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Abstract

This report presents the common research in IPCity on issues of presence and interaction in mixed reality undertaken in project year 3.

Section 1 of the report presents the new agenda for research on Presence, in Mixed Reality, which we develop in IPCity. We argue that presence research that is meaningful for MR needs a broader conceptual framework, which encompasses traditional perceptual elements of Presence, but has an emphasis on Social Presence, affordances, beliefs and longitudinal effects. We also argue for and practice a shift of attention 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 are among the first to perform longitudinal social analysis of MR. With respect to the key question raised in the Presence community - 'what are the implications for our notion of reality and self? Is what we have thought of as reality simply one amongst many parallel realities that we now inhabit?' - our approach is: 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. This means that there is always also a social and cultural dimension of Presence.

Section 2 of the report contains an overview of sound research undertaken in year 3, namely observations from field trials involving sound (WP6, WP8), and the results of interviews with sound experts, which confirmed many of our empirical findings and provided us with a deeper understanding of the observed phenomena.

Participants in the urban renewal workshops in the *MR-Tent* did not work explicitly with the sound. The sound, which at times seemed quite invasive to us, stayed in the background their activities. However, 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. Exploring the scenario with the hearing position made them enter the scenario in a way that the visual representation in itself cannot achieve. The 'flow sound' provides spatial feedback, such as on the vicinity of objects to a road, and it provides feedback on the type of objects. A main result from field trials with *TimeWarp* was that audio formed a key part of the gaming experience for all users. The sound cues provide another method of linking game content and objectives to the underlying cityscape and invisible aspects such as history, famous characters and ambience. They had a significant impact on user experience ranging from providing navigational support to raising questions about the effect of narratives and non-player characters on presence.

Section 3 presents Presence research carried out in the showcases. Urban renewal is a key issue of our work and we are among the first to design outdoor MR experiences. We have analyzed in-depth three experimental applications developed within IPCity that all are to do with experiencing the city. In the case of *MapLens*, action is in the real environment, while participants orient their task to remote locations and people. In *TimeWarp*, action takes place in an augmented environment, which is carried around by participants in the streets of Cologne. One of the key elements of the experience here is the feeling of connection between the virtual and real gaming elements. 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. In this complex set-up we can observe the challenges of mapping events and representations within the physical environment to those in the Mixed Reality scenes.

The discussion of our empirical findings refers to the philosophical- epistemological level of our approach and highlights the characteristics of three MR applications we discuss as exemplifying variations in where action takes place and dealing deal with multiple events. It also addresses the issue of how to 'measure' user experience in MR.

Section 4 summarize our findings in the form of 'design guidelines' on five topics: making interaction tangible; an experience point of view on different MR set-ups; working with 2D abstractions of 3D environments and objects; MR on mobile devices; enabling the user experience.

1 State of the art

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, 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*, 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.

1.1 Similarities and dissimilarities of Presence and Mixed Reality research

1.1.1 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, 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 that the perception of ones own body in a standard VR environment such as a CAVE.

Transitional interfaces (Billinghurst, Kaot & 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.

1.1.2 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, Fuhrmann, Szalavari & Gervautz, 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., ones 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 this 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.

1.2 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 TelePresence 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 more practical one interested in dealing with specific research issues.

1.2.1 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 an 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 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 1.1.2. Gibson's view challenges many of the points of the mainstream position. Gibson (1971a) 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 which 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 and Riva, 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.

1.2.2 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 in 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", 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 (2003a, 2003b) 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 and 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. He proposes to enrich Gibson's ecological psychology of affordances with concept of frames developed by Goffman (1951) 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 perspectival 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 (2003, 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 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 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, Mudler & Martz, 2002), the work on urban ambiences (e.g. Amphoux, Thibaud & Chelkoff, 2004), as well as in artistic-architectural installations (e.g. Wilson, 2002).

2 Sound research in IPCity

Working with sound in IPCity is not so much directed towards technical innovation but focuses on conceptual issues, namely:

- How can adding sound enrich the mixed reality experience of users, hence the experience of presence?
- How can in particular users spatial understanding and experience be strengthened?
- How can, in the case of the MR-Tent, users' perceptual field be increased by enhancing the transition from the (spatially limited) projection of a visual scene into the acoustic space, thereby increasing users' immersion?
- How can sound be used to provide users with feedback about their interventions?

The empirical background of this report is field trials within WP6 and WP8 as well as a (not yet completed) series of sound interviews with sound experts. We have yet to carry out a more in-depth analysis of the sound experiences in Cergy-Pontoise and will also include some material from the Grand Palais event in our further analysis.

2.1 State of the art in sound

Urban research on ambience is at the intersection of sensible, perceived and experienced. It orients spatial issues towards immaterial and sensorial aspects. This research field is particularly relevant in French research since the French term "ambiance" is semantically rich and covers aspects that can hardly be translated in a unified concept in other languages: environment, atmosphere, context, comfort, sensation, ambience etc. The focus can be on different aspects - physical phenomena, sensible-physiological perception, socio cultural appropriation.

Sound contributes to qualify an urban situation in terms of ambience since the media through which it diffuses (i.e. the space and its shape, its open/closed character, the distances, the materials, etc.) is as important as the origin (the source) and the destination (the listener) of the signal. Crossing approaches is the most fruitful way of studying sound in urban situations. Research teams such as the CRESSON in Grenoble (www.cresson.archi.fr), CERMA in Nantes (www.cerma.archi.fr), and GRECAU (www.bordeaux.archi.fr/recherche/GRECAU/default.htm) in Toulouse and Bordeaux gather specialists of different origins.

A technical approach is developed by physicists and engineers specialized in acoustics modelling sound propagation in order to study noise pollution and its perception, to find ways of representing sound levels (indicators, noise maps according to European legislation, etc.) and to produce decision-making tools (Raimbault and Lavandier 2002**)**. Applications fields are, for example, noise pollution in airport areas or, more generally, in urban contexts (Euronoise 2003). Such studies are done in immersive (laboratory simulation) or real environments (perception questionnaires). Sometimes the two situations are put in relation by comparing the perception of sounds on site to the same sound recorded and reproduced in a laboratory situation (Viollon and Lavandier 2000). These approaches insist on troubles occurring especially in private spaces in order to give politicians and deciders tools to improve everyday life quality. It is a problem solving approach.

Architects and urban designers are often associated to a more positive approach, insisting on public space as a "soundscape" (EAA, 2006). Research in this field is more directly connected to ambience, in a qualitative approach and in a design perspective (Building with sounds, 2005). Research concerns the contribution of sound as a new dimension for the sensible perception of the city, the cultural and imaginary aspects, comfort instead of trouble or disease, etc. This research area includes also studies on the impact of visual upon sound (Viollon et al. 2002) and vice versa (Anderson 1983, Carles et al. 1999) and opens up to psychological and linguistic components.

A more peripheral approach in research on sound and the city is the one lead by musicians. Their contribution is also qualitative and brings in a particular sensitivity to soundscape. Institutions like IRCAM (www.ircam.fr) in Paris host composers like Louis Dandrel who become urban sound designers when they work on and with the city (Dandrel 2000). Pierre Mariétan (2005) contributes to research on sensitive approaches to urban studies and ambiences in the Laboratory of Acoustics and Urban Musics (LAMU) of Paris La Villette School of Architecture.

As noted by many researchers, the pioneering research in soundscape was carried out by Schafer the 1960s. In his classic book, *The Turning of the World* (1977), he defines sound as keynotes (the fundamental tonality around which a piece of music modulates), signals or foreground sounds (sounds that are intended to attract attention), and sound marks (sounds that are particularly regarded by a community, in analogy to landmarks). To him ‚acoustic design' meant discovering the principles by which the aesthetic qualities of an acoustic environment may be improved (Brown and Muhar 2004). A distinction has been made between strategies such as the elimination or restriction of ‚sounds of discomfort' (defensive), the preservation of sound that gives character to a place (offensive), and the imaginative placement of sounds to create attractive and stimulating environments (creative) (Hellström 2002).

Further pioneering research was carried out by Southworth (1969) who studied the reactions of different population groups to soundscape, analyzing their pleasantness. One of his findings was that hearers' delight increased when sounds were novel, informative, responsive to personal action, and culturally approved. This suggests that people's subjective experiences of sound are much more complicated than its physical qualities. Sound preferences may be primarily reflect attitudinal and evaluative rather than purely sensory components. Inspired by these findings, Yang and Kang (2005) have carried out an extensive study of people's sound preferences in urban contexts in Sheffield, UK. Their main observations can be summarized as follows:

- In a given soundscape the first noticed sounds do not have to be the loudest;
- In an urban square, people generally prefer natural and culturally related sounds and their specific preferences to a large degree depend on age, cultural background, and log-term environmental experience;
- The source of a sound matters, e.g. if music comes from an open window, a passing car or a live band.

Introducing sound marks may have dramatic effects. Yang and Kang distinguish between passive sound marks, such as fountains and sonic sculptures, and active sound marks, which are sounds generated by interesting activities.

Multimedia artists are working with sound. Stuart Jones (2006), in reflecting on his artistic strategies, emphasizes that different media have different time-space logics. He argues that there are myriads of ways in which they can play with or against each other. Characteristic of sound space is its plasticity. Sound is „continually setting the boundaries of the perceptual space in a fluid way and can move around and occupy any part of that space or several at once" (p. 22). Jones talks about a sound's *varipresence* arguing that sound can be used for setting the agenda for our reading of reality more than any other medium. He also emphasizes our capability of handling multiple sound strands – we can focus on a single strand or on several related and unrelated ones. He compares sound to the interaction space, which is also fluid, allowing interactants attract, evoke, summon, bring close, release objects, real or virtual. Jones in his analysis coins the term ‚audiointeractivity' by which he means users' activities precipitating a change in the sound space.

Jones describes several of his own art works. Of particular interest are strategies such as locking a sound to a specific spatial reality by carefully placing loudspeakers in a space (such as the spatial reality of a garden, containing the sound within it); or working with dichotomies that encourage interactive participation. One of his examples here is a piece that „sets up dichotomies at the level of experience (intimate/remote, close/edgeless) and understanding (expression/contentlessness) that encourage us to simultaneously become immersed in and deconstruct it. Examples such as these can be used quite directly as sources of inspiration for how to use sound in IPCity.

Another artist, Justin Bennett, member of the Netherlands-based audio/visual performance group BMB con, describes the group's use-based approach to audio-visual performances, which is based on a lot of improvisation (Bennett 1999). With respect to sound he characterizes types of situations that help deal with the accidental and unexpected, such as accumulation (repeating action, building it up, layering it into a texture), impedance (making certain actions difficult by introducing obstacles), instability, interruption, forsaking of control, as well as accidents. He also describes interventions such as manipulating the audience's point of hearing by placing loudspeakers.

Working with a rotating panorama and spatial sound, such as in IPCity, Doornbush and Kenderdine (2004) report on the strong sense of presence achieved. They identify several crucial elements for sound to enhance the sense of presence: the identification of source, setting, and space. Their example is drawn from the creation of a VR presentation of the Angkor ruins in Cambodia. They used recordings from the site but found that the recordings needed to be modified substantially to achieve the experience of presence; they had to be made 'suitable in terms of setting-identification and space identification'. They for example successfully experimented with 'early reflections from nearby walls coming from the appropriate locations' within the rotating panorama.

2.2 Sound interviews

TUW, FIT and UMVL are carrying out a series of sound interviews with different kinds of sound specialists. The aim is to learn about different conceptual approaches to working with sound in an urban environment, as well as about techniques of producing, editing, using sound.

The interviews were guided by a set of research questions, from which the most appropriate ones for each interviewee were selected:

1. *How to categorize the informative content of sound – what to consider when developing a sound library that classifies sounds according to their source, material origin, and physical determinants?*
2. *How to evaluate and describe the personal and cultural meanings of sound – how to develop a taxonomy using semantic criteria for describing sound?*
3. *When and how does a connection with a sound change/extend the meaning of a visual object? Can you give examples from your own experience/work.*
4. *Can we put the sound at the same level as visual or verbal expression?*
5. *How can we tell a story of an urban site, an event, a project with sound? How to plan the acoustic environment of a site?*
6. *Differences between realistic and abstract-synthetic sounds?*
7. *Differences between simulation and expressive uses of sound? Arguments for both types of uses.*
8. *When you think of 'users' creating their own sound for expressing their story of a place past, present, imagined, their expectations and emotions? What would your strategy be?*
9. *How to create a sound language (sound icons) for interactions – how to strengthen the experience of an interaction through sound?*
10. *How many sound strands can users handle – do you have any experiences with this?*

11. *And, associated with this, how to better understand users' experiencing and manipulating these different sound strands, as well as how to control sound densities?*

2.2.1 Catherine Lavandier

Physical acoustics D.Sc and lecturer at Cergy-Pontoise University (France), her research interests are about sound in urban environments. She has worked on topics, such as the quality of sound environments dependent on the use of schools*, aircraft noise for people living around airports, and the impact of image upon the perception of sound.*

Her opinion is interesting since she is experienced with sound in urban issues, but in the opposite perspective than WP6 of IPCity, which works on the introduction of sound in tools that were originally essentially visual. Catherine Lavandier was interviewed in two steps: before and after the workshop in Cergy-Pontoise (Caserne Bossut) in September 2008.

