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On the Role of Presence in Mixed Reality

Abstract

Previous paradigms for presence research were primarily established in the context of virtual reality (VR). The objective of this paper is to introduce a new agenda for research on presence suitable for the domain of mixed reality (MR). While established assumptions and methods of presence research from VR are applicable to MR experiences, we argue that they are not necessarily meaningful or informative. Specifically, a shift of attention is needed away from psycho-physiological studies coming from a laboratory experiment tradition, toward an ecological-cultural approach that is applicable in real world situations and relies on ethnographic rather than fully controlled methods. We give a series of examples taken from the work on the European integrated research project IPCity, and discuss the implications of our findings.

1 Introduction

The growing interest in mixed reality (MR) environments raises a number of significant challenges for our understanding of presence that go beyond the existing explorations of telepresence or presence. MR environments need to take account of the real world, that is, of the situated and social nature of the inhabited spaces they are embedded in. A central question is how to approach the design, construction, and assessment of MR environments to promote an appropriate sense of presence in relationship to the real world, the mediated mixed reality experience, and other users. This perspective requires a shift of attention:

- from virtual environments to mixed environments that mesh or augment places and times.
- from psycho-physiological studies of sensing and perception to understanding social action, interaction, and construction of meaning.
- from a focus on the individual to collectives of interacting users, both co-located and distributed.
- from immaterial environments to environments with material objects and properties that engage all our senses.
- from passive presence to active place-making (giving things a place) and expressionals (using things for experiencing and expressing).

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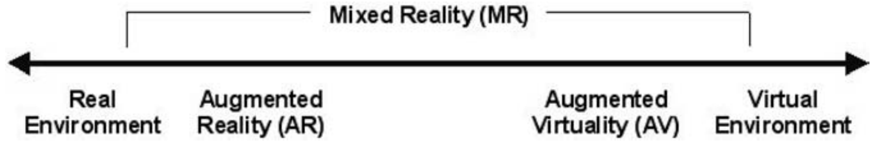

Figure 1. *Milgram's virtuality continuum.*

As part of our experiments with MR technologies in the four-year European integrated research project IPCity (http://www.IPCity.eu, contract no. FP6-2004-IST-4-27571), we are developing a conceptual framework that takes account of the social and situated nature of interacting in MR environments. It seeks to bring together concepts from presence research, Computer Supported Cooperative Work (CSCW), and activity theory with more creative concepts that have been inspired by urban studies and the arts, as well as from our previous research. We will first examine these issues from a more theoretical perspective in Section 2, then give examples from three extensive experiments conducted in IPCity in Section 3, and finally discuss our findings in Section 4.

2 Relationship of Presence and Mixed Reality Research

2.1 The Virtuality Continuum

Milgram and Kishino (1994) defined mixed reality (MR) as the "merging of real and virtual worlds somewhere along the virtuality continuum which connects completely real environments to completely virtual ones. It is a sliding scale of complete virtuality on one end (virtual environments) to complete reality on the other (the real world)." MR systems either augment the real world with added virtual features (augmented reality, AR), or augment the virtual world with real features (augmented virtuality, AV). MR systems span across this continuum (see Figure 1). But first, we discuss MR experiences and MR interactions.

MR interaction, we could argue, occurs when the task involves actions in and processing of information from both the real environment (RE) and virtual environment (VE). However, as suggested by Hirose, Ohta, and Feiner (2002), MR interactions and experiences typically only occupy a specific point along the virtuality continuum, rather than spreading over the whole continuum. For example, finding a location in a city with the aid of a mobile AR system is still primarily a task in the RE, although it involves some actions in the VE. Conversely, many AV experiences happen primarily in the VE, with only minimal aspects of the RE added. For example, the well known pit experiment (Meehan, Insko, Whitton, & Brooks, 2002) heightens the fear of falling into a virtual pit experienced through a head mounted display by adding a physical ledge. This experiment has sometimes been called AV, but we can argue that the haptic feedback from the ledge (which is just a wooden plank) is actually less real than the perception of one's own body in a standard VR environment such as a CAVE.

Transitional interfaces (Billinghurst, Kato, & Poupyrev, 2001), which sequentially present experiences along different positions on the virtuality continuum, have the potential of deepening one's understanding of the problem domain by experiencing different viewpoints. In general, a plurality of experiences offered by a mix of technologies and prolonged exposure to a variety of representations along the virtuality continuum can address more involved and interesting real world problems, which cannot be sufficiently addressed with a single computer-mediated experience. We will later see how this is critical for our take on presence in MR.

2.2 Mainstream Presence Research

Presence is a phenomenon of human experience that occurs in the context of technologically mediated perception. It has a complex, multifaceted background. As a result, there is no single, universally accepted definition of presence, except for relatively simple, nonexhaustive ones such as "the feeling of being there" (Heeter, 1992) and "the perceptual illusion of nonmediation" (Lombard & Ditton, 1997). The phenomenon of presence is obviously not only grounded in physical perception. Most researchers agree with Slater and Steed (2000) that presence has a subjective and psychological, as well as an objective and physical, component. Consequently, evaluation methods range from assessing subjective phenomena (e.g., through questionnaires) to observing objective phenomena (e.g., by measuring biosignals).

IJsselstein and Riva (2003) review various discussions of presence and suggest a decomposition of presence into physical presence, the feeling of being in a place, and social presence, the feeling of being together with another person. The overlap of both, co-presence, describes the feeling of being together in a shared space. The concept of co-presence is very important for MR, because MR specifically facilitates the construction of shared spaces (Szalarari, Schmalstieg, Fuhrmann, & Gervautz, 1998; Billinghurst, Weghorst, & Furness, 1996) by presenting matching virtual and real stimuli to multiple users. While physical presence is mostly investigated in the context of purely immersive VR applications (immersion denoting the quality of computer-mediated stimuli), social presence is studied in a wider context. It therefore has cognitive and cultural-ecological aspects that can no longer be studied under laboratory conditions. This is problematic insofar as there is a tendency among researchers to prefer studying phenomena that are easily observable, while the relevance of more elusive phenomena is simply ignored.

Other approaches to exploring presence have been put forward by Waterworth and Waterworth (2003a, 2003b) who argue that presence is the ability of a person to see how he or she relates to the wider environment; for example, a person is himself or herself and not the table situated in the corner. In contrast, Biocca (1997) maintains that presence is primarily an internal or conceptual experience. This view is shared to some extent by the International Society for Presence Research (ISPR, 2008). Adopting either of these approaches leads to the classic division of body and mind, a view that is criticized by Turner (2007). Turner argues that there can be no such separation and that intentionality is the critical component. Forms of intentionality include corporeal intentionality (e.g., one's body moves away from something), social intentionality (e.g., understanding our own mental states and the states of others), affective intentionality (e.g., fear, boredom, etc.), and cognitive or perceptual intentionality (e.g., brain-mind link).

This approach provides a starting point from which to consider presence research within the domain of MR as it removes the need to consider the real/virtual divide and places at its core the intentions of users toward the various aspects of the MR environment. These intentions include not only the physical ability to interact within the new MR environment, but also higher level cognitive processes and desires.

The problems with the various definitions of presence become more acute when the objective is to measure a given experience. For example, a purely internal (cognitive model approach) to presence often results in the use of subjective measures such as questionnaires and interviews. Floridi (2007) criticizes these both from a theoretical and methodological perspective. He notes that measurement should be both objective and observable. However, an approach based on objective observation leads to problems in relating external observations to internal mental states. Hence there can be no single research methodology that fulfills all these diverging requirements.

2.3 Critical Discussion of Presence within the Research Community

As the research on presence has matured and its scope has broadened, a critical thread has emerged in the discussions. This has been at least partially related to an increasing interest in other fields than original immersive telepresence and VR systems, such as AR and MR, and also to a movement out from the laboratory toward more real-life-like settings. This critical discussion can be divided into two threads: a general philosophical-epistemological one, and a more practical one interested in dealing with specific research issues.

2.3.1 Philosophical-Epistemological Discussion. The overarching theme of this discussion is that the "traditional" presence research has tacitly and unreflectively adopted some fundamental assumptions about humans that are severely limiting. The critics aim to reveal these assumptions and search for alternative theoretical frameworks that could be used as the new foundation for presence research.

As was the case for the discussions on artificial intelligence in the 1980s (see Winograd & Flores, 1987), one of the recognized sources of criticism and potential alternative foundation is Heideggerian philosophy. Zahorik and Jenison (1998) suggest a shift in ontological view from the prevailing rationalistic tradition, where the studies and systems of explanation are based on the separation between physical and psychological domains and on the relationship between them, toward a Heideggerian view that addresses this ontological question differently. They see that the centrality of the representation of the physical world in the mind puts an intractable problem at the heart of the enterprise: it can never be determined with certainty if the research can reliably uncover the perceiver's phenomenal state.

To avoid this pitfall, they suggest Heidegger's phenomenal existentialism based on "being-in-the-world" as an alternative. To characterize this approach, they discuss two Heideggerian concepts: "thrownness" and "readiness-at-hand." In Heidegger's view, the analytical detachment, modeling, and reflective analysis of the world cannot be the source of our actions: we are "thrown" into the world and have to continuously interpret our surroundings and act in the situations without the possibility of stopping for analytical detachment and reflection. This being-in-the-world is our primary and everyday mode of existence. Reflection is possible only during "breakdowns"; when something that has been and should be ready-at-hand in the flow of actions no longer functions properly and the flow actually breaks down. Heidegger defines being in terms of actions in the world. Following that, Zahorik and Jenison (1998) suggest that presence is tantamount to successfully supported actions in the environment, whatever the environment may be.

Similarly, Mantovani and Riva (1999) suggest that Gibson's ecological theory of perception would offer a better starting point than the mainstream position presented in Section 2.2. Gibson's view challenges many of the points of the mainstream position. Gibson (1986) states, "I assume that affordances are not simply phenomenal qualities of subjective experience. I also assume that they are not simply the physical properties of things as now conceived by physical science. Instead, they are ecological, in the sense that they are properties of the environment relative to an animal. These assumptions are novel, and need to be discussed." In other words:

- Organism and environment are not separated but united in a reciprocal relationship;
- Organisms perceive in the environment features relevant for actions (affordances);
- Valid perception is what makes successful actions in the environment possible.

