Integrated Project on Interaction and Presence in Urban Environments

FP6-2004-IST-4-27571

ipcity.eu

D3.5 Consolidated approach to studying presence and interaction

Doc-Id:	**D 3.5**
Version:	**1.0**
Author(s):	**Ina Wagner, Maria Basile, Lisa Ehrenstrasser, Valerie Maquil, Rod McCall, Ann Morrison, Dieter Schmalstieg, Zsolt Szalavári, Jean-Jacques Terrin, Burcu Ozdirlik**
Date:	**2010-03-10**
Status:	**Final**
Availability:	**Public**

Table of Content

Abstract

This deliverable starts out with the three overall research questions addressed by IPCity and gives an Overview of the IPCity approach to studying presence, Mixed Reality, and tangible as well as embodied interaction, highlighting the main issues for technologies and design (Section 1).

Section 2 provides a detailed description of the common set of methods applied in all four showcases, giving an overview of evaluation formats (field trials, participatory workshops) and the collected data. It explains the methods of analysis, starting with the breakdown of participants' interactions with IPCity technologies into activity categories and lists the observational units for a quantitative analysis of the video analysis. Some space is dedicated to the explanation of multimodal analysis, a rather novel approach to understanding how participants use different semiotic resources – talk, gestures, object manipulations, use of space and body configurations – and to the visual analysis of MR scenes. The methods part provides information about the use of questionnaires and structured interviews in IPCity and details the notion of 'method triangulation'.

Section 3 presents the evaluation of showcases from an urbanist perspective, using 'understand space', 'relate to space', 'manipulate space', and 'augment space with content' as main categories of analysis.

Section 4 describes the key findings from all showcases and their implications for design, illustrating each of these findings by small examples and pictures.

Section 5 synthesizes these findings and spells out design guidelines – the common conclusions to be drawn from experiences with a diversity of outdoor urban Mixed Reality applications.

Intended Audience

This document is intended to all partners of the project, the EC, and to the reviewers for the fourth project's phase.

1 IPCity approach to studying presence and interaction in MR

1.1 Common research questions

In the final round of evaluation the four showcases focused on three overall research questions:

1. Which **design features** of Outdoor Urban Mixed Reality are essential in supporting participants in engaging in novel ways with the city?
2. What is the potential of the concept of **presence** in analyzing participant experience?
3. What do we learn from this analysis for the design of MR applications, interfaces, as well as for how to enable participant experience?

These research questions were detailed for each of the showcases in order to take account of its specific constellation of technologies and scenarios of use while ensuring the common focus (see showcase deliverables).

1.2 Presence in IPCity

> "(presence is the) the perceptual illusion of non-mediation"(Lombard and Ditton, 1997)

Traditional presence research draws heavily upon the technical and psychological aspects of interacting with virtual environments; where the aim is to make people feel present in a new or alternative reality without any awareness of the mediating technology (see quote). However while this basic approach is relevant it is important to note that both virtual and mixed reality[1] have one fundamental difference: namely that virtual environments intend primarily to replace reality by providing artificial sensory experiences (e.g. synthetic audio in place of real sounds) while in contrast mixed realities aim to co-construct a "new reality" where individuals feel in some form of blended experience. While the former draws heavily on the idea of immersion via sensorial substitution, the latter seeks to enhance real environments and importantly awareness of the mediating technology can often be a desirable part of the experience. Furthermore, urban mixed reality and virtual environment research come from and require different experimental traditions. For example, virtual environment research draw heavily on laboratory studies designed to explore specific psychological and/or physical behaviours. These laboratory traditions while appropriate within controlled environments are not so readily usable or relevant to mixed realities, especially those taking place within uncontrollable urban spaces.

Presence in an Urban Context

There is no universally agreed definition of presence[2], however researchers broadly agree that it is a complex multidimensional experience consisting of a combination of sensory data and cognitive processes (Ijsselsteijn and Riva, 2003). As a starting point however Floridi (2007) highlights two useful conceptualisations relating to tele-presence:

- Forward presence: when a person is taken to a remote location. e.g. to control a bomb disposal robot
- Backward presence: where an experience is brought to the user, e.g. a location in Second Life.

While these two overarching forms of presence provide a useful starting point, O'Neil (2005) notes that to date most experiences provide only one of them, when the objective should be to support both. This is a problem which is particularly true within mixed reality environments

1 We define mixed reality here as being either augmented virtuality or augmented reality

2 For a more thorough review of presence definitions see deliverable 3.3

that combine tangible interfaces with virtual representations, and where reality may be seen as both existing simultaneously in real (fully interactive) and virtual form. Further to the two conceptualisations of presence, the research community often also highlights three types (outlined below), which can be thought of as the objectives of any experience. For example a system may attempt to make people feel as if they are visiting an ancient building, thus altering their sense of spatial presence while at the same time attempting to make them feel present with other people (social) from the given time period (temporal). Each form of presence relies upon the altering the users perception of the space in such a way that they feel as if one or more of these elements have changed.

- Spatial: feeling of being somewhere else as opposed to the reality in which they are situated;
- Social: feeling of being with others;
- Temporal: feeling that the time frame has been altered in some way, for example going back or forward in time.

While the above categories provide a starting point or set of objectives, they mask what elements are required in order to engender such experiences, or the any underlying theoretical position; both of which are critical when evaluating or designing mixed reality environments. They also broadly speaking see the various types of presence as being an attempt to remove the individual from reality, and instead place them in an isolated alternative reality, through the use of various form and content elements (Lombard and Ditton, 1997). While the division between form and content is a useful issue when exploring many of the IPCity showcases the types of form used goes beyond that of Lombard and Ditton who focus on virtual environments to include the materiality of the objects (e.g. mobile phones, tracked objects, and the real environment) that form part of the experience.

The complex nature of mixed realities results in them often relying on narrative or contextual elements to provide a scaffold upon which the presence experience is built. Indeed as argued by Turner and Turner (2002) it is the context of the experience, which can often overcome many of the problems associated with limited technologies, especially when the potential for a fully immersive experience is difficult or impossible. These contextual elements include aspects such as role, social interaction, rules and objectives. They further point out that the ability of an experience to create a sense of place is often as important as the state-of-the-art technology, which may rest beneath. This perspective shares some similarities with the view of presence advanced by Biocca (1997) and Jones (2006) who argue to varying degrees that presence is or contains a significant mental model element, and it is the intentions and active interpretation of this model (Turner, 2007) which gives rise to a sense of presence. Conversely it is when this model breaks (e.g. a technical or narrative error occurs) that the level of presence is reduced (Zhanovik and Jenison, 1998). Although Turner discusses place and presence in the context of virtual environments it is equally if not more relevant within mixed realities, where the aim of such experiences may be to allow people to create new places as a result of bringing together both reality and augmentations. However as noted by Heidegger and Gibson (1986) the emphasis on models is in itself problematic as it is impossible to know with certainty the perceivers mental state, indeed in his view models can only be analysed when they break down.

Mixed reality environments should strive to blend, even if this does not involve realism, virtual and real artefacts in such a way that the users feel a new sense of spatial, social and temporal presence. While there may be differences in how people perceive the realness of the virtual elements, it could be argued that this is not and should not be the objective of mixing realities. Indeed by adopting the position put forward by Gibson reality is how people perceive the affordances available to them within a given space, regardless of whether the artefacts within the space are real or virtual, for example he argues that people perceive environments in the following way:

- An organism and its environment are not separated but are united in a reciprocal relationship.
- An organism perceives its environment in relation to how features are relevant for its

desired actions (affordances).
- Valid perception is what makes successful actions possible.

The Gibsonian perspective to some extent is drawn from the Heideggerian phenomenological view that people are “thrown” into space and it is the “ready-to-handness” of the artefacts which in turn give rise to the action, which in turn shape our feeling of being somewhere. Although Gibson makes it clear that his view of affordances is more than a phenomenological perspective as at all times they arise entirely due to the relationship between the person and their environment: critically however he points out that the perception of reality is unique to the individual. Furthermore an affordance only arises when a person has a need for such an action and the environment can provide support for it. However as noted by Mantovani and Riva (1999) perception is not isolated from the wider context and that perception (regardless of the reality) is shaped by social and cultural aspects, which therefore means that even in this case perception and affordances will be motivated to some extent by prior models of place, even if the perceiver is not concious of this.

The problem of defining presence is also reflected in the variety of measurement approaches which are used, these range from physiological measures such as heart rate to those focussing on subject aspects of the experience such as the MEC questionnaire (Vorderer et al,, 2004). Even within the various subjective and objective approaches, each one often focuses on a different set of variables and in some cases a range of media. For example some practitioners argue that a sense of presence can arise from becoming engaged within a book, while other argue that it can only arise within virtual environments. Furthermore, many of the approaches are ill suited in their entirety or on their own for use with mixed realities, in particular experiences such as Urban Renewal where presence is largely derived from the combination of social and interaction possibilities provided through a mix of tangible interfaces and display technologies.

The IPCity approach to presence

As a result of the conflicts between more traditional presence research and mixed reality design and evaluation. IPCity views sense of presence as something which arises from the ability of people to perceive their environment (regardless of which form it takes) thus creating a model of possible interactions. Actions in this context include interacting with others, in groups, alone and with real or virtual objects. Therefore at the outset such an approach implicitly supports social presence; however instead of seeing social presence as an isolated concept, it sees this social element as vital in shaping the users perception of the environment, their development of a sense of place and ultimately the degree to which they feel present. The range of possible interactions is derived from the users purposeful activities, which can range from a high level goals through to smaller more specific actions. In common with Gibson these purposeful activities and possible interactions give rise to affordances, which in turn are what drives the users particular actions. Therefore the concept of presence within IPCity is largely something, which arises through a co-constructed perception of the environment and the belief on the part of the users that they are situated in a new place which provides them with certain interaction possibilities. As a result IPCity proposes some changes in the direction of presence research from the perspectives of theory, design and evaluation:

- 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).

1.3 Mixed Reality in IPCity

Mixed Reality is a broad concept, and IPCity encompasses a wide range of experience. We therefore necessarily take a broad approach towards using and studying Mixed Reality, which encompasses traditional perceptual elements of Presence, but has an emphasis on social presence, affordances, beliefs and longitudinal effects.

Mixed Reality 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

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

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

Aura and Engagement. Goldiez & Dawson (2004) discuss if Presence is present in AR systems. They build on work by Heeter (1992), and discuss a personal, social, and environmental component of Presence. The personal component is discarded on the grounds that it is trivially fulfilled by the RE portion of AR. 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, which they call *aura*. This approach is much closer to our research than the one suggested by Goldiez & Dawson (2004).

Physical structure of the experience. The first aspect concerns the physical representation of the MR experience. First and foremost, one needs to determine what display is used. A key factor here is if optical see-through (e.g., using half-silvered mirror optics) or video-see through (capturing and digitally augmenting an image) is desired. Traditionally, MR has relied on head mounted displays (HMDs). HMDs support both optical see-through and video-see through. However, good HMDs are usually rather expensive.

More recently, handheld displays of various sizes, ranging from Tablet PCs to mobile phones, have become popular. Compared to HMDs, they are much less immersive, but can be used comfortably for extended periods of time. Since the display – size permitting - can be observed by multiple users at a time, it is also naturally collaborative.

If unencumbered collaboration is desired, stationary MR displays are often used. This encompasses large-screen and projected MR displays, but also Spatial AR, where the real part of MR is a specific object, the surface of which is directly modified using projected imagery (Bimber & Raskar, 2005).

Large-screen AR will be used mostly with video-see through, but can also be used with transparent screen materials for a “ghostly” kind of AR suitable for artistic expression. This kind of display is sometimes used in theater productions and has been used in some MR-Tent experiments. Large displays will often be used together with touch-based or tangible interaction. In this case, the display and its surrounding can be seen as different instances along the MR continuum, with corresponding MR boundaries. A similar argument applies when multiple MR displays are combined side by side. Stationary MR displays are also important when aiming at AV displays, which are primarily virtual. In these cases, the technology will often resemble traditional VR setups, such as stereo projection theaters.

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

A very different flavor of physical setup is necessary for mobile MR experiences. This is becoming increasingly important, as evident in all four IPCity showcases, where mobile users play an important role. Clearly, handheld (maybe HMD) devices are prevalent here. The key question for mobility is not only the ergonomic properties of the personal MR device, but also what the range and quality of tracking is available for the user. A large number of commercial tracking technologies exist, but none for proper outdoor AR use. In IPCity we have therefore emphasized a lot of new tracking technology development that is needed for the various showcases.

Note that the way mobility is supported in MR directly relates to the freedom of movement a users has – this is roughly the same consideration than the assessment of sensori-motor contingencies that are recently the interest of study in Presence research (compare the Presenccia approach). However, it must be emphasized that mobile MR occurs in outdoor urban situations. The situations encountered in the IPCity showcases are complex and have a high amount of uncontrolled stimuli. They do not lend itself to the direct study of biological responses, but must rather observe behaviors and purposeful actions.

Concerning the visual representation of the MR experience, it is important to note that unlike for many VR applications, photorealism is not necessarily a goal of MR. On the one hand, the fidelity of the real world cannot be matched easily, and it will often be more effective to just add some simple information augmentations (text, lines) to communicate relevant information. On the other hand, there are instances of MR applications where it is desired to create a fusion of real and virtual that is indistinguishable for a human observed. For example, computer controlled characters in an MR game may appear much more life like if they cast shadow on real objects and vice versa.

Apart from physical movement and visual observation, MR (like) can include stimuli of other senses – aural, tactile and possibly olfactory. Aural simulation can be integrated in MR experiences with limited effort, but it is not often done. Instead, it is common to use the audio channel for narration and instructions, which is necessary to manage the complex scenarios in outdoor MR. However, ambient aural simulation is used in the MR-Tent. Concerning olfactory displays, it is interesting that unlike VR, where complicated devices are necessary for providing dynamic olfactory stimuli, olfactory display can naturally occur in the real world part of an MR experience. Note how MacIntyre, Bolter & Gandy (2004) metaphorically speak of the “scent of a place”, while it can be a literal scent in some cases.

An important goal for a successful MR experience is how natural the interface appears. Manipulation can be design to resemble real world interactions, or can simply be designed in a way that requires a minimum of interaction steps for the user, who is engaged in observing the real world and should not focus on the interface. Note that interfaces can be 3D or they can be 2D – the latter is appropriate if considering interaction surfaces such as the Color Table or City Wall interface, or if interacting with distant, out-of-reach objects through image plane techniques (Pierce et al 1997).

Finally, a designer should consider the collaboration needs and aspects of the MR experience. Since MR is grounded in the real world, it is natural to support co-located interaction. In fact, MR permits to re-purpose applications designed for single users to quasi collaboration of co-located users through social sharing (Morrison et al 2009). Since both social and mobile computing are becoming increasingly important as new styles of human-computer interaction, it may be important to support collaborative interfaces in MR as much as possible.