The first interview was made on the basis of guidelines common for all researchers in IPCity. The second one was a feedback on the workshop, since Catherine had assisted to the session where a blind person was learning to use the tools, and the sound was a particularly important issue.

Sound and the city

Sound perception and capacity of description by users took an important place in the interview. The elements that qualify a place from the sound point of view are the **objects** that compose it and the **background** sound or noise. The first is a single source, associated to an object (e.g. a bus passing by); the second one is a diffused and global sound, associated to a space (e.g. a road). When lay people are asked to describe a place by its sound characteristics, they often make reference to concrete elements more than to abstract impressions; they often concentrate on sources they can identify, sometimes even if they don't see them. Probably simulation is easier to manipulate rather than making people react to abstract sounds since people usually have a limited vocabulary and listening to recognizable sounds helps concepts they would not know how to express to emerge.

Moreover, since we are not used to focus on sound in our everyday life, the tests CL has made in several research contexts (live or in laboratory) show that it is difficult to describe a sound alone, while it is much easier to qualify it by difference with another sound of the same nature, having different "sound signatures": two trains (a high speed train and a train transporting goods, for example), but not two different objects (a train and a plane). There can be qualitative and quantitative characteristics: the sound of a train passing by can be "*brusque*" (abrupt: qualitative, with negative connotation) and "*bref*" (brief, quick: a more quantitative characteristic, because it refers to a measure of time, even if sensible). Danièle Dubois, as a linguist, has worked on words to describe sounds. Another possibility is to ask the users to give a score but it must within a frame: if the users feel the question is too wide, if they feel they do not understand, they cannot go further than "I like" or "I don't like" or they prefer not to answer (rather than to be critical about the question).

The relation between quantitative and qualitative characteristics is also present in the definitions of **sound and noise**. Sound includes physical and sensible characteristics: it can be described through time elements, intensity, frequency and spectrum, but also, in the second register, through presence, pervasiveness, proximity. On the other hand, noise is emotional, always with a connotation, connected to perceptions and effects.

The relation **image-sound** strengthens the feeling of pleasant/unpleasant. CL worked on the impact of image upon sound and observed that if the visual is positive, the sound is also easier, to accept. IPCity is working on the reverse situation: does the introduction of pleasant/unpleasant sounds have an impact on the perception of the visual scene? The visual dimension guides our perception and the ear is a waking organ, for diffuse surveillance, it never rests, even while sleeping.

To make people interested in both visual and sound dimension (to feel present?) it is important that they are of the same quality: if the definition of the image is rougher than the subtlety of sound (or vice-versa) the attention will be focused on the weaker point, as a disturbing element. Moreover, it is more difficult to **play with imagination** with sound than with images: this perception is very much connected to concrete reality concerning place description. For example, the idea of a park is usually positive, but its real experience can be more problematic, because of the multiple sounds that can intervene. On the imaginary level, the mind makes a selection and keeps what is considered essential and rubs out the ideal representation some elements, sometimes disturbing, that are part of the real experience.

Human presence has a particular impact: it generally catches attention, and has a positive connotation. It cancels the importance of other sound events: it is a super-event. Working with blind people, CL realized that hearing the sound of their own steps is very important, otherwise they feel as if they had disappeared. To give other examples, usually a scooter is considered very noisy, intrusive and individual, while birds generally irritate nobody. Proximity with a school is less consensual.

Urban designers have difficulties to work with the sound, to design spaces where sound really plays a role. The first step is to understand the site through sound. There are attempts in stations, both to develop sound icons and to work on sound ambience. Manon Raimbault is an architect from Toulouse who has worked on sound at secondary school. CRESSON is a French research laboratory connected to Grenoble school of Architecture, which works on sound ambience, have this approach, but in a very conceptual and qualitative way. CL thinks that deciders need also more quantitative elements, where the person is always the main focus, but which include characteristics that can be measured, evaluated, making the connection between the human and the physical dimension.

Ideas for IPCity

The table proposed with the **cultural probes** suggests interesting categories, especially qualitative, to which intensity and texture of sound could be added. The sound data base organization is an interesting issue. Realistic sounds can be associated to objects: it is interesting to have the choice among different sounds for each object since imagination capacity is more limited for sound than for images. Concerning abstract sounds, it is probably more interesting to consider them as a separate category, not yet associated to specific content, both in the cultural probes and in the workshop situation.

In the **workshop situation**, CL found that sound works well when the image is fixed. The sound database could be enriched with steps, voices, and elements marking the human presence, which is particularly important to understand and work on an urban scene.

It could be interesting to play with volume: sound can be augmented at certain moments to arise attention to it and as a form of provocation, but it should be possible to low it down once the question is focused and to avoid it to become disturbing. The sound should have the same quality as the visual content and if it lasts too long in repetitive cycles, the risk is that it gets tiring and then becomes the weak point of the scene: people tend then to focus on it and get disengaged from the general discussion. While we look in different directions and “disconnect” from the image, we cannot do the same with sound, which is pervasive.

When there is movement in the scene, the situation can be more difficult. The panorama gives a central point of view and the position of the red token or the red person in the flows obliges to operate a disconnection between points of view: the users have to imagine they are inside the scene (like the red person) while the images they see are those from the central point of view of the color table. There is a gap in perception if the red person moves and the visual scene does not accompany this movement. Moreover, visually, we can easily pass from a viewpoint to another (several screens next to each other) but this is much more difficult from the hearing perspective where can be activated one point of view at a time.

From the **technical point of view**, IPCity system seems complete to CL, because of the various hearing points available. Generally, five hearing points are satisfactory for a background sound and two points give a good idea of specific sources and objects.

When realism is wanted, it should be possible to hear the difference between an open space and reverberation effects due to buildings nearby. This does not correspond to the aims, the specificities and the precision possibilities (both for visual and sound dimension) of IPCity since simulation is not an issue.

It could be interesting to work in two different workshop situations (with and without sound) in order to compare the reactions of participants.

CL finds it also interesting to give participants the possibility to express new ideas through abstracts sounds, playing with provocation and going to the limit of incongruence, but it is important not to go beyond, otherwise the connection with reality (and the feeling of presence?) gets too complicated, and this can be valid also for visual content. For example, in a discussion about the possibility of putting a monumental statue in a public space, Michelangelo's "David" could be put in the scene even if it would never be the real statue that could really be in that space. However the message is clear because "David" is recognizable as a statue. Sound is there to help imagining oneself there, in the site, in a particular ambience. CL finds also interesting to invite the participants to create their own "ambience" by mixing available sounds or bringing their own sound. The questions then could be: does the sound correspond to what they imagined/ wanted to express for the site? What is the potential of the tool? Is it constraining or does it open new perspectives?

2.2.2 Raymond Usher – Realtime Worlds

Raymond Usher, audio lead, started working with DMA design while at university, this was the company behind the successful Lemmings franchise. He has worked on the Grand Theft Auto series up to and including Vice City. He works with audio designers to ensure that sound is a key element and that it is correctly implemented within games. Recent work includes under development games and the successful Crackdown. These are among the biggest and most successful games of all times, hence he has experience of being at the top of the games development market.

The numbering relates to order in which the interviewee answered the questions; this roughly correlates to the questions, which were chosen prior to the interview. However as is noted later their model of presence and sound is different from ours so the replies are not always strictly within the related questions. The notes were taken at the time of the interview and are not a verbatim copy the discussion but rather a summary of what was said.

1. They use an iterative process of testing sounds. Usually starting with the functional requirements as specified by the requirements. An example is "how many gears in a car" have then designing the sound for that object around these properties. The soundscapes are multilayered, although it is not always clear if the players are aware of this as they may hear all of them combined as one sound. To create a sound the location (in particular the acoustics) are examined, e.g. city with closed or open spaces, first order reflections and reverb. Sounds are divided between three categories (1) natural – e.g. in world (2) super natural – over the top of the game world e.g. UI sounds (3) hybrid a mix. One of the main aspects in designing such experiences is the player expectation from comparisons with other games, films and reality (e.g. a car engine).
2. Cultural and personal effects: Objective is often to create one single mood for a product, this is reflected in the sound design.
3. Music is the main method of chanting the mood with respect to objects or locations. For example high- octane music for (high octane) cars in Crackdown. Also background ambient soundscapes are used, for example in Crackdown to draw people into tunnels.

4. Audio is used in combination with other methods. However it can imply much more than the visual field, is not so immediate, often goes deeper and can have a longer lasting experience. It can also provide implied and non-specific information. However the desire is to use it always to improve the overall experience.
5. Designing urban games (example city centre Dundee): would research real location to explore the sounds, which exist in the real space, e.g. traffic, seagulls and background ambience. Time dependant sounds are also important, these should also be connected to the directional element. Sounds which are overheard and not specific to the user experience are important. Care should be taken to avoid repetitious sounds (i.e. using the same sound cue several times) as these are quickly noticed by users, and are a problem. If they must be used then they should involve changes in pitch, frequency and volume.
6. User generated sounds have been tried in the PC version of Grand Theft Auto, where people create their own “radio station” from the MP3 content on their computer – people loved this! However his view is that the sound (including volume) is specifically tied to the design and experience, therefore it is open to question whether even letting people vary the volume of specific elements (e.g. UI or ambience etc) is a good idea. In general the sounds of props (e.g. guns or furniture) are so tightly coupled with the experience that they should not be changed.
7. When creating UI sounds these are often linked to the visual field for example within game and by observing users. Typically they include looking at how users move and interact with the UI elements so that the sounds can be tightly coupled to their physical movement. This should always be done to strengthen the experience only.
8. Sound layers: are experimenting with the sound approach used in Apocalypse Now where layers are added or removed and drop off. Technology no longer limits the number of channels so the challenge is to find what is appropriate for the user, in particular aspects such as the heard volume for the user. In appropriate heard volumes may cause problems and frustration. One example may be to selectively amplify certain elements which are key to the overall experience. In GTA there was a general rain soundscape, however six droplets were selectively amplified during rain sequences to give the user a greater feeling of proximity.
9. Realism in sound is not always a good thing, for example ambulances. In the real environment the spatial elements work well, however current technology is not good enough within games to make this seem exactly the same. Thus sounds are often enhanced to reflect the game environment and not necessarily reality.
10. Abstract Vs Real. Would like to try experimenting with abstract sounds but as yet games demand something based on reality. However abstract soundscapes may suffer from being novel and quickly bore the user. Moreover they may be so complex that they demand attention, this drawing the users away from the overall gaming experience. Furthermore repetition may become a serious problem.

Note: again one main result from this interview is that game sound designers use a different “language” when discussing sound design and presence than those within IPCity. There was little if any reference to considering presence per-se rather experience, which presumably incorporates presence. Also the soundscapes are developed from a practical, often reality led viewpoint rather than from any underlying theoretical model.

2.2.3 Ross Nicol – Realtime Worlds

Ross Nicol, audio engineer, Has worked on Crackdown and APB – All Ports Bulletin (both Realtime Worlds). Previously he worked at VIS Interactive on Brave and other games. Prior to that he worked in a music shop and studied audio engineering. He works mainly on integrating sounds into the gaming experience, rather than creating them.

The numbering relates to answered questions, which may in part be those on the list but they are not specifically related to them.

1. He splits sounds into groups e.g. weapons, environment and props (chair table etc). Then on the basis of whether they are internal or external. Nearly all sounds are initially recorded then modifications are made.
2. Creackdown uses a futuristic soundscape so more emphasis is placed on synthetic sounds. Others like APB focus on real life urban experiences so that is reflected in the soundscape. Also the soundscape is developed based on drawings sent by the artists.
3. Sound must be appropriate with respect to the experience, for example using a high powered car sound for such a car and not a moped, even small changes have the potential to radically alter the feelings the user experiences. Weapons must focus on more than just "bang bang" but also the subtle elements such as clinks etc.