Affordance is a relational concept: it is not subjective but exists objectively in the environment. Neither is it an intrinsic feature of an environment: it can exist only for a subject who has both capability and the need for a particular action. Thus most tables can have an affordance of sitting upon for an adult, but not for a small child.

According to the Gibsonian view of reality, knowledge and perception differ radically from that of mainstream presence research. In the latter case, perception is valid to the extent it faithfully reproduces the "given" external environment, which is the same to everyone. In Gibson's view, valid perception is that which allows affordances that make successful actions possible in the environment, and this perception can vary from one person to another and from one moment to the next, depending on what actions one needs to initiate.

If we accept a Gibsonian view, there is no fundamental difference between the real and the artificial environment—both of them are mediated, we do not perceive either of them as such, but always filtered through the purpose of our actions where we are engaged. The origin of our perception is in our actions and purposes rather than in the environment. According to Mantovani and Riva (1999), this means that there is always also a social and cultural dimension of presence: because our actions and need for actions are socially motivated, our reality is always co-constructed.

2.3.2 Practical Criticism Around More Specific Issues. Turner and Turner (2002, 2006) discuss the importance of context of use in designing virtual environments. In their 2002 paper, they compare two marine training simulators, one where a lot of emphasis has been put on the realistic visual rendition of the bridge of a ship, and another one with no attempt toward visual realism, but featuring a number of contextual clues embedded in the situation. Despite the difference, both are found to be effective in training. They believe that, contrary to the normally held belief, more improvement in engagement and presence can be gained by focusing on contextual cues external to the virtual environment instead of representational realism. In their 2006 paper, Turner and Turner continue the contextual theme by a discussion about places, in particular, spaces that are overlaid with meanings by individuals or groups. They discuss a sense of place that can be seen as a prerequisite for presence, but which needs a personal and historical first-person relation to a particular space, which in turn is at odds with the objective and scientific measures common in presence research.

Marsh (2003) is particularly interested in the continuity of experience, "staying there," which he assumes to be important for presence. He continues to further specify the action-based, socio-cultural approach to presence suggested by Mantovani and Riva (1999) using cultural-historical activity theory based on Leontjev's (1981) ideas, and also advances the topic of contextual continuity suggested by Turner and Turner. He develops concepts and models to describe the user's activities from low-level operations to the holistic level as an arena to reason about experience in mediated environments, and also as a way to study the shifts in consciousness.

These approaches resonate well with Rettie (2005), who compares the experience of presence in phone calls and in VR environments. She proposes to enrich Gibson's ecological psychology of affordances with the concept of frames developed by Goffman (1959) and the concept of embodiment by Merleau-Ponty (1962). According to Merleau-Ponty, there is no "in here" and "out there," just a holistic sense of the body-subject within the world. What we experience is a perspective grasp upon the world from the "point of view" of the body. MR or VR can be seen as diminishing or enlarging our "corporeal schemata" through the incorporation of alien elements (Rettie, 2005).

Spagnolli and Gamberini (2005) try to find an alternative to mental, intimate models of presence. They have developed an ethnographic, action-based approach to analyze presence as the ongoing result of the actions performed in an environment and the local and cultural resources deployed by actors. They show that the physical place, in which the user is present, and the material resources it offers are crucial to the experience of presence in MR.

In IPCity, we focus on MR applications for urban environments. These environments are not necessarily static; they are multi-layered and dynamic. While a full discussion of presence and urban environments would reach beyond the scope of the present paper, it is worthwhile noting that architecture, as the discipline of representing and forming the spatial experience of everyday life, has always been exploring various forms of spatial and social presence (Boradorri, 2000). We can refer to the virtuality of space taking into consideration the definition of "virtual" by Deleuze (1968), who—in a nutshell—contends that the virtual is a state of reality opposed to the actual. We also witness today the emergence of a new perception of urban planning that entails new languages of a strongly narrative character, appealing to social imagery and reaching beyond traditional representational techniques (Terrin, 2005).

Moreover, the development of cyberspace and the notion of telepresence is attracting a constantly increasing interest, inciting new approaches to urban environments, as can be seen for example in practices and theories like transarchitectures (e.g., Brouwer, Brookman, & Mudler, 2002), the work on urban ambiences (e.g., Amphoux, Thibaud, & Chelkoff, 2004), as well as in artistic-architectural installations (e.g., Wilson, 2002).

2.4 Conceptualizing Presence in Mixed Reality

The main difference between any kind of MR and traditional VR obviously is the addition of reality, the RE. Milgram and Kishino (1994) state that the virtuality continuum is actually a simplification of a design space with at least three factors: reproduction fidelity (of the mediated stimuli), extent of presence, and extent of (real) world knowledge. By extent of presence they denote the conditions under which physical stimuli are received, so in current research terminology, this should better be called immersion. While immersion and reproduction fidelity are directly comparable to the concepts used in presence research dealing with VE issues, the extent of world knowledge characterizes to what degree and in which capacity the RE is involved.

The notion of MR introduced by Milgram and Kishino (1994) already goes beyond what can be comfortably described with concepts developed for pure VR. However, this very notion of MR has itself been criticized as too narrow by Benford, Greenhalgh, Reynard, Brown, and Koleva (1998). Milgram and Kishino describe MR as the combination of RE and VE "presented together within a single display." Benford et al. argue that a complex environment will often be composed of multiple displays and adjacent spaces, which constitute "mixed realities" (note the plural). These multiple spaces meet at "mixed reality boundaries." Obviously, the combinatorial power of multi-space environments allows for a much wider variety of situations to be included, leading to a better match for the cultural-ecological study of urban environments such as considered in IPCity. For example, it is a known problem that longitudinal studies can hardly be performed under laboratory conditions afforded by mainstream presence research, that is, in a single space. Conversely, mixed realities can encompass all environments relevant for the subjects in the context of the study.

Goldiez and Dawson (2004) discuss whether presence is present in AR systems. While this topic sounds conceptually similar to the theme of this paper, they purposely deal with AR in a very narrow sense. Their approach is based on the decomposition of presence suggested by Heeter (1992), which contains a personal, social, and environmental component. Goldiez and Dawson abandon the personal component on the grounds that it is trivially fulfilled by the RE portion of AR, and suggest a subjective evaluation method mainly based on presence questionnaires modified to assess the VE aspects of the MR experience, such as avatars or computer-controlled entities presented to the user. They also state that a prerequisite to this approach is that the AR technology does not get in the way of the user, that is, the boundaries in the above sense are considered a disturbing artifact rather than an asset.

This approach to interpreting presence relative to AR/MR captures only a narrow portion of the phenomena, because it purposely ignores the most interesting element of MR, the real world. When tasks and actions are primarily grounded in the RE, presence rooted in immersion may either not be observable or may be simply irrelevant. The problem can be traced back to the following implicit assumptions.

1. Being aware of the mediating technology is always undesirable.
2. The experiences are uniform and continuous. This is not the case in MR, where to date it has been difficult to ascertain whether people constantly switch between real and virtual elements or are present in a continuous blend of realities.
3. Presence is about replacing reality rather than augmenting it.

MacIntyre, Bolter, and Gandy (2004) recognize that this interpretation of presence in an AR/MR context is very narrow, and suggest an extended concept they call *engagement,* which encompasses aspects of presence, but also of place and meaning of place. This approach is much closer to our research than the one suggested by Goldiez and Dawson (2004). However, this approach still relies much more heavily on the concept of perceived nonmediation compared to our approach.

What we need for presence research that is meaningful for MR is a broader conceptual framework that encompasses traditional perceptual elements of presence, but has an emphasis on social presence, affordances, beliefs, and longitudinal effects. Consequently, a mixture of evaluation techniques, including questionnaires, automated logs, observation, or interviews, is required to approach the full range of phenomena. Because it is hard to make a formal, brief definition of this methodology, we will use the following sections, which have been investigated as part of the IPCity fieldwork, to illustrate our approach.

3 A Range of Mixed Reality Examples

In IPCity, we are working on three mixed reality experiences that are further detailed here—*MapLens, TimeWarp,* and *MR Tent.*

MapLens is a mobile AR system for mixed digital-physical maps. It uses mobile phones to augment physical maps with useful and interesting real-time information. Paper maps have a large static surface and AR can provide a see-through lens without forcing the user to watch map data only through the small "keyhole" of the display. Our system, called MapLens, allows using a normal map that has not been visually altered. The MapLens can be used for displaying cues about the environment and other people. In our project we applied and evaluated this technology using an environmental awareness location-based game.

TimeWarp (Herbst, Braun, McCall, & Broll, 2008) is an augmented reality game that takes place in the city of Cologne. It revolves around the idea of rescuing the city's famous *Heinzelmännchen* (small elves) from various time periods, through the completion of a series of tasks. As players walk around various locations in the city, including some famous landmarks such as the Cathedral, they can see augmented characters and objects, as well as hear narratives from various nonplayer characters. The early version of the game was for single players and used a see-through visor. The version discussed in this paper uses ultra-mobile PCs and is a cooperative game for two players.

The MR Tent targets urbanists and other stakeholders in urban renewal applications. It consists of a complex assembly of mixed reality tools, including a sound application, and a tangible user interface within the physical space of a semi-stationary shelter. This tent is set up outdoors in an urban planning area. The focus is on supporting small groups of urbanists, planners, politicians, and ordinary citizens to collaboratively envision an urban project through constructing mixed reality scenes against the background of one or several panoramas of the area, a real-time video captured by a rotating camera, or a see-through screen (Maquil, Psik, Wagner, & Wagner, 2007; Maquil, Psik, & Wagner, 2008).

All three mixed reality applications have been tested outdoors, in real use settings. They have been used repeatedly and redesigned in several cycles. Their very different nature made different evaluation strategies necessary.

In MapLens trials, we enlisted a mix of 37 early-adopters, environmental researchers, scouts, and their families to use MapLens, to play an environmental awareness-raising location-based game. A comparative trial was run with a non-AR digital system. Analyses of videos, field notes, interviews, questionnaires, and user-created content expose phenomena that arise uniquely when using AR maps in the wild.

For TimeWarp, a combinatory approach was developed that would use post-experience analysis as well as data from the actual experiences. To achieve this, questionnaires, interviews, direct observation, and video analysis were used. Several presence questionnaires were combined and adapted by adding specific questions. While the majority of users were videorecorded, some were also observed as they took part in the game. For this, we adapted an observation technique developed within IPerG (Integrated Project on Pervasive Gaming), and used it to consider which notes were taken and also to act as a method of analysis for the videos.