The following table summarizes design options and suggestions for MR interfaces (Table 1).

What kind of display to use?	Use HMD if hands must be free (be prepared to pay a significant amout for a high quality device) Use handheld devices if mobility is important Use cellphones if extended mobility and wide user base are important Use stationary displays if addressing a larger audience or a rapidly changing audience Use tabletop displays to support complex workspace manipulation and tangible interaction
Use of video see through or optical see through?	Most configurations use video see through because devices are more accessible. Video see thru can use ordinary screens and is accessible to multiple users. Be cautious with video-see through HMD because users loose direct contact to environment. Transparent screens may an option of see optical through for multiple users is desired.
How much mobility is required?	Emphasize mobile MR if personal presence across a wide outdoor area is a key ingredient of the application. Consider that wide area mobility makes many things very

	difficult: Physical co-presence of users is not automatic. Filling the whole area with content requires special techniques. Tracking in a wide area may be very difficult with low quality (GPS). For applications where users mostly stay in one place, a stationary MR display may be better suited.
What senses are to be stimulated?	MR almost always uses visual (although there could be exceptions). Use audio to convey ambient properties. For audio/olfactory, possibly rely on natural environment ("scent of a place")
What amount of virtual and real should be presented?	Most MR experiences are either AR (mostly real, just add selected virtual content, often not photorealistic) or AV (mostly virtual, add selected real content such as streaming video insets). A half-half mixture would require a lot of effort, since it requires careful registration (owed to the real part) and lots of virtual content (owed to the virtual part) and may therefore be ineffective.
Is there a need for MR boundaries?	There are several reasons why it makes sense to combine multiple interfaces: The complexity of the application may not be addressed well with a single interface. The application is collaborative, and multiple users can naturally interact with multiple interfaces in a simultaneous way. There are several given pieces, such as real locations or the maps in MapLens, which can easily be "glued" together with MR components. In all these cases, a compound interface will emerge, which naturally created MR boundaries.
Is the aura of a place important?	Does the application refer to a specific place, which is reachable to the user? In such cases it will almost always be a good decision to use the real location. Note that this will often imply the use of a mobile interface.
How photorealistic should the graphics be?	Use photorealism if the visual impression provides insight or can help convey a mood. This may for example be the case for MR games. By comparison, in architecture a coarse representation may often be preferred in the earlier phases of design.
What kind of interaction is possible?	Make the interaction as simple as possible. Users are busy learning to "see in MR", and should not have to master a complex interface on top. For in-reach interaction, tangible interfaces may be a good choice. For at-a-distance interaction, image plane interaction ("point and shoot") seems a good choice at it is now well known from conventional computer games and devices such as digital cameras.
How to support collaboration?	Most MR interfaces (except for HMD) are naturally collaborative, as the device/display can be shared and used together. However, explicit support for co-located collaboration may be welcomed by users (e.g., provide multiple tangible control objects). For MR tele-presence or AV applications, explicit support for collaboration is mandatory in the same sense as for VR applications.

Table 1: Overview of design options for MR interfaces

1.4 Interaction types

Tangible interaction:

In the last fifteen years, a growing number of research groups dealt with the concepts of tangible interaction and a huge diversity of different systems has been developed. The first steps for establishing a definition were taken by Fitzmaurice, Ishii and Ullmer in two different approaches called Graspable User Interfaces and Tangible User Interfaces. Both approaches provide their definition by comparing the tangible idea to the idea of graphical user interfaces.

The core aspect of Fitzmaurice's (1996) definition of Graspable User Interfaces lies in the conceptual shift in thinking about physical input devices not as graspable devices but as graspable functions. Such a graspable function consists of a specialized physical input device which is bound to a virtual function and can serve as a functional manipulator.

The more generic and elaborate approach of Ullmer and Ishii (2000; 2005) is built upon the relationship of representation and control of digital data in a user interface. In their proposed interaction model (MCRit model), the view component is split up in two different subcomponents: the tangible, physical representation of the digital information, and the intangible representation of the digital data (e.g. video, projection and audio). The key characteristics of the MCRit model define how physical representations are coupled to underlying digital information.

Although this definition is commonly mentioned in publications, several researchers criticize it as being to narrow and excluding several aspects of tangible interaction. Arising from the field of HCI, it focuses on the representation of data as physical containers. To provide a broader view upon tangible interaction and include research from related areas such as interactive spaces, Hornecker and Buur (2006) propose a framework around the four themes of Tangible Manipulation, Spatial Interaction, Embodied Facilitation and Expressive Interaction. The themes provide concepts addressing design issues from a specific and a generic point of view, such as Haptic Direct Manipulation, defining if users can "grab, feel and move the important elements" or Multiple Access Points to provide users with the possibility to see what is going on and reach the central objects of interest.

Interesting concepts dealing with a similar approach can be found in literature. Hummels et al. (2007) suggest "methods, tools and knowledge" to support rich movements and provide 7 guidelines for designers to become an expert in movement. An analysis of "Action" and "Function" in tangible interaction is given by Djajadiningrat et a. (2004). The framework describes practical characteristics for coupling users' actions with information such as time, location, dynamics or expression (Wensveen et al. 2004). Chang et al. (2007) explore solutions for attaining simplicity in interaction design and present a few lessons learned from a design study.

At IPCity we gained grounded experience by developing a collaborative Tangible User Interface called ColorTable. Our approach to tangible interaction relates to the concepts of Tangible Interaction proposed by Hornecker and Buur (2006), considering the interface as part of a larger ecology.

The following table summarizes main issues for technologies and design for Tangible User Interfaces (Table 2):

What types of tracking technology to use?	Use optical tracking to support continuous detection of movements and rotations of a small amount of physical objects. Use RFID tags and readers to detect a high amount of different physical objects on a small set of different locations. Use barcodes for fast prototyping, for user created

	content or for triggering processes.
How to design optical tracking from above or underneath?	Use tracking from above when using multiple layers of physical information (e.g. maps and objects) and limited digital information (e.g. simple projection). Use tracking from underneath when detecting one layer of physical information and a complex digital projection.
What kind of physical objects to design and use?	Use small objects to support quick and flexible manipulation with one hand. Design objects to support collaborative use. Use various forms, materials and colors to awake multiple senses (visual, acoustic and haptic sense) and creative use.
What kind of interaction space to use and how big does it have to be?	Use round table to support discussions and collaborative interactions of an equal small group. Plan adequate open space around the interface to enable simultaneous interaction by 1-6 persons. Use horizontal and vertical areas to support interaction by 1-4 persons and a high number of observers.
How to store and present physical objects?	Create a place for each of the tangibles, devices and interaction modules near the interface. Create a clear presentation showing all objects when supporting intensive discussions during selection process. Attach objects to predefined fixedmounted places to support quick finding of frequently used objects and devices. Use mobile objects that can be passed around to support collaboration. Visually separate places for different types of objects or interaction modules (e.g. using different heights).
How to support complex and precise interactions?	Break the task down into different steps that can be performed with tangible interactions, in order to create consistent chains of actions for the overall task. Use barcodes and/or RFID tags to provide exact input values. Consider that a long chain of actions is usually difficult to learn, so use them only when essential for the long-term goal.
How to support quick learning of interaction possibilities?	Favour simple and consistent interactions, simple to learn and clear to perform Organize a tutorial (maximum length is half an hour) including main interactions in the beginning of a workshop. Give participants tasks to be done during of after the tutorial to enforce and fasten the learning progress.

How to support collaboration?	Use small, handy objects that can be passed around. Design interactions to be done with multiple handles, to allow several hands collaborating. Provide space to allow each participant to be at equal distance from the interactions. Present information and feedback to be visible for all participants.

Table 2: Overview of interaction design issues for tangible interaction

Embodied interaction:

Embodied interaction is 'forced' in various ways within the showcases. In IPCity we gained grounded experience by producing circumstances that ensured our participants responded to the devices and artifacts, as well as with each other in embodied ways through *MapLens, TimeWarp* and *CityTales* applications.

Paul Dourish (2001, p. 3) has introduced the concept of embodied interaction to highlight the idea that people have active representations embodied in the systems that they use–we are not interacting with a computer as such, but with our idea of the computer which is obtained and inherited through social interaction shared culture with other people. Embodiment is about the fact that all things, including technology, are embedded in the world, and about the ways in which their reality depends on being embedded. According to Dourish (2001, p. 19–20) it is important for designers to understand that interaction is intimately connected with the settings in which it occurs and this embodiment determines how it is that computation and the setting will fit together. This focus on settings has impact on how design user research studies: instead of abstraction, the emphasis has been changing towards particular, real-life use situations, and naturally organized interaction within these settings.

When designing a system that works like the real world, we have to first observe how the real world works, and consider how technology participates, or could participate, in the world it represents. When designing novel MR technologies, we need to be aware of the assumptions and pre-knowledge—embodiments—that are connected to the new interaction style or user interface we are bringing to the world.

When working with a totally new interface, the way to work with the new system might not be obvious to the user and she tries to figure out the proper way to use the system by trial and error. She has to rely on her similar experiences and social resources, for example the other participants, to make sense of the system. This might lead the user to do things with the system it was not designed for or come up with new uses, appropriations, for the designed features (Salovaara et al., 2006). Similarly, to be really aware how a novel MR system is or could be used, how the users figure out its affordances and appropriate new possible ways to use it, we need observe and analyse what happens in interaction.

While abstractions, for example measures of efficiency or user satisfaction provide ballpark estimations of future potentials, concrete design opportunities (i.e. what to implement) emerge from particular usage experiences of the users.

The following table highlights main issues for technologies and design in supporting embodied interaction (Table 3).

What types of tracking technology to use?	Robust systems that support use close-up and far away. This supports both singular use and *clustered* use (people gathered around). In these instances people in using the technology and artefacts provided, are given permission to cluster closer

	together than usual circumstances would allow. Robust systems also support use on the move, or while semi-stationary. This supports more ad-hoc and spontaneous interactions including gestures, pointing, looking between AR info and Real Environment etc., as people are more agile while in this state.
What kind of physical objects to design and use?	A mix of sizes and hi and low-fi artefacts. Non-precious larger objects allow the group to cluster around in close physical proximity. Plan adequate open space around the interface to enable simultaneous interaction by required number of persons. Small artefacts and/ or technologies force people to be physically more proximate to share and discuss and 'see-the-same-thing'.
How to support embodied gesturing: pointing, looking, sharing through devices?	Break down tasks into simple manageable chunks Design tasks so that they can support multiple levels of functionality taking place by multiple people at the same time. Design tasks that explicitly support or 'force' physical proximity between participants, Design tasks that require 'finding things' in the MR and physical environment. In this way people when in negotiation are forced to look and show each other what they have found—looking, pointing and gesturing are obvious means to achieve this.
How to support collaboration?	Use low-fi and hi-fi objects that support common-ground understandings and gesturing type interactions Use low-fi artifacts that are large enough to provide a *place* in order for people to actively meet and be able to negotiate. Provide a set of tasks that can be performed either solo or together Provide space for movement and the gathering around of people Design interactions to be done with multiple handles, to allow several hands collaborating. Present information and feedback to be visible for all participants. Present technology with screens that allow collaborating through the screens and onto larger surfaces.

Table 3: Overview of interaction design issues for embodied interaction

1.5 The notion of presence in urban studies

An extended research in various relevant bibliographic resources reveals that there is no explicit reference to the notion of presence in the discourses and documents within urban studies. However this does not mean that this concept is not participating in the design process, the formation of emerging theories and the conceptual approaches of contemporary architects, urban planners or researchers. A range of various concepts currently used in theoretical and professional architectural and urban discourses can be identified.

Materiality/immateriality. Architects and urban planners have always been working on and with the virtuality of physical space and by extension of social space. If one considers virtuality as a state of reality opposed to the actual (Deleuze and Guattari 1980), one could argue that architecture, as the discipline of forming the spatial experience, has always been exploring material and immaterial forms of spatial and social presence. For architects and urban planners the urban project has always been a virtual-potential space where future physical artefacts were conceived, questioned and tested. Christopher Alexander (Alexander, 1977) proposes a scientific approach that foregrounds urbanism schemas he calls patterns where people's movements and activities entangle urban spaces and architecture.

Identity. Identity of a place is one of the most important virtual notions that interfere with the reality of a space. Referring to Heidegger in *Building, Dwelling, Thinking* and his description of architecture "as a continual play between the concealed and the unconcealed", Christian Norbert-Shulz (Norbert-Shulz, 1962) gives to architecture the task to "evoke an image, be concrete and have significance" in places that are characterized by a *genius loci*. The "image of the city" belongs as well to the physical order as to the virtual one. Kevin Lynch uses the word *imageability* to explain "a physical object which gives a high probability of evoking a strong image in a given observer". (Lynch, 2000). Henri Lefebvre (*The Right to the City)* defends "the need for information, symbolism, the imaginary and play". Identity finds its roots in the experience of the inhabitants of the city. Aldo Rossi (Rossi, 1982) identifies the "soul" of urban space as resulting from the city's aptitude for codifying history, as the locus of the collective memory of its people.

Ephemeral. Walter Benjamin in The *Arcades Project* on the history of Paris decrypts the ephemera of everyday life, placing a particular emphasis on the experience of street life, providing a taxonomy of urban experience including fashion, catacombs, the *flâneur*, the streets, urban renewal… Cultural or sport events, art installations, seasons, etc, produce an urban ephemeral environment.

Representation. The communicational dimension is extremely crucial in the urban project process. Therefore the question of representation is major. How to represent the unrepresentable? (Derrida and Eisenman, 1997). This new perception of the urban project entails new languages of a strongly narrative character appealing to social imaginary and lying beyond the "traditional" representation methods (Terrin 2005). Designing and discussing projects means to supply the stakeholders with images, references and metaphors which appear, in other forms and "languages", in political speeches, program descriptions, architectural presentations, etc. How can a designer make a client understand at an early stage of the project such a description: "a glass partition appearing as an irregular tissue upon which light can be projected"? The wanted effect can be hardly understood before the project is actually built. Nevertheless, this is the challenge of expressing ideas in such a complex situation as the urban multi-stakeholders arena. Analogical and metaphorical representation is probably the most suitable expression mode. Beyong a truthfully technical and scientific simulation (e.g. static, light, temperature, etc.), the urban project needs to search for seduction by means of subjective images (evocating everyday life, imaginary, uncertainty…).