6. The sound design tries to complement visuals where possible, e.g. use GUI effects by using little bleeps of sounds to reflect what is going on in the GUI screen as well as in the wider gaming environment.

7. InOn sci-fi games the sounds are more synthetic. There is a lot of Much work is being put into developing sounds, which arecarried out on creating realistic, e.g. the sound of a (lots of detail) car engine. However this is difficult and hence the results are not quite compelling. sounds but the technology is not currently good enough.

8. User generated content is a good idea in general but he does not have much experience of it.

9. Sound is very important and mainly focussed on the subconscious level.

Note: Although the standard list of questions was used during this interview, it became apparent during it that these are not the way that sound engineers think. Indeed as can be noted above the categorisation and use of sounds is much more rooted in normal terminology and linking real to in game sounds rather than thinking about the topic from any academic viewpoint. For them presence is about realism and linking game elements to the sounds, it is not about thinking about presence per-se, indeed the word was never used.

2.2.4 Karlheinz Essl

Born 1960 in Vienna. Austrian composer, improviser and performer. He studied composition with Friedrich Cerha and musicology in Vienna (doctorate 1989 with a thesis on Anton Webern). As a double bassist, he played in chamber and jazz ensembles. Besides writing instrumental music and composing electronic music, he performs on his own electronic instrument m@ze?2, develops software environments for computer-aided composition and creates generative sound and video environments – often in collaboration with artists from other fields.

Essl served as composer-in-residence at the Darmstadt summer courses (1990-94) and completed a commission for IRCAM. In 1997, he was presented at the Salzburg Festival with portrait concerts and sound installations.

Since 1994, Karlheinz Essl curates experimental music concerts and sound installations at the „Essl Museum" in Klosterneuburg. Between 1995-2006 he was teaching „Algorithmic Composition" at the Anton Bruckner University in Linz. Since 2007 he is professor of composition for electro-acoustic and experimental music at the University of Music and Performing Arts in Vienna.

Question: Can sound be treated on the same level with visual expressions and language?

Essl: It is a fact that we can hear before seeing. Seeing has to be learnt while hearing starts before we are born. Acoustic impressions become registered in the limbic part of the brain. Which is connected with feelings and emotion and it is for this reason that we react to sound in more immediate and emotional ways than to images. Images are closely connected with analysis, activities of the cortex, hence concepts, while sound acts almost reflexively. Example: we can hear a car before we can see it. We can close our eyes but not our ears.

Question: Conscious and subconscious hearing – how do you describe these modes of perception?

Hearing is always connected with a specific situation. I a concert I have a completely different expectation than when I am hiking in the mountains. There I listen carefully since I try to orient myself while listening and eventually identify a source of danger. In the concert hall I focus on the music itself. As regards conscious hearing, there is the aesthetic hearing situation in a concert on the one hand, the hearing that helps orient in an environment on the other hand. Subconscious hearing describes being affected, aroused by sub frequencies which you sense, affect your body, and affect you, sometimes also in negative ways.

Essl describes the experience of a refrigerator in his apartment that created 'acoustic knots' of subfrequency waves that made him leave the room. Further examples are: In a church, a big, tranquil, sacral space – when we suddenly hear birds singing, this can be touching but also irritating. Bill Fontana's sound sculpture Landscape sounding, which he produced 1990 in the wilderness close to the Danube (in trees, under water, on the ground) and which was transmitted to the space between the two big museums in Vienna – "reinforcing the acoustic signals and shifting the context from nature to city produces irritation, hence increased awareness".

Question: When you translate an object, scene, event or quote acoustically, how do you proceed conceptually?

Essl: The process differs according to the artistic idea and the intended result. When I work on a piece for bass clarinet I work differently from producing theatre music for a piece by Andreas Otopenko. In the first case I would start with exploring the instrument itself to see if it can be played in a new not yet common way. In the second case I would examine the text for a structure or ambience that the music might support or contrast. I always start from the situation but also try to find something new. At the moment I focus more on the instrument and on the possibility of using live electronics to make its embedded history speak.

Question: How do you validate your work with respect to the recipient's perception?

Essl: I always try to validate my work, even if it is rather abstract, also trying to imagine what happens musically during rehearsals in order to eventually make some modifications. When performing live, I am in a feedback process, reacting immediately on what is happening with variations of my music and the sound. This reacting, also to the feedback from the audience, is something that happens subconsciously and has a mysterious aspect.

Question: What are the perceptual differences between synthetically and acoustically produced sounds?

Essl: The so-called concrete sounds that we know from our immediate experience of nature are closely connected with our embodied being. For example, an object (he demonstrates with an eraser) that drops and bounces several times – this is a complex but familiar event. When we use instruments for by means of composition evoke such an event, it may sound rather 'organic'. Here we produce sounds that structurally imitate basic physical events and are connected with our experiences of the world. These sounds can also be produced synthetically. Techniques, such as the 'physical modelling synthesis', allow define characteristics of the body, of the surrounding walls, and materials; you can also define if an instrument should be stroked, blown or plucked. You can also construct impossible instruments, such as a flute with a length of 100m, which is stroked with a rubber hammer. This mean we can use sound synthesis for producing perceptual effects, which cannot be created with natural sounds. I here speak of difference without judging.

Question: What is the difference of perception between a real space and a virtual space (e.g. a movie)?

Essl: The movie (theatre) as a virtual space creates a high density, since visual and acoustic impacts can be concentrated to a degree that is not possible in reality. This may increase the sense of reality. On the other hand, there are aspects of the real world that cannot be created virtually. Such as smell, warmth, feeling – the movie does not contain tactile and haptic experience.

Question: Sound can influence an image, eventually even change its meaning – can you bring examples?

Essl: I have no example but the fact that film and TV cannot live without sound nowadays. Every movie comes with sound that works with stereotypes so as to evoke particular emotions. Think of the dissonant violin clusters that have been used since the beginning of the sound film as a sign of danger or fear. This can be easily manipulated.

2.2.5 Hendrik Jakoby

Hendrik Jakoby works as a sound designer and composer for Sproing Interactive, one of Austria's leading game development studios. He is also an active musician, member of different groups of different styles, performing as bass, guitar, and voice. His background is History.

Question: Can sound be treated on the same level with visual expressions and language?

Jakoby: As concerns its informational value, yes. Not when it comes to the level of experience.

Question: Why does a radio play work without the image but a still movie not without music? What results from this for the design of computer games or virtual worlds?

Jakoby: Silent movies work without sound but adding acoustic information enlivens and helps reinforce the intended artistic expression. The early computer games had no or only minimal sound support. They are appreciated for their minimalist approach and some of them have reached cult status. The effect here is 'less is more', since the reduced acoustic background (due to limits of the technology) inspires (rather than informs) the consumer.

Question: Conscious and subconscious hearing – how does computer game design work with these different modes of hearing?

Jakoby: All of us continuously perceive acoustic signals and most of those do not pass the filter from the subconscious to the conscious. However, we perceive the absence of these signals. We perceive consciously those things that we cannot blend out, that come close (due to their volume or frequency), or those things that we look for and listen to.

As regards the subconscious dimension in computer games, I seek to design them as subtly as possible, working with factors, such as ambient sfx, music and the experience of space (reverb, delay, etc.). My experience is though that this is too subtle for most people and highly dependent on you personal sensations.

To direct players acoustically, it is necessary to foreground the sound or music.

Question: How do you understand the notion of 'presence' with respect to constructed acoustic spaces?

Jakoby: As regards the construction of acoustic spaces, I start with the idea and try to obtain a desired outcome. In case something does not work, I explore and probe until it fits. Here I have to add that the possibilities are restricted. Many consoles have strict limits concerning sound.

I interpret the notion of presence of a sound, apart from its frequency and volume, may be experienced as close to the hearer (and this closeness is determined by many parameters). Immersion, embedding the hearer in an acoustic environment, is salient for the hearer's spatial orientation in a constructed 3D world.

Question: Can you describe in which ways the acoustic dimension enters a computer game and how this is implemented on a practical level?

Jakoby: Sound design is mostly done by one person alone, who also does the implementation, eventually in cooperation with a programmer. In the beginning there is some visual reference material and the game design concept. Usually there are technical limitations to observe. Questions of taste are difficult to resolve. There are also the requirements of the publisher and the testing team.

Question: Sound can strongly influence the reception of an image, sometimes even result in a different interpretation. Dou you have examples from game design?

Jakoby: I find the music to *Fantasy General* excellent - this is an optically simple strategy game with beautiful music. Also Oblivion. In general I think that in most games sound is experienced as supportive, hence it is difficult to judge if it changes the meaning of a game.

Question: I how far does the perception of a real and a virtual game differ?

Jakoby: In general a virtual space is perceived as less complex and more as 'generic'. Sound has to be transported through a system of loudspeakers and despite the fact that we have multi-channel systems, the effect is different from a real space.

Question: Which perceptual differences do you see between synthetic and acoustic/real sound?

Jakoby: If you think about the difference between a synthesizer sound and a natural sound – this is difficult to describe. I my perception a synthesized sound is less complex, less subtle, less warm and also less chaotic. I also experience it as 'new', inspiring new imaginations, since it is not part of 'this acoustic world'.

2.2.6 Conclusions

We interviewed experts with very different background and experience: a trained scientist (physical acoustics) who has done research in sound in urban environments; a well-known composer; and three sound designers for computer games, again with a rather different focus. Some of their arguments are very specific. With regard to other they converge. These can be summarized as follows:

- People in general (non-experts with regard to sound) find it difficult to talk about sound, in particular abstract sound. Their vocabulary is limited and if they talk about sound they do this with reference to concrete elements and sources. Such 'concrete sound' is linked to our immediate experience and embodied being. When produced by instruments such sound is perceive as 'natural'. Abstract sound is more difficult to relate to spontaneously for most people and can be rather complex. Hence, it usually demands attention, is not experiences as a 'natural' aspect of an environment.
- Our conscious hearing depends on the situation. While we focus on the sound/music in a concert hall, in everyday situations we listen to sound for e.g. orientation, avoiding danger, recognizing a person we are waiting for. This means that in an urban situation we have to understand what could motivate people to actively listen to the sound.
- However, sound does not always have to reflect reality. It may be used for strengthening or contradicting an experience in more subtle ways. 'Subconscious' hearing affects the body and a person's emotions in a direct way. This may even be irritating. On the other hand, people often do not become aware of a subtle and multi-layered soundscape.
- All interviewees stress the importance of coupling sound and image, respectively sound and movement.

The expert in sound in urban environments, who had been present at one of the tutorials in Cergy-Pontoise, confirmed some of our own observations concerning sound. She found it interesting to have the choice between several sounds attached to a visual object. She suggests to add sounds marking human presence, such as steps and voices. She also points to having sound too long and short loops as easily becoming boring or even irritating. .

2.3 Future work on sound

One of the main challenges for Year 4 is to succeed in making participants actively engage and work with the soundscape. This has to start with finding ways of stimulating them to be aware of and pay attention to the sound aspect from the beginning. We have observed (and confirmed) that sound is immersive, which strengthens the experience of presence. Paying attention to sound literally draws participants into the scene. The backside of being immersed is that this makes conscious intervention difficult. We have learned to live with high levels of sound pollution and are not used to changing sounds in our environment (apart from our own immediate living space). Also, reflection on sound is unfamiliar to most people, unless they have developed their perception of sound (e.g. by practicing or listening to music). There are different options that need further analysis. A simple one is to provide a short description of the sound files on the info screen; another one a sound tutorial at the beginning of each workshop. A more complex one is to freeze the visual part of a scene and to work on sound only for a while.

Other challenges are to do with the qualities of the soundscape. We will address questions, such as

- Is there a limit to sound density? Should we work more with single sounds than with complex atmospheric sounds? What can we learn from sound track production in filmmaking, where particular events or activities are highlighted through sound (e.g. hearing the footsteps approaching a fountain rather than the water)?
- Sound flows – how can we make them more ‘flowing’, achieve a variation of density?
- Panorama sounds – how can we make them more significant and also strengthen source identification?
- How to improve the mixing of sound so that a homogenous ‘sound carpet’ is produced? Here we plan to experiment with 3D sound.
- How can we improve the role of sound as bringing a temporal element into a static visual scene?
- How can users be supported in identifying the hearing position? As it is not possible or desirable to entirely remove sounds from the real environment, to what extent must we include knowledge of the types of sounds from the real environment within the experience?
- How can sound be used to represent underlying and often invisible elements from the real and virtual space? Should these be rooted in realism (as seems to be the case in computer games) or focus on abstraction? Also how much should such background elements intervene in scenes?
- Music appears to be a key changer of mood within traditional games, how can we learn from this and extend it to urban mixed realities?
- How can we improve the correlation of the visual scenes with the soundscape when using the sound token or sound scout?

