On the Role of Presence in Mixed Reality

Ina Wagner, Vienna University of Technology, Austria, ina.wagner@tuwien.ac.at

Wolfgang Broll, Fraunhofer FIT, Germany

Giulio Jacucci, Helsinki Institute for Information Technology, HUT and UH, Finland

Kari Kuutii, University of Oulu, Finland

Rod McCall, Fraunhofer FIT, Germany

Ann Morrison, Helsinki Institute for Information Technology, HUT and UH, Finland

Dieter Schmalstieg, Graz University of Technology, Austria

Jean-Jacques Terrin, Université Marne la Vallée, Champs sur Marne, France

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, towards 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 "Tele-Presence" or "Presence". MR environments need to take account of the real world, i. e., 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).

As part of our experiments with MR technologies in the 4-year European integrated research project *IPCity*[1], 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, CSCW, and Activity Theory with more creative concepts that have been inspired from urban studies and arts, as well as from own previous research. We will first examine these issues from a more theoretical perspective (section 2), then give examples from three extensive experiments conducted in *IPCity* (section 3), and finally discuss our findings (section 4).

2. Relationship of Presence and Mixed Reality research

2.1. The Virtuality Continuum

Milgram & 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 (Figure 1). But can we talk about MR experiences or MR interactions?

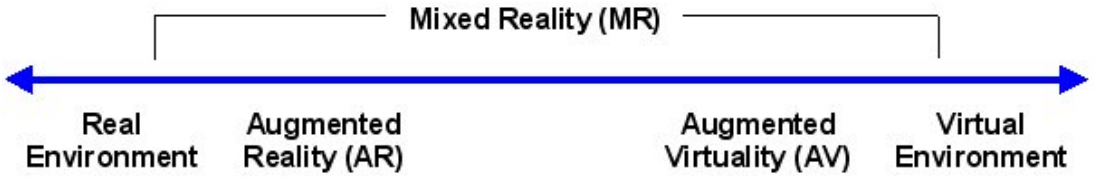

Figure 1 Milgram's Virtuality continuum

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 & 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 et al., 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

[1] http://www.*IPCity*.eu, contract no. FP6-2004-IST-4-27571

the haptic feedback from the ledge (which is just a wooden plank) is actually less real that 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, multi-faceted background. As a result, there is no single, universally accepted definition of Presence, except for relatively simple, non-exhaustive ones such as "the feeling of being there" (Heeter, 1992) and "the perceptual illusion of non-mediation" (Lombard & Ditton, 1997). The phenomenon of Presence is obviously not only grounded in physical perception. Most researchers agree with Slater & Steed (2000) that Presence has a subjective, psychological, as well as an objective, physical component. Consequently, evaluation methods range from assessing subjective phenomena (e.g., through questionnaires) to observing objective phenomena (e.g., by measuring bio-signals).

Ijsselstein & 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 (Schmalstieg et al., 1996; Billinghurst, Weghurst & 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, which 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 & Waterworth (2003) who argue that Presence is the ability of a person to see how they relate to their wider environment, for example they are themselves 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, which 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 towards 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 mort 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 fulfils all these diverging requirements.

2.3. Critical discussion of Presence within the research community

As the research on Presence has matured and its scope 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 Tele-Presence and VR systems, such as AR and MR, and also to a movement out from the laboratory towards 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.

Philosophical-epistemological discussion

The overarching theme of this discussion is that the "traditional" Presence research has tacitly and unreflectively adopted some fundamental assumptions on humans which 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.

Like in the AI discussion in the 1980s (see Winograd & Flores, 1987), one of the recognized sources of criticism and potential alternative foundation is Heideggerian philosophy. Zahorik & 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, towards a Heideggerian view which 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 be never 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 does no longer function properly and the flow actually breaks down. Heidegger defines being in terms of actions in the world. Following that, Zahorik & Jenison (1998) suggest that Presence is tantamount to successfully supported actions in the environment – whatever the environment may be.

Similarly, Mantovani & 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.

The Gibsonian view on reality, knowledge and perception differs radically from that of the 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 & 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.