The MR Tent application was evaluated and redesigned in five participatory workshops in the context of real urban planning projects with urban planners and a variety of stakeholders as users. For each of these workshops, we studied the site, selected participants, prepared scenarios as well as content (panoramas from different viewpoints, architectural models, and other assets), and developed an experimental protocol for the participatory sessions. The workshop sessions were videorecorded, and transcripts of significant episodes were produced. In addition, we used several digital cameras to capture interesting situations and included saved images of visual scenes in our analysis.

What these three examples have in common is that the user experience depends on the users' own purposeful activities and that the specific relationship of virtual and real in each case is essential to this experience. However, the examples also differ in ways that help better understand the richness of mixed reality experiences and the need to widen the conceptual and methodological apparatus for capturing them. MapLens, which operates with mobile phones, is a non-immersive augmentation of a physical artifact conveying cues of other people and sites, and locating them in the urban environment. However, the field trials revealed that its potential lies not so much in use for navigation, but in its use as a co-located collaborative tool. TimeWarp focuses on the sense of presence created through augmenting the real environment, and it also explores presence between users and nonplayer characters. In doing so, it explores higher-level topics such as collaboration, switches, and unified experiences. MR Tent uses a complex representation of the real and envisioned scene, leveraging MR boundaries and offering many opportunities to co-construct the architectural intervention. Action is anchored within the RE and augmented in both a visual and an acoustic manner.

3.1 MapLens—Mobile Mixed Reality Collaboration on a Physical Map

Mobile phones are by far the most common and pervasive computing platform. How can they be seen to contribute to a mixed reality landscape and to presence research? While mobile phones originally were tools to synchronously or asynchronously support two parties in communication, they are currently turned into powerful tools for creating media, sensing situations, and tracking users in the physical and digital world. Recent developments even make true AR based on computer vision tracking possible directly on phones (Wagner, Reitmayr, Mulloni, Drummond, & Schmalstieg, 2008).

In the study, we gathered data with a triangulation of quantitative and qualitative methods. Methods included collecting demographic data and ascertaining perceived experience with technology, phones, use of maps, and knowledge of environmental issues and of the Helsinki center itself where the game was located. Each team of test users was accompanied throughout by one researcher observing and taking notes and photographs or videos. The researchers as observers had been briefed to look for particular aspects of interaction. These included: how participants negotiated and with what types of tasks; how turn-taking was negotiated, the shifting of focus (between real and virtual); when did participants seem most involved (most present); in what kinds of circumstances did people gesture and at what (switching between real and virtual); and if it occurred, at what point in the game did teams establish some kind of system of use.

On return from the game, participants completed a three-page questionnaire from flow, presence, and intrinsic motivation research to gauge reactions to the technology and the game (see below in this section for more detail on findings for this). This activity also focused participants on their experience in the trial, familiarizing them with an extended vocabulary to better articulate those experiences. Participants then described their experiences, highlighting aspects that had caught their attention in semi-structured one-on-one recorded interviews.

MapLens is an application for Symbian OS S60 Nokia mobile phones with camera and GPS. When a paper map is viewed through the phone camera, the system analyzes and identifies the coordinates of the map area visible on the phone screen. Based on these coordinates, location based media (photos and their metadata) are fetched from a server. To access the media, displayed icons can be selected, which in turn show a thumbnail of the photo on top of the map image on the phone screen (see Figure 2, left). MapLens uses predetermined map data files to identify the paper map and associate its visible area to geographical coordinates. To accurately overlay information of the image of the map in the mobile phone's display, the 3D pose—translation and rotation—of the phone's camera with respect to the map is determined using natural feature tracking. As a comparison baseline for the user trial, we also instigated a non-augmented map, DigiMap, the design of which echoes

Figure 2. *(Left) MapLens in use with a paper map, overlaying digital information on screen. With the red square (center) user locates and selects markers—as one user states—"catches them." (Right) DigiMap version, Google map with markers.*

Google maps for mobile phones (see Figure 2, right). While a physical map was not essential, one was supplied and we used the same map, red icons, and updated data to be switched on and off across both systems. We used joystick phone navigation for scrolling across the map, using two buttons to control zoom in and out.

The trials were run as a location-based treasure hunt style game. The game was designed to raise users' awareness of their local environment. With the assistance of the technology, the players followed clues and completed the given tasks within a 90 min period, and in doing so learned about specific environmental concerns. The players uploaded photos that gave awareness information to the other players in the form of the location of players and possible clue answers.

The trial began at the Natural History Museum where players completed indoor tasks, two of which included follow-on components outside the museum. We wanted the players to solve a variety of tasks (12 in all), some of which were complex sequential problem chains. The game required players to visit green areas in the city. One task was for the whole group to walk barefoot in the grass, and upload a photo as evidence; another to gather a specific leaf (the leaf was also found as a museum clue) and then take a sunlight photograph with a kit supplied, using water to develop the photo; another was to test a sample of seawater and a sample of pond water with a supplied kit for readings on chlorine, alkalinity, and pH balance. We added the task of taking a photo of the whole group to many tasks to encourage physical proximity and team bonding. After the more physical tasks, in particular with the lifting of a 27.4 kg salmon replica in the museum—where teams needed to either contort to fit the whole team into the photo (including the held salmon) or outwardly engage strangers to take the photo—the players noticeably settled into a more relaxed game mode. We sought to specifically include physical activities in order to force the players to continually reorient their relationship to themselves as physical beings (and objects) within a world consisting of other physical beings and objects (Merleau-Ponty, 1969); essentially a confrontation with the self as both an entity in the world, as well as an object among other objects in the world. One's progress through the game is represented virtually as a trail of activity, where all the players are continually co-present to each other. This co-presence keeps the game meaningful, where competition, keeping to the tasks, and time frame are continually thrown up for the players, in turn heightening the intensity of their experience.

Each team was handed a kit bag that contained seven objects in all (see Figure 3). By design, these tangible

Figure 3. *Kit bags contained seven items that needed to be managed: sunlight photographs, map, phone, water testing kits, voucher for internet use, clue booklet, and pen.*

objects required some coordination between team members to manage well. Participants needed to coordinate use of these objects as a team in order to complete the tasks. This required they self-organize some way of use, as well as become adept at navigating.

The participants filled in three questionnaires: a shortened version of the MEC spatial presence questionnaire (MEC-SPQ; Vorderer et al., 2004), a GameFlow questionnaire based on Sweetser and Wyeth (2005), and an intrinsic motivation inventory (IMI) questionnaire (Deci & Ryan, 2000). As a Likert (ordinal) scale was used as a measure and Shapiro-Wilk's test revealed our data are not normally distributed, the Mann-Whitney U-test was selected to test the differences between the MapLens and DigiMap teams.

When comparing total presence, flow, and motivation score medians between MapLens and DigiMap participants, no significant differences were found. However, both groups scored above average on most items, indicating that motivation, being present in the game and/or map system, and experiencing a sense of concentrated engagement were activated for users of both systems. When comparing individual presence, flow, and motivation items, significant differences were found. This may be due to discrepancies where some questions address solely the use of the mapping systems (the technology), others address the "play" in the game, and still others address both aspects.

As a general conclusion from evidence provided in the questionnaire format, we found that while the MapLens users felt confident using the technology and enjoyed the experience, the DigiMap users did so even more. The technology also enabled the DigiMap users to perceive their surroundings better than users of the MapLens system; however, the MapLens users concentrated more on the technology and the procedure to effectively use the system, as well as being more focused on the game as a whole, for example, more thorough completion of game tasks. Also, MapLens users were socially active and more helpful of others. MapLens users were more focused, with both groups scoring high on sense of control, understanding requirements, interest, and enjoyment. The results from the questionnaires provided additional evidence and supported the main findings from observational data which is presented in the following.

3.1.1 Collaborative and Public Configurations. In situ creative problem solving was required and solutions varied according to the immediate environment. Tasks were designed with a view to promote internal and external group activities and awareness, negotiation of tasks and artifacts, awareness of the environment, higher level task management, and finally awareness of physicality, proximity, embodiment, and physical configurations around artifacts. There was particular emphasis on the mix of the digital with the real and overtly tangible. These tasks were designed to facilitate proximate bodily configuration, to draw users away from small-screen absorption, and to remind the participants of their own corporeal selves. The two setups afforded and facilitated different types of configurations during these tasks. In the following figures, we mark the pictures referring to MapLens the AR solution with "M" and the one referring to the DigiMap with "D." In Figure 4 it is apparent how MapLens suggested to users a more collaborative configuration and use (left), while DigiMap encourages individual interactions (right).

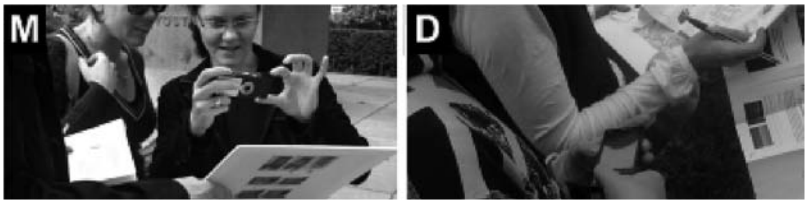

Figure 4. *MapLens (M) was held in a way that it could be shared in the group, whereas DigiMap (D) users held the device more privately.*

Figure 5. *The physical map as a common ground, established by showing with the lens (M) and pointing with finger, and the clue booklet.*

3.1.2 Establishing Common Ground. Given that the typical way of using MapLens involved a team gathered around the map and the main user gesturing on the map with the lens, establishing *common ground* was made easier for MapLens groups. By this term, we refer to shared understanding about the objects that are the focus of co-conversants' attention (Clark, 1996). The location of MapLens on the paper map, and the contents that are revealed to others on its display, help all to understand what the discussion is about without explicitly needing to ask or negotiate. In Figure 5, a young woman browses the map by using MapLens. After finding an interesting place, she suggests it to her father by pointing to it with her finger. The father proposes a nearby location instead and points to it by using the corner of a clue booklet. The tangible objects provided in the game are integrated into the means for problem-solving and communication.

The groups using DigiMap were not able to share the map that fluently. In Figure 6, a young boy is trying to identify a place by pointing to a relevant location on a screen and glancing around. After this, he gestures toward the direction he suspects to be correct and hands the device over to his uncle, who then assesses the situation.