3 Evaluating mixed reality experiences

3.1 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 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 & Koleva (1998). Milgram & Kishino describe MR as the combination of RE and VE "presented together within a single display." Benford et al. argues 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 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 questionnaire 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. However, it still relies too heavily on the concept of perceived non-mediation.

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.

3.2 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 augmented reality (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. This is the first study that operates a markerless solution on a mobile phone. 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 which takes place in the City of Cologne. It revolves around the idea of rescuing the city’s famous *Heinzelmenchen* (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 PC’s 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, 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 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 taped 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 content – and developed an “experimentation protocol” for the participatory sessions. The workshop sessions were video-recorded, and transcripts of significant episodes were produced. We, in addition, 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 what users experience is depending on their own purposeful activities and that the specific relationship of virtual and real in each case is key to this experience. However, the examples also differ in ways that help better understand the richness of Mixed Reality experience sand 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 lays not so much in use for navigation, but in its use as a collocated 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, blend 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.

3.2.1 *MapLens*: Mobile AR 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 Helsinki center itself where the game was located. Each team of test users was accompanied through-out by one researcher observing, taking notes, photographs and/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 markerless 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 (**Fehler! Verweisquelle konnte nicht gefunden werden.** 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 must be known. Because we do not modify the template image and do not require special fiducial markers to be applied, this is a so-called *natural feature tracking method*. 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 (**Fehler! Verweisquelle konnte nicht gefunden werden.** 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 games. 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 kinds 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 kilo 'salmon' in the museum—where teams needed to either contort to fit the whole team into the photo (including the held 'salmon')—or outwardly engage other teams or 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.

Each team was handed a kitbag which contained seven objects in all (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). 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 they organize some kind of system of use, as well as become adept at navigating, for example a paper fold-out clue book within the elemental environment which the game took place within; as an example one clue booklet was rescued the lake.

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.

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, "noticing" and 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, and augmented with real and overtly tangible. These tasks were designed to facilitate proximate bodily configuration, to "jolt" 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 **Fehler! Verweisquelle konnte nicht gefunden werden.** 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 others understand what the discussion is about without explicitly asking or negotiating. In **Fehler! Verweisquelle konnte nicht gefunden werden.** 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.

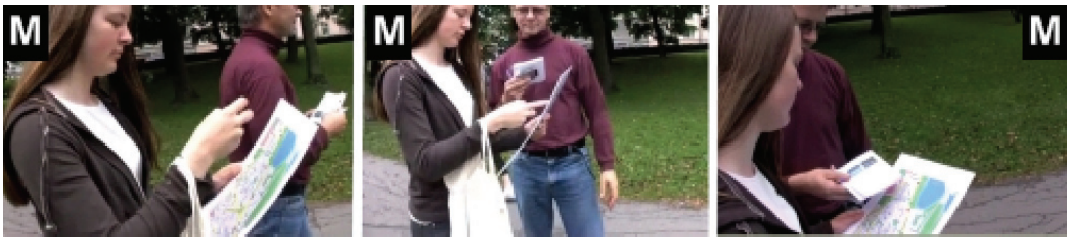


Figure 5 **The physical map as a common ground, established by showing with the lens (M) and pointing with finger, and the clue booklet.**

The groups using DigiMap were not able to share the map that fluently. In **Fehler! Verweisquelle konnte nicht gefunden werden.**, 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.

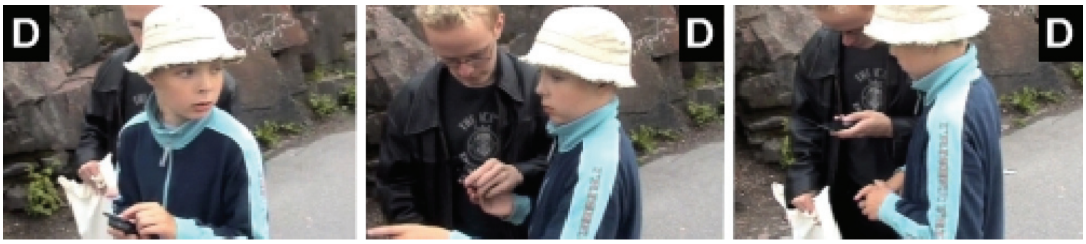


Figure 6 **DigiMap (D) Attempting to share the map as a common ground.**

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 **Fehler! Verweisquelle konnte nicht gefunden werden.** 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 **Fehler! Verweisquelle konnte nicht**

gefunden werden. 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 up 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 and 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 more-readily reached by means of participants being able to see and manipulate and demonstrate and then agree upon action. The teams in 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 also stabilised the map and re-looked through *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 stabilise 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 collocated mixed reality “surface & lens” view, in order to negotiate and anticipate the next best move within the game sequence and the real environment.

3.2.2 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 Heinzelmenchen 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 PC´s (UMPC´s) 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 lens is effectively a video stream which receives input from a camera mounted on the back of the UMPC, augmented 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 (from players to passersby), the nature of the blended 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 through a precise blend and finally to feeling more connected to the virtual elements. The remainder of the questionnaire focused on which elements within the experience users felt more part of (or present with) for example 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, for example looking 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

Playting 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 gaming elements. For example players would often stop and talk to discuss gaming 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 gaming elements.

Figure 9 Players collaborating during the game experience.

Non-player characters (e.g. the Heinzelmenchen) feature heavily within the game, and provide not only its underlying narrative but also form critical aspects of the challenges, which players must complete. As would be expected the sense of *Presence* experienced between players was higher than between users and NPC´s, in part due to the reality of such cartoon like characters and the interaction techniques involved. Interestingly people reported a moderate awareness of non-participants, but their degree of involvement in the game resulted in them paying little attention to them; this points to the game being the dominant factor rather than the real environment.

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 while playing, in particular see figure 10 when marriages were 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 gaming 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 city hall.

The players liked the strong connections between gaming elements and the city of Cologne, for example the challenges reflecting aspects of the city´s history. This interplay between real and virtual elements resulted in interesting feedback with respect to place and sense of *Presence*. Many of the challenges in particular within the past and current time periods appeared to map on to believable elements. For example some old buildings remain in Cologne thus the virtual objects appear at least to be within a valid contextual frame of reference. This contextual element played an important part in the player's perceptions and preferences within the game, indeed many reported how a break in this did one of two things. Firstly many people reported that they felt more present within the future time period, this was in part due to the available actions 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. Indeed it is from the outset unreal with features objects and activities feeling out of place. Therefore the surrounding environmental context is less relevant, and as such players do not expect reality either in terms of the actions available, graphics or sense of place. However such enthusiasm by many users for this location was counterbalanced by lack of a link between the real and virtual contexts by others. Thus the requirement for suspending disbelief would appear to be heavily dependent on user preferences (ranging from actions to gaming style) through to the relationship between real and virtual elements. This view was further reinforced by comments from some users who pointed out that the Heinzelmenchen felt unreal, however for many players it was this sense of unrealness which made the characters and hence the game engaging.

Layers, Borders and Switches

Moving between real, virtual and blended experiences was a common issue for the players. As noted in other literature sense of place is often shaped by the paths between locations as much as the actual locations themselves - and many players commented on the need for content between locations; the long walks between locations resulted in them feeling like they were constantly entering and leaving the game experience. By far the strongest indication of a change in experience would occur when players had to enter a Time portal, with players often changing posture and stance and running through the portal. The Time portal was regarded as one of the best elements of the game, and although no difference in feeling of temporal *Presence* were noted it was clear that the level of engagement and involvement would increase dramatically when players either searched for a portal or entered one. Other switches would occur when the players left the gaming experience, however they reported not feeling and 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 there was no real blended experience, this can partially be explained by aspects such as concentration which many players noted was focused more on the virtual or gaming elements. Technical aspects such as the cartoon nature of the graphics also had an impact. However it was also due to the sudden changes people would experience while walking through the city, for example the fact that streets often contained little if any content resulted in a situation where players would actively seek out gaming elements. This again points to the need to consider integrating paths and streets more thoroughly within such experiences. Furthermore it was noted that players felt a disconnection from reality by indicating that it was easier to interact with virtual than real elements. Therefore although the game was clearly linked to physical and historical aspects of the city this lack of integration with the real environment was considered a negative aspect.

3.2.3 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 centre 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, colour, 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 set-up is truly collaborative; it supports simultaneous interaction in building a scene, but also revisiting and reworking previous scenes in a cooperative way.

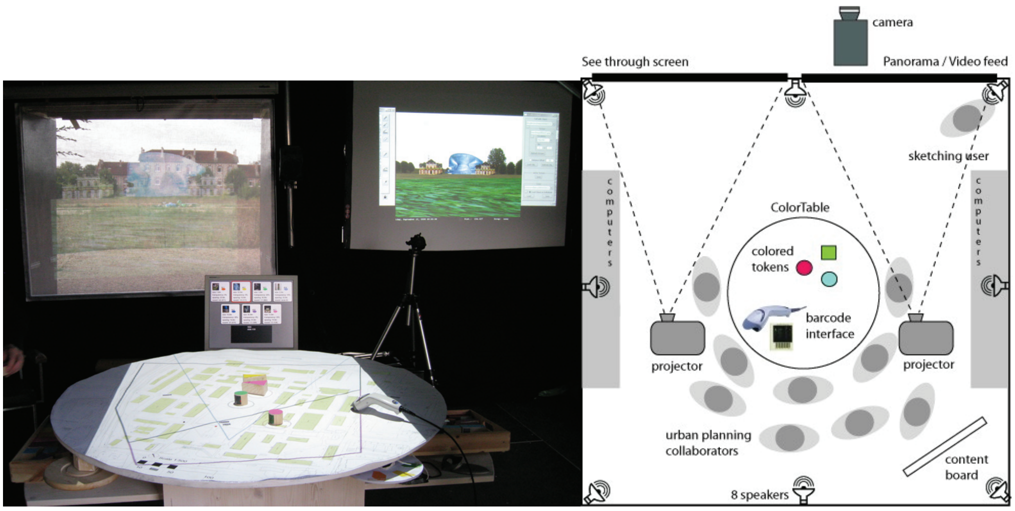


Figure 11 The technical setup inside the MR Tent is centred around the two projection walls and the projection table

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 different views onto them.

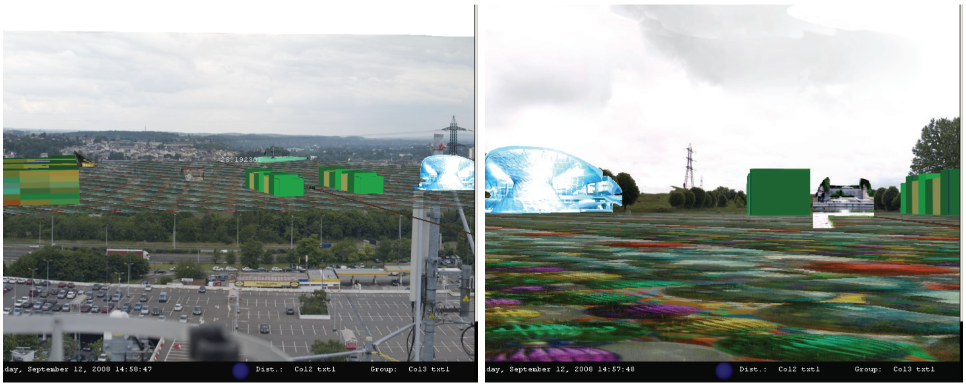


Figure 12 Looking at a scene from different viewpoints (panoramas)

This includes sound, which provides additional spatial information. Each visual content was associated with several sound files participants could chose from. 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.

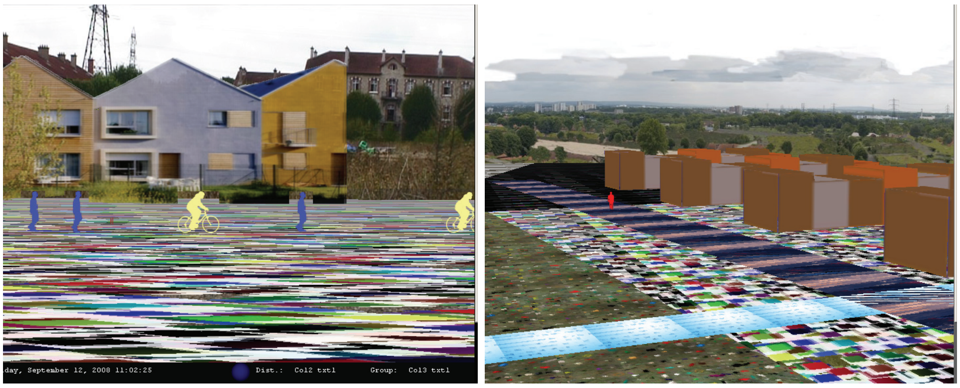


Figure 13 Adding roads and flows to a MR scene

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).

