for changes in the state of presence. Since interviews provide quite specific and detailed information of people's feelings and experiences, they may be useful in developing and pretesting questionnaires.

Interviews have similar type of reliability problems as questionnaires. People may, for example, have problems to retrieve the relevant information from memory. Different types of interviewer effects may, in turn, reduce the validity of interview data. The verbal data is also unique, and the findings are not easily replicable. However, since verbal protocols may provide information of the possible causes of presence experience or the lack of it, they may be quite diagnostic. Several methods such as content analysis can be used to analyse interview data. All data analysis techniques are quite labour-intensive.

8.2.4.2 Continuous Verbal Reporting

Verbal protocols could also be gathered during the experimental session. 'Think aloud'-method has been quite widely used in different domains (e.g., van Someren et al. 1994). Turner et al. (2003) used the think-aloud method in a study investigating presence and sense of place in a soundscape. They found that, even though verbal protocols provided rich qualitative data, speaking aloud interfered with presence. In another study, Turner et al. (2003) found that there were considerable differences in the richness and level of detail of the verbal reports.

'Think aloud'-protocols should be more reliable than interviews, because there is no need to recall experiences. Reliability of coding may be a problem, however. One solution is to use several coders and evaluate inter-coder reliability. Many factors may reduce the validity of verbal protocols. For example, people are not necessarily able to verbalize the relevant information, and having to give a verbal protocol contaminates cognitive processes and may have an effect on media experiences. The method is, thus, not applicable if the participant has to read or listen verbal material. On the other hand, since 'think aloud'-method may provide evidence of determinants of presence and different processes and stages leading to presence, it may be a quite diagnostic tool (Wirth et al. 2004).

8.2.4.3 Experience Sampling Method (ESM)

Gaggioli et al. (2003) studied presence by using an approach which emphasizes the active role of individuals in interacting with different types of environments. The experience sampling method is based on online assessment of the external situation and people's state of consciousness as events occur. Participants carry with them an electronic beeper, and fill out a form every time they receive a signal. The form contains open-ended questions and rating scales regarding different components of quality of experience. A specific model called the Experience Fluctuation Model was developed to analyze the results.

8.2.4.4 Repertory Grid Analysis

Repertory grid analysis is a conversational tool that is based on the theory of personal constructs developed by George Kelly (Steed and McDonnell 2003). According to Kelly, people's interpretations of their experiences are based on their personal constructs about how the world works. The aim of the method is to identify those individual personal constructs.

In the repertory grid analysis a variety of experiences are, at first, identified, and these are compared with one another to elicit personal constructs. Participants assign a rating to each construct for each experience. Discussions with the participant are an essential part of the technique. This method may also be a useful tool in constructing and refining questionnaires.

8.2.4.5 Ethnographic Techniques

A typical feature of ethnographic studies is that relatively few users are studied by analysing their case histories. For example, McGreevy (1992) studied presence among people in relatively extreme circumstances, e.g. geologists in the field of Mars-like terrain, by interviewing them.

Ethnographic techniques are valuable to give insight with detailed personal aspects of experiences, and how people theorize and conceptualize their own behaviours. Since it is difficult to replicate natural events, the reliability of ethnographic techniques may be quite low. The researcher's own subjective feelings may influence the results which reduces their validity. Ethnographic studies are also very laborious and take a long time to conduct.

8.2.4.6 Focus Groups

Focus group exploration means that small groups of users discuss together their experiences with a mediated environment (Heeter 1992; Freeman and Avons 2000). This method is helpful, when there is quite little previous knowledge of a complex mental phenomenon such as presence. In getting closer to participants' understandings and perspectives on certain issues, focus groups can provide an in-depth look at presence. Focus groups can also be used to make it clearer the relevance of the presence concept. Since tape recordings of conversations have to be transcribed, the method is very time-consuming and laborious.

Freeman and Avons (2000) have applied the focus group methodology to examine people's media experiences. They found that novice users related their experiences to such aspects of the media stimuli as involvement, realism and naturalness which are often associated with presence.

8.2.4.7 Evaluation

Qualitative methods provide an insight to participants' unique ways of interpreting the world, and they make it possible to explore issues in more depth. On the negative side, since experiences of only a small number of people can be studied in detail, qualitative research may have reliability problems. On the other hand, in many ways qualitative research is better sheltered from validity problems than quantitative research. Participants are, for example, allowed to challenge the researcher's assumptions about the presence concept. Since unique cases are studied in detail, qualitative research methods should be quite sensitive and diagnostic. Even though all qualitative methods are not applicable to all media contexts, their overall applicability should be quite high. Since qualitative research produces enormous amount of data, analysis of the data is a laborious and time-consuming process.

8.2.5 Overall Evaluation of Subjective Measures of Presence

When subjective measures are used, information of users' subjective experiences are collected and evaluated. Since presence is a subjective mental phenomenon, it is reasonable to directly ask people about their thoughts and feelings. For example, subjective methods may be the only way to acquire information of the multiple factors which may lie behind the phenomenon. On the other hand, because of limitations of attention and memory, people cannot focus their attention to all aspects of a stimulus and recall all the relevant information.

Subjective methods typically have better face validity than other research methods, that is, they appear to measure the concept they are aimed to measure. Subjective measures can also be quite sensitive, and they can be applicable to different types of media environments.

Evidence has been gathered for the validity of the five extensive questionnaires, the PQ, IPQ, ITC-SOPI, MEC-SPQ/SPES, and TPI, but, overall, the validation of the questionnaires is still at the beginning stage. One of the main problems with nearly all the questionnaires is that since they are not theoretically derived, they do not provide adequate guidance on the measurement of presence.

Since questionnaires provide only a holistic evaluation of people's experiences, some continuous assessment methods have been suggested as possible approaches for giving an insight to the time-varying aspects of presence. Psychophysical techniques, in turn, have shown to be useful for providing accurate information of the relationship between a physical stimulus and a psychological reaction to this stimulus, but, so far, they have mainly been theoretical possibilities in presence research. Qualitative research methods, in turn, make possible to identify subtle aspects of presence experience and stimulate quantitative research.

In sum, since presence is a subjective mental phenomenon, subjective methods are ideal for providing information of internal sensations and feelings related to the use of different types of media. However, more effort should be taken to increase the reliability and validity of subjective measures of presence. One prerequisite for this is that a more explicit and detailed theory of spatial presence is developed, and that subjective measures are constructed in such a way that they are based on the assumptions of the theory.

8.3 Objective Methods

When objective methods are used, it is investigated the effects or consequences of a particular mental state. According to Meister (1985), objectivity is defined in terms of the operations needed to report a datum. A measure is objective if means of measurements (e.g. clocks) are largely external to the observer and if there is little need to interpret the data when it is recorded. Objective measures are correlative in nature, that is, they do not provide us evidence of the direct cause of a certain mental state. Objective measures are typically preferred for quantification of phenomena. However, in case of a subjective mental state like presence, objective methods are difficult to implement for (Nash et al. 2000). They should be always corroborated with subjective ratings of the mental phenomenon.

Objective measures of presence are based on the principle of behavioural realism. According to it, when the stimulus display better approximates the environment it represents, an observer responds to the stimuli within the display in a similar way he/she would respond to the environment itself. Usoh et al. (1999) have defined behavioural presence as the extent to which actual behaviours or internal states and perceptions indicated a sense of being in the mediated environment rather than being in the real world.

Objective measures of presence can be categorized in different ways. Here we categorize them as three types, behavioural, performance-based and physiological measures (see IJsselsteijn 2002). First, we could measure behavioural responses that are correlated with some properties of the medium. For example, it could be measured changes in automatic and reflexive responses and effects of attentional distraction. Second, we could assess user performance. For example, it could be measured how well the user accomplishes a particular task in a mediated environment and how much he/she can recall information that is presented in the mediated environment. Third, we could measure physiological responses and brain activation patterns. Possible psychophysiological measures are, for example, pupil dilation, heart rate change, galvanic skin response, EEG and fMRI.

8.3.1 Behavioural Measures

Typically, these measures are based on direct observation of behaviour. Quite often, behavioural measures are categorized as subjective measures, because they are based on scaling or rating of behaviour of participants on the basis of particular dimensions or attributes – which is basically a subjective act.

Behavioural measures are here categorized as measures based on direct observation of behaviours evoked by virtual dangers, measurement of postural adjustments and body movement, and measures based on a user's attentional direction.

8.3.1.1 Direct Observation of Adaptive Behaviours Evoked by Virtual Dangers

This group consists of measures that are based on direct observation of behaviour.

Typically, a list of typical behaviours is first constructed, and then the number of occurrences of each behaviour is counted (Usoh et al. 1999). Examples of automatic responses that can be used are such as grasping one's chair, catching a ball, avoiding an approaching object by ducking etc. (Held and Durlach 1992; Sheridan 1992, 1996). The idea behind the measurement of these types of responses is that the motor system is tuned differently to different degrees of presence (Cohn et al. 1996).

Mel Slater and his group has investigated presence by behavioural measures in several studies. Results have been somewhat mixed and inconclusive. Slater and Usoh (1993) recorded participants' behavioural reactions to a plank and virtual objects flying at them. There was no prominent correlation between subjective and behavioural presence in this study. Usoh and his colleagues (1999; see also Slater et al. 1995) have measured a combination of subjective and behavioural aspects in a virtual corridor in which there was a virtual pit. They were interested in to what extent people were willing to walk out over the pit. The behavioural measure they used was the path participants actually chose when they navigated to the chair on the other side of the pit. They found that there was a positive correlation between behavioural presence and subjective presence measured by a questionnaire. Those who walked over the recipe reported a lower sense of presence than those who walked around the ledge at the other side of the room. In Lepecq et al's (2009) study, participants walking through a virtual aperture swivelled their body similarly to those who walked through a real aperture, and interestingly, the body rotation was a function of aperture and shoulder width.

Provided that behaviour classes are quite distinct, and behaviours are measured systematically, these types of measures should be highly reliable and valid (see, e.g., Meehan 2000). However, observer effect or reactivity may reduce the validity; experimenter bias is also possible. Also, it is not always clear whether a particular behaviour was caused by the experimental condition or not. Perhaps the biggest problem for the validity is that there is not necessarily a positive correlation between sense of presence and amount and quality of behaviour. Stappers et al. (1999), for example, have shown that users may behave naturally in a 'not-very natural' virtual environment and behave less naturally in a 'real' virtual environment. Hence, subjective sense of presence does not necessarily increase as a function of the naturalness of the mediated environment, and even high fidelity matches between the real and virtual environments may be insufficient to create identical behaviours.

If the behaviours are rather complex, the observations may be distorted which reduces the reliability and accuracy of a measure. The more simple and discrete the actions are the more reliable and accurate the observations will be. On the other hand, very simple behaviours may not be very meaningful.

There is mixed evidence of the sensitivity of observational methods of presence. Insko (2001) found that observed behavioural response to a fear-inducing stimulus could differentiate between a virtual precipe and a virtual precipe which has been augmented with a 1.5 in. physical ledge. Behavioural presence was, thus, higher with a physical ledge. Observed behavioural responses correlated also well with reported behavioural presence in Meehan's (2001) study. Meehan (2000), on the other hand, found that behavioural measures did not perform well in a study in which the frame rate was varied.

Primarily, observational responses to virtual dangers can only be used as a measure of presence in case of high-immersive media environments. Their applicability is, thus, restricted. These measures are typically also quite obtrusive, and they are not very easy to administer.

8.3.1.2 Postural Adjustments and Other Forms of Body Movement

There is some indication that the magnitude of body movement could be used as an objective measure of presence (Slater et al. 1998; Slater and Steed 2000; Stanney et al. 2002; Usoh et al. 1999). Slater and Steed (2000) found a positive two-way relationship between body movement and presence. According to them, high presence leads to greater body movement, and greater body movement reinforces high presence. The close link between body movement and presence reflects the fact that a match between proprioception and sensory data is required for high levels of presence.

Postural adjustments occur as a proprioceptive response and as a response to real or illusory observer motion. If there is a relationship between feeling of self-movement and presence, participants' postural adjustments during a virtual-environment session may be a valuable measure of presence, (Prothero 1998; Ohmi 1998). The idea is here that the more a user felt present in the mediated environment, the more postural adjustments he/she would make. One advantage of postural responses is that they occur automatically without conscious effort, and, thus, they do not influence concurrent subjective evaluations. Additionally, they can produce differential levels of response, which make them easier to relate to subjective ratings of presence (Freeman et al. 2000).

There is controversial evidence of the value of postural responses as a measure of presence. Freeman et al. (2000) studied to what degree participants swayed back and forth while watching a video shot. A magnetic position tracker was used to collect the observer's x, y and z positions. In their study postural responses and subjective presence were not correlated across the participants, but the magnitude of postural adjustments was higher for a stereoscopic presentation than that for the monoscopic presentation. This result gives a weak support for the use of postural responses as an objective measure of presence.

There are some problems with the use of postural responses. Using the magnetic position tracker has shown to produce quite unreliable postural responses (e.g., IJsselsteijn et al. 2001). Because of this, the reliability and validity of the measure is questionable. The fact that postural responses may interact with other features of the mediated environment may further reduce their validity. What is even more problematic is that a sense of presence may occur without any postural reflex (IJsselsteijn et al. 1998). There are also other problems: For example, the method applies only for stimuli containing motion, and, because it is a rather specific method, there is a need an extra setup in the VE. Looking at the positive side, since differential levels of response are easily generated, the measure may be quite sensitive.

8.3.1.3 Attention-Based Measures

The idea is that the more a participant allocates effort to the primary information, fewer attentional resources are available for the secondary information. It is assumed that "as presence increases, more attention is allocated to the stimulus display, which would mean an increase in secondary reaction times and errors" (IJsselsteijn et al. 2000). Dual-task measures can be categorized as (1) second reaction-time and error measures; (2) methods that measure the extent to which information from another source is processed (shadowing tasks, memory tasks); (3) methods that measure the integration of information from the real world into the experience of the mediated environment (e.g., IJsselsteijn et al. 2000). So far, there are few studies that have used attention-based measures, and most of them belong to the categories 2 or 3.

The simplest task is to ask participants whether they were consciously aware of real-life background events, e.g., background music and speech or flashing lights and abrupt movements of external stimuli (Nichols et al. 2000).

In Nichols et al.'s (2000) study, it was measured participants' recall of different styles of background music played in the real-environment during the presentation of the media stimulus. They found that participants who reported a higher level of presence were less likely to recall the background music. Bracken et al. (2011) used secondary reaction time to measure involvement to a movie and compared this measure to subjective presence measured by a multidimensional scale. A significant correlation between secondary reaction time and immersion was found in that the reaction time was slower when participants were more engaged into the movie.

Another possibility is to study the extent to which information from the real world is integrated into the experience of the virtual world and use the magnitude of integration as a measure of presence. One way to do this is to incorporate external stimuli to the mediated environment. If the participants interpret an external event or an object in the context of the VE then he/she must be present in that environment (Schuemie et al. 2001). Slater and his colleagues (1995) incorporated conflicting cues to the VE. Participants were first shown a real radio, then they were entered the virtual environment which included a virtual radio at the same location. During the experiment the real radio was moved and turned on. The participant's task was to point to the location of the radio. The more present the participant was, the more likely he/she would point to the location of the virtual radio rather than the real one. They (1995) found that there was a significant correlation between users' behaviour and presence measured by a questionnaire.

8.3.1.4 Summary Evaluation of Behavioural Measures

In principle, observational methods are reliable and valid. However, there is quite little evidence of reliability of behavioural measures of presence (Insko 2003). As mentioned above, there are reliability problems with methods to assess postural stability. To a degree, the responses are reflexive and automatic, these measures avoid problems of demand characteristics, that is, participants cannot respond in accord with or against their expectations. Sometimes they may be somewhat exposed to subject bias, however. For example, in some situations participants may suppress their fear. They can also be opened to experimenter bias, that is, the experimenter may bias the ratings in favour of the results he/she wants. The basic question concerning the validity of behavioural measures is whether it is possible to measure presence by looking on reactions. The relationship between behaviour and subjective sense of presence is necessarily indirect. First, it is difficult to know for certain that a particular behaviour was caused by the experimental condition. Second, and more importantly, amount and quality of behaviour is not necessarily related to sense of presence.

The intrusiveness of these methods varies: Dual-task measures are typically intrusive, other methods are not. Many of the methods based on direct observation of behaviours are quite specific, so that they are applicable only to a particular type of media environment. Some of them are also quite impractical. For example, it may be costly and time-consuming to make a virtual environment really frightening.

8.3.2 Performance Measures

What is common to performance measures is that there is a positive or negative performance change between pre-and post-test measurements or there are performance changes during the exposure to media stimuli. The central assumption is that people perform better in a highly-immersive virtual environment in which the sense of presence is also higher. Hence, if there is a positive link between task performance and presence, presence can be measured by measuring the users' performance in a particular task. Different types of perceptual, cognitive or motor tasks have been suggested as possible measures of presence.

A link between task performance and presence can be questioned, however. Immersion in the task performance is not the same as presence (e.g., Slater and Steed 2000). For example, reducing realism of media stimuli may sometimes increase performance but diminish presence.

8.3.2.1 Performance on Manipulation Tasks

Different types of manipulation tasks could be used as a possible measure of presence (for a taxonomy, see, e.g., Poupyrev et al. 1997). For example, different types of sensorimotor tasks (e.g., manual tracking; Ellis et al. 1997) and search tasks (Pausch et al. 1997) can be positively correlated with presence.

In an extensive study, Stanney et al. (2002) investigated human performance in a virtual environment. Participants travelled through a VE and performed several tasks that were based on the Virtual Environment Performance Assessment Battery (Lampton et al. 1994). The battery includes locomotion, object manipulation, tracking, reaction time and recognition tasks. It was found that performance scores and sense of presence were related: Those who completed more tasks reported a higher sense of presence. Also, shorter times on task and shorter distances travelled resulted in a higher sense of presence. Similarly, Youngblut and Huie (2003) found a positive relationship between presence measured by the SUS questionnaire and learning of mission procedures. However, evidence is mixed as to whether there is a correlation between subjective assessment of presence and measures of performance in simple psychomotor tasks and tests of spatial knowledge (Witmer and Singer 1998).

It is possible that the higher the sense of presence, the more positive is the transfer from the mediated environment to reality. There is a lot of evidence that those who learn skills in simulators perform better than those who learn from low presence media (e.g., Lombard and Ditton 1997). For example, Pausch and his colleagues (1997) found that users with a VR interface complete a search task faster than users with a stationary monitor and a hand-based input device. In their study, no subjective measure of presence was used, but it can be assumed that the sense of presence was higher with a VR interface.

Task performance can be measured reliably. Performance measures may also be sensitive. However, since the link between task performance and presence is unclear, validity of these measures can be questioned.

8.3.2.2 Memory for Events/Recollection

Presence has shown to be a positive effect on memory. For example, Kim and Biocca's (1997) carried out a study in which they measured both factual memory and visual recognition. Recognition speed for 'hits' was measured. They found that arrival to the mediated environment had no effect on memory, but departure from the physical environment improved memory.

Mania and Chalmers (2001) studied participants' level of presence, task performance and cognition state employed to complete a memory task. Memory questions have four possible answers, and each memory question included a 5-scale confidence level in order to identify differences in the mental processes of recollection across conditions. They found that presence was significantly higher for the real condition compared with the desktop condition, but there was no statistical difference between different recall tasks. On the other hand, the probability for a "remembering" response to be accurate was much higher for the VE condition than for the other two conditions.

Increased presence is not always correlated with memory performance. In Slater et al.'s (1996) study, participants had to reproduce on a real chess board the state of the board learned from the sequence of moves shown in the virtual environment. They found that increased immersion improved performance, but presence was not associated with it.

There is quite little evidence of the validity of memory performance as a measure of presence. Overall, it seems to be that its value is limited.

8.3.2.3 Other Possible Performance Measures

Users may experience different types of negative symptoms following the use of a media stimulus. For example, people may feel disoriented when they return from a mediated world to the real environment. A longer reorientation time and a greater degree of disorientation may indicate that the user has experienced higher levels of presence (Barfield and Weghorst 1993; Nash et al. 2000). Even though the most convenient way to measure these negative effects is to use self-report rating scales or to interview the users, objective methods can also be used. Since reliable assessment of different types of aftereffects is difficult or impossible by objective means, this group of measures may have only a marginal value.

The magnitude of size-scaling errors in estimation of geometrical illusions could be used as a measure of presence (Riener and Proffitt 2002). Riener and Proffitt have called it as a litmus test for spatial presence. The preliminary evidence is somewhat controversial. Yang et al. (1999) found that the magnitude of overestimation using the vertical-horizontal illusion was comparable between the real scene and the virtual scene. However, the magnitude of the Ponzo illusion in the virtual environment was comparable to that of photographs having strong perspective cues, even with a surround sound environment.

It has been suggested that estimates of subjective duration of time could serve as a useful measure of presence (IJsselsteijn et al. 2001; Waterworth and Waterworth 2001). IJsselsteijn and his colleagues found that the subjectively judged speed of task completion and the sense of presence correlated, but there was no correlation between duration estimation and presence. Factors that have an effect on state of presence such as attention, amount of information processing, emotional arousal and valence apparently also have a predictable effect on duration estimation. That is, people may underestimate a temporal interval if the stimulus is interesting. An interesting stimulus may require more attentional resources which will allow for fewer time units to be processed. Whether higher presence is associated with shorter or longer experienced temporal interval remains an open question, however (IJsselsteijn et al. 2001; Waterworth and Waterworth 2001).

Recently, Mühlberger et al. (2007) showed that pain perception can be modulated by exposure to cold and hot virtual environments. In their study the participants walked through landscapes with different seasons while cold and heat stimuli were delivered on their arm. The rated pain perception was reduced in cold and hot virtual environments as compared to neutral environments, but there was no difference in ratings between the two types of VRs.

8.3.2.4 Summary Evaluation of Performance Measures

In principle, performance measures should be quite reliable. As with behavioural measures, there are threats to validity, however. Since task performance is influenced by many other factors than presence, performance and presence are not always very highly correlated. Since performance can be typically accurately measured, these measures should be quite sensitive. Basically, performance measures are only applicable to interactive, high-immersive environments (IJsselsteijn et al. 2000), and a particular performance measure is normally applicable to only a restricted number of environments and contents. If performance is measured afterwards these measures are not intrusive. Some of them may be costly and difficult to administer.

8.3.3 Psychophysiological Measures

Psychophysiology strives to understand the relationship between people's cognitive and emotional processes and the changes in their physiology. Both central and peripheral nervous system activity can be examined in studying the relationship between psychological phenomena and physiology.

Psychophysiological measures can be categorized in different ways. Here we will classify psychophysiological measures into four categories: (1) eye-related measures, (2) brain-related measures, (3) heart-related measures and (4) other common physiological measures.

Physiological presence would mean that a user is responding physiologically to the mediated environment in a manner consistent with the human response to similar real situations (Meehan 2000). There is evidence for the value of psychophysiological measures in studying complex cognitive phenomena such as attention, mental workload, fatigue, and situation awareness. Similarly, Meehan et al. (2002) have found evidence for the use of physiological responses (heart rate, skin temperature, electrodermal activity) as a measure of presence in VEs. For example, there were significant correlations between psychophysiological and subjective measures of presence in their study. Additionally, display manipulations that have been shown to enhance the sense of presence have also been shown to produce more intense patterns of autonomic arousal, elicit more intense reports of subjective arousal, and accentuate some differences between contents (Detenber et al. 1998; Simons et al. 1999; Reeves et al. 1999; Lombard et al. 2000).

8.3.3.1 Eye-Related Measures

Eye-related measures are based on the recording of saccadic eye movements or pupillary responses. In general, recordings of saccadic eye movements tell where people direct their attention when they scan their visual environment. Pupillary movements, i.e. the changes in the diameter of a pupil, in turn, indicate how much mental activity the processing of a particular stimulus requires. So far, these measures have not been extensively used in studying presence.

Eye Movements

Eye movements can be monitored in many different ways. One widely used approach is to simultaneously track two features of the eye that move differentially in relation to one another as the line of gaze changes (e.g., Duchowski 2003). There are different types of head-mounted video systems that are based on this principle.

To what degree people attend to a continuous stimulus flow is apparently related to their state of presence, and the position of our eye at each point of time can give information of where our attention is directed. For example, it can be assumed that the greater the amount of time a user's gaze is directed to stimuli of the real-life environment the lower the state of presence is (Laarni et al. 2003). A major assumption is that there is a close link between attention and eye movements. Specifically, it is assumed that a covert attentional system drives eye movements (e.g., Rayner and Pollatsek 1989). This is, however, a controversial issue (e.g., Findlay 1997).

In one of the few presence studies in which eye tracking has been used, participants rode a virtual roller coaster simulation in two conditions (Wissmath et al. 2009): In the high-presence condition, the participants had a richer sensory environment with sound effects; in the low-presence condition, the system sounds were muted. Wissmath et al. found several differences in eye-movement parameters between the conditions: number of fixations was higher, duration of fixations shorter, amplitude of saccades smaller and their velocities lower in the high presence condition.

Even though eye tracking is subject to data artefacts, it is a quite reliable method. It may be highly sensitive and diagnostic (Rehmann 1995). Its temporal resolution is also excellent. Validity is dependent on which aspects of eye-movement behaviour we are interesting in. Eye tracking only provides information of the overt movements of the eyes. Attention is, however, not totally linked to these overt movements. The possible covert component of attention is, thus, not detectable by eye tracking methods. This fact reduces the value of eye tracking as a measure of attention, and thus also reduces the value of eye tracking as a measure of presence.

Since binocular three-dimensional eye tracking in virtual environments is difficult (see Duchowski 2003), the eye-tracking method is better applicable to low-immersive media environments. The head-mounted eye-tracking system may be somewhat intrusive. Also, the need to stay immobile during a session may reduce the sense of presence. Even though the prices of commercially-available trackers have been decreased, they are still quite expensive. The cost of this measure is also high, because data analysis is labour-intensive and time-consuming. High expertise is needed in set up and design of supporting computer programs and in the data analysis.

Pupillary Responses

For measuring pupil size, a participant's eyes are illuminated with low-level infrared light, and a special type of video camera equipped with digital signal processing of the images is used to provide a continuous measurement of pupil size (e.g., Barrett and Sowden 2000). It is well known that the pupil of the eye varies in size depending on several internal (e.g., emotional state) and external factors (e.g., lighting conditions). The pupil size is, for example, shown to be a sensitive measure of relative workload in different tasks (O'Donnell and Eggemeier 1986). Pupillary responses also tend to reflect the quantity of attentional processing (Beatty and Lucero-Wagoner 2000). Since presence and the magnitude of attentional processing seem to be interrelated, it is possible that pupillary responses provide a valuable tool for the assessment of the attentional component of presence.

Pupil size has shown to be a reliable, sensitive, and consistent measure of cognitive load (e.g., Beatty and Lucero-Wagoner 2000). One problem is that it lacks face validity as a measure of brain function. This is, apparently, one reason for why it has not been widely used. Even though the reliability of pupillometric responses is high, they are subject to data artefacts. It remains to see whether pupil size is a valid measure of attentional component of presence. Its temporal resolution is high, but the measure is somewhat intrusive. The recording apparatuses are still quite expensive. Even though not very high expertise is needed in data analysis, the recording of pupil size is quite labour-intensive. Overall, since pupil size is very sensitive to many factors, special care is needed in experimental design. Because of these requirements, its value as a measure of presence may be limited.

Endogenous eye blinks can be measured with electrodes placed above and below the eye. Reflexive eye blinks are thought to reflect general arousal. Different types of measures have been derived from the eye-blink recordings, such as eye blink rate, eye blink variability, blink amplitude, and closure duration. It has been shown that the number of blinks is smaller and their duration is shorter as more attention is needed (e.g., Goldstein et al. 1985; Bauer et al. 1985). Whether the number and duration of eye blinks and experienced presence are correlated is not known, however.

The reliability of eye blink measures should be high, but since many factors have an effect on them, their validity may be limited. Sensitivity and diagnosticity are probably low. Also, temporal resolution is low, and they are quite intrusive methods which limits their use. On the other hand, they are not very costly, and no special expertise is needed.

Overall Evaluation of Eye-Based Measures

So far, there are only few studies in which eye-related measures had been used, but Laarni et al. (2003) provided some suggestions on how to apply these measures in the study of presence. They also gave suggestions on how to combine eye tracking with other continuous measures. For example, we could measure at the same time eye movements and cardiac parameters. By this way, it may be possible to determine which aspects of the mediated stimuli caused the observed changes in presence.

8.3.3.2 Brain-Related Measures

Brain-related measures can be classified into two categories: those measuring hemodynamic changes, which is the technique used in Positron Emission Tomography (PET), and functional Magnetic Resonance Imaging (fMRI) and Transcranial Doppler (TCD) sonography; and methods based on imaging electromagnetic fields, which is used in Electroencephalography (EEG) and Magnetoencephalography (MEG).

EEG

Brainwaves could reflect the momentary informational content of the stimuli, or they may be correlates of more durable psychophysiological states. EEG recording has shown to be possible when using a VR helmet (Strickland and Chartier 1997), and recently, it has been suggested that EEG might be useful for investigating the breaks in presence experience (Schlögl et al. 2002).

Task-relevant stimuli occurring during an experience may elicit detectable event-related potentials (ERPs). They enable a fine-grained analysis of time and intensity relationships between sensory and motor events and between stimuli and responses. For example, an effortful mode of information processing could be differentiated from an automatic mode of processing if mismatch negativity (MMN) occurs (Näätänen 1992).

Evoked potentials (EP) occur to frequent, monotonous, highly-predictable and task-irrelevant stimuli. It has been shown that the amplitude of N1 component is modulated by the level of participants' engagement or perceived difficulty of the task (Kramer et al. 1995). Buildup of mental fatigue after an exposure to a relatively stressful VE is the main cause of EP changes (Pugnetti et al. 2000).

The third possibility is an analysis of an ongoing EEG. There may be long-lasting changes in psychophysiological conditions as a result of a prolonged exposure to mediated environments. For example, the level of alertness may cause changes. In addition to group average findings, the EEG can also provide valuable information on the individual style of adaptation to the experimental setup and performance (Pugnetti et al. 2001).

There have been EEG differences between virtual and real images (Strickland and Chartier 1997). Strickland and Chartier (1997) found that alpha activity decreased because of increased cognitive engagement with a novel environment. Higher theta and lower Beta1 activity was caused by less intellectual and more symbolic type of processing required. An increase in theta activity during VE sessions may reflect greater cognitive engagement (Wiederhold et al. 2003). Baumgartner et al. (2006) also found that a high spatial presence condition (a more realistic roller coaster ride) elicited strong event-related alpha band power decreases over parietal leads, indicating cortical activation in this region. They also used low-resolution brain electromagnetic tomography (LORETA) to calculate the intracerebral electrical sources for the surface EEG. More recently, Kober and Nauper (2012) studied ERPs of the EEG elicited by task-irrelevant sound signals in an interactive VR environment as a function of the subjectively measured experience of spatial presence. It was found that the late negative-going slow waves recorded from frontal lobe sites were the only ERP variable that could discriminate the participants reporting a high sense of presence from those reporting a low sense of presence.

In general, EEG-based measures have shown to be reliable, valid, and sensitive, and their temporal resolution is excellent. For example, ERPs provide information of electrical changes that are time-locked to a particular stimulus. There are several sources of unreliability and insensitivity, however. One of the main problems with EEG is that since the signal to noise ratio is poor, sophisticated data analysis is needed (Pugnetti et al. 2000). A big question is how to discriminate different brain states (the state of presence from the state of non-presence). First, there have been several kinds of artefacts in the delta range (0.5 Hz to 3.5–4 Hz) and in the beta2 band (higher than 18–20 Hz). Some of them are caused by muscle interferences. Second, sometimes the session has to be paused because of failures in equipment or sensors. Third, some people show abnormal EEG patterns, for example, because they are not able to concentrate or relax enough or control certain aspects of their behaviour. Fourth, it has also been noticed that users may increase the production of artefacts during the VR session in an attempt to reduce cybersickness. For example, people may look away, close their eyes, change body position, and mentally calm themselves.

EEG-based measures are highly intrusive. EEG electrodes and other sensors may interfere the participants' ability to concentrate on the task, may reduce the feeling of presence, and may increase the awareness of the outside world. An additional weakness with EEG is the fact that data analysis is a difficult and labour-intensive process. High expertise is, thus, needed in analyzing and interpreting EEG patterns.

Pugnetti et al. (2000) have presented several ways to overcome the above-mentioned problems. First, it is useful to run a standard EEG on every user before the experiment in order to accustome participants to experimental conditions. Second, some participants can be excluded, if they show invariable data or if they produce eye artefacts. Third, it is preferable to use both the EEG and the EMG data as inputs. Fourth, it is also preferable to reduce cabling around the participant by using a large-screen projection VE (Nelson et al. 1997; Pugnetti et al. 2000; Meehan et al. 2002). One possibility is also to record the EEG before and after an experimental session.

Other Brain-Related Measures

MEG is based on the recording of the weak magnetic induction that is produced by neural currents. Because of high temporal resolution, MEG is an ideal method for studying the dynamics of neural activity. To our knowledge, MEG has not been used in studying the sense of presence to date.

In PET and fMRI, local hemodynamic changes are investigated. Of these two methods, fMRI is more widely used. Spatial resolution of fMRI is very high, while temporal resolution is limited. Interpretation of fMRI data is complicated, since the relationship between the neurochemical changes and the underlying neural activity is rather complex.

It would be a difficult task to produce a sense of presence during an fMRI for several reasons (Hoffman et al. 2003). For example, the participant has to stay immobile during the measurement, the scanner makes loud noises, and the participant is laying inside a magnet tube, which may be unpleasant. In addition, the magnetic field may interfere with the equipment that are used in the presentation of the media stimulus.

There are, however, some findings (Hoffman et al. 2003; Bouchard et al. 2009) suggesting that fMRI may be a valuable tool in presence research. Hoffman et al. (2003) proposed that a strong sense of presence could be experienced during an fMRI despite the above-mentioned constraints. Bouchard et al. (2009) found that parahippocampal cortex was significantly activated by the high presence condition.

Beeli et al. (2008) tested whether transcranial direct current stimulation (tDCS) is able to affect brain activation during the confrontation with a virtual stimulus (Beeli et al. 2008). It was, however, found that tDCS to the right dorso-lateral prefrontal cortex was not able to modulated the experience of presence while watching a virtual roller coaster ride. It may be possible that stimuli were not optimal for these purposes since there was no difference in self-reported presence either.

Variations in cerebral blood flow velocity (BFV) measured with Transcranial Doppler (TCD) sonography has widely used as a psychophysiological method to measure cognitive performance. Since TCD sonography is quite non-invasive, and there is no need to sit in an uncomfortable immobile position for a lengthy periods of time, it is a suitable psychophysiological tool for study presence in VR environments. Since neural activity is recorded from a quite large cortical area, the spatial resolution of the method is low, however. Rey et al. (2010) studied mean BFV variations when participants had to move through a VR setting with two different levels of immersion. It was found that the variations were larger in more immersive experimental conditions. Rey et al. (2011) have also studied mean BFV responses during breaks in presence in a virtual environment and, for example, found a significant difference among the maximum percentage BFV variations induced by breaks of different intensity.

Summary Evaluation of Brain-Based Measures

So far, there is very little evidence for the applicability of brain-based measures to the investigation of presence. Overall, brain-based measures are reliable and valid. They might also be quite sensitive and diagnostic. Disadvantages of them are that they are very intrusive, and they are not applicable to all kinds of media environments. Cost of equipment is high, special expertise is required, and data analysis is labour-intensive.

8.3.3.3 Heart-Related Measures

Changes in Heart Rate

HR is the measure of how many times the heart beats in a minute. The most common way to measure heart beats is to measure the electrical potentials generated by the heart during each cardiac cycle. HR is a relatively easy and unobtrusive measure to obtain. Another potential advantage of HR is that the beating of the heart can tell us something about a number of processes important in presence research, such as attention, effort, arousal, and emotion (e.g., Papillo and Shapiro 1990).

Given that attentional phenomena may be important in presence research, the relationship of attention to HR is of interest here. It is well established that that HR decelerates as a result of increased cardiac parasympathetic activity when attention is paid to an external stimulus or information is taken in (i.e., a sensory intake task; e.g., Lacey and Lacey 1970; Mulder and Mulder 1981). HR has been shown to be a good measure of both short-term attentional selection (i.e., automatic resource allocation associated with the orienting response) and long-term attentional effort (i.e., voluntary attention).

Meehan et al. (2002; see also Meehan et al. 2005) showed that a stressful VE depicting a pit room (with an unguarded hole in the floor leading to a room 20 ft below) evoked notable HR acceleration. In addition, change in HR correlated positively with self-reported presence. In contrast, Wiederhold et al. (2003) found that change in HR correlated negatively with self-reported presence when participants were presented with a VE depicting an airplane flight. Apparently, the VE (pit room) in the former study was stressful enough to elicit a sympathetically-mediated defense response (HR acceleration), while the latter VE (airplane flight) elicited increased attention as indexed by para-sympathetically-mediated HR deceleration. Thus, although HR may clearly be a useful measure in presence research, it is an unwarranted expectation that HR would always increase with increasing presence.

So far, there are only a few presence studies in which HR has been monitored. In general, HR has been thought to be a quite reliable method with a high signal-to-noise ratio. The reliability of HR was also supported by the Meehan et al. (2002) study, given that the virtual stimulus elicited similar HR patterns across exposures. In regard validity and diagnosticity, it is important to recognize that, as noted above, the interpretation of HR responses is highly dependent on the research paradigm (e.g., task demands, nature of stimuli). This is partly due to the fact that HR carries information on both parasympathetic and sympathetic activity (Papillo and Shapiro 1990). Sensitivity of HR may be quite high, given that HR could differentiate the two conditions in Insko's (2001) and Meehan et al.'s (2002, 2005) studies. Meehan et al. (2002) also suggested that changes in HR showed multi-level sensitivity; the evidence they presented was inconclusive, however. Temporal resolution is relatively high, but lower than that of EEG, for example, and diagnosticity is apparently moderate at best. The method is not intrusive: In Meehan et al.'s study no participants reported that they noticed the electrodes. Equipment is not very costly, but some special expertise is needed. Despite its limitations, HR may be the most useful of the different types of psychophysiological measures (Meehan et al. 2002). Recently, Slater et al. (2009) employed also HR variability as measured by the standard deviation of HR (i.e., a time-domain measure of variability) to examine the influence of visual realism (illumination realism) on presence.

Respiratory Sinus Arrhythmia

Given the aforementioned limitations associated with HR, more selective measures of PNS activity and attention, such as respiratory sinus arrhythmia (RSA), may be fruitful in presence research. RSA is often quantified by the high-frequency (HF) component of HR variability, i.e., the frequency band ranging from 0.15 to 0.40 Hz (Berntson et al. 1997). High baseline level of RSA has been associated with the ability to maintain attention (Porges 1991). RSA is suppressed during states of sustained attention, however (e.g., Porges 1991, 1995; Weber et al. 1994). RSA holds particular promise for presence research, given its relationship to sustained attention and the apparent importance of attention to the presence phenomenon (see Wirth et al. 2007). Recently, Slater et al. (2009) found that the HF component of HR variability differentiated the low and high presence conditions.

RSA has typically been thought to be a reliable and valid measure. However, since different analysis techniques are possible, its validity may vary. It has shown to be highly sensitive, but as noted above, it indexes primarily attentional engagement, not presence as such; it may also be affected by other factors that are not necessarily related to presence. Given that, as opposed to HR, it is influenced by only parasympathetic activity, it is more diagnostic than HR. In addition, it is not very intrusive. Cost of equipment is moderate, and quite high expertise is needed.

8.3.3.4 Other Psychophysiological Measures

Electrodermal Activity

EDA gives direct information about the electrical conductance of the skin that is related to the level of sweat in the eccrine sweat glands. Given that the neural control of the human sweat glands is entirely under sympathetic control, EDA is an excellent measure of the activation of the sympathetic nervous system (SNS; Boucsein 1992). SNS activation is the physiological component of emotional arousal, and several studies have shown that EDA is highly correlated with self-reported emotional arousal (e.g., Lang et al. 1993).