Practical criticism around more specific issues

Turner & 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 towards 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 & 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 & Riva (1999) using cultural-historical activity theory based on Leontjev’s (1981) ideas, and also advances the topic of contextual continuity suggested by Turner & Turner. He develops concepts and models to describe user’s activities from low-level operations to holistic level as an arena to reason about experience in mediated environments, and also as a way of 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 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 & 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 are focusing 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 (Borradori, 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 imaginary and reaching beyond traditional representational techniques (Terrin, 2005).

Moreover, the development of cyberspace and the notion of Tele-Presence 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 & 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 & 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 et al., 1998. Milgram & Kishino (1994) describe MR as the combination of RE and VE "presented together within a single display." Benford et al. (1998) 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, i. e., in a single space. Conversely, Mixed Realities can encompass all environments relevant for the subjects in the context of the study.

Goldiez & Dawson (2004) discuss if 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 & Dawson (2004) 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 into the way of the user, i. e., 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 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 if 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 & 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 & Dawson (2004). However, this approach still relies much heavier on the concept of perceived non-mediation compared to our approach.

What we need for Presence research that is meaningful for MR is a broader conceptual framework, which 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* field work, 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 et al., 2008) is an augmented reality game which 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 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 non-player 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 co-operative 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 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 et al., 2007; Maquil, Psik & Wagner, 2008).

All three Mixed Reality applications have been tested outdoors, in real use settings. They have been used repeatedly and re-designed 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, which 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 video recorded, 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 re-designed 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 a well as content – panoramas from different viewpoints, architectural models, and other assets – and developed an experimentation protocol for the participatory sessions. The workshop sessions were video-recorded, 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 is depending on their 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, it also explores Presence between users and non-player 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 et al., 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 Helsinki center itself where the game was located. Each team of test users was accompanied through-out by one researcher observing, 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. This activity also focused participants on their experience in the trial, familiarizing them with an extended vocabulary to better articulate those experiences. Each participant then described their experience, highlighting aspects that had caught their attention in semi-structured one-to-one recorded interviews.

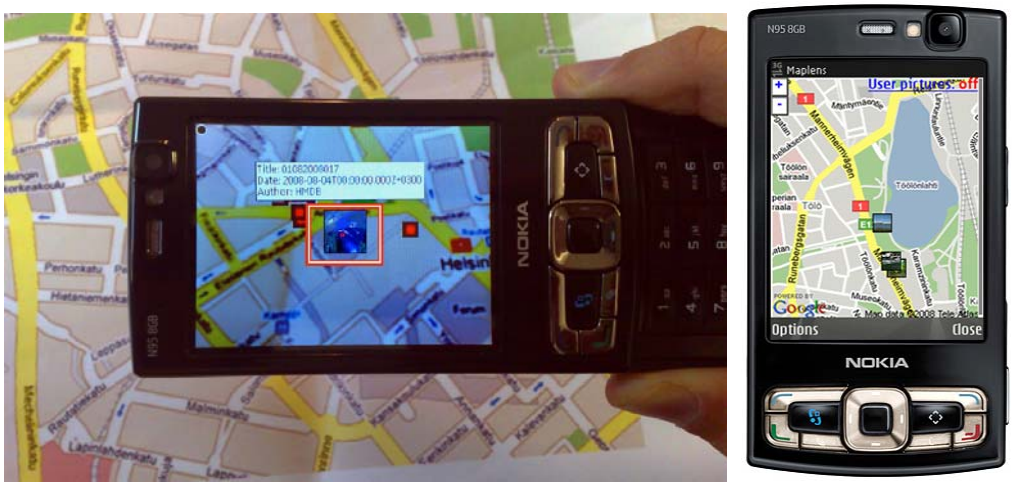

Figure 2 Left *MapLens* in use with a paper map, overlaying digital information on screen. With the red square (centre) user locates and selects markers—as one user states—"*catches them*". Right *DigiMap* version, Google Map with markers

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 analyses and identifies the coordinates of the map area visible on the phone screen. Based on these coordinates, location based media (photos and their metadata) is 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 (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, the design of which echoes Google Maps for mobile phones (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 minute period, and in doing so learned about specific environmental concerns. The players uploaded photos which 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 visit green areas in the city. One task was for the whole group to walk bare-foot in the grass, and upload a photo as evidence; another to gather a specific leaf (the leaf 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 sea water 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 include specifically 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, 1996); essentially a confrontation with the self as both an entity in the world, as well as an object amongst 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.