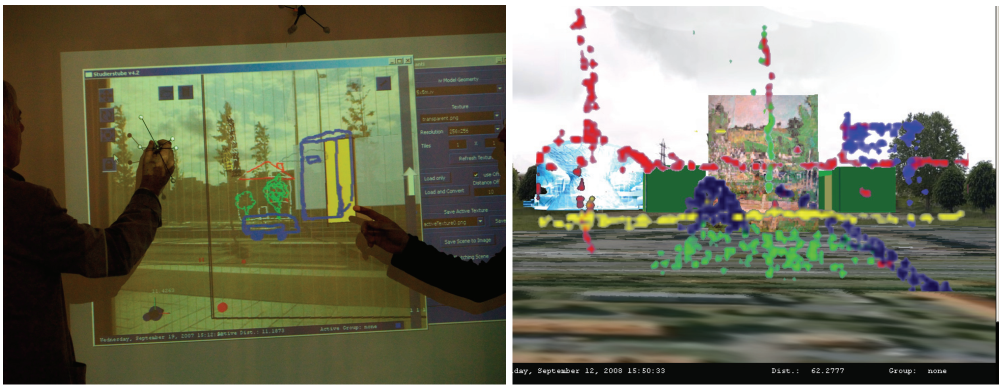


Figure 14 Sketching on a life video, creating a spatial collage (left) and annotating a scene (right)

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).

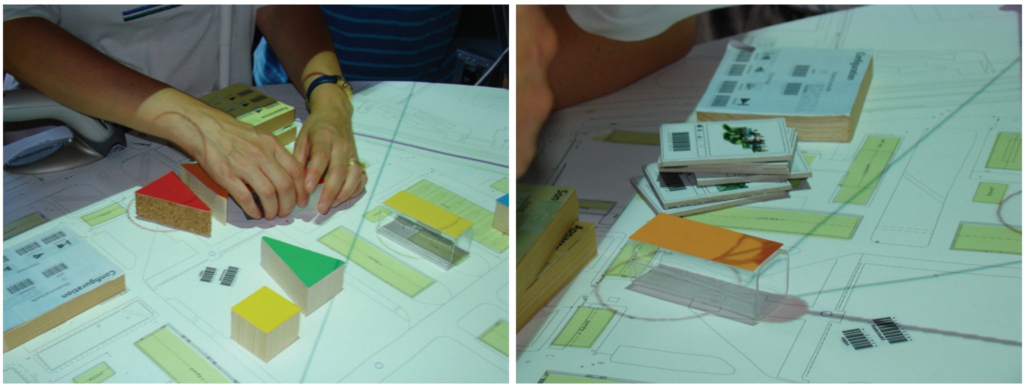


Figure 15 Tokens of different color, shape, and material (left); Content cards and barcode trays for changing object attributes and settings

Participants quickly learned to work with these material features. They liked the small cards representing content. At 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. All this points to being in a physical space and interacting with tangible objects as 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 awareness supporting cues. We already mentioned how changing hearing position 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.

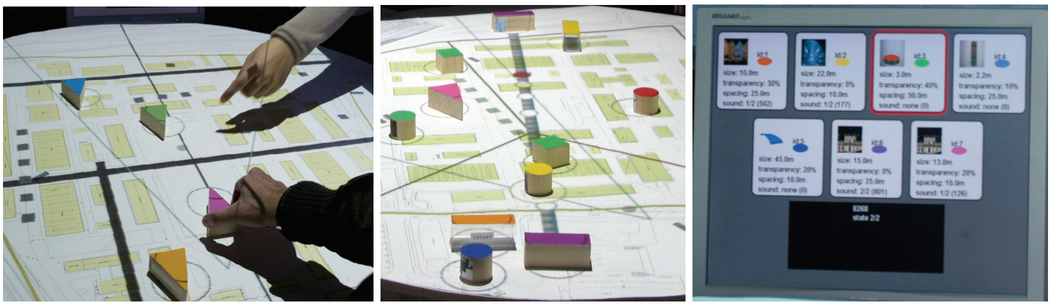


Figure 16 Participants performing a MR scene (left); Diagrammatic representation of a scene (middle); Info screen (below)

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.

3.3 Field experiences with sound

Sound is much less exploited than visual perception in everyday life and in urban studies. We started out with the assumption that working with sound is expected to have a profound influence on users' experience of mixed-reality scenes, hence also on presence:

- *Spatial orientation* - the sound of a space contains information about its materiality and is part of our presence in the space; sound sets the boundaries of a physical space – it can be locked to this space or spread over it;

  Content – as content sound can be used for defining themes, providing information; 'qualifying' particular places (e.g. through introducing sound marks); and emphasizing movement and flow, and so forth;

- *Ambience* – sound may convey a strong sense of place and culture, it may be used to evoke and express social, cultural and emotional aspects;
- *Awareness* – sound icons may be used in support of awareness of people and events.

3.3.1 Working with sound in the MR Tent

The guiding research questions in WP6 concerning sound were (and still are):

- When and how does a connection with a sound change/extend the meaning of a visual object?
- How can we enhance the telling of a story, a site, an event, or a project with sound?
- Is there a limit to the 'sound density' that users can process and what are the best strategies to deal with the complexity of sound content and sonic atmospheres?
- Can we put the sound at the same level as visual or verbal expression, another element for the negotiation? Which proportion does it take compared to image and word?

Our first extended experimentation with sound occurred during the workshop in Cergy-Pontoise, which is reported on extensively in D 6.3 as well as in D 3.4. The sound application

Within WP6 we have developed a sound application, which uses Ambisonics – Max/MSP as a framework (see D 4.3). The advantages of this platform are several:

- It provides a 360° spatial resolution (in comparison to other surround sound formats, which are focusing in one direction);

- The spatial resolution comes with a bigger ‘sweet spot’ than other surround sound formats;
- The number of speakers is almost unlimited (in the Cergy-Pontoise workshop we used 8 speakers);
- There is the possibility to arrange sound in 3D (in practice this means arranging the speakers on different levels of the MR-Tent).

Currently, sound is positioned spatially assuming an acoustic radius of 200m. As we work with several panoramas taken from different viewpoints (and heights), the hearing position changes with panorama view. One of the issues that came up in the workshop was how to better adapt the acoustic radius to the map.

There are different modes of changing the hearing position. First, when changing the panorama; second by activating the ‘sound scout’. The scout is part of a flow and visible as a red moving dot on the table, respectively as a red moving person in the panorama (Fig. 17).

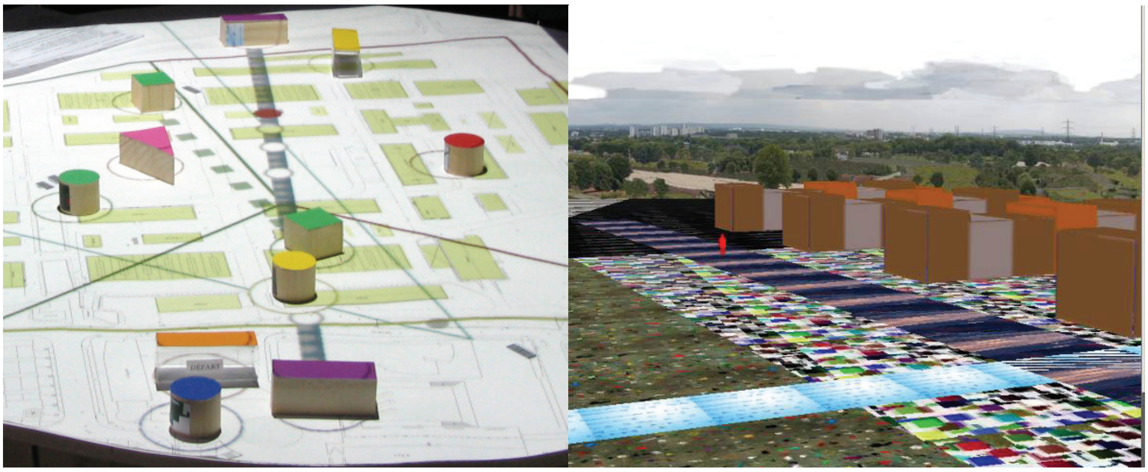


Figure 17 Sound scout a) as moving red dot (left); b) as moving red person (right)

A third option is to select a position with the red sound token, rotate direction, as well as move the token through the visual scene (Fig. 18).

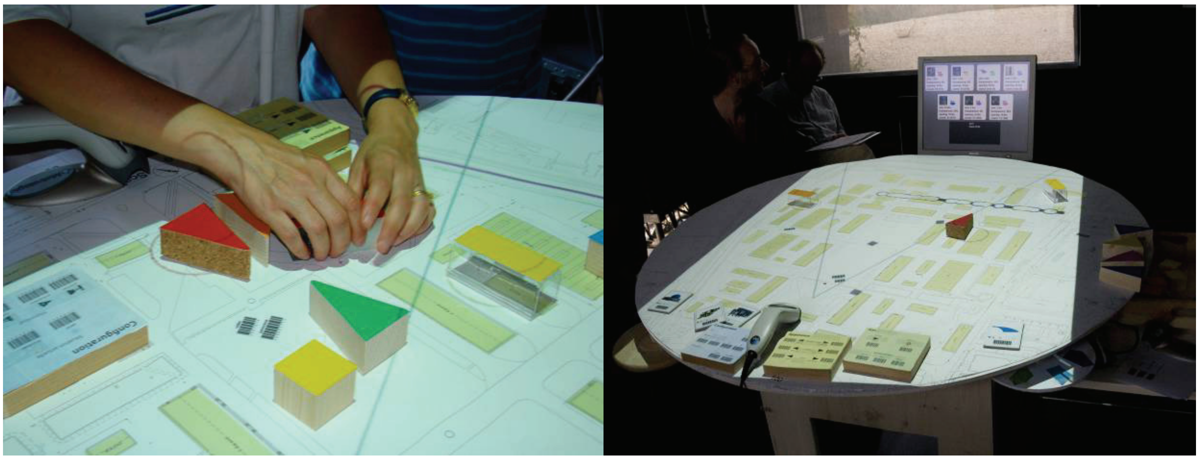


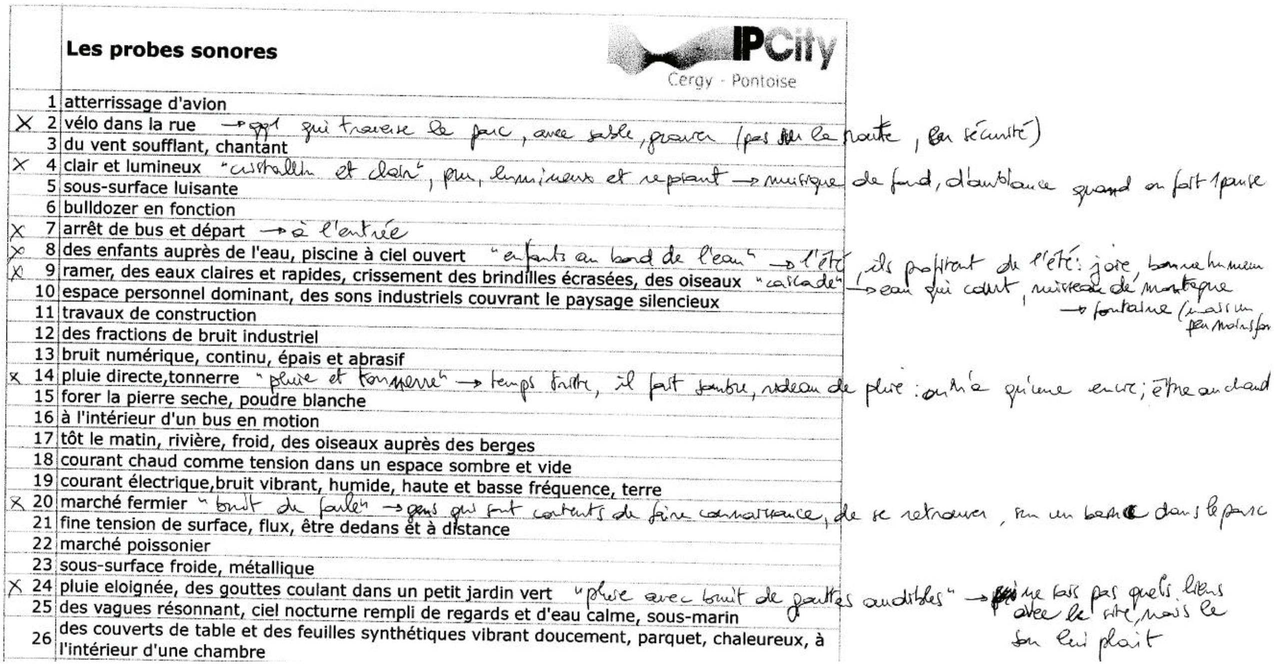
Figure 18 Non-seeing user using red sound token for orientation (left); Sound token close to a building (black dot) and pointing in direction of the highway (right)

Certain features, such as the default volume for selected sound files, and the fade in of sound (to make transitions smooth) have been automated; so has the regulation/filtering of each sound file, depending on its distance from the centre (hearing position).