Emotional arousal as measured by EDA may be an important variable in the research on the presence phenomenon. It has been suggested that mediated stimuli that evoke a high sense of presence are often also arousing (Lombard and Ditton 1997). EDA has recently been used in a couple of studies examining presence in VEs. These studies showed that EDA was positively associated with self-reported presence during exposure to VEs depicting an airplane flight (Wiederhold et al. 1998, 2003) and a pit room with an unguarded hole in the floor leading to a room 20 ft below (Meehan et al. 2002). Meehan et al. also found that EDA was higher during exposure to the frightening (i.e., arousing) virtual height situation compared to a non-frightening virtual room. Although this study did not compare two different media with identical content, it provided rather compelling evidence that EDA increases with increasing presence when the content of the mediated environment is arousing (see also Baumgartner et al. 2006).

Overall, although Meehan et al. (2002) suggested that EDA is a not-as-good method as changes in HR, it has some advantages. Reliability is apparently quite high: Meehan et al. (2002) found that skin conductance was reliably higher for the more stressful environment in all the three experiments. There was also support for its validity in their study, because it was quite highly correlated with self-reported presence. However, since EDA is a measure of general arousal, it is obvious that there can be no one-to-one relation between EDA and presence. For example, when the content of the mediated environment is not arousing (e.g., a deserted beach of a Caribbean island), there is no reason to expect that EDA would increase, even if there would be a high sense of presence.

There is mixed evidence for its sensitivity: EDA could differentiate the two conditions in Insko's (2001) study, but it did not differentiate the frame rates in the Meehan et al. (2002) study. EDA may be diagnostic, given that it is an unalloyed measure of sympathetic activity. On the other hand, since it can be affected by several psychological processes, careful experimental control is needed so that only one factor is varied at a time, thereby ensuring that differences in EDA between the conditions are not due to message confounds, for example. EDA is quite discriminable: on a single presentation of a stimulus it can be determined by quick inspection whether or not a SCR has occurred. It is inexpensive to record and risk-free. On the negative side, since these responses are relatively slowly developing, EDA is not suitable if very rapidly occurring processes are measured.

Electromyography

Electromyography (EMG) has often been used to measure emotional facial expressions, although it can also be used to assess activity of other than facial muscles. The contraction of facial muscles is an important form of emotional expression. The facial EMG provides a direct measure of the electrical activity associated with these facial muscle contractions (Tassinary and Cacioppo 2000).

It is well established using a picture-viewing paradigm that increased activity at the zygomaticus major (cheek muscle) and corrugator supercilii (brow muscle) muscle regions is associated with positive emotions and negative emotions, respectively (e.g., Lang et al. 1993). Positive and negative emotional reactions as indexed by facial EMG would not be expected to be directly related to the presence phenomenon, but rather to the content (pleasant vs. unpleasant) of the mediated stimuli. Nevertheless, it is possible that positive and negative content elicit more positive and negative emotional reactions, respectively, as measured by EMG when there is a high sense of presence. Ravaja et al. (2006) have found that the engagement dimension of the ITC-SOPI correlated positively with zygomatic and orbicularis oculi EMG responses (delta scores) when playing digital games.

Surface muscle activity can also be recorded from those sites of the body that are activated when walking. Antley and Slater (2011) recorded onsets of muscle activity using EMG sensors attached to lower spine and showed that an increase in muscle activation that is induced by walking on a narrow platform could also be elicited within an immersive VR.

Facial EMG measurement is quite intrusive, because electrodes attached to the surface of the facial skin can restrict the participant's movements or make him/her self-conscious and may thus reduce the sense of presence.

8.3.3.5 Summary Evaluation of Psychophysiological Methods

In general, psychophysiological measures provide access to implicit, intermediate processes that are not accessible to consciousness (Tomarken 1995). Thus, if the sense of presence is an end product of a set of intermediate implicit processes, psychophysiological measures can give information of these subprocesses. Additionally, if presence is a continuous phenomenon, psychophysiological measures are also useful, because they are continuously available, and they may provide information of brief changes in the state of presence.

On the negative side, there are several problems in using psychophysiological measures for studying presence. Since presence is a subjective sensation, "it is [...] not so amenable to objective physiological definition and measurement" (Sheridan 1992). There is no presence nerve or evidence of its activity obtainable via psychophysiological measurements (cf. Eggemeier 1988). These measures, thus, do not provide direct evidence of the state of presence. Since there is not a one-to-one correspondence between the state of presence and the psychophysiological state, the fact that manipulating the state of presence leads to a particular physiological response does not enable definitive inferences about the former based on observations of the latter (Caccioppo and Tassinary 1990). As Cacioppo and Tassinary have proposed, a particular measure can be linked to several psychological processes, and a particular stimulus may have several physiological influences. In addition, many measures are influenced by physiological processes that may have no clear psychological relevance.

There are several ways to cope with the fact that there is often a many-to-one or a many-to-many relation between psychological processes and psychophysiological measures. For example, it has been suggested that multiple measures should be used, and the pattern of responsivity over time should be examined (Strube 2000).

Even though within-session reliability of psychophysiological measures has been fairly good, temporal stability (test-retest reliability) has sometimes been quite poor. For example, test-retest correlations for HR have been quite low (Tomarken 1995).

There are several reasons for that. First, it is not always possible to get good bioelectric signals in complex media environments (Pugnetti et al. 2001). To prevent these problems, good-quality equipment is needed. Second, psychophysiological measures are quite easily sensitive to non-related factors. It is important to demonstrate what causes the responses, and experimental and control conditions should differ only with respect to the experimental factor (Insko 2003). Third, related to the previous one: Paying more attention to a task may cause changes in physiological responses and, thus, supersede possible presence effects (Jang et al. 2002). Prior exposure to the mediated environment may prevent this. Fourth, physiological levels vary widely between individuals. Therefore, some baseline adjustment has to be applied (e.g., percentage change or residualized change scores).

In general, psychophysiological measures are quite sensitive, but it is unclear how well these measures work in less intense media environments. There is little evidence for monotonic sensitivity to variations in the state of presence (see, however, Meehan et al. 2002). What is also problematic is that all the psychophysiological measures are more or less intrusive. Some measures (e.g., brain-based measures) may limit a user's movements to such a degree that they are not suitable for the measurement of the state of presence in all types of media contexts. The implementation requirements are also rather high: special equipment and technical expertise are needed, and the recording and analysis of psychophysiological parameters is time-consuming.

8.3.4 Prospects and Limitations of Objective Measures of Presence

Because many behavioural and psychophysiological responses are automatic and unconscious, prior experiences and expectations should have a smaller effect than in case of subjective measures. For example, demand characteristics and time error should not cause problems and the effect of context should be smaller. As a result, the reliability and validity of objective measures should be higher than those of subjective methods (Meister 1985).

However, there are several problems with objective methods of presence. First of all, presence is a complex mental phenomenon. Its operationalization is difficult, because the 'distance' from the construct to the operation is typically long (Strube 2000). There should be a clear relationship between the physiological and behavioural responses that are measured and the psychological responses that represent or are associated with presence. However, there is no clear evidence that these measures correlate well with presence. Additionally, if we manipulate presence and find that this manipulation leads to a particular behavioural and psychophysiological response, this does not mean that there is causal relationship between these phenomena, since several psychological events could produce this particular physiological signal. Each of these measures may also capture only part of the presence concept. For example, EDA may be an indication of several different types of processes (Strube 2000).

It is very difficult to determine the molecular behaviours of presence, and determine how these molecular behaviours are integrated and combined to a subjective sense of presence. Those who experience presence may, however, easily integrate simultaneously these molecular behaviours to a subjective sense of presence (Meister 1985). One solution to this problem is that we gather simultaneously convergent and divergent validation evidence. That is, we gather evidence of the validity of interpreting any given operation as representing presence, and we test the interrelatedness of different sets of operations.

There are also problems with sensitivity and diagnosticity. Overall, it seems to be that objective measures are less sensitive and diagnostic than subjective measures.

A basic challenge for objective measures is that they are not very well suited to investigate presence in less intense virtual environments that simulate normal environments. It is quite possible that everyday situations do not produce perceptible behavioural or physiological responses (i.e., Insko 2003). Since behavioural and psychophysiological measures are quite often binary ("all-or-none") and limited in the dimensions they describe, they are not very diagnostic, and they provide us less information than subjective measures (Meister 1985). For example, they do not provide information for the basis of suggesting how to increase the feeling of presence. Additionally, on the negative side, objective measures are clearly more intrusive than subjective measures; they are more demanding and expensive; and special expertise is also normally needed.

Overall, even though objective measures are, in general, preferable over subjective measures, it has to be remembered that subjectivity cannot totally be ruled out. Also, in case of objective measures, there are always subjective elements throughout the process of measurement. These elements are, for example, related to selecting measures and collecting, analyzing and interpreting data (Muckler and Seven 1992).

Therefore, to guarantee the validity of a particular objective measure, it should be combined with a subjective measure of presence (IJsselsteijn et al. 2001). As IJsselsteijn et al. (2001) have suggested, we need reliable, valid and sensitive subjective measures for the evaluation of objective measures of presence. It is also evident that there will be not a single objective measure of presence, which is better than other objective measures, but measures should be selected for particular applications (IJsselsteijn et al. 2001).

8.4 Comparing Different Methods to Measure Presence

What makes it difficult to compare different methods is, on the one hand, the fact that a huge number of different types of measures have been used. On the other hand, since the history of measurement of presence is short, evaluations of these methods are necessarily based on little evidence. For example, test-retest reliability is typically not known so that there is little evidence of transient error.

One additional problem is that different measures have been tested in a diverse set of media environments which makes it difficult to compare different measures. A set of standard media stimuli should be used. A good example of such a standard set of stimuli is the Virtual Environment Performance Assessment battery (VEPAB; Lampton et al. 1994). It consists of simple VEs in which simple tasks such as movement, tracking, object manipulation and reaction time tasks can be performed.

It might be worth to develop such standardized stimuli for other types of media environments.

Several criteria can be used to compare presence measures. In the first hand, we should investigate, how reliable and valid they are. For example, the measures should have proven test-retest reliability. Subjective ratings are based on cognitive interpretation and evaluation of the media stimulus, and, thus, they are influenced by the individual's goals, motives and plans (Annett 2002). Overall, since there is less need for a subjective interpretation, objective measures are typically more reliable and valid than subjective measures. However, since presence is a mental phenomenon and since perceptual and cognitive activities are difficult to measure by objective means, operationalization of presence is a difficult task. Therefore, subjective measures that are based on self-report may, in fact, be more accurate and valid (Muckler and Seven 1992).

We should also investigate how sensitive different measures are, that is, whether there is a monotonic trend with respect to state of presence, and whether they have high test-power. To be valuable measures, they should be sensitive to variations in those factors that have an effect on presence (Sadowsky and Stanney 2003). Subjective measures are presumably more sensitive than objective measures at low task loading (Annett 2002). Since subjective measures can better tap the multiple factors that lie behind the phenomenon, they may also predict performance better than objective measures during cognitive tasks, and, thus, be more diagnostic than objective measures of presence.

We should also evaluate the implementation requirements of different measures. In general, subjective measures are less intrusive than objective measures. They are also more convenient – they are a cheaper alternative, and they are easy to learn and administer (Jex 1988; Sadowsky and Stanney 2003).

It may be possible that presence experience comprises both subjective and objective elements, and subjective experience and objectively measured variables are not necessarily monotonically related. Thus, subjective and objective measures need not agree, since they may measure different aspects of what is going on. According to Muckler and Seven (1992), this is not, however, a disaster, because these measurements may signal interesting information, even though there are differences between them. Apparently, we need methodological triangulation in which both objective and subjective indicators of presence are used and, and they should be combined in a single study (Turner and Turner 2009). As Muckler and Seven (1992) have proposed, the trick is to learn to combine both subjective and objective measures in a way that makes sense for the specific research question. Purpose of each study should determine which measures we should use. – And sometimes the use of 'quick and dirty' methods is well justified.

8.5 Conclusions

We need reliable and valid measures of presence for several reasons (IJsselsteijn et al. 2000). They make it possible to determine those factors that produce an optimal level of presence for the user of a particular application; they make it possible to investigate the relationship between presence and task performance and other related constructs; they are useful in increasing our understanding of the experience of presence in the real world; and they may aid to refine and further develop the theory of presence.

Because we have to determine the component behaviours that make up the state of presence, we need a theory. Since the component behaviours should be detailed and easily observable, it may be a difficult task. As mentioned earlier, it is very difficult to determine the molecular behaviours of presence, and determine how these molecular behaviours are integrated and combined to a subjective sense of presence.

The questionnaire will be the basic tool in the measurement of presence also in the future. More comprehensive and better-validated questionnaires are, thus, desperately needed. The trend is for cross-media questionnaires that are applicable both to interactive and non-interactive media forms.

As stated earlier, the five extensive questionnaires, the PQ, IPQ, ITC-SOPI and MEC-SPQ/SPES, and TPI, are quite reliable and valid measures of presence. It is, however, questionable whether they can always pass the reality test, that is, whether they can differentiate between virtual and real environments.

There is quite little evidence of reliability and validity of behavioural measures. Since it is often difficult to shown whether the observed behaviour is caused by sense of presence rather than other factors, their validity is questionable. The same conclusion can also be applied to psychophysiological measures. One disadvantage is that they are quite labour-intensive and demanding methods.

Peripheral psychophysiological measures, EDA and heart rate, seem to be better than brain imaging methods. Evaluation of their usefulness, however, requires more carefully designed and implemented experiments. The value of eye-related measures is not yet settled. Since there is an intimate link between attention and eye movements, eye tracking may provide useful information of the attentional component of presence.

There is an apparent need for a test battery which includes both subjective and objective measures and which is applicable to different media environments. In addition to a comprehensive questionnaire, the battery should also consist of psychophysiological measures and eye-related measures.

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Chapter 9
An Integrative Approach to Presence and Self-Motion Perception Research

Bernhard E. Riecke and Jörg Schulte-Pelkum

Abstract This chapter is concerned with the perception and simulation of self-motion in virtual environments, and how spatial presence and other higher cognitive and top-down factors can contribute to improve the illusion of self-motion ("vection") in virtual reality (VR). In the real world, we are used to being able to move around freely and interact with our environment in a natural and effortless manner. Current VR technology does, however, hardly allow for natural, life-like interaction between the user and the virtual environment. One crucial shortcoming is the insufficient and often unconvincing simulation of self-motion, which frequently causes disorientation, unease, and motion sickness. The specific focus of this chapter is the investigation of potential relations between higher-level factors like presence on the one hand and self-motion perception in VR on the other hand. Even though both presence and self-motion illusions have been extensively studied in the past, the question whether/how they might be linked to one another has received relatively little attention by researchers so far. After reviewing relevant literature on vection and presence, we present data from two experiments, which explicitly investigated potential relations between vection and presence and indicate that there might indeed be a direct link between these two phenomena. We discuss theoretical and practical implications from these findings and conclude by sketching a tentative theoretical framework that discusses how a broadened view that incorporates both presence and vection research might lead to a better understanding of both phenomena, and might ultimately be employed to improve not only the perceptual effectiveness of a given VR simulation, but also its behavioural and goal/application-specific effectiveness.

Keywords Behavioural effectiveness • Cognitive factors • Experimentation • Framework • Higher-level factors • Human factors • Human-computer interfaces • Immersion • Perception-action loop • Perceptual effectiveness • Perceptually-Oriented Ego-Motion Simulation • Presence • Self-motion illusion • Self-Motion Simulation • Spatial Presence • Vection • Virtual environments • Virtual reality

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This chapter is concerned with the perception and simulation of self-motion in virtual environments, and how spatial presence and other higher cognitive and top-down factors can contribute to improve the illusion of self-motion ("vection") in virtual reality (VR). In the real world, we are used to being able to move around freely and interact with our environment in a natural and effortless manner. Current VR technology does, however, hardly allow for natural, life-like interaction between the user and the virtual environment. One crucial shortcoming in current VR is the insufficient and often unconvincing simulation of self-motion, which frequently causes disorientation, unease, and motion sickness (Lawson et al. 2002). We posit that a realistic perception of self-motion in VR is a fundamental constituent for spatial presence and vice versa. Thus, by improving both spatial presence and self-motion perception in VR, we aim to eventually enable perceptual realism and performance levels in VR similar to the real world. Prototypical examples that currently pose considerable challenges include basic tasks like spatial orientation and distance perception, as well as applied scenarios like training and entertainment applications. Users frequently get lost easily in VR while navigating, and simulated distances appear to be compressed and underestimated compared to the real world (Chance et al. 1998; Creem-Regehr et al. 2005; Ruddle 2013; Hale and Stanney 2014; Witmer and Sadowski 1998).

The specific focus of this chapter is the investigation of potential relations between presence and other higher-level factors on the one hand and self-motion perception in VR on the other hand. Even though both presence and self-motion illusions have been extensively studied in the past, the question whether/how they might be linked to one another has received relatively little attention by researchers so far. After a brief review of the relevant literature on vection and presence, we will present data from two experiments which explicitly investigated potential relations between vection and presence and indicate that there might indeed be a direct link between these two phenomena (Riecke et al. 2004, 2006a). In the last part of this chapter, we will discuss the theoretical and practical implications from these findings for our understanding of presence and self-motion perception. We will conclude by sketching a tentative theoretical framework that discusses how a broadened view that incorporates both presence and vection research might lead to a better understanding of both phenomena, and might ultimately be employed to improve not only the perceptual effectiveness of a given VR simulation, but also its behavioural and goal/application-specific effectiveness.

The origins of the work presented here were inspired by an EU-funded project on "Perceptually Oriented Ego-motion Simulation" (POEMS-IST-2001-39223). The goal there was to take first steps towards establishing a lean and elegant self-motion simulation paradigm that is powerful enough to enable convincing self-motion perception and effective self-motion simulation in VR, without (or while hardly) moving the user physically. This research was guided by the long-term vision of achieving cost-efficient, lean and elegant self-motion simulation that enables compelling perception of self-motion and quick, intuitive, and robust spatial orientation while traveling in VR, with performance levels similar to the real world. Our approach to tackle this goal was to concentrate on perceptual aspects and task-specific effectiveness rather than aiming for perfect physical realism (Riecke et al. 2005c). This approach focuses on multi-modal stimulation of our senses using VR technology, where vision, auditory information, and vibrations let users perceive that they are moving in space. Importantly, we broadened the research perspective by connecting the concepts of top-down or high-level phenomena like spatial presence and reference frames to vection research (Riecke 2011). It is well-known that quite compelling self-motion illusions can occur both in the real world and in VR. Hence, the investigation of such self-motion illusions in VR was used as a starting point in order to study how self-motion simulation can eventually be improved in VR.

Spatial presence occupies an important role in this context, as we expected this to be an essential factor in enabling robust and effortless spatial orientation and task performance. Furthermore, according to our spatial orientation framework (von der Heyde and Riecke 2002; Riecke 2003), we propose that spatial presence is a necessary prerequisite for quick, robust, and effortless spatial orientation behaviour in general and for automatic spatial updating in particular. Thus, increasing spatial presence would in turn be expected to increase the overall convincingness and perceived realism of the simulation, thus bringing us one step closer to our ultimate goal of real world-like interaction with and navigation through the virtual environment. A first step towards this goal would be to show that increasing spatial presence in a VR simulation increases perception of illusory self-motion. This issue will be elaborated upon in more detail in Sect. 9.4.

9.1 Motivation and Background

Although virtual reality technology has been developing at an amazing pace during the last decades, existing virtual environments and simulations are still not able to evoke a compelling illusion of self-motion that occurs without any delay to the visual motion onset (Hettinger et al. 2014; Riecke 2011; Schulte-Pelkum 2007). Similarly, presence – i.e., the feeling of being and acting in the simulated virtual environment – is often limited or disrupted for users exposed to a VR simulation: Slater and Steed have introduced the concept of breaks in presence (BIP), which describes the frequent phenomenon that users suddenly become aware of the real environment and do not feel present in the VR simulation anymore (Slater and Steed 2000).

While the use of VR applications has widely spread in various fields, such as entertainment, training, research, and education, there are a number of problems that users are confronted with. In this section, we will highlight some of these problems that we see as crucial for the further use and promotion of VR technology.

9.1.1 Spatial Orientation Problems in VR

One important limitation of most VR setups stems from the observation that users get easily disoriented or lost while navigating through virtual environments (e.g., Chance et al. 1998; Ruddle 2013). Moreover, it is not yet fully understood where exactly these problems arise from. Several studies have shown that allowing for physical motions can increase spatial orientation ability, compared to situations where only visual information about the travelled path is available (Bakker et al. 1999; Chance et al. 1998; Klatzky et al. 1998; Riecke et al. 2010; Ruddle and Lessels 2006; Waller et al. 2004). Ruddle and Lessels demonstrated for example that allowing participants to physically walk around while wearing a head-mounted-display (HMD) dramatically improved performance for a navigational search task, whereas adding only physical rotation did not show any improvement (Ruddle and Lessels 2006). Other studies, however, showed that physical rotations are critical for basic spatial orientation tasks (Bakker et al. 1999; Chance et al. 1998; Riecke et al. 2010; see, however, Avraamides et al. 2004) but not sufficient for more complex tasks (Ruddle and Peruch 2004; Ruddle 2013). In apparent conflict to the above-mentioned studies, there are also several experiments that demonstrate that physical motions do not necessarily improve spatial orientation at all (Kearns et al. 2002; Riecke et al. 2002, 2005a; Waller et al. 2003). Highly naturalistic visual stimuli alone can even be sufficient for enabling good spatial orientation (Riecke et al. 2002) and/or automatic spatial updating (Riecke et al. 2005a, 2007) if they include useful landmarks, whereas simple optic flow typically seems insufficient (Bakker et al. 1999; Klatzky et al. 1998; Riecke et al. 2007; Riecke 2012). Especially when the visually displayed stimulus is sparse, display parameters such as the absolute size and field of view (FOV) of the displayed stimulus, but also the type of display itself (e.g., HMD vs. monitor vs. curved or flat projection screen) become critical factors (Bakker et al. 1999; Bakker et al. 2001; Klatzky et al. 1998; Riecke et al. 2005b; Tan et al. 2006).

We propose that spatial presence in the simulated scene might play an important – although often neglected – role in understanding the origins of the spatial orientation deficits typically observed in VR. In particular, the potential interference between the reference frames provided by the physical surroundings and the simulated virtual environment should be considered, as will be elaborated upon in Sect. 9.3.1 (see also Avraamides and Kelly 2008; May 1996, 2004; Riecke and McNamara submitted; Wang 2005).

9.1.2 Spatial Misperception in VR

Apart from the spatial orientation problems often observed in VR, there are also serious although well-known systematic misperceptions associated with many VR displays. Several studies showed for example that especially head-mounted displays (HMDs) often lead to systematic distortions of both perceived distances and turning angles (Bakker et al. 1999, 2001; Creem-Regehr et al. 2005; Grechkin et al. 2010; Riecke et al. 2005b; Tan et al. 2006). The amount of systematic misperception in VR is particularly striking in terms of perceived distance: While distance estimations using blindfolded walking to previously seen targets are typically rather accurate and without systematic errors for distances up to 20 m for targets in the real world (Loomis et al. 1992, 1996; Rieser et al. 1990; Thomson 1983), comparable experiments where the visual stimuli were presented in VR typically report compression of distances as well as a general underestimation of egocentric distances, especially if HMDs are used (Creem-Regehr et al. 2005; Grechkin et al. 2010; Thompson et al. 2004; Willemsen et al. 2008; Witmer and Sadowski 1998). Even a wide-FOV (140°×90°) HMD-like Boom display resulted in a systematic underestimation of about 50 % for simulated distances between 10 and 110 ft (Witmer and Kline 1998). A similar overestimation and compression in response range for HMDs has also been observed for visually simulated rotations (Riecke et al. 2005b). So far, only projection setups with horizontal field of views of 180° or more could apparently enable close-to-veridical perception (Plumert et al. 2004; Riecke et al. 2002, 2005b; see, however, Grechkin et al. 2010), even though the FOV alone is not sufficient to explain the systematic misperception of distances in VR (Knapp and Loomis 2004). Hence, further research is required to compare and evaluate different display setups and simulation paradigms in terms of their effectiveness for both spatial presence and self-motion simulation.

9.1.3 The Challenge of Self-Motion Simulation

When we move through our environment, either by locomotion or transportation in a vehicle, virtually all of our senses are activated. The human senses that are considered as most essential for self-motion perception are the visual and vestibular modalities (Dichgans and Brandt 1978; Howard 1982). Most motion simulators are designed to provide stimulation for these two senses. The most common design for motion platforms is the Stewart Platform, which has six degrees of freedom and uses six hydraulic or electric actuators that are arranged in a space-efficient way to support the moving platform (Kemeny and Panerai 2003). Typically, a visualization setup is mounted on top of the motion platform, and users are presented with visual motion in a simulated environment while the platform mimics the corresponding physical accelerations. Due to technical limitations of the motion envelope, however, the motion platform cannot display exactly the same forces that would occur during the corresponding motion in the real world, but only mimic them using sophisticated motion cueing and washout algorithms that ideally move the simulator back to an equilibrium position at a rate below the motion human detection threshold (e.g., Berger et al. 2010; Conrad et al. 1973). To simulate a forward acceleration, for example, an initial forward motion of the platform is typically combined with tilting the motion platform backwards to mimic the feeling of being pressed into the seat and to simulate the change of gravito-inertial force vector.

Apart from being rather large and costly, the most common problem associated with current motion simulators is the frequent occurrence of severe motion sickness (Bles et al. 1998; Guedry et al. 1998; Kennedy et al. 2010; Lawson et al. 2002). As already mentioned, the technical limitation in self-motion simulation is imposed by the fact that most existing motion platforms have a rather limited motion range.

Consequently, they can only reproduce some aspects of the to-be-simulated motion veridically, and additional filtering is required to reduce the discrepancy between the intended motion and what the actual platform is able to simulate (e.g., Berger et al. 2010; Conrad et al. 1973). The tuning of these "washout filters" is a tedious business, and is typically done manually in a trial-and-error approach where experienced evaluators collaborate with washout filter experts who iteratively adjust the filter parameters until the evaluators are satisfied. While this manual approach might be feasible for some specific applications, a more general theory and understanding of the multi-modal simulation parameters and their relation to human self-motion perception is needed to overcome the limitations and problems associated with the manual approach. Such problems are evident for example in many flight and driving applications, where training in the simulator has been shown to cause misadapted behaviour that can be problematic in the corresponding real-world task (Boer et al. 2000; Burki-Cohen et al. 2003; Mulder et al. 2004). Attempts to formalize a comprehensive theory of motion perception and simulation in VR are, however, limited by our insufficient understanding of what exactly is needed to convey a convincing sensation of self-motion to users of virtual environments, and how this is related to the multi-modal sensory stimulation and washout filters in particular (Grant and Reid 1997; Stroosma et al. 2003; Telban and Cardullo 2001). Over the last decade, we investigated the possibility that not only the motion cueing algorithms and filter settings, but also high-level factors such as spatial presence might have an influence on the magnitude and believability of the perceived self-motion in a motion simulator. In order to increase spatial presence in the simulator, we provided realistic, consistent multi-modal stimulation to visual, auditory and tactile senses, and evaluated how vection and presence develop under different combinations of conditions (Riecke et al. 2005c, e; Riecke 2011; Schulte-Pelkum 2007).

Such above-mentioned shortcomings of most current VR setups limit the potential use of virtual environments for many applications. If virtual environments are to enable natural, real life-like behaviour that is indistinguishable from the real world or at least equally effective, then there is still a lot of work to be done, both in the fields of presence and self-motion simulation. VR technology is more and more turning into a standard tool for researchers who study self-motion perception, and many motion simulators use immersive setups such as head-mounted-displays (HMDs), wide-screen projection setups or 3D display arrays. It is thus important to systematically investigate potential influences of presence on self-motion perception and vice versa. It is possible that inconsistent findings in the recent self-motion perception literature might partly be attributable to uncontrolled influences of presence or other higher-level factors. Similarly, in presence research, the possibility that perceived self-motion in VR might have an effect on the extent to which one feels present in the simulated environment has received only little attention so far.

The following sections will provide brief literature overviews on self-motion illusions ("vection") (Sect. 9.2) and some relevant aspects of the concept of presence (Sect. 9.3), followed by some theoretical considerations regarding how these two phenomena might be inter-related. In this context, we present and discuss in Sects. 9.4 and 9.5 results from two of our own experiments that demonstrate that not only low-level, bottom-up factors (as was often believed), but also higher cognitive contributions, top-down effects, and spatial presence in particular, can enhance self-motion perception and might thus be important factors that should receive more research attention. We finish the chapter by proposing an integrative theoretical framework that sketches how spatial presence and vection might be inter-related, and what consequences this implies in terms of applications and research questions (Sects. 9.6 and 9.7).

9.2 Literature Overview on the Perception of Illusory Self-Motion (Vection)

In this section,[1] we will provide a brief review of the literature on self-motion illusions that is relevant for the current context. More comprehensive reviews on visually induced vection are provided by, e.g., Andersen (1986), Dichgans and Brandt (1978), Howard (1982, 1986), Mergner and Becker (1990), Warren and Wertheim (1990). Vection with a specific focus on VR, motion simulation, and undesirable side-effects has more recently been reviewed in Hettinger et al. (2014), Lawson and Riecke (2014), Palmisano et al. (2011), Riecke and Schulte-Pelkum (2013), Riecke (2011), Schulte-Pelkum (2007).

When stationary observers view a moving visual stimulus that covers a large part of the FOV, they can experience a very compelling and embodied illusion of self-motion in the direction opposite to the visual motion. Many of us have experienced this illusion in real life: For example, when we are sitting in a stationary train and watch a train pulling out from the neighbouring track, we will often (erroneously) perceive that the train we are sitting in is starting to move instead of the train on the adjacent track (von Helmholtz 1866). This phenomenon of illusory self-motion has been termed "vection" and has been investigated for well over a century (von Helmholtz 1866; Mach 1875; Urbantschitsch 1897; Warren 1895; Wood 1895). Vection has been shown to occur for all motion directions and along all motion axes: Linear vection can occur for forward-backward, up-down, or sideways motion (Howard 1982). Circular vection can be induced for upright rotations around the vertical (yaw) axis, and similarly for the roll axis (frontal axis along the line of sight, like in a "tumbling room"), and also around the pitch axis (an imagined line passing through the body from left to right). The latter two forms of circular vection are especially nauseating, since they include a strong conflict between visual and gravitational cues and in particular affect the perceived vertical (Bles et al. 1998).

[1] Sections 9.2, 9.6 and 9.7 of this chapter are, in part, based on (Riecke and Schulte-Pelkum 2013), with kind permission from Springer Science+Business Media: Riecke BE, Schulte-Pelkum J (2013) Perceptual and Cognitive Factors for Self-Motion Simulation in Virtual Environments: How Can Self-Motion Illusions ("Vection") Be Utilized? In: Steinicke F, Visell Y, Campos J, Lécuyer A (eds) Human Walking in Virtual Environments. Springer, New York, pp 27–54, © Springer Science+Business Media New York 2013.

One of the most frequently investigated types of vection is circular vection around the earth-vertical axis. In this special situation where the observer perceives self-rotation around the earth-vertical axis, there is no interfering effect of gravity, since the body orientation always remains aligned with gravity during illusory self-rotation. In a typical classic circular vection experiment, participants are seated inside a rotating drum that is painted with black and white vertical stripes, a device called optokinetic drum. After the drum starts to rotate, the onset latency until the participant reports perceiving vection is measured. The strength of the illusion is measured either by the duration of the illusion, or by some indication of perceived speed or intensity of rotation, e.g., by magnitude estimation or by letting the participant press a button every time they think they have turned 90° (e.g., Becker et al. 2002).

In a similar manner, linear vection can be induced by presenting optic flow patterns that simulate translational motion. The traditional method used to induce linear vection in the laboratory is to use two monitors or screens facing each other, with the participant's head centred between the two monitors and aligned parallel to the screens, such that they cover a large part of the peripheral visual field (Berthoz et al. 1975; Johansson 1977; Lepecq et al. 1993). Optic flow presented in this peripheral field induces strong linear vection. For example, Johansson (1977) showed that observers perceive an "elevator illusion", i.e., upward linear vection, when downward optic flow is shown. Other studies used monitors or projection screens in front of the participant to show expanding or contracting optic flow fields (Andersen and Braunstein 1985; Palmisano 1996). Comparing different motion directions shows greater vection facilitation for up-down (elevator) vection, presumably because visual motion does not suggest a change in the gravito-inertial vector as compared to front-back or left-right motion (Giannopulu and Lepecq 1998; Trutoiu et al. 2009).

In recent times, VR technology has been successfully introduced to perceptual research as a highly flexible research tool (Hettinger et al. 2014; Mohler et al. 2005; Nakamura and Shimojo 1999; Palmisano 1996, 2002; Riecke et al. 2005c). It has been shown that both linear and circular vection can be reliably induced using modern VR technology, and the fact that this technology allows for precise experimental stimulus control under natural or close-to-natural stimulus conditions is much appreciated by researchers (see reviews in Hettinger et al. 2014; Lawson and Riecke 2014; Palmisano et al. 2011; Riecke and Schulte-Pelkum 2013; Riecke 2011; Schulte-Pelkum 2007).

Before discussing possible inter-relations between presence and vection, let us first consider the most relevant findings from the literature on both vection (subsections below) and presence (Sect. 9.3). Traditionally, the occurrence of the self-motion illusion has been thought to depend mainly on bottom-up or low-level features of the visual stimulus. In the following, we will review some of the most important low-level parameters that have been found to influence vection (Sects. 9.2.1, 9.2.2, 9.2.3, 9.2.4, 9.2.5 and 9.2.6) and conclude this section with a discussion of possible higher-level or top-down influences on vection (Sect. 9.2.7).

9.2.1 Size of the Visual FOV

Using an optokinetic drum, Brandt and colleagues found that visual stimuli covering a large FOV induce stronger circular vection and result in shorter onset latencies than when smaller FOVs are used (Brandt et al. 1973). The strongest vection was observed when the entire FOV was stimulated. Limiting the FOV systematically increased onset latencies and reduced vection intensities. It was also found that a black and white striped pattern of 30° diameter that was viewed in the periphery of the visual field induces strong vection, at levels comparable to full field stimulation, whereas the identical 30° stimulus did not induce vection when it was viewed in the central FOV. This observation led to the conclusion of a "peripheral dominance" for illusory self-motion perception. Conversely, the central FOV was thought to be more important for the perception of object motion (as opposed to self-motion). However, this view was later challenged by Andersen and Braunstein (1985) and Howard and Heckmann (1989). Andersen and Braunstein showed that a centrally presented visual stimulus showing an expanding radial optic flow pattern that covered only 7.5° was sufficient to induce forward linear vection when viewed through an aperture. Howard and Heckmann (1989) proposed that the reason Brandt et al. (1973) found a peripheral dominance was likely due to a confound of misperceived foreground-background relations: When the moving stimulus is perceived to be in the foreground relative to a static background (e.g., the mask being used to cover parts of the FOV), it will not induce vection. They suspected that this might have happened to the participants in the Brandt et al. study, and they could confirm their hypothesis in their experiment by placing the moving visual stimulus either in front or in the back of the depth plane of the rotating drum. Their data showed that a central display would induce vection if it is perceived to be in the background. Thus, the original idea of peripheral dominance for self-motion perception should be reassessed. The general notion that larger FOVs are more effective for inducing vection, however, does hold true. In fact, when the perceived depth of the stimulus is controlled for, the perceived intensity of vection increases linearly with increasing stimulus size, independent of stimulus eccentricity (how far in the periphery the stimulus is presented) (Nakamura 2008). For virtual reality applications, this means that large-FOV displays are better suitable for inducing a compelling illusion of self-motion.

9.2.2 Foreground-Background Separation Between a Stationary Foreground and a Moving Background

As already briefly mentioned in the subsection above, a moving stimulus has to be perceived to be in the background in order to induce vection. A number of studies have investigated this effect (Howard and Heckmann 1989; Howard and Howard

1994; Nakamura 2006; Ohmi et al. 1987). All those studies found a consistent effect of the depth structure of the moving stimulus on vection: Only moving stimuli that are perceived to be in the background will reliably induce vection. If a stationary object is seen behind a moving stimulus, no vection will occur (Howard and Howard 1994). That is, the perceived foreground-background or figure-ground relationship can essentially determine the occurrence and strength of vection (Kitazaki and Sato 2003; Ohmi et al. 1987; Seno et al. 2009). Following the reasoning of Dichgans and Brandt, one could argue that the very occurrence of vection might be due to our inherent assumption of a stable environment (Dichgans and Brandt 1978) or a "rest frame" (Prothero and Parker 2003; Prothero 1998): When we see a large part of the visual scene move in a uniform manner, especially if it is at some distance away from us, it seems reasonable to assume that this is caused by ourselves moving in the environment, rather than the environment moving relative to us. The latter case occurs only in very rare cases in natural occasions, such as in the train illusion, where our brain is fooled to perceive self-motion. It has been shown that stationary objects in the foreground will increase vection if they partly occlude a moving background (Howard and Howard 1994), and that a foreground that moves slowly in the direction opposite to that of the background will also facilitate vection (Nakamura and Shimojo 1999). In Sect. 9.4, we will present some recent data that extend these findings to more natural stimuli and discuss implications for self-motion simulation from an applied perspective.

9.2.3 Spatial Frequency of the Moving Visual Pattern

Diener et al. (1976) observed that moving visual patterns that contained high spatial frequencies are perceived to move faster than similar visual patterns of lower spatial frequencies, even though both move at identical angular velocities. This means that a vertical grating pattern with, e.g., 20 contrasts (such as black and white stripes) per given visual angle will be perceived to move faster than a different pattern with only 10 contrasts within the same visual angle. Palmisano and Gillam (1998) revealed that there is an interaction between the spatial frequency of the presented optic flow and the retinal eccentricity: While high spatial frequencies produce most compelling vection in the central FOV, peripheral stimulation results in stronger vection if lower spatial frequencies are presented. This finding contradicts earlier notions of peripheral dominance (see Sect. 9.2.1) and shows that both high- and low spatial frequency information is involved in the perception of vection, and that mechanisms of self-motion perception differ depending on the retinal eccentricity of the stimulus. In the context of VR, this implies that fine detail included in the graphical scene may be more beneficial in the central FOV, while stimuli in the periphery might be rendered at lower resolution and fidelity, thus reducing overall simulation cost (see also discussion in Wolpert 1990).

9.2.4 Velocity and Direction of the Visual Stimulus

Howard and Brandt et al. reported that the intensity and perceived speed of self-rotation in circular vection around the yaw axis is linearly proportional to the velocity of the optokinetic stimulus up to values of approximately 90°/s (Brandt et al. 1973; Howard 1986). Note that the perceived velocity interacts with the spatial frequency of the stimulus, as detailed in Sect. 9.2.3. While Brandt et al. (1973) report that the vection onset latency for circular vection is more or less constant for optical velocities up to 90°/s, others report that very slow movement below the vestibular threshold results in earlier vection onset (Wertheim 1994). This apparent contradiction might, however, be due to methodological differences: While Brandt et al. accelerated the optokinetic drum in darkness up to a constant velocity and measured vection onset latency from the moment the light was switched on, the studies where faster vection onset was found for slow optical velocities typically used sinusoidal motion with the drum always visible.

Similar relations between stimulus velocity and vection have been observed for linear motion: Berthoz et al. (1975) found a more or less linear relationship between perceived self-motion velocity and stimulus velocity up to a certain level where an upper limit of the sensation of vection was reached. Interestingly, thresholds for backward and downward vection have been found to be lower than for forward and upward vection, respectively (Berthoz and Droulez 1982). The authors assumed that this result reflects normal human behaviour: While we perceive forward motion quite often and are thus well used to it, we are hardly exposed to linear backward motions, such that our sensitivity for them might be lower. In general, so-called elevator (up-down) vection is perceived earlier and as more compelling than other motion directions (Giannopulu and Lepecq 1998; Trutoiu et al. 2009). This might be related to up-down movements being aligned with the direction of gravity for upright observers, such that gravitational and acceleration directions are parallel. Interestingly, Kano found that onset latencies for vertical linear vection are significantly shorter than for forward and backward vection when observers are seated upright, but this difference disappeared when participants observed the identical stimuli in a supine position (Kano 1991). It is possible that this effect might be related to different utricular and macular sensitivities of the vestibular system, but it is yet unclear how retinal and gravitational reference frames interact during vection.

Although vection is generally enhanced when the visuo-vestibular conflict is reduced, e.g., in patients whose vestibular sensitivity is largely reduced, such as bilaterally labyrinth defective participants (Cheung et al. 1989; Johnson et al. 1999), Palmisano and colleagues showed convincingly that adding viewpoint jitter to a vection-in-depth visual stimulus consistently enhances vection, even though it should enhance the sensory conflict between visual and vestibular cues (Palmisano et al. 2000, 2011).