Figure 3 Kitbags contained 7 items that needed to be managed: sunlight photographs, map, phone, water testing kits, voucher for internet use, clue booklet and pen.

Each team was handed a kitbag which contained seven objects in all (see Figure 3). By design, these tangible 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 to organize some kind of system of use, as well as become adept at navigating.

Collaborative and public configurations

There were no ready-made solutions, 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 digital with 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 the *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.**

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 to understand what the discussion is about without explicitly asking or negotiating. 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 their means for problem-solving and communication.

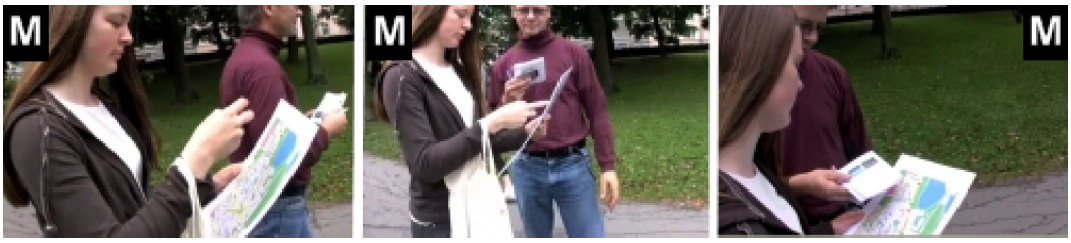

Figure 5 The physical map as a common ground, established by showing with the lens (M) and pointing with finger, and the clue booklet.

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 towards the direction he suspects to be correct and hands the device over to his uncle, who then assesses the situation.

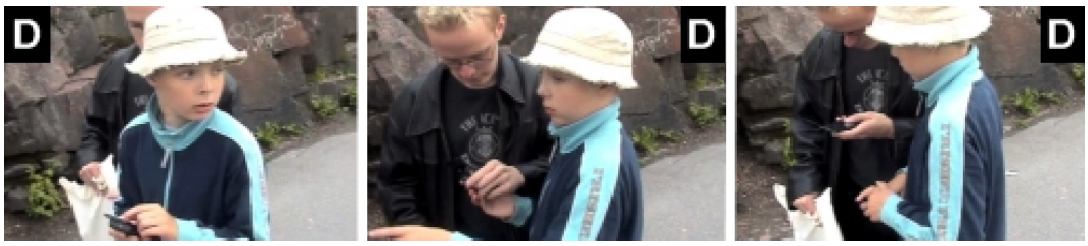

Figure 6 ***DigiMap*** **(D) Attempting to share the map as a common ground.**

The physical paper map supported the players better in establishing a common understanding of the area and referring to different locations. Some players though 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 less often occurred with both trying to look at the mobile phone screen. Within a team of 2 close friends we observed constant pointing at the mobile screen, establishing common ground, 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.

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

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 et al., 1999, Ehn & Linde, 2004), and we encounter a special multi-user 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 became again 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.

Usability problems for co-located and collective experiences of AR mediated cues

The collaboration described above however 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 non-augmented 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 & 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 Tele-Presence 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 co-experience 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 lamp-post. Participants gather around the "surface & 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 running even, 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 & lens" view, in order to negotiate and anticipate the next best move within the game sequence and the real environment.

3.2. Time Warp – A Mobile Mixed Reality Game

TimeWarp is a Mixed Reality game which 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 which 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.

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

TimeWarp is a collaborative game which uses ultra-mobile 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 are then added to the scene. Audio is used at various points throughout the game either to provide narrative or instructions, or to indicate proximity to game element.

One of the main objectives of the evaluation was to explore where players felt present during the experience, with whom (players, other pedestrians), the nature of the Mixed Reality experience and any switches which occurred when moving between realities. To reflect these issues, a number of study methods were chosen, ranging from a questionnaire which was based on MEC (Vorderer et al., 2004) and earlier work (Herbst et al., 2008), video 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.