Building the sound library and providing options for interacting with sound

We had originally planned to build a sound library that a) that allows classifying sounds according to their source, material origin, and physical determinants and b) also have users describe the personal and cultural meanings of sound.

We experimented with this approach when working with 'cultural probes' as part of preparing participants for the workshop in Cergy-Pontoise. Each participant received a CD with 99 sound files and a sheet describing each of those files. Their task was to first select sounds they would like to work with as part of their scenario and, secondly, to annotate the descriptions we had provided. In fact, as not all participants had done their 'homework', we listened to the sounds they were interested in together and they made their annotations, sometime contradicting the description, sometimes filling in their own associations in addition (Fig. 19). Interestingly, only one participant was interested in the artificial sound we provided, with the rest preferring natural sounds, which confirms findings from the literature (e.g. Yang and Kang 2005).



	Les probes sonores
1	atterrissage d'avion
2	vélo dans la rue
3	du vent soufflant, chantant
4	clair et lumineux
5	sous-surface luisante
6	bulldozer en fonction
7	arrêt de bus et départ
8	des enfants auprès de l'eau, piscine à ciel ouvert
9	ramer, des eaux claires et rapides, crissement des brindilles écrasées, des oiseaux
10	espace personnel dominant, des sons industriels couvrant le paysage silencieux
11	travaux de construction
12	des fractions de bruit industriel
13	bruit numérique, continu, épais et abrasif
14	pluie directe,tonnerre
15	forer la pierre seche, poudre blanche
16	à l'intérieur d'un bus en motion
17	tôt le matin, rivière, froid, des oiseaux auprès des berges
18	courant chaud comme tension dans un espace sombre et vide
19	courant électrique,bruit vibrant, humide, haute et basse fréquence, terre
20	marché fermier
21	fine tension de surface, flux, être dedans et à distance
22	marché poissonier
23	sous-surface froide, métallique
24	pluie eloignée, des gouttes coulant dans un petit jardin vert
25	des vagues résonnant, ciel nocturne rempli de regards et d'eau calme, sous-marin
26	des couverts de table et des feuilles synthétiques vibrant doucement, parquet, chaleureux, à l'intérieur d'une chambre

Figure 19 Annotations to the 'sound probes' made by a non-seeing participant

As interesting as this exercise was, it proved not to be practical, as it demands additional preparatory work from participants and also poses conceptual problems as to how much the sound descriptions should take account of the different perceptive details participants provided, some of which already reflected their vision of the scene they wanted to build.

The sound library as it stands now is a folder, in which each sound file has been given a 4-digit number followed by a caption. In the HMDB this number gets linked with visual content.

Instead of asking participants to select their own sound files to associate with each visual object – something that seemed unrealistic to expect, given the complexity of the whole MR-Tent set-up – we associated a selection of 1-5 sounds with each visual object in advance, with the option for users to either change the default sound or to disconnect the sound from the object. When selecting sound files our intention was not only to support the visual content but also to extend it and introduce elements that might provoke and stimulate.

As we worked with different panoramas from different viewpoints, we produced 4-channel recordings for each of them. The problem here was that the soundscapes we found on each of these points was not sufficiently 'specific' to make a real difference to the listener when switching between panoramas. We also associated sounds with each of the flows – highway (50 km), road for slow traffic (30 km), path for pedestrians and cyclists, and canal.

After the workshop sessions we asked participants to fill in a short questionnaire. Which included a few questions concerning sound. In total 12 participants filled in the questionnaire. Here is a brief description of the feedback we received:

- Almost all (10) participants thought of the fact that each visual object is already associated with one or several sound files and that the sound is to be heard immediately as efficient. One participant remarked: “This puts reflection close to reality and allows asking unusual questions”.
- Participants were divided as concerns the two options – a) to immediately disconnect the sound if it does not fit, or b) to search for another more appropriate sound. One participant would like to have a more diverse ‘database’. Another one commented that this ‘essential dimension’ (sound) should be preserved in any case.
- Five (out of 12) participants said that they would be interested in the possibility to bring their own sound selection; with one of them adding that this would require “some real research”. One comment was that “too much choice could be counterproductive”.
- Almost all participants prefer realistic sound or “sounds that evoke reality without being necessarily too close”. Only one participant indicated an interest in artificial sound and another one remarked that for her/him this did not make much difference.
- Responses to whether separate the construction of the visual scenario from the sound scenario were also divided, with seven participants answering ‘no’. One participant feels more comfortable with the visual elements of the scenario, another one would like to on principle pay separate attention to both dimensions, and a third one remarks that s/he in general would prefer “a rather soft sound background”.
- Concerning the interaction possibilities provided so far seven participants express satisfaction, two would like to see some refinement or improvement and one of them comments: “They are sufficient since there are already many variables to manipulate”. Another participant positively comments the possibility to move with the hearing position through a scene.

Experiencing the sound aspects of mixed-reality

Our general observation was that participants, with the exception of the non-seeing participant (Laurence), did not work explicitly with the sound. The sound, which at times seemed quite invasive to us, stays in the background of participants’ activities. It takes quite a while until somebody changes an annoying or disruptive sound. Some participants listened to all sound files connected to a visual object before selecting the most appropriate for them, but in general they were rather ‘tolerant’ as regards sound. On the other hand they got interested in the sound dimension when invited to explore the soundscape with the help of the sound scout or the sound token. Here is an excerpt from a scene observed in the afternoon session of the first workshop day.

Laurence started these explorations. We had observed already during the special ‘tutorial’ with her that she used sound systematically for building a scene. The first step always consisted in placing ‘her’ fountain, for which she had selected the sound that corresponded best to her imagination, for an acoustic orientation when rotating the panorama. It had taken her a while to understand that the tip of the token indicates the hearing direction (Figure 20 left). We discussed if the sound token is sufficiently ‘different’ to be easily recognized. We came to the conclusion that the material (cork) is important – participants referred several times to ‘celui en liège’ (the one made from cork). In this phase Laurence and L (a participant from the municipality) were cooperating in moving the sound token. M at one point suggests adding a flow close to the highway and listening to the sound scout.

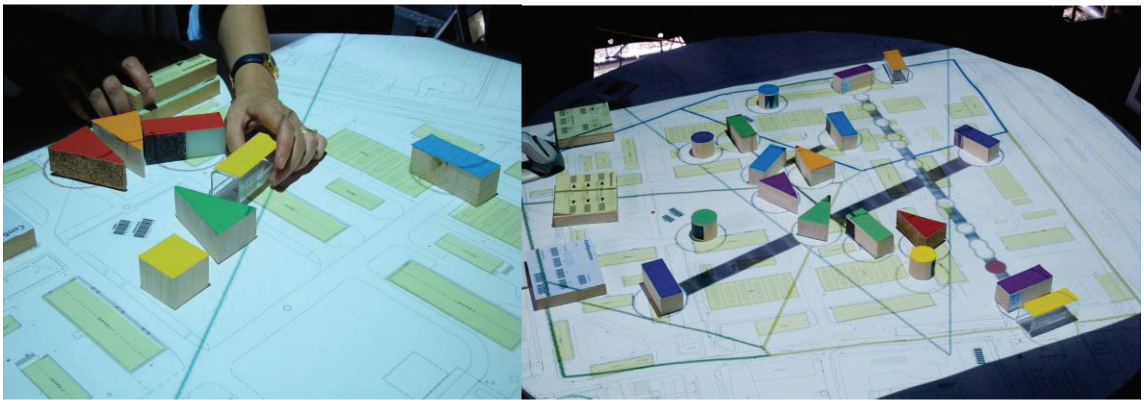


Figure 20 Non-seeing participant using sound associated with green token ('fountain' and sound token for orientation (left); A densely populated scene with both options to change hearing position

Changing the hearing positions in both ways 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 (Figure 20 right). 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'. This poses the more general question of how to avoid these kinds of disruptions that are to do with the fact that we work with sound loops that can get irritating if they are repeated too often.

We observed how working with sound reactivated 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. But it was difficult to bring the visual scene as represented in the panorama or video and the sound together, especially when switching view the hearing position is not clear – we hear something but cannot interpret it as connected to what we see. We have to work on how to make the hearing position visible in the panorama, use the life camera and scout, etc.

We have used sound for feedback. One example is the 'eraser', which, when action is completed, emits a rather satisfying sound. This was very well received. The sound emitted by the barcode reader proved to be crucial. The 'flow sound' provides spatial feedback, such as on the vicinity of objects to a road, and it provides feedback on the type of objects. However, we think that the flow sounds, although clear as regards the source- and space identification, are not yet 'flowing'.

3.3.2 Sound in TimeWarp

TimeWarp is an interactive time travel game, which lets players experience the City of Cologne in a range of different time periods, each time period consists of a series of challenges, which players must solve in order to complete the game. At present the game uses UMPC's (ultra mobile PC's) which act as a window into the mixed reality world, in essence as the players move around the display contains streamed video of the locale combined with augmented objects. There are two players one uses the UMPC as previously described the other uses one which contains a map and information display (see Figure 21). At the time of writing a visor-based version has also been implemented and is currently undergoing testing and the data from the first test consisting of the UMPCs is being analyzed.

Figure 21 Two scenes illustrating the collaborative nature of TimeWarp.

One of the main challenges within TimeWarp is how to use sound cues to not only inform the player(s) of their physical location within the City of Cologne (with respect to the game and real world) but also to use the cues to alter their sense of temporal presence as they move within and between different time periods (Roman, Middle, New Age and Future).

Ambience is a key part of the experience both from the perspective of the overall game scenario (time travel), specific locations and within specific time periods. This multi-layer approach was reflected within the game structure and *content*. For example an overall narrative is provided by an invisible non-player character. This character (main agent) sets the tone of the game and explains how time travel is now possible and required, in addition to providing guidance about how to interact with the various game elements. Furthermore ambience for specific time periods is achieved by using a combination of graphical augmentations, in combination with narratives, sounds and appropriate music. A series of non-player characters provide narratives for each challenge, explaining how the challenge relates to an aspect of the city's history. As a result the sound cues provide another method of linking game content and objectives to the underlying cityscape and invisible aspects such as history, famous characters and ambience.

Figure 22 A player gestures to their partner that the direction of the next location. He is doing this by listening to sounds while viewing location of objects within the augmented display device, he is holding the map display.

Sound is also used to shape *awareness* of events and people within TimeWarp. The narratives provide a method of not only explaining what to do but also to make users aware of the various characters, in particular when the character may not be in the immediate field of view of the player. Other sounds such as those from objects within the game are also audible from a distance or when outside the users field of views, they therefore also provide a method of *orientation* (Figure 22).

Audio cues are also used to indicate actions and events. The most obvious being when players change time periods after entering a time portal. Initially they hear a sound of the time portal warming up followed by a sound to indicate they have passed through the portal before hearing another sound which indicates where they have arrived (e.g. Roman or New Age). Furthermore as they users have a finite time to enter the portal, the combination of time and sounds serves not only to alert players to the portal but also to heighten their sense of urgency. This combined with the physical movement of the users creates a sense of flow between different time periods, thus clearly marking any change and making the transition itself interesting and fun. Audio cues are also used during tasks to indicate something has occurred, for example the sound of stone panels moving when users interact with the mosaic challenge.