9.2.5 Eye Movements

It has long been recognized that eye movements influence the vection illusion. Mach (1875) was the first to report that vection will develop faster if observers fixate a stationary target instead of letting their eyes follow the stimulus motion. This finding has been replicated many times (e.g., Becker et al. 2002; Brandt et al. 1973). Becker et al. investigated this effect in an optokinetic drum by systematically varying the instructions how to "watch" the stimulus: In one condition, participants had to follow the stimulus with their eyes, thus not suppressing the optokinetic nystagmus (OKN, which is the reflexive eye movement that also occurs in natural situations, e.g., when one looks out of the window while riding a bus). In other conditions, participants either had to voluntarily suppress the OKN by fixating a stationary target that was presented on top of the moving stimulus, or they were asked to stare through the moving stimulus. Results showed that vection developed faster with the eyes fixating a stationary fixation point as compared to participants staring through the stimulus. Vection took longest to develop when the eyes moved naturally, following the stimulus motion. Besides fixating and staring, looking peripherally or shifting one's gaze between central and peripheral regions can also improve forward linear vection (Palmisano and Kim 2009).

9.2.6 Non-visual Cues and Multimodal Consistency

Most of the earlier vection literature has been concerned with visually induced vection. Vection induced by other sensory modalities, such as moving acoustic stimuli, has therefore received little attention, even though auditorily induced circular vection and nystagmus have been reported as early as 1923 (Dodge 1923) and since been replicated by several researchers (Hennebert 1960; Lackner 1977; Marme-Karelse and Bles 1977), see also reviews in Riecke et al. (2009b) and Väljamäe (2009). Lackner (1977) demonstrated, for example, that a rotating sound field generated by an array of loudspeakers could induce vection in blindfolded participants. More recent studies demonstrated that auditory vection can also be induced by headphone-based auralization using generic head-related transfer functions (HRTFs), both for rotations and translations (Larsson et al. 2004; Riecke et al. 2005e, 2009b; Väljamäe et al. 2004; Väljamäe 2009). Several factors were found to enhance auditory vection (see also reviews in Riecke et al. 2009b; Väljamäe 2009): For example, both the realism of the acoustic simulation and the number of sound sources were found to enhance vection. It is important to keep in mind, however, that auditory vection occurs only in about 25–70 % of participants and is far less compelling than visually induced vection, which can be indistinguishable from actual motion (Brandt et al. 1973). Hence, auditory cues alone are not sufficient to reliably induce a compelling self-motion sensation. However, adding consistent spatialized auditory cues to a naturalistic visual stimulus can enhance both vection and overall presence in the simulated environment, compared to non-spatialized sound or no sound (Keshavarz et al. 2013; Riecke et al. 2005d, 2009b). Similarly, moving sound fields can enhance "biomechanical" vection induced by stationary participants stepping along a rotating floor platter (Riecke et al. 2011). This suggests that multi-modal consistency might be beneficial for the effectiveness of self-motion simulations.

This notion is supported by Wong and Frost, who showed that circular vection is facilitated when participants are provided with an initial physical rotation ("jerk") that accompanies the visual motion onset (Wong and Frost 1981). Even though the physical motion did not match the visual motion quantitatively, the qualitatively correct physical motion signal accompanying the visual motion supposedly reduced the visuo-vestibular cue conflict, thus facilitating vection.

Similar vection-facilitating effects have more recently been reported for linear vection when small linear forward jerks of only a few centimetres accompanied the onset of a visually displayed linear forward motion in VR. This has been shown for both passive movements of the observer (Berger et al. 2010; Riecke et al. 2006b; Riecke 2011; Schulte-Pelkum 2007) and for active, self-initiated motion cueing using a modified manual wheelchair (Riecke 2006) or a modified Gyroxus gaming chair where participants controlled the virtual locomotion by leaning into the intended motion direction (Feuereissen 2013; Riecke and Feuereissen 2012). For passive motions, combining vibrations and small physical movements (jerks) together was more effective in enhancing vection than either vibrations or jerks alone (Schulte-Pelkum 2007, exp. 6).

Helmholtz suggested already in 1866 that vibrations and jerks that naturally accompany self-motions play an important role for self-motion illusions, in that we expect to experience at least some vibrations or jitter (von Helmholtz 1866). Vibrations can nowadays easily be included in VR simulations and are frequently used in many applications. Adding subtle vibrations to the floor or seat in VR simulations has indeed been shown to enhance not only visually-induced vection (Riecke et al. 2005c; Schulte-Pelkum 2007), but also biomechanically-induced vection (Riecke et al. 2009a) and auditory vection (Riecke et al. 2009a; Väljamäe et al. 2006; Väljamäe 2007), especially if accompanied by a matching simulated engine sound (Väljamäe et al. 2006, 2009). These studies provide scientific support for the usefulness of including vibrations to enhance the effectiveness of motion simulations – which is already common practice in many motion simulation applications. It remains, however, an open question whether the vection-facilitating effect of adding vibrations originates from low-level, bottom-up factors (e.g., by decreasing the reliability of the vestibular and tactile signals indicating "no motion") or whether the effect is mediated by higher-level and top-down factors (e.g., the vibrations increasing the overall believability and naturalism of the simulated motion), or both.

As both vibrations and minimal motion cueing can be added to existing VR simulations with relatively little effort and cost, their vection-facilitating effect is promising for many VR applications. Moreover, these relatively simple means of providing vibrations or jerks were shown to be effective despite being physically incorrect – while jerks normally need to be in the right direction to be effective and be synchronized with the visual motion onset, their magnitude seems to be of lesser importance. Indeed, for many applications there seems to be a surprisingly large coherence zone in which visuo-vestibular cue conflicts are either not noticed or at the least seem to have little detrimental effect (van der Steen 1998). Surprisingly, physical motion cues can enhance visually-induced vection even when they do not match the direction or phase of the visually-displayed motion (Wright 2009): When participants watched sinusoidal linear horizontal (left-right) oscillations on a head-mounted display, they reported more compelling vection and larger motion amplitudes when they were synchronously moved (oscillated) in the vertical (up-down) and thus orthogonal direction. Similar enhancement of perceived vection and motion amplitude was observed when both the visual and physical motions were in the vertical direction, even though visual and physical motions were always in *opposite* directions and thus out of phase by 180° (e.g., the highest visually depicted view coincided with the lowest point of their physical vertical oscillatory motion). In fact, the compellingness and amplitude of the perceived self-motion was not significantly smaller than in a previous study where visual and inertial motion was synchronized and not phase-shifted (Wright et al. 2005). Moreover, for both horizontal and vertical visual motions, perceived motion directions were almost completely dominated by the visual, not the inertial motion. That is, while there was some sort of "visual capture" of the perceived motion direction, the extent and convincingness of the perceived self-motion was modulated by the amount of inertial acceleration.

In two recent studies, Ash et al. showed that vection is enhanced if participants' active head movements are updated in the visual self-motion display, compared to a condition where the identical previously recorded visual stimulus was replayed while observers did not make any active head-movements (Ash et al. 2011a, b). This means that vection was improved by consistent multisensory stimulation where sensory information from own head-movements (vestibular and proprioceptive) matched visual self-motion information on the VR display (Ash et al. 2011b). In a second study with similar setup, Ash et al. (2011a) found that adding a deliberate display lag between the head and display motion modestly impaired vection. This finding is highly important since in most VR applications, end-to-end system lag is present, especially in cases of interactive, multisensory, real-time VR simulations. Despite technical advancement, it is to be expected that this limitation cannot be easily overcome in the near future.

Seno and colleagues demonstrated that air flow provided by a fan positioned in front of observers' face significantly enhanced visually induced forward linear vection (Seno et al. 2011b). Backward linear vection was not facilitated, however, suggesting that the air flow needs to at least qualitatively match the direction of simulated self-motion, similar to head wind.

Although multi-modal consistency in general seems to enhance vection, there seems to be at least one exception: while biomechanical cues from walking on a circular treadmill can elicit vection by themselves in blindfolded participants (Bles 1981; Bles and Kapteyn 1977) and also enhance visually induced vection (Riecke et al. 2009b; Väljamäe 2009) as well as biomechanically induced circular vection

(Riecke et al. 2011), linear treadmill walking can neither by itself reliably induce vection, nor does it reliably enhance visually-induced vection, as discussed in detail in Ash et al. (2013) and Riecke and Schulte-Pelkum (2013).

It remains puzzling how adding velocity-matched treadmill walking to a visual motion simulation can impair vection (Ash et al. 2012; Kitazaki et al. 2010; Onimaru et al. 2010) while active head motions and simulated viewpoint jitter clearly enhance vection (Palmisano et al. 2011). More research is needed to better understand under what conditions locomotion cues facilitate or impair linear vection, and what role the artificiality of treadmill walking might play. Nevertheless, the observation that self-motion perception can, at least under some circumstances, be impaired if visual and biomechanical motion cues are matched seems paradoxical (as it corresponds to natural eyes-open walking) and awaits further investigation. These results do, however, suggest that adding a walking interface to a VR simulator might potentially (at least in some cases) *decrease* instead of increase the sensation of self-motion and thus potentially decrease the overall effectiveness of the motion simulation. Thus, caution should be taken when adding walking interfaces, and each situation should be carefully tested and evaluated as one apparently cannot assume that walking will always improve the user experience and simulation effectiveness.

Note that there are also considerable differences between different people's susceptibility to vection and different vection-inducing stimuli, so it can be difficult to predict a specific person's response to a given situation. Palmisano and colleagues made recent progress towards that challenge, though, and showed that the strength of linear forward vection could be predicted by analysing participants' postural sway patterns without visual cues (Palmisano et al. 2014), which is promising.

In conclusion, there can often be substantial benefits in providing coherent self-motion cues in multiple modalities, even if they can only be matched qualitatively. Budget permitting, allowing for actual physical walking or full-scale motion or motion cueing on 6 degrees of freedom (DoF) motion platforms is clearly desirable and might be necessary for specific commercial applications like flight or driving simulation. When budget, space, or personnel is more limited, however, substantial improvements can already be gained by relatively moderate and affordable efforts, especially if consistent multi-modal stimulation and higher-level influences are thoughtfully integrated. Although they do not provide physically accurate simulation, simple means such as including vibrations, jerks, spatialized audio, or providing a perceptual-cognitive framework of movability can go a long way (Lawson and Riecke 2014; Riecke and Schulte-Pelkum 2013; Riecke 2009, 2011). Even affordable, commercially available motion seats or gaming seats can provide considerable benefits to self-motion perception and overall simulation effectiveness (Riecke and Feuereissen 2012).

As we will discuss in our conceptual framework in Sect. 9.6 in more detail, it is essential to align and tailor the simulation effort with the overarching goal: e.g., is the ultimate goal physical correctness, perceptual effectiveness, or behavioural realism? Or is there a stronger value put on user's overall enjoyment, engagement, and immersion, as in the case of many entertainment applications, which represent a considerable and increasing market share?

9.2.7 Cognitive, Attentional, and Higher-Level Influences on Vection

The previous subsections summarized research demonstrating a clear effect of perceptual (low-level) factors and bottom-up processes on illusory self-motion perception. In the remainder of this section, we would like to point out several studies which provide converging evidence that not only low-level factors, but also cognitive, higher-level processes as well as attention might play an important role in the perception of illusory self-motion, especially in a VR context (see also reviews in Riecke and Schulte-Pelkum (2013) and Riecke (2009, 2011)). That is, we will argue that vection can also be affected by what is outside of the moving stimulus itself, for example by the way we move and look at a moving stimulus, our pre-conceptions, intentions, and how we perceive and interpret the stimuli, which is of particular importance in the context of VR.

As mentioned in Sect. 9.2.2, it has already been proposed in 1978 that the occurrence of vection might be linked to our inherent assumption of a stable environment (Dichgans and Brandt 1978). Perhaps this is why the *perceived* background of a vection-inducing stimulus is typically the dominant determinant of the presence of vection and modulator of the strength of vection, even if the background is not physically further away than the perceived foreground (Howard and Heckmann 1989; Ito and Shibata 2005; Kitazaki and Sato 2003; Nakamura 2008; Ohmi et al. 1987; Seno et al. 2009). This "object and background hypothesis for vection" has been elaborated upon and confirmed in an elegant set of experiments using perceptually bistable displays like the Rubin's vase that can be perceived either as a vase or two faces (Seno et al. 2009). In daily life, the more distant elements comprising the background of visual scenes are generally stationary and therefore any retinal movement of those distant elements is more likely to be interpreted as a result of self-motion (Nakamura and Shimojo 1999). In VR simulations, these findings could be used to systematically reduce or enhance illusory self-motions depending on the overall simulation goal, e.g., by modifying the availability of real or simulated foreground objects (e.g., dashboards), changing peripheral visibility of the surrounding room (e.g., by controlling lighting conditions), or changing tasks/instructions (e.g., instructions to pay attention to instruments which are typically stationary and in the foreground).

In the study by Andersen and Braunstein described in Sect. 9.2.2, the authors remark that pilot experiments had shown that in order to perceive any self-motion, participants had to believe that they could actually be moved in the direction of perceived vection (Andersen and Braunstein 1985). Accordingly, participants were asked to stand in a movable booth and looked out of a window to view the optic flow pattern. Similarly, in a study by Lackner who showed that circular vection can be induced in blindfolded participants by a rotating sound field, participants were seated on a chair that could be rotated (Lackner 1977). Note that by making participants believe that they could, in fact, be moved physically, Andersen and Braunstein were able to elicit vection with a visual FOV as small as 7.5°, and Lackner (1977) and Larsson et al. (2004) were able to induce vection simply by presenting a moving sound field to blindfolded listeners. Under these conditions of limited or weak sensory stimulation, cognitive factors seem to become a relevant factor. It is possible that cognitive factors generally have an effect on vection, but that this has not been recognized so far due to a variety of reasons. For example, the cognitive manipulations might not have been powerful enough, or sensory stimulation might have been so strong that ceiling level was already reached, which is likely to be the case in an optokinetic drum that covers the full visible FOV.

In this context, a study by Lepecq and colleagues is of particular importance, as it explicitly addressed cognitive influences on linear vection (Lepecq et al. 1995): They found that 7 year old children perceive vection earlier when they are previously shown that the chair they are seated on can physically move in the direction of simulated motion – even though this never happened during the actual experiment. Interestingly, this vection-facilitating influence of pre-knowledge was not present in 11 year old children.

Prior knowledge of whether or not physical motions are possible do show some effect on adults as well: In a circular vection study in VR, 2/3 of the participants were fooled into believing that they physically moved when they were previously shown that the whole experimental setup can indeed be moved physically (Riecke et al. 2005e; Riecke 2011; Schulte-Pelkum 2007). Note, however, that neither vection onset times, nor vection intensity or convincingness were significantly affected by the cognitive manipulation. In another study, Palmisano and Chan (2004) demonstrated that cognitive priming can also affect the time course of vection: Adult participants experienced vection earlier when they were seated on a potentially movable chair and were primed towards paying attention to self-motion sensation, compared to a condition where they were seated on a stationary chair and instructed to attend to object motion, not self-motion.

Providing such a cognitive-perceptual framework of movability has recently been shown to also enhance auditory vection (Riecke et al. 2009a). When blindfolded participants were seated on a hammock chair while listening to binaural recordings of rotating sound fields, auditory circular vection was facilitated when participants' feet were suspended by a chair-attached footrest as compared to being positioned on solid ground. This supports the common practice of seating participants on potentially moveable platforms or chairs in order to elicit auditory vection (Lackner 1977; Väljamäe 2007, 2009).

There seems to be mixed evidence about the potential effects of attention and cognitive load on vection. Whereas Trutoiu et al. (2008) observed vection facilitation when participants had to perform a cognitively demanding secondary task, vection inhibition was reported by Seno et al. (2011a). When observers in Kitazaki and Sato (2003) were asked to specifically pay attention to one of two simultaneously presented upward and downward optic flow fields of different colours, the non-attended flow field was found to determine vection direction. This might, however, also be explained by attention modulating the perceived depth-ordering and foreground-background relationship, as discussed in detail in Seno et al. (2009). Thus, while attention and cognitive load can clearly affect self-motion illusions, further research is needed to elucidate underlying factors and explain seemingly conflicting findings. A recent study suggests that vection can even be induced when participants are not consciously aware of any global display motion, which was cleverly masked by strong local moving contrasts (Seno et al. 2012).

Studies on auditorily induces circular vection also showed cognitive or top-down influences: sound sources that are normally associated with stationary objects (so-called “acoustic landmarks” like church bells) proved more potent in inducing circular vection in blindfolded participants than artificial sounds (e.g., pink noise) or sound typically generating from moving objects (e.g., driving vehicles or foot steps) (Larsson et al. 2004; Riecke et al. 2005e).

A similar mediation of vection via higher-level mechanisms was observed when a globally consistent visual stimulus of a natural scene was compared to an upside-down version of the same stimulus (Riecke et al. 2005e, 2006a). Even though the inversion of the stimulus left the physical stimulus characteristics (i.e., the image statistics and thus bottom-up factors) essentially unaltered, both participants’ rated presence in the simulated environment and the rated convincingness of the illusory self-motion were significantly reduced. This strongly suggests a higher-level or top-down contribution to presence and the convincingness of self-motion illusions. We posit that the natural, ecologically more plausible upright stimulus might have more easily been accepted as a stable “scene”, which in turn facilitated both presence and the convincingness of vection. The importance of a naturalistic visual stimulus is corroborated by a study from Wright et al. (2005) that demonstrated that visual motion of a photo-realistic visual scene can dominate even conflicting inertial motion cues in the perception of self-motion.

Already 20 years ago, Wann and Rushton (1994) stressed the importance of an ecological context and a naturalistic optic array for studying self-motion perception. Traditional vection research has, however, used abstract stimuli like black and white striped patterns or random dot displays, and only recently have more naturalistic stimuli become more common in self-motion research (Mohler et al. 2005; Riecke et al. 2005c, 2006a; van der Steen and Brockhoff 2000). One might expect that more natural looking stimuli have the potential of not only inducing stronger vection, but also higher presence. Consequently, it seems appropriate to consider possible interactions between presence and vection.

Even though presence is typically not assessed or discussed in vection studies, it is conceivable that presence might nevertheless have influenced some of those results: For example, Palmisano (1996) found that forward linear vection induced by a simple random dot optic flow pattern was increased if stereoscopic information was provided, compared to non-stereoscopic displays. Even though presence was not measured in this experiment, it is generally known that stereoscopic displays increase presence (Freeman et al. 2000; IJsselsteijn et al. 2001). In another study, van der Steen and Brockhoff (2000) found unusually short vection onset latencies, both for forward linear and circular yaw vection. They used an immersive VR setup consisting of a realistic cockpit replica of an aircraft on a motion simulator with a wide panoramic projection screen. Visual displays showed highly realistic scenes of landscapes as would be seen from an airplane. Even though presence was not assessed here, it is possible that the presumably high level of presence might have contributed to the strong vection responses of the observers.

In conclusion, cognitive factors seem to become more relevant when stimuli are ambiguous or have only weak vection-inducing power, as in the case of auditory vection (Riecke et al. 2009a) or sparse or small-FOV visual stimuli (Andersen and Braunstein 1985). It is conceivable that cognitive factors generally have an effect on vection, but that this has not been widely recognized for methodological reasons. For example, the cognitive manipulations might not have been powerful enough or free of confounds, or sensory stimulation might have been so strong that ceiling level was already reached, which is likely the case in an optokinetic drum that completely covers the participant's field of vision.

9.3 A Selective Review on Presence

"Presence" denotes the phenomenon that users who are experiencing a simulated world in VR can get a very compelling illusion of being and acting in the simulated environment instead of the real environment, a state also described as "being there" or "spatial presence" (Hartmann et al. 2014). Several different definitions for presence have been suggested in the literature, and comprehensive reviews of different conceptualizations, definitions, and measurement methods are provided in the current book and, e.g., Biocca (1997), IJsselsteijn (2004), Lee (2004), Loomis (1992), Nash et al. (2000), Sadowski and Stanney (2002), Schultze (2010), Steuer (1992).

The fact that presence does occur, even though current VR technology can afford only relatively sparse and insufficient sensory stimulation, is remarkable by itself. Even with the most sophisticated current immersive VR technology, a simulated environment will never be seriously mistaken as reality by any user, even if one's attention might be primarily drawn to the virtual environment. So, what is presence, and what is its relevance for the use of current VR systems?

One central problem associated with the concept of presence is its rather diffuse definition, which evokes theoretical and methodological problems. In order to theoretically distinguish presence from other related concepts, the term "immersion" is often used to clarify that presence (and in particular "spatial presence") is about the sensation of being at another place than where one's own body is physically located, while immersion usually refers to a psychological process of being completely absorbed in a certain physical or mental activity (e.g., reading a book or playing a game), such that one loses track of time and of the outside world (Jennett et al. 2008; Wallis and Tichon 2013). Note that we distinguish here between "immersion" as the psychological process and "immersiveness" as the medium's ability to afford the psychological process of immersion (Vidyarthi 2012), which is and extension of what Slater (1999) referred to as "system immersion". "Immersive VR", then, describes VR systems that have the technical prerequisites and propensities (e.g., high perceptual realism and fidelity) to create an immersive experience in the user. It has been pointed out that presence and immersion or involvement are logically distinct phenomena, even though they seem to be empirically related (Haans and IJsselsteijn 2012). A captivating narrative or content in VR might draw off attention from sensorimotor mismatches due to poor simulation fidelity, such as a noticeable delay of a visual scene that is experienced using a head-tracked HMD. On the other hand, a low-tech device such as a book can be highly immersive, depending on its form and content. It is commonly assumed that highly immersive VR systems can also create a high sense of presence, but the relation between the concepts still remains unclear, and attempts to capture these phenomena in one comprehensive theoretical framework are rare (Haans and IJsselsteijn 2012; Vidyarthi 2012).

The most frequently used measurement methods of presence rely on post-exposure self-report questionnaires like the Presence Questionnaire (PQ) by Witmer et al. (2005), or the IGroup Presence Questionnaire (IPQ) by Schubert et al. (2001). Here, VR users are asked to report from memory the intensity of presence they perceived in the preceding VR-scene. Factor analytic surveys suggest that such questionnaires seem to be able to reliably identify different aspects of presence, and a number of questionnaires have gained a significant level of acceptance in the community, with reliability measures of Cronbach's α at .85 for the IPQ, for example. However, some authors have questioned the validity of self-report measures of presence, and suggested physiological measures, such as heart-rate, skin conductance or event-evoked cortical responses etc. as more objective alternatives that allow for real-time measurement of presence (Slater and Garau 2007; Slater 2004). The idea is that a high level of perceived presence of a user in a simulated environment should be associated with similar physiological reactions as in the real world. Following this logic, Meehan et al. observed systematic changes in a number of physiological responses when users approached a simulated virtual pit that induced fear, which correlated with reported levels of presence (Meehan et al. 2002). Freeman et al. (2000) used postural responses to visual scenes of a driving simulator as a measure of presence. Postural responses to visual scenes depicting accelerations, braking, taking a curve etc. from the perspective of a rally car driver were stronger in conditions with stereoscopic visual stimulation in which reported presence was higher.

While such approaches might potentially help circumventing some of the problems associated with subjective report measures of presence, their utility remains unclear so far. Recently, the fMRI paradigm has been adopted in presence research, and some neural correlates of presence have been observed (Bouchard et al. 2012; Hoffman et al. 2003). However, this endeavor is only at its beginning yet, and this method will be practicable only to a limited number of research labs, at least for the near future.

Finally, another approach in this field is the use of behavioral measures (Bailenson et al. 2004; Wallis and Tichon 2013). If users could intuitively behave in a virtual environment in a natural manner and perform tasks as well as in reality, such as wayfinding, controlling a vehicle in a simulation etc., one central goal in VR research might be considered as fulfilled. Behavioural measures have the advantage that they can be recorded unobtrusively, in an ongoing perception-action-loop. Differential analyses of behavioural outcomes and their relation to presence have the potential to reveal new insights to this field. Along this line, a recent study about simulator-based training efficacy showed that reported presence levels of trainees in a train simulator correlated moderately with overall training efficacy after 1 year, but was not sensitive to performance differences in three different simulator types used in the study. In contrast, a perceptual judgment task about speed perception was able to predict different training efficacy of the three types of simulators (Wallis and Tichon 2013).

What becomes apparent from the considerations so far is that depending on the purpose and context of the VR simulation, be it training, entertainment, research, education etc., the relevance of presence and other concepts might vary, and there might be interactions. We will argue that a pragmatic, behaviorally oriented approach appears promising for the near future.

For the purpose of our study, the definition by Witmer and Singer which states that "…presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another" (Witmer and Singer 1998) describes well the relevant aspects of spatial presence in the context of self-motion simulation in VR, as we will outline in the following.

9.3.1 Presence and Reference Frames

One important aspect VR simulations we would like to point out here is that in any VR application, the user is always confronted with two, possibly competing, egocentric representations or reference frames: On the one hand, there is the real environment (i.e., the physical room where the VR setup is situated). On the other hand, there is the computer-generated VE, which provides an intended reference frame or representation that might interfere with the real world reference frame unless they present the same environment in perfect spatio-temporal alignment. Riecke and von der Heyde proposed that the degree to which users accept the VE as their primary reference frame might be directly related to the degree of spatial presence experience in the VE (von der Heyde and Riecke 2002; Riecke 2003). In their framework, the consistency or lack of interference between the VR and real world reference frame is hypothesized to be a necessary prerequisite for enabling compelling spatial presence. Conversely, any interference between conflicting egocentric reference frames is expected to decrease spatial presence and thereby also automatic spatial updating and natural, robust spatial orientation in the VE (Riecke et al. 2007; Riecke 2003). This notion of conflicting reference frames is closely related to the sensorimotor interference hypothesis proposed by May and Wang, which attributes the difficulty of imagined perspective switches (at least in part) to processing costs resulting from an interference between the sensorimotor and the to-be-imagined perspective (May 1996, 2004; Wang 2005; see also discussion in Avraamides and Kelly 2008; Riecke and McNamara submitted).

This emphasizes the importance of reducing users' awareness of the physical surroundings, which has already been recognized by many researchers and VR designers. If not successful, a perceived conflict between competing egocentric reference frames arises which can critically disrupt presence, i.e., the feeling of being and acting in the virtual environment (IJsselsteijn 2004; Slater and Steed 2000), see also Hartmann et al.'s chapter in this volume (Hartmann et al. 2014).

9.3.2 Resence and Self-Motion Perception

In the following, we will review a selection of papers that investigated presence in the context of self-motion perception. Slater and colleagues found a significant positive association between extent and amount of body movement and subjective presence in virtual environments (Slater et al. 1998). Participants experienced a VE through a head-tracked HMD, and depending on task condition, one group was required to move their head and body a lot, while the other group could do the task without much body movement. The group that had to move more showed much higher presence ratings in the post-experimental presence questionnaires. It is plausible that the more an observer wearing an HMD experiences perceptual consequences of his or her own body movements in the simulated environment, the more he or she will experience presence in the simulated VE and not in the real world.

There are several studies that investigated the influence of stereoscopic presentation on presence and vection: Freeman, IJsselsteijn and colleagues observed that presence and postural responses were increased when observers watched a stereoscopic movie that was shot from the windshield of a rally car, as compared to a monoscopic version of the film (Freeman et al. 2000; IJsselsteijn et al. 2001). Vection, however, was not improved by the stereoscopic presentation. Note that in the studies by Freeman et al. and IJsselsteijn et al., presence was assessed with only one post-test question: Participants were simply asked to rate how much they felt present in the displayed scene as if they were "really there". Participants were to place a mark in the scale depicting a continuum between the extremes "not at all there" and "completely there" on a line connecting the two points.

Since presence is conceptualized as a multi-dimensional construct, it is possible that assessing presence with only one item was too course to reveal a correlation with vection. This motivated us to perform a more fine-grained analysis on possible relations between presence and vection using the IPQ presence questionnaire (see Sect. 9.4.5).

9.3.3 Conclusions

In the preceding two subsections, we reviewed the relevant literature on vection and presence, and extracted a number of observations that indicate that attentional, cognitive, and higher-level factors might affect the occurrence and strength of vection. Since VR is increasingly being used as a standard tool in vection research, it seems worthwhile to investigate possible connections between presence and vection, be they correlational or causal. Previous studies that failed to show such a connection have the limitation that presence was assessed only coarsely (Freeman et al. 2000; IJsselsteijn et al. 2001). Furthermore, a number of studies measured vection but not presence, even though factors that are known to influence presence (such as stereoscopic viewing) were manipulated (Palmisano 1996). Given these circumstances, we aimed to perform a more detailed investigation of the potential relations between presence and vection. We were guided by the hypothesis that the different dimensions, which in sum constitute presence, might have differential influences on different aspects of the self-motion illusion. We decided to measure presence using the IPQ presence questionnaire by Schubert et al. (2001), and to assess vection by measuring vection onset latency, vection intensity, and the convincingness of illusory self-motion. Correlation analyses between the IPQ presence scales and the three vection measures are the core of the analysis.

9.4 Experiments Investigating the Relations Between Spatial Presence, Scene Consistency and Self-Motion Perception

In the following, we will briefly present the results of two of our own studies that directly addressed the potential relations between presence, naturalism of the stimulus, reference frames, and self-motion perception. A detailed description of the experiments can be found in Riecke et al. (2006a) (Experiment 1) and Riecke et al. (2004) (Experiment 2). Based on the above-mentioned idea that vection depends on the assumption of a stable environment, we expected that the sensation of vection should be enhanced if the presented visual stimulus (e.g., a virtual environment) is more easily "accepted" as a real world-like stable reference frame. That is, we predicted that vection in a simulated environment should be enhanced if participants feel spatially present in that environment and might thus more readily expect the virtual environment to be stable, just like the real world is expected to be stable.

Presence has been conceptualized as a multi-dimensional construct, and is usually measured with questionnaires where users are asked to provide subjective ratings about the degree to which they felt present in the VR environment after exposure, as discussed above (IJsselsteijn 2004; Nash et al. 2000; Sadowski and Stanney 2002; Schultze 2010). Despite being aware of problems associated with this introspective measurement method, we decided to use the Igroup Presence Questionnaire (IPQ) by Schubert et al. (2001) for our current study, which allowed us to test specific hypotheses about relations between different constituents of presence and vection. Using factor analyses, Schubert et al. extracted three factors that constitute presence based on a sample of 246 participants. These three factors were interpreted as *spatial presence* – the relation between one's body and the VE as a space; *involvement* – the amount of attention devoted to the VE; and *realness* – the extent to which the VE is accepted as reality. The results of our own correlation analyses between vection in VR and the IPQ presence scores will be presented later in Sect. 9.4.5.

The goal of the first study presented here in more detail (henceforth named Experiment 1)[2] was to determine whether vection can be modulated by the nature of the vection-inducing visual stimulus, in particular whether or not it depicts a natural scene that allows for the occurrence of presence or not. On the one hand, the existence of such higher-level contributions would be of considerable theoretical interest, as it challenges the prevailing opinion that the self-motion illusion is mediated solely by the physical stimulus parameters, irrespective of any higher cognitive contributions. On the other hand, it would be important for increasing the effectiveness and convincingness of self-motion simulations: Physically moving the observer on a motion platform is rather costly, labour-intensive, and requires a large laboratory setup and safety measures. Thus, if higher-level and top-down mechanisms could help to improve the simulation from a perceptual level and in terms of effectiveness for the given task, this would be quite beneficial, especially because these factors can often be manipulated with relatively simple and cost-effective means, especially compared to using full-fledged motion simulators. The second study to be presented (subsequently referred to as Experiment 2) is an extension to the first study and investigated effects of minor modifications of the projection screen (Riecke et al. 2004; Riecke and Schulte-Pelkum 2006).

9.4.1 Methods

In the following, we will present the main results of Experiment 1 & 2 together with a novel reanalysis and discussion of possible causal relations between presence and self-motion perception. In both experiments, participants were seated in front of a curved projection screen (45° × 54° FOV) and were asked to rate circular vection induced by rotating visual stimuli that depicted either a photorealistic roundshot of a natural scene (the Tübingen market place, see Fig. 9.1, top) or scrambled (globally inconsistent) versions thereof that were created by either slicing the original roundshot horizontally and randomly reassembling it (Fig. 9.1, condition b) or by scrambling image parts in a mosaic-like manner (Fig. 9.1, condition B).

9.4.2 Hypotheses

Scene scrambling was expected to disrupt the global consistency of the scene and pictorial depth cues contained therein. We expected that this should impair the believability of the stimuli and in particular spatial presence in the simulated scene. All of these factors can be categorized as cognitive or higher-level contributions

[2] This section presents a re-analysis of the most relevant experimental conditions from Riecke et al. (2006a) (experiment 1) and is in part based on that paper, with an additional discussion in the context of presence and experiment 2 and the framework presented in this chapter.

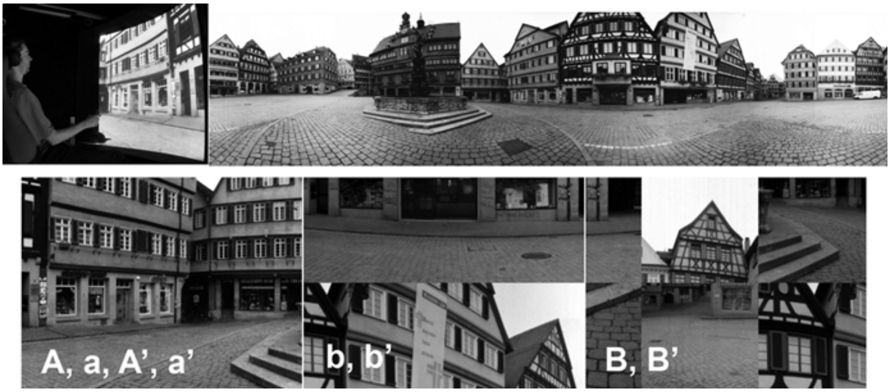

Fig. 9.1 Setup and subset of the stimuli used in Experiment 1 and 2 (Riecke et al. 2004, 2006a). *Top left*: Participant seated in front of curved projection screen displaying a view of the Tübingen market place. *Top right*: 360° roundshot of the Tübingen Market Place. *Bottom*: 54° × 45° view of three of the stimuli discussed here. *Left*: Original, globally consistent image (*a, A, a', A'*), *Middle*: 2 slices per 45° FOV (*b, b'*), and *Right*: 2 × 2 mosaics per 45° × 45° FOV (*B*, *B'*). Note that the original stimuli were presented in colour

(Riecke et al. 2005e; Riecke 2009, 2011). Note, however, that scene scrambling had only minor effects on bottom-up factors (physical stimulus properties) like the image statistics. Thus, any effect of global scene consistency on vection should accordingly be attributed to cognitive, top-down effects, and might be mediated by spatial presence in the simulated scene.

The original experiment followed a 2 (session: mosaic, slices) × 4 (scrambling severity: intact, 2, 8, 32 mosaics/slices per 45° FOV) × 2 (rotation velocity: 20°/s, 40°/s) × 2 (turning direction) within-subject factorial design with two repetitions per condition. In terms of our current purpose of discussing the relation between presence and vection, the comparison between the globally consistent and the most moderate scrambling level (2 slices/mosaics per 45° FOV) is the most critical, and we will constrain our discussion to those conditions (i.e., we omit the 8 & 32 slices/mosaics condition and the 40°/s conditions, which are discussed in detail in Riecke et al. 2006a). Presence was measured for each visual stimulus using the 14-item Igroup Presence Questionnaire (IPQ, Schubert et al. 2001) after the vection experiments.

9.4.3 Results and Discussion

As indicated in Figs. 9.3 and 9.4, global scene consistency played the dominant role in facilitating vection and presence, and any global inconsistency reduced vection as well as spatial presence and involvement consistently. As discussed in detail in (Riecke et al. 2006a), this result cannot be convincingly explained on the basis of bottom-up factors alone, as the physical stimulus parameters and images statistics were hardly affected by the scene scrambling. In fact, the mosaic-like scrambling (condition B) introduced additional vertical high-contrast edges and thus higher spatial frequencies – both of which are bottom-up factors that would, if anything, be expected to *enhance* the perceived stimulus speed (Distler 2003) and vection (Dichgans and Brandt 1978). Nevertheless, vection ratings were identical to the horizontally sliced stimuli (condition b) that lacked these additional high-contrast vertical edges. Together, these results support the notion that cognitive and top-down factors like the global consistency of the pictorial depth and scene layout might have caused the increased self-motion sensation, and that spatial presence and involvement (which were arguably directly manipulated by the scene scrambling) might have mediated this effect.

9.4.4 Experiment 2 – Unobtrusive Modifications of a Projection Screen Can Facilitate Both Vection and Presence

Results from Experiment 1 suggest that spatial presence might have mediated the increase in vection observed for the globally consistent stimuli. It is, however, also feasible that vection might conversely be able to mediate an increase in spatial presence. In fact, Experiment 2 seems to suggest just that (Riecke et al. 2004; Riecke and Schulte-Pelkum 2006): The experimental stimuli and procedures were identical to Experiment 1 described above, apart from the fact that subtle marks (scratches) were added to the periphery of the projection screen (upper left corner, as illustrated in Fig. 9.2). Ten new participants were used in this study. The motivation for this experiment stemmed from pilot experiments that revealed a strong, unexpected vection-enhancing effect when the screen was accidentally scratched.

As can be seen in Figs. 9.3 and 9.4, Experiment 2 showed a similar benefit of the globally consistent stimulus for both vection and presence. The comparison between the clean screen (Exp. 1) and marked screen (Exp. 2), however, showed a considerable and highly significant vection-facilitating effect of the subtle marks on the screen for all dependent measures (see Fig. 9.3 and Table 9.1). The marks reduced vection onset time by more than a factor of two, and vection intensity and convincingness ratings were raised to almost ceiling level. Moreover, even spatial presence and involvement were unexpectedly increased by a significant amount. Note that the marks enhanced presence and vection even though only 10 % (i.e., 1 out of 10) of the participants were able to report that they had noticed these marks in a post-experimental interview.

Note that different participant populations were used for Experiment 1 and 2, and systematic differences in the participant populations might have contributed to the observed facilitating effect of the marks on the screen. Nevertheless, given that the results proved highly significant (see Table 9.1), and the magnitude of the effect was relatively large (see Figs. 9.3 and 9.4), this suggests that the observed facilitation of vection and presence by the added marks is unlikely to be merely an artefact.