The questionnaire data was derived from the MEC spatial Presence questionnaire, however some additional sections were 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 virtual world. For this they were asked to rate their experience on a seven point scale ranging from feeling more connected to the real or to the virtual elements. The remainder of the questionnaire focused on which elements within the experience users felt more part of - other players, non-game participants or non-player characters. Additional qualitative questions were added to explore these aspects and certain questions from the place probe (Benyon et al., 2006) were added to capture information about sense of place.

Data was analyzed using a triangulation method to see if similar themes or responses emerged across the various collection methods. Preliminary analysis of the video data revealed little additional information to that which was captured within the questionnaires and interviews; hence the information presented here is predominantly drawn from questionnaires and interviews.

Social Encounters

Playing *TimeWarp* is collaborative experience, which requires players to co-operate on many aspects, this also provides a method of comparing differences between

player, non-player characters and passers-by. There was a very strong sense of Presence between 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 in which the user inhabited. Co-operation took many forms, ranging from navigational information, negotiating strategies, to sharing ideas concepts and discussing game elements. 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 them to experience more of the virtual game elements.

Figure 9 Players collaborating during the game experience.

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, which players must complete. As expected, the sense of Presence experienced between players was higher than between users and agents, in part due to the cartoon-like graphical representation and limited interaction techniques.

Context and Place

Place making is shaped by many elements including social interactions, physical, material and historical elements (Gustafson, 2001). Within *TimeWarp*, sense of place was shaped through various methods including the negotiated understanding of the new aspects which 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.

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.

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 player's perceptions within the game.

However, we also noted that players reported to feel more present within the future time period. This may be in part owed to the due to the gameplay in that time period, but also it does not require a suspension of disbelief – in essence the contextual link between the game and the real environment was significantly broken by design. 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 do not reality in terms of the actions, graphics or sense of place. However other users missed exactly this link between real and virtual. We conclude that presence in MR is strongly influenced by user preferences. This view was confirmed by users who pointed out that the Heinzelmännchen felt unreal, but found this aspect engaging.

Layers, Borders and Switches

Moving between real, virtual and blended experiences was a common issue for the players. As noted in literature, sense of place is often shaped by the paths between locations as much as the actual locations themselves – and many players complained about the lack of content between game locations. The long walks between locations resulted in them feeling like they were continuously entering and leaving the game experience. The strongest indication of a change in experience would when players had to enter a time portal, players often changed posture and ran through the portal. The time portal was regarded as one of the best elements of the game, and although no differences in reported 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.

From the interviews it was apparent that many people felt the computer graphics were a layer on top of the real environment, rather than part of it. Thus we cannot speak of a blended experience. 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, frequently players would actively seek out game elements. Furthermore players indicated that it was easier to interact with virtual than real elements. Despite the game's clear link to physical and historical aspects of the 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, which can be

transported to a site of an urban project and where real city scenes can be interactively augmented with computer-generated visualizations to illustrate, debate and experiment different design possibilities between various stakeholders of design. The round table in the center of the *MR Tent* is a multi-user tabletop in support of urban planners and diverse stakeholders collaboratively envisioning urban change. It provides users with the possibility to arrange and position tokens on a surface, representing a 3D scene on physical maps of the site of an urban project in different scales. A tabletop projection augments the surface of the table by a map, which provides a bird's eye view of the site. A vertical projection renders the scene against a background, which is produced by either a real time video stream, a panorama image of a site or a see-through installation (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 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.