Ambiences. The increasing concern for issues related to the notions of perception and interaction brought in foreground by researches in the field of urban and architectural ambiences (Amphoux, Thibaud and Chelkoff, 2004) and the development of the information

and communication technologies yield new perspectives for experimenting new ways of understanding architectural and urban space or conceiving and designing forms through immaterial elements. New languages are needed to start imagining and describing the city through shared narrative descriptions, metaphors, atmospheres, ambiences.

Telepresence. Although the notion of presence is not used by the members of the academic and professional urban community, the development of cyberspace and the notion of telepresence is attracting a constantly increasing interest inciting new approaches to urban environments: practices and theories like transarchitectures (Novak, 1998), visionary approaches (Mitchell, 1996), theoretical questions on urban evolution and development (Castells, 1996) theories for the mutations of the notion of place (Augé, 1992), artistic-architectural installations, etc.

ICT. ICT provide architects and urban planners with new and more effective ways to express and explore interactively the virtuality of the urban environment as well as to carry out complex tasks, through various means of representation and simulation (CADD, parametric design, photorealism, etc). Nevertheless, while the computational power is being exploited at a high degree, it seems that the communicational aspects of these new technologies is quite limited since it concerns those who are implicated directly in the design process and have special skills that permit them to be in some way “present” and intervene in these virtual environments.

Negotiation. Negotiation is the moment when information exchange and processing (stakes, objectives, technical specifications, visions, interests etc.), communication and interaction between the different stakeholders but also between them and the virtual object of urban development, reach a particularly crucial point. The project approach corresponds to the evolutions in the urban development field (sustainable development, incertitude, social representation, risk management, multiplication of stakeholders, etc.) that require negotiation and call for management methods that facilitate the constitution of multidisciplinary teams founded generally on public-private and local actors-global operators partnerships (Callon, Lascoumes and Barthe, 2001). It gives hence rise to innovative practices that take into account a large spectrum of economic, social and environmental issues. In other words, the negotiation scene brings together heterogeneous virtual presences in order to generate a real potential through the various interactions that take place.

2 Common set of methods

In the last project year the evaluation approach as specified in D3.2 was thoroughly examined. The team strengthened the common elements in their approach, which is outlined in the following section. It is a central outcome of IPCity, which argues for 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 more controlled methods.

2.1 Evaluation formats

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

structured interviews and the analysis of artefacts, with the use of (standardized) presence questionnaires where appropriate.

Observational studies, such as the ones we carry out within IPCity, are based on ethnography. 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 (Hammersley and Atkinsons 1995). It is important to mention that ethnography is not only a research method but also involves a particular way of writing. "Ethnographic accounts" typically contain information about the context, they are expressive-narrative, they present what has been observed from particular perspectives – "ethnographic truths are thus inherently partial-committed and incomplete" (Clifford, 1986), and are written for a particular audience. The ethnographer acts as archivist, writer, and interpreter, with the studied subjects, whose actions and voices are represented, as 'co-authors'. Hence, writing an ethnographic account always requires contextualizing the ethnographer's own positionality and reflecting on the 'organizational character' s/he imposes on the ethnographic material (Madison 2005).

The following table provides an overview of evaluation formats and collected data in all four showcases (Table 4).

	WP6	WP7	WP8	WP9
Field trials/participatory workshops (PWS)	*Pointoise*: Preparatory WS, May 2009; 25 participants Participatory WS June 2009, 14 participants *Oslo*, PWS Nov 2009, 17 participants	Helsinki: Environmental Awareness Game with *MapLens* Two field trials 1)16.08.2009. 23 participants in 9 teams 2) 23.08.2009, 14 participants in 6 teams Total 37 in teams of 1, 2 or 3.	TimeWarp Cologne, Germany. User test 66 participants (33 groups of two players) 06.1.2010-06.2.2010 TimeWarp NZ Christchurch, New Zealand 10 players February 2010	Vienna: 1) 1st Urban Strategies Workshop; May 2009; N=12 2) 2nd Urban Strategies Workshop; July 2009; N=14 3) Summer School Workshop; Sept. 2009; N=10 4) Field Trial: Naschmarkt Stories; Okt/Nov. 2009; N=6 5) Field Trial: Naschmarkt Stories; Jan. 2010; N=8
Video documentation	*Pontoise*: 9.5 hours, 2 cameras *Oslo*: 5.5 hours, 2 cameras	*MapLens,* 2.5 hours, 15 cameras with 15 teams (9 on 16.09, 6 on 23.09	TimeWarp, Cologne 1 camera with steady cam recorded 33 groups Qualitative and quantitative data captured.	2) Urb. Strat. WS: 1 camera; 1,5h video 3) Sum. School: 1 camera; 1h video by students
Photo documentation	*Pontoise*: 1500 pictures *Oslo*: 1063 pictures	*MapLens:* still pictures from video footage	TimeWarp Cologne Still images from videos TimeWarp NZ Limit number of photographs taken.	2) Urb. Strat. WS: ~300 pictures + video stills 3) Sum. School: ~250 pictures 5) Field Trial: ~150 pictures

Log-in data	*Pontoise*:1588 screenshots, 73 saved MR scenes *Oslo:* 477 screenhots, 54 saved MR scenes	*MapLens:* all phone activity logged	TimeWarp Cologne Auto-logging of all key presses, object selection and navigation on device.	Database transactions logged, phone activities logged
Interviews	*Pontoise*: 26 free form interviews in preparation of WS; 14 free form interviews after WS *Oslo*: 19 cultural probes interviews before WS; 15 free form interviews after WS	*MapLens:* Semi-structured interviews with 1) participants and 2) with researchers	TimeWarp Cologne Post-experience questionnaire with participants to discuss any key issues observed during trial or seen in questionnaire answers.	Open interviews with participants, discussions, and presentations by qualified participants after participatory workshops
Questionnaires		*MapLens:* demographics and mix of Presence, Flow and Intrinsic Motivation questionnaires	TimeWarp Cologne Modified MEC presence questionnaire including elements of social presence and MR topics. Also profile questionnaire TimeWarp NZ 2x post experience questionnaires for each stage. Repertory grid knowledge elicitation	Demographics, mix of Presence, Usability questionnaires

Table 4: Overview of fieldwork data

2.1.1 Field trials

During 2009-2010 W9 7, WP8 and WP9 organised a series of field trials in the urban environment around their showcase prototypes. Where the use of field trials is deliberately implemented in IPCity, we look to address a more real-world evaluation of use. We seek rigorous use and feedback and more realistic use-case scenarios, with the view to iterate, progress and implement the applications in commercial/ actual future use.

For the showcases, the field trial methods implemented were largely in the form of games or some other form of social activity between two or more people, and were all situated within the urban environment. Evaluating use in real settings is difficult as can also be seen by the very few studies with MR and AR applications that are mostly carried out in laboratory settings. Some studies are aimed at building predictive models (Rohs, 2007, Rohs & Oulasvirta, 2008, Cao et al., 2008, Mehra et al., 2006). Other studies of handheld AR carry out in-laboratory formative evaluations (Henrysson et al., 2005). Schmalstieg & Wagner (Schmalstieg & Wagner, 2007) describe one of the first AR group collaboration in a larger indoor space, a museum. The observation of outdoor AR users “in the wild” is limited to very few recent reports (Morrison et al., 2009, Herbst et al., 2008).

Our field trial evaluations were for the main part organised so that different members of IPCity project could participate to some degree in decision-making processes around methods, negotiations around implementation, organising the trials, and/ or taking part as researchers in other showcases trials, and in this way guaranteeing us input from as wide a group of professionals from a diverse array of expertise as possible. As well as pooling

expertise, we were looking at where and why we would implement certain methods and not others. As well with each trial we took from other instances of use, with an aim to continually iterate and improve our methods. As an example, visiting researchers from FIT, TUG, UOulu, Nokia Research, New York University, University of Otago and HitLabNZ participated in planning and joining TKK field trials during the summer (this instance included MARCUS researchers). HitLabNZ also inputted into WP8 and WP9 trials. The TKK process with *MapLens* application was then written up into a large evaluation report (available now as a public resource on the web site), and in particular available to other showcases as a resource to work with and from. At the same time continuing discussions around questionnaires (and the resulting joint ECS questionnaires) fed into decisions for questionnaire processes, and WP8 questionnaire methods were then customised for use in WP9 evaluation field work trials. All showcases were aware of the precedents and issues with the various methods employed over time with each set of trials, and were therefore better informed on rationales and successes and better able to make and implement meaningful choices for their case-by-case circumstances.

2.1.2 Participatory workshops

In WP6 we chose the format of participatory workshops for evaluating the successive prototypes, as it allowed us come as close as possible to the 'real life' situation of participatory urban planning. The *MR Tent* application was evaluated and re-designed in six cycles of design-evaluation-redesign in the context of real urban planning projects with urban planners and a variety of stakeholders as users. We invited participants to be creative without prescribing how they should make use of the resources at hand. Given the long duration of urban projects and the complexities of the political and technical issues to be dealt with, a single intervention, although within a real' context', is of limited impact on the whole process.

For each of these participatory workshops we studied the site, selected participants, prepared scenarios, a well as content – panoramas from different viewpoints, architectural models, and other assets, and developed an experimentation protocol for the participatory sessions. As in all real-life urban projects selecting participants is a highly political process and cannot be dictated by the evaluation criteria of a research team only. For each workshop we had to negotiate with the local authorities a 'good mix' of planning experts, politicians and concerned citizens, representing a diversity of experiences and interests.

Furthermore, participatory creativity needs preparation. In the last two workshops we used two different methods for preparing participants. In both participants were given cultural probes (Gaver et al. 1999) about two months before the workshop, with the request to explore the site and the urban issues at stake and to collect material representing their 'vision' of the future of the site. In the 2008 workshop in Cergy-Pontoise we conducted individual interviews with each of the participants to help them develop this vision; in the 2009 workshop we invited them to work in small groups (with traditional methods) on their ideas. In both cases, participants explored the site using maps, stories (from the past), images, small objects, hands, crayons, and so forth. This helped them express their specific knowledge, experiences and interests, as well as construct elements of scenarios to later enact in the MR-Tent. In the Oslo workshop the cultural probes method was used for preparing participants and free form interviews with selected participants were conducted after the workshop.

Another aspect crucial to participants' opportunities for creativity is content preparation. Participants want to bring their own content but also find content that helps them express their ideas. We used participants' input, partly transforming the content they brought with them, partly working with the themes they evoked, searching for visualizations of these themes. Eliciting 'user-generated' content in the context of an urban project is not as easy as it may appear.

The workshop sessions in MR-Tent were video-recorded using two cameras (a fixed camera and a manually operated one) , and transcripts of significant episodes were produced. In

addition, we used several digital cameras to capture interesting situations and included screenshots and saved MR scenes in our analysis.

In order to prepare an analytical base-line for further investigations in WP9 we created an in-depth urban site analysis of the “Naschmarkt” region during 2008 with students of the Urban Strategies studies at the UniAK. Particular information was collected and mapped to the location by spending several hours on different days of the week on the place, documenting observations with photographs, videos and notes (written and sketched), followed with internet and library research. This step generated a huge set of initial data.

To explore the potential of the various devices and technologies used within WP9, together with students we developed concepts for applications based on story-telling concepts in relation to urban issues in May 2009. As the theoretical background of investigation the students were first asked to experience the city in a particular way, which allows for creating subjective narratives tight to the urban environment by strolling through the city – called “dérive” (drifting).

In the course of a five-day tightly scheduled workshop in July 2009 the creation of story based gaming in the urban environment was prototyped. After a brainstorm session for the whole of the first day two of the presented ten concepts were selected and further developed. Following days included implementation workshops and the production of the game materials. Day four was reserved for playing the games consecutively, where photo and video documentation was used with open interviews and game logging to record evaluation data. Recorded material was evaluated in detail later, as part of the workshop however participants – both “game developers” and “players” – created presentations to an audience of thirty as immediate reflection to the participatory experience.

Based upon these results during the IPCity Summer School in September 2009 we were organizing a successful participatory story-telling workshop with international students. During the workshop authored, geo-located stories of professional authors were investigated, re-told using Mixed-Reality story-telling methods and media, and extended further with participatory authored content.

2.2 Video analysis

Observational studies yield representations of the observed in different media: video, photo, sound recordings, notes, and physical artefacts. Each medium provides different perspectives on the observed.

There is a substantial body of research on video analysis (Pink 2007). Video recordings account for the situatedness of the visual, temporally and spatially, with respect to the environment; they make it possible to examine the gestural and scenic details of how people interact (Knoblauch et al. 2008). Hence, video material allows us analyze participants’ embodied interaction (Dourish 2001) with each other and the technologies within physical space. Interpretative video analysis prefers "natural" data and social situations, which have not been specially set up for research. In studying participants’ interactions with novel technical devices, such as in IPCity, arranged situations or quasi-experimental settings have to be used.

There are some “rules” connected to the use of video (Schnettler and Raab 2008). There is a big difference between automated and “authored” video recordings. This is why we combined both of them. The advantage of the latter is that a scene is captured through the eye of an interpreting observer whose eye is led by research questions. The video camera does not replace the observer; the body of video data has to be substantially augmented by observational data (e.g. notes). An important element is “the mobilisation of the camera itself, in the shifts and zooming, dynamizing the images and producing new temporal and spatial modulations” (p.). Another important step consists in the selecting and cutting of the video material, which is done in what Laurier et al. (2008) describe as “forming the film as an object out of the materials that are there” in many cycles of previewing and reviewing, making visible what the researchers think are relevant instantiations of participants’ interactions.

All types of media have their own characteristics and everything that has been documented need to be transcribed. Transcription systems for video data are still in an experimental stage. We have used already existing transcription practices, as those described by Iedema (2001) and Norris (2004).

Ethnographic analysis is mostly qualitative, with analysis of the ethnographic material (video, photographic images, screenshots, notes, etc.) being carried out collaboratively in the research team. The team typically watches the video material several times, selecting significant scenes. The significance of scenes is judged on the basis of a set of concepts that reflect the theoretical approach developed within IPCity. These scenes are connected with other fieldwork material (pictures, transcripts, sound files, screenshots, etc.) into a 'storyboard' (see Table 5), in which descriptions of key observations are organized around key concepts. Working with this documentation allows the team arrive, step-by-step, at consolidated interpretations of its observations.

Engage with scene	
File	2
Visual frames	
	Soundfile (removed)
Context - description of activity	11:54:52 Eric activates zoom – all look at panorama 11:55:10 "Du bleu, tout est bleu" 11:55:13 S: "Ah, fantastique!" 11:56 …. Lots of laughter – all look outside Ch: "Mais c'est pas, c'est pas … magnifique, le chant du merle" E: "Donc c'est là et Monsieur pense que cèst là!" B: "Where is the sound coming from? G: "Ça … du Hitchcock!" 11:58 While they are talking Ch continues pointing at place on the map, enters side conversation with EV – all look again at panorama which disappears and reappears
Analytical category	Manipulate scene Gesture Gaze Sound
Transcript - spoken language	(Removed for reasons of space)

Table 5: Example of scene description from WP6

An example of the video observations of one team engaging with situated use of an augmented reality system *MapLens*, and the ways teams learn to manage themselves and the system is detailed in Table 6, another one showing *TimeWarp* players discovering as virtual time portal in Table 7.