Although the data has yet to be fully analysed it was clear the audio cues had a significant impact on user experience ranging from providing navigational support to raising questions about the effect of narratives and non-player characters on presence. For example over-use of the narratives by non-player characters was deemed distracting from the game, as they would often seem very long and not very useful. Furthermore such an over-use (in particular of the main agent) discouraged users from feeling involved in the location they were currently visiting, possibly having an effect on their sense of place and presence. Therefore it is clear that such narratives and characters should be used with caution. However the use of characters specific to each location was in general well received, as they were deemed entertaining and relevant. As has been noted by several authors, sense of place is often a combination of social elements, which includes those who inhabit or visit the location. Therefore when a character, which exists across all spaces within a game, seems to be overused it could be implied that this in turn conflicts with creating a unique sense of place for each game location. In a game such as TimeWarp sense of place is critical when it comes to shaping the players sense of temporal presence.

Audio formed a key part of the gaming experience for all users. This could be observed by watching them stop to hear information, etc. Therefore audio provides much more than simply a background channel for information, furthermore if they were unable to hear the narrative or sounds they would often ask if it was possible to listen again. It should be noted that the merging of sounds between the real and virtual elements remains a problem for such games, for example it is impossible and undesirable to remove all noises emanating from the real environment without having a seriously detrimental effect on player experience. Conversely it is not possible within TimeWarp to screen out or enhance certain background noises. However without the ability to do either of these, background noises will continue to have both positive and negative effects on the players of such games.

3.4 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:

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

3.4.1 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 and 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 imaginativeness 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* in 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.

3.4.2 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 set up facilitates turning these mediated cues of remote locations and people into resources of collocated collaboration. In *TimeWarp*, action takes place in an augmented environment, which is carried around by participants in the streets of Cologne. One of the key elements of the experience here is the feeling of connection between the virtual and real gaming elements and how care must be taken as much in the provision of augmented content as in the selection of the real locations where the game takes place - thus the “here and now” of reality becomes important. This was evident from the fact that users actively searched out virtual content and would often find themselves “outside” the blended gaming 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 set-up 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*, where over the game, many things may happen that 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 gaming event itself is predefined, but as soon as we take other players and non-players into account, there is a strong element of unpredictability.

3.4.3 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 and Wyeth 2005) and an Intrinsic Motivation Inventory (IMI) questionnaire (Deci and 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 be-tween *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 DigiMaps.

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.

4 Design guidelines

Having worked with now rather mature prototypes in Year 3 allows us for the first time seriously consider extracting 'design guidelines' for the diverse features of the IPCity technologies we build from the field trials we conducted. We arrange these design guidelines in five topics:

- What to observe when making interaction tangible;
- How to understand and design the different mixed reality set-ups from the experience point of view;
- How to work with 2D abstractions of 3D environments;
- How to design for mobility and mixed reality;
- How to enable and motivate users to work with the IPCity technologies.

As we provide ample descriptions and analyses of the use of IPCity technologies in our field trials, we here only provide a short summary of the design considerations resulting from these experiences.

4.1 Making interaction tangible

The Colortable is a 'classical' tangible user interface. In contrast to multi-touch screens (such as the CityWall) that 'enable fluidity of interaction and switching of roles between co-located users' (Hornecker et al. 2008), it clearly emphasize the hapticity provided by physical objects, building on haptic directness (meaning that there is no 'interface' other than the shape, texture, temperature, and moisture of the object itself (Hornecker and Buur (2006). What not only touching with one's fingertips but grasping brings is maybe best captured by the notion of 'engaging objects', which Verbeek and Kockelkoren (1998) define as the capacity of objects to absorb people's attention, thereby increasing their engagement with each other and the world. The haptic interface of the ColorTable consists of physical table with physical map with physical features (annotated for a blind person to work with), tokens, command tablets, content cards and whiteboard, as well as barcode reader.

Our observations can be summed up as follows:

Work with the haptic qualities of different materials: The ColorTable tokens are made from common materials (wood, cork, Plexiglas, foam) and shapes. Participants 'discover' these materials and shapes in a new context and easily learn how to associate them with the different functionalities the ColorTable offers. As the set of tokens needs to be sufficiently complex in order to be able to perform complex tasks, the design of the tokens, namely the use of materials, colours, and shapes needs to be carefully thought out.

Work with familiar interaction modes from everyday life: The interaction modes we chose for the ColorTable are simple and intuitive: place/remove, rotate, move across the table (on a physical map), place two (square) tokens for creating a line of objects, place two (rectangular) tokens for setting a path, place 'eraser token' on representation of object to be erased.

Enable simultaneous interaction: The ColorTable offers space for several (up to 7-8) participants to assemble around the table. Simultaneous interaction consists in being able to place two tokens at the same time, to move a token while another person is placing a new one, to select a content card while another person is selecting colour and token, but also to gesture, points, etc. while others are interacting with the tokens. In this way a rich pattern of interactions can develop.

Provide immediate feedback: In the ColorTable several visual, haptic, and acoustic feedback mechanisms have been implemented. For example, when selecting a colour to work with, the representation of this colour is highlighted on the info screen; when registering an object and associating it with the colour, information related to this object appears on the info screen.

When placing a token on the table, a (projected) circle indicates whether the camera has registered the object; also the sound associated with this object can be heard. Footprints on the physical map give an overview of all interventions.

Distinguish between tool and equipment: The spatial set-up of tools and collaboration space matters and there needs to be a clear workspace design. For example, the tools needed to run the application should be located at the periphery so as not to impede collaboration. Relevant parameters are:

- Size and height of the table – the table needs to be big enough not only to enable group collaboration but also to make it 'unavoidable' since not everything is within reach of a single user;
- Align the table with the projection screen so as to support the 'mixing of realities';
- Design workspace for all interaction tools to be within reach and 'have their place' but also allow for flexibility (e.g. participants can place the content cards on the edge of the table).

4.2 An experience point of view on different MR set ups

4.2.1 Mixed reality in the MR-Tent

Specific to the MR Tent is the mixing of many elements – views onto an urban planning site, a diversity of materials and forms of content – in one application. Participants engage with maps, projections, content cards, they sketch directly on a scene, switch between different panoramas, real video view, see-through, and Google Earth map. Hence, they work with different types of representations of the urban site:

- Real (being on the site, stepping out of the Tent);
- Mediated (static photographic view, camera produced real video stream, Google Earth map);
- Abstracted (physical map on the table; projected footprints of interventions on the map).

From an experience point of view these different representations provide different resources for understanding and experiencing and they pose a variety of design challenges.

Real site: The real site allows an appreciation of the space and an experience of its 'aura', which is multi-sensorial. These affordances are important to consider when setting up the MR-Tent. This includes questions, such as: the main axis, in which to view the site (which is also the view for the see-through); immersion or shelter from the 'natural' sound (to be considered with respect to the sound application); 'liveliness' of the site – how to capture it.

See-through: IT provides a 'framed' (by a window), hence limited view onto the site. Although it raises well-known problems concerning parallax and focus, it provides a unique augmented view onto the real scene. The main problem with the see-through installation is how to get an understanding of the space. The difficulty is to do with the lack of depth information, with the fact that users have to focus and to construct their own image, merging real and virtual into one. Moreover, the virtual objects don't adapt (their transparency, brightness, etc.) to changing light conditions outside nor to their distance from the viewer – this creates a lack of congruency between virtual and real. On the other hand, the see-through installation comes closest to the idea of making the site of an urban project present. The presence of the real site, even if blurred by the finely meshed projection screen, adds an important dimension to participants' understanding of project and site. Design challenges connected with the see-through installation are the screen material as well as protection from direct sun light and ambient light.

Real video stream: It provides a particular view onto the real site (as seen through a video camera), together with the possibility of zooming and moving the direction of the camera. It also captures important reality elements, such as, leaves moving in the wind, people or cars passing by. A limitation is the lack of depth information.

Panorama: The 360° photographic panorama offers several advantages: a panorama can be produce from different viewpoints at different times of the day; viewers can rotate (a wheel fixed to the table), hence 'move around' in the panorama, as well as zoom in and out. The depth map creates a sense of space and supports the spatial placing (and appearance) of objects. There is the possibility to prepare and edit a panorama, e.g. remove buildings that will be replaced. Preparing a panorama entails several challenges, including choice of viewpoint, editing, constructing depth information.

Google Earth map: It is more 'realistic' than a physical map, as it is based on a photographic view; at the same time it does not provide the same overview quality.

Physical map: It provides a highly abstracted and coded representation of a site and contains more details than, for example, a projected map. Maps can be printed out in different scales and levels of detail. In the MR-tent we provide projected information of participants' interventions on top of the physical map.

The strength of the MR-Tent lies in the combination of real site and physical map with other perspectives on reality.

4.3 Working with 2D abstractions of 3D environments and objects

The problem of presentation of tangible physical elements and environments in 2D representational space is addressed through various methods in many of the showcases.

4.3.1 Working with 2D abstractions in the MR-Tent

In the MR-Tent we work with maps and other representations of a 3D environment but also with 2D representations of 3D objects (billboards) and (spatial) sound. Several design issues stand out:

Depth information: There is always the need for two aligned representations to understand depth information. For example, if participants place an object they have associated with a particular content on the physical map, they need the info screen for understanding the height of the object, its offset from the ground, as well as the spacing (in case of a row of objects). Moreover, depth information varies amongst different representations: on the physical map (furnished with tokens or footprints), the height of objects is missing; the video projection contains perspective only; as concerns the panorama view, the perspective and, based on depth information, the occlusions with real objects have to be calculated correctly. In the Grand Palais exhibition we experimented with a thin line connected with an object to visualize the offset from the ground. Shadows (created by an object) are more difficult to understand unless calculated directly. Our argument here is that working in a de facto 2.5 D environment requires designing for the missing 3D dimension being represented in ways that facilitate users' spatial understanding.

2D representations of 3D objects: 3D objects are important elements of the constructed mixed reality scenes. Some content, such as for example buildings, has to be 3D so as to maintain the sense of volume and orientation within space. On the other hand, 2D objects are needed for conveying 'telling detail' and creating ambience. They support the construction of narrative on top of an architectural intervention. The 2D content we provided is based on photographic images, sketches, architectural renderings, and paintings. To lend them a spatial dimension these images had to be cut out and 'abstracted' so that they no longer appear as flat canvasses. As we refrain from applying true 3D techniques such as a virtual model of the site, positioning objects in the panorama is supported by occlusion based on a depth image. We found that the 2D images aligned themselves well with the panorama. Interestingly, the real size of both, 2D and 3D objects, something the urban planners had deemed crucial in an urban composition, did not matter so much to non-expert participants.

They often made an object bigger to emphasize an intervention, and they arranged the object optically in relation with other objects and the panorama view, without necessarily focusing on the real size.

Sound: The main design question here is how to make use of the potential to extend the (spatially limited) projection of a visual scene into the acoustic space, sound offers. Critical issues (to be explored in year 4) concern: sound density (should we work more with single sounds than with complex atmospheric sounds); source identification; identification of hearing position; improving the correlation of the visual scenes with the soundscape.

4.3.2 TimeWarp: Combining 2D and 3D Content in MR Worlds

The TimeWarp experience consists of 2D and 3D elements, with 2D maps and content on UMPC´s being used to provide information about the game space. However the core gaming elements e.g. non-player characters, objects and time portals were all 3D augmentations.

2D maps as a navigation aid: navigation within towns and cities can take a variety of forms, from exploring without any specific goal in mind, to semi-goal directed exploration through to wayfinding (seeking out specific locations). Furthermore people adopt a variety of strategies with the types of navigational cues varying based on a range of factors such individual differences through to using landmarks and main roads as methods for finding their way around. Within TimeWarp the map is a blend of real city elements, and additional virtual content for example indicating time portals or areas of interest. Although only anecdotal evidence at this stage can be provided the navigational strategy of players was focussed very heavily upon locating game related content then searching for that specific location; with real world locative cues (e.g. Cologne Cathedral) being used to identify where such content was placed. Therefore within the context of time warp navigation was predominantly based around wayfinding.

3D soundscapes: sound is used within TimeWarp to alert people to objects, locations, options and activities. All sounds are located with respect to real world co-ordinates and are activated when the user is within a pre-defined range. Such an approach not only alerts to players to such content, but also provides navigational cues as they walk around the city.

A Magic Lens into augmented 3D space: as users look through the UMPC they see a camera stream which contains the real location, to this is added one or more 3D augmented objects. The position of the objects is related to the users location in the physical world, hence the size of the object reflects the users GPS co-ordinates. Therefore as they move towards or away from objects the size of the objects will change. This allows for a true blended experience between real and virtual elements.