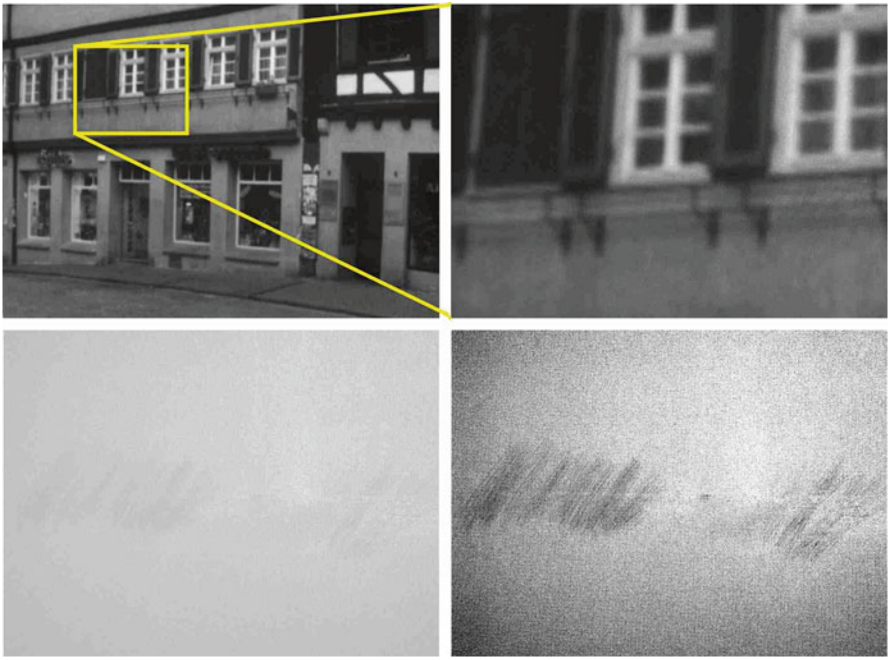

Fig. 9.2 *Top left*: View of the projection screen displaying the market scene. The marks are located at the upper-left part of the screen, as illustrated by the close-ups to the right and below. *Bottom*: Close-up of the same region as above (right), but illuminated with plain white light to illustrate the marks. *Left*: The original photograph demonstrating the unobtrusive nature of the marks (diagonal scratches). *Right*: Contrast-enhanced version of the same image to illustrate the marks (Image reprinted from Riecke et al. (2004, 2005c) with permission)

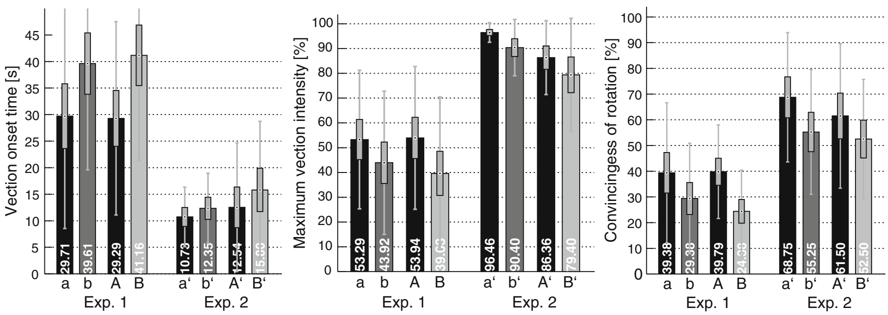

Fig. 9.3 Mean of the three vection measures for the clean screen (Experiment 1) and the marked screen (Experiment 2), each plotted for the globally consistent stimuli (*a*, *A*, *a'*, *A'*) and the sliced (*b*, *b'*) and scrambled (*B*, *B'*) stimuli. Boxes and whiskers depict one standard error of the mean and one standard deviation, respectively. Note the strong vection-facilitating effect of the additional marks on the screen (Exp. 2) for all measures

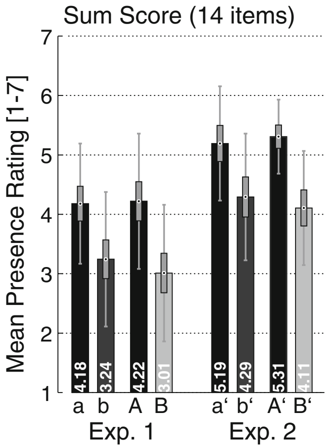

Fig. 9.4 Mean presence ratings for the clean screen (Experiment 1) and the marked screen (Experiment 2), each plotted for the globally consistent stimuli (*a, A, a', A'*) and the sliced (*b, b'*) and scrambled (*B, B'*) stimuli. Note also the consistently higher presence ratings for globally consistent stimuli and the marked screen

Table 9.1 ANOVA table for Experiment 1 & 2

	Vection onset time		Convincingness of vection		Vection intensity		Presence sum score	
	F(1,20)	p	F(1,20)	p	F(1,20)	p	F(1,20)	p
Globally consistent vs. inconsistent	6.63	.018*	24.8	<.0005***	12.3	.002**	41.7	<.0005***
Horizontally slices vs. mosaic-like scrambled	0.562	.46	0.797	.38	2.07	.17	0.159	.7
Clean vs. marked projection screen	13.8	.001**	9.38	.006**	21.3	<.0005***	9.13	.007**

*p < .05, **p < .01, ***p < .001
Table of ANOVA results for all four dependent variables of Experiment 1 & 2. The natural, intact scene ("globally consistent") induces higher vection and presence, and no difference is found between the two degraded stimuli (sliced vs. scrambled). For the screen with the marks (Experiment 2), all vection and presence ratings are higher than in Experiment 1 with the clean screen. Note that the first two factors are within-subject factors, whereas the third factor is a between-subject factor

9.4.5 Correlations Between Presence Factors and Vection Measures

To investigate the structure and constituting elements of presence, a factor analysis was performed for the IPQ presence questionnaire data of Experiments 1 & 2. First, separate analyses were performed for both experiments. Subsequently, data from both experiments were pooled, since the patterns of results were very similar.

In all three analyses, a two-dimensional structure of presence was revealed: Factor 1 contained items about realism of the simulated scene and spatial presence (e.g., sense of being in the virtual environment), while factor 2 contained items that addressed attentional aspects or involvement (e.g., awareness of real surroundings of the simulator vs. the simulated environment). It is noteworthy that presence in the current study showed a structure similar to the one observed in Schubert and co-workers' original study (Schubert et al. 2001), even though the current study used only 22 participants, and there was not really much interactivity involved in our experiments: As soon as participants pressed a button, the visual scene started to rotate, and after a fixed time, the motion stopped automatically. Apart from that, there was no perceivable consequence of any of the participants' actions. One small difference between the Schubert et al. (2001) and the current study is that for the latter, realism and spatial presence were subsumed in one factor (named "spatial presence" here for convenience) and not in two separate factors.

In order to investigate how the different aspects of presence related to different aspects of self-motion perception, separate correlation analyses were performed between factor 1 (interpreted as "spatial presence") and factor 2 ("involvement") of the presence questionnaire and the three vection measures onset time, intensity, and convincingness for Experiment 1 & 2. The resulting paired-samples correlations (r) and the corresponding p-values are summarized in Table 9.2.

To ensure higher statistical power and better interpretability of the correlations, the data of the 22 participants of two experiments were in addition pooled, and the same analyses were performed as before (see Table 9.2, bottom row). This is a valid method since the stimuli and procedures were exactly identical; the only difference was the presence or absence of subtle marks on the projection screens. The results for the pooled data are qualitatively similar to the two separate analyses, but they show a clearer pattern now, as was expected from the larger sample size:

While the online measures of vection onset time (and to some degree also vection intensity) were more closely related to the involvement/attention aspect of overall presence (factor 2, as assessed using the IPQ), the subjective convincingness ratings that followed each trial were more tightly related to the spatial presence

Table 9.2 Correlations between vection and presence measures

		Factor 1 (spatial presence)			Factor 2 (involvement)		
		Vection onset time	Convincingness of vection	Vection intensity	Vection onset time	Convincingness of vection	Vection intensity
Experiment 1 (N = 12)	r	.041	**.579***	−.229	**−.620***	.307	.469
	p	.90	**.049**	.474	**.031**	.332	.124
Experiment 2 (N = 10)	r	.015	.479	**.673***	.629	.306	.535
	p	.970	.192	**.049**	.070	.424	.138
Exp. 1 & 2 pooled (N = 22)	r	−.259	**.630***	.232	**−.710****	**.473***	**.616****
	p	.257	**.002**	.311	**<.001**	**.030**	**.003**

*p < .05, **p < .01, ***p < .001
Bold numbers indicate significant effects (p < .05)
Paired-samples correlations for Experiment 1, Experiment 2, and the pooled data from Experiments 1 & 2. Correlations were computed between all three vection measures (vection onset time, convincingness, and vection intensity) and the factor values of the two presence factors

aspects of overall presence (factor 1). It should be pointed out that given the small sample size (N = 10, 12, or 22 (pooled data)), these correlations are quite substantial. This asymmetry between spatial presence and attention/involvement should be taken into consideration when attempting to improve VR simulations. Depending on task requirements, different aspects of presence might be relevant and should receive more attention or simulation effort – we will elaborate on this topic below.

9.5 Discussion: A Direct Link Between Presence and Vection?

In the previous section, we presented results from two experiments that suggest that not only low-level, but also higher-level factors such as spatial presence and the interpretation of the stimulus might have an influence on vection. Notably, different dimensions of presence correlated differentially with different aspects of vection: While spatial presence seems to be closely related to the convincingness of the rotation illusion, involvement and attentional aspects in the simulation were more closely related to the onset time and intensity of the illusion. Previous studies that failed to reveal such connections had used only rather coarse methods (Freeman et al. 2000; IJsselsteijn et al. 2001). In the following, we will discuss how low-level as well as higher-level effects might have contributed to produce these results.

9.5.1 Low-Level vs. Higher-Level Influences in Experiment 1 & 2

In past vection research, self-motion illusions were typically induced using abstract stimuli like black and white geometric patterns. Here, we showed that the illusion can be enhanced if a natural scene is used instead: Experiment 1 & 2 revealed that a visual stimulus depicting a natural, globally consistent scene can produce faster, stronger, and more convincing sensation of illusory self-motion than more abstract, sliced or scrambled versions of the same stimulus. There are a number of possible low-level and high-level mechanisms that might have contributed to this effect, as we will discuss in more detail below. Figure 9.5 provides a schematic overview of these different proposed influences and underling mechanisms.

9.5.1.1 Number of Vertical High-Contrast Edges

There are at least two bottom-up factors that would predict an increase in vection for the mosaic-like scrambled stimuli, compared to the intact and sliced stimuli. First, adding vertical high-contrast edges is known to enhance vection (Dichgans and

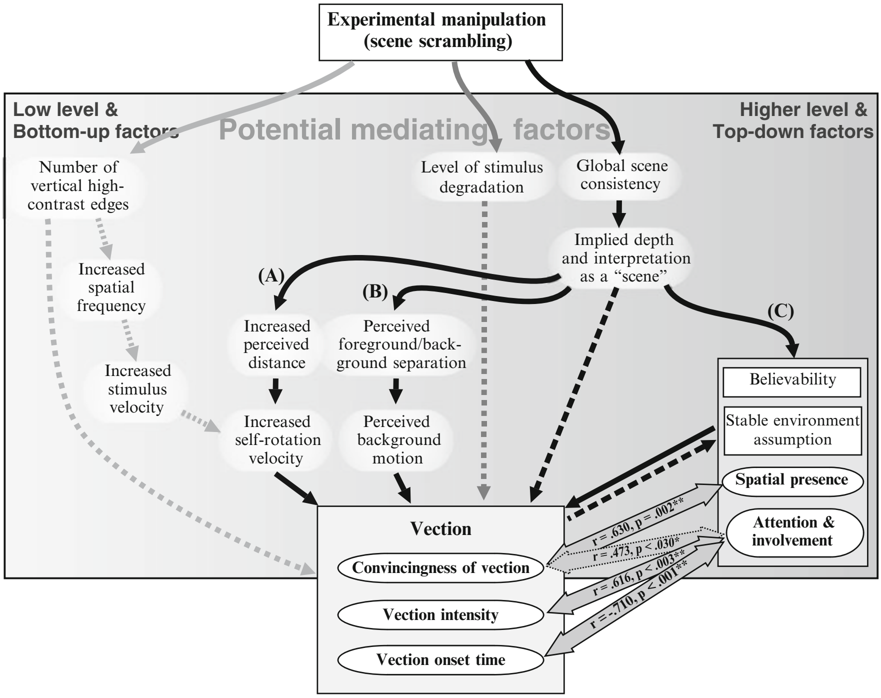

Fig. 9.5 Schematic illustration of the different mechanisms and mediating factors that might have contributed to the systematic effect of scene scrambling on vection and presence in Experiment 1 & 2 (Riecke et al. 2004, 2006a). These hypothesized mechanisms range from lower-level and bottom-up factors (*left side* of figure) to more cognitive and higher-level factors (*right*). *Solid black arrows* indicate pathways that are most likely and consistent with the current data, whereas *dashed and dotted arrows* indicate pathways that are less and least probable/supported by the current data, respectively. Presence and vection measures are depicted as *oval framed boxes*, and the *grey double-sided connecting arrows* depict significant correlations between presence and vection measures. Results from the scene scrambling in both experiments suggest that vection might at least in part be mediated by higher-level and/or top-down mechanism like pictorial depth cues, global scene consistency, or presence. The factor "level of stimulus degradation" was not presented in the current analysis in this chapter, see Riecke et al. (2006a) for a more detailed discussion (Figure adapted from Riecke et al. (2006a))

Brandt 1978). Second, these additional high-contrast vertical edges increase the contrast and spatial frequency of a moving stimulus, which has been shown to result in higher perceived stimulus velocities (Distler 2003). As higher rotational velocities induce vection more easily than slower velocities for the current setup and stimuli (Riecke et al. 2006a; Schulte-Pelkum et al. 2003), one would predict that the mosaics should improve vection as compared to the horizontal slices or intact stimulus. The results of Experiment 1 & 2 showed, however, no such vection-facilitating effect of the additional vertical edges at all. Instead, adding the vertical high contrast edges actually *reduced* vection, compared to the intact stimulus. This is illustrated by the left pathway in Fig. 9.5. This suggests that the data cannot be convincingly explained by low-level, bottom-up processes alone, and that the bottom-up contributions (more vertical contrast edges in the mosaic-like scrambled stimulus) were dominated by cognitive and top-down processes (consistent reference frame for the intact market scene). This is corroborated by the fact that the additional vertical contrast edges in the mosaic-like scrambled stimulus did not increase vection compared to the horizontally sliced stimulus (which did not have any more vertical contrast edges than the intact stimulus).

In the following, we will discuss three possible cognitive or higher-level mechanisms that might have contributed to the vection-enhancing effect of the globally consistent stimulus. These different mechanisms are visualized in Fig. 9.5 as different pathways labelled (A), (B), and (C). Note, however, that the current studies were not designed to disambiguate between those different mechanisms, and future experiments would be needed to tackle this issue.

9.5.1.2 Pathway (A): Increase in Perceived Depth and Perceived Self-Motion Velocity

Wist and colleagues demonstrated that the perceived velocity of circular vection (which is often used as a measure of vection intensity) depends not only on the angular velocity of the stimulus as one might expect, but also on the perceived distance of the stimulus (Wist et al. 1975). In a carefully designed study, they systematically manipulated the perceived distance of the vection-inducing stimulus using different methodologies (Pulfrich effect or accommodative and fusional convergence), and observed a linear increase of perceived self-motion velocity with increasing perceived distance.

Even though none of these depth cues were employed in the current experiment, the unscrambled stimulus contained an abundance of globally consistent pictorial depth cues (e.g., relative and absolute size, occlusion, texture gradients, and linear perspective) that might have increased its perceived distance. The scrambled stimuli, however, contained hardly any consistent pictorial depth cues and were thus more likely to be perceived as a 2D-surface at the distance of the projection screen. In fact, some participants mentioned in post-experimental interviews that the scrambled stimuli looked a bit like flat wallpaper. Thus, one might argue that the pictorial depth cues present in the globally consistent stimulus might have been sufficient to increase the perceived distance and thus indirectly increase perceived vection velocity – which is in turn associated with enhanced vection for the stimuli in Experiment 1 & 2 (Riecke et al. 2004, 2006a). This hypothesis is illustrated as pathway (A) in Fig. 9.5. Further studies that explicitly measure vection, perceived distance, and perceived velocity would be required, though, to test this hypothesis.

9.5.1.3 Pathway (B): Perceived Foreground-Background Separation and Perceived Background Motion

As discussed in Sect. 9.2.2 above, not only absolute perceived distance of the vection-inducing stimulus, but also the perceived foreground-background separation can affect vection: When the vection-inducing stimulus consists of several parts (superimposed or spatially separated), vection seems to be dominated by the one that is *perceived* to be further away – even in cases when it is, in fact, physically closer (Howard and Heckmann 1989; Ohmi et al. 1987; Seno et al. 2009).

This opens up another possibility about how scene scrambling might have affected vection: The globally consistent scene structure and depth cues of the intact stimulus might have resulted in a *perceived* foreground-background separation between the projection screen and surrounding setup (both being perceived as foreground) and the projected globally consistent stimulus (being perceived as further away and thus as a background). Consequently, the globally consistent stimulus motion might have been perceived as background motion and thus indirectly facilitated vection, even though there was no physical depth separation between the projection screen and the moving visual stimulus (cf. pathway (B) in Fig. 9.5). Hence, presentation of a natural, globally consistent scene that contains an abundance of pictorial depth cues might be sufficient to yield a perceived foreground-background capable of enhancing illusory self-motion perception. This would have interesting implications both for our basic understanding of self-motion perception and for self-motion simulation applications (see also discussion in Riecke and Schulte-Pelkum 2013; Seno et al. 2009).

9.5.1.4 Pathway (C): Presence and the Assumption of a Stable Reference Frame

Results from the presence questionnaires show that the natural, globally consistent scene was not only associated with enhanced vection, but also with higher presence ratings than any of the sliced or scrambled stimuli. Together with the consistent correlations between vection and presence ratings, this raises the possibility that presence and vection might be directly linked. That is, we propose that the globally consistent, naturalistic scene might have afforded (i.e., implied the possibility of) movement through the scene and allowed for higher believability and presence in the simulated environment. Thus, the natural scene could have provided observers with a more convincing, stable reference frame with respect to which motions are being judged more easily as self-motions instead of object or image motions. The proposed mediating influence of presence for the self-motion illusion is in agreement with the "presence hypothesis" proposed by Prothero, which states that "the sense of presence in the environment reflects the degree to which that environment influences the selected rest frame" (Prothero 1998). This is illustrated as pathway (C) in Fig. 9.5. Even though this study showed a clear correlation between vection and presence, further research is needed to determine if there is actually a *causal* relation between presence and vection. Most importantly, the discussion of Experiments 1 & 2 in Sect. 9.5.1 suggests that higher-level, top-down factors do, in fact, play a considerable role in self-motion perception and thus deserve more attention both in motion simulation applications and in fundamental research, where they have received only little attention until recently – see, however, noteworthy exceptions mentioned in Sect. 9.2.7 and Riecke (2009, 2011).

9.5.2 Origin of Vection- and Presence-Enhancing Effect of Adding Marks to the Projection Screen

When comparing Experiment 1 and Experiment 2, both vection and presence clearly benefited from using a projection screen that contained additional minor marks (scratches) in the periphery, but was otherwise of the identical size, material, and reflection properties. Note that this effect occurred consistently across all dependent measures. So how might this rather surprising effect be explained?

It is known from the vection literature that the visually induced self-motion illusion can be enhanced rather easily by asking participants to fixate on a stationary object while observing the moving stimulus (Becker et al. 2002; Brandt et al. 1973). This effect can be further increased if the visual stimulus is perceived as being stationary *in front* of a moving background stimulus (Howard and Heckmann 1989; Nakamura and Shimojo 1999), whereas stationary objects that appear to be *behind* the moving objects tend to impair vection (Howard and Howard 1994). Note that observers in these studies were asked to explicitly fixate and focus on those targets. The observed vection-facilitating effect of a static fixation has been attributed to an increased relative motion on the retina. The novel finding from the comparison of Experiment 1 and 2 is that a similar effect can also occur even if the stationary objects (or marks) are not fixated and are hardly noticeable – only one participant was, in fact, able to report having noticed the marks. Note that observers in our study were instructed to view the stimulus in a normal and relaxed manner, without trying to suppress the optokinetic reflex (OKR) by, e.g., staring through the screen or fixating on a static point. Furthermore, there was no physical foreground-background separation between the static marks on the screen and the moving scene (Nakamura and Shimojo 1999). Hence, these low-level factors cannot account for the observed vection-enhancing effect.

Nevertheless, the vection-facilitating effect of the marks was quite obvious and the effect size was comparable to that of an explicit fixation point in traditional studies using full-field stimulation in an optokinetic drum: Becker et al. reported for example a decrease of vection onset latencies from 30s without fixation to 10s with fixation at a rotational velocity of 30°/s (Becker et al. 2002).

From the current data, we can only speculate about the underlying processes that could explain the vection-enhancing effect of the marks in our study. We propose

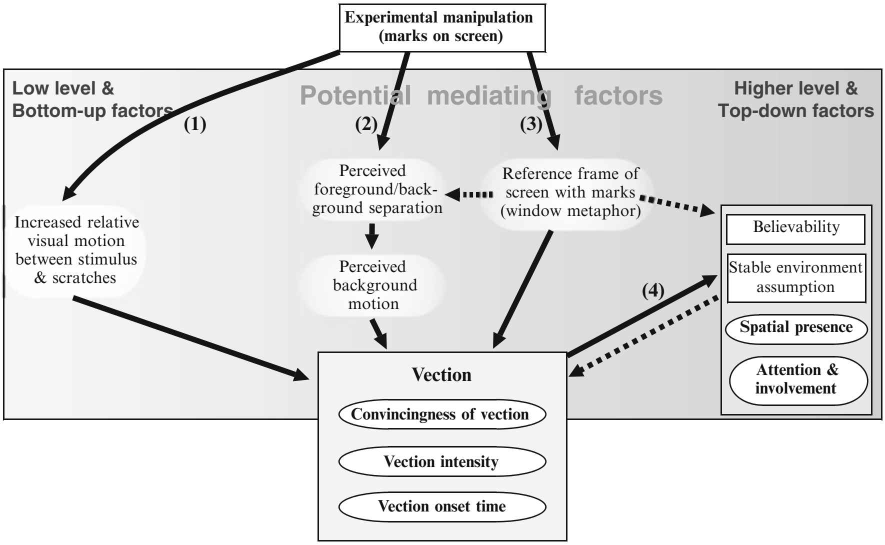

Fig. 9.6 Schematic representation of the proposed mechanisms about how the experimental manipulation of adding marks to the screen might have affected vection and presence. *Solid black arrows* indicate pathways that seem likely and are consistent with the current data, whereas *dotted arrows* indicate more tentative lines of logic. The comparison of the two experiments suggests that the experimental manipulation of adding marks to the screen (*top* of the graph) might have indirectly affected spatial presence and involvement, in the sense that the enhancement of vection might have mediated or indirectly caused the observed increase in spatial presence. The marks are proposed to have facilitated vection via three potential pathways, labelled (*1*) – (*3*): First, they increased the relative visual motion between the moving stimulus and the stationary marks; Second, the marks might have fostered a perceptual foreground/background separation, such that the moving stimulus is more likely to interpreted as background motion, which is known to facilitate vection; Third, the marks might have provided a stable reference frame with respect to which visual motion might be more easily interpreted as self-motion than stimulus motion

three mechanisms that might have contributed (see Fig. 9.6, pathways (1) – (3)): First, adding the marks increased the relative visual motion between the moving stimulus and the stationary screen and marks, which might have facilitated vection as illustrated in pathway (1). Second, even though there was no physical depth separation whatsoever between the marks on the screen and the visual motion stimulus presented on the same screen, there might have been a perceptual foreground-background separation that might have facilitated vection, as depicted in pathway (2). That is, participants might somehow have attributed the marks to the foreground, similar to stains on a cockpit window, and the projected stimuli as moving with respect to that cockpit in the background, much like in an actual vehicle. The pictorial depth cues present in the intact or mildly scrambled stimuli might have supported this percept, as the displayed scene suggested a distance of several meters from the observer. This perceived background motion might have facilitated vection (Howard and Heckmann 1989; Nakamura and Shimojo 1999; Seno et al. 2009).

Third, the marks might have provided some kind of subtle stationary reference frame with respect to which the moving stimulus is being perceived (pathway (3)). A related study by Lowther and Ware demonstrated a similar vection-facilitating effect when using a stable foreground stimulus (Lowther and Ware 1996). Instead of using a subtle modification as in the current study, however, Lowther and Ware overlaid a clearly visible rectangular 5×5 grid onto a large flat projection screen that was used to present the moving stimuli in a VR setup. Nevertheless, the marks in the current study that were hardly noticed showed a vection-facilitating effect that was even stronger than for Lowther and Ware's clearly visible grid that extended over the whole screen. Obviously, further investigations are required to test the proposed explanation that the marks on the screen might provide some kind of subtle foreground reference frame that influences self-motion perception. If our hypothesis were true, it would have important implications for the design of convincing self-motion simulators, especially if participants would not have to be aware of the manipulation.

For most applications, it is neither desired nor feasible to restrict users' eye and head movements unnaturally. Hence, the current study could be exploited for self-motion simulations by including for example dirt or stains onto the real or simulated windshield of a vehicle cockpit – a minor, ecologically plausible manipulation that might also increase the perceived realism of the simulation. The current data would predict that such a simple measure might increase the convincingness and strength of self-motion perception without imposing unnatural constraints on the user's behaviour. The effect could probably be further enhanced by including stereoscopic depth cues that support the foreground/background separation between the cockpit/windshield and the outside scene (Howard and Heckmann 1989; Lowther and Ware 1996; Nakamura and Shimojo 1999; Seno et al. 2009).

In addition to the vection-facilitating effects, the minor scratches on the screen also clearly enhanced presence, which we had not at all predicted. In fact, we are not aware of any theoretical reason why simply adding scratches to the screen should *directly* increase presence or involvement in the simulation. Instead, one might expect a presence decline because of the degradation of the simulation fidelity due to the scratches. Nevertheless, adding the marks to the screen did significantly increase spatial presence and even involvement. Furthermore, observers who experienced stronger vection with the scratches on the screen reported also significantly higher presence. We posit that this effect might be attributed to the dynamical component of the visual stimulus, in the sense that the increase in the self-motion illusion might have indirectly caused or mediated the increase in presence and involvement. This hypothesis is illustrated in Fig. 9.6, pathway (4). If this were true, it would mean that an increased sensation of vection might also increase presence in VR. In fact, a similar finding was reported by Slater et al. (1998): As already mentioned in Sect. 9.3.2, they had found that observers who moved more in the VE reported higher presence. In the current study, however, observers experienced *passive* self-motion, similar to traveling in a vehicle and not self-generated motion by locomotion.

9.6 Conclusions and Conceptual Framework

In conclusion, the current experiments and the above literature review support the notion that cognitive or top-down mechanisms like spatial presence, the cognitive-perceptual framework of movability, as well as the interpretation of a stimulus as stable and/or belonging to the perceptual background, do all affect self-motion illusions, a phenomenon that was traditionally believed to be mainly bottom-up driven, as discussed in detail in Riecke and Schulte-Pelkum (2013). Riecke (2009, 2011), and Schulte-Pelkum (2007). This adds to the small but growing body of literature that suggests cognitive or top-down contributions to vection, as discussed in Sect. 9.2.7. Furthermore, the comparison of Experiment 1 and 2 suggests that presence might also be mediated by the amount of perceived self-motion in the simulated scene. Thus, it appears as if vection and presence might be able to mutually affect or support each other. While still speculative, this would be important not only for our theoretical understanding of self-motion perception, presence, and other higher-level phenomena, but also from an applied perspective of affordable yet effective self-motion simulation. In the following, we would like to broaden our perspective by trying to embed the current hypotheses and results into a more comprehensive tentative framework. This conceptual framework is sketched in Fig. 9.7 and will be elaborated upon in more detail below. It is meant not as a "true" theoretical model but as a tentative framework to support discussion and reasoning about these concepts and their potential interrelations.

Any application of VR, be it more research-oriented or application-oriented, is typically driven by a more or less clearly defined goal. In our framework, this is conceptualized as the "***effectiveness concerning a specific goal or application***" (Fig. 9.7, bottom box). Possible examples include the effectiveness of a specific pilot training program in VR, which includes how well knowledge obtained in the simulator transfers to corresponding real world situations, or the degree to which a given VR hardware and software can be used as an effective research tool that provides ecologically valid stimulation of the different senses.

So how can a given goal be approached and the goal/application-specific effectiveness be better understood and increased? There are typically a large number of potential contributing factors, which span the whole range from perceptual to cognitive aspects (see Fig. 9.7, top box). Potentially contributing factors include straightforward technical factors like the FOV and update rate of a given VR setup (which are typically low-level, bottom-up factors), the quality of the sensory stimulation with respect to the different individual modalities and their cross-modal consistency (which may have both a low- and higher-level component), and task-specific factors like the cognitive load or the users' instructions (which are often higher-level, top-down and thus more cognitive factors).

All of these factors might have an effect on both our perception and our action/behaviour in the VE. Here, we propose a framework where the different factors are

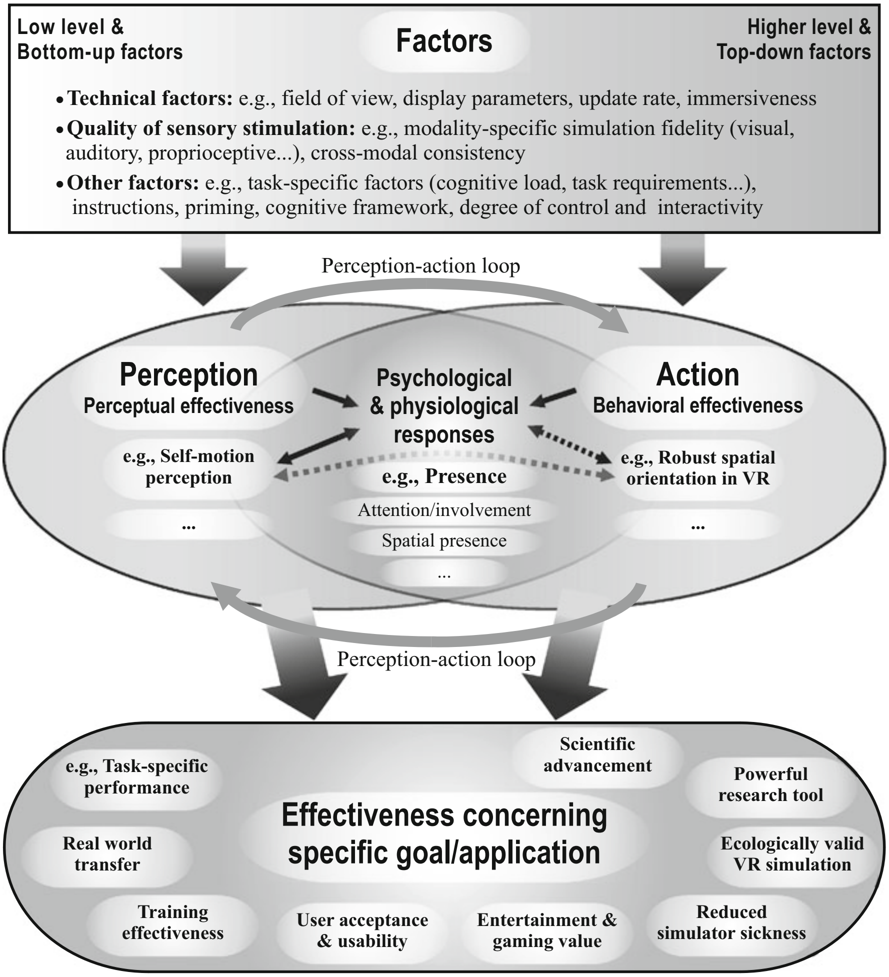

Fig. 9.7 Tentative conceptual framework that sketches how different factors that can be manipulated for a given VR/research application (*top box*) might affect the overall effectiveness with respect to a specific goal or application (*bottom box*). Critically, we posit that the factors affect the overall goal not (only) directly, but also mediated by the degree to which they support both the perceptual effectiveness and behavioural effectiveness and the resulting perception-action loop (*middle box*). There are a number of physiological responses (e.g., fear or pleasure) and psychological responses (e.g., higher-level emergent phenomena like spatial presence or involvement) that can potentially both affect and be affected by the users' perception and action

considered in the context of both their ***perceptual effectiveness*** (e.g., how they contribute to the perceived self-motion) and their ***behavioural effectiveness*** (e.g., how they contribute by empowering the user to perform a specific behaviour like robust and effortless spatial orientation and navigation in VR), as sketched in Fig. 9.7, middle box.

Perception and action are interconnected via the ***perception-action loop***, such that our actions in the environment will also change the input to our senses. State-of-the art VR and human-computer interface technology offer the possibility to provide highly realistic multi-modal stimuli in a closed perception-action loop, and the different contributing factors summarized in the top box of Fig. 9.7 could be evaluated in terms of the degree to which they support an effective perception-action loop (Ernst and Bülthoff 2004).

Apart from the perceptual and behavioural effectiveness, we propose that psychological and physiological responses might also play an important role. Such responses could be emergent and higher-level phenomena like spatial presence, immersion, enjoyment, engagement, or involvement in the VE, but also other psychological responses like fear, stress, or pleasure on the one hand and physiological responses like increased heart rate or adrenalin level on the other hand. In the current framework, we propose that such psychological and physiological responses are not only affected by the individual factors summarized in the top box in Fig. 9.7, but also by our perception and our actions themselves. Slater et al. (1998) demonstrated, for example, that increased body and head motions can result in an increased presence in the VE. The comparison between Experiment 1 and 2 suggests that presence might also be affected by the strength of the perceived self-motion illusion.

Conversely, certain psychological and physiological responses might also affect our perception and actions in the VE. Experiment 1 and 2 suggest, for example, that the degree of presence in the simulated scene might also affect self-motion perception. Our actions and behaviours in a VE might, however, also be affected by our psychological and physiological responses. Von der Heyde and Riecke proposed, for example, that spatial presence might be a necessary prerequisite for robust and effortless spatial orientation based on automatic spatial updating or certain obligatory behaviours like fear of height or fear of narrow enclosed spaces (von der Heyde and Riecke 2002; Riecke 2003).

In the context of presence, we have seen that different aspects of presence interrelate differentially to different perceptual aspects (see factor analysis and correlations in Sect. 9.4.5). Thus, it might be conceivable that different aspects of presence (e.g., involvement vs. spatial presence) also relate differentially to specific behavioural and task-specific aspects. In general, more fine-grained analyses seem to be necessary in order to reveal such connections between presence and other measures such as vection, as we were able to show in our analysis.

In summary, we posit that our understanding of the nature and usefulness of the cognitive factors and higher-level phenomena and constructs such as presence and immersion might benefit if they are embedded in a larger conceptual framework, and in particular analysed in terms of possible relations to perceptual and behavioural aspects as well as goal/application-specific effectiveness. Similar benefits are expected if other higher-level phenomena are analysed in more detail in the context of such a framework.

9.7 Outlook

A growing body of evidence suggests that there is a continuum of factors that influence the perceptual and behavioural effectiveness of VR simulations, ranging from perceptual, bottom-up factors to cognitive, top-down influences. To illustrate this, we reviewed recent evidence suggesting that self-motion illusions can be affected by a wide range of parameters including attention, viewing patterns, the perceived depth structure of the stimulus, perceived foreground/background distinction (even if there is no physical separation), cognitive-perceptual frameworks, ecological validity, as well as spatial presence and involvement. While some of the underlying research is still preliminary, findings are overall promising, and we propose that these issues should receive more attention both in basic research and applications.

These factors might turn out to be crucial especially in the context of VR applications and self-motion simulations, as they have the potential of offering an elegant and affordable way to optimize simulations in terms of perceptual and behavioural effectiveness. Compared to other means of increasing the convincingness and effectiveness of self-motion simulations like increasing the visual field of view, using a motion platform, or building an omni-directional treadmill, cognitive factors can often be manipulated rather easily and without much cost, such that they could be an important step towards a lean and elegant approach to effective self-motion simulation (Riecke et al. 2005c, e; Riecke and Schulte-Pelkum 2013; Riecke 2011). This is nicely demonstrated by many theme park rides, where a conducive cognitive-perceptual framework and expectations are set up already while users are standing in line (Nunez and Blake 2003; Nunez 2003). Although there is little published research on these priming phenomena in theme parks, they likely help to draw users more easily and effectively into the simulation and into anticipating and "believing" that they will actually be moving. Thus, we posit that an approach that is centred around the perceptual and behavioural effectiveness and not only the physical realism is important both for gaining a deeper understanding in basic research and for offering a lean and elegant way to improve a number of applications, especially in the advancing field of virtual reality simulations. This might ultimately allow us to come closer to fulfilling the promise of VR as a believable "window onto the simulated world". That is, a virtual reality that is readily accepted as an alternate "reality" that enables us to perceive, behave, and more specifically locomote and orient as easily and effectively as we do in our real environment.

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Chapter 10
Patterns of Place: An Integrated Approach for the Design and Evaluation of Real and Virtual Environments

Michael Smyth, David Benyon, Rod McCall, Shaleph O'Neill, and Fiona Carroll

Abstract This chapter describes an approach to the development of virtual representations of real places. The work was funded under the European Union's €20 m Future and Emerging Technologies theme of the 5th Framework Programme, "Presence". The aim of the project, called BENOGO, was to develop a novel technology based on real-time image-based rendering (IBR) for representing places in virtual environments. The specific focus of the work presented here concerned how to capture the essential features of real places, and how to represent that knowledge, so that the team developing the IBR-based virtual environments could produce an environment that was as realistic as possible. This involved the development and evaluation of a number of virtual environments and the evolution of two complementary techniques; the Place Probe and Patterns of place.

Keywords Place • Design • Evaluation • Real & Virtual

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10.1 Introduction

There are two main approaches to the generation of virtual representations of places. In the traditional approach images are generated from 3D models of objects and scenes. This approach uses a compact data representation and has the flexibility to generate any new view that may be required. Its main drawback is the reliance on the availability of models. Many objects (such as trees, hair and flowers) and many physical phenomena (such as shadows) are very hard to model and as a result, synthetic images generated from models often appear artificial and lack a sense of realism. Another approach to creating virtual places is called Image-Based-Rendering (IBR), (Shum et al. 2007). In one approach to IBR, a scene is photographed from many points of view, and new images are generated through complicated computations, re-sampling and interpolation of this image collection. The main advantage of this approach is the realistic nature of the images. The main drawbacks arise from the necessity to have in storage every possible point of view of every possible point in space. As a result the storage load of this approach is huge, and the image acquisition is very tedious. In the past these drawbacks have made IBR impractical for most applications (Shum et al. 2007).

During the BENOGO project significant advances were made in the techniques used for image collection and rendering. These advances meant that environments could be rapidly photographed and stitched together to provide photo-realistic scenes with effective stereoscopic characteristics. These were rendered in different arenas; a six-sided fully immersive CAVE, a panorama, or in a head mounted display (HMD). The head movements of a person viewing the scene in an arena were tracked and used to select the images presented to the person. This produced a very realistic effect that the person was in a particular location and could look around, fully 360°. However, where there were no photographic images, there were gaps in the rendering. For example, photographs taken with a fish-eye lens in a circle with a radius of 60 cm would allow the person to see almost 180° up and down and 360° around. They could move about within the 60 cm radius, but if they looked directly up or down the image was blank. The fish-eye lens also distorted the images in certain parts of the scene.

There were a variety of cameras used, employed in a variety of ways (rotated around a point, moved forward along a line and so on). These were rendered in different arenas (HMD, CAVE, etc.) using different algorithms that produced slightly different effects. The photo-realistic scenes could also be augmented with graphical images. This rich technology created one of the major challenges for the project. How should the different parts of the technological infrastructure be deployed to create what effects? For example, where should the camera be positioned to photograph a scene? If it is placed at 1 m high this might be suitable to create a realistic view for a child, if at 2 m it might be suitable for a tall person. If photographs were taken every 10 cm between 1 and 2 m it would allow the viewer of the scene to move up and down, and could accommodate both child and adult views, but it would mean capturing and rendering in real time ten times as many images where each image requires several tens of megabytes of storage.

Our role in the project was to design for a high quality user experience (UX). Our approach to deliver the best UX consisted of two parts. The first focused on understanding the essential characteristics of a place. We wanted to find what gave a place its 'sense of place'. This allowed us to compare any virtual representation of that place with descriptions and measures of the real place. It also allowed us to specify to the engineers and designers of the virtual environments which characteristics needed to be most realistic, and which were less important. The first part of this approach is known as the Place Probe, the second part consists of Patterns of Place.

In this chapter we will describe the specifics of this approach as applied in the BENOGO project. However, we also wish to recommend the general nature of the approach to understanding and representing sense of place. In Sect. 10.3 of the chapter we introduce the characteristics of The Place Probe. Details of how this instrument was designed are described in (Benyon et al. 2006). The Place Probe was to inform the design of future virtual environments through the development of Patterns of Place. Based on the application of the probe a series of patterns were abstracted and categorised into three broad categories: physical properties; affect and meaning; and activities associated with place. The rationale for choosing these categories, along with illustrations of the patterns and how they can be applied are described in Sect. 10.4. These categories constitute the sense of presence in a particular place (Lombard and Ditton 1997; Benyon 2012; Riva et al. 2011). Technological patterns specific to the IBR approach adopted within the BENOGO project were also developed. Together the technological patterns and the place patterns form the basis of a nascent "Pattern Book" aimed at connecting the case based approach to the measurement of sense of presence to the design of virtual environments. In order to frame the discussion, Sect. 10.2 provides a brief background to presence and place from a human-computer interaction perspective. Section 10.5 concludes the chapter with a look forward to how the approach may be further developed and generalised.

10.2 A Human Computer Interaction Based Approach to Sense of Presence

Over the years, a variety of tools and techniques for the measurement of sense of presence have been developed. The Immersive Tendencies Questionnaire (ITQ) was developed to identify real world tendencies (e.g. using computer games) that may affect a person's sense of presence, (Witmer and Singer 1998). The ITC-SOPI was developed for the UK's Independent Television Commission. It is a cross-media questionnaire that explores spatial presence, levels of engagement, sense of naturalness and negative aspects that effect presence (Lessiter et al. 2000). The MEC questionnaire (Vorderer et al. 2004) was developed as part of the Presence initiative. It focuses on spatial presence.