The physical paper map supported the players better in establishing a common understanding of the area and referring to different locations. Some players found it challenging to identify the current location on the map with the focus of the lens, especially while it was being used by another player. The players using DigiMap often referred more directly by pointing at their surroundings.

The combination of the lens and the physical map provided the group a means to be collaborative in a more physical way. For example, it was possible to pinpoint locations from the physical map either with a finger or a pen so that the participant using MapLens could easily target that point on the map (see Figure 7, left). As DigiMap use did not require using the physical map and the mobile phone screen is rather small in size, negotiations in DigiMap groups didn't often happen with two people trying to look at the mobile phone screen at the same time. Within a team of two close

Figure 6. *DigiMap (D) Attempting to share the map as a common ground.*

Figure 7. *Referring to objects by pinpointing. (Left) Pointing with a pen while using MapLens (M). Right: pointing with finger from DigiMap (D) screen.*

friends, we observed constant pointing at the mobile screen, establishing common ground, while others looked at the screen behind the "navigator's" shoulder (see Figure 7, right), but most often this was not done at all. Two DigiMap groups chose to use the physical map in addition to the digital map. For example, in one group a son searched for locations using DigiMap and either spoke aloud the options to his mother or pointed at them on the screen. The mother then used the physical map for a more detailed view of the surroundings.

3.1.3 Place-Making. The act of stopping walking, raising the paper map and the lens, and gathering around for a while creates an ephemeral opportunity, isolated from the surroundings with the physical map and the bodies, to momentarily focus on a problem as a team. The phenomenon of place-making has been raised previously in the literature looking at mobile use of technology (Kristoffersen & Jungberg, 1999; Ehn & Linde, 2004), and we encounter a special multiuser form of it. Here, the physical map as a tangible artifact acts as a meeting point, a place where joint understandings can be readily reached by means of participants being able to see, demonstrate, and then agree upon action. The teams pausing for discussion created a series of temporary spaces, places for collaboration. For example, they put bags down, swapped or rearranged objects they were carrying, and stabilized the map, then consulted the MapLens to be sure they were on the right path. At this rapidly-made "place" the tasks again became shared, negotiation and switching of roles often occurred, and we witnessed a different kind of social usage in this temporary place. Other pedestrians walked around these "places."

Conversely, the DigiMap teams only needed to stop at places that the tasks themselves dictated, the rest of the action and decisions and way-finding were mainly done while on the move.

3.1.4 Usability of Co-Located Interactions and AR Mediated Cues. The collaboration described above came at a cost. While "forcing" users to create a common ground and engage in place-making, users had to adjust their interactions to cope with several problems in operation. While the nonaugmented digital counterpart of MapLens, DigiMap, is also susceptible to direct sunlight, it is much easier to cover such a small object with the palm of one's hand. Secondly, the use of MapLens, but not of DigiMap, effectively requires two hands, because either one has to steady the surface (the map) or use two hands to stabilize the phone in hand. For these reasons, use while walking is not possible, whereas DigiMap was often used while on the go. Moreover, the need for careful operation and focus on the surface and lens restricted their attention to the surroundings. Users echo this description, describing interaction with MapLens as difficult and unstable.

MapLens turns AR mediated cues into resources for collaborative action, but this came at a cost. In VR related telepresence, we can exclusively focus on how a person feels in another place or connected to remote people. Conversely, MapLens forces us to look at how several persons coexperience and act with an AR mediated device. MapLens works as a system that provides a space for "mixing realities" that can be viewed and evaluated together. Presence to the location, presence to the game, along with competing between teams, added a sense of urgency to the experience. The interaction space is enlarged, in the way in which the participants can express themselves within and experience this space. For example, one participant was so engaged in the activity of looking at MapLens and the paper map that he walked into a lamppost. Participants gather around the surface and lens system and point to the augmented view of the world they are standing within. When they experience difficulties, they raise their heads and look around and continue to point. They may need to move away, scouting, walking, or even running, looking and experiencing the actual physical reality view. Then they return and add this real information to the group-present co-located mixed reality surface and lens view, in order to negotiate and anticipate the next best move within the game sequence and the real environment.

Figure 8. *An augmented character at one of the locations in TimeWarp.*

3.2 TimeWarp—A Mobile Mixed Reality Game

TimeWarp is a mixed reality game that takes place in the city of Cologne. The objective of the game is for the players to rescue Heinzelmännchen which have been banished to different time periods, and in order to do so they must complete a series of tasks that relate the history of the city. Such a game requires an understanding of how new realities are created through the blending of real and virtual elements, along with how, when, and why people switch their sense of presence between different realities. Therefore, it becomes important to examine which elements encourage the creation of new realities, or result in switches between different realities.

TimeWarp is a collaborative game that uses ultramobile PCs (UMPCs) that are equipped with a variety of sensors capable of detecting movement and the players' current position (via GPS). One UMPC is used as a map and information device, while the other provides a lens into the new world. The video stream from a camera on the back of the UMPC is augmented with elements such as characters, objects, and buildings that are then added to the scene (see Figure 8). Audio is used at various points throughout the game either to provide narrative or instructions, or to indicate proximity to a game element.

TimeWarp used a triangulation approach to collecting data based on a modified version MEC spatial presence questionnaire (Vorderer et al., 2004), the place probe (Benyon, Smyth, O'Neill, McCall, & Carrol, 2006) in combination with a direct observation approach from the IPerG project, limited video analysis and postexperience interviews. The main objectives were to explore where people felt present during the experience, whether more in the real or more in the virtual elements, and which aspects gave rise to these changes.

We started by exploring existing presence questionnaires. However, these were not always suited to evaluation settings or the types of experience being explored. Furthermore, such questionnaires had to support assessment of physical presence (including where the user felt location in the mixed reality experience), social presence (with real and virtual people), and sense of place. One of the main objectives of the TimeWarp evaluation was to explore where players felt present during the experience, with whom (players, nonplayers in the street), the nature of the mixed reality experiences, and any switches that occurred when moving between realities. Initially, the MEC questionnaire (Vorderer et al., 2004) was chosen having formed part of an earlier work (Herbst et al., 2008). The questionnaire was then used in combination with video data, observation, interviews, and pictures. The pictures consisted of scenes from the game, including the user interface. The pictures were used to stimulate discussion during the interviews. While the majority of users were videotaped, many were also observed as they took part in the game. For this we adapted an observation technique developed within IPerG (integrated project on pervasive games), and used it to consider which notes were taken and also to act as a method of analysis for the videos. This observation technique focuses on the following areas: player-player interaction, player-device interaction, player-spectator interaction, and player-game interaction management. The IPerG method proved useful while observing people, although not all aspects were relevant.

The MEC questionnaire was quite substantially changed, with questions being modified or added and the scoring system changed. For example, the first section was modified to reflect mixed rather than virtual reality and focused on which aspects the players concentrated on, for example the real or the virtual world. For this, they were asked to rate their experience on a seven point scale which explored whether they felt more within the real or virtual elements (the original MEC questionnaire used a five point scale). The remainder of the questionnaire focused on their sense of presence toward other players, non-game participants, or non-player characters, and was based on the Bailenson et al. (2001) social presence questionnaire. Additional qualitative questions were added to explore aspects of place and were drawn from the place probe (Benyon et al., 2006).

On completing the game experience, players were invited to fill out the questionnaires and take part in the interviews. The interviews were used as a method of probing the players about their overall views of the system, for example, if they commented in the questionnaire that they particularly liked a certain time period, they would be asked to justify this answer. They were also asked about individual aspects of their experiences, for example, sudden changes in body language when they entered or left a time portal. Thus, the interviews were semi-structured in the sense that they followed already identified lines of inquiry drawn from the players' real data and our overarching theme of exploring "where" people felt present. However, a specific list of questions was not drawn up in advance. Having completed the interviews, the questionnaire data was analyzed in combination with interview responses. Although the video and observation data were again viewed, we found that the video data did not add much to the overall data collection. This was in part due to the method of recording the data, which was often at a distance from the players. Therefore, the pictures are used primarily to illustrate certain phenomena which emerged and in some cases where they also corresponded to interview comments or questionnaire data.

3.2.1 Social Encounters. Playing TimeWarp is a collaborative experience that requires players to cooperate on many aspects. This also provides a method of comparing differences between player, nonplayer characters, and passers-by. There was a very strong sense of

Figure 9. *Players collaborating during the game experience.*

presence among the players, and many pointed to this being a positive aspect of the game—and one which had a substantial impact on creating the game world the user inhabited. Cooperation took many forms, ranging from navigational information and negotiating strategies, to sharing ideas and concepts and discussing game elements (see Figure 9). For example, players often stopped and discussed game elements before agreeing on common strategies. Furthermore, they often took into account the level of engagement with the game and would swap devices, to ensure that the navigator could now become the first player, thereby allowing navigators to experience more of the virtual game elements.

Agents (in particular the Heinzelmännchen) are very important in the game, and provide not only its underlying narrative but also form critical aspects of the challenges that players must complete. As expected, the sense of presence experienced among players was higher than between users and agents, in part due to the cartoon-like graphical representation and limited interaction techniques.

3.2.2 Context and Place. Place-making is shaped by many elements including social interactions and physical, material, and historical elements (Gustafson, 2001). Within TimeWarp, the sense of place was shaped through various methods including the negotiated understanding of the new aspects that people were experiencing in combination with content such as building facades, challenges, and audio information. Such experiences also extended to being aware of when not to intervene in a space, for example, Figure 10 shows a situation when a wedding ceremony was occurring at the Town Hall. The sense of being inside the game (presence) and where people felt located (place) was very heavily influenced by the connection between game elements (the virtual dimension) and reality (the actual city). Players also noted that imagination became a key element in helping to shape their sense of place.

The players liked the strong connections between the game narrative and the city of Cologne, for example, the challenges reflecting aspects of the city's history. This interplay between real and virtual elements prompted interesting feedback with respect to place and sense of presence. For example, the old buildings in Cologne support a valid contextual frame of reference for the Heinzelmännchen narrative. This contextual element played an important part in the players' perceptions within the game.