4.3.3 MapLens: augmenting physical maps with virtual information

With MapLens we work with a physical map and a digital map that is augmented with information. Our players then navigate by using clues on the digital map. Several design Issues stand out:

Reading physical environments as 2D maps: Maps are a learnt navigational device predominant within western society (Kahn, 1997). We look to translate a living breathing environment with static and dynamic objects. For example we present moving cars, bikes, animals and people, or statues, parks, architecture, city squares, and the smells, noises etc of an urban environment as a flatland representation where one sees only streets as lines and names, and green areas by colour only. The richness of the environment is simplified and on our MapLens trial we had 2 eleven-year old girls who used a map for navigating their first time. They viewed a flatland representation (Tufte, 1994) which they needed to interpret and then re-read back to understand where it was they were located within the environment. The addition of landmark pointers would be a useful addition to the maps.

Adding Zoom and a Box Zoom Feature: We have added a red box zoom feature that freezes the screen and allows users to navigate easily between the icon representations that augment the digital map. This allows users to easily ‘catch’ the information that one area of the map holds. The icons were semi-transparent to avoid overlaying map areas where information such as street names needed to be read.

Location, navigation: Locating oneself on the map and translating that position onto the physical world with the correct orientation is a familiar problem with map reading. We will add a “you are here” button in our further iterations, and are considering how to approach the orientation problem from several perspectives.

Zoomed in map: The digital and physical map were zoomed in, to cover a smaller area of Helsinki and as such were much easier to read than maps in our earlier trials, where users had difficulties with viewing a large area on a small screen.

Digital versus Tangible Maps: We found that locating oneself in the environment on a small digital representation was more difficult for the groups than locating oneself on a larger physical map. For younger players more habituated to mobile phone use, and with better eyesight this was not such an issue. However, zoom and scroll beyond one or two clicks causes difficulties for many users. These are common mobile phone interface considerations when designing for a small screen.

Crowding of the Digital Environment: Adding more landmarks and images to the digital environment exacerbates legibility as the screen space becomes easily crowded. We introduced layers of information that can be turned on and off with the aim of keeping the viewing space uncluttered.

Adding Landmarks as orientation: We will trial adding a layer of landmarks (buildings, statues, trees etc) on a layer that can be turned on and off to see if this assists orientation on the map in our further trials.

4.3.4 CityWall: manipulating 3D objects on a 2D multi-touch display.

With CityWall we moved from its original 2D representation to 3D representational system to enable multiple content, multiple timelines and a more immersive environment.

Body Meets 2D screen: Gesture—a bodily action—meets with a flat 2D screen. The interaction is somewhat flattened and limited to operating along the breadth of one surface plane. We added 3D objects into the surface of this plane, extending and re-designing the gestural language—using by now recognised gestures and adding some of our own—in order that people learn the language to manipulate these objects and interact with the ‘information’.

Accessing multiple content at the same time: With the original CityWall 2D interface the whole display was treated as a single interaction space, meaning that one user’s actions would sometimes have effects on the actions of another. For example, resizing an image to a very large size might overlap another user’s focus of interaction, and moving the single timeline means disruptions for others because all the photos in the content then start moving left or right accordingly. As a response, we designed a series of worlds that could be navigated and interacted with at the same. The worlds housed different themes, for example multitouch videos, MRTent world, Paris and Grand Palais world, Helsinki Flickr World, SMS, MMS and email world, so users could explore different world synchronously without disrupting other co-located players.

3D Objects have their own timelines: Most of the worlds are designed with their own timelines that users can spin back and forward through accessing content at different days, weeks, months, years. We designed a spin interface and an axes interface to test which one was more intuitive or helpful for our users.

3D navigation for content structure and system. In order to access the information, participants also need to learn how to navigate the system—as well as being able to learn through interacting with the content itself. Here we aimed to design a structured learning process, with help animations to assist where needed. Walk up and use interfaces support novice use and most users do not return to re-engage. We recognised a more contemplative interaction with the content on the screen with users 'working out' how it worked. Three-dimensional interfaces are largely recognised as being more immersive and supporting 'as if real', or 'being there' experiences; concepts found within presence research.

4.4 Mobility

When developing MR applications for mobile devices, and in general any kind of mobile application, it is necessary to cope with unique properties of mobile devices such as their form factor, their limited display and keypad. Work in the recent field of Mobile Information Visualization (Chittaro, 2006) suggests that several interaction and visualization approaches should be reformulated rather than simply ported from other fields to the handheld platforms.

Interacting with information on mobile devices cannot rely on well-established guidelines such as those existing for WIMP interfaces. The problem is further emphasized in MR applications where interaction is often extended from the 2D space of the screen to the 3D space of the real environment. The interaction space of 3D mobile user interfaces is still largely unexplored (Ballagas, 2008). Given the limited but also peculiar input peripherals of handheld devices, solutions can be tailored on the specific hardware. In ZoneZoom (Robbins, 2004) the information is divided in 9 segments aligned in a grid, miming the layout of buttons on the numeric keypad: Each of the segments is zoomed in by pressing the corresponding button on the phone. An alternative solution, and a recent trend in research on interaction for mobile devices, is to use the whole device as an embodied input peripheral, as in the work of Rohs (2007). Hachet (2005) and – within the scope of IPCity – the MapLens project exploit physical props and the users' proprioception to perform interaction by movements of the dominant hand, holding the phone, with respect to the non-dominant one holding the prop.

Mobile phones, as compared to dedicated MR devices (e.g., a UMPC specifically set up for a certain application), have the advantage and the disadvantage of being personal devices. The pervasiveness of the device in everyday's life of users can give an advantage: The phone is not seen as something unconventional and obtrusive but rather as a cool gadget, thus allowing transparently merging phones with the normal life of users when conducting longitudinal user studies, as done in (Jacucci, 2005). On the other side when developing an application that will run on the mobile phone of a user it is very important to make sure that such application will not disrupt the normal functionalities of the phone itself. E.g., it is important to consider how the application behaves if the user receives a phone call. In one of our previous project, a prototype we implemented did not disable correctly the phone camera when the application was sent to background: This issue caused a quick drain of the device's battery, with a lifetime of just a few hours, provoking annoyance of users.

The small form factor of mobile devices can constitute an inherent limitation to multi-user interaction on a single device. As experienced in the MapLens project, users find it difficult to cooperate on a single device, issue that can be leveraged by introducing a tangible shared prop (e.g., the physical map in MapLens) that users can exploit to mediate the interaction. In case of collaborative activities, providing each user with an own small and unobtrusive device is an alternative solution that can still preserve the social interaction aspect (Mulloni, 2008). This solution can be particularly tailored for the case of MR systems running on mobile phones, since each user might already own one device.

Finally, the interaction paradigm in mobility is often on-demand and users cannot be expected to look at their devices continuously. The information can be retrieved in both *push* mode (users are sent some information) and *pull* mode (the users themselves ask the device for some information). We noticed this in MapLens (see section 2.3.3 – Place-making) where devices were mostly used when users stopped to pull some information they needed, before proceeding with their physical navigation task in the real world. In TimeWarp information was both pushed to users (e.g. audio to inform about proximity of a game location) and pulled by users at each specific game location.

4.5 Enabling the user experience

4.5.1 Preparing for and engaging in collaboration in the MR-Tent

In particular the experience of the Cergy-Pontoise workshop confirmed our conviction that extensive preparations, not only for the lay participants but also for the planning experts, are a necessity. The aim is to have participants arrive with their knowledge of the site, their own vision of the kind of interventions they would like to explore, and that they find the content they need for entering the debate of an urban project. We formulate six principles for how to motivate participants and facilitate their engagement:

Combine familiarity and excitement: Many aspects of the MR-Tent are based on familiarity: the meeting place of a tent, the experience of a round table, physical maps, the simple objects made from well-known material we provide, as well as interaction modes participants know from everyday life. Participants could even recognize a part of the content as 'theirs'. At the same time, we use these elements in a somewhat unusual way. Participants are invited to not just talk about their vision but to enact it; in fact the action temporarily moves to the foreground and the talking to the background. They engage in a mixing of realities, which is new to them: composing a scene on the physical map with physical objects while feedback in the form of footprints is projected on the table; seeing the same scene presented in different perspectives – panoramas taken from different viewpoints, real video stream, or see-through; being exposed to a soundscape that changes with each object they place and with the hearing position.

Design for openness and freedom of expression: In order to be able to open a dialogue between inside (urban planning specialists) and outside (stakeholder) perspectives we need to design for openness. In the case of the MR-Tent this meant that we for example did not implement any 'rules' or 'constraints' beyond the technical limitations of the tools, and with this made an explicit step away from simulation tools. This moved decisions away from the technology into the responsibility of the participants. The floor was theirs with regard to the actions they wanted to set and the level of complexity they wanted to address.

Help participants develop their own vision of the urban project: The main aim of the cultural probes method (Gaver et al. 1999) and interviews is to stimulate participants' imagination and help them prepare for the urban planning workshop. The probes need to be appropriate to the urban site and issues at stake. They also should motivate users to bring their own content and/or articulate topics and concerns for which to prepare content.

Content preparation: Preparing content (3D, 2D, sound) requires special expertise, including artistic skills. The main challenge here is to select and edit content that allows represent urban issues in ways professionals but also lay people can relate to.

Help participants familiarize themselves with the tools: Providing a tutorial for participants in which they learn how to handle the tools is crucial to their engagement with the site, their co-participants, and the urban issues at stake.

Help participants engage with the reality of the site: This is the basic idea of bringing mixed reality technologies outdoors, with the MR-Tent as a shelter and meeting place. Challenges here are: ensuring the mobility of the MR-Tent was a formidable task in itself; the changing and sometimes adverse light and weather conditions – direct sunlight, wind, humidity – creates numerous practical problems to be taken care of; also, finding the right place on a site for creating augmented views relevant to the planning process needs to be considered.

4.5.2 Scaffolding sustained engagement conditions at CityWall

Help animations give simple instructions: to enable learning the interaction gestures. These animations float around the screen and are also housed in a 'help-world'.

Learning how to use: We designed a 3D navigation for content structure and system. In order to access the information, participants also need to learn how to navigate the system—as well as being able to learn through interacting with the content itself. Much learning is done by testing and discovering, as well as watching others. With continuing use participants skill level increases. Their interaction can be scaffolded so that small but incremental learning steps are supported (with floating help animations adding more information).

Topical issues relevant to participants: The Helsinki content is designed to deal with local urban issues of environmental awareness relevant to the regular community who pass by CityWall. The navigational interface mimics the interlinked global nature of these issues. The information—in the form of text, images and videos from Finnish Environment Institute SYKE shows examples of the benefits and nuisances of urban nature. At the time of the Helsinki opening (8th October, 2008), the Wall presents images, videos, descriptions and discussions on how nature in Helsinki benefits and disturbs dwellers. The exhibition is designed to evoke discussion e.g. on what nuisances people should just adapt themselves to, what nuisances they should fight or control, how different nuisances can be prevented and how the benefits of nature can be improved. We aim to find out what benefits and uses people contribute and how an interaction-based multitouch input display works as a type of community chat tool to enable discussion on topical environmental issues.

Multiple Input formats for our participants: By enabling SMS, MMS, email, tagging images on Flickr, allowing comments on Flickr (the comments are displayed on the hind-side of the commented-upon images), we are extending the ways in which the citizens can input into issues that affect them—an extended version of *Letters to the Editor*—extending the bi-directional means of input. We have seen already much discussion on for example, a local issue around increase in rabbit population, in the local broadsheets, and have added examples of these to the wall to invigorate discussion. In local newspapers immediacy is restricted and we designed this electronic system to allow for more ad-hoc and spontaneous inputs.

4.6 Blending Real and Unreal Worlds: TimeWarp

An extensive list of high level design guidelines relating to TimeWarp was published in Herbst et. al. 2008 (a list is at the end of this section). The items below relate to new elements from the study of the second prototype.

Provide support for shared and negotiated understanding: one core element of the prototype two experience was allowing people to discuss the gaming elements. This improved their feelings towards the game as well as participation in game elements, and their ability to navigate.

Understand spatial context: experiences by default take place in real world spaces, therefore there is a need to careful consider the impact a game will have on reality. As noted within the study weddings took place at one location, this frequently caused problems for the players as they did not wish to disrupt the wedding party.

Consider the frame of reference: as time travel is currently not possible, and seeing the future is also not possible it is important to consider when and how to employ realism. For example some users felt a stronger appreciation for elements which were clearly futuristic (both graphics and sound), than those which attempted to be realistic. This raises important questions about how and when to employ realism as any attempt to do so is heavily shaped by the gaming and location context.

From our earlier prototype the following guidelines were devised: Attention allocation, simplify the interaction scheme, user safety, design appropriate, understand the locale, interaction with others, seamful design and provide a continuous experience.

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