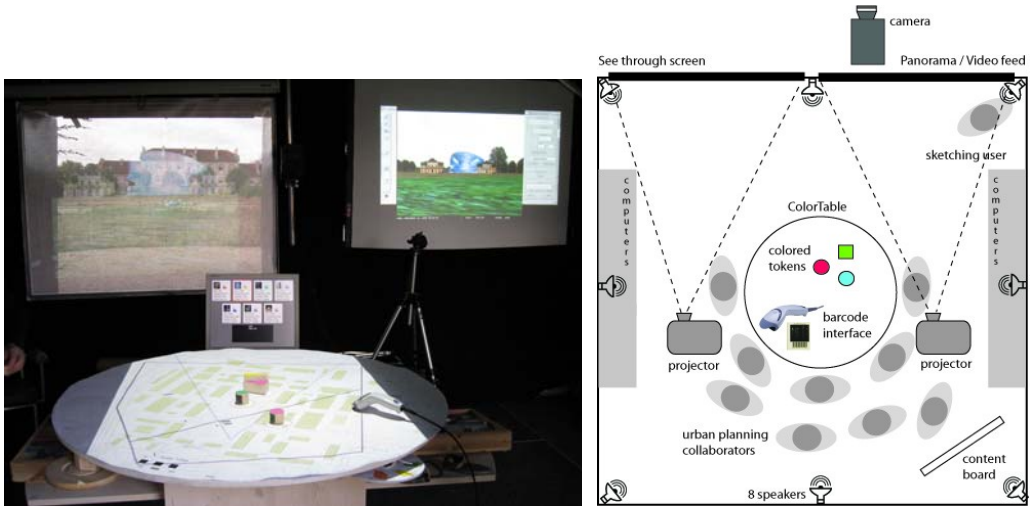

Figure 11 The technical setup inside the *MR Tent* is centered around the two projection walls and the projection table

Creating and connecting layers of real and virtual

Our video-supported observations and interviews allow us 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 barcode) 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 barcode reader for activating different views onto the scene. At the same time they orient themselves in the space of the tent towards the two projection screens, one of which provides a direct view of the site through the frame of a window (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 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 (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 views onto them.

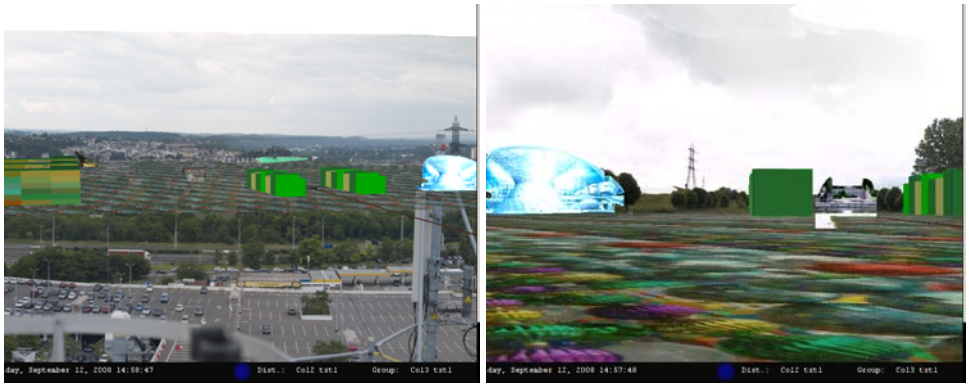

Figure 12 Looking at a scene from different viewpoints (panoramas)

This includes sound, which provides additional spatial information. Each visual content item was associated with several sound files from which participants could chose. 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 seemed too noisy by 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 (Figure 13). This does not only introduce an additional scale in the scene and provide depth information, but also animates it. 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 they had created in relations to these flows, eventually changing the position or type of road.

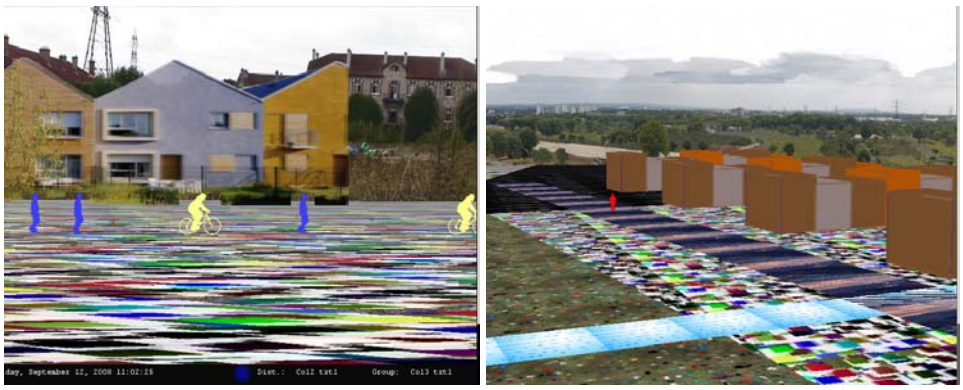

Figure 13 Adding roads and flows to a MR scene

Sketching brings another dynamic element into a visual scene, reinforcing the connection between real and 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 (Figure 14).