These approaches have been primarily quantitative and designed to be applied *post hoc* to developed environments. Whilst such measures might be useful in some circumstances, there is little evidence to suggest how such measurements will inform the design of future environments. In contrast, an enduring belief of Human Computer Interaction (HCI) practitioners is the intimate relationship between the generation of requirements for future systems and the subsequent criteria for evaluation of those systems (e.g., Benyon 2013). Requirements and evaluation are two sides of the same coin. One goal of our work, then, was to reconnect the measurement of presence to the articulation of requirements for the design and development of virtual environments, to their evaluation and re-design.

Another key feature of our approach from the HCI perspective is that we reject a traditional cognitive view of presence and instead adopt a conceptual framework based on the concept of embodied interaction (or embodiment). Embodiment is a development of the phenomenological school of philosophy developed by Edmund Husserl at the turn of the Nineteenth century and used, changed and expanded by philosophers such as Heidegger, Merleau-Ponty and more recently Dourish (2001). For Husserl, an individual's experience was the experience of *something*. By focusing attention on the act of this 'experiencing of' rather than on the thing being experienced or the person who was having the experience, he aimed to produce a new kind of knowledge that could account for things beyond the reach of science. Heidegger introduced 'Beings', entities which exist in the world and are able to reason about Being. Continuing in the phenomenologist tradition, Merleau-Ponty's account of 'being-in-the-world' emphasises the importance of the body. He places the body at the centre of our relation to the world and argues that it is only through having bodies that we can truly experience space.

In *Where the Action Is* Paul Dourish develops his ideas on the foundations of embodied interaction (Dourish 2001). The embodied interaction perspective considers interaction 'with the things themselves'. For Dourish, phenomenology is about the tight coupling of action and meaning. Actions take on meaning for people. Coupling is concerned with making the relationship between actions and meaning effective. If objects and relationships are coupled then effects of actions can be passed through the system. Dourish uses the familiar example of a hammer (also used by Heidegger) to illustrate coupling. When you use a hammer it becomes an extension to your arm (it is coupled) and you act through the hammer onto the nail. You are engaged in the activity of hammering.

These ideas are important to a study of presence. If you feel present, you are unaware of any mediating technology: indeed presence has been defined as the illusion of non-mediation (Lombard and Ditton 1997). A sense of presence may be true of some communication technology such as a phone or video screen that really makes you feel that you are dealing directly with other people (called social presence). Alternatively it may be that you are able to operate a remote vehicle with all the accuracy as if you were there and with the full range of tactile, auditory, olfactory and other feedback that being in the real place would allow. Designing for presence is about designing the illusion of non-mediation. When you put on a head mounted display you are immediately transported into the computed world beyond the headset. You are not aware that there are two tiny displays sitting close to your eyes; that part of the interaction is apparently unmediated.

But presence is nothing if it is not about place (Turner and Turner 2006). Presence is the sense of non-mediation; it is the sense of 'being there'. The Heideggerian phenomenology of being leads us to understand that 'to be' is to be *somewhere*. Being is' being-in-the-world', or *dasein* as Heidegger called it. Presence is inherently commingled with place. This view of presence and our project's interest in representing real places, lead us naturally to investigate the philosophy of place.

Sense of place has been considered extensively in environmental psychology, sociology, geography, literary and media theory. Relph's (1976) monograph takes an explicitly phenomenological and holistic stance towards appreciating places. He defines three components of 'place identity': physical setting; activities afforded by the place; meanings and affect attributed to the place. Relph's model of place provides us with the basic framework within which we developed the Place Probe and subsequently the Patters of Place. However we also explored the idea of place from the perspective of Gustafson's conceptualization (Gustafson 2001). He draws on empirical work in the form of an interview survey and builds on a review of earlier conceptualizations of place to identify three poles that can be used to understand places; self, environment and other people. Other accounts of space and place, notably the work of Edward Casey (e.g., Casey 1997), Y-F Tuan (1977), and Jorgensen and Stedman (2001) have also informed our work.

As a means of trying to better understand the criteria that contribute to sense of presence, a series of studies of real places were undertaken (McCall et al. 2004 Turner et al. 2003, 2005; Turner and Turner 2003; Smyth 2005). Figure 10.1 is an image from a photo realistic virtual representation of a glasshouse in the Prague botanical gardens. Participants experienced a 360° panorama of the interior of the glasshouse via a head-mounted display. Figure 10.2 is a series of images of the Jenck's Landform in Edinburgh that was a location for one of the early studies of place. Each of the studies formed the basis of the initial BENOGO demonstrators and critically shaped both the approach to the measurement of sense of presence in both real and virtual environments, but also the subsequent debate as to what constitutes presence and its relationship with place.

In their paper *Place, Sense of Place and Presence,* Turner and Turner (2006) provide a detailed consideration of both empirical and theoretical evidence for a phenomenological view of presence and place. They point to the need for a more complete understanding of place than is provided by the cognitive. Affective and conative aspects are clearly present in people's descriptions of places. They also identify the importance of semantic associations that people have with places and the importance of individual associations. Whilst they identify four components of place, these correspond to the activities, meanings and affect and physical characteristics identified by Relph (1976). They conclude by pointing out that presence

Fig. 10.1 An image captured from the Botanical Gardens in Prague (Turner et al. 2005)

Fig. 10.2 Series of images from the Jenck's Landform, Edinburgh (Smyth 2005)

and sense of place are first-person constructs, experienced by individuals, and they highlight the difficulty of creating virtual representations that capture the multi-sensory, impressionistic nature that characterises people's feelings about places.

Despite these inherent difficulties, we were faced with the demand to create virtual representations of real places that achieved a real sense of presence, or sense of place, for the people experiencing these environments. Our approach is to capture the essential features of places as best we can—through the Place Probe—and to represent our accumulating design knowledge as number of templates or, Patterns of Place.

10.3 The Place Probe

Probes are collections of stimuli and data gathering instruments to help in design. Cultural probes (Gaver et al. 1999) were used for the generation of rich data related to the context of use of technology. Technology probes (Westerlund et al. 2001) have been used to explore the use of technology in primarily domestic settings. Typically these probes contain a variety of instruments for data collection in order to give designers insights into the key issues that people find important in different contexts. The Place Probe was designed to enable the articulation of experiences at a specific time and place. We wanted to organise a number of complementary techniques into an easy to administer instrument that would allow us to understand the essential characteristics of a place.

The Place Probe was developed over a period of 3 years and involved a whole range of techniques that were tested, used, reviewed and discussed (Benyon et al. 2006). These were mostly qualitative techniques based on talk-aloud protocols, video, questionnaires and so on. The final version of the Place Probe is included in Appendix. It includes three sections. The first gathers impressions of the place using a number of techniques. The second part includes a number of semantic differentials that seek to distinguish the main characteristics of a place along pre-defined dimensions in a quick and intuitive way. Lawson (2001) uses a semantic differential to understand people's perceptions of place in a similar way. The final part of the Place Probe is a short version of the MEC spatial presence questionnaire (Vorderer et al. 2004).

As the Place Probe has evolved, the different components have been used in a variety of settings such as a real environmental architecture (Smyth 2005), a real botanical garden (O'Neill and Benyon 2003), a virtual environment representation of a botanical garden in an HMD (Turner, Turner, Carroll, O'Neill et al. 2003), a university stairwell rendered in an HMD, a city view of Prague rendered in an HMD (O'Neill et al. 2004), a virtual environment of the Technical Museum in Prague in both a fully immersive, six sided CAVE and HMD (McCall et al. 2005). The main contributing studies to the development of the Place Probe are summarized in Table 10.1.

During the studies of places we have identified specific elements that are experienced within each of the three categories of our model. For example, in our initial Place Probe study of the Prague Technical Museum people described it as bright and open and one felt close to objects. It was exciting, interesting and so on. This then amounts to our understanding of the experience of being in, being present in, the Technical Museum in Prague. This is the sense of place as approximated by the Place Probe.

Accordingly each of the three elements of the place model was given its own section in the semantic differential part of the Place Probe. The Activity differential includes ratings on the scales: passive-active, free-restricted, disorientated-oriented, inside-outside, mobile-immobile. The Physical differential focuses on characteristics of the space: small-big, empty-full, light-dark, enclosed-open, permanent-temporary, colorless-colorful, static-moving, responsive-inert, far-near, untouchable-touchable. The Affective/meaning differential is rated on the scales: ugly-beautiful, pleasant-unpleasant, stressful-relaxing, harmful-harmless, exciting-boring, interesting-uninteresting, memorable-forgettable, meaningful-meaningless, confusing-understandable, significant-insignificant.

Ratings on these dimensions can be used to inform the design of representations of the place (see Table 10.2). People's ratings on these differentials can be used to compare representations of the place with the real place or with another representation. For example in the studies of the viewpoint in Prague, ratings on the differential scales were consistently less pronounced in the virtual environment than in the real (Benyon et al. 2006). We took this to indicate that the experience of the virtual place was less engaging than the experience of the real place. A portion of this is shown in Table 10.2.

While we know that it is almost impossible to directly reproduce the exact experience of being in a real place, we also know that the BENOGO technology offers new opportunities to produce experiences that are as close to the real experience as we can make them. In developing the BENOGO technology what is important to understand is the aspects of the technology that affect the elements of the experience. In other words, how can we develop BENOGO technology towards the illusion of non-mediation.

Thus in the final version of the Place Probe we included a semantic differential specifically aimed at eliciting views on how effective the technology was and hence how aware people were of its mediating effect in the VE. Images are rated as: grainy-clear, realistic-unrealistic, unbelievable-believable, distorted-accurate. The

Table 10.1 Summary of the methods utilized within the BENOGO project

Location	Date	Mediating technology	Participants	Data analysis methods
Real study: Edinburgh Botanical Gardens	February 2003	Video Camera (subjects talked whilst videoing the scene).	4 male	Quantitative analysis of ITQ and SOPI questionnaires.
				Qualitative analysis and identification of reoccurring themes of talk aloud and structured interview data.
Virtual study: Prague Botanical Gardens	February 2003	Head Mounted Display	29–22 male, 7 female	Quantitative analysis of ITQ and SOPI questionnaires.
				Qualitative analysis and identification of reoccurring themes through video talk aloud and structured interviews.
Virtual study: Stairway at university in Prague	April 2003	Head Mounted Display	32–20 male, 12 female	Quantitative analysis of ITQ and SOPI questionnaires.
				Qualitative analysis of talk aloud, structured interviews and repertory grids.
Real study: Viewpoint in Prague	November/ December 2003	None	30–17 male, 13 female	Qualitative analysis and identification of reoccurring themes based on Gustafson's Place model, based on Place Probe version 1.
Virtual study: Viewpoint in Prague	March 2004	Head Mounted Display	30–17 male, 13 female	Qualitative analysis and identification of reoccurring themes based on Gustafson's Place model based on Place Probe version 1.
Technical museum, Prague	December 2004	Head Mounted Display and CAVE	28–17 male, 11 female	Quantitative analysis of distance estimates, and MEC questionnaire data.
				Qualitative analysis of Place Probe version 2.
Comparative study – Image-based rendering vs. modeled scene	August 2005	Head Mounted Display	40–22 male, 18 female	Quantitative analysis based on Place Probe version 3 (including MEC questionnaire).

Table 10.2 Semantic differential tables of the real (Left) and virtual (Right) environments

	Very	Quite	Neither	Quite	Very			Very	Quite	Neither	Quite	Very	
Attractive	23	3	1	1	1	Ugly	Attractive	7	15	7			Ugly
Big	7	12	6	2	1	Small	Big	2	11	13	2	1	Small
Colorful	5	12	8	4		Colorless	Colorful		14	5	9	1	Colorless
Noisy	4	8	5	8	4	Quiet	Noisy	3	7	9	6	4	Quiet
Temporary	1	7	6	8	7	Permanent	Temporary	3	6	8	8	4	Permanent
Available	4	11	10	4		Unavailable	Available	1	9	11	5	2	Unavailable
Versatile	2	11	8	7	1	Limited	Versatile	2	6	12	7	2	Limited
Interactive	5	8	5	6	5	Passive	Interactive	1	7	6	10	5	Passive
Pleasant	23	5			2	Unpleasant	Pleasant	4	16	5	4		Unpleasant
Interesting	19	6	2	1	1	Boring	Interesting	8	11	5	4		Boring
Stressful	1	1	3	4	20	Relaxing	Stressful		5	5	11	8	Relaxing

movement of images is rated as smooth-jerky, broken-unbroken, slow-fast, consistent-erratic.

Data from the fifth study undertaken (see Table 10.1) provided some interesting insights into the importance of the various aspects of sense of place in virtual environments. Twenty-eight participants took part in a number of experimental settings over a period of 2 days and data was gathered using a variety of methods, including the Place Probe. This allowed us to compare experiences across different technological renderings of the images (e.g. in an HMD and in a CAVE) and to compare different versions of the different arenas (e.g. comparisons of a rendering of the technical museum just in an HMD and a rendering in an HMD that included the physical augmentation of the arena with a guard rail).

Another interesting similarity is the sense of space. Participants in both arenas felt that they were looking into the technical museum as opposed to being totally there. Two quotations from participants illustrate this:

> *I thought it looked real, it was …I got the feeling it was a museum …and but I don't think I got the feeling I was there I was kinda of looking into it so…but fun experience* (Female, Cave)

> *I really felt I was standing in a room and looking at this old museum.* (Female, HMD)

And when asked what they thought their function in the environment was, participants replied:

> *Ya well I felt a bit awkward because it felt like it was after closing hours ha ha …I would loved to be there as a tourist but it felt more like I was a thief or maybe as a cleaning lady …so dark…. so something like that maybe a cleaning lady.* (Female, Cave)

The general impression from both arenas is a positive one, even though some participants were annoyed with the restricted movement. When asked how they could improve the experience, participants replied:

> *Well I would have liked to have been able to walk down a stairs and walk in between the old steam locomotives and cars* (Male, Cave)

> *I want to touch …no maybe I would have been much more satisfied if I could have got closer to see more specific details. Ok* (Male, HMD)

> *Movement restriction has to be altered and to a lesser extent* (Male, Cave)

> *Well I was very restricted in movement I couldn't see what the signs said.* (Male, Cave)

While the Place Probe was considered to be successful in revealing some of the essential attributes of place, it failed to adequately engage with the specific needs of the designers of such technologies. Discussions with the designers generated the requirement for the method to produce detailed findings about specific technological issues associated with the creation of virtual environments. For the second part of the approach we looked at producing patterns of place.

10.4 A Pattern Based Approach to Design

While the final version of the Place Probe was undoubtedly better tuned to the requirements of the designers of virtual environments, it was still found wanting. It failed to bridge the 'design gap'. A more formal mechanism was required to assimilate the probe data and to enable its application during the design process associated with future environments. To specifically address this issue a pattern based approach was undertaken.

Patterns have long been used in Software Engineering (e.g., Gamma et al. 1995). The use of patterns in Interaction Design, HCI and related fields such as web design and GUI design is gaining momentum in practice. Initial research into the applicability of patterns in Interaction Design (Borchers 2001) has paved the way for the production of pattern books (van Duyne et al. 2002; Graham 2003; Borchers 2001), together with a growing number of on-line pattern resources, reflecting the dynamic nature of the approach (van Welie 2006; Tidwell 2005). While individual patterns may provide a valuable resource for designers, their potential impact is dramatically increased when they are constructed into a pattern language.

The pattern approach was inspired by the work of Christopher Alexander (1977) in the field of architecture. Alexander attempted to formalise architectural knowledge based on case studies through the use of templates that described a series of patterns referring to the layout of urban spaces. For example, if an urban planner had the requirement to increase the sense of community associated with a particular location, they might choose to adopt the pattern that suggests the creation of squares and plazas that incorporate seating and spaces for cafes at appropriate road junctions. The strength of Alexander's approach lies, not in the individual patterns that superficially can appear simplistic, but in their connectedness resulting in a 'pattern language'. In a pattern language, each pattern is linked to others, some more specific, some more general, giving the designer a sense of the implications associated with particular design decisions. The pattern based approach to place aims at harnessing a similar gestalt.

The pattern based approach is a method designed to formalise the knowledge gained through the application of the Place Probe. The patterns described in the remainder of this chapter reflect the aggregation of the understanding of sense of place through the studies conducted as part of the BENOGO project. The approach encapsulates design knowledge and makes it available to the creators of virtual environments. Further applications of the Place Probe will provide more data that, in turn, can contribute to existing patterns, or the creation of new ones. The strength of the patterns is that they provide designers of virtual environments with grounded evidence to support design decisions and the choice between alternatives. Both of these factors are characteristic of the early phase of design that the patterns aim to support. The patterns, while informed through the data generated from the use of the Place Probe, can be used independently of the probe and, it is contended, contribute to the design of virtual environments.

As the pattern based approach has been developed from the Place Probe, the underpinning structure is based on Relph's model of place (1976), but also reflects the development of the probe and includes a category concerning the impact of technologies on the experience of a virtual environment. The patterns are, therefore, organised into the four components; technology, spatial characteristics, meanings and affect, and activities. Our aim in presenting these patterns is not to suggest that the endeavour of producing a definitive set of patterns of place is complete. Quite the reverse. Our aim is to illustrate the idea and to suggest that the overall structure of the patterns is valid. We expect the list of patterns to grow as the approach is more widely adopted and the experience of others feeds into the language.

10.4.1 Technology Patterns

There are currently fifteen patterns relating to the IBR technology. These include three that relate to the arena (pattern 8) in which the environment is displayed. The panorama arena is described in pattern 9, the Cave in pattern 10 and the HMD in pattern 11. Four patterns are concerned with the quality of the display. Display resolution is pattern 7, image quality is pattern 5, field of view is pattern 6 and frame rate is pattern 4. Three patterns relate to motion resolution (pattern 12) including three different types of the important 'region of exploration' (REX). Pattern 13 describes the point REX, pattern 14 describes the disc REX and pattern 15, the line REX. Pattern 1 describes the acquisition point, pattern 2 is the acquisition resolution and pattern 3 is the texture resolution.

These patterns refer specifically to the IBR approach adopted within the BENOGO project. Of course other technologies will have other technological patterns associated with them. The pattern describing the Acquisition Point (Pattern 1) is illustrated in Table 10.3. This pattern relates to the location from which images are captured. As with all the patterns, the aim is to capture key aspects of design and engineering knowledge associated with a particular design problem. The standard format that we use is to identify a general description, the other patterns that are influential on the main design problem that is the focus of this particular pattern, the problem to be addressed, the solution proposed, and other patterns affected. The rationale for this pattern may be explained as follows.

Evidence from the Place Probe suggests that it is important to establish a position from which to capture images of a place in order to represent it in an optimum manner. Factors that impact on this decision are firstly, the nature of the scene that is to be portrayed and secondly, what activities are to be supported within the scene. A solution to this requirement is to scope the real place as early and often as possible. By observing the activity and behaviour of individuals at the real place, it is possible to establish a suitable acquisition point that is in keeping with the technological objectives of the study and captures the important features of the real place. The Place Probe can capture the elements that are perceived within the environment and these can, in turn, be turned into a design template. Furthermore, it is important that an appropriate REX be selected to enable the observed behaviours to be replicated within the virtual environment.

Table 10.3 The acquisition point pattern relating to the BENOGO IBR technology.

1. Acquisition point
Description
Specific to Benogo IBR. The acquisition point is the specific location where the images are captured.
Influential patterns
Problem
It is important to establish the best position to acquire the images from, in relation to representing the real place in the best way. This requires taking into account what scene the images will portray and what type of activities might occur there.
Solution
The best way to solve this problem is by Scoping the real place first, as well as performing a Place Probe. By observing the activity and behaviour of individuals at the real place, it is possible to establish a suitable acquisition point that is in keeping with the technical objectives of the demo while making sure the most important features of the real place are captured in the images. The Place Probe captures elements of the environment that can be turned into a design template. It is also essential that the appropriate type of REX e.g. Point, Disc, or Line is chosen in line with the requirements derived form the real environment.
Affected patterns
Acquisition resolution (2), Point REX (13), Disc REX (14), Line REX (15)

10.4.2 Patterns of Spatial Characteristics

Analysis of the various applications of the Place Probe as it developed over the lifetime of the project revealed a series of common themes relating to the properties of both real and virtual places. These patterns of place are divided up into spatial characteristics, activities in the place and meaning and affect engendered by the place. Patterns 16 to 27 deal with the spatial characteristics and broadly speaking map onto the spatial differentials of the place probe. The patterns are: big/small (17), open/closed, (18) full/empty (19), colourful/colourless (20), identifiable features (21), dark/light (22), static/moving (23), touchable/untouchable (24), responsive/inert, (25) near/far (26), permanent/temporary (27). Spatial characteristics (16) is a super ordinate pattern that is required to link with activities and technology.

Table 10.4 presents the pattern entitled Big/Small and relates to the responses participants have to the volume and scale of different places. In certain cases the perceived volume of a place can be either magnified or diminished as an attribute of the technology used to represent the place. This pattern also illustrates how supporting evidence for the design knowledge can be included in the patterns. Indeed Alexander's patterns often ran to several pages and included illustrations, rich descriptions, quotations and other forms of qualitative data. It is exactly this interweaving of patterns and capturing of rich, qualitative data that gives the pattern language approach its strength.

An illustration of this comes from our efforts to develop a virtual representation of the Prague Technical Museum. Pattern number 18 entitled Open/Enclosed and Pattern number 19 Full/Empty pointed to the importance of capturing, accurately, the spatial characteristics of a place.. Further supporting evidence was provided by

Table 10.4 Big/small pattern relating to the physical properties of places

17. Big/small (P)
Description
Different places are different sizes in reality. They can be big, small or somewhere in between. The technical museum for example is a large room, while the viewpoint is much smaller but feels bigger due to being outside **Open/Enclosed(18)**.
'It was a very large room I couldn't see what was on the other side of the room very well' (technical museum)
'scale was too small… seemed artificially too small' (botanical garden)
Influential patterns
FOV(6), Acquisition point (1), Motion resolution (12), Arena (8)
Problem
Size Matters. Getting the size right for IBR environments is about combining different factors. The problem is in understanding how these factors relate to one another. Our studies of the Technical Museum for example identified that it was considered to be a **big** place, that it was also **enclosed (18)** and **full (19)** of objects.
Solution
Important things to consider in sizing a virtual IBR space are firstly how do the spatial characteristics relate to one another and secondly how can the technology support this relationship in the rendered environment. For example we have already seen how the museum is big, full and enclosed. It was important in terms of technology that these three aspects of the environment were supported. It was therefore imperative that the **Acquisition point (1)** was established that was at least open to the large scale of the room on one side and yet close enough to the objects in the room to make it feel full.
Another important thing to consider is whether people are moving through the environment **Motion resolution (12)**. A **Disc REX (14)** was used in our version, which allowed some movement but not exploration. Therefore the sense of scale in the IBR environment was different from the real because participants could not **explore (29)** the IBR environment fully. However the sense of scale was enhanced locally by the parallax provided by the Disc REX i.e. near objects occluded objects that were further away but moving allowed you to see them.
Affected patterns
Explore (29); Interesting/uninteresting (40)

the inclusion of quotations from participants in studies that highlighted the issue of the perception of size with respect to the environment. From a technological perspective Pattern 17 was linked to Field of View (6), Acquisition Point (1) Motion Resolution (12) and choice of Arena (8). Participants in the study of the real Technical Museum reported that they saw the environment as big, full and enclosed. This finding places a requirement on the technology and specifically the choice of Acquisition Point (1) such that it was open to the large scale of the location but also was close enough to objects contained within to give the viewer the impression that the room was full. Furthermore, if there is a requirement for people to be able to move through the environment this impacts on Motion Resolution (12). In the case of the BENOGO technology a Disc REX (14) was used which allowed some movement but not real exploration. This design decision resulted in the perception of scale in the IBR environment being different from the real environment because participants could not Explore (29) the environment fully. However the sense of scale was enhanced locally by the parallax provided by the Disc REX (14) resulting in objects near to the viewer occluding objects further away but supporting head movement so occluded objects could be revealed.

10.4.3 Patterns of Meanings and Affect

Analysis of the meanings elucidated by the participants in the real and virtual environments studied as part of the BENOGO project resulted in the themes relating to meanings and affect engendered by the place. Patterns 31–40 aim to capture key features of the meanings and emotional response that people have to a place. They map onto the meaning and affect differentials of the place probe: stressful/relaxing (31), meaningful/meaningless (32), ugly/beautiful (33), harmful/harmless (34), pleasant/unpleasant (35), significant/insignificant (36), confusing/understandable (37), exciting/boring (38), memorable/forgettable (39), interesting/uninteresting (40).

In order to explore this class of pattern the Stressful/Relaxing (31) will be described in more detail (see Table 10.5). Some environments are more relaxing, or conversely more stressful than others. The degree of relaxation or stress associated with a particular place is deeply linked to a person's subjective experience of activity in that place; as such it cannot be designed—only designed for. For example, outdoor places have the potential to be more peaceful and allow an experience of nature at an easy steady pace are often considered relaxing, whereas outdoor places where people encounter unexpected testing circumstances might be considered stressful, (i.e., bad weather conditions, or a loss of orientation).

In the case of virtual environments there is the added dimension of the mediating technology interfering with the experience. A beautiful and relaxing scene might be rendered in an HMD and yet the technology might create stressful affects by displaying poor quality images that are hard to focus on, or by disorienting the participant. The Stressful/Relaxing pattern has been found to impact primarily on Technology patterns, namely Image Quality (5), Acquisition Point (1), Motion Resolution (9) and the Activity related patterns (41, 28, 29 and 30). Mediation with a virtual environment is essentially illusionary and any interference with this can result in stress on the part of the user and ultimately a break in presence. In the case of rendering a relaxing scene, it is important to ensure that factors such as Image Quality (5) and REX (13, 14 & 15) do not interfere with the experience. Low quality out of focus images as well as blind spots and image drop outs all lead to disorientation and stress, distracting the user and increasing the potential for a stressful experience. Similarly, if the intention is to create a stressful scene, for example a cliff edge it is important to concentrate on the detail in order to make the experience believable. To avoid such problems it is important to have high Image Quality (5) and a suitable REX (13, 14 & 15). The choice of environment and its associated Acquisition Point (1) is important, together with the activity type that matches the expectations of the participants. Another technique for reducing stress within a virtual environment is to augment images where small details, such as text, cannot easily be read.

Table 10.5 The stressful/relaxing pattern relating to the meanings associated with real and virtual places

31. Stressful/relaxing (M)
Description
Some environments are more relaxing, or conversely more stressful than others. The degree of relaxation or stress associated with a particular place is deeply linked to a person's subjective experience of activity in that place; as such it cannot be designed—only designed for. For example outdoor places that are peaceful and allow an experience of nature at an easy steady pace are often considered relaxing, where as outdoor places where people encounter unexpected testing circumstances might be considered stressful, i.e. bad weather conditions, or a loss of orientation. In the case of VR there is the added dimension of the mediating technology interfering with the experience. A beautiful and relaxing scene might be rendered in an HMD and yet the technology might create stressful affects by displaying poor quality images that are hard to focus on, or by disorienting the participant.
'Very good view but only from one place as trees get in the way everywhere else. Paths are poor and there is no information to direct or explain' (viewpoint)
'There was some text but it was unreadable but I could easily identify the object' (technical museum)
'Viewpoint close to the monastery, very beautiful view, peace, relaxing' (viewpoint)
Influential patterns
Image quality (5); Acquisition point (1); Activity (14); Motion resolution (9)
Problem
VR mediation is essentially illusory. Interference in this illusion can cause stress and often leads to breaks in presence. In the case of rendering a relaxing scene, it is important to try and ensure that factors such as **image quality (5)** and **REX (13, 14, 15)** do not interfere with the experience. Low quality out of focus images as well as blind spots and image drop out all lead to disorientation and stress, distracting the user from a possibly relaxing experience. Similarly, in creating a stressful scene such as a cliff edge for example the same attention to detail is necessary to make it believable.
Solution
To avoid this, it is important to have high **image quality (5)** and a suitable **REX (13, 14, 15)** that does not impede the user experience i.e. it is important to choose an appropriate environment (**Acquisition point (1)**) and activity type that is compatible with the expectations of the participants. Also a useful aid is to augment images where small details such as text cannot be read.
Affected patterns
Pleasant (35), Exciting/boring (38)

10.4.4 Activity Patterns

Analysis of the real and virtual environments studied using the Place Probe during the BENOGO project revealed four main activities associated with place. Pattern 41 is another super ordinate pattern dealing with the overall feelings of ego motion. Patterns 28 (static/observational), 29 (local/explorative) and 30 (locomotive) deal with specific aspects of activity in BENOGO environments. The patterns are presented in full in the appendix. In the following sections examples are used to illustrate each of the different types of pattern. The Ego Motion (27a) will be considered in more detail in this section. Ego motion is the sensation of movement afforded to participants in virtual environments by the number of images or Motion Resolution (12) rendered by the system (Table 10.6).

In general, the more images that are rendered at run time, the smoother and clearer the feeling of movement through the REX (13, 14 and 15) resulting in a higher motion resolution. As in the previous example, quotations from studies that refer explicitly to ego motion are included in the pattern by way of illustration. From the perspective of the BENOGO technology, ego motion influences both Motion Resolution (12) and the REX (13, 14 and 15).

Pattern (41) describes the problem resulting from ego motion as follows. Natural ego motion always produces parallax and occlusion between objects in the environment. IBR ego motion attempts to reproduce this effect but is generally restricted by the massive processing power necessary to compute the position of potentially thousands of images. BENOGO IBR uses special algorithms that reduce the number of images necessary to achieve a realistic representation of natural ego motion. When considering the issue of ego motion it is important to establish the type of activity that users will perform in the rendered environment. Accordingly an appropriate

Table 10.6 The ego motion pattern relating to activities associated with real and virtual places

41. Ego motion
Description
Ego motion is the feeling of movement that is afforded by the number of images, or **Motion Resolution (12)**, rendered by the system. The higher the motion resolution i.e. the more images there are rendered at run time, the smoother and clearer the feeling of movement through the REX.
'I noticed time when I turned my head world was moving a little' (botanics)
'I thought it looked real, it was … I got the feeling it was a museum… and but I don't think I got the feeling I was there I was kinda of looking into it so …' (technical museum)
Influential patterns
Motion resolution (12), REX (13, 14, 15)
Problem
Natural ego motion always produces parallax and occlusion between the objects in our environment. IBR ego motion attempts to reproduce this affect but is generally restricted by the massive processing power necessary to compute the position of potentially thousands of images. Benogo IBR uses special algorithms that reduce the number of images necessary, however no system as yet has come close to natural ego motion, although BENOGO despite some restrictions comes pretty close.
Solution
It is important to establish the type of activity that users will perform in the rendered environment. Accordingly an appropriate **REX (13, 14, 15)** has to be selected as well as a suitable motion resolution. If restrictions are still evident then ego motion can be supported through augmentation that culturally enforces restricted movement e.g. a guide rope or railing. Similarly augmentation might provide a focus of attention offering interesting parallax effects.
Affected patterns
Static observational (28), Local explorative (29), Locomotive (30), Spatial characteristics (16), Identifiable features (21)

REX (13, 14 & 15) should be selected together with suitable Motion Resolution (12). If restrictions are still evident then ego motion can be supported through the judicious use of augmentations that culturally enforce restricted movement (e.g.. a guide rope or railing). A related technique is to use augmentation as a distraction owing to its potential for parallax effects.

10.5 Conclusions

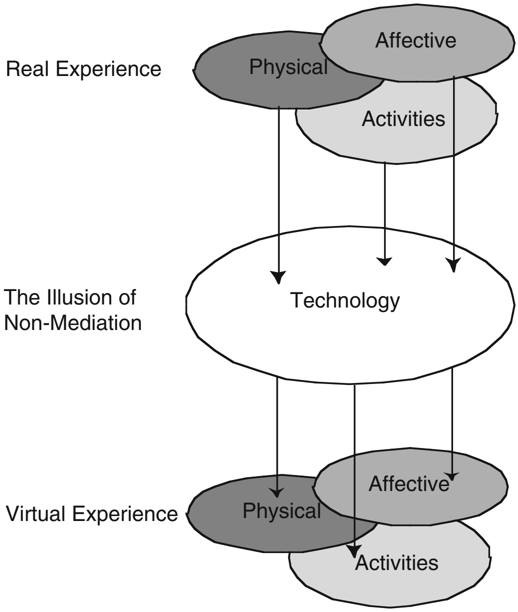
Existing tools and techniques for the measurement of the sense of presence in real and virtual environments have failed to provide formal mechanisms through which to inform the design process associated with their creation. From an HCI perspective this was viewed as a major shortcoming. An analysis instrument, the Place Probe has been introduced. The probe utilised a blended approach to the generation of both qualitative and quantitative data concerning the experience of place associated with a range of real and virtual environments. Based on the responses of developers of virtual environments, the design team and the experiences of several studies of real and virtual environments, the probe has been refined to include three parts: the qualitative parts, the semantic differentials and the MEC Spatial Presence Questionnaire.

Associated with the Place Probe, a pattern based approach has been developed to articulate the data generated from using the probe into a form that is accessible and pertinent during the design phase associated with the creation of virtual environments. The Patterns of Place have been classified relative to participants' responses to a series of real and virtual environments developed over the course of the work into: the physical properties of the space, the activities supported, the meanings associated and affect engendered, and the technology necessary to create the illusion of non-mediation.

We conceptualise the situation as indicated in Fig. 10.3. The characteristics of real and virtual places are represented in terms of the three characteristics of Relph's model of place. In between the real and the virtual representation of the place lies some technology. In our case this was the BENOGO IBR technology and so the current version of technology patterns refer to the BENOGO IBR approach. However, the method generalises to any other mediating technologies. These could include rich and complex technologies such as film where there are many, many technologies (set design, costume design, choreography, lighting, script, location and so on) that together provide the mediating technology for the experience. They too could be used in conjunction with the Place Probe and could generate new patterns to be substituted into the existing set of patterns.

The integrated approach to the design of virtual environments presented in this chapter is a nascent attempt at connecting the measurement of sense of presence to the design of virtual environments. Presence demands a qualitative, phenomenological

Fig. 10.3 The characteristics of places and mediating technology



approach to its understanding. Presence is a personal response to a social and physical setting, experienced through an embodied interaction. A key part of presence is the sense of place; a person's feelings, understandings and attitudes to a place. If people are to experience a strong sense of presence through some technologically mediated interaction, they will need to experience a sense of place; that is they will need to feel that they are somewhere. The pragmatics of delivering this sensation comes from the designers and engineers of the technologies and their understanding of the experience of being there.

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Appendix: The Place Probe

Instructions

Please read the following questions carefully and answer all parts of the booklet. It should take around 10 min to complete. Once finished please return the booklet to the researchers. Thank you for your co-operation.

Background Information

Age: Sex:

Nationality:

First time visitor/Regular visitor:

Description

Please write a paragraph of description telling us about your experience of being in the place you have just visited.

Map

Please draw us a map of the place you have just visited. Indicate the most important features that you remember and the best place to stand to see them.

Features

Pick 3 features of the environment that you remember and rank them in order of importance:

1
2
3

Pictures

From the photographs provided, please select one that best captures your experience of being in the place you have just visited. Write down the number from the back of the photograph onto this page and tell us why you chose it (if no photographs are provided skip this section).

Sounds

Please describe any sounds that you remember from the environment you have just visited.

Words

Please write down six individual words that best capture your experience of being in the place you have just visited.

On the tables provided in each question below, please mark a cross in the box that best describes your experience in relation to the adjectives provided at either side. Below is an example for an experience that was 'quite bad' and 'very light'.

(Example)

	Very	Quite	Neither	Quite	Very	
Good				x		Bad
Light	x					Dark

Did the images that were displayed seem?

	Very	Quite	Neither	Quite	Very	
Grainy						Clear
Realistic						Unrealistic
Unbelievable						Believable
Distorted						Accurate

Did the movement of the images seem?

	Very	Quite	Neither	Quite	Very	
Smooth						Jerky
Broken						Unbroken
Slow						Fast
Consistent						Erratic

Did you feel that you were?

	Very	Quite	Neither	Quite	Very	
Passive						Active
Free						Restricted
Disorientated						Oriented
Inside						Outside
Mobile						Immobile

Did you feel that the environment was?

	Very	Quite	Neither	Quite	Very	
Small						Big
Empty						Full
Light						Dark
Enclosed						Open
Permanent						Temporary
Colorless						Colorful

(continued)

	Very	Quite	Neither	Quite	Very	
Static						Moving
Responsive						Inert
Far						Near
Untouchable						Touchable

Did you feel that the environment was?

	Very	Quite	Neither	Quite	Very	
Ugly						Beautiful
Pleasant						Unpleasant
Stressful						Relaxing
Harmful						Harmless
Exciting						Boring
Interesting						Uninteresting
Memorable						Forgettable
Meaningful						Meaningless
Confusing						Understandable
Significant						Insignificant

Please answer the following questions by placing a tick in the box that best expresses your feelings.

1 = I totally disagree
2 = I disagree
3 = I neither agree nor disagree
4 = I agree
5 = I totally agree

	1	**2**	**3**	**4**	**5**
Q1.1 I devoted my whole attention to the [medium].					
Q1.2 I concentrated on the [medium].					
Q1.3 The [medium] captured my senses.					
Q1.4 I dedicated myself completely to the [medium].					
Q2.1 I was able to imagine the arrangement of the spaces presented in the [medium] very well.					
Q2.2 I had a precise idea of the spatial surroundings presented in the [medium].					
Q2.3 I was able to make a good estimate of the size of the presented space.					
Q2.4 Even now, I still have a concrete mental image of the spatial environment.					
Q3.1 I felt like I was actually there in the environment of the presentation.					
Q3.2 It was as though my true location had shifted into the environment in the presentation.					
Q3.3 I felt as though I was physically present in the environment of the presentation.					
Q3.4 It seemed as though I actually took part in the action of the presentation					
Q4.1 I had the impression that I could be active in the environment of the presentation.					

(continued)

Q4.2 I felt like I could move around among the objects in the presentation.					
Q4.3 The objects in the presentation gave me the feeling that I could do things with them.					
Q4.4 It seemed to me that I could do whatever I wanted in the environment of the presentation.					
Q5.1 I thought most about things having to do with the [medium].					
Q5.2 I thoroughly considered what the things in the presentation had to do with one another.					
Q5.3 The [medium] presentation activated my thinking.					
Q5.4 I thought about whether the [medium] presentation could be of use to me.					
Q6.1 I concentrated on whether there were any inconsistencies in the [medium].					
Q6.2 I didn't really pay attention to the existence of errors or inconsistencies in the [medium].					
Q6.3 I took a critical viewpoint of the [medium] presentation.					
Q6.4 It was not important for me whether the [medium] contained errors or contradictions.					
Q7.1 I am generally interested in the topic of the [medium].					
Q7.2 I have felt a strong affinity to the theme of the [medium] for a long time.					
Q7.3 There was already a fondness in me for the topic of the [medium] before I was exposed to it.					
Q7.4 I just love to think about the topic of the[medium].					
Q8.1 When someone shows me a blueprint, I am able to imagine the space easily.					
Q8.2 It's easy for me to negotiate a space in my mind without actually being there.					
Q8.3 When I read a text, I can usually easily imagine the arrangement of the objects described.					
Q8.4 When someone describes a space to me, it's usually very easy for me to imagine it clearly					

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Part III
Telepresence Applications

Chapter 11
Collaboration in Immersive and Non-immersive Virtual Environments

Anthony Steed and Ralph Schroeder

Abstract There is a huge variety of tools for synchronous collaboration including instant messaging, audio conferencing, videoconferencing and other shared spaces. One type of tool, collaborative virtual environments (CVEs), allows users to share a 3D space as if they are there together. Today, most experiences of virtual environments (VEs), including games and social spaces, are constrained by the form of non-immersive interfaces that they use. In this chapter we review findings about how people interact in immersive technologies, that is large-screen displays such as CAVE-like displays, and how they provide a number of advantages over non-immersive systems. We argue that modern immersive systems can already support effective co-presence in constrained situations and that we should focus on understanding of what is needed for effective and engaging collaboration in a broader range of applications. We frame this discussion by looking at the topics of co-presence, representations of users and modalities of interacting with the VE. Different types of immersive technologies offer quite distinct advantages, and we discuss the importance of these differences for the future of CVE development.