Many players reported feeling more present within the future time period. This may be in part due to the game's "future" area. By this we mean that as it is impossible for people to time travel in real life, they will never have experienced a space-like future time

Figure 10. *The wider environment had a significant impact on participation in a game. Here two players are deciding what to do as a wedding is taking place at the Town Hall.*

period. Therefore, beyond what they will have experienced in computer games or in the media, they will have minimal predispositions as to what behaves in a real or unreal fashion. As a result (and in classic presence terms) the future time period does not require the same suspension of disbelief, as users have no prior experiences of the future from which to benchmark the experience. Furthermore, as there is little or no contextual link between reality (the real Cologne) and the future dimension, they again have no expectations about how the two are related. In contrast, if a building facade from the past does not resemble what they expect (as they have seen something from that period before) or if the past building exists in present-day Cologne, then they will be more aware of when there are inconsistencies. Indeed, the future period is from the outset unreal, involving objects and activities that are out of place. Therefore, the surrounding environmental context is less relevant, and players perceive the new reality as being more heavily connected to the futuristic objects and actions. As a result, we conclude that presence in MR is strongly influenced by user preferences and prior experiences. This view was confirmed by users who pointed out that the Heinzelmännchen felt unreal, but who found this aspect engaging.

3.2.3 Layers, Borders, and Switches. Moving between real, virtual, and blended experiences was a common issue for the players. For example, perception of spaces (and consequently places) are often shaped by the paths between locations and their relationship to the surrounding space (Ching, 2007) as much as the actual locations themselves—and many players complained about the lack of content between game locations. Ching (2007, p. 240), for example, notes that since "we move in time through a sequence of spaces" we experience space "in relation to where we've been and where we anticipate going," therefore ignoring this aspect will have a negative effect. The long walks between locations resulted in players feeling as if they were continuously entering and leaving the game experience. The strongest indication of a change in experience was when players entered a time portal, as they would often change posture and then run through it. The time portal was regarded as one of the best elements of the game, and although no differences in temporal presence were noted, it was obvious that the level of engagement and involvement increased dramatically when players searched for a portal or entered one. Other switches in presence occurred when the players left the game experience; however, they reported not feeling any change in presence when they first entered the game world.

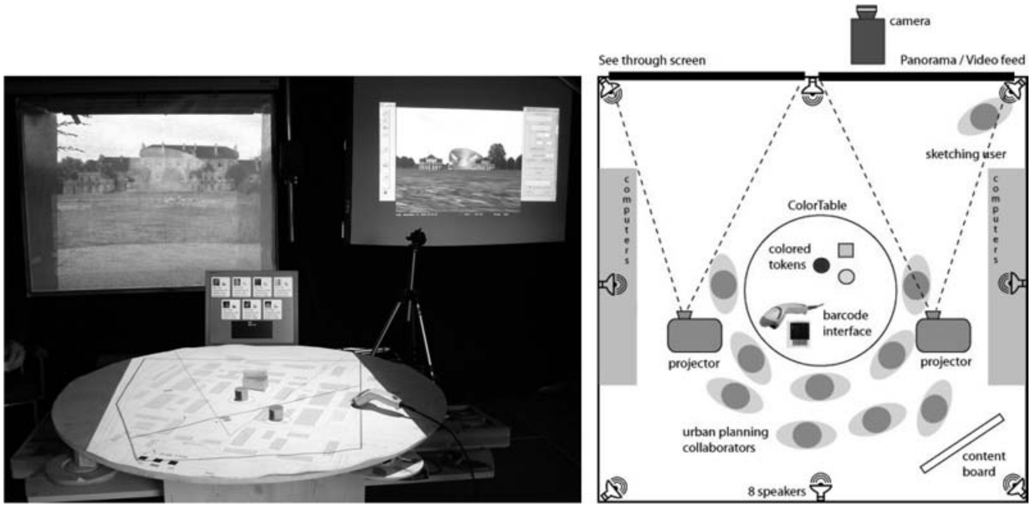

Figure 11. *The technical setup inside the MR Tent is centered around the two projection walls and the projection table.*

From the interviews, it was apparent that many people felt the augmented elements were a layer on top of the real environment, rather than part of it. This would point to the users feeling as if the two environments (real and augmented) were not sufficiently blended. This can partially be explained by players concentrating more on the virtual elements of the game, and by the cartoon-style graphics. However, we also attribute this observation to the sparse distribution of virtual objects, as frequently players would actively seek out game elements. Furthermore, players indicated that it was easier to interact with virtual than with real elements. Despite the game's clear link to physical and historical aspects of the city of Cologne, this lack of integration with the real environment was considered a negative aspect.

3.3 Collaborative Envisioning for Urban Renewal in the MR Tent

The MR Tent uses a complex arrangement of mixed reality tools and tangible user interfaces to stimulate participants' imagination and their active co-construction of MR scenes for urban renewal. It is a mobile urban design laboratory that can be transported to the site of an urban project and where real city scenes can be interactively augmented with computer-generated visualizations to illustrate, debate, and experiment about different design possibilities between various stakeholders of a design. The round table in the center of the MR Tent is a multiuser tabletop in support of urban planners and diverse stakeholders collaboratively envisioning urban change. It provides users with the possibility of arranging and positioning tokens on a surface, representing a 3D scene on physical maps of the site of an urban project at different scales. A tabletop projection augments the surface of the table by a map that provides a bird's-eye view of the site. A vertical projection renders the scene against a background that is produced by either a real-time video stream, a panorama image of a site, or a see-through installation (see Figure 11). Objects of the mixed reality world can be modified and adapted in scale, transparency, color, and offset to the ground. Users can define land use, add roads and flows to a scene, and create and explore the soundscape connected with the visual scene. They can also sketch on the scene, on multiple layers, or on 3D objects, applying paint and textures. The setup is truly collaborative; it supports simultaneous interaction in building a scene, but also revisiting and reworking previous scenes in a cooperative way.

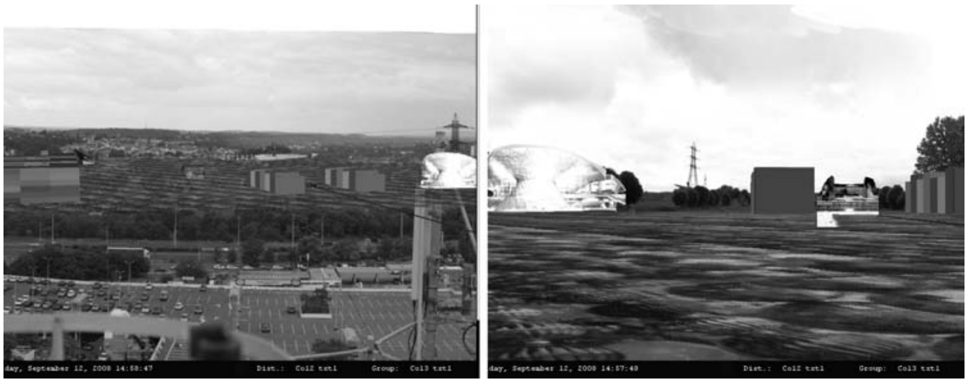

Figure 12. *Looking at a scene from different viewpoints (panoramas).*

3.3.1 Creating and Connecting Layers of Real and Virtual. Our video-supported observations and interviews allow us to identify key factors in the creation of these real-virtual connections. One is the importance of spatial aspects in participants' activities and their experience of presence. The physical place, in which the user is present, and the material resources it offers are critical to the experience of presence. Users construct the mixed reality space as part of the physical space they inhabit (Spagnolli & Gamberini, 2005). In all our workshops, we observed how close contact with the reality outside—being exposed to a lively scene (in contrast to an empty, static one) of wind, humidity, smell, background noise, passers-by continuing to walk through the projected mixed reality scene, and so forth—increased the reality element of the mixed reality configuration.

In the MR Tent, participants assemble around the table with a view onto the map to discuss an intervention; they select content cards (small cards showing a thumbnail of the visual content plus the associated sound files, together with a bar code) from the whiteboard, pick up different types of tokens for enacting their interventions (building roads, activating flows, placing objects or creating rows of them), and they use the bar code reader for activating different views onto the scene. At the same time they orient themselves in the space of the tent toward the two projection screens, one of which provides a direct view of the site through the frame of a window (see Figure 11).

The MR scenes themselves have a strong spatial aspect. We provide 2D (billboards) and 3D objects, moving elements, land use tokens, and sound. 3D objects are key to constructing mixed reality scenes. They help players understand the spatial aspect of participants' interventions in terms of volume, position, and orientation. For example, making an object transparent can add to participants' spatial understanding, as it makes the background visible, thereby anchoring virtual objects more firmly in the scene and providing additional depth information. Also, switching between the different views offered by the application—four different panoramas, the video-augmentation, as well as the top view of the physical map on the table—helped them better understand the spatial arrangements they were constructing (see Figure 12). We can see from these findings how spatial presence requires active co-constructing and exploring of the relative position and size of objects and the different views onto them.

This includes sound, which provides additional spatial information. Each visual content item was associated with several sound files from which participants could choose. Participants could explore the soundscape associated with a scene from the point of view of a pedestrian's moving position, as well as by moving the hearing position (represented by a red token). Changing the hearing positions made participants more aware of some their interventions, such as, for example, the closeness of the road they had introduced to some of the buildings they had planned. They replaced a bus (that

Figure 13. *Adding roads and flows to an MR scene.*

seemed too noisy) with a tram. They also used the sound token to identify an object that emitted an annoying "casino sound." We also observed how working with sound activated the group, motivating it to continue. Exploring the scenario with the hearing position made them enter the scenario in a way that the visual representation in itself cannot achieve. They truly started walking through the scenario and exploring.

Connecting the real with the virtual scene is facilitated by what we call dynamic representations. Users can create a network of streets and paths and add flows to them—moving pedestrians, cyclists, cars, and boats (see Figure 13). This not only introduces an additional scale in the scene and provides depth information, but also animates the scene. Participants' gaze drifted between the map view, where the flow was represented as moving dots, and the animated mixed reality scene. They examined the spatial arrangements of 2D and 3D objects that they had created in relation to these flows, eventually changing the position or type of road.

Sketching brings another dynamic element into a visual scene, reinforcing the connection between the real and the virtual. It means connecting the imagined with what is there, anchoring it in the real scene. For example, participants sketched on a composed scene, adding a whole layer onto it, making annotations, adding an object on the fly, and explaining some of the implications of their decisions. Working with layers and transparencies, they created spatial collages with the sketching application, thereby lending additional depth to a scene (see Figure 14).