	Engage as a team with situated use of device and map
File Visual frames	
	Soundfile (removed)
Context - description of activity	11:22:50 Both trying looking through 2 devices on map on floor in museum 11:23:10 3rd member arrrives and looks at own device on own map 11:25:14 He moves to other map and looks through own device to discuss another aspect of a different clue. 11:31:01 Outside with wind, first all try to use, then one folds map 11:32:10 Then two hold map and one uses with all looking at the one screen 11:39:09 In MBar on table, both start using for next clue. Then just one uses and skews phone around so both can see screen.
Analytical category	Gesture Gaze Looking through own device Sharing device Using one/two maps Division of labour
Transcript - spoken language	(Removed for reasons of space)
Summary of this group use to obtain general picture of use with each team, and each condition.	All tried at first, showing screen to each other earlier in piece. First worked 2 maps, then outside one, only this one team folded as soon as hit the wind. Sharing device and pointing at screen and below on map. Tried walking, discussed and demo-ed best way to use while walking. Parked using aside from in e.g. museum, MBar where table. Short stops with 2 on device. Two handed use for e.g. connecting to elisa with first photo after battery change. Showing use for potential game on journey back. Device in hand from beginning to end. They switched the stuff between them easily. Working well as a team (e.g. all holding the map on first use). Experimenting how to use, and happy about it. Fluid switching of all stuff. Many iconic gestures.

Table 6: Example of interaction via mobile devices with WP7 MapLens field trial

Visual frames	 
	Soundfile (removed)
Context - description of activity	a) Player 2 (navigator) chooses a time and sets a time portal. The players stand next to each other and are concentrated on their roles. Player 1 is watching his display. b) After the time portal sound occurs, player 2 asks player 1 (AR player) if he can already see something on this display. He is turning towards player 1 and tries to look on his display. c) Player 1 is spinning around to scan the environment. Player 2 waits and checks his display again. d) Player 1 finally discovers the virtual time portal e) Player 1 is quickly approaching the virtual time portal while player 2 accompanies him. f) Both players abruptly stop walking when they hear the success-sound of the time portal.
Analytical category	Time portal Gesture Gaze Sharing device Division of labour
Transcript - spoken language	(Removed for reasons of space)
Summary of this group use to obtain general picture of use with each team, and each condition.	

Table 7: Example of finding a virtual time portal with TImeWarp

The enormous amount of video material also lends itself to a quantitative analysis, with e.g. a focus in certain interactions, and the objective to identify significant patterns. For this purpose a breakdown of the larger activity into fairly generic tasks is needed. The following table (Table 8) gives an overview of the activity categories on which the analysis in each showcase is based. Subcategories for each of these activities were identified, which are described in the individual showcase reports.

	Activities			
WP6	**Co-construct, discuss and evaluate MR scenes representing a vision of the future of an urban site**			
	Plan intervention	Perform intervention	Understand MR scene	Evaluate result of intervention
WP7	**Environmental Awareness: become more aware of local urban environment and environmental issues via AR and MR technologies**			
	Design Game	Run trials	Interact via device and AR information with game	Participants design awareness task as indicator of success
WP8	**TimeWarp: using location-aware augmented reality technology to change perception of reality and to encourage interaction, collaboration and presence**			
	Interaction at the boundaries of reality	Decision making through collaboration	Embodied Social Interaction	Place Dependent Behaviour and Perception
WP9	**Experience real or fictional stories distributed over the urban tissue using MR technologies as story-participant or game-player**			
	Author Story, Design Game	Run trials	Stroll around place, experience MR info and act	Evaluate comprehension; game success as indicator
Analysis of urban issues				

Table 8: Overview of activity categories

Each showcase also selected units for a quantitative analysis (Table 9). This varied with each showcase depending on the research questions asked, as well as the kinds of findings the data revealed.

WP6	**Gestures**	**Representation of MR scene**	**Scale of MR scene**	**Object manipulations**
	- Single pointing on map/on screen - Collaborative pointing on map/on screen - Tracing on map	- Switch of attention between map and screen - Change of representation (panorama, real time video, scout, etc.)	- Change of scale (physical map) - Rotate - Zoom	Object placements (single object, flow, texture), 3D line
WP7	**Gestures**	**Representation of AR scene**	**Scale of AR scene**	**Object manipulations**
	Non map lens (ML) user points the map, device screen, kit objects, the environment ML user points device screen, the map, the environment ML user Quiet when point Other person points the map, while ML	-switch of attention between screen, map and environment -Change of representation (map, real world, Augmented info on device, browse online for more info)	-Zoom in and out: 1) device view 2) map view 3) world view -Physical map one size only -Kit objects varied from long folding-out clue booklet to small water test strips	- two objects (device + map) needed to be used in tandem to get the system working -Constant negotiation: handling, distributing and sharing of multiple objects e.g. kit bag, clue booklet, writing answers with pen, as well as device

	used Screen shared with X people: horizontal/ vertical/ tilted Phone not used (time)/ Using another phone/ moved because of colliding Changing user (mid.session) Tracing route on path/on device screen/ in clue booklet/ in environment		-urban environment, objects, and architecture with in the environment and navigation to and interaction with these	and map between team members -People proximity negotiation of body space in order to complete team tasks (hold heavy object and all in one photo) - Alignment of the phone (e.g. vertical/horizontal, near/far from the body, can others see the screen etc.)
WP8	**Gestures**	**Representation of Story**	**Scale of MR**	**Object manipulations**
	Gestures between players to indicate locations or content Posture and gesture to indicate interaction with virtual characters Gestures and movement to indicate movement between reality boundaries e.g. at time portals.	Position and use of device implies involvement in story. Switch of attention between device and real world. Story world and augmented world are aligned through narrative constructs and characters. Environment structure including routes which players take represent narrative structures within the mixed world. Thus altering player behaviour.	AR world view is represented on second player (navigator device). AR local view is represented by main player AR view. Direct 1:1 relationship between walking “real” distance and AR work. Augmentations are scaled and positioned according to real space.	Players collaborate through device sharing, looking at the other device and swapping over. Augmented object interactions take place through focussing device, selection and interaction.
WP9	**Gestures**	**Representation of Story**	**Scale of MR**	**Object manipulations**
	Pointing of onward direction when pair of users discuss path Pointing at markers in environment as sign of localization Pointing device against markers in environment Alignment of device with real surroundings when using map based view	Switch attention between screen and environment Change of representation (real world, MR info on device, browse inside info, map display)	Zoom attention in and out: 1) content focus 2) map view 3) world view Urban environment gives 1:1 scale story stage and requires interaction with it	Only object is the device for participating the story experience Alignment of the device (e.g. vertical/horizontal, near/far from the body, can others see the screen etc.) Usage of buttons for scrolling content, switching pages, switching functions (e.g. MR-view, map-view)

Table 9: Overview of activity categories used for quantitative analysis

2.3 Multimodal analysis

As Scollon and Scollon (2003) write in the introductory chapter to their book. “Any and all social action takes place at some intersection of the interaction order (…) of visual semiotics (the design layout, and production of all the signs, pictures, books …), and place semiotics (the built environment along with the ‘natural’ landscape within which the action takes place” (p. 9). Multimodal research is a rather young field, which was stimulated by the seminal work of Kress and van Leeuwen (1996) who explored the semiotics of images, and O’Toole (1994) who analyzed sculpture, architecture and painting. He distinguished between the “modal function” (how the viewer’s attention, thought and emotions are engaged by and related to an artefact), the “representational function” (what is depicted), and the “compositional function” (how the artist organizes the available space, makes use of colour, form, lines, etc.). Much of research in this area focuses on visual material, such as film, comics, painting, etc., while acoustic modes (speech, music, sound) in their relation to images are much less explored.

2.3.1 Gestures

Gestures are seen as an important part of referential practice and researchers analyze how bodily gestures and actions are used in relation to talk in order to direct and encourage one another to look at a particular object. Gestures help to render a feature of the world visible and gaze (as well as the whole body) follows the gesture that displays an object. Goodwin (1998) sees pointing as part of entities and events provided by other meaning making resources - talk, properties of space, body posture, as well as the larger activity (collaborative action) of which it is part. “Pointing” consists of:

- The pointing gesture
- The domain of scrutiny (e.g. a map)
- The target of the point.

Pointing takes place within a participatory framework, which is defined by participants’ postural orientation and addressee orientation – people orient toward other participants, maybe also to specific phenomena located beyond them in the surround. The human body serves as a special visual field – a complex entity that can construct multiple displays, which mutually frame each other (Goodwin 1998).

In our analysis we distinguish different types of gestures:

- Deictic pointing gestures – pointing something out on a map, on a screen, in the environment:
- Tracing gestures – gestures that follow the shape of a building or path;
- Iconic gestures – gestures that bear some sort of pictorial resemblance to the thing being represented;
- Relational gestures – gestures that connect real or imagined places or objects in different representations (e.g. something on a screen with something on a map);
- Collaborative gestures – two or more people pointing or tracing or gesturally describing simultaneously.

Haviland (1996) talks about “creative pointing gestures”. They are often those directed towards non-present objects' - things imagined (e.g. a person pointing at an imagined building or event while telling a story). Table 10 gives an overview of gesture categories analyzed in the different showcases.

WP6	WP7	WP8	WP9
Individual pointing gestures (on map, on projection screen, to real/imagined place outside the MR-Tent) Tracing gestures (on map) Collaborative gestures Relational gestures Iconic gestures (e.g. encircling a place, outlining a shape, defining distance/height, indicating barrier/boundary)	Individual and group Pointing on device, Map, Environment, Clue book with pen or other objects Tracing gestures to indicate route or location on map or device Iconic Gestures (e.g. indicating direction and motion, size or shape of object Deictic Gestures (e.g. point to an object near or far or between players—interactional space	Collaborative or individual gestures, when discussing where to go or how to complete a game action. Often accompanied by a decision. Deictic gestures when pointing out where a virtual character or object exists. Referential gestures when crossing between map view of game world and real environment. Creative pointing gestures when interacting with virtual characters. For example orienting the body towards a virtual character or following it.	Collaborative Gestures (when discussing direction of further path during story or game) Deictic Gestures (pointing at markers in environment as sign of localization) Creative Pointing Gestures (e.g. trying to identify story elements – hidden door, dead person – in real environment)

Table 10: Overview of gesture categories

2.3.2 Object manipulations

Analysis of object manipulations involves different types of objects in the different showcases. Aspects to consider are:

- Touch dimensions - size, weight, form, position in space, texture, temperature, flexibility, continuity of surfaces, etc.
- Type of manipulation – grasp, lift/heave, turn, shift, stroke, press, align/adjust, etc.
- Number and structure of activities – different manipulations in a particular sequence may be necessary to perform an activity
- Character of manipulation – flowing, accentuating each step, etc.

Larssen et al. 2007 bring another aspect of our interactions with things to the fore:

"Attending to the thing and acting on the thing. This is when we are very much aware of a thing, when we are new to the thing or the hammer breaks. We are focusing on the thing itself; it is present-to-hand.

Acting through the thing: The thing has become an extension of the body. In our activity we are unaware of the thing, we are acting through the thing to complete our activity; rather than attending to the thing, we feel the end of the stick or the tennis racket; they are ready-to-hand.

Attending to and acting through. We are aware of the thing, but it is not our focus of attention. The thing allows us focus on something else, it has become a mediator. Interaction design is concerned with how people manipulate objects".

This is to do with participants' focus of attention – how much of it goes into the object manipulation itself, how much into the task/goal. Table 10 gives an overview of the types of object manipulations examined in each showcase.

WP6	WP7	WP8	WP9
Select content cards Assign content Place content (single objects, flows, textures, 3D lines, sound) Manipulate content (reposition, in/decrease size, change transparency) UrbanSketcher manipulations (Paint on screen, Create 3D objects) Paper Sketcher manipulations Manipulate scene (change physical map, change background, change scale, rotate, zoom, freeze) Organize workspace	Rolling out the map, and putting the map away begins and ends a larger use session. Sharing or tilting the device or communicating by looking through devices at the same time with multiple users Organise and distribute or re-distribute kit objects Use map and device and other kit objects to point to other objects in environment while stationary and walking Use map or device to demonstrate e.g. how used or e.g. hit each other with rolled map/ mock sword fight while walking Use clue booklet in tandem with map and device to plan and adjust route	The main player positions the device with reference to the virtual content. E.g. pointing it up towards the top of the UFO tower. The main player refers to the navigators device, and navigator refers to the main players device. The main player selects and interacts with virtual element using buttons on the virtual PC. The navigator player answers challenges by selecting the answer on the screen. Players lower devices when focussing on goal oriented behaviour when the location is already known or when interest in the game has fallen.	Position device to look at display. Pointing device towards marker in environment. Sharing device screen when reading/observing content. Aligning it (e.g. horizontal/vertical, near/far the body) to get more details. Moving closer when listening to audio. Usage of buttons for scrolling content, switching pages, switching functions (e.g. MR-view, map-view). Aligning device with environment in map-view to get better spatial reference with surroundings.

Table 11: Overview of categories of object manipulations

2.3.3 Use of space - body configurations

The language of space has been developed within different domains, mostly within architectural design, urban planning, and, more recently, by scholars of cultural studies and social geography. It has been connected to themes dealing with power, knowledge, gender, and social practice.

There are at least three levels of analysis we can engage with:

- A descriptive level of location, size, shape, orientation, which is to do with issues of accessibility, space for activities of different kinds, connection to other spaces, etc.;
- A social semiotic level, where we analyze the semiotic resources the space offers to participants – what are the cultural connotations with a particular space;
- An analysis of use level, where we describe how activities unfold within the space.

Stenglin (with Halliday 1978) distinguishes three communicative functions of space:

The ideational function – how space shapes our activities and experiences. Here we focus on identifying the activities that take place in the space and the objects involved in these activities (e.g. what are the activities that people pursue in a market place and how are these supported by the space and the objects in it).

The interpersonal function – what enables us to interact and bond: do people feel exposed or protected; is there the possibility to have visual contact; is there space structured for common activities? Here characteristics such as openness/closedness (boundaries, regions dedicated to different activities/people) come into play.

The textual function – how is the space organized into a meaningful whole. Are there spatial characteristics that orient people where to go to, where not to intrude, what to do? Portals, signs, barriers, size, etc. can have such a function.