Keywords Synchronous collaboration • Collaborative Virtual Environments (CVE's) • 3D Space • Interaction • Social space • Immersive technologies • Co-presence

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11.1 Introduction

What is most people's experience of synchronous collaboration at a distance? The most common experience is voice over the telephone or text messaging. Over the past few years video conferencing and other forms of web-based collaboration tools have become more popular (Hinds and Kiesler 2002). We individually might have preferences for some or other of these tools, but we would all agree that using these tools is nothing like being there together with our collaborators. For example, the problems of maintaining shared references with video-conferencing have been well understood for two decades (Gaver et al. 1993). However such technologies are very convenient since, even if the software might need some configuration, there is little or no per-user configuration required.

An emerging collaboration technology is shared or collaborative virtual environments (SVEs or CVEs). CVEs have developed rapidly over the last decade or so. Apart from applications in a few niche industrial projects and a variety of academic demonstrator projects, the most widespread uses of CVE are shared spaces for socializing and gaming such as Second Life and World of Warcraft. In this chapter, we will focus on collaboration in VEs and the effective and engaging use of these immersive spaces. Whether these will become as widespread as the leisure uses of non-immersive VEs is a question we will leave to one side, although one point to make at the outset is that even if online gaming and socializing continue to lead the uses of SVEs, the requirements of workaday uses of CVEs will need to be tackled if immersive (and indeed non-immersive) systems will be able to deliver on their dual promise of bridging distance between people and allowing them do things in spatial environments together. Therefore, regardless of whether future developments come from the 'pull' of applications, or from the 'push' of more powerful and less expensive immersive systems – one of the arguments that will be made here is that we need a better understanding of the benefits of immersion and of how people are able to interact with each other and with the environment using media.

In this chapter we will cover a range of CVE technologies. The range of technologies can be characterised in two ways: the *spatial extent* that is shared and the *degree of user modelling*. Just as there are different models for audio collaboration (e.g. point to point versus conference call) or text messaging (SMS versus Twitter), a CVE has a model with a particular spatial extent. We distinguish two particular spatial extents: *face-face extent* and *extended extent*. In a face-face extent the CVE simulates the situation of being across the table from a user. Examples include the Spin3D system (Louis Dit Picard et al. 2002) and the Office of the Future system that we will discuss in more detail in a later section (Fig. 11.1) (Raskar et al. 1998). Both these systems simulate a particular situation of a pair or a small group around a table (e.g. Spin3D, see below). Virtual objects can be shared in the common space in front of the users. Unlike videoconferencing, this type of CVE allows proper capture of or simulation of eye-gaze between users and objects in the common space. Extended extent refers to the majority of CVEs where users can independently navigate through complex information, walkthroughs of buildings and landscapes, and manipulate a range of objects.

Fig. 11.1 Two illustrative CVE systems that simulate a face-face situation. *Left*, Spin3D system (Image courtesy of Laboratoire d'Informatique Fondamentale de Lille). *Right*, Office of the Future system (Image courtesy of Department of Computer Science, University of North Carolina at Chapel Hill)

The degree of user modelling is also illustrated by the Spin3D and Office of the Future systems. The former uses a set of pre-modelled avatars. Users interacting with the system indirectly control the avatar, effectively acting as puppeteer. In Office of the Future though, the system completely reconstructs a representation of the user in real-time. In between these two extremes is a spectrum of systems that track some of the movements of the user in order to manipulate an avatar representation. We refer to these three types as *puppeteered*, *reconstructed* and *tracked*.

These two characterisations of CVEs pose many technical challenges and opportunities. It might seem that ideally we would support extended extent and reconstructed avatars, but this is an incredible technical challenge. If we take a step back to either face-face/reconstructed or extended extent/tracked we find that the technical challenges are much more tractable. In any case, we will see that there are already many opportunities and configurations of systems for enhanced communication.

In this chapter we explore the opportunities and challenges in more detail. To this end we go back to what is known about how people interact with each other and with the environment, both for immersive and non-immersive CVE systems. One area that has been investigated extensively is *presence*, or how people experience 'being there' in the environment (see Scheumie et al. 2001 and other chapters in this volume). There have been extensive debates about how to measure presence, but people tend to experience a greater sense of presence in immersive as opposed to desktop systems. *Co-presence*, the 'experience of being with others' is much more difficult to gauge (see also Schroeder 2011). One way to understand co-presence is by looking for situations when it is absent or much reduced – such as when using instant messaging or a phone call. In these situations it can be difficult to keep attention on the conversation and misunderstandings can occur in ways that don't in real conversations.

One reason for raising the topic of co-presence is that so far, co-presence has been studied as a psychological state, by asking the user, or otherwise ascertaining their state of mind at a particular time or for a particular experience. But, from the user's point of view, it is not the psychological 'state' that is important (however measured), but what they experience in terms of being able to interact with the other person and with the environment. In other words, the study of co-presence will need to become much more complex: it is not just that co-presence depends on the 'context', the application or the setting, but that several factors will affect co-presence. It may be, for example, that the spatial experience of the environment and the experience of being there with another person (the spatial versus communication uses of CVEs) will require quite different lines of investigation.

Howsoever this research is undertaken and whatever its findings may be, ultimately the factors affecting co-presence will need to be brought into a single model so that a body of cumulative research can be built up – as it has for presence. Yet the task of studying co-presence is made more difficult and uncertain by the fact that technology development and the uses or applications of the technology are indeterminate. We shall argue later that we can nevertheless foresee what the end-states of immersive CVEs will be, and this mitigates this uncertainty and indeterminacy and will allow us considerable insight into the effectiveness of different systems.

In the rest of this chapter we talk first about technologies for collaboration. We then give some initial observations about the impact that user representations have, and how these are used in collaboration. In Sect. 11.4 we introduce studies of co-presence, and we cover a three-way classification of factors that affect co-presence: modality, realism and context. Next we discuss end-states of collaboration technologies and we claim that CVE technology is actually heading in at least two different directions. We conclude with a short list of challenges for CVE developers.

11.2 Technologies

As mentioned in the introduction, one of the characteristic features of any CVE is the degree of user modelling. In this section we give a more detailed characterisation of the different degrees: puppeteered, tracked and reconstructed.

11.2.1 Puppeteered Avatars

Recently the burgeoning market for online 3D games has pushed this type of avatar into the limelight. Two common genres are first-person shooter (FPS) games and massively-multiplayer online games (MMOGs). The former are well known and described in non-academic writing, examples include the Halo series from Microsoft, the Quake and Doom series from Id Software and the Unreal

Fig. 11.2 Eyes of a high-quality avatar suitable for real-time rendering. Eye blinks, eye gaze and pupil dilation are all modelled as part of the behaviour of the avatar (Courtesy of Will Steptoe, UCL)

series from Epic Games. The latter genre has attracted more attention in academic literature (e.g. contributions by Persky and Blascovich, Jakobsson, Yee 2006; Brown and Bell, and Steen et al. in Schroeder and Axelsson 2006; Williams et al. 2006). Important examples include Everquest from Sony, Second Life from Linden Lab, Lineage II from NCSoft Corporation and World of Warcraft from Blizzard Entertainment.

In both genres of games the user is typically represented in the world by an avatar and the user explores the virtual environment by using that avatar. Figure 11.2 represents an example high-end avatar figure that typifies those in games in 2014. These days these avatars are obviously sophisticated enough that they could represent the gender, identity, role, emotional state and intentions of the user dynamically over time. But crucially these avatars are like puppets: they do not directly represent the actual player, because the appearance of the avatar is constrained by the visual metaphor of the environment and the constraints of the animations built in to the avatars.

Players will go to great length to customise these avatars, even creating representations that look like themselves (Cheng et al. 2002) but still these avatars have to be controlled through an interface.

11.2.2 Tracked Avatars

The most common use of tracked avatars is with immersive systems. In 2014 most high-end immersive systems are using Cave Automatic Virtual Environments (CAVE) -like displays, though there is renewed interest in high field of view head-mounted displays driven by consumer technology. Figure 11.3 shows a 3D model and a view into a four-walled CAVE-like system, in the lab of one of the authors. Such a facility is typical of those in academic labs, though there is increasing usage of these technologies in industrial applications (e.g. Weaver 2010).

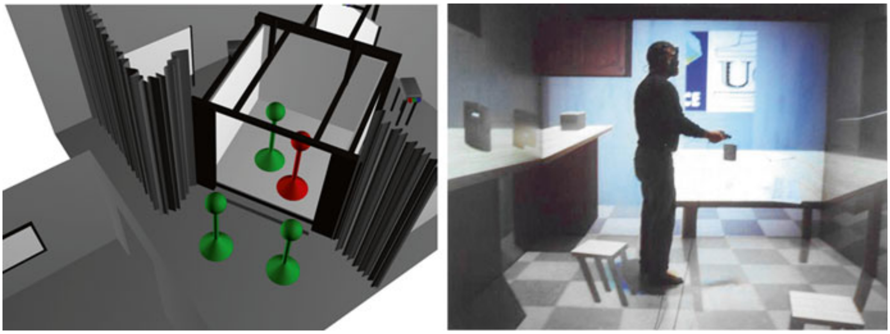

Fig. 11.3 *Left*, a 3D model of UCL's immersive systems representing the four walls and a number of users. *Right*, a view into the system with a user in front of the walls

The key components of this technology are that the images are in stereo on the walls and the head is tracked. This combination provides the ability to create images that show correct parallax when the head moves, creating the illusion of depth in objects. Unlike some other 3D stereo technologies, the limits of parallax are quite high so objects can appear to be distant and proximate to the user, in particular objects can appear to be inside the walls. Because of this property and because of the size of the screens, this technology is highly "immersive" in that it can create imagery that surrounds the user and isolates them from the real world. It provides the capability to represent objects at a one-to-one scale, and in particular people can be represented at a one-to-one scale.

The head needs to be tracked to create the correct imagery on the screen, but a side effect of this is that the user's position is known. Usually between one and three additional tracked points on the person are known, typically at least the dominant hand, and often both hands and the torso. This very limited tracking information allows us to generate a 3D model of the user of the system (e.g. Badler et al. 1993). This tracking can be seen as a limited form of motion capture. Motion capture is a technology most commonly used in the animation industry to create animation sequences for rendering offline (Jung et al. 2000). It typically uses quite a few tracked points all over the body in order to track deformations of all major limbs. Such systems can be integrated into CAVE-like systems, but current technologies are usually limited by the discomfort and inconvenience of "dressing" in sensors or markers before entering the system. Later in this chapter we will come back to experimental evidence from studies of collaborative tasks that show that simple tracked avatars can create a highly expressive representation of another person. For the moment, it suffices to note that the perception literature shows us that we can recognise human motion from very little information. For example, it has been shown that from a few moving point lights on the wrists and ankles we can tell not only gender of a subject, but aspects of their mood (Pollick et al. 2002). This suggests, and our later review will provide more evidence, that limited motion capture conveys a lot of the important information about a user's behaviour and state.

11.2.3 Reconstructed Avatars

Motion capture provides information about user motion, but can't provide real-time information about appearance. We will need to capture full 3D models in real-time order to satisfy our requirements of being able to place the user inside the virtual model. Currently detailed 3D models can only be captured offline, and whilst the resulting model is animated, this is tricky to do accurately. Of course appearance can change quickly and such animated models might not capture the subtlety of face expression, eye-gaze and so on.

What we would like is systems that can capture the 3D model of the user's appearance as well as movement in real-time. This has been a goal of computer vision for decades, and recently we have started to see the integration of these techniques into immersive virtual environments. We will briefly discuss two systems: the Office of the Future project and the Blue-C system.

The Office of the Future project (see Fig. 11.1, *right*) integrated real-time 3D model capture with head-tracked video display (Raskar et al. 1998). A number of demonstrations have been done, the key theme of the research being real-time reconstruction of the user in front of the screen. To date only one-way systems have been built; that is, one user is reconstructed and presented remotely to another user, but it is expected that advances in capture and processing equipment will make this easier. Figure 11.1, right showed an example of a real-time reconstruction. The background is statically captured, and the user is updated at interactive rates. The view of the remote user is somewhat blocky. This is a facet of the underlying algorithms which creates a "voxel" representation of the user – effectively a reconstruction out of small virtual cubes. The technology works by using an array of cameras around the screen to take the video of the user.

The Office of the Future system simulates the situation of being across a desk from the other person. For more general immersive systems we have to deal with capturing a user standing up in a more immersive display. The Blue-C system (see Fig. 11.4) is an example of a system that manages to combine vision-based reconstruction with an immersive format display (Gross et al. 2003). The system is able to reconstruct a 3D volumetric model of the avatar inside a CAVE-like system of three walls. The key enabling technology is a type of display surface that can be switched from transparent to opaque, see Fig. 11.4, left. The walls are turned transparent at a high frame rate to capture the user, and when opaque the user's view is blocked and the environment displayed. Simultaneously images from around the user are captured and these are turned into a 3D volumetric model. Figure 11.4, right shows a view of a user standing in front of their own reconstruction.

Recently, with the availability of depth cameras, there has been a lot of interest in reconstruction of static and dynamic scenes. At the time of writing, the state of the art in real-time reconstruction of avatars is typified by the work of Dou et al. (2013). They are able to reconstruct a 3D mesh representation of a person based on a sequence of captured scans from a Microsoft Kinect camera, and then animate that 3D mesh depending on live data from that camera.

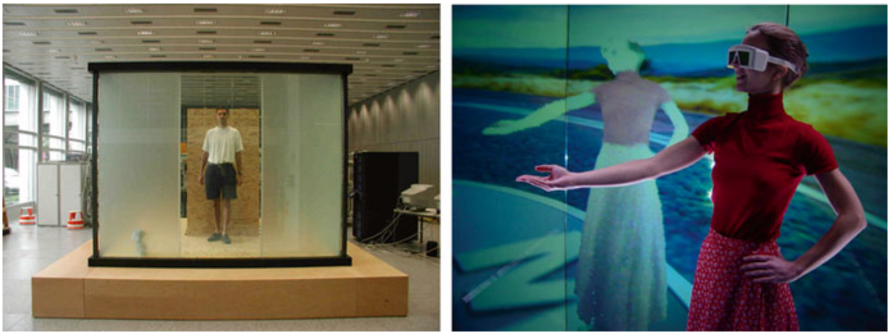

Fig. 11.4 *Left*, the walls of the Blue-C system. *Right*, a user standing in front of their own reconstruction (Both images courtesy of Markus Gross, the blue-c project, ETH Zürich)

Such systems provide us a way to capture a representation of the user into our virtual environment in real-time. However once we have this representation, it is hard to change it. There are two immediate reasons we might have for wanting to change the representation: making the representation appear visually consistent with the virtual environment into which it is inserted, and masking or changing the representation to change the identity or apparent role of the user. In many online games, for example, although users are expected to customise their avatars, customisation is done within some limits imposed by the theme of the world; many of them have strong science fiction or fantasy themes and players are forced, either by the customisation tools, or by the social rules of the system, to build appropriate avatars. More generally, when we look at potential applications, we see that there is a dichotomy emerging: reconstructing the user because this is the easiest way of capturing their posture and emotion; and wanting to hide aspects of this reconstruction such as actual appearance and perhaps even mask or tone down the actual emotion or posture. In the rest of this chapter we argue that even simple geometric avatars can support very successful collaboration between people, and that reconstruction and motion capture might be considered separately to be two “ideals” of immersive environments.

11.3 Impact of Avatars

In the previous discussion we focussed on how a single user is represented within the system. Now we turn to surveying evidence of the impact that representations have on other users. We start by looking at the potential response of a user to a simulated audience. This generates a very effective response, but is a very constrained social situation. In the second section we turn to evidence about interaction between immersed users. We then discuss what is different when we display a modelled or reconstructed avatar, and go on to give some specific examples of comparing different types of avatar representation.

11.3.1 Individual Response

We know that games have a significant impact on their players, and much of this comes from the interaction between players and avatars (Williams et al. 2008). Obviously, no matter the technology, the presence and representation of another person can have significant impact; we see such impacts in visual media such as film and TV. Here we do not want to get into the argument about differences in the impact of media representations, rather we just want to see what the potential space of impacts of avatars can be.

The first evidence we present about the power of avatar representation comes from studies of autonomous audiences of avatars. In a series of studies, Pertaub, Slater and colleagues have used simulations of audiences to investigate phobia of speaking in public (e.g. Pertaub et al. 2001). They simulate a variety of meeting scenarios using a small group of autonomous avatars (avatars with individually programmed behaviours). This is a mediated environment that causes many people, even experienced speakers, some mild anxiety. Experimental subjects who speak in front of an audience that is scripted to behave badly generally have a negative response to the situation on measures of social anxiety. Subjects who speak in front of an audience scripted to behave well, generally have a positive response to the experience. It should be noted that in those experiments, the avatars are not even reacting to the subject, but are following a fixed script of actions that range from applause (in the well-behaved audience) to muttering and turning away from the speaker (in the badly-behaved audience). See Fig. 11.5 for examples of audiences used in later studies in the series.

This system and variations of it have been used for initial trials as tools to assist with the treatment of certain types of mild phobias. Potential paradigms for this include exposure to a series of audiences that react in a more and more hostile manner. What this tells us is that having the avatars there can have an impact, even if the avatars are autonomous. What is uncharacteristic about this situation for the purposes of this chapter is that the user has no clue about the identity of the avatars. The subject might speculate that the avatars represent other individual people, or

Fig. 11.5 *Left*, an attentive audience of avatars. *Right*, a less attentive audience of avatars

that they might be controlled by the experimenter, but this is not supported or encouraged by any information that they are given. So it is left open whether the audience actually represents a group whilst it is in fact almost completely autonomous. The social situation is also constrained so that the subject doesn't attempt to engage with the audience or interact one on one. Of course these are exactly the properties that we need to support in a CVE. In fact, simulating more complex scenarios is very difficult, and the use of avatars even in structured conversations is hard to do satisfactorily (Johnsen et al. 2005).

11.3.2 Responses to User Avatars

Non-immersive CVEs are becoming quite prevalent and services like XBox Live make it very easy for players to log on to network services and find friends or enemies to socialise and play with. Such services have been available for much longer for PC and workstation class machines (e.g. Alphaworld from the Activeworlds Corporation has been active since 1995). Such worlds are well studied and they continue to attract media attention as well as academic attention (e.g., Schroeder 2011; Wardrip-Fruin and Harrigan 2004). However the interaction of people in the CVE and with each other is patently not like interaction in the real world. At one level this is obvious: virtual worlds are not based on real physical laws and social constraints, so why should we expect people to interact with them in that way? At another level it is controversial: obviously they are actually collaborating with another person, so we should rather ask whether this interaction is "normal". Certainly the type of interface has an effect. With systems similar to the Office of the Future system, a smile is captured and transmitted automatically, whereas with a typical game, if it is possible to make the user's avatar smile, this will have to be achieved through some user interface or inferred from the content of the conversation and gesture.

So far, most studies of collaboration in virtual environments have dealt with desktop systems (a variety of studies can be found in Churchill, Snowdon and Munro 2002; Schroeder 2011: 131–38). Further, the focus has typically been on the way in which the individual interacts with the system in order to collaborate rather than on the collaboration itself. This overlooks the complex interplay of the interactions between the avatars inside the virtual environment, though some recent work has examined how avatars interact with each other in terms of the social dynamic (Schroeder 2011: 61–91).

Hindmarsh et al. (2000) showed that collaboration on desktop systems has severe limitations due to the limited field of view and difficulties in referencing parts of the world. The study also shows that participants have problems in being able to take their partner's point view inside the environment. Typical errors that users would make include misinterpreting a pointing gesture or not realising that the other user can not see the object being pointed at. In immersive systems, many of these problems are overcome because of the better capture of participant behaviour through tracking and the wide field of view of the displays (Heldal et al. 2005). This means that participants are much more peripherally aware of their collaborator. Peripheral awareness supports communication about the task at hand but it also supports the maintenance of the collaboration itself since the participants rarely lose track of their collaborator.

A few studies have investigated how collaboration is affected by the use of various combinations of display system. A number of studies have shown that immersed participants naturally adopt dominant roles when collaborating with desktop system participants – even when they don't know what type of the system the other persons are using (Slater et al. 2000; Heldal et al 2005). Studies by Schroeder et al. (2001) and Roberts et al. (2003) have investigated the effect of display type on collaboration of a distributed team. Schroeder et al. (2001) showed that doing a spatial task together using a CAVE-like system, in this case a Rubik's cube type spatial puzzle, can be practically as good as doing the same task face-to-face, whereas the same task takes considerably longer on desktop systems. Roberts et al. (2003) have shown that it is possible to successfully do a construction task (building a gazebo) in networked CAVE-like systems, a task that requires that partners work closely together and in a highly interdependent way. With the cube task and gazebo tasks mentioned above, perhaps the most notable aspect of the interaction is the amount of movement that the users make when gesturing. In the cubes trials we would often see the users making very rapid pointing gestures simultaneously with voice gestures – something that is very hard to synchronise on a puppeteered interface. Users make quite complex spatial references relative to their own body ("on my left"), the body of the other user ("down by your feet") and objects in the environment ("next to the red and blue one"). Breakdowns of these types of reference are rare because it is easy to see whether your collaborator is following your gesture by watching their gaze. Figure 11.6, left shows an example view of two users in CAVE-like systems collaborating over the cube puzzle. Figure 11.6, right shows tracks of the head and hand gestures from a network trial where two users collaborate to build a gazebo (Wolff et al. 2004). The amount of head and hand gesturing is very apparent, and in fact we can even tell a difference between instructor (right) and pupil (left): the instructor makes many more gestures to indicate to surrounding objects and they even pick up a tool to help point. Spatial references of these types are discussed in Steed et al. (2005) and Heldal et al. (2005).

11.4 Presence and Co-presence

In the previous two sections we have discussed technology that affords what we have claimed to be novel styles of collaboration at a distance and we have given preliminary evidence of the impact of these technologies. We now turn to a broader discussion of the factors that might affect co-presence, or interpersonal interaction more broadly conceived. These factors can be grouped into three categories: *modality*, *realism* and *context*.

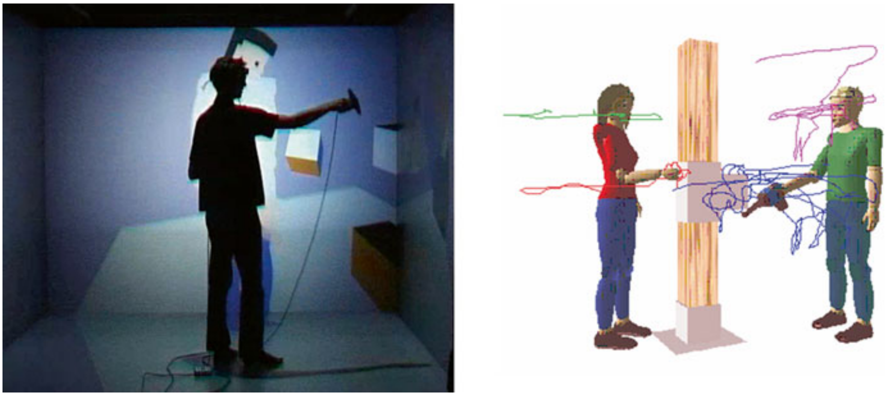

Fig. 11.6 *Left*, two users, one in foreground and one on the screen, in a CAVE-like system collaborating with the representation of another user in the cube task (Image courtesy Ilona Heldal, Chalmers University of Technology, Gothenburg). *Right*, a visualisation of two users in the gazebo task with tracks indicating recent head and hand motion of both (Image courtesy of Robin Wolff, The Centre for Virtual Environments, University of Salford)

11.4.1 Modality

The sensory modality whereby users interact with the system is a good starting point because it is relatively straightforward. The vast majority of systems are visual and auditory. Haptic systems and systems for smell and taste have been developed, and haptic systems will be used in certain settings (Kim et al. 2004), but this essay can confine itself to visual and auditory systems. These two sensory modalities also provide us with the bulk of our information in our face-to-face encounters with others in the physical world.

Two findings are important for CVEs: one is that people ‘compensate’ for missing cues. For example, when they cannot see certain parts of their interaction with each other, they put this part of interaction into words. Conversely, they may use exaggerated body movements to underline something they are saying. How, and under what circumstances they do this, has not been systematically investigated, though there are several potential methods for capturing and analyzing interaction (Schroeder et al. 2006). It is noteworthy that this is something that people will often be unaware of. But clearly, in this respect interaction in immersive CVEs is quite different from face-to-face interaction, and immersive systems differ in terms of how they support auditory and visual interaction. This ‘compensating’ behaviour (which will be quite different for situations with tracked as opposed to reconstructed avatars, for example) is perhaps the single most important aspect of interaction requiring research. Compensating is possibly the wrong term here, since users are also able to ignore the absence of many cues: it would be easy, for example to list a host of visual and auditory cues that users do not comment on as being ‘missing’. Conversely, they are able to make creative use of the ‘superpowers’ that CVEs afford them without finding this remarkable – for example, picking up oversize objects.

The second important aspect of sensory modality is how the senses relate to one another in CVEs. Sallnas (2004), for example, has shown that 'voice' outweighs (or overshadows) the visual sense in the setting that she studied. This finding has important ramifications. Anecdotally (e.g. Finn et al. 1997), the greatest obstacle, or the most annoying feature of, videoconferencing is the sound quality – not the image of the other person. The balance between the two will vary with the applications. But a considerable amount of effort has been devoted to achieving realistic 3D sound, not to speak of realistic visual environments: What if these are far outweighed by being able to hear the nuances in the other person's voice with high fidelity? Much research remains to be done on the interrelation between these two – most common – modalities.

11.4.2 Realism

Realism can be subdivided into several components: eye gaze, facial expressions, body movement and gesture, and the overall appearance of the environments. But apart from these different elements, the critical distinction here is between appearance and behavioural realism (Garau et al. 2003, see also Blascovich 2002), or between faithfulness of the representation of how the avatar looks and how they behave (move, blink their eyes, etc.).

It is well known that eye gaze is critical for interpersonal interaction. Various means of tracking eye gaze have been developed. Note that one basic obstacle for immersive systems (such as the CAVE-like and blue-c systems discussed earlier) is that, if users need to wear 3D glasses to see a 3D space, the system will need to be designed to track the eyes behind the glasses. Garau et al. (2003) showed that a simple model of eye-gaze that takes into account, for example, average eye saccade frequencies, changes the perceived realism, but obviously such a model can't convey important information such as attention.

Eye gaze and facial expression are critical for interpersonal interaction, and bodily movement and gesture for successful instrumental interaction. Note, however that in many circumstances, people seem to be able to cope with highly unrealistic avatars or not to pay much attention to them (Heldal al. 2005).

As for the environment, this is important for orientation. Note that in the environment, cues can be missing in a way that is different from real-world environments. For example, when people walked around in a landscape where many features are similar and where there is no obvious horizon, people complained about not knowing whether they had been to particular landmarks before, and found it difficult in general to orient themselves (Steed et al. 2003; Heldal et al. 2005). In the equivalent real-world scenario, it is much harder to experience this kind of confusion because so many cues in a landscape tell us where we have been (horizon, different experience of objects in relation to each other, etc.) The use of landmarks or other tools for orientation (or footprints to mark where one has been) are easy to implement, but again, a key question is in which circumstances these are needed and effective.

11.4.3 Context

The importance of context is obviously multifaceted; unlike the other two which are clearly delimited, this is a catchall category. Therefore context can be broken down into subcomponents:

What is the relation to the other person(s)? Are they people one is familiar with, or people one is interacting with for the first time (Steed et al. 2003)? What is the task? Perhaps it is unspecific socializing, in which case it seems inappropriate to call it a 'task'. And finally, but not least, what is the size of the group? If, for example, one is interacting with a larger group, it is difficult in a CVE, unlike in the real world, to monitor the behaviour of several copresent others simultaneously. Put differently, when one is interacting with several other people in the VE, does the attention one can pay to any one of the other people become 'diluted'? (This is much more likely in a VE because mutual awareness is more difficult).

One reason for making these distinctions is that they highlight the combinations of features that CVEs need, as well as those that are unlikely. For example, in the various applications used in the Strangers and Friends trial (Steed et al. 2003), there are many examples when the tracked bodies and gestures were critical to joint coordination, but the absence of eye gaze and facial expressions was not an important obstacle in this set of tasks.

This draws attention to a crucial point: in *immersive* collaborative systems, the task will likely be one in which people have to focus their attention on the space and the objects in it (which includes, for joint orientation, the other person(s) avatar body), but in these systems people may not need to focus on each other's facial expressions. Furthermore, they may not need realistic-looking bodies; it will be sufficient to be able to follow the other's movements and gestures – their appearance is irrelevant for tasks such as manipulating objects together, building things together, exploring the space and the like (Steed et al. 2003). One way to underline this is by noting that if there is more than one other person in the immersive space, the most important feature of the avatar bodies of others is that the user is able to tell them apart, not what they look like. Note that these features – a small group of tracked life-size avatars, their bodies perhaps distinguished by being different colours (Mr. Blue, Mr. Green, etc.) – will, in turn, have an important, perhaps 'overshadowing', influence on co-presence.

If we now add that immersive spaces are likely to contain only a small number of (non- co-located) people at any given time, it is possible to get a sense of the requirements of immersive spaces for collaboration: for instrumental tasks, all those aspects of the environment that facilitate joint orientation and manipulation should be adequate to the task (whereas appearance of the avatar, including expression, is relatively insignificant). In contrast, for tasks mainly involving interpersonal communication, facial expressions will be important – *but*, it is unlikely that these will play a dominant role in a shared immersive *space*: after all, people will not spend much time in close face-to-face contact in these spaces. When eye gaze *is* useful in this case, it will be mainly for people to indicate to the other person where they are looking (as opposed to, say, conveying their mood or emotional state) (Steptoe et al. 2009). Finally, there are various ways to design expressive avatar faces that have the capability to facilitate interaction without relying on capturing the user's real facial expression or their eye gaze (Bailenson and Beall 2006; Garau et al. 2003).

In immersive spaces then, the expressiveness of faces (including eye gaze) is likely to be highly context-dependent: the office in which one collaborates with another person in a trauma counselling or public speaking training or acting session (where facial expressions are critical) will be quite different from that required for a molecular visualization or vehicle design session (where joint orientation and referencing objects is most important). Perhaps an avatar face with the possibility to express only certain emotions or certain acknowledgements of the other person's effort will not only be sufficient in immersive space – but superior since it will reduce the 'cognitive load' in the task.

11.5 End-States

Many of the issues in the study of co-presence and collaboration can be illuminated by considering two end-states of CVE technology: captured versus puppeteered or tracked (for the following, see also the extended discussion in Schroeder 2011: 275–92). In the following discussion we will use the term *simulated avatars* to refer collectively to puppeteered or tracked avatars.

In the simulated avatars end-state, the environment can be configured so that any appearance and different behaviours are possible. In particular the appearance of the avatar is modelled prior to the experience so that it can fit with the visual appearance of the world. For example, everyone in a game such as World of Warcraft has a user avatar that fits with the overarching fantastic visual theme of that world. With captured avatars, such as the capture of the person and the scene in blue-c, appearance is limited to a faithful recreation of real world. This latter will have some advantages from the user's point of view: since they know what to expect, they can experience the environment (and also the devices that they use and that are used to create it) naturally and behave accordingly. The point is, however, that even the other end-state, of completely computer-generated artificial worlds with simulated avatars, will need to be designed so as to put constraints and possibilities into the environment that the user experiences as being at ease with; an environment that they feel at home in and that they can establish good interpersonal relations in. And here, as we have seen, users are able to accept certain 'unnatural' features of CVEs (not caring about avatar appearance), they adapt easily to some others (absence of touch), and find yet others impossible or difficult to cope with (being unable to distinguish between others' avatars). Nevertheless, CVEs will need to provide them with a place for being there together in which they are able to do things and interact with each other as they need to, for a variety of technologies and situations.

A simple point that highlights this difference between the two end-states is that in a captured environment, people will be certain of another person being there, just as in a videoconference (they are, after all, being captured). In generated CVEs with simulated avatars, on the other hand, mechanisms need to be put in place to ensure that users are 'really there' since the presence of avatar is not sufficient to establish that the person that was controlling that avatar is still connected to the system. Even if the avatar is moving, it may be automated or someone else may have taken control. This is taken to its logical conclusion in experiments in the BEAMING project, where avatars can blend between control by a human through to complex automated behaviour (Friedman and Tuchman 2011).

If we think about general captured and simulated immersive environments and what they may one day develop into, then it becomes clear that much of the technology is already in place, and that two end-states will be quite different: captured environments will take the form of 3D holographic videoconferencing. In other words, they will be similar to the blue-c system, except that they will be able to capture larger extended spaces accurately and put many interacting people into the shared space without the encumbrances of 3D glasses and the like. Simulated environments, on the other hand, will be extensions of today's immersive systems, though again, the environments and avatars will appear completely realistic (including in behaviours) and again, the encumbrances of 3D glasses and position-tracking equipment and the like will be minimized. In other words, both types of systems will provide perfect presence, co-presence and interaction with the environment – except that in the one case, the environment will reproduce persons and the world around them in 3D, and in the other, it will generate persons' likenesses and virtual worlds.

A more realistic expectation is that there will be a variety of systems that approximate these end-states, and these approximations are *unlikely* to be simply steps towards either *completely* realistic computer-generated or 3D video-captured systems and environments. Instead, they will reflect the combination of particular features that are required for successful interpersonal interaction and interaction with the environments. For example, there may be environments that combine captured faces with generated environments, or vice versa. Additionally the environments will have different spatial extents: some will display the face-to-face extent plus perhaps some nearby objects that people are working on together, others will display the extended extent of a large space that needs to be jointly visualized or explored. Again, these may not be realistic environments, but, for example, environments which focus on the fidelity of certain parts of the environments and not others, feature certain facial characteristics that convey essential information but leave out a host of information that is conveyed in face-to-face information, and consist of environments designed to facilitate easy orientation and mutual awareness by means of various 'artificial' features. These 'artificial' features may, for example, consist of facial expressions that are 'enhanced' to facilitate interpersonal awareness, or 'enhanced' to provide a better awareness of the environment.

It is possible then to recognize that the two end-states, with their quite different possibilities and constraints, may be combined in some way. It may be that the computer-generated end-state has distinct advantages in being much more flexible in terms of which features of modality, appearance (the face, body and environment) and context can be combined to support interaction in different ways. The constraint in this case is that the lack of realism will need to be compensated for in particular ways. The video-captured end-state, on the other hand, offers different possibilities, for example providing a realism that the user can trust in a different way, but it is constrained by capturing the real appearance of people and of the environment without being able to enhance or reconfigure them in a powerful way.

The combination of thinking about two end-states and thinking about systems for captured and simulated environments on the way towards them therefore allows us to recognize that there are different types of affordances and requirements that will be necessary for various scenarios for CVEs. We are still far from a good understanding of the likely future uses and configurations of immersive CVE systems. However, we can channel research towards forms of CVEs and CVE uses that will yield insights about the end states we have identified. These insights can then benefit the improvement of tools that support collaboration at-a-distance.

11.6 Challenges

We have described the range of current CVE technologies from computer games consoles through to highly-immersive CAVE-like systems that support real-time capture of the user standing within them. Given the fact that people invest so much time in them, collaboration through desktop interfaces has the capability to be compelling, though it is easy to see that in many ways people do not collaborate together in a similar way as they would in the real world. In an immersive system we see some evidence of people behaving as if the situation were the real world – that is, using voice and gesture as they might in a similar situation in the real world. We also see complex gestures and very fast paced interaction of types that are impossible in other media.

The question we have opened up is how CVE technology will develop in the long term. There is a push towards making real-time captured avatar systems, where the users have a faithful 3D representation of their collaborators. However we have argued that supporting presence and co-presence can be done with simulated avatars, and in some situations these will be preferred.

Aside from obvious technical challenges in further developing captured, tracked and puppeteered avatars, there are many challenges in studying collaboration with these technologies and designing to support better collaboration. We can do this by looking at remaining misunderstandings, looking at personality bias arising from collaborative situations and studying how people use these technologies over longer periods. One challenge we would highlight is understanding how well collaborators understand the intention of the others as this is one key to successful communication – being able to tell what the other person intends to do based on the subtle gestures and eye gaze alongside their speech.

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Chapter 12
Presence-Inducing Media for Mental Health Applications

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Abstract Presence inducing media have recently emerged as a potentially effective way to provide general and specialty mental health services, and they appear poised to enter mainstream clinical delivery. However, to ensure appropriate development and use of these technologies, clinicians must have a clear understanding of the opportunities and challenges they will provide to professional practice.

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This chapter attempts to outline the current state of clinical research related to the use of presence-inducing technologies, virtual reality in particular. Through presence, virtual reality helps the patient both to confront his/her problems in a meaningful yet controlled and safe setting. Further, it opens the possibility of experiencing his/her life in another, more satisfactory, way. In fact, virtual reality therapists are using presence to provide meaningful experiences which are capable of inducing deep and permanent changes in their patients. Finally, the chapter discusses the possible evolution of presence-inducing media from virtual reality to augmented reality, to interreality.

Keywords Virtual reality • Psychological treatment • Mental health • Presence • Clinical psychology • Augmented reality • Interreality

12.1 Introduction

What is the possible role of presence in mental health treatment? How will the use of presence inducing technologies impact mental health therapists and patients? A panel of 62 psychotherapy experts tried to answer these questions using the Delphi methodology (Norcross et al. 2002).

According to their responses, the use of presence-inducing technologies may play an important role in the near future. Within the leading mental health treatments, Virtual Reality (VR) and computerized therapies ranked 3rd and 5th, preceded only by homework assignments (1st), relapse prevention (2nd) and problem solving techniques (4th). Additionally, traditional psychotherapy interventions such as hypnosis (32nd), paradoxical interventions (33rd) or dream interpretation (35th) were predicted to drastically diminish. These data are confirmed by two growing trends (Gaudiano and Miller 2013): the declining psychotherapy utilization and the increasing impact of evidence-based medical practices.

Even if these data may seem provocative to some therapists, there is no doubt that rapid and far-reaching technological advances are changing the ways in which people relate, communicate and live (Laxminarayan and Istepanian 2000); the possible impact of presence in therapy could be even higher than that offered by new communication technologies. In fact VR, the most often used presence inducing technology, is at the same time a technology, a communication interface and a compelling experience (Biocca and Levy 1995).

To ensure appropriate development and use of these technologies, clinicians must have a clear understanding of the opportunities and challenges they will provide to professional practice. As underlined by Clough and Casey (2011): “Most importantly, although electronic therapies have their place in psychology, there is more to the use of technology than simply broadening the reach of psychological interventions. Many clients will still want face to face therapy, and the use of technological adjuncts may be able to enhance this experience. It is important that researchers and clinicians begin to become aware of and build on these possibilities." (p. 290). To support this goal, the chapter outlines the current state of clinical research related to the use of presence-inducing technologies, virtual reality in particular.

12.2 Virtual Reality as Presence-Inducing Technology

Since 1986, when Jaron Lanier used the term for the first time, VR has been usually described as a collection of technological devices: a computer capable of interactive 3D visualization, a head-mounted display and data gloves equipped with one or more position trackers. The trackers sense the position and orientation of the user and report that information to the computer which updates the images for display in real time.

However, in the behavioral sciences, VR is usually described as "an advanced form of human-computer interface that allows the user to interact with and become immersed in a computer-generated environment in a naturalistic fashion" (Schultheis and Rizzo 2001, p. 82).

In general, what distinguishes VR from other media or communication systems is the sense of *presence* (Baños et al. 1999; Riva 2007, 2008; Riva and Mantovani 2012a, b; Steuer 1992; IJsselsteijn and Riva 2003): VR can be considered the leading edge of a general evolution of present communication interfaces such as television, computer and telephone whose ultimate goal is the full immersion of the human sensorimotor channels into a vivid and interactive communication experience. Specifically, we argue that the higher sense of presence induced by VR may be used to elicit optimal experiences that will support the process of change (Botella et al. 2012; Baños et al. 2008; Riva 2006, 2012a, b; Riva et al. 2006a, b, 2012a, b).

According to Csikszentmihalyi (1975, 1990), individuals preferentially engage in opportunities for action associated with a positive, complex and rewarding state of consciousness, defined as "optimal experience", or "flow." There are some exceptional situations in real life in which the activity of the subject is characterized by a higher level of presence. In these situations the subject experiences a full sense of control and immersion. When this experience is associated with a positive emotional state, it can create a flow state. An example of flow is the case wherein a professional athlete is playing exceptionally well (positive emotion) and achieves a state of mind where nothing else matters but the game (high level of presence). For Ghani and Deshpande (1994) the two main characteristics of flow are (a) total concentration in an activity and (b) the enjoyment which one derives from the activity. Moreover, these authors identified two other factors affecting the experience of flow: a sense of control over one's environment and the level of challenge relative to a certain skill level.