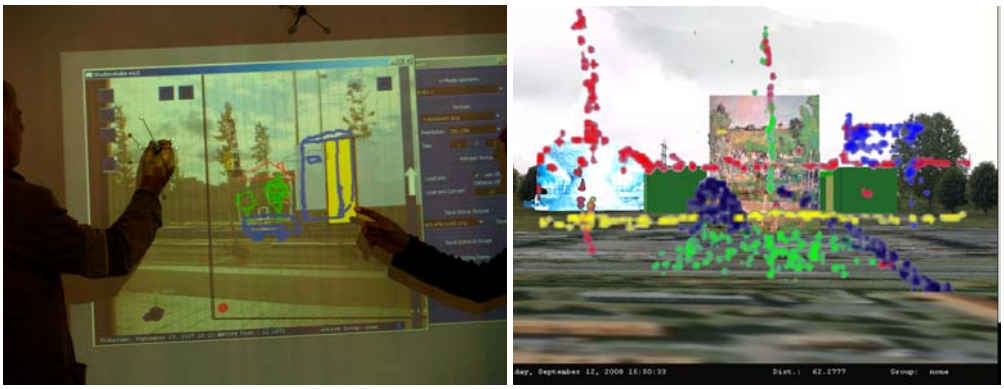

Figure 14 Sketching on a life video, creating a spatial collage (left) and annotating a scene (right)

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 et al., 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.

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, moving them on the map, changing their parameters, directing flows on the map, and so forth, participants "perform" a MR configuration, adding a dynamic element to (Maquil, Psik & Wagner, 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 take a key role in this process. Having a non-seeing 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 (Figure 15).

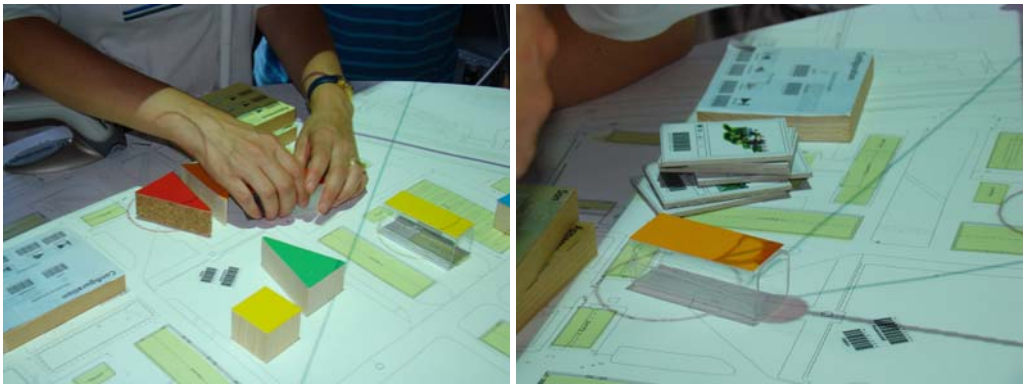

Figure 15 Tokens of different color, shape, and material (left); Content cards and barcode trays for changing object attributes and settings

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 tokens seem to have a strong engaging capacity (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 (Figure 16, right) displays detailed information on a specific object being manipulated. The exocentric top view onto 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 if an object has been recognized by the camera), dots and bars (roads and objects), as well as moving dots/flows (Figure 16 centre). This "diagrammatic" representation also provides important feedback – participants can check all the elements of the scene even when the tokens have been removed.

Figure 16 Participants performing a MR scene (left); Diagrammatic representation of a scene (middle); Info screen (below)

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, the look for content, they zoom into the video-augmentation, they may even step out of the tent to look around.

4. Discussion

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 onto 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 & 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" (p.11 and 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 Tele-Presence. 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 place for collaboration while connecting to images, stories, etc. 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 experimentations 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 in where 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 collocated 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 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, cars or people passing, 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 participant 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. Measuring Presence in Mixed Reality

Given the characteristics of Mixed Reality and the focus on users’ purposeful actions (rather than on mental states), “measuring” becomes a topic. In our research, we have used an ethnographic approach, which is based on observational methods in combination with interviews and the analysis of artifacts. A definition of ethnography that includes most ethnographic studies is given by Hammersley & Atkinsons (1995:1). 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.