Stenglin distinguishes the static framing of space (through walls, corridors, openings, etc.) and its dynamic framing. An aspect to be analyzed concerning the dynamic framing is the parameter of path-venue. Paths are the (built) medium along which people move. Prominence is another aspects. Prominence may be created through visual elements, sound, smell.

As Hindmarsh and Pilnick (2007) argue, the body has central and critical role "as a resource for real-time coordination". From previous research we also know that an ubiquitous organizational feature of face-to-face conversations is the use of space to frame interactions. Much of this research goes back to Kendon (1996) who has described how people actively use the position and orientation of their bodies to collaborate in the management of their conversational interactions. He has coined the term F-formation for these spatial configurations, arguing that changes in interaction often correlate with changes of the F-formation. Common formations are e.g. the O-formation typical of people who enter a conversation and create a shared interaction space or a circular arrangement, which is used for co-operative, symmetrical interactions (Healey et al. 2000). Other studies investigate how the framing of the space (walls, objects), its accessibility and connectedness, as well as the cultural meanings shape social interaction (e.g. Stenglin 2009).

Kirsh's research on the use of space focuses on the body posture and position itself, on the spatial location as an integral part of the way we think, plan, behave and shape (Kirsh 1995). His goal is to provide principal classifications of some ways space is used and create a framework. The data is drawn from videos of cooking, assembly and packing, observations at supermarkets and so forth. His classifications are among others spatial arrangements that simplify choice and perception. In his later research with colleagues he tries to understand the organization of cognitive systems and workspace by using the theory of distributed cognition. They observed peoples behavior with Pad++ and found difference between how they manipulate icons, objects or emergent structure and their cognition. They argue that we constantly organize and reorganize our workplace to enhance performance and state that space is a resource that must be managed (Hollan, Hutchins and Kirsh 2000).

According to Tang and Minneman users can enact body and gestures in space, or even bring physical objects to an interface. The use of an interface is influenced by the spatial arrangement of the interface and the collaborators (Tang and Minneman 1991). New media, such as collaborative environments and novel interfaces, force researchers to analyse what is fundamental about communication (Gerhard, Moore and Hobbs 2004) besides language including non-verbal communication and the bodily engagement in the provided surrounding.

All these viewpoints and categories help improve our understanding of how activities unfold – how the space encourages, supports, constrains, prevents certain types of activity.

2.3.4 Analysis of MR scenes

Visual representations are at the core of mixed reality technologies - in physical form (e.g. content cards, maps), as well as on screens of different types. Participants in field trials attend to multiple visual fields.

As already mentioned, researchers (Kress and van Leeuwen 1996, O'Toole 1994, to whom also Stenglin 2009 refers in her analysis of space), distinguish between the representational, the modal and the compositional aspect of visual material. Key concepts in the analysis of visual material are:

The concept of *salience* addresses the fact that elements of an image attract the viewer's attention to different degrees, depending on their placement, their size, their colour, their sharpness, etc.;

Composition is to do with the internal values and relations of the content and the interaction space it creates with the viewer. Framing is an aspect to do with composition produced through format, background surface, physical frames or overlays of surfaces and

substances. Framing allows setting a focus, creating relationships and boundaries, thereby also redefining the action space;

Modality markers have a guiding function for the viewer's attribution of realistic value to a representation: "Modality both realizes and produces social affine", by aligning the viewer, reader, listener with certain representations and not with others, it produces what we call true/untrue, real/not real, thereby having the potential to produce new values and modes of thinking (Kress and van Leeuwen 1996);

Narrative image structures are based on the connection of visual elements through vectors. Narrative patterns serve to present unfolding actions and events, processes of change, as well as transitory spatial arrangements.

Besides analysis of visual material an initial study of sound importance as an element of MR has been addressed. We are interested in

- How sound in connection with images influences participants' relationships to a scene;
- Sound as contributing to 'immersion' by introducing a dynamic element into an otherwise static scene;
- Sound elements as representing aspects/ideas that otherwise would be invisible, difficult to express.

2.3.5 Collaborative aspects – co-constructing

A core focus of IPCity is on the collaborative aspects of MR technologies. We use a set of key concepts form CSCW research:

Articulation work denotes the ongoing adjustment of action in view of the contingencies that are to do with the situatedness of all social action, hence the fact that practice takes place locally, in specific and known contexts of interdependence, uncertainty, particular resources, competing tasks, shared conventions, and so on (Gerson and Star 1986). Collaborative activities require co-actors to articulate – distribute responsibilities, explain, guide, align, clarify misunderstandings, and so forth. Articulation work is an integral part of collaborative work and, at the same time, a sort of 'meta' activity: "Articulation work is work to make work work"; it comprises all the "activities undertaken to ensure the articulation of activities within the cooperative arrangement" (Schmidt 2002, 462).

Large parts of what participants talk about, whilst engaging with MR technologies has this character of articulation work. Analyzing talk allows us derive i.a. conclusions with regard to a number of issues concerning the usefulness and usability of the technologies.

Artefacts: Many researchers have addressed the crucial role of inscription and material artefacts in cooperative work. They have studied how artefacts are created and shared as part of collaborative activities. Schmidt and Wagner (2004) talk about the crucial part representational artefacts, such as CAD plans, scale models, samples of building materials, 3D visualizations, have in making the invisible visible, specifying, making public, persuading others (of a design idea), enabling designers to explore, evaluate options, and so forth. They also point at the multiplicity, multimediality, multimodality, and openness of many of these design artefacts.

In IPCity we study different kinds of artefacts: tables, handheld devices, maps, displayed images, etc. The focus is on how these artefacts (e.g. particular design features) explicitly and implicitly support and encourage collaboration on the one hand, how they are transformed collaboratively on the other hand.

Boundary objects: CSCW research has examined the role of boundary objects (Star and Bowker 1999) – objects that are at the interface between various communities of practice – in collaboration. We can think of MR technologies as supporting the creation of 'boundary objects' that help make the transformation process of an urban site more collective or

augment the local urban experience with remote experiences represented by shared images, etc.

Lee (2007) introduced the notion of '*boundary negotiation artefacts*', arguing that negotiating boundaries may be considered a special form of cooperative work, where actors discover, test and push boundaries. In relation to the IPCity technologies, this notion suggests we may look at the emerging new digital designs as challenging boundaries and notions of artefacts, and as inviting participants to negotiate and redefine those boundaries: between private and public, material-physical and projected, design and use, professional competence and the perspective of informed citizens, and so forth.

Awareness: Another powerful concept connected to CSCW research is awareness. It was first thematised by Heath and Luff (1992) as 'peripheral awareness', as an aspect of professional practice in co-located environments. Previous work in CSCW argues that there is no uniform awareness, but many types of awareness depending on the cues, the users, and the use situation (Gross et al., 2005, Schmidt, 2002). Within cognitive psychology, awareness refers to an end product of social cognitive processing of technical elements called 'awareness cues' (for an extensive discussion see D3.1). Gaver (2002) has explored aspects of awareness, which he calls "provocative awareness", concentrating on forms of interaction that are more sensuous, less explicit and symbolic, such as 'ambient' information provided by heat, smell, and light.

Place-making: Kristoffersen and Ljungberg (1999) revealed the need for new interaction styles in particular for mobile computing (outside the usual workplace environment), as people are required to "make place" for activity to happen in a way that is practical to the situation at hand. In IPCity technologies, we work directly on designing for an on site scenario, within a portable environment or to address interaction problems encountered while on the move. Inherent to WP6, and the design of MR tent is the problem designing a MR and mobile environment (a place) with interactive objects useful for the ad-hoc interactions. The iterative process addresses continually refining and addressing the specific immediacy of such an environment. With WP7, WP8 and WP9, using MR and AR with mobile devices, on the move and in more game-like scenarios, the act of stopping walking, raising up common ground artefacts to problem-solve we find a multi-user, collaborative and agile form of place-making evolving.

2.4 Questionnaires and structured interviews

The work in each showcase varied in terms of focus, and so too the questionnaires varied to address these different requirements. For example, CityWall and MapLens questionnaires were designed to cross-check the relationship between the states of flow, presence, immersion and intrinsic motivation, as indicators of levels of engagement. Eighteen Likert-type items, rated on a scale of 1–7 were analysed. Participants completed shortened versions of a MEC Spatial Presence Questionnaire (MEC-SPQ), a GameFlow questionnaire and an Intrinsic Motivation Inventory (IMI) to gauge reactions to the display , (Sweetser & Wyeth, 2005), (Deci & Ryan, 2000)For Presence, we asked participants to come up with five words to describe the experience and measured concentration, errors, activated thinking, and imagining space. For IMI, we measured interest/enjoyment, perceived competence, pressure/tension, and effort/importance**.** For Flow, we measured challenge-skills balance, goals, concentration on task, and sense of control. For social presence, we added questions under development and validation through our research project that investigates presence and interaction in urban environments.

There is a similarity in the kinds of states being queried with presence, flow and intrinsic motivation research, even though different language is used. For example, where presence inquires into levels of activated thinking, flow queries conditions required to achieve an optimal state, and intrinsic motivation queries how people perceive they did, and how motivated they were to play with the work for its own sake. These are comparable states of experience, alongside concentration and enjoyment, also queried across all questionnaires. Social presence (awareness and sharing with others) has similar parameters as engagement

with others (asked in both Presence and Flow questions). Flow, engagement, presence and intrinsic motivation are elusive concepts, and, as such, hard to measure. It is difficult to measure how engaging the user experience really is, and so we cross-checked with similar categories from different evaluation methods, rather than just pursuing one system in order to mine for richer information.

Demographics and questions on experience with technology, that would impact the experience were also gathered. Questionnaires provided us with quantitative data about the user experience, as did the ensuing one-to-one semi-structured interviews. We looked at the questionnaire analysis results as an additional resource that was used as support for the video analysis. From previous studies, we found the default presence questionnaires are sometimes too abstract and sometimes too specifically designed for virtual reality research to be used as such in Mixed Reality research, where the experience is created through technologies that vary greatly depending on how they are used. We also needed to translate them into a 'common-sense' language, still retaining the original meaning and with consistent meaning for their translation into Finnish/ German etc. (to ensure they made sense in that culture).

In the semi-structured oral interviews, participants responded to some questions, as well as being encouraged to describe their experience, or highlight aspects that had caught their attention. Interviews were recorded, positive and negative experiences and repeated instances of unsolicited phrases etc were noted.

2.5 Method triangulation

Using just a single method to evaluate a system's usability is an economical but perspective limiting choice. This is especially true for Reality-Based type of interaction systems as there are numerous variables affecting their use: the actual UI interaction paradigm, the physical and cultural setting where the system is used and the social interaction happening around the system. To capture all this and to obtain also information of the users' internal state, a multi-method approach can be used to form a comprehensive understanding of what are the all factors affecting the system's use.

Most often, multi-method use is understood in terms of triangulation schemes, meaning that collected data is validated through cross verification from multiple sources. O'Donoghue and Punch (2003, p. 78) have defined triangulation as a "method of cross-checking data from multiple sources to search for regularities in the research data." Applied this way, triangulation can be seen as a way to enhance the validity and reliability of the study—using a method B one can ensure the correctness of method A's finding.

However, in addition to the methodological triangulation described above, triangulation can also be understood as investigator triangulation (using multiple researchers to do observations) or theory triangulation (using multiple theoretical frameworks to interpret the data) (Denzin, 1978). We have found that mixing these different approaches together can create a powerful toolbox for the RBI evaluation process.

Multi-method use is justified also when the complexity of phenomenon increases, or when research operates on new horizons where it cannot rely on accumulated body of scientific understanding. RBI is exactly about this, as most of the advanced service concepts are only emerging to the market. Also, there are numerous variables affecting the use of advanced RBI systems: the actual UI interaction paradigm, the physical, cultural and social setting where the system is used, etc. This means that the outcome is contingent upon highly situated circumstances and ad hoc interactions, and that there is no way to foresee where service use will evolve in the future.

Therefore, parallel to ensuring correctness of findings related to some research questions, it is equally important to discover what the relevant research questions or research themes are. Using several methods ensures we capture more viewpoints than any single method alone.

Triangulation can be also used as a tool to discover relevant research questions and phenomena from the data when using a grounded theory based approach. Sometimes it is beneficial to dig into the data without any preconceptions of what we can find. This usually means going through the data marking the interesting/relevant episodes with codes, which will be then categorised. If we have collected a substantial set of data, coding can be a very time consuming task. To make the task more economical, we have used a method we call triaging to overcome this problem: another method is then used to find the relevant episodes from the data that will be analysed.

The main drawback of using multiple methods is research economical. Unless one of the methods is used to triage the data, we can end up gathering so much information that it creates time-wise an impossible analysis task for the researchers. Also, having multiple datasets usually means that they will be analysed by a group of researchers which means more effort for organising the process when trying to piece the different results together.

2.6 Comparative analyses

Using test conditions that are comparative and isolate singular aspects, e.g., multi-use, single-use is an efficient way to test singular characteristics, particularly with field testing where many unknown factors from the real environment impact upon the trials. However, where the comparative conditions are synchronously tested, real understanding of the singular conditions is easily measured. A robust way to cross-check findings or to check for discrepancies is to match the findings from one kind of analysis with another. For example to look at video findings and match with logged findings an then again where there are discrepancies or unexplainable findings, to look again at information held within oral interviews or answers in questionnaires or even with researcher interviews. To check with the researchers on hand, looking across these 3-4 sources adds substantially to the richness of the understandings and deals directly with the gap between observational and self-reported understandings. The gap is where *e.g.,* a person is unaware of their habitual or unconscious motives and actions and a video records but does not understand the rationale behind behaviours noted. A rounding up or summation of why or how certain behaviours are repeated across several circumstances is included but the richer the information to support why or how this occurs, the more substantial and accurate is the summation.

As an extended example in MapLens trials, we found no differences in log analysis between AR functionalities. Rather than contradicting the video analysis findings, this apparent *non-finding* (no significant differences) highlights the importance of the role of qualitative analysis: looking just at the logs we could easily come to the conclusion that there were no differences in use when comparing the different group configurations. But the fact that the users viewed the same amount of thumbnails in general does not tell us much: for example, in which situations did they use the system, how many usage sessions did the users have, what were the differences in roles while using the system? Finding out these kind of differences is only possible with qualitative analysis, observing how the users actually used the system. A more detailed understanding of the situated use provides more information on the situated work of the game (Suchman, 1994) and *situated action*, with the actions ever “contiguously changing around [use]” with the activity involved in this process “contingent on specific, unfolding circumstances (Suchman, 2006, b).