A corollary of the proposed vision is critical for our goals: it is possible to design mediated situations that elicit a state of flow by activating a high level of presence (Morganti and Riva 2004; Riva 2004, 2012b; Riva et al. 2012a, b; Waterworth et al. 2003).

The work of Gaggioli (Gaggioli 2004, 2012; Gaggioli et al. 2003, 2013) supports this vision. Gaggioli (2012) compared the experience reported by a user immersed in a virtual environment with the experience reported by the same individual during other daily situations. To assess the quality of experience, the author used a procedure called Experience Sampling Method (ESM), which is based on repeated on-line assessments of the external situation and personal states of consciousness (Csikszentmihalyi and LeFevre 1989). Results showed that the VR experience was the activity associated with the highest level of optimal experience (22 % of self-reports). Reading, TV viewing and the use of other media—both in the context of learning or leisure activities—obtained lower percentages (respectively 15 %, 8 % and 19 % of self-reports) of optimal experiences.

To verify the link between VR and optimal experiences in a clinical setting, the "V-STORE Project" investigated the quality of experience and the feeling of presence in a group of ten patients with Frontal Lobe Syndrome who were involved in VR-based cognitive rehabilitation (Castelnuovo et al. 2003). The project employed the Experience Sampling Method (Csikszentmihalyi and LeFevre 1989) for repeated on-line assessments of the external situation and the emotional, cognitive and motivational components of daily experience of these patients in a 1 week period, including traditional cognitive rehabilitation and sessions of exposure to the V-STORE VR environment. In addition, after the VR experience the project employed the ITC-Sense of Presence Inventory (Lessiter et al. 2001) to evaluate the feeling of presence induced by the VR sessions. Findings highlighted the association of VR sessions with both positive affect and a high level of presence. In particular, during the VR sessions, the "spatial presence," the first scale of the ITC-Sense of Presence Inventory, was significantly correlated with the positive psychological feelings of "being free" ($r = 0.81$, $p < 0.01$) and "being relaxed" ($r = 0.67$, $p < 0.05$).

12.2.1 The Link Between Presence and Therapeutic Change

How is it possible to achieve the desired change in a patient? This question has many possible answers according to the specific psychotherapeutic approach; however, in general change occurs through an intense focus on a particular instance or experience (Wolfe 2002). By exploring this experience as thoroughly as possible, the patient can relive all of the significant elements associated with it (i.e., conceptual, emotional, motivational, and behavioral) and make them available for reorganization. Within this general model there exist many other methods, including the insight-based approach of psychoanalysis, the schema-reorganization goals of cognitive therapy, the functional analysis of behavioral activation, the interpersonal relationship focus of interpersonal therapy, and the enhancement of experience awareness in experiential therapies.

What are the differences between them? According to Safran and Greenberg (1991), behind the specific therapeutic approach there are two different models of change: bottom-up and top-down. Bottom-up processing begins with a specific emotional experience and leads eventually to change at the behavioral and conceptual level; top-down change usually involves exploring and challenging tacit rules and beliefs that guide the processing of emotional experience and behavioral planning.

These two models of change are focused on two different cognitive systems, one for information transmission and one for conscious experience, both of which may process sensory input (Brewin 1989; Kahneman 1973, 2002, 2011). Stanovich and West (2000) noted that in the last forty years, different authors from different disciplines suggested a two-process theory of reasoning. Even if the details and specific features of these theories do not always match perfectly, nevertheless they share the following properties:

- Intuitive operations are faster, automatic, effortless, associative, and difficult to control or modify.
- Rational operations, instead, are slower, serial, effortful, and consciously controlled.

The differences between the two systems are described in Table 12.1.

Table 12.1 Differences between the Rational and the Intutive systems

	Rational System	Experiential/Intuitive System
Main Features	Rational: Conscious, deliberative and affect-free	Intuitive: Preconscious, automatic, and intimately associated with affect
	Abstract: Encodes reality in symbols, words, and numbers	Concrete: Encodes reality in images, metaphors, and narratives
	Analytic: Connections by cause-and-effect relations	Associative: Connections by similarity and contiguity
	Slower processing: Capable of long delayed action	Rapid processing: Oriented toward immediate action
	Less resistant to change: Can change with speed of thought	Resistant to change: Changes with repetitive or intense experience
	More highly differentiated: nuanced thinking	Differentiated: Broad generalization gradient; categorical thinking
	More highly integrated: Organized in part by cross-situational principles	Integrated: Situationally specific; organized in part by cognitive-affective modules
	Experienced actively and consciously: We believe we are in control of our thoughts	Experienced passively and preconsciously: We are seized by our emotions
	Not Self-evident: Requires justification via logic and evidence	Self-evidently valid: "Experiencing is believing"
How it works	Operates by reality principle (what is logical and supported by evidence)	Operates by hedonic principle (what feels good)
	Acquires its beliefs by conscious learning and logical inference	Acquires its schemas by learning from experience
	More process oriented	Outcome oriented
	Behavior mediated by conscious appraisal of events	Behavior mediated by "vibes" from past experience

The existence of two different cognitive systems is also clearly shown by the dissociation between verbal knowledge and task performance: people learn to control dynamic systems without being able to specify the nature of the relations within the system, and they can sometimes describe the rules by which the system operates without being able to put them into practice.

Even if many therapeutic approaches are based on just one of the two change models, a therapist usually requires both (Wolfe 2002). Some patients seem to operate primarily by means of top-down information processing, which may then lead the way to corrective emotional experiences. For others, the appropriate access point is the intensification of their emotional experience and their awareness of both it and its related behaviors. Finally, different patients who initially engage the therapeutic work through top-down processing only may be able to make use of bottom-up emotional processing later in the therapy.

In this situation, the sense of presence provided by advanced technologies can be a critical advantage, in VR in particular (Botella et al. 2012; Riva and Gaggioli 2008; Riva et al. 2012a, b). Used appropriately, it is possible to target a specific cognitive system without any significant change in the therapeutic approach. For instance, behavioral therapists may use a virtual environment for activating the fear structure in a phobic patient through confrontation with the feared stimuli; a cognitive therapist may use VR situations to assess situational memories or disrupt habitual patterns of selective attention; experiential therapists may use VR to isolate the patient from the external world and help him/her in practicing the right actions; psychodynamic therapists may use VEs as complex symbolic systems for evoking and releasing effects.

VR contributes an important benefit to treatment because it affords a feeling of presence that can rarely be achieved with imaginal exposure. In fact, a central element of VR is that it provides the person *a place where he/she can be placed* and live the experience. In this line Baños et al. (2005) compared the sense of presence between virtual and imaginary environments. Participants were randomly assigned to one of the two conditions (imagined versus virtual spaces) and the subjective sense of presence was measured in three moments (beginning, middle, and end). Results showed that the participants in "imagery" spaces indicated a decrease of their sense of presence, whereas the opposite occurs in participants in "virtual" spaces. That is, VR seems to help users to stay "there" as time goes by; it provides a "physical" context in which the self can be placed. In fact, VR can also be described as an *advanced imaginal system*: an experiential form of imagery that is as effective as reality in inducing emotional responses (North et al. 1997; Vincelli 1999; Vincelli et al. 2001b). As underlined by Baños et al. (1999), the VR experience can help the course of therapy for "its capability of reducing the distinction between the computer's reality and the conventional reality." In fact, "VR can be used for experiencing different identities and… even other forms of self, as well" (p. 289). The possibility of structuring a large amount of realistic or imaginary controlled stimuli and, simultaneously, of monitoring the possible responses generated by the user of the technology offers a considerable increase in the likelihood of therapeutic effectiveness, as compared to traditional procedures (Riva and Davide

2001). As noted by Glantz et al. (1997): “One reason it is so difficult to get people to update their assumptions is that change often requires a prior step – recognizing the distinction between an assumption and a perception. Until revealed to be fallacious, assumptions constitute the world; they seem like perceptions, and as long as they do, they are resistant to change.” (p. 96). Using the sense of presence induced by VR, it is easier for the therapist to develop realistic experiences demonstrating to the patient that what looks like a perception – e.g., a body image distortion – in fact is a result of his/her mind. Once this has been understood, individual maladaptive assumptions can then be challenged more easily.

However, as underlined by Price and Anderson (2007) presence alone is not enough to guarantee a positive clinical outcome. In their clinical study, that used a virtual airplane to treat individuals with fear of flying, these authors explored the relation between presence, anxiety, and treatment outcome. The results support presence as a conduit that enabled phobic anxiety to be expressed during exposure to a virtual environment. Nevertheless, presence was not supported as contributing to treatment outcome: feeling present during exposure may be necessary but not sufficient to achieve benefit from VR therapy. Recently Côté and Bouchard (2009) investigated the cognitive mechanisms associated with therapeutic change after a VR exposure treatment. The analyses showed that changes in perceived self-efficacy and dysfunctional beliefs were the best predictors of change.

12.2.2 The Link Between Presence and Emotions

According to current scientific literature (see the other chapters of the book as well) sense of presence in VR is determined by both features of the medium (characteristics of the visual displays, sensory richness, vividness, realism, content, etc.), and characteristics of the user. Literature on psychological aspects of presence has studied primarily perceptual and cognitive aspects of VR representations. However, in order for VR to be clinically relevant in a psychotherapeutic context, the study of emotions is critical.

Huang and Alessi (1999) have pointed out that even if emotions are an essential part of how people experience the world, most definitions of presence are cognitively or environmentally based, generally ignoring emotions. However, emotions play an important role in our subjective judgments and automatic responses, influencing our learning and how we understand, describe and react to the world and ourselves.

On the other hand, one of the most important effects of presence for clinical practice is that a virtual experience may evoke the same reactions and emotions as a real experience. For instance, Slater and colleagues (2006a) used VR to reproduce the Stanley Milgram’s 1960s experimental approach: the participants were invited to administer a series of word association memory tests to a female virtual human (avatar) representing the stranger; when the avatar gave an incorrect answer, the participants were instructed to administer an ‘electric shock’ to her, increasing the voltage each time; the avatar then responded with increasing discomfort and protests, eventually demanding termination of the experiment. Their results show that in spite of the fact that all participants knew for sure that neither the avatar nor the shocks were real, the participants who saw and heard her tended to respond to the situation at the subjective, behavioural and physiological levels as if it were real. As noted by the researchers (2006a), "In the debriefing interviews many said that they were surprised by their own responses, and all said that it had produced negative feelings – for some this was a direct feeling, in others it was mediated through a 'what if it were real?' feeling. Others said that they continually had to reassure themselves that nothing was really happening, and it was only on that basis that they could continue giving the shocks."

This effect is even stronger in clinical patients. As will be described later, numerous studies have shown that virtual environments are capable of increasing subjectively reported anxiety in phobic participants when they are confronted with a virtual threatening situation. Furthermore, it has been proven that the "virtual exposure" technique reduces anxiety in phobic participants. Regenbrecht et al. (1998) investigated the relationship between presence and fear of heights, and the results showed that presence was the best predictor of fear.

Slater et al. (1999) also found that presence tended to amplify the subject's emotional responses. In two studies (Baños et al. 2000, 2004), Baños and colleagues have found important differences in the responses to VR between non patients and mental health patients (individuals suffering from claustrophobia, fear of flying, arachnophobia and eating disorders, including anorexia and bulimia nervosas) that proved the importance of emotions to induce presence in clinical users. Participants were immersed for 15 min in one of four different "clinical" virtual environments (scenarios for the treatment of claustrophobia fear of flying, spider phobia, and body image distortion).

After the immersion, participants filled out a questionnaire about presence and reality attribution (PRJQ) and the results showed that patients felt themselves more present in the virtual environments than non-patients, and they also attributed more realness to the scenarios (Baños et al. 2000). Furthermore, regarding non-patient participants, the items of the presence questionnaire inquiring about emotions were not relevant; they were excluded from the factor analysis because they failed to have the necessary factorial loading. However, for the clinical sample, the virtual environments capable of eliciting emotions in the participants, and in this case, the items related to emotions and sensations proved to be the most related to presence. Furthermore, for clinical participants, the very high quality of the computer displays was not a key issue in eliciting presence and reality judgment. In contrast, these items about media variables (i.e., quality of graphics) were significant for the normal population, indicating that in this case users might be acting more as observers than as participants in the virtual world. These studies seem to indicate that emotions felt in the virtual environments are an important variable to consider when investigating why some people feel themselves more present in virtual environments than others.

Along this line of thinking, Hoorn et al. (2003), in a paper entitled "Virtual Reality: Do not augment realism, augment relevance" argue that VR experience gains more from increased emotional relevance than from higher realistic solutions. These authors claim that to design VR, experience is more important than technology, and they recommend that VR designers focus on developing features that sustain relevance to the goals and concerns of the user. According to them, "The sophisticated technology of VR may be powerful but it is not enough to initiate a reality-experience that is true-to-life. Basic to reality-experiences that are true-to-life is that the experience is emotionally loaded (…) The basis of emotion psychology is personal meaning: without relevance no emotion occurs. Thus VR needs personal relevance for the user to arrive at the intended (total) involvement as manifested in the experiences of immersion and presence."

Baños et al. (2004) have shown that the emotional content of a VR environment influences the user's sense of presence, modulating the effect of other formal variables like immersion. These authors compared three immersive systems (a monitor, a big screen, and a head mounted display) and two virtual environments, one involving emotional content and the other not. The results suggested that both immersion and affective content have an impact on presence, but immersion was more relevant for non-emotional environments than for emotional ones. These results were extended for stereoscopy. It was found that stereoscopic presentation is not so crucial a and are more relevant for non-emotional environments than for emotional ones (Baños et al. 2008).

Riva and colleagues (2007a, b) also analyzed the possible use of VR as an affective medium focusing on the relationship between presence and emotions. Their data showed a circular interaction between presence and emotions: on one side, the feeling of presence was greater in the "emotional" environments; on the other side, the emotional state was influenced by the level of presence.

In a recent meta-analysis Zheng and colleagues (2014) explored the relation between sense of presence and level of anxiety in clinican and non clinical studies. Their data showed a medium effect size for the correlation between sense of presence and anxiety. Moderation analyses revealed that the effect size of the correlation differed across different anxiety disorders, with a large effect size for fear of animals and a no to small effect size for social anxiety disorder. Further, the correlation between anxiety and presence was stronger in studies with participants who met criteria for an anxiety disorder than in studies with a non-clinical population.

Taking this and the empirical data into account, it appears that emotions may play a role both as causes and as consequences of presence (Bouchard et al. 2008). It may be said that the higher the presence, the higher intensity of emotions the user experiences. Therefore, if the focus is on designing applications capable of eliciting emotions with the goal of reducing or modifying them (as in psychological therapy), the environments must be able to produce the feeling of being "there" and of being "real" in the users. However, the opposite could also be claimed: the higher the intensity of the emotions and feelings, the higher the presence and reality judgment. From this point of view, the focus for psychological treatment would lie on designing relevant environments, providing intellectually and/or emotionally significant content for the specific sample involved in the treatment. For instance, a recent study by Gorini and colleagues (2009) comparing a sample of 20 Mexican participants – 8 living in El Tepeyac, a small rural and isolated Mexican village characterized by a very primitive culture, and 12 highly civilized inhabitants of Mexico City – clearly showed that VR exposure to a relaxing environment has different physiological and psychological effects according to the cultural and technological background of the users.

Data from this study suggest a vision of presence as a social construction, in which reality is co-constructed in relationship between actors and their environments through the mediation of physical and cultural artifacts. Gorini and colleagues (2011) found that both immersive technology and a meaningful narrative context influence the users' sense of presence, providing a more compelling experience than a non-immersive and non-contextualized virtual space.

On one side, as demonstrated by Villani and colleagues (2012), it is even possible feel more present in a virtual simulation than in a real simulation. This is allowed by the coherence between the features of the virtual environment and the expectations related to the simulated experience .

On the other side, as shown by a recent study (Pallavicini et al. 2013a) technological breakdowns are critical issue for the efficacy of VR in exposure-based therapies.

In the study 39 undergraduate were exposed to a stressful situation using text, audio, video, and VR introducing technological breakdowns. Psychometric scores and psychophysiological indexes showed that VR was less effective than other procedures in eliciting stress responses. Moreover, VR induced a sense of presence similar to that experienced during the exposition to other media.

In conclusion, technological breakdowns significantly reduce the possibility of VR eliciting emotions related to complex real-life stressors. Without a high sense of presence, the significant advantages offered by VR disappear and its emotional induction abilities are even lower than the ones provided by much cheaper media (Pallavicini et al. 2013a).

12.3 Virtual Reality in Mental Health Treatments

Research over the past three decades has shown that the "in vivo exposure" technique is quite effective in treating several psychological problems, especially anxiety disorders. For these disorders, avoidance of feared situations is an element that contributes to maintenance of the problem. The clearest form of avoidance is not facing the situation; for instance, not using elevators, not staying in places where the windows are closed, etc. This kind of behaviour provides relief in the short term, but causes important problems in the long term. Consequently, one of the main aims of treatment consists of coping with feared situations. This is achieved by "exposure", a treatment technique that is used precisely to activate pathological fear structures in order to disconfirm sufferers' beliefs and teach them to cope with phobic situations. In fact, most studies stress that the most effective treatment for many psychological disorders is in vivo exposure to the feared situations (Marks 1987; Harris 1999; Öst 1997). In fact, exposure therapy is considered the treatment of choice for several mental disorders, and is included in many multicomponent treatment programs (Nathan and Gorman 2002)

In short, exposure procedures involve presenting a person with anxiety-provoking material (situation, objects, etc.) for a long enough time to decrease the intensity of their emotional reaction. Usually, in vivo exposure is presented in a graded or graduated way; that is, the patient is exposed to the feared situation in a gradual manner. However, in vivo exposure has a number of limitations and VR has been considered a viable alternative to this technique. Generally, the works devoted to analyzing the contribution of VR to the field of psychological treatments highlight the following advantages that VR has over traditional therapies (Botella et al. 1998a, 2004a, b, c; Côté and Bouchard 2005; Gorini and Riva 2008; Repetto and Riva 2011; Riva 2005; Riva et al. 2004b; Wiederhold and Wiederhold 1998; Zimand et al. 2003):

1. Firstly, in vivo exposure is costly, as many times it requires the therapist to go to the feared place. Exposure interventions "without a therapist" are still not very frequent and patients are often reluctant to participate in this type of treatment. In addition, the feared place is not always easily accessible, and imaginal exposure (that is, exposure to imagined situations) in these cases is less effective. The additional difficulty of individual differences in imaginative ability must also be taken into account. VR technology can help overcome these difficulties by generating different settings that would not otherwise be readily available without leaving the office
2. VR exposure allows almost total control of everything occurring in the situation experienced by the person in the virtual world. If a patient fears being trapped in an elevator, or turbulence and bad weather during a flight, we can assure him/her that these threats are not going to occur until he/she feels prepared to cope with them and, in fact, he/she accepts them to happen in the virtual world. The same can be said for numerous elements that are present in the situation which can make it more or less threatening. For instance, number of feared persons, animals or objects, size and degree of closing/opening of virtual spaces, the height of the spaces, the presence of protecting elements, duration of a determined situation, etc. This makes a personalized construction of the exposure hierarchy possible by enabling the user to cope with the feared situation or context at his/her own pace.
3. As highlighted formerly, VR helps the person feel present and judge a situation as real. In fact, a central element of VR is that it provides the person *a place where he/she can be placed* and live the experience (Baños et al. 2005). VR contributes an important benefit to treatment because it affords a feeling of presence that can rarely be achieved with imaginal exposure. This aspect is fundamental, since exposure therapy is intended to facilitate emotional processing of fear memories. Furthermore, the therapist is able to know what is always happening in the situation, what elements are being faced by the patient and by what is disturbing him/her. Obviously, this also contributes to the control of the situation and the protection of the patient.

4. VR makes going beyond reality possible. In therapy, (and also in the real world) one can witness the importance of certain situations considered extreme in order to definitively overcome a problem. There are different thresholds of difficulty/threat; once a very high threshold is overcome, it is much easier to cope with the remaining ones. Virtual worlds allow creating situations or elements so "difficult or threatening" that they would not be expected to happen in the real world. For instance, in a VR claustrophobia application one of the walls could be displaced (producing a loud noise) reducing the room to a very small space. The first patient who was treated with this application indicated precisely this: "If I am able to cope with *that wall* I can confront everything" (Botella et al. 1998b). The same can be created in other virtual worlds; a person with phobia of spiders unexpectedly has to cope with thousands of spiders, or spiders whose size increase so much that they turn into monsters.
5. VR is an important source of personal efficacy (Botella et al. 1998a, b, 2004b, c). According to Bandura (1977), from all possible sources of personal efficacy, performance achievements are especially useful. VR is an excellent source of information on personal efficacy. VR allows the construction of "virtual adventures" in which the person experiences him/herself as competent and efficacious. VR is flexible enough to permit the design of different scenarios in which the patient can develop personal efficacy expectations of the highest magnitude (including from easy performances to very difficult ones) generalization (referring to very different domains) and strength (difficult to extinguish, and to achieve the patient perseveres regardless of difficulties). The goal is for the person to discover that the obstacles and feared situations can be overcome through confrontation and effort. A problem posed by in vivo exposure treatment is that patients are sometimes so afraid of facing what they fear that they either refuse this type of program or drop out after beginning (Marks 1987, 1992; Marks and O'Sullivan 1988).
6. Safety is an important advantage of VR. Patients can control the context and the computer-generated setting with the therapist as they wish and with no risk involved. Indeed, the "virtuality" of the setting is precisely what makes patients feel safe (they can act, experiment and explore the feared setting "as if" it were real). This provides the important intermediate step between the therapist's office (where patients feel safe and sheltered) and the real world (which may seem so threatening that patients decide they cannot cope with it). Furthermore, VR allows the feared object to be graded very precisely according to individual differences. This means that treatments can be "custom-made" for each patient and each problem.
7. Moreover, patients usually accept the use of VR very well. Garcia-Palacios and colleagues compared the acceptance of in vivo exposure vs. VR exposure therapy in a subclinical sample (undergraduate students who scored high in a fear of spiders questionnaire). The data support the acceptability of VR exposure versus in vivo exposure. More than 80 % of the sample preferred VR to in vivo exposure (García-Palacios et al. 2001). These findings have been replicated in a clinical sample of 150 participants suffering from specific phobias. Seventy-six

percent chose VR over in vivo exposure, and the refusal rate for in vivo exposure (27 %) was higher than the refusal rate for VR exposure (3 %). Results suggest that VR exposure could help increase the number of people who seek exposure therapy for phobias (Garcia-Palacios et al. 2007).

8. VR offers privacy and confidentiality. The possibility offered by VR of confronting many fears inside the consulting room, without the necessity of in-vivo exposure, represents a significant advantage.

Besides these advantages of VR over the traditional exposure technique VR offers other advantages from a more general treatment perspective (Opris et al. 2012; Gorini and Riva 2008). On one hand, VR becomes a new sense that is incorporated in our "perceiving apparatus", using Popper's (1962) and Lorenz's (1973) terminology. The virtual worlds allow us to access more information about both ourselves and the world. By watching him/herself confronting different feared agoraphobic situations, an agoraphobic changes the perception he/she has of him/herself (perhaps I am not so weak) and about the world (perhaps it is no so dangerous). The magic of virtual worlds and its importance regarding treatment lies precisely there. They are "safe" contexts, the "safe base" that therapy offers to the patient (Bowlby 1973). In these protected contexts, people can freely explore, experience, feel, live, revive feelings and/or thoughts whether they are current or past. Nothing prevents them from knowing the world and their selves. Assuming this new perspective provides an enormous sensation of freedom. It is possible to be aware of the world and the self, which were considered absolutely given and finished; in fact, they are just an interpretation, a simulation, which (at least to a certain extent) can be changed. The patient can construct a new reality about him/herself and the world ("I have been an agoraphobic until today, but starting now there is no need to keep doing it"). Therefore, as discussed before, the goal of VR is not necessarily to "recreate" reality, but rather to achieve virtual environments that are relevant and significant to the person (Hoorn et al. 2003).

The first study using VR for the treatment of a psychological disorder was focused on acrophobia and exposed the user to virtual anxiety-provoking environments instead of real anxious situations. Since then, there have been significant advances in the number of problems studied, as well as their complexity.

In Table 12.2 are reported the available meta analyses and systematic reviews related to the use of VR in the different areas of mental health. A review of the main results obtained with VR therapy in mental health is presented below.

Table 12.2 Meta analyses and systematic reviews related to the use of VR in the different areas of mental health

	Review type	Paper	Included studies	Conclusions
Anxiety Disorders	Meta-analysis	Parsons, T. D., & Rizzo, A. A. (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: a meta-analysis. J Behav Ther Exp Psychiatry, 39(3), 250–261. doi: 10.1016/j.jbtep.2007.07.007	21 studies	Although meta-analysis revealed large declines in anxiety symptoms following VRET, moderator analyses were limited due to inconsistent reporting in the VRET literature
	Meta-analysis	Powers, M. B., & Emmelkamp, P. M. (2008). Virtual reality exposure therapy for anxiety disorders: A meta-analysis. J Anxiety Disord, 22(3), 561–569. doi: 10.1016/j.janxdis.2007.04.006	13 studies	Analysis showed a large mean effect size for VRET compared to control conditions, Cohen's d = 1.11 (S.E. = 0.15, 95 % CI: 0.82–1.39). This finding was consistent across secondary outcome categories as well (domain-specific, general subjective distress, cognition, behavior, and psychophysiology). Also as expected in vivo treatment was not significantly more effective than VRET. In fact, there was a small effect size favoring VRET over in vivo conditions, Cohen's d = 0.35 (S.E. = 0.15, 95 % CI: 0.05–0.65)
	Meta-analysis	Zheng, H., Luo, J., & Yu, R. (2014). From memory to prospection: The overlapping and the distinct components between remembering and imagining. *Frontiers in psychology, 5*(856). doi: 10.3389/fpsyg.2014.00856	33 studies	Analysis showed a medium effect size for the correlation between sense of presence and anxiety (r = .28; 95 % CI: 0.18–0.38). Moderation analyses revealed that the effect size of the correlation differed across different anxiety disorders, with a large effect size for fear of animals (r = .50; 95 % CI: 0.30–0.66) and a no to small effect size for social anxiety disorder (r = .001; 95 % CI: –0.19–0.19). Further, the correlation between anxiety and presence was stronger in studies with participants who met criteria for an anxiety disorder than in studies with a non-clinical population

	Systematic review	Meyerbroker, K., & Emmelkamp, P. M. (2010). Virtual reality exposure therapy in anxiety disorders: a systematic review of process-and-outcome studies. Depress Anxiety, 27(10), 933–944. doi: 10.1002/da.20734	20 studies	Only in fear of flying and acrophobia there is considerable evidence that VRET indeed is effective. In more complex anxiety disorders as panic disorder and social phobia, which form the core clinical groups, first results of VRET are promising, but more and better controlled studies are needed before the status of empirically supported treatment is reached. More severe cases of panic disorder with agoraphobia and social phobia are often not reached with existing treatments
	Systematic review	Goncalves, R., Pedrozo, A. L., Coutinho, E. S., Figueira, I., & Ventura, P. (2012). Efficacy of virtual reality exposure therapy in the treatment of PTSD: a systematic review. PLoS One, 7(12), e48469. doi: 10.1371/journal.pone.0048469	10 studies	The results suggest the potential efficacy of VRET in the treatment of PTSD for different types of trauma. VRET proved to be as efficacious as exposure therapy. VRET can be particularly useful in the treatment of PTSD that is resistant to traditional exposure because it allows for greater engagement by the patient and, consequently, greater activation of the traumatic memory, which is necessary for the extinction of the conditioned fear
	Systematic review	Serino, S., Triberti, S., Villani, D., Cipresso, P., Gaggioli, A., & Riva, G. (2013). Toward a validation of cyber-interventions for stress disorders based on stress inoculation training: a systematic review. *Virtual Reality, 18*(1), 73–87. doi: 10.1007/S10055-013-0237-6	10 studies	VR based cyber-SIT cyber-SIT may play an important role in the future clinical psychology, but it is crucial to enhance the validation of this approach from a methodological point of view: controlled trials testing a greater number of participants are needed
Eating disorders and obesity	Systematic review	Ferrer-Garcia, M., & Gutierrez-Maldonado, J. (2012). The use of virtual reality in the study, assessment, and treatment of body image in eating disorders and nonclinical samples: A review of the literature. Body Image, 9(1), 1–11. doi: 10.1016/j.bodyim.2011.10.001	12 studies	Although examined results suggest that VR-based therapy is an effective intervention for treating body image disturbances, more controlled studies with larger clinical samples are needed

(continued)

Table 12.2 (continued)

	Review type	Paper	Included studies	Conclusions
	Systematic Review	Ferrer-Garcia, M., Gutiérrez-Maldonado, J., & Riva, G. (2013). Virtual Reality based treatments in Eating Disorders and Obesity: A review. *Journal of Contemporary Psychology, 43*(4), 207–221. doi: 10.1007/s10879-013-9240-1	17 studies	Although several methodological deficiencies were detected in the reviewed studies, there is fair evidence for the effectiveness of VR-based treatments in ED and obesity. VR-based interventions usually combine exposure to VR environments with cognitive therapies. The VR component seems to be especially suitable for reducing body image disturbances and for increasing self-esteem and self-efficacy
Pain reduction	Systematic review	Malloy, K. M., & Milling, L. S. (2010). The effectiveness of virtual reality distraction for pain reduction: a systematic review. Clin Psychol Rev, 30(8), 1011–1018. doi: 10.1016/j.cpr.2010.07.001	11 studies	VR distraction was shown to be effective for reducing experimental pain, as well as the discomfort associated with burn injury care. Studies of needle-related pain provided less consistent findings
	Systematic review	Triberti, S., Repetto, C., & Riva, G. (2014). Psychological Factors Influencing the Effectiveness of Virtual Reality-Based Analgesia: A Systematic Review. *Cyberpsychology Behavior and Social Networking, 17*(6), 335–345. doi: Doi 10.1089/Cyber.2014.0054	11 studies	Results suggest the importance of different psychological factors in the effectiveness of the analgesic distraction. While sense of presence influence the effectiveness of VR as a distraction tool, anxiety as well as positive emotions directly affect the experience of pain

12.3.1 Phobias

12.3.1.1 Acrophobia

The first experience aimed at testing the utility of VR for the treatment of acrophobia, fear of heights, was carried out by the Kaiser-Permanente Medical Group of California. A system wherein the patient had to pass through a deep gully crossing over a suspension bridge and a narrow board was developed (Lamson 1994). The use of the system with 32 patients obtained a 90 % success rate.

Apart from this first experience, six case studies and four controlled studies have been reported to date. The first case studies were carried out by Rothbaum and North's groups at the University of Clark Atlanta (North et al. 1996a, b, c; Rothbaum et al. 1995a, b). Furthermore, Choi et al. (2001), and Jang et al. (2002) also demonstrated that VR exposure technique is effective in the treatment of acrophobia. Nevertheless, in a single case study, Kamphuis et al. (2002) did not find a clinically significant improvement. In a more recent work, Bouchard et al. (2003b) found significant improvement in fear of heights in a series of 7 patients (5 females and 2 males). Moreover, the gains were maintained at 6-month follow-up.

The first controlled study on the effectiveness of VR exposure for the treatment of acrophobia was carried out by Rothbaum et al. (1995a, b). Students with fear of heights were randomly allocated to one of two experimental conditions: a VR exposure group (N = 12) versus a no-treatment control group (N = 8). The results showed significant differences between the students who completed the VR treatment and those on the waiting list.

The remaining three controlled studies made with clinical populations were conducted by Emmelkamp's research group. In the first one, Emmelkamp et al. (2001) evaluated the effectiveness of a low-cost virtual reality exposure versus exposure in vivo in a within-group design. Although VR exposure was as effective as in vivo exposure, firm conclusions could not be drawn due to the limitation of a potential order effect influencing the results. In the second study (Emmelkamp et al. 2002), participants were also randomly allocated to either VR exposure treatment or in vivo exposure. VR exposure was shown to be as effective as in vivo exposure for all measures (including a Behavioral Avoidance Test consisting of climbing open stairs) and improvement was maintained at 6-month follow-up.

Finally, two other studies developed by this group (Krijn et al. 2004a, b, 2007a, b) was aimed at examining different conditions of VR exposure treatment. The 2004 study varied the degrees of immersion by using either a head-mounted display (HMD) for low immersion, or a computer automatic virtual environment (CAVE) for high immersion. The 2007 study investigated whether coping self-statements would enhance the effectiveness of VR exposure treatment.

Thirty seven patients took part in the 2004 study, and they were assigned randomly to one of the three conditions. Results showed that VR exposure was more effective than no treatment, with no differences found between the two presence conditions (HMD versus CAVE). Gains were maintained at 6-month follow-up. All studies used visual and audio stimuli and some form of tactile stimuli (such as a platform or a railing that the participant could hold on to), thus increasing the sense of presence.

The 2007 study, including 26 patients with acrophobia, showed that VRET, regardless of addition of coping self-statements, decreased anxiety of heights, decreased avoidance of height situations, and improved attitudes towards heights. However, at 6-month follow-up, most gains during treatment were not fully retained.

Coelho and colleagues (2006) exposed ten subjects to three sessions of simulated heights in a VR system. The participants show significant progress in anxiety, avoidance, and behavior measurements when confronted with real height circumstances. The results obtained 1 year later at follow-up are statistically significant in the Behavioral Avoidance Test (BAT) and the Attitudes Toward Heights Questionnaire (ATHQ), but not the Acrophobia Questionnaire (AQ).

In conclusion, it appears that VR exposure has proven to be effective in the short-term treatment of fear of heights. Further studies are required to verify the long-term efficacy of the treatment.

12.3.1.2 Claustrophobia

Positive results about the effectiveness of VR exposure for the treatment of claustrophobia, fear of enclosed or confined spaces, have been reported in the three studies carried out by Botella's research group. The first study (Botella et al. 1998a) consisted of a case report. The participant was a 43-year-old woman who received 8 VR exposure sessions. All fear measures were reduced after treatment and were maintained at 1-month follow-up. In the second work (Botella et al. 1999) the same VR exposure therapy was applied to a patient with a diagnosis of two specific phobias (claustrophobia and storms), panic disorder and agoraphobia. Results showed an important change in all measures after treatment. In addition, a generalization of improvement to other phobic and agoraphobic situations not specifically treated was observed. Furthermore, changes were maintained at 3-month follow-up. In another study, Botella et al. (2000) tested the effectiveness of VR exposure therapy following a controlled design. Results again supported the effectiveness of VR exposure. An improvement was observed in all measures (including a Behavioral Avoidance Test consisting of keeping the person in a closet) and gains were maintained at 3-month follow-up.

In a later study Malbos and colleagues (2008) tested the effectiveness of a multiple components therapy regarding claustrophobia and involving virtual reality (VR). In the study six claustrophobic patients experienced multiple context-graded enclosed virtual environments. The results of the questionnaires and behavior tests exhibited a significant reduction in fear towards the enclosed space and quality of life improvement. Such gains were maintained at 6-month follow-up. Presence score indicated the patients felt immersed and present inside the environment.

In short, although results obtained in the aforementioned studies are promising, additional studies with larger samples, using group designs including control groups, are still needed in order to draw firmer conclusions.

12.3.1.3 Small Animal Phobia

The group at the University of Nottingham and the Institute of Psychiatry developed the first VR system for the treatment of arachnophobia (Grimsdale 1995). Through an HMD, participants viewed a spider whose realism gradually increased until the patient's tolerance allowed him/her to face the spider. In addition, Hoffman's research group has reported three studies examining the effectiveness of VR exposure for the treatment of phobia of spiders: a case report and two controlled studies. The case report (Carlin et al. 1997) showed the efficacy of immersive computer-generated virtual reality and mixed reality (consisting of touching real objects which patients also saw in VR) in a 37-year old female with severe and incapacitating fear of spiders.

Later, this promising result was supported by two controlled studies. In the first one, García-Palacios et al. (2002) compared VR exposure therapy with a waiting list condition in a between group design with 23 participants who received an average of four 1-h exposure sessions. Results showed that 83 % of patients in the VR treatment group improved in a clinically significant way (including a Behavioral Avoidance Test, consisting of exposure to real spiders) compared with 0 % in the waiting list no treatment condition. The second work (Hoffman et al. 2003) explored whether treatment effectiveness was increased by providing the patient the illusion of physically touching the virtual spider. Results showed that the participants in the tactile augmentation group showed the greatest progress on behavioral assessment as observed in the Behavioral Avoidance Test at post-treatment. Therefore, we can conclude that the effectiveness of VR exposure for the treatment of arachnophobia is well established, since it has been proven that is more effective than non treatment. However, its effectiveness compared with in vivo exposure still remains unknown.

Recently, the possibility of using Internet to apply a totally self-applied VR-based exposure program for the treatment of small animal phobia (spiders, cockroaches, and mice) is being tested. The name of the program is Without Fear. Preliminary data in a series of 12 cases showed the utility of the system. Participants showed an improvement in all clinical measures at post-treatment, and the therapeutic gains were maintained at a 3-month follow-up (Botella et al. 2008).

12.3.1.4 Flying Phobia

Several case studies have been reported, all of them providing results favoring the utility of VR therapy for the treatment of fear of flying (Baños et al. 2002; Hirsch 2012; Klein 1999; North et al. 1997; Rus-Calafell et al. 2013; Rothbaum et al. 1996; Wallach and Bar-Zvi 2007; Wiederhold et al. 1998).

On the other hand, different studies, which differ in the degree of methodological control achieved, also provide support for the effectiveness of VR for the treatment of flying phobia. Wiederhold (1999) compared VR exposure therapy with "Imaginal exposure therapy" (that is, exposure treatment done through imagination). Three groups were included in the study: VR with no physiological feedback (wherein users did not receive information about their physiological state) (N = 10), VR with physiological feedback (wherein users received information about their physiological state) (N = 10) and imaginal exposure with no physiological feedback (N = 10).

Contrary to what was expected, there were no differences between groups after treatment. However, statistically significant differences between groups at three-month follow-up were found: 80 % of the VR Exposure with no physiological feedback group, 100 % of the VR Exposure with physiological feedback group, and 10 % of the imaginal exposure group could fly without medication or alcohol at follow-up. Kahan et al. (2000) investigated the effects of anxiety management training (techniques focused on coping anxiety symptoms) and VR exposure therapy; the results showed that 21 out of 31 patients flew after treatment. However, as Krijn et al. (2004b) point out, no conclusion about the effectiveness of VR exposure can be drawn due to several methodological shortcomings (e.g., the design consisted of a package rather than pure VR exposure, and the number of sessions differed across patients).

In the study carried out by Mühlberger et al. (2001), 30 patients were randomly assigned to either VR exposure condition or relaxation condition. Results showed that fear of flying improved in both treatment groups. VR exposure was found to be more effective than relaxation on specific fear of flying questionnaires. In a more controlled study, Rothbaum et al. (2000), three experimental conditions were used to compare VR exposure therapy (four sessions of VR exposure and four sessions of anxiety management therapy) with in vivo exposure therapy (two sessions of traditional in vivo exposure and four sessions of anxiety management therapy) and a waiting list (that is, no treatment). Forty-five patients were randomly allocated to one of these conditions. Both treatment conditions were more effective than a waiting list period, with no differences between treatments, neither after treatment nor at 12-month follow-up (Rothbaum et al. 2002).

A second, more controlled study was carried out by Maltby et al. (2002). Using a between group design they compared VR exposure therapy (psycho-education and graded exposure) with an attention-placebo condition (education about the safety of a flight and mechanisms of airplanes). The VR exposure group showed a better outcome on most measures at post-treatment; however this superiority of the VR exposure group disappeared at 6-month follow-up. In another randomized controlled work, Mühlberger et al. (2003), compared three experimental treatment conditions: (1) cognitive treatment and VR exposure therapy with motion simulation; (2) cognitive treatment and VR exposure therapy with no motion simulation; and, (3) cognitive treatment alone. A non-random waiting list group was also used. Only participants who received VR exposure (with or without motion simulation) showed reductions in their fear of flying measured by questionnaires at post-treatment. Furthermore, motion simulation did not enhance treatment effectiveness.