What is remarkable about these scenes is that they combine realistic elements (representations of the site of an urban project from different viewpoints) with imagined ones. They populate a high-resolution photorealistic panorama or a video with rather abstract virtual objects. While the abstractness of a scene may support participants' spatial understanding, it does not necessarily allow for a sense of place and culture to emerge. We want to emphasize the role of narrative and expressive material, such as sound or other ambient content, as helping participants to connect the real with the imagined. There is the experience of dramatic presence (Dow, Mehta, Harmon, MacIntyre, & Mateas, 2007) in the sense of becoming emotionally involved with an imagined world. In the MR Tent, participants do not interact with virtual characters but with one another, thereby creating expressions of ideas that become visible in the MR scene and mix with the ideas of others. In general, we could observe how scenes with a certain distance from reality encourage reflexivity, since they require users to actively construct meaning and they leave space for imagination.

3.3.2 Tangible Interactions and Awareness Features. The tangible user interface we have built for creating MR scenes affords simultaneous (embodied) interaction. Through activities, such as placing tokens,

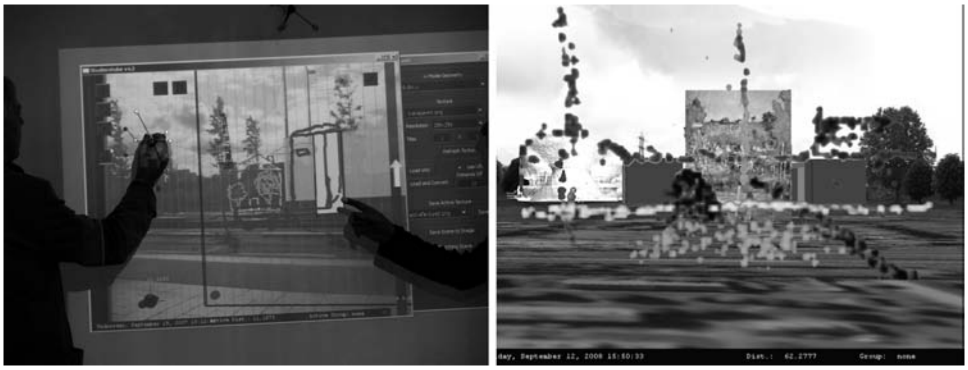

Figure 14. *Sketching on a life video, (left) creating a spatial collage, and (right) annotating a scene.*

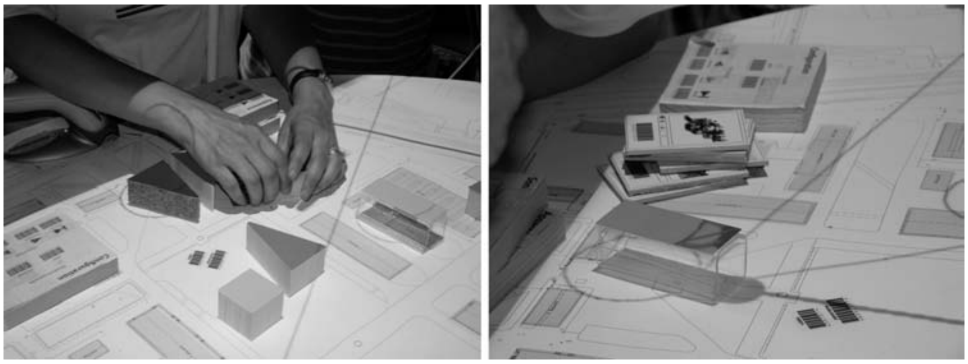

Figure 15. *(Left) Tokens of different color, shape, and material. (Right) Content cards and bar code trays for changing object attributes and settings.*

moving them on the map, changing their parameters, directing flows on the map, and so forth, participants "perform" an MR configuration, adding a dynamic element to the study by Maquil et al. (2008). Participants communicate through the construction of the MR scene, and this highly visible, expressive enactment of ideas is in turn an invitation for others to participate, co-experience, and contribute. The material artifacts we have designed play a key role in this process. Having a nonseeing participant in our last workshop had spurred our focus on hapticity. Apart from annotations in Braille printed out on transparent material, we made use of different materials (wood, Plexiglas, cork) to distinguish the different types of tokens. An additional layer of transparent paper placed on top of the buildings supported haptic orientation on the site map (see Figure 15).

Participants quickly learned to work with these material features. They liked the small cards representing content. In the beginning, they sometimes positioned them directly on the table, but after having understood the need to link them with a token, the cards they had selected remained on the edge of the table, signaling "this is a pile of our images." Although participants often forgot to print out a significant step themselves, they were pleased to receive the printouts, which show the scene together with the table view. Participants confirmed that being in a physical space and interacting with tangible objects is an important part of expressing and experiencing a mixed reality scene. In particular, the

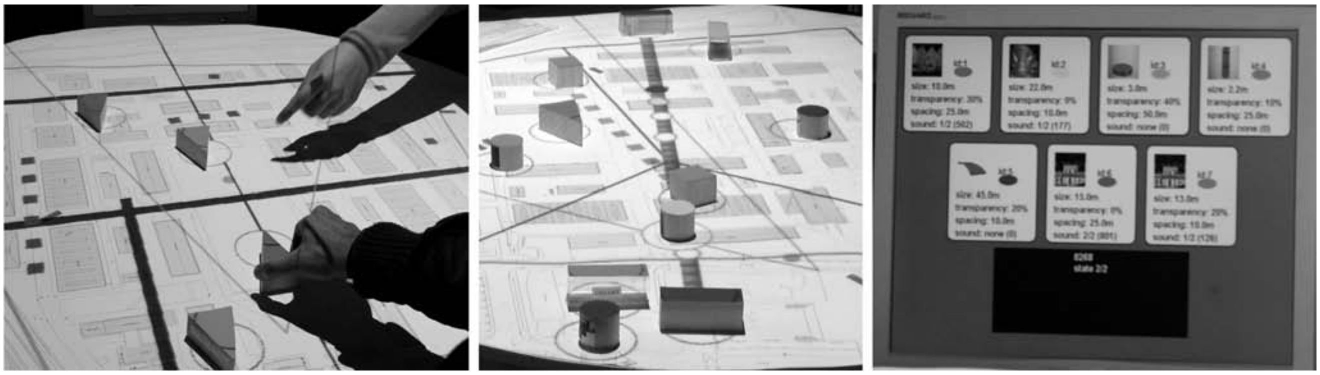

Figure 16. *(Left) Participants performing a MR scene. (Middle) Diagrammatic representation of a scene. (Right) Info screen.*

tokens seem to have a strong engaging capacity (see Figure 16, left). We observed how size and materiality influenced the way people interact with the tangible objects.

In addition to haptic feedback, the MR tools also provide several cues. We already mentioned how changing the position of the audio observer provided participants with additional feedback about elements of a scene. The info screen (see Figure 16, right) displays detailed information on a specific object being manipulated. The exocentric top view of the map provides the best overview of the site, represented by a map. It also shows the objects placed in the scene, represented by circles (indicating whether an object has been recognized by the camera), dots and bars (roads and objects), as well as moving dots/flows (see Figure 16, center). This "diagrammatic" representation also provides important feedback—participants can check all the elements of the scene even when the tokens have been removed.

The MR Tent provides a space for mixing realities that can be viewed and evaluated together. The diversity of perspectives as well as the presence on the site enlarge this interaction space, hence also the means of expressing and experiencing. People point to the panorama view, they cluster in front of the see-through, they look for content, they zoom into the video-augmentation, they may even step out of the tent to look around.

4 Discussion and Conclusions

What do these examples tell us about presence as a conceptual approach? What can we learn about design in support of presence? We try to address this question in three steps.

1. We revisit the philosophical-epistemological arguments, asking in which ways they are supported by our research.
2. We then examine the nature of the mixed reality experiences we describe here with a view into their main characteristics.
3. We also look into the question of how to measure mixed reality experiences.

4.1 The Philosophical-Epistemological Level

Our observations have a clear focus on intentionality and people's purposeful activities. MapLens is a good example. Participants in the field trials use the augmented mobile phone on a physical map while orienting their tasks to both remote and real places, and experiencing both remote and real others, as they engage in place-making for collaboration with a constant need to reference the physical. The AR map allows for ease of bodily configurations for the group, encourages establishment of common ground, and thereby invites discussion, negotiation, and public problem-solving. There is a strong element of mixed local/remote social presence or co-presence in these experiences—social presence that is not perceived passively, but actively constructed. It does not come naturally, but requires the conscious effort of all participants. Licoppe and Inada (2006) observed players of a geo-localized game and describe this situation as follows: "Equipped players are hybrid beings; they perceive the world from their own bodies, but also perceive themselves as icons on the map of the radar interface. . . . The 'onscreen encounter' in which the protagonists are able to perceive their respective icons on the screen map and to share that perception configures a form of encounter peculiar to context-aware cooperative devices" (pp. 11, 14).

This leads us to what has been termed the perceptual illusion of non-mediation and that has guided much of technology development in support of telepresence. The main idea is that each medium by which the experience is conveyed must be hidden or systematically removed from this experience (Bolter & Gromala, 2003). Conversely, in MapLens there is no unified space of reality. On the contrary, participants' activities are firmly anchored in their immediate physical environment organizing their bodies and map to create a common ground and make a place for collaboration while connecting to images, stories, and other attributes of remote others. The degree to which the presence of distant others captures their imagination, melting into the here and now, is open to speculation, and has more to do with the specifics of the situation and the person's imagination than anything else. This observation is supported by the urban renewal experiments where participants are fully aware of the mediation; they are actually co-constructing the architectural scene. But this does not obstruct the experience. On the contrary, the experience is created by participants actively connecting the real (which itself is mediated) and the virtual. O'Neill (2004, 2005) makes the distinction between inhabiting a scene, which requires agency, engaging in activities, and "simply" representing. The urban mixed reality scenes are not just representational. Dynamic change is introduced by participants' activities, and some of the scenes are hybrid, in the sense of passers-by walking through.

Our final argument has to do with recent research that examines how real action in virtual environments occurs (RAVE, 2008). Rather than focusing on observable behavior, we already pointed to Gibson's argument that all experiences are mediated and therefore all experiences are real. But realism can be an issue in mixed reality, as we can see in the urban renewal example, where—at least from the point of view of the participating architects—arriving at a spatial understanding of a site and of the interventions participants perform (volumes, their position in space, etc.) is crucial. However, the means to achieve this understanding is through abstraction (where architects excel), and there is no illusion of realism on the participants' side, although they may feel drawn into the scene. While some degree of plausibility is needed for participants to interpret the mixed reality scene, they are free to play with abstraction and imagination.