As well in cases where we wanted to track and understand particular instances for a behaviour where necessary we also performed cross checking of recorded conversations, looking at what written as a response in the checked boxes and comments sections of questionnaires, checking oral interviews or following up researchers with more specific questions. As the two-core team worked with the same video sections but for counting different aspects, both researchers were very familiar with the footage. Daily discussions during this process to uncover what not only had the other found, but also what they had begun to perceive might be rationale, and to cross-check as odd pieces of the puzzle emerged. For example, during analysis of team roles, one researcher had noted that one main device ‘made the decisions’ and the other devices were kept in more-support-style

roles. The other researcher who had been recording times and frequencies of phone use per user, and per team and condition, then checked this by counting the amount of time and frequency of use to identity the decision (*alpha)* phone in order to cross-check this accurately.

Again comparative analyses and cross-referencing varied across the showcases, with the process dependent largely on what was being investigated. In follow-up studies where a more fine-grained analysis is in process, this proved to be a useful way to better comprehend the more detailed drill-down analysis.

2.7 Urban evaluation approach

The approach to evaluating the four showcases from an urban perspective has been the following:

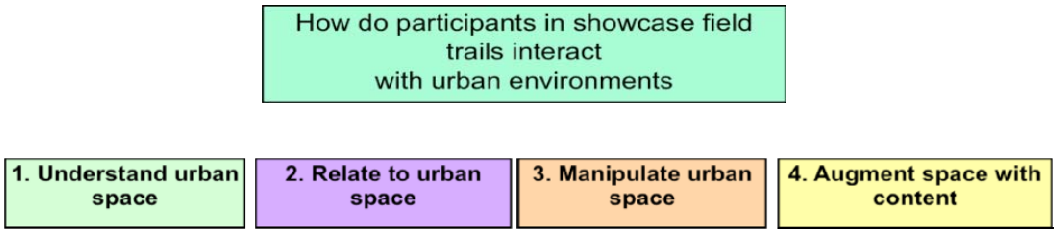


Figure 1: Overview of urban evaluation approach

Understanding urban space. Participants use different medias and technologies to have a common apprehension of the site at its different scales, orient themselves, identify milestones and centralities, main flows and other characteristics of the urban context.

Relating to urban space. Participants develop several types of relationship to the urban space: direct and physical by being located on the site, indirect and virtual through the medias and technologies, but also using their experience and memory of the site.

Manipulating urban space. The technologies empower the participants to interact each other but also collectively with urban space, and allow them to confront ideas, behaviors, decisions, etc.

Augmenting space with content. Participants add information to the urban space, share experiences, visualize eventual modification, emerge in the past or the future, add narrative elements, compose stories, etc.

These four moments should not be considered as linear steps of a work process, participants moving continuously and iteratively from one to the other.

3 Evaluation from the perspective of urbanism

This section contains a summary of evaluation results from an urban planning perspective.

3.1.1 Urban Renewal showcase (WP6)

Figure 2: The MR-Tent in Pontoise

Inputs	System	Output
Varying communication media (Maps, aerial photos-geo referenced or not-, photos, panoramas, videos -fixed and mobile-, other documents produced with GIS or CAD, etc. Multi-sensorial perception of space through their knowledge of the city and the site Individual knowledge, memory, know-how and experience of the site	*In situ* location of the work done by the participants (on the project site) Static positioning of participants (under the tent) Conviviality and user friendliness Visual access to the site is regulated by the placement of the tent and the technologies, the panoramas and the camera views	A shared representation of the site (past, present and future) A collective expertise of existing uses and behaviours A common understanding of the urban problems and controversial issues A set of guidelines which will serve for the construction of the coming debate and which will help decision making.

Table 12: MR-Tent characteristics

Understanding space. The communication media that the participants use are necessary to orient themselves, to identify places and the landmarks and to communicate with the others. These seem to serve less for the construction of a common understanding of space and it is often personal experiences and know-how on uses, habitudes and behaviour which is expressed orally by the participants which allow the constitution of a common culture of the site. These discussions contribute to the construction of the problematic and could eventually lead to the production of content material in real time. Actually, this is done through the organisation of cultural probes sessions and preliminary urban workshops.

Relating to space. The work space is a mobile in situ laboratory designed as a shelter to be placed on the project site where the participants meet with a common objective, get to know each other, exchange, and decide. The table and the roof above are archetypes of a convivial place and the real and virtual windows opening to the neighbouring urbanscape help the research for a collective view of the site. Participants work in this workspace where technologies and communication media (maps, panoramas, etc.) regulate their access to the site. Being on the project site allows participants to be confronted to the reality and the complexity of urban space. The space is collectively experienced and appropriated. It allows at the same time to verify and correct together personal assessments in real-time. Furthermore, the impact of the manipulations implemented can be observed in situ, evaluated and refined.

Manipulating space. The topics on which participants work are by nature controversial. Yet, the characteristics of the workspace being very different from the traditional forms, people are brought together in a mixed-reality gaming environment (in a metaphoric way) which empowers them and which allows them to interact in a constructive way and not to confront each other.

Augmenting space with content. The ideas highlighted during the understanding and the manipulation sessions are put together using content material predefined by the research team or selected by the participants during previous sessions. Although the visual characteristics of this material do not seem to have as much weight as their inspirational capacities, these images are used to compose scenes, which summarise a collective representation of the potential future of the site.

3.1.2 Environmental Awareness showcase (WP7)

Figure 3: The MapLens field trials

Inputs	System	Output
Varying communication media (Aerial photos-geo referenced- with a "you are here" icon, street names for orientation, photos of site, texts, clues for the game (visual/written) Multi-sensorial perception of space through their knowledge of the city Individual knowledge, memory, know-how and experience of the site	*In situ* location of the work done by the participants (on the game site) and their access to city space is not predefined. Dynamic flow of participants in the city through semi-defined pathways and place making activities to realise tasks Conviviality and user friendliness, collaborative dynamics	A shared experience of the city space (present): photos taken by the participants leave a trace of the experience. A better knowledge on city spaces. A better knowledge on issues related to the game scenario (environmental issues and the city, in this case)

Table 13: WP7 MapLens characteristics

Understanding space. One of the main objectives of the showcase is to raise user's awareness of their local environment. This is why the game is designed through questions concerning the real environment and is location specific: the city place is at the origin of the path structure, the tasks and the localisation of these tasks. The idea is to make people rediscover their city and its different sites which become less visible in time to its users: this experience should allow them to build their own narrative of city space on which they can continue to build afterwards. The game allows players to discover new places (for example, the natural history museum and the waterfront), walk along the city, read a map, go around with strangers, enjoy nature and thus to experience the city space in a different way. This adds to the players' memory and understanding of the city. It allows at the same time to gain knowledge on issues related to the game theme, in this case environmental issues concerning the city of Helsinki. Moreover, certain tasks interwoven into the game line such as

“walking barefoot in the grass, gather a specific leaf, test a sample of seawater” allow participants to have another experience of space. Players have been reported to be attentive to their environment while going from one site to the other and have taken photos that are not related to the game while walking around the city to share with others or as keepsake.

MapLens is a tool that provides additional information on city space (photos and street names stored in the database by the researchers), to share information with other teams on city space (teams have access to photos that are automatically uploaded to the database by other teams) and to follow the progress of the teams and their experience during the games. The map (the paper map as well as the aerial photo) allows them to orient themselves within the city, to spatially visualise the different sites, to define a scenario concerning the course that they will take to go from one site to the other (to decide on the order in which they will realise the tasks and the paths that they will take for this). The physical map seems to function better in establishing a common understanding of the area and for referring to different locations: this may be because the size of the Maplens screen does not allow people to collectively study it even though the positioning of the Maplens and the paper map demands their collaboration.

Researchers explain that the Maplens, the game and the timeline oblige the players to be focused on the tasks in hand which might reduce at the same time their understanding of their immediate surroundings and subtract from their experience of the surrounding urban space.

Relating to space. The game is made up of tasks that are subject specific and interwoven into the city fabric. The players occupy space during this time in two ways: they move within city space with aim which necessitates identification of target location and route planning. They then stop either along the way to reorient themselves, to locate a clue or to realise a task. The players move in teams in urban space using clues provided by the game to decide on their direction. The game provides sufficient information for this to become a semi-guided movement where most of the teams use similiar pathways to go from one place to the other.

MapLens system necessitates referencing to the physical map which obliges players to stop and collaborate to accomplish this task. This “encourages the creation of temporary work places (placemaking) along the route. The physical map acts as a meeting point (very much like the ColorTable in WP6) where participants can discuss, demonstrate and then agree upon action. The tasks are related to site specific questions: their realisation necessitate the mobilisation of different types of appropriation (like walking barefoot on grass) and underlines (1) the specificities of the site and (2) transforms them temporarily.

Manipulating space. City space in this showcase acts as the container of the game, the players and their activities. Players interact directly with this space, using its different elements to orient themselves and to decide on the paths that they will take. The road from one task to the other is mainly used to converse/discuss the last or the next task. Players take photos of their environment that are not part of the game while walking which shows that they pay attention to their surroundings while going from one site to the other. A detailed analysis of these photos and a questionnaire concerning the urban elements that have helped them orient themselves would allow us to have more understanding on this question. This should allow to see if and how MapLens modifies our perception of space in relation to the common elements and relations defined by Lynch (1960), pathways, limits, nodes, zones and landmarks.

Augmenting space with content. The city space is temporarily altered by the way the players occupy it. Maplens allows users to fetch location-based media from a HyperMedia Database and visualising them and to upload new ones onto the HyperMedia Database which can be viewed by other users. This allows others to share their newly acquired experience of city space with other teams and other citizens.

3.1.3 CityWall (WP7)

Figure 4: Participants interacting with CityWall

Inputs	System	Output
Photos, images, maps, texts, videos User's individual knowledge, memory, know-how and experience of the city	Is not systematically used in relation to a city theme and location not always correlated *Adhoc* user participation, and this results in place making activities and temporarily transforms the city scape Conviviality and user friendliness, collaborative dynamics	A shared experience of the city space (present) Nonlinear collaborative cycle enriched by individual contributions through sharing of experiences, thoughts Used within the scope of a public consultation, this might be used to inform citizens or public authorities and serve as an exchange platform

Table 14: CityWall characteristics

Understanding space. CityWall aims to get people engaged in the urban environment and interested in what is going on in the city. The objective is to provide citizens with an interactive billboard that would allow them to communicate concerning an event, a project and/or a controversial subject and share their experiences, thoughts or interrogations with others. First trials have focused on the use of this interface as a billboard for photos focusing on city scale events. This has proven non-productive, "users have not processed the actual information on the wall" and the activity has been restricted to learning a new medium." (Morrison et al., 2008) Researchers have decided then to use the interface within the scope of a public consultation, to make the content relevant to a local question. "The aim is to initiate discussions of events that directly impact the lives of the residents of Helsinki." The theme chosen is "nature as nuisance", a question that seems to preoccupy the population of Helsinki due to the ever-growing population of rabbits in the city. Researchers "aim to provoke contributions of texts and images by providing initial content relevant to an urban community." Citywall can serve within this context to create public awareness concerning a given issue. It can inform people of certain evolutions, serve as a blackboard where people share their ideas within the same time frame or in a non-linear time frame. It aims as thus to work as a community chat tool with the integration of SMS, MMS, email and tagging images. It might within this framework help the citizens' understanding of urban space by informing him on certain issues, events or projects.

Relating to space. Citywall is a tangible interface that is placed in city square where passers are attracted by the presence of others interacting with the scene. A vacant and pedestrian place before the scene is a must and allows people to regroup before the screen to interact with it, to watch people interact with it, to discuss on what is being done, to comment on it and to propose an action. This constitutes a public event that draws others to the "attraction". At the moment there is not great freedom on CityWall's placement in the urban context. Numerous meetings with the cultural office, central university buildings etc. have not proved

fruitful for a better-placed venue. This is nevertheless an important issue and the question of frequentation must not be the only issue. There may be other reasons that direct the placement of the screen. For example, a project that attracts interest and controversy may be discussed using this tool on/near the project site. The same thing is true for a city scale event.

Manipulating space. City space is the container of CityWall and houses the events that its use entails. It might at the same time be the main theme of exchange. We do not yet have sufficient information on how users may mobilise CityWall to discuss on issues related to their city, which themes evoke more interest and are central to their discussions and if the interface modifies the concepts, themes and medium which are more often used by citizens on such questions. The information provided (the uploaded data by for example public authorities and by citizens) would at the same time underline certain issues and thus modify the user's perception of city space. This concerns mainly those spaces that are addressed by the content that is used and/or the scenario that is built for its use. The way the CityWall is placed in the city and is articulated to space is another important issue because this seems to temporarily alter this space and the use citizens make of it.

Augmenting space with content. The Citywall allows people to have access and exchange information on city space. This information would naturally "augment" the user's awareness of this space. The localisation of the CityWall in relation to the discussion theme, the possibility to produce data (take photos of the site of a project) and to share it *in situ* (immediately upload it into the system and to be able to visualise it) are the elements which might accentuate this effect.

3.1.4 Timewarp Showcase (WP8)

Figure 5: Walking through Bonn with TimeWarp application

Inputs	System	Output
Varying communication media (Geo referenced map, magic lenses) and clues for the game (visual/oral/written) Multi-sensorial perception of space through their knowledge of the city Individual knowledge, memory, know-how (finding their way) and experience of the city	*In situ* location of the work done by the participants (on the game site) and their access to city space is not predefined Dynamic flow of participants in the city through semi-defined pathways and place making activities to realise tasks Conviviality and user friendliness, collaborative dynamics	A shared experience of the site (present) and a perception of past and future ambience through MR elements introduced into space. A better knowledge on city spaces related to the game scenario (interaction in open space and with landmark).

Table 15: TimeWarp characteristics

Understanding space. The goal of the game is to collect elements from elves (Heinzelmännchen=HM) in different parts of the city and in different time periods. The game scenario induces the participants to find their way in the city and to identify main elements of the site, but also to explore the temporal dimension (past present and future). For security reasons, the game site has been moved from a location which was spread all over the centre of Köln and in a smaller test Christchurch to a unified open space along the river. In the first situation the tasks were planned in meaningful places for the scenario and the participants looked for hints both by using the technical devices and by finding their way in the city.

Relating to space. Performing the game implies to walk all over the site by semi-structured path and to accomplish tasks that have place-making effects. The creation of time portals in particular produce an alignment between the virtual elements of the game and the point where the participants place the portal. The connexion to the city could be strengthened in this case by relating to landmarks for the portal location. Nevertheless, performing the game is a way of occupying the space and creates interactions with passers-by.

Manipulating space. The game scenario is more about experiencing than about manipulating space. The MR tool being split into two devices, the discovery of the site is truly collaborative.