Botella et al. (2004a) carried out a study using a multiple baseline across individuals design where the use of VR exposure was the only therapeutic component (consisting of 6 exposure sessions). Nine participants took part in the study, and results showed that VR produced a decrease of the fear, avoidance and belief in catastrophic thoughts; all participants flew after treatment. Moreover, these results were maintained at 1-year follow-up.

Rothbaum and colleagues (2006) tested VR exposure therapy for the fear of flying and compared it to standard (in vivo) exposure therapy and a wait list (WL) control with a 6- and 12-month follow-up. Seventy-five participants, 25 per group, completed the study. Results indicate that VR was superior to waiting list on all measures and essentially equivalent to in vivo exposure. Follow-up assessments at 6 and 12 months indicated that treatment gains were maintained, with more than 70 % of respondents from both groups reporting continued flying at follow-up.

As noted by a systematic review by da Costa and colleagues (2008) results obtained thus far suggest the utility of VR for the treatment of flying phobia: controlled studies demonstrate that this treatment is effective with or without cognitive behavior therapy and/or psychoeducation and that it is considered to be an effective component of the treatment of flying phobia. However, more controlled studies are needed with larger samples and comparable treatment conditions with regard to number of sessions and length of sessions in order to draw firmer conclusions. In particular, both group cognitive behavioral training (Krijn et al. 2007a) and computer aided exposure treatments (Tortella-Feliu et al. 2011) might be superior in cost-effectiveness when compared to VR exposure treatment.

12.3.1.5 Driving Phobia

Wald and Taylor (2000) carried out the first case report examining the efficacy of VR exposure therapy for treating the fear of driving. A decrease in anxiety and avoidance was produced, with gains maintained at 7-month follow-up. In a controlled work (Wald and Taylor 2003) five patients were given eight weekly VR exposure therapy sessions. Three patients showed a clear improvement in driving fear and avoidance at post-treatment. However, the improvement only was marginal in one patient, and the remaining participant did not show any improvement at all. Moreover, some gains were lost at the 1- and 3-month follow-up assessment.

More, Walshe et al. (2003) have reported an open study aimed to investigate the effectiveness of the combined use of computer generated environments involving driving games and a VR driving environment for the treatment of driving phobia. Participants who experienced “immersion” in one of the driving simulations (7 out of 14) completed the exposure program. Significant reductions for all measures were produced at post-treatment.

Beck and colleagues (2007) reported the results of a VR-based therapy for driving phobia on a sample of six subjects. Results indicated significant reductions in posttrauma symptoms involving re-experiencing, avoidance, and emotional numbing, with effect sizes ranging from d = .79 to d = 1.49. Additionally, high levels of perceived reality ("presence") within the virtual driving situation were reported, and patients reported satisfaction with treatment.

Finally, Muhlberger et al. (2007) examined the reaction of 15 highly tunnel-fearful and 15 matched control participants in 3 virtual driving scenarios. Results indicate that virtual environments are valuable tools for the assessment of fear reactions and should be used in future experimental research.

In conclusion, the preliminary results available suggest that VR exposure therapy may be promising for treating driving phobia. Nevertheless, additional control trials are needed to draw any conclusion.

12.3.1.6 Public Speaking Fear/Social Phobia

Anderson et al. (2003) reported two case studies using anxiety management treatment, in vivo exposure and VR exposure. Results showed a decrease in specific anxiety symptoms at post-treatment. The authors also informed that the results for these two cases were similar to the effectiveness of "traditional" treatment (cognitive behavior therapy). Légeron's group has also designed (Roy et al. 2003) and recently tested (Klinger et al. 2005) a VR-based protocol to treat social phobia. This last work is a preliminary controlled study in which a VR exposure therapy group was compared with a cognitive behavior therapy group (control condition). The virtual environments used recreated four situations related to social anxiety: performance, intimacy, scrutiny, and assertiveness. The results showed that both groups improved significantly.

Slater and colleagues (Slater et al. 1999, 2006b) have been working on a software designed for fear of public speaking and its validation (Pertaub et al. 2002). In this last work, Pertaub et al. studied the anxiety response of 40 individuals with fear of public speaking in a virtual reality environment. Participants had to give a 5-min presentation to a neutral, positive, or negative audience that consisted of eight avatars. Results confirmed that all three virtual environments could generate anxiety in participants. In a later study, Slater and colleagues (2006b) involved 20 people who were confident public speakers and 16 who were phobic, assessed on a standard psychological scale. Half of each group spoke within a VE depicting an empty seminar room, and the other half within the same room but populated by a neutrally behaving virtual audience of five people: the people with phobia showed a significant increase in signs of anxiety when speaking to the virtual audience compared to the empty room, whereas the confident people did not.

Harris et al. (2002) reported a study with a subclinical population. Two conditions were contemplated: VR exposure therapy and a waiting list control group. VR exposure therapy included four exposure sessions of 15 min each. Participants in the VR condition showed an improvement on several questionnaires after treatment.

In a series of study Safir and colleagues (Safir et al. 2012; Wallach et al. 2009, 2011) used a sample of 88 public speaking anxious subjects to compare the efficacy of VR exposure with CBT and waiting list. No significant differences were found between VRCBT and CBT at the end of the treatment and after 1-year follow-up. However, twice as many clients dropped out of CBT (15) than from VR exposure (6). A similar result was found by Klinger and colleagues (2005) in the comparison between VR exposure and CBT in the treatment of social phobia.

In summary, research results suggest that VR may be a useful tool for the treatment of fear of public speaking. In the near future more controlled studies will likely be conducted. Fear-provoking virtual environments are already available and results, although preliminary, are in favor of the efficacy of VR exposure for the treatment of social anxiety.

12.3.2 Panic Disorder and Agoraphobia.

Panic disorder and agoraphobia (PDA) is a highly incapacitating psychological disorder. PDA is an anxiety disorder characterized by attacks of anxiety or terror, often (but not always) occurring unexpectedly and without reason. These attacks are associated with somatic symptoms such as dyspnea, palpitations, dizziness, vertigo, faintness, or shakiness and with psychological symptoms such as feelings of unreality (depersonalization or derealization) or fears of dying, going crazy, or losing control; there is usually chronic nervousness and tension between attacks. Agoraphobia is the fear of having a panic attack in general in any place whether it is the grocery store, at work or in the privacy of one's own home.

Virtual environments for the treatment of PDA are available (Botella et al. 2004c; Moore et al. 2002; Vincelli et al. 2000). Due to the complexity of PDA compared to specific phobias, studies carried out to test the effectiveness of VR exposure therapy for the treatment of this disorder have included the exposure to anxiety-provoking virtual environments as a part of a cognitive behavioral treatment program. This program also includes other techniques such as breathing retraining, relaxation, cognitive restructuring (that is, techniques focused on replacing irrational beliefs with more accurate and beneficial ones), psychoeducation (that is, information about the problem and how to manage it)

In a first study published in 1996, North et al. compared VR exposure therapy with a no-treatment control group using a subclinical population. Results showed that participants in the treatment group improved more significantly at post-treatment. Jang et al. (2000) studied the effectiveness of VR therapy using subjective and objective measures (blood pressure, respiration, and heart rate). Seven people participated in the study, however, the data failed to support the efficacy of VR therapy since most of the participants were not able to feel present in the virtual environment (tunnel with traffic jam).

More recently, three controlled randomized studies have been conducted. In the first study Vincelli et al. (2003) compared eight sessions of experiential cognitive therapy (including psychoeducation, VR exposure, cognitive therapy, exposure to feared physical sensations, in vivo exposure, homework assignments, and relapse prevention) with 12 sessions of cognitive behavior therapy (consisting of cognitive restructuring, exposure to feared physical sensations, and imaginal exposure to feared situations) and a waiting list group. Twelve people suffering PDA participated in the study.

Results showed that both treatment conditions produce a significant decrease in anxiety and depression symptoms on all measures. No differences were found between pre-treatment and post-treatment in the waiting list group. The second controlled study was conducted by Botella et al. (2007) A randomized between group design with three experimental conditions were used: VR exposure that permits both exposure to external stimuli and exposure to feared physical sensations; in vivo exposure; and a waiting list. Thirty-six participants were randomly assigned to one of the three experimental conditions. The treatment programs lasted nine sessions. Results showed that VR exposure and in vivo exposure were equally effective, both treatment conditions being superior to a waiting list condition and therapeutic outcomes were maintained at 1-year follow-up.

More recently, Perez-Ara and colleagues (2010) developed a specific protocol based on the VR interoceptive exposure (both audible effects, such as rapid heartbeat and panting, and visual effects, such as blurry vision, double vision and tunnel vision) for the treatment of panic disorder and agoraphobia. They used 29 individuals to compared it with a traditional treatment based on interoceptice exposure. Results obtained showed that both treatment conditions significantly reduced the main clinical variables at post-treatment; these results were maintained or even improved at three month follow-up.

Despite the few studies available and the limitations of the studies that have been presented, results indicate so far that VR exposure can be useful for the treatment of PDA. However, it is necessary to replicate these in larger clinical samples, and to validate the virtual interoceptive exposure component.

12.3.3 Eating Disorders and Obesity

Distorted body image, negative emotions, difficulty in maintaining positive outcomes in the long term and lack of faith in the therapy are typical features of obesity and eating disorders treatment. To address these issues two main research groups are using VR technology in the treatment of ED, obesity, and other related pathologies: One is the group of Riva in Milan (Italy) and the other the group of Perpiñá in Castellón and Valencia (Spain). Both groups use VR to improve cognitive-behavioral therapy, and they have also developed VR-based software for the assessment and treatment of body image disturbances (Ferrer-García and Gutiérrez-Maldonado

2012; Ferrer-Garcia et al. 2013; Myers et al. 2004; Perpiña et al. 2003; Riva et al. 2002, 2004a).

The first approach is offered by the VR-enhanced cognitive behavior therapy (ECT) developed by Riva and his group inside the VREPAR and VEPSY Updated European funded projects: a relatively short-term, patient oriented approach that focuses on individual discovery (Riva et al. 2002, 2003). ECT shares with the Cognitive Behavioral Therapy the use of a combination of cognitive and behavioral procedures to help the patient identify and change the maintaining mechanisms. However, it is different for the following reasons:

- Use of VR: 10 VR sessions.
- Focus on the negative emotions related to the body, a major reason patients want to lose weight.
- Focus on supporting the empowerment process. VR has the right features to support the empowerment process, since it is a special, sheltered setting where patients can explore and act without feeling threatened.

In the VR sessions, an approach similar to guided imagery is used to lead the subject through various zones over the course of ten sessions. Stimuli that contribute to abnormal eating behaviors are identified, and associated anxiety and body experiences are targeted for modification. Subjects are also asked to identify figures that most closely resemble their current and ideal body sizes. They are also presented with a photograph of their actual body.

This approach was validated through various case studies (Riva et al. 1999) and trials. In the first one, which was uncontrolled, three groups of patients were used (Riva et al. 2000): patients with Binge Eating Disorders, patients with Eating Disorders Not Otherwise Specified, and obese patients with a body mass index higher than 35. All patients participated in five biweekly sessions of the therapy. All of the groups showed improvements in overall body satisfaction, disordered eating, and related social behaviors, although these changes were less noticeable in the Eating Disorders Not Otherwise Specified group.

The approach has been tested in various controlled studies. The first one involved 20 women with Binge Eating Disorders who were seeking residential treatment (Riva et al. 2002). The sample was assigned randomly to ECT or to Cognitive Behavior Treatment based nutritional therapy. Both groups were prescribed a 1,200-cal per day diet and minimal physical activity. Analyses revealed that although both groups were binge free at 1-month follow-up, ECT was significantly better at increasing body satisfaction. In addition, ECT participants were more likely to report increased self-efficacy and motivation to change.

In a second study, the same randomized approach was used with a sample of 36 women with Binge Eating Disorders (Riva et al. 2003). The results showed that 77 % of the ECT group quit binging after 6 months versus 56 % for the Cognitive Behavior Treatment group and 22 % for the nutritional group sample. Moreover, the ECT sample reported better scores in most psychometric tests.

In the final study, ECT was compared with nutritional and cognitive-behavioral treatments, using a randomized controlled trial, in a sample of 211 obese female patients. Both IET and Cognitive Behavior Treatment produced a better weight loss than non treatment condition after a 6-month follow-up. However, ECT was able to significantly improve, over Cognitive Behavior Treatment and non treatment condition, both body image satisfaction and self-efficacy.

The most recent controlled trial (ISRCTN59019572) included 90 obese (BMI > 40) female patients with BED (Cesa et al. 2013). ECT was compared with a Cognitive Behavior Treatment and an integrated treatment (IT) including nutritional groups, a low-calorie diet (1,200 kcal/day) and physical training.

Only ECT was effective at improving weight loss at 1-year follow-up. Conversely, control participants regained on average most of the weight they had lost during the inpatient program. Binge eating episodes decreased to zero during the inpatient program but were reported again in all the three groups at 1-year follow-up. However, a substantial regain was observed only in the group who received the inpatient program alone, while both ECT and CBT were successful in maintaining a low rate of monthly binge eating episodes.

The group led by Perpiñá compared the effectiveness of VR to traditional Cognitive Behavior Treatment for body image improvement (based on Cash 1996) in a controlled study with a clinical population (Perpiña et al. 1999). Specifically, they developed six different virtual environments, including a 3d figure whose body parts (arms, thighs, legs, breasts, stomach, buttocks, etc.) could be enlarged or diminished. The proposed approach addressed several of the body image dimensions: the body could be evaluated wholly or in parts; the body could be placed in different contexts (for instance, in the kitchen, before eating, after eating, facing attractive persons, etc.); behavioral tests could be performed in these contexts, and several discrepancy indices related to weight and figure could be combined (actual weight, subjective weight, desired weight, healthy weight, how the person thinks others see her/him, etc.).

In the published trial eighteen outpatients, who had been diagnosed as suffering from eating disorders (anorexia nervosa or bulimia nervosa), were randomly assigned to one of the two treatment conditions: the VR condition (cognitive-behavioral treatment plus VR) and the standard body image treatment condition (cognitive-behavioral treatment plus relaxation). Thirteen of the initial 18 participants completed the treatment. Results showed that following treatment, all patients had improved significantly. However, those who had been treated with the VR component showed a significantly greater improvement in general psychopathology, eating disorders psychopathology, and specific body image variables. Besides, these results were maintained at 1-year follow-up (Perpiña et al. 2003). Since then, the group has also developed a VR simulator of food and eating currently under evaluation with patients.

Their most recent controlled trial included 34 patients diagnosed with Eating disorders (Marco et al. 2013): 17 experienced VR enhanced CBT while 17 experienced classical CBT. The CBT program for eating disorders enhanced by a body image-specific component using VR techniques was shown to be more efficient than CBT alone. Furthermore, improvement was maintained in post-treatment and at 1 year follow-up.

VR technology has also been used to increase knowledge about the body image concept. The team of Gutiérrez-Maldonado at the University of Barcelona (Spain) studied the intra-individual variability of body image in women with anorexia and bulimia nervosa (Ferrer-Garcia et al. 2009; Ferrer-Garcia and Gutierrez-Maldonado 2010, 2012). First, data obtained from the research of Gutiérrez-Maldonado and colleagues suggest that VR environments are useful for producing similar responses to those observed in real world. Therefore, these environments can be useful for studying intra-individual variability of body image disturbances. More, the results suggest that body image can indeed be understood as a state rather than solely as a trait, and that these states are modified when participants are exposed to situations which are emotionally relevant for them (e.g. food exposure). Thus, body image distortion and body image dissatisfaction can be influenced by situational factors, and VR exposure is a useful technology for their study.

In summary, the available data suggest that VR can help in addressing two key features of eating disorders and obesity not always adequately addressed by existing approaches: body experience disturbances and self-efficacy (Ferrer-Garcia and Gutierrez-Maldonado 2012; Ferrer-Garcia et al. 2013; Perpiña et al. 2003). But why is virtual reality effective in dealing with these aspects of eating-related disturbances?

As suggested by Ferrer-García and colleagues (2013) VR can be considered an "embodied technology", due to its effects on body perceptions. A number of studies have demonstrated that it is possible to use VR to induce controlled changes in the experience of the body (Lenggenhager et al. 2007; Riva et al. 2000; Slater et al. 2010), and this is particularly relevant given the role of body image disturbances in eating disorders and obesity.

Recently, Riva and colleagues proposed the *allocentric lock hypothesis* (Gaudio and Riva 2013; Riva 2011, 2012a, 2014; Riva and Gaudio 2012; Riva et al. 2013, 2014), suggesting that ED and obesity may be the outcome of a primary disturbance in the way the body is experienced and remembered: Individuals with these disorders may be locked into an allocentric (observer view) image schema of their body that is no longer updated by contrasting egocentric representations driven by perception. This situation usually has one of two effects: Either subjects turn to more radical dietary restraint, or they decide to stop any form of food control and engage in "disinhibited" eating behaviors. The shift from a locked allocentric representation to an eating or weight disorder may be explained by social influence, since the media and culture promote dieting as the best way to improve one's body image satisfaction. However, the impossibility of improving body image, even after a demanding diet, locks the patient into an unsatisfying body.

A recent clinical trial involving 163 women with morbid obesity used VR as a way of unlocking this image schema and found that this approach was significantly better at 1-year follow-up in maintaining the results of the treatment, as compared with both CBT and nutritional treatment (Riva 2012b).

A final area that may be targeted in the near future is the use of VR to help eating disordered subjects to avoid emotional eating (Riva et al. 2008; Manzoni et al. 2009).

12.3.4 Post-traumatic Stress Disorder

Post-traumatic Stress Disorder (PTSD) is a psychological disorder that can occur following the experience or witnessing of life-threatening events such as military combat, natural disasters, terrorist incidents, serious accidents, or violent personal assaults such as rape. People who suffer from PTSD often relive the experience through nightmares and flashbacks, have difficulty sleeping, and feel detached or estranged, and these symptoms can be severe and long enough to significantly impair the person's daily life.

The use of cognitive behavioral programs that include exposure-based techniques is currently the treatment of choice for PTSD. The treatment program for PTSD with the most empirical support is Prolonged Exposure, developed by Foa and Rothbaum (1998), which involves imaginal exposure to the traumatic experience.

Rothbaum et al. (1999) published the first case study in the use of VR exposure in the treatment of PTSD. In 2001, these researchers reported data from an open trial with ten Vietnam veterans (Rothbaum et al. 2001). Results showed a trend toward reduction in some PTSD symptoms using exposure to virtual environments recreating combat situations in the Vietnam War. In a recent book, Rothbaum et al. (2004) described a case study to highlight the use of VR exposure and psycho-physiological monitoring in PTSD with a Vietnam veteran. Another case study presented by this team (Gerardi et al. 2008) involved a veteran returning Operation Iraqi Freedom (OIF).

There are already case reports of positive results in the use of VR exposure for the treatment of PTSD in survivors of the September 11th attack in New York (Difede and Hoffman 2002; Difede et al. 2007) and in a subject surviving a deadly terrorist bulldozer attack on two civilian buses and several cars in Jerusalem (Freedman et al. 2010). The importance of the approach of Difede and Hofffman's team is that they are treating patients who did not respond to traditional imaginal exposure. In their case studies, they showed that VR could be an alternative for patients who present problems with imaginal exposure.

Rizzo and colleagues explored the potential of a Iraq War PTSD VR application (Virtual Iraq) in different case studies and controlled studies (Rizzo et al. 2005, 2008, 2009; Roy et al. 2013). The Virtual Iraq environment was developed using input from Veterans returning from Iraq and Afghanistan and from military information experts. It allows for the simultaneous delivery of visual, audio, vibrotactile, and olfactory stimuli to create an immersive and multisensory experience for the user. The environment includes two general scenario settings with different first person user perspective options: a Middle Eastern city and Humvee driving down a desert highway alone or in a convoy. All scenario settings are adjustable for time of day or night, lighting illumination and weather conditions.

Initial analyses of results from the first 20 Virtual Iraq treatment completers in an open clinical trial at an active duty military base have produced clinically meaningful and statistically significant outcomes with the use of VRE on standard PTSD and related anxiety assessment measures (Rizzo et al. 2008, 2009). Sixteen of the 20 completers no longer met DSM criteria for PTSD at posttreatment on a self-report measure of PTSD.

Finally, another approach is proposed by Botella's team (Botella et al. 2006b). In the previously mentioned studies, the approach is to simulate traumatic events with high realism with the aim of exposing the participants to the feared aspects of the trauma. Botella's design follows a different approach. The aim is to design clinically significant environments for each participant, while attending to the meaning of the trauma for the individual, rather than to simulating the physical characteristics of the traumatic event with high realism. The aim is not realism, but using customized symbols and aspects which provoke and evoke an emotional reaction in the participant. This can help to achieve the emotional processing of the trauma, while creating a safe and protective environment.

In summary, VR technology may provide a useful means to treat PTSD (Reger and Gahm 2008; Rothbaum et al. 2010; Goncalves et al. 2012). The results thus far are preliminary but encouraging. It remains to be seen, however, what the appropriate applications of the technology will be, whether or not there is a significant advantage to using this technology compared to other strategies that are currently available, and what factors may contribute to its effects.

12.3.5 Pain Treatment

Pain is a complex and multidimensional construct that involves sensory, emotional and cognitive processes that can modulate the experience of pain. This multidimensional perspective of pain was introduced with the gate-control theory (Melzack and Wall 1965). This theory revolutionized the conceptualization of pain and has generated an increasing number of investigations and publications about pain in different scientific fields. This theory has contributed to the consideration of psychological aspects in the study of pain and pain control. Many authors agree that attention and other affective-motivational characteristics play an important role in pain (i.e. Eccleston and Crombez 1999). Psychological techniques focusing on distraction, cognitive reappraisal, behavioral modification, preliminary information and hypnosis can be effective in reducing pain (i.e. Patterson 1992, 1995).

VR pain control is a new psychological intervention among the distraction techniques that have been recently applied to the treatment of pain (Gold et al. 2007). VR has already been used as a distraction technique in acute pain related to medical procedures. The logic for how VR could be a useful tool in the treatment of pain is related to the role of attention in the experience of pain. Attention involves the selection of relevant information. Each human has a finite amount of attention that can be divided between tasks (Kahneman 1973; Shiffrin 1988). Immersive VR gives patients the illusion of "going into" the computer-generated environment. The strength of the illusion of presence is thought to reflect the amount of attention drawn into the virtual world (Hoffman et al. 1998). Because VR is a highly attentiongrabbing experience, it may prove to be an especially effective psychological pain control technique, reducing the amount of attention available to process pain.

Researchers from the University of Washington pioneered the use of VR analgesia in acute pain caused by procedures such as wound care and physical therapy in burn patients. Hoffman et al. (2000b) presented two case reports providing the first evidence of the effectiveness of VR as a powerful adjunctive non-pharmacological analgesic. They compared the analgesia of two distraction procedures, playing a video game versus being immersed in VR. While undergoing wound care, the patients spent 3 min in VR and 3 min playing a video game. The order of administering the treatments was randomised and counterbalanced.

Results showed that VR was more effective in reducing pain than the video game in both cases in all measures of pain. In another study, Hoffman et al. (2000a) explored the use of immersive virtual reality (VR) to distract patients from pain during physical therapy. Twelve patients performed physical therapy with no distraction for 3 min and physical therapy in VR for 3 min. All patients reported lower pain and less time thinking about pain when in VR, compared to having no distraction. Additionally, the amount of VR analgesia was statistically significant.

For the above mentioned VR studies, patients received only one short VR session. It is theoretically possible that VR only works well the first time the patient tries it, because it is a novel experience. If so, its practical medical value would be limited. In a case study, Hoffman et al. (2001a, b) explored whether immersive virtual reality continues to work when used more than once. After five sessions using VR, the results suggest that VR retains its analgesic properties with multiple treatments. This finding is encouraging for the wound care field, given the fact that burn patients usually need multiple wound care and physical therapy sessions during their recovery. These results have been replicated in a study with more and different patients (Hoffman et al. 2001b, 2008). The authors conclude that these findings provide preliminary evidence that VR can be used as a strong non-pharmacologic pain reduction technique for burn patients during physical therapy. In addition, data already suggest that VR not only changes the way patients interpret pain signals, but also reduces the amount of pain-related brain activity (Maani et al. 2011; Hoffman et al. 2004, 2007; Schmitt et al. 2011). Eight healthy volunteers underwent a brain scan (fMRI) while receiving a pain stimulus using a thermal pain stimulator. VR reduced pain-related activity in all five regions of interest: the anterior cingulated cortex, primary and secondary somatosensory cortex, insula, and thalamus. This is the first study that shows the neural correlates of VR analgesia. The University of Washington team uses Snow World, a virtual world specifically designed for burn patients, where the user flies through a virtual icy canyon with a river, a waterfall, and snow.

Encouraging results with adolescents during conscious burn wound care procedures were reported by Kipping and colleagues (2012): nursing staff reported a statistically significant reduction in pain scores during dressing removal, and significantly less rescue doses of Entonox given to those receiving VR, compared to those receiving standard distraction.

The results of VR analgesia are also encouraging in the field of procedural pain related to cancer. Schneider and Workman (1999) reported in a case study that VR was useful in reducing anxiety related to chemotherapy. Gershon et al. (2003) conducted a single case study during an invasive medical procedure called "port access" in a child: (a) no distraction; (b) non-VR distraction with a computer screen; and (c) VR distraction. The virtual world was Virtual Gorilla wherein the user could interact with gorillas in a gorilla habitat. Results showed lower pain and anxiety ratings and reduced blood pressure in the VR distraction condition. The same authors (Gershon et al. 2004) conducted a between-subject study with two conditions: no distraction and VR distraction in children going through the "port access" procedure. Reductions in pain and anxiety were found in the VR condition in comparison with the control condition. Steele et al. (2003) reported encouraging results about the use of VR analgesia during post-surgical physiotherapy sessions in a 16-year-old patient with cerebral palsy. Hoffman et al. (2001a, b) compared no distraction, watching a movie, or VR distraction in two adults with periodontitis while undergoing periodontal scaling and root planning. Results showed a higher reduction in pain in the VR distraction condition. Similar results were obtained by Asl Aminabadi and colleagues (2012) during dental treatment in 4–6 year-old children,

Murray et al. (2006) proposed a study protocol to investigate the use of immersive virtual reality as a treatment for amputees' phantom limb pain. Specifically, their approach transposes movements of amputees' anatomical limbs into movements of a virtual limb presented in the phenomenal space of their phantom limb, an approach that is similar to the mirror therapy used by Ramachandran and colleagues (2009, 2010). VR does have certain advantages over mirror therapy (e.g., more flexibility, more complicated bodily mappings), however, the cost of a VR system versus a mirror, makes mirror therapy a viable and more realistic alternative for some patient groups. Nevertheless, recent trends in VR (e.g., the fact that VR displays have entered the consumer market – see Oculus Rift) will make ubiquitous access to VR a more realistic option.

Although the findings summarized are still preliminary, they suggest that VR is a promising technique for adjunctive pain reduction during medical procedures. It can be more effective than other distraction techniques due to its unique characteristics, such as the possibility of full immersion and interaction (Sharar et al. 2007; Malloy and Milling 2010). As suggested by a recent systematic review (Triberti et al. 2014), different psychological factors play a critical role, too, in the effectiveness of the analgesic distraction. While sense of presence influence the effectiveness of VR as a distraction tool, anxiety as well as positive emotions directly affect the experience of pain.

The future of VR analgesia is open to the application of this technique to treat acute pain in many other medical procedures. Another field of study is the possible use of VR in the treatment of chronic pain (Ramachandran and Seckel 2010; Keefe et al. 2012). For example, Won and Collins (2012) successfully tested a virtual reality mirror visual feedback therapy for persistent idiopathic facial pain while Botella and colleagues (2013) presented preliminary data on the effectiveness of VR as an adjunct to CBT in the treatment of fibromyalgia FM in a sample of 6 patients:

the results showed the long-term benefits of significantly reduced pain and depression and an increased positive affect and use of healthy coping strategies.

To explore the potential of VR in these fields, Loreto-Quijada and colleagues (2013) assessed the validity of a VR intervention designed specifically to gain control over pain. Results showed that prior to the conditioning procedure, the extreme state figure reflecting pain was evaluated as significantly more arousing and more unpleasant than the extreme state figure representing no pain. Furthermore, the results suggest that VR could be more widely used in the pain field, specifically in chronic pain patients for purposes other than distraction.

A different approach to this problem was recently offered by Llobera and colleagues (2013). They suggested the induction of virtual body ownership combined with simple electrophysiological measures to assess patients suffering chronic pain: VR body ownership induced changes on electromyography and BCI performance in a chronic pain patient that were different from those in five healthy controls.

12.3.6 Other Treatments

The main applications of VR to mental health have been described in the former sections. In this section we will briefly summarize the application of VR for the treatment of other conditions. In the field of psychiatric disorders, virtual reality has been applied to the treatment of childhood disorders such as autism (Strickland 1997). Rizzo has developed a virtual classroom for the assessment and rehabilitation of attention deficits in Attention Deficit Hyperactivity Disorder (Rizzo et al. 2000).

In the field of adult psychopathology Botella's team is testing the efficacy of a virtual environment (EMMA's World) for the treatment of several emotional disorders, Its utility has been tested in the treatment of adjustment disorders. The virtual environment allows making the meaning related to the loss objective by means of virtual tools and objects that symbolize that loss, specifically tailored for each individual. The findings demostrated that this process helps in processing the loss (Baños, in press). It has been also uses for the treatment of Complicated Grief and both short-term (from pre-test to post-test) and long-term (2-, 6- and 12-month follow-ups) efficacy data offer preliminary support of the use of EMMA's World in this problem (Botella et al. 2008). On the other hand, given the flexibility of EMMA's World it has been used also for the treatment of storm phobia in a severe case of a 71 years old lady (Botella et al. 2006a).

Optale and his team (Optale et al. 1997, 1999) used immersive virtual reality to improve the efficacy of a psychodynamic approach in treating male erectile disorders. In the proposed VR four different expandable pathways open up through a forest, bringing the patients back to their childhood, adolescence and teens, when they became interested in sex. Different situations are presented with obstacles that the patient has to overcome in order to continue. VR environments are used as a form of controlled dreams, allowing the patient to express transference reactions and free associations related to his sexual experience in a non-verbal way. General principles of psychological dynamisms such as the difficulty with separations and ambivalent attachments are used to inform interpretive efforts. The obtained results show that VR seems to hasten the healing process and reduce dropouts: 30 out of 36 patients with psychological erectile dysfunction and 28 out of 37 patients with premature ejaculation maintained partial or complete positive response after 6-month follow up. Moreover, Optale used *PET* scans to analyze regional brain metabolism changes from baseline to follow-up in patients treated with VR (Optale et al. 1998). The analysis of the scans showed different metabolic changes in specific areas of the brain connected with the erection mechanism.

An emerging field is the application of VR for the treatment of addictions, specifically for the delivery of cue exposure. Several research teams are developing virtual worlds for the assessment and treatment of several toxic addictions such as alcohol, and nicotine (i.e. Bordnick et al. 2005, 2008; Carter et al. 2008; García-Rodríguez et al. 2013; Gatti et al. 2008) and non-toxic addictions such as pathological gambling (i.e. Giroux et al. 2013; Lee et al. 2003; Nemire et al. 1999).

Another emerging area is the treatment of persecutory delusions. Virtual reality (VR) has begun to be used to research the key psychotic symptom of paranoia. The initial studies have been with non-clinical individuals and individuals at high risk of psychosis (Freeman et al. 2003; 2008). The next step is to develop the technology for the understanding and treatment of clinical delusions. A study by Fornells-Ambrojo and colleagues (2008) explored the possible use of VR for the understanding and treatment of clinical delusions. Their study indicates that brief experiences in VR are safe and acceptable to people with psychosis. Further, patients with paranoia can feel engaged in VR scenes and experience persecutory thoughts.

A final important field not directly discussed in this chapter is rehabilitation. To explore this area, Riva and colleagues edited two books whose aim was to establish theoretical and practical issues in the use of VR for assessment and treatment in neuro-psycho-physiology (Riva 1997; Riva et al. 1998). A more recent contribution is the book "Advanced Technologies in Rehabilitation" edited by Gaggioli and colleagues (2009).

12.3.7 The Limitations of Virtual Reality

As we have seen, there has been a steady growth in the use of VR in mental health due to the advances in information technology and the decline in costs (Riva 2002). It is worth mentioning that, regarding anxiety disorders there are already rigorous review papers that support the use of VR (Parsons and Rizzo 2008; Powers and Emmelkamp 2008). As Powers and Emmelkamp, stated, the obtained results related to the efficacy and advantages of VR justify a broader application of these systems in the clinical practice PRJQ. However, several barriers still remain.

The first is the lack of standardization in VR devices and software. The PC-based systems, while inexpensive and easy-to-use, still suffer from a lack of flexibility and capabilities necessary to individualize environments for each patient (Riva 1997). To date, very few of the various VR systems available are interoperable. This makes their use in contexts other than those in which they were developed difficult.

The second is the lack of standardized protocols that can be shared by the community of researchers. In the two clinical databases – Medline and PsycInfo – there are only five published clinical protocols: for the treatment of eating disorders (Riva et al. 2001a, b), fear of flying (Klein 1999; Rothbaum et al. 1999), fear of public speaking (Botella et al. 2000), panic disorders (Vincelli et al. 2001a, b) and social phobia (Roy et al. 2003).

The third is the costs required for the set-up trials. As we have just seen, the lack of interoperable systems added to the lack of clinical protocols forces most researchers to spend a lot of time and money in designing and developing their own VR application: many of them can be considered "one-off" creations tied to proprietary hardware and software, which have been tuned by a process of trial and error. According to the European funded project VEPSY Updated (Riva et al. 2001a, b) the cost required for designing a clinical VR application from scratch and testing it on clinical patients using controlled trials may range between 150,000 and 200,000€.

To address at least partially this issue, Riva's team presented NeuroVR (http://www.neurovr.org), a free virtual reality platform based on open-source software (Riva et al. 2007, 2009, 2011). The last version of the software (NeuroVR 3), allows non-expert users to adapt the content of 14 pre-designed virtual environments to the specific needs of the clinical or experimental setting.

Using NeuroVR, the user can choose the appropriate psychological stimuli/stressors from a database of objects (both 2D and 3D) and videos, and easily place them into the virtual environment. The edited scene can then be visualized in a Player using either immersive or non-immersive displays.

Finally, the introduction of patients and clinicians to VEs raises certain safety and ethical issues (Durlach and Mavor 1995). In fact, despite developments in VR technology, some users still experience health and safety problems associated with VR use. However, for a large proportion of VR users, these effects are mild and subside quickly (Nichols and Patel 2002).

12.4 Conclusions and Future Perspectives

As explained previously, the feeling of presence induced by VR has helped this medium to find a significant space in mental health treatment. In particular, VR is playing an important role as a presence-enhanced supportive technique. Through presence, VR helps the patient to confront his/her problems in a meaningful yet controlled and safe setting. Furthermore, it opens the possibility of experiencing his/her life in a more satisfying way. In fact, VR therapists are using presence to provide meaningful experiences capable of inducing deep and permanent change in their patients.

However, significant efforts are still required to move VR into commercial success and therefore routine clinical use: the more a complex and costly a technology is, the less the user is likely to accept it. Therefore, a critical challenge for the future is the development of easy-to-use and customizable virtual environments that may be adapted in real time to the patient's needs. An example of this approach comes from the European funded EMMA Project. The EMMA project developed a VR application (EMMA's World) in which the therapist is free to tune the patient experience according to the specific therapeutic needs. Specifically, it allows real-time modifications of the virtual scenarios (a beach, a field, a desert, a solitary and snow-covered place); the use of different realistic natural effects (fog, rain, change from night to day, earthquake, rainbow); the use of objects and significant symbols (from 3D objects to real photographs of something/someone significant to the person) to anchor the virtual experience to the personal history. All this possibilities are designed in order to facilitate the expression of emotions in therapy and to help to catalyze, potentate and facilitate the process of change.

A second challenge for the future is the evolution of a typical VR experience. Currently, most of the existing VR applications for mental health are based on single PCs located in the office of a therapist. However, the enormous diffusion of the World Wide Web and the introduction of the Web 2.0 have facilitated the development of new forms of collaborative interaction between multiple users based on 3-D virtual worlds. Compared with conventional VR system, 3D shared virtual worlds like Second Life (http://www.secondlife.com) may convey greater feelings of presence, facilitate the clinical communication process, positively influence group processes and cohesiveness in group-based therapies, and foster higher levels of interpersonal trust between therapists and patients (Gorini et al. 2007, 2008; Riva 2003). However, challenges related to the potentially addictive nature of such virtual worlds and questions related to privacy and personal safety have to be addressed by researchers and clinicians.

More, from the clinical viewpoint, the actual VR protocols consider VR a "closed" experience, produced and lived in the therapist's office only, separated from the emotions and behaviors experienced by the patient in the real world.

To overcome this issue, an important role will be played by intelligent environments for health care in which complex multimedia contents integrate and enrich the real space (Riva 2000; Gorini et al. 2007, 2008). Examples of this tendency are, on one hand, the complex systems that combine different Information and Communication Technologies like the Butler system, a technological e-health platform that uses the Internet to connect various users designed to deliver health care to the elderly (Botella et al. 2009); and, on the other hand, sophisticated systems that incorporate intelligent e-therapy in the clinical context (Alcañiz et al. 2009).

A further step is the use Augmented Reality – AR (Rosenblum 2000), the enhancement of information a user has about a real scene through the embedding of one or more objects (3D, images, videos, text, computer graphics, sound, etc.) within his/her sensorial field. These objects may be part of a wider virtual space whose contents can be accessed in various ways using different media (cellular phones, tablet PCs, PDAs, Internet, etc.). AR shares some advantages with VR in respect to in vivo treatments. First, the virtual elements that appear in the scene are not real, so these elements that represent patients' fears cannot hurt them. Further, the therapist can control the virtual elements and how these elements interact with patients. Nevertheless, the feeling of presence and reality judgment is greater in AR, given the reduced mediation of the technology.

To test this concept, Botella and colleagues developed an AR system based on the exposure guidelines from Öst et al. (1991), to treat phobia of small animals (cockroaches or spiders). The preliminary results obtained in a case study (Botella et al. 2005) and in a series of cases (Juan et al. 2005) are very promising. Before the exposure session, patients were not able to approach real animals. After the session with the AR system, patients were able to approach a real animal, to interact with it and to kill it by themselves. The improvement was maintained after 2 months of the treatment. Mott and colleagues (2008) successfully used an augmented virtual reality system to alleviate pain in children undergoing burns dressing changes, while Fidopiastis et al. (2009) evaluated the potential of a mixed reality experience for the assessment of post-traumatic stress disorder.

A further advancement can be offered by a new technological paradigm, Interreality (Cipresso et al. 2012; Gaggioli et al. 2014; Pallavicini et al. 2013b; Riva 2009; Riva et al. 2010; Repetto and Riva 2011): an hybrid, closed-loop empowering experience bridging physical and virtual worlds. The main feature of Interreality is a twofold link between the virtual and the real world (Riva 2009): (a) behavior in physical world influences the experience in the virtual one; (b) behavior in the virtual world influences the experience in the real one. On one side, the patient is continuously assessed in the virtual and real worlds by tracking the behavioral and emotional status in the context of challenging tasks (*customization of the therapy according to the characteristics of the patient*). On the other side, feedback is continuously provided to improve both the appraisal and the coping skills of the patient through a conditioned association between effective performance state and task execution behaviours (improvement of self efficacy).

Pallavicini, Gaggioli and colleagues (2013b) started in early 2013 the first controlled trial for assessing the added value of an interreality a protocol for reducing psychological stress. The trial includes three groups of approximately 50 subjects each who suffer from psychological stress: (1) the interreality group, (2) the control group, receiving traditional stress management CBT-based training, (3) the waiting list group.

However, to exploit the full potential of this evolving situation the development of future presence-inducing media will require multi-disciplinary teams of engineers, computer programmers, and therapists working in concert to treat specific clinical problems. Hopefully, by bringing this community of experts together, further interest from granting agencies will be stimulated. In particular, information on presence-enhancing technology must be made available to the health care community in a format that is easy-to-understand and which invites participation.

All the applications described in this chapter entailed important advances in the field of health. It is important to highlight that powerful and sophisticated tools are being developed with a notable capacity of provoke important effects in the users. Therefore, it is necessary for all the researchers interested in this field to take into account the ethical considerations that these new developments entail. We cannot forget the classical statement that is essential in our field: "*Primum non nocere*".

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