4.2 Some Characteristics of Mixed Reality

The three applications we discuss here exemplify variations about where the action takes place. In MapLens, action is in the real environment, while participants orient their task to remote locations and people. The mobile AR setup facilitates turning these mediated cues of remote locations and people into resources of co-located collaboration. In TimeWarp, action takes place in the augmented streets and places of Cologne. One of the key elements of the experience here is the feeling of connection between the virtual and the real game elements. Care must be taken concerning the provision of augmented content and the selection of the real locations for the game. Thus the here and now of reality becomes important. This was evident from the fact that users actively searched for virtual content and would often find themselves "outside" the game experience when walking between locations.

In the MR Tent, action takes place in the real environment and participants make use of the resources of this environment to construct mixed reality scenes—the spatial arrangement of the technologies, their material features, all the co-players, even the unexpected ones, such as people passing by. In this complex setup, we can observe the challenges of mapping events and representations within the physical environment to those in the mixed reality scenes. We have seen how dynamic representations, such as flows, and activities, such as sketching on a scene, support this mapping. We also noted the importance of impressions, such as wind blowing, cars or people passing, and leaves moving, that animate the mixed reality scenes, making it easier for participants to feel present in the scene, which is itself mediated—a photographic panorama, a real-time video, a see-through screen being the representational medium of the real world outside. We have observed that sound is the most immersive element of the mixed reality scenes. Paying attention to sound literally draws participants into the scene. Our conclusion is again that some degree of realism, in particular elements that enliven the mixed reality scene, are crucial to the participants' experience of being present.

Another characteristic of our mixed reality examples is that they deal with multiple events that stretch out in time and, in the case of MapLens, also in space. These events are co-constructed by multiple participants (in more active or more passive roles) and co-experienced by them. They have no predefined sequence or duration. Whatever the intentions of the designers are, these mixed reality experiences are beyond their control and open to all kinds of unforeseeable events. In MapLens, during the game, many things may influence participants' experience: unexpected actions of other players, controversial content, intervention of other teams, interaction with strangers in the environment, pressing incorrect buttons on the device, discrepancy in knowledge levels about the surrounding environment, weather, and other interruptions, to mention a few. In the MR Tent, the time frame of a participatory workshop is usually well defined, and so are the invited participants. However, the nature of the events themselves (even if guided by a scenario) is beyond control, and is so on purpose, because participants are invited to be creative and it is not clear how they will make use of the resources at hand. In TimeWarp, the game itself is predefined, but as soon as we take other players and non-players into account, there is a strong element of unpredictability.

4.3 From "Measuring" to "Observing" Presence in Mixed Reality

Given the characteristics of mixed reality and the focus on users' purposeful actions (rather than on mental states) the established methods of inquiry for presence are put into question. Complex mixed reality applications that combine multiple displays and spaces, including the real world, cannot be evaluated in the laboratory, for a variety of reasons. The negotiation process within urban projects, in which use of the MR Tent is embedded, is by definition open, the purpose being to elicit stakeholder participation and the co-construction of something new. MapLens and TimeWarp lend themselves to field trials carried out in the wild. Although these trials are more specifically task-oriented, participants' interactions cannot be controlled and are open to all kinds of interventions from reality. Hence, evaluating our complex mixed reality applications, we have chosen a combination of an ethnographic approach, which is based on observational methods in combination with semi-interviews and the analysis of artifacts, with the use of (standardized) presence questionnaires where appropriate.

Ethnography is not only a research method but also involves a particular way of writing. A definition of ethnography that includes most ethnographic studies is given by Hammersley and Atkinson (1995, p. 1). In its most characteristic form it involves the ethnographer participating, overtly or covertly, in people's daily lives for an extended period of time, watching what happens, listening to what is said, asking questions—in fact, collecting whatever data are available to throw light on the issues that are the focus of the research. Ethnographic accounts typically contain information about the context, they are expressive-narrative, they present what has been observed from particular perspectives, "ethnographic truths are thus inherently partial-committed and incomplete" (Clifford, 1986), and are written for a particular audience. The ethnographer acts as archivist, writer, and interpreter, with the studied subjects, whose actions and voices are represented, as "coauthors." Hence, writing an ethnographic account always requires contextualizing the ethnographer's own positionality and reflecting on the organizational character he or she imposes on the ethnographic material (Madison, 2005).

In the urban renewal case, observation, supported by video and photographic images, provided the main data. As the space in the tent was quite congested, we introduced only one video camera, which provides a particular view. We explained our research questions before the event so as to ensure that the researcher responsible for the camera knew what he or she had to look for. In the participatory workshop we describe in this paper 10 hr of video material was collected, including recordings of participants' evaluation of the workshop, as well as hundreds of screen shots and photographs taken by different observers. These observers each had a particular set of research questions to take care of and took notes on top of the pictures. We also included material from open preinterviews with participants, in which they presented their vision of the urban project and issues, using maps of different scales, images, small objects, and colored pens.

Analysis was carried out collaboratively in the team, which watched the videos several times, selecting significant scenes. The significance was judged on the basis of a set of concepts that reflect the theoretical approach developed within IPCity, namely: participants co-constructing MR scenes and mapping events by using different views of the scenes; spatial, temporal, material, and social aspects of presence; the role of sound, dynamic representations, fuzziness, and content specifically expressive of ambience, providing a sense of place and culture. When analyzing the selected scenes, attention was paid to the details of participants' interactions. We compared what people actually did with what they said, when on the one hand talking about the urban project and debating their interventions, on the other hand also expressing their feelings and the quality of their experiences. Our understanding of the unfolding co-constructions was enhanced by the knowledge we had collected in the preinterviews with participants about their ideas and motivations. These different elements—video clips and photographs showing interactions on the table, the composed scenes (also available as screen shots), and participants' multilevel talk—allowed us to arrive, step-by-step, at consolidated interpretations of our observations within our conceptual framework. The ethnographic account, which is the result of such a time-consuming analysis, consists of a storyboard in which descriptions of key observations in the form of selected images, pieces of transcripts, and interpreting texts are organized around key concepts.

The enormous amount of video material also lends itself to a quantitative analysis, with, for example, a focus on certain interactions, and the objective to identify significant patterns. Analysis of the MapLens trials combined a qualitative with such a quantitative analysis of the video material. This was encouraged not only by the larger number of participants but also the greater simplicity of being able to assess the completion of tasks performed. The evaluation of MapLens combined a number of methods, such as pre-phase forms, observations recorded in the form of video, photographs, and notes, questionnaires, open-interviews, and photos that participants took as evidence of completing tasks. Within the proceeding two weeks researchers were interviewed with their notebooks, images (theirs and users') to get a richer overview of the experience and to assist in deciphering their notes, although most wrote theirs up in legible form.

As can be seen from the report in the previous sections on the trials, with an ethnographic approach largely relying on direct and video observation and their analysis we could gather more descriptive and explanatory insights in differences of usage and experience between the MapLens and the DigiMap teams. The questionnaires and free-form interviews coupled with the logged data, researcher interviews with images to support conjecture, or trigger memory on real usage, word mapping from free interviews, game results, and photographic use was constructive in building this more complete picture of how people used the technology and for what purposes. In this way, we were able to build a more complete picture of the experience of presence for our players as the evidence built up from elements found within each format.

TimeWarp made use of questionnaires in combination with interviews, direct observation, and video analysis. The approach within TimeWarp was successful in exploring why people behaved in certain ways and their varying sense of presence with respect to real and virtual elements. Furthermore, it allowed for some analysis of the purposeful activities they were undertaking as at a high level as these activities were often stimulated by specific gaming elements, such as entering or leaving a time portal, trying to find a new location, or indeed the gaming experience itself. For example, people reported a higher feeling of change when leaving the game than when entering it. Therefore, the approach within TimeWarp was primarily useful in identifying phenomena and areas of future work, and provided a basis upon which more specific studies can be conducted.

In any case, the methods that seem most appropriate to inquire into mixed reality experiences are interpretative. The ethnographic approach also resonates with the phenomenological tradition, which focuses on the phenomenon of *human perception* as, in Merleau-Ponty's reading, active, embodied, and always generative of meaning. It also relates to the concept of *embodied interaction,* which was introduced by Dourish (2001). The notion of embodied interaction addresses how a situation must be considered as a whole. Meaning is created in the use of shared objects, and social interaction is related to how we engage in spaces and with artifacts. In this interplay, the body has a central role. In many ways the body can be seen as the medium for having a world; for participating, navigating, negotiating, and being-in-the-world. It is significant to note that phenomenological and pragmatist movements have changed inquiry approaches in human-computer interaction from measuring oriented and cognitivist to observation oriented and anthropological approaches.

The examples we reported and the approach taken in the inquiry are well aligned with the critical positions summarized at the beginning of the paper. From a phenomenological standpoint, Zahorik and Jenison (1998) suggested that presence is tantamount to successfully supported actions in the environment. We showed with the examples and trials how MR setups provided rich opportunities to observe action. Mantovani and Riva (1999) move from a Gibsonian view and indicate that the origin of our perception is in our actions and purposes and that our actions and need for actions are socially motivated, our reality is always co-constructed. In the examples, MR is often a setup where experiences are co-constructed, where both VE and PE (physical environment) mediated, and we do not perceive either of them "as such" like in the envisioning of the MR Tent, but always filtered through the purpose of the actions in which we are engaged. Turner and Turner (2006) point to sense of place as a prerequisite for presence, needing a personal and historical first-person relation to a particular space. Marsh (2003) continues the action-based, socio-cultural approach and focusing on context and continuity by further detailing the users' activities.

All these positions, while they have been developing independently of recent advancements in interface technologies, are even more appropriate and fitting when considering MR. The consequences for inquiry methods as hinted at by Spagnolli and Gamberini (2005) are ethnographic, action-based approaches to analyze presence. These can make presence an object of evaluation and observable by showing the richness in appropriation of technology such as creating and connecting layers and expressive enactments in MR Tent. Furthermore, by considering actions as resourceful and goal oriented, these approaches can contribute to uncovering mechanisms that underlie the co-construction of presence as establishing common ground, place-making in MapLens, or social encounters in TimeWarp.