Augmenting space with content. Participants do not contribute to the process of augmentation (MR environment is created by the research team): the game invites them to experience it. The degree of realism of the avatar and of the virtual urban elements participates to the questioning around the capacity of being involved in the mixed environment. Walking through the site to accomplish tasks for the game generates immersion essentially into the virtual game space but material aspects (obstacles and unevenness of the ground) oblige to be confronted with real environment.

The TimeWarp concept implies the creation of past and future environments through several ambience clues:

- Virtual buildings and urban elements (a triumphal arch in the roman age step of the scenario)
- Sound ambience (flute for the medieval time, electronic music for the future)
- HM (avatar) clothes

The (re)construction of scenes corresponding to the city in other time periods than present could generate urban situations beyond the game scenario: original city tours and futuristic events.

3.1.5 CityTales Showcase (WP9)

Figure 6: Storytelling on Naschmarkt

inputs	system	output
Varying communication media (user entered texts, photos taken by mobile phones, mp3 audio files, videos and 3D content in magic lense view) Location-based aerial photos Multi-sensorial perception of space through their knowledge of the city and the site Individual knowledge, memory, know-how and experience of the site	*In situ* location of the work done by the users (in the city) and their access to city space is not regulated. Dynamic flow of users in the city and place making activities to realise tasks encourages users to get into contact with the citizens (during the games designed for the summer school).	A co-constructed multi sensorial (audio-visual) and multi-media (static and dynamic) narration of the city (past, present and future). A geo-located data base enriched by individual contributions without a research for coherence and which allows users to explore different aspects of city space through the experience of others.

Table 16: CityTales characteristics

Understanding space. The Storytelling showcase has for objective the creation of a mixed media based platform that allows the co-construction of a story concerning city space based on the exchange of individual experiences, thoughts, ideas by users (mass audience). Data is geo-referenced, temporally located and indexed with visual fiducials and is accessible *in situ* there where they have been produced.

The MR-Player uses a set of functions on mobile devices that allow on-site urban observations, build a continuous database and collect information from the Second City database.

Relating to space. The user can interact in different ways with the urban space: by strolling around in the search for content elements he or she creates a subjective map of the environment. Creating location based information and other actions of documentation, multi-sensorial perception of experiences and visualization the urban fabric contributes to place making.

Manipulating space. The urban scene is acting as both the object of observation and visualization and the support of a mixed-reality system where real-actual environment and virtual past-future narrative expression reach a certain balance and produce a new experience of the city.

Augmenting space with content. Groups of users co-construct narrative layers of information that augment the urban space. These layers could eventually constitute coherent data that can be exploited by specific group of people: tourists, archaeologist, historians, students, professionals, associations, citizens of special interest groups etc.

4 Key findings and their implications for design

This section summarizes the key findings from each showcase together with the related design guidelines. Detailed descriptions of the observations underlying these key findings can be found in the showcase deliverables.

4.1 Key findings from WP6 Urban renewal

Mapping between events in the RE and events in the VE is done through relational gestures (connecting events on the CT, the screen, and also the physical site), talking, gaze, and bodily orientation within the MR-Tent.

Understand MR scene: A participant tries to match places on the map with the MR scene: “This path here is this path over there” – points first on map (left) and then on screen (right)

Design guidelines:

Provide a sufficiently big map space ‘within reach’ for communicating urban issues with gestures that also supports the public visibility of action.

Consider screen size as an invitation to pointing and as an important aspect of immersion.

Participants collaboratively engage, enact and interact with small handles (content cards, command cards, barcode trays, and tokens) trough touching, holding, placing and moving these objects while discussing, reflecting or waiting. The objects stimulate different senses, creative use and support distributed attention.

Left: Participant moves the sound token with the different material slowly coordinated with the speed of tracking from above. Middle: While discussing the flows across the bridge, a participant grasps a flow token gently beating with it on the map. Right: A participant places a command card on the configuration area while holding a second one.

Design guidelines:

Provide same conditions for each participant (equal accessibility to content, interface and projection) as common basis for discussions and visions.

Provide multiple handles using several small objects varying in form and material to support collaborative interactions and stimulate different senses and creative use.

Through haptic engagement with physical objects (content cards, tokens) participants signal forthcoming action in a way visible to all. Haptic lends an expressive dimension to their interactions. The physicality of the map invites grown practices of touching, pointing, and annotating that support the focused attention of all on an area of intervention.

Left: Participants feel and touch the tokens while gently moving them. Middle: A participant's hand moving a content card in the middle of the table and withdrawing it immediately to grab a token, place it on the table and the content card on top of it.

Design guidelines:

Design possibilities to touch, feel and hold objects of various materials and forms.

Support multiple and creative ways for people to enact and interact with them.

Crossing MR boundaries forms an integral part of participants' understanding the urban site and their interventions. Being on site and sound play a large role in this process.

Switching to a real time camera view – fixed as well as mobile – requires another reassessment of the scene. Reality elements come into play, which stimulate boundary crossings. Participants are delighted to have real people mix into the scene (left).

Participants discuss and create boundaries. They place flows and 3D lines of objects, lines and textures (right).

Design guidelines:

Explore different ways of relating real and virtual in a complex interface, including visual openings to the real site and sound.

Dynamic content (e.g. flows), 3D lines textures, and expressive content (e.g. content representing activities), the size and colour of objects influence the impression of 'realness' of a scene and help participants create narrative structures, insert borders and manipulate the salience of a scene.

Left: The two objects (parking for cars and bikes) that had been placed in the Google map view introduce an element of 'surrealism' into the MR scene. The participants are surprised, but content with the impact of what they perceive as symbolic interventions. Right: The narrative elements of different MR scenes are strengthened by objects that represent activities.

Left: Participants have just placed lines and textures that mark the parking zone they have planned. Right: Coloured in blue the row of cabins pulls the blue building towards them, whilst the trees bind them even stronger together since they are encircling them and these geometrical forms step into the foreground; the green space with the cabins balances the CCI volume having an equal weight.

Design guidelines:

Provide dynamic and expressive content for participants to be able to create narrative structures and to compose a scene expressive to their ideas.

The availability of different forms of representations is a key feature of the MR-Tent; it offers participants different possibilities for constructing, understanding, and evaluating MR scenes.

Left: The physical map lends itself to planning and performing intervention at different scales. Right: One participant directs action. Her pointing gesture is coupled with object manipulations performed by two other participants (right).

Left: The panoramas are strongly edited views of the site with the advantage of providing a 360° view and space for interventions. It is mostly used for constructing scenes. Right: Both real time video streams, fixed camera and scout, have a special 'realness' quality, which however makes the virtual elements stand out as 'model' or 'surreal'.

Design guidelines:

Provide a sufficient number of representations and scales that together cover the whole site, thereby enriching the opportunities for participants to realize interventions.

Permit that the same area or spot can be seen in different representations and from different viewpoints.

Sound is a key element of the participant experience, pervading what they discuss, see and do. Sound contributes to the blurring of MR boundaries; it strengthens immersion into a MR scene; it contributes to the experience of spatial transformations; it evokes ambiences, thereby influencing action; particular interventions trigger engagement with sound.

There is the sound of birds. (11:56) Lots of laughter – all look outside
Ch: *But this not, this is not … magnifique, le chant du merle.* - E pointing outside: *So it is here* (as part of the panorama: in the bushes) *and Monsieur thinks it is there* (outside)! - B to G: *It is the sound of your small garden!* - B: *Where is the sound coming from? Is it here?* - 11:57:21 G: *This … du Hitchcock!* - G says this facing outside, the entire tent front is open, a sound of a motorbike starting up at the rue des Etannets driving past, softly breaking the silence.

In this scene we have three different sources of sound: the panorama sound (with a bird singing), real birds outside the tent, as well as a motorbike passing by. There is a blurring of MR boundaries – the bird sound could be part of the scene but also come from outside and it is associated with the imagined nearby garden of one of the participants.

Design guidelines:
Consider the importance of the real sound at different viewpoints (e.g. add panorama sound; transmit the sound of the AR view of the Scout) as increasing the sense of realness and immersion.
Create surround sound to strengthen immersion.

4.2 Key Findings from WP7 Environmental Awareness

4.2.1 MapLens key findings:

Using AR is more enjoyable in teams. People preferred to work on the same problems together—distributing tasks and working alone did not occur. AR on mobile phones is easily used in multi-user situations. Multi-user teamwork has more 'feel-good' factor than solo use.

Left. Multi-lens team members watching the same location through their own devices, gathering around and discussing. *Centre (two pictures)*: Sharing the AR lens in a single-lens team**,** although distributing non-MapLens tasks to other team members could have been more efficient (all AR tests could have been completed solo). *Right*. Teams started with multiple maps but quickly learnt to share through one map.

Multi-lens teams figured out their own ways to collaborate. Given the opportunity to establish common ground through shared space, teams appear compelled to do so. This may be due to social norms—it is 'usual' to work together when placed in a team, as well as it being more fun to work with others.

Design guidelines:

Ensure the design affords ease of place-making, and establishment of common-ground— by low-fi artefacts, shareable surfaces, screens to share through and collaborative tasks..

Make artefacts that can be easily brought out for use at a moments notice. Clumsy artefacts that require over-careful positioning get used only when it is an extreme necessity.

Agile use extends ad-hoc place-making. A more robust AR system allowed for new forms of place making to evolve: parking and stopping.

In the trials we witnessed much AR use while on the move, half-stopped, while in discussion. Stopping was more casual than with 2008 version as less steady hand was required for the tracking to work.

The more robust system enables *parking* and *stopping* as new forms of place-making to the more traditional *setting-down.* This ability to make quick stops is the direct result of the technical improvements, and consequently adds to the ways in which people managed cooperation around the system. This agile place-making maximises experience and engagement by increasing mobility and extends how collaboration can now occur around *MapLens.*

Design guidelines:

Design AR systems for agile use, for temporary stops, and for use on the move.

Use smaller lightweight tangible artefacts for easier manoeuvring.

Ensure (where needed) tracking systems are robust and can be used close or far.

Economical sharing through displays. Collaboration in the multi-lens situation is characterised by sharing of AR information among the members through the displays that are visible to others. This decreases the amount of communication work necessary.

When not sharing one AR display, participants in multi-lens teams used their own phones to view same augmented information. This minimised the communication work needed (pointing and looking to the environment) and allowed to use the system less frequently and for shorter periods of time. Players could synchronously experience the same view of the information, and established multi-lens common ground procedures on-the-fly.

Maximum amount of devices easily fitting simultaneously on a map of this size was two; additional phones were frequently moved up or to the side. This maximum is dependent on the size and information density of the shared space and on the distance to the augmented object.

Design Guidelines:

Always allow to share a view through the devices available.

Ensure to calculate how much movement is needed between devices and the augmentation target to avoid clashing or inefficiently use of devices.

More devices provide more flexible use. This allows for individual agency.



Multi-lens AR use provides more flexibility for use to teams opportunities to overcome problems of team composition, such as overly dominant users. The use of multiple devices expands individual agency by extending the range of interactions possible and ways in which groups can collaborate, enabling additional tasks such as web browsing, asynchronous use, and less need for co-location.

Design guidelines:

Support more devices where other kinds of activities are to be encouraged as well.

Enable more devices where team composition will impact on user experience.

One alpha lens. Even when multiple AR lenses are simultaneously used and/ or available, one lens emerges as dominant.




Regardless of the number of phones available to a team, there was one dominant *alpha* phone that facilitated the viewing and the decisions. This phone could change, for e.g. depending on which device the latest clue was found with.

Design guidelines:

Assume only one alpha device at a time (else leadership clashes)

Understand who holds the alpha device can change rapidly.

4.2.2 CityWall Key Findings:

People interacted with the display together. CityWall was used most frequently in groups or pairs (or by two individuals in tandem).




In our trials we witnessed that the multi-touch system frequently accommodated multiple users, and different coupling styles.

Design guidelines:

Design with synchronous use in mind, to enable multiple participants at the wall in some kind of relationship to each other.

Design with multiple content (and timelines) in mind.

Unexpected interactions need to be continuously iterated through UCD process.

Mobile territories support active use.


The CityWall 3D worlds proved to be effective solutions to provide mobile territories (Forlines et al., 2008) and access and entry points (Hornecker et al., 2007). In particular Worlds, when they are unused, invite passersby to interact, explicitly, even if someone else is interacting with another world.

Design guidelines:

Enable flexibility in the interface, allowing shift between items and many access points.

Users influenced each other. Users were influenced by others, both through observation and collaborative exploration, as pairs and groups often influenced each other on the wall.


Users felt that they engaged in shared experience with others without the need to change their own actions, indicating that they could share the space without compromising their individual goals

Design guidelines:

Support social presence by allowing learning by observation and collaboration.

Maintain individuality by allowing enough private physical space content on the UI.

Mutual engagement sparks enjoyment.

By allowing worlds and content to overlap, participants were required to be aware of each others activity. This mutual interaction was found to be engaging and enjoyable.

Design guidelines:

Allow overlapping of content to enable joint spontaneous activities.

The UI paradigm can be complex to learn if guided use and gradual exploration are not supported. A novel multi-user natural interface without clear territories having much different functionality can be difficult to learn at first.

With our first 3D prototype we found that browsing through the time with the provided calendar view was hard as the user had to learn many different types of functionalities and interaction styles at once. This was especially hard in multi-user situations, where other people's content could overlap with your own stealing for e.g. the whole screen estate.

Design guidelines:

Users should be guided through the exploration of the functionality, for e.g. using help spheres, which can be brought contextually to the attention of the user at the right moment or made more intuitive in design.

Gradual exploration should be supported so that the interface adapts to the situation a provides a similar starting phase to all users

Add complex functionality gradually with appropriate interactions.

Keep the design holistic. Too many activities and ways to do things can confuse users.

Manage territoriality to support parallel interaction (while still allowing some overlap for spontaneous interaction).

4.3 Key Findings from WP8 Time Warp

Utilizing the underlying environment



Figure 7. a) A car is approaching, b) A crowd is watching the players, c) An innkeeper feels disturbed by the players

(1) Players who are familiar with the locations (in the game space) and know where to go often ignore the game environment as they can achieve their desired goal more easily by simply going towards their destination in the real space. This draws them out with the mixed world into primarily focussing on reality.

(2) The routes taken by players within the gaming environment play a significant part in shaping their level of interest. For example placing the Rose Garden in the middle of the TimeWarp game had the effect of negating the end stage of the game as it was deemed more interesting. Conversely large landmarks such as cathedrals can be used to indicate a clear game end point. It is therefore important to use the potential paths taken by users to infer a narrative structure within the games.

(3) The choice of location has a significant impact on the users perception of the new reality, this can range from feelings of increased danger through to how certain attributes can make it seem more instructive and educational. Therefore care should be taken to use locations, which are relevant both in terms of available activities, size and semantic importance.