Commonly, ethnography is characterized as the study of activities and events as they occur in ”natural settings”, from the perspective of the people that are observed. This is based on the assumption that the complex and evolving character of social action and interaction can only be understood from the context in which it occurs (Jordan, 1997). Ethnographic accounts typically contain information about the context, they are expressive-narrative, and they present what has been observed from particular perspectives – “ethnographic truths are thus inherently partial-committed and incomplete” (Clifford, 1986). Ethnographic methods have been successfully used for many years in participatory design, as well as in CSCW research, informing technology design. Their success is due to the richness in social (and interactional)

detail they unravel and the contextualized nature of the data they create. This is why we believe ethnography to be particularly suited for research on Mixed Reality, with its focus on users' purposeful activities, including the mapping of events in the real and the virtual environment.

In the urban renewal case, observation, supported by video and photographic images, provided the main data. Analysis was carried out collaboratively in the team, with attention paid to the details of participants' interactions (as revealed in selected video clips) and to the intense discussions that took place during the workshop sessions, where participants addressed questions of the project – which architectural interventions to carry out – but also commented on features of the tools and on their potential role in urban planning. Rich data, with an attention to interaction details, are necessary for understanding the participants' mapping activities, and they need to be connected to the Mixed Reality scenes that are produced, talked about, and modified. As the group of participants was by necessity rather small (6-8 people around the *MR Tent* table), the use of Presence questionnaires for statistical purposes did not make much sense.

In *MapLens* trials that made use of a control group utilizing a non AR mobile solution (*DigiMap*), the participants filled in three questionnaires: a shortened version of MEC Spatial Presence Questionnaire (MEC-SPQ) (Vorderer et al, 2004), a GameFlow questionnaire based on (Sweetser & Wyeth, 2005) and an Intrinsic Motivation Inventory (IMI) questionnaire (Deci & Ryan, 2000). As Likert (ordinal) scale was used as a measure and Shapiro-Wilk's test revealed our data is not normally distributed, the Mann-Whitney U-test was selected to test differences between *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 to the game and/or map system, and experiencing a sense of concentrated engagement was activated for users of both systems. When comparing individual Presence, Flow and Motivation items, significant differences were found. This may be due to questions addressing whether the system related to map system use, the game played or both.

As a general conclusion it can be stated 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, who concentrated more on the technology as such, as well as being more focused on the game as a whole. Also *MapLens* users were socially active and more helpful of others. *MapLens* users were more focused and both groups scored high on sense of control, understanding requirements, interest and enjoyment.

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*.

TimeWarp made use of questionnaires, in combination with interviews, direct observation and video analysis. 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. Additionally we also had to explore if the users felt present in different time periods (temporal Presence). For this task we chose to build upon the MEC spatial Presence questionnaire (Vorderer et al, 2004) by adding questions specifically related to the issues already highlighted. The primary changes to MEC included adding questions which specifically explored the blending of experience and the comparison between real and virtual elements, including non-game participants. With the exception of the first section, all questions asked the user to respond on a standard seven point Likert scale (the original MEC questionnaire used a 5 point scale). MEC itself was insufficient for exploring issues to do with social presence, in particular with respect to virtual characters. It was for this reason that we added questions from the Bailenson et al., 2001, social presence questionnaire. Finally, we added some questions from the Place Probe (Benyon et al., 2006) to find out about which place(s) people felt they had visited as they took part in the experience; these were also modified to reflect aspects of Time Warp, in particular the temporal dimension. However questionnaire based approaches only provide small hints as to the overall experience that the user has within such environments. In particular, they are not suitable for identifying where breaks or changes in Presence occur.

While the majority of users were video-taped, some were also observed as they took part in the game. For this we adapted an observation technique developed within *IPerG*, 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.

As the intention was to inform design as well as provide a method of evaluation, we used semi-structured interviews to drill down. The questions in the interview were often determined from interesting phenomena observed during the trial or from data obtained in the questionnaire. These interviews tended to focus on the question of "where" people felt and in addition what cues or other aspects caused them to feel there.

In any case, the methods that seem most appropriate to 'measuring' 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 has been 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.

5. Conclusion

This article aims to establish 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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