5 Conclusion

This paper aims at establishing the ground for examining phenomena related to presence in mixed reality applications. We have argued how a narrow psychological interpretation of presence is useful for VR, but not so meaningful in the broader scope of mixed reality. From the experimental applications described here—MapLens, TimeWarp and MR Tent—we have learned about a number of social phenomena such as co-construction and place-making that are hard to observe in a laboratory. However, these observations can only mark the beginning of a research agenda. MR constitutes a large design space for applications, and much more work on the systematic assessment of complex experiences will be necessary to establish a sound theory of presence in MR.

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References

Amphoux, P., Thibaud, J. P., & Chelkoff, G. (Eds.). (2004). *Ambiances en débats.* Bernin, Collection Ambiances, Ambiance. Grenoble: Bernin F: À la Croisée.

Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. (2001). Equilibrium revisited: Mutual gaze and personal space in virtual environments. *Presence: Teleoperators and Virtual Environments, 10,* 583–598.

Benford, S., Greenhalgh, C., Reynard, G., Brown, C., & Koleva, B. (1998). Understanding and constructing shared spaces with mixed reality boundaries. *ACM Transactions on Computer-Human Interaction, 5*(3), 185–223.

Benyon, D., Smyth, M., O'Neill, S., McCall, R., & Carrol, F. (2006). The place probe: Exploring a sense of place in real and virtual environments. *Presence: Teleoperators and Virtual Environments, 15*(6), 668–687.

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). The MagicBook: A transitional AR interface. *Computers & Graphics, 25*(5), 745–753.

Billinghurst, M., Weghorst, S., & Furness, T. (1996). Shared space: An augmented reality interface for computer supported collaborative work. *Virtual Reality, 3*(1), 25–36.

Biocca, F. (1997). The cyborg's dilemma: Embodiment in virtual environments. In *Proceedings of the Second International Conference on Cognitive Technology, Humanizing the Information Age.*

Bolter, J. D., & Gromala, D. (2003). *Windows and mirrors: Interaction design, digital art, and the myth of transparency.* Cambridge, MA: MIT Press.

Boradorri, G. (2000). Virtuality, philosophy, architecture. *Columbia Documents for Architecture and Theory, 7,* 57–73.

Brouwer, J., Brookman, P., & Mudler, A. (Eds.). (2002). *Transurbanism.* Rotterdam: V2 Publishing/NAI Publishers.

Ching, F. D. K. (2007). *Architecture, form, space and order.* New York: Wiley.

Clark, H. (1996). *Using language.* Cambridge, UK: Cambridge University Press.

Clifford, J. (1986). Introduction: Partial truths. In J. Clifford & G. E. Marcus (Eds.), *Writing culture. The poetics and politics of ethnography* (pp. 1–26). Berkeley, CA: University of California Press.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11,* 227–268.

Deleuze, G. (1968). *Différence et répétition.* Paris: Presses Universitaires de France.

Dourish, P. (2001). *Where the action is: The foundations of embodied interaction.* Cambridge, MA: MIT Press.

Dow, S., Mehta, M., Harmon, E., MacIntyre, B., & Mateas, M. (2007). Presence and engagement in an interactive drama. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* 1475–1484.

Ehn, P., & Linde, P. (2004). Embodied interaction—design in beyond the physical-digital divide. *Futureground, Design Research Society International Conference.* Melbourne: Monash University.

Floridi, L. (2007). The philosophy of presence: From epistemic failure to successful observation. *Presence: Teleoperators and Virtual Environments, 14*(6), 656–667.

Gibson, J. J. (1986). *The ecological approach to visual perception.* Mahwah, NJ: Erlbaum.

Goffman, E. (1959). *The presentation of self in everyday life.* New York: Harmondsworth.

Goldiez, B., & Dawson, J. W. (2004). Is presence present in augmented reality systems? In *Proceedings of Presence 2004. VII. International Workshop on Presence,* 294–297.

Gustafson, P. (2001). Meanings of place: Everyday experience and theoretical conceptualizations. *Journal of Environmental Psychology, 21,* 5–16.

Hammersley, M., & Atkinson, P. (1995). *Ethnography: Principles in practice.* London: Routledge.

Heeter, C. (1992). Being there: The subjective experience of presence. *Presence: Teleoperators and Virtual Environments, 1*(2), 262–271.

Herbst, I., Braun, A., McCall, R., & Broll, W. (2008). TimeWarp: Interactive time travel with a mobile mixed reality game. In *Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services,* 235–244.

Hirose, M., Ohta, Y., & Feiner, S. (2002). Guest editors' introduction: Special issue on mixed reality. *Presence: Teleoperators and Virtual Environments, 11*(2), iii–iv.

IJsselstein, W., & Riva, G. (2003). Being there: The experience of presence in mediated environments. In G. Riva, F. Davide, & W. A. IJsselstein (Eds.), *Being there: Concepts, effects and measurements of user presence in synthetic environments* (pp. 3–16). Amsterdam: IOS Press.

International Society for Presence Research (ISPR). (n.d.). *About presence—An explication of presence.* Retrieved August, 2008, from http://www.temple.edu/ispr.

Kristoffersen, S., & Jungberg, F. L. (1999). "Making place" to make IT work: Empirical explorations of HCI for mobile CSCW. In *Proceedings of the International ACM SIGGROUP,* 276–285.

Leontjev, A. N. (1981). *Problems in the development of the mind.* Moscow: Progress Publishers.

Licoppe, C., & Inada, Y. (2006). Emergent uses of a multiplayer location-aware mobile game: The interactional consequences of mediated encounters. *Mobilities Journal, 1*(1), 39–61.

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer Mediated Communication, 3*(2). Retrieved July 22, 2009 from http://jcmc.indiana.edu/vol3/issue2/lombard.html.

MacIntyre, B., Bolter, J. D., & Gandy, M. (2004). Presence and the aura of meaningful places. *Presence: Teleoperators and Virtual Environments, 6*(2), 197–206.

Madison, D. Soyini. (2005). *Critical ethnography: Methods, ethics, and performance.* Sage.

Mantovani, G., & Riva, G. (1999). "Real" presence: How different ontologies generate different criteria for presence, telepresence, and virtual presence. *Presence: Teleoperators and Virtual Environments, 5*(8), 538–548.

Maquil, V., Psik, T., & Wagner, I. (2008). The ColorTable—A design story. *Proceedings of Tangible and Embedded Interaction,* 97–104.

Maquil, V., Psik, T., Wagner, I., & Wagner, M. (2007). Expressive interactions supporting collaboration in urban design. *Proceedings of GROUP '07: International Conference on Supporting Group Work,* 69–78.

Marsh, T. (2003). Presence as experience: Film informing ways of staying there. *Presence: Teleoperators and Virtual Environments, 12*(5), 538–549.

Meehan, M., Insko, B., Whitton, M., & Brooks, F. P., Jr. (2002). Physiological measures of presence in stressful virtual environments. *ACM Transactions on Graphics, 21*(3), 645–653.

Merleau-Ponty, M. (1969). *The visible and the invisible.* A. Lingis (Trans.). Evanston, IL: Northwestern University Press.

Merleau-Ponty, M. (1962). *Phenomenology of perception.* London: Routledge.

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information Systems, 77,* 1321–1329.

O'Neill, S. J. (2004). The interactive spectacle and the digital situationist. *Proceedings of the 2nd Space Spatiality and Technology Workshop,* 75–77.

O'Neill, S. J. (2005). Presence, place and the virtual spectacle. *PsychNology, 3*(2), 149–161.

Real Action in Virtual Environments (RAVE). (n.d.). *Workshop manifesto.* Retrieved August 2008, from http://www.starlab.info/peach/files/RAVEv8r4.pdf .

Rettie, R. M. (2005). Presence and embodiment in mobile phone communication. *PsychNology, 3*(1), 16–34.

Slater, M., & Steed, A. (2000). A virtual presence counter. *Presence: Teleoperators and Virtual Environments, 9,* 413–434.

Spagnolli, A., & Gamberini, L. (2005). A place for presence. Understanding the human involvement in mediated interactive environments. *PsychNology, 3*(1), 6–15.

Sweetser, P., & Wyeth, P. (2005). Gameflow: A model for evaluating player enjoyment in games. *ACM Computers in Entertainment, 3*(3), 1–24.

Szalarari, Z., Schmalstieg, D., Fuhrmann, A., & Gervautz, M. (1998). Studierstube—An environment for collaboration in augmented reality. *Virtual Reality, 3*(1), 37–48.

Terrin, J. J. (2005). *Maîtres d'ouvrage, maîtres d'œuvre, entreprises, de nouveaux enjeux pour les pratiques de projet.* Paris: Editions Eyrolles.

Turner, P. (2007). The intentional basis of presence. In *Proceedings of the 10th International Workshop on Presence,* 127–134.

Turner, P., & Turner, S. (2002). Embedded context of use in CVE design. *Presence: Teleoperators and Virtual Environments, 11*(6), 665–676.

Turner, P., & Turner, S. (2006). Place, sense of place, and presence. *Presence: Teleoperators and Virtual Environments, 15*(2), 204–217.

Vorderer, P., Wirth, W., Gouveia, F. R., Biocca, F., Saari, T., Jäncke, F., et al. (2004). *MEC spatial presence questionnaire (MEC-SPQ): Short documentation and instructions for application*. Report to the European Community, Project Presence: MEC (IST-2001-37661). Online. Available at http://www.ijk.hmt-hannover.de/Presence.

Wagner, D., Reitmayr, G., Mulloni, A., Drummond, T., & Schmalstieg, D. (2008). Pose tracking from natural features on mobile phones. In *Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality*.

Waterworth, J. A., & Waterworth, E. L. (2003a). The meaning of presence. *Presence-Connect, 3*(February). Retrieved July 22, 2009 from http://presence-connect.com .

Waterworth, J. A., & Waterworth, E. (2003b). The core of presence: Presence as perceptual illusion. *Presence-Connect, 3*(July). Retrieved July 22, 2009 from http://presence-connect.com .

Wilson, S. (2002). *Information art: Intersections of art, science and technology*. Cambridge, MA: MIT Press.

Winograd, T., & Flores, F. (1987). *Understanding computers and cognition*. Norwood, NJ: Ablex.

Zahorik, P., & Jenison, R. L. (1998). Presence as being-in-the-world. *Presence: Teleoperators and Virtual Environments, 7*(1), 78–89.