(4) Walking around while being immersed in an AR environment strongly inhibits the user's abilities to correctly judge dangers or notice them in the first place. This includes obvious ones like roads. If players do not pay enough attention to traffic, they are in serious danger.

(5) In an open environment like a city players get easily distracted from the game by typical elements that belong to an urban environment. People are one very unreliable element for your game. It is hard to foresee how strangers will react when they see the players equipped with (possibly strange looking) devices. However, this especially becomes a problem when there happen to be crowds.

(6) The cityscape typically changes a lot during the days, weeks, months, seasons or years. In that way, events like ongoing construction work, festivities or other urban events that take place can completely change the chosen game area and might even result in not-playable areas. At this point in time it is typically too late to change anything, and postponements might also not be possible.

Design guidelines:

Avoid making use of the same locations and routes within a game

When you lead players along a path, choose a route designed to the fit the game and narrative structure.

Select potential paths which have clear start, middle and end points

Use locations which reflect the physical and mental objectives of the game

Choose locations that are secure for the users

Avoid crowds

Beware of a series of unforseen events taking place in the chosen game areal

Collaboration is appreciated by players and exploring a new technology together can be more fun.

(1) Collaboration within the gaming experience helps shape the players new sense of a shared reality. By using narrative and game play elements which encourage players to look at, swap an use each others devices it is possible to greatly enhance the gaming experience. This was further extended through the players frequent use of gestural and verbal information to inform the other player about where to go and what to do.

(2) Players prefer situations where they perceive decisions have a clear impact on gaming outcomes, this is even stronger when the decision involves some moral or important decision. Within TimeWarp this applies predominantly when deciding whether to send the HMs to the good or bad timeportal. Conversely players were negative towards the gaming experience when they discovered that their answers to the questions had no relevance to the game.

(3) Collaboration requires that all players feel as if they are important to the experience, in TimeWarp while the navigator played a key role in guiding the players (often through gestural and verbal cues) they often felt their own device was not particularly exciting.

Design guidelines:

Ensure the devices allow for easy collaboration e.g. can be viewed easily by the other player and are easy to hold

Develop content on the devices which promote discussion

Provide clear dilemmas and decisions

Coping with technical issues

Figure 8. a) Time portal, b) GPS fix, c) Players lowering their device

Technical problems can easily distract the player from the game experience.

(1) GPS jitter easily will make your objects float around, which can be very distracting to the users. The graphical quality of your virtual objects can be photo-realistic but when buildings and characters start moving as if by magic people will hardly believe the mixed reality.

(2) Head-mounted displays come with other problems, but their alternative comes with its own problems. Although tablet PCs and especially Ultra Mobile PCs are designed to be carried around and do not seem to be too heavy, this changes if you use them as a see-though device for Augmented Reality applications. Players need both hands to hold up the device in front of their face when walking around the area and looking at the virtual scenery, characters and objects. You can certainly do this for a short time, but when you are expected by the game or application to do this for a longer time, your arms tire easily.

(3) Occlusion between real objects and their virtual counterparts is a common issue with AR applications. If a virtual character moves around the corner of a real house, the house should hide the character from sight. If you have an accurate virtual model of reality (and accurate tracking) you can use this to achieve the effect. Cars, trees or temporary construction sites nevertheless remain a problem.

Design Guidelines:

Use objects where imprecision is not harmful for their believability (e.g. objects in the air or without local reference)

Create technical aids (like e.g. the GPS-Fix which freezes the GPS signal) to support the user when the GPS signal jitters

Provide breaks in which the players do not have to use the device at all or at least can point it at the ground instead of in front of them.

Scout out your locations in advance and make sure you are aware of real life obstacles, and if you cannot solve the occlusion technically in a convincing manner, rather place your virtual objects elsewhere.

Time-critical activities can increase engagement and presence in the game.

Figure 9. The images illustrate the typical process of time travelling: a) Player 2 creates a time portal by choosing a time and clicking on the map, b) Both players look if they can see a time portal on the UMPC of player 1. c) Player 1 spins around to find the time portal, d) Both players walk quickly towards and then through the time portal

(a) Time pressure requires the users to solve the game tasks in a limited time. This effect had a positive impact on many players and helped them to fully concentrate on the game and get engrossed in the story. This does not mean that the entire game needs to have a time limit, but rather that certain tasks should be time critical. In TimeWarp the most time-critical action was time-travelling.

(b) One big advantage from Augmented Reality games set in the outside world is the fact that players have to physically move around to explore the game area. Try to create situation where they not only have to casually stroll along but have to walk faster or even run. This creates a more engaging gaming experience.

Design guidelines:

Integrate time critical tasks

Create situations in which the players not only have to casually stroll along but have to walk faster or even run

Narrative

(a) A problem that comes along with narrative game design is the adequate length of storytelling elements. When your virtual characters engage in dialogue with the players or other virtual characters, play close attention to the length of this dialogue. Make sure to tell them enough to understand the important things, but be short

enough to not bore them. Do not let them stand around just waiting for somebody to finish their monologue.

(b) Players will expect the same high-end graphics in an Augmented Reality game as in the latest first person shooter for their desktop PC. Unfortunately this is hardly reachable with current mobile devices. Nevertheless, virtual characters also profit from a convincing character design to a great extend.

(c) While adjusting and connecting the virtual content with the real world, make use of narrative to make the link. Instead, clearly relate them to the locations and have your characters reference real objects frequently.

Design guidelines:

Avoid long monologues of virtual characters

Create convincing characters by choosing professional sounding voice actors and emotionally engaging dialogue

Relate virtual content with real

4.4 Key Findings from WP9 City Tales

Personal mobility is a key aspect in urban environment

and that is what highly influences the way content should be integrated into the urban tissue. Lengthy text, videos or MR content calling for more complicated interaction is causing users to settle at locations for longer times and distract from the flow in the city. This literally removes the user from the urban environment, transforming him or her into a foreign particle.



Left: in the very crowded and pulsating environment of the Naschmarkt target investigation area user (outlined person on left) often had to face encounters with other pedestrians (two ladies on left) so moving/walking while browsing content was a hardly possible option.

Middle: Two users (outlined) using one device clog the way, have to move close to the seated guests of a restaurant where the flow of persons is stopped, so they can concentrate on the content and share this among each other.

Right: User (outlined) is reading a lengthy text on the mobile device again standing in the way for other pedestrians. If such stops can be minimized the experience and the connection of it to the urban flow is much more viable.

Design guidelines:

Provide shorter experiences rather often than longer 'chapters'!

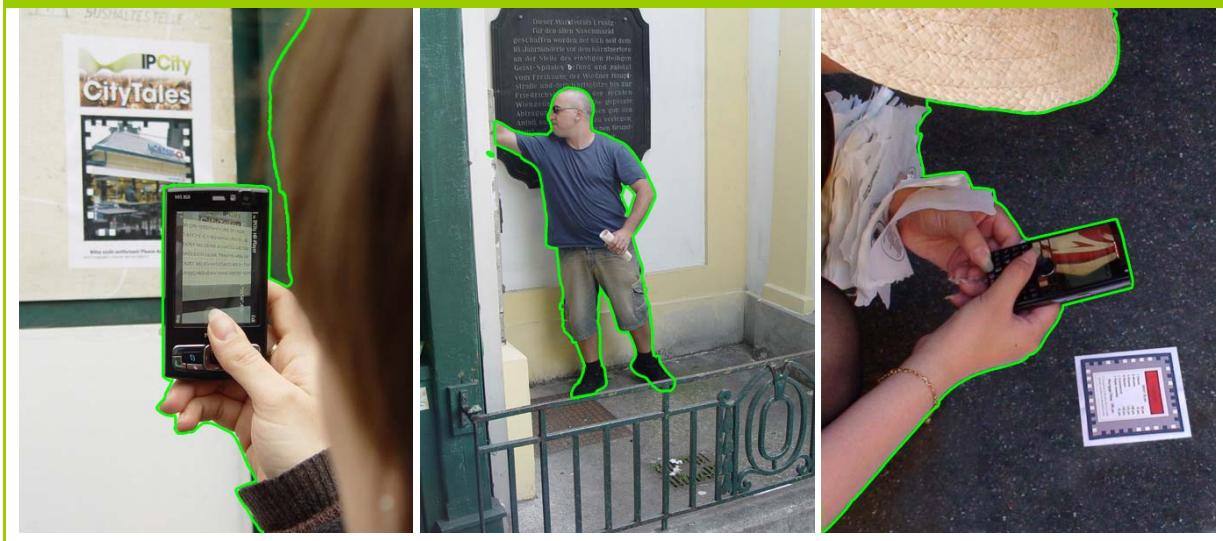
If text is needed keep it to a minimum, not longer than a minute to read!

Favour audio, video, MR, images, over text!

Use audio in a consistent and supporting way in high-quality as narration or to personate your characters. This can bring them 'alive'!

MR content for story-telling in urban environment is a valuable feature,

but not a continuous must. From our field trials we can deduct that story-telling on the go by just one type of media only creates an imperfect balance of sensual stimulation. As the urban environment itself excites us with visual, aural, tactile, etc. influences the mixed-reality experience should not rely on one channel only! To tell stories a careful design and balance between text, imagery, audio and – what we call – "augmented artefacts" creates the best user experience.



Left: User is decoding a hidden poem as part of the story "The lovers on the Naschmarkt". After having identified the exact location of the content in the environment by finding the standardized fiducial marker the mobile phone is used to decode the content. The love poem is displayed as a virtual scrap of paper placed on the wall. Additionally the user can hear protagonist conversation as an addition.

Middle: the user passes even fences to decode 'secret' content, such as the 3D model of a mystic symbol of an underground society. Finding such 'augmented artefacts' enhances the story experience and engage users more in depth.

Right: User is decoding a marker placed on the ground, displaying a message augmented over the otherwise readable instructions and adds a message for the community. Tagging in 3D with content created by users on the go in combination with the urban environment allows extension of the metaphor to the community aspect.

Design guidelines:

Design the assets well to understand where and why to include MR-content!

Depending on the story universe this can be more or less, but it should definitely fit!

Go first to the actual location before starting to design something! Misfit MR content can ruin more than help.

The idea of "augmented artefacts" seems to create the best suspension of disbelief – objects or place extensions you would expect when entering the story!

Content integrating the actual urban environment

is the only way to create compelling stories! With the different scenarios tested during the course of the project and attempting to transfer content to other locations a very important finding influencing future urban story-telling was discovered. Relocating stories is hardly possible as taking out all urban context completely destroys the experience or creates an enormous overhead on the integration to a new site.

Understanding the place is a key issue to a succesful story-telling experience in urban environments as we discovered. It is not enough to visit the place once as – especially busy spaces as the Naschmarkt – constantly change with the times of day, show different faces on weekends in summer/winter. To do this significant effort was put in "understanding" the place by creating a baseline for story-telling and investigations. Our experience suggests that this is crucial to any new project!

Left: Based on the knowledge of the locality the course placement of story elements is an offline procedure. Here the situation aware parts of the story are localized or in actually "staged" making it problematic to transfer the content easily to a new urban location.

Middle: On the fine level placement – in our case of fiducial markers – is an on-site task. Integrating the marker or/and the content attached to it influences the success of the experience. Embedding the marker next to other stickers on an advertisement poster seems natural and well integrated. In this case even the augmented artefact fits well as it displays a scrap of paper with a hidden love poem.

Right: Situations where the augmentation merges with the real can be really powerful. Here a dead person (outlined) is lying on the tracks of the subway that can be seen from a bridge within Naschmarkt are. In the story this character was murdered by an unknown person. Discovering him on the tracks really creates a moment of shock at the actual location as mind starts to process possible consequences of such an event!

Design guidelines:

Start from the real environment by investigating it deeply!

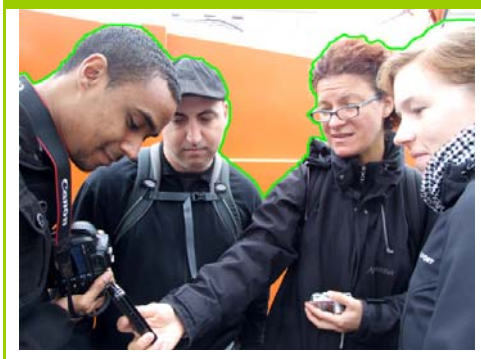
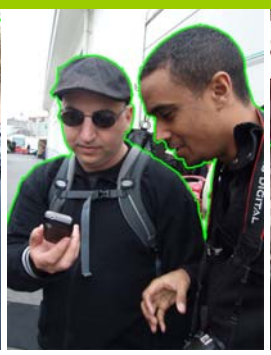
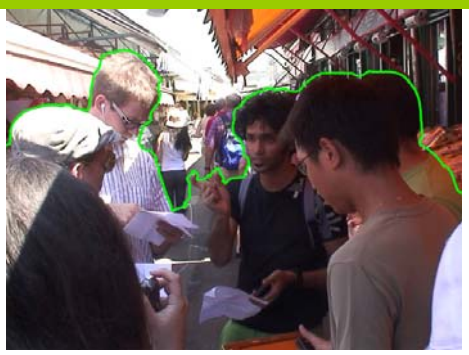
Do create the story in conjunction with the urban environment's features!

Do rather 'stage' – like a play for theatre, rather than write a book.

The improbable way experiencing the pieces of your story must warn you to create rather momentary 'snapshots' in the story-line acting at places, than a fully engineered story-line. Think of the MR-experience as a separate 'story universe' that you document and the user will enter to explore!

MR story-telling is a community building shared experience,

in the sense that users do interact, communicate both during and away from the experience what they have discovered or found interesting. Much like after holiday experiences which are shared in a group if participants who did visit the same location, users are sharing their distributed know-how on the stories.

Left two: Users – even while using one device or just meeting by coincidence – are sharing information discovered during their experience. In this situation their mobile device cached story elements that could be retrieved later. Originally this feature was integrated to shorten download times when returning to the same location. The feature was then rather used to show-off to others and synchronize what was found.

Right: In the "SoundMeal" urban game based on the Second City story-telling architecture users had to meet after a certain period in time at a specific location – the target shop of the actual round (see details in D9.4). This meeting point recurring during the experience regularly was encountered as a major event of the game as it provided the opportunity to exchange. In this field trial even the final aim of the game was to organize a picnic together what further enhanced the effect of community building.

Design guidelines:

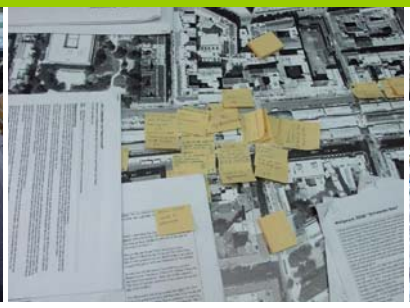
Entering the 'story universe' brings users onto a journey! Make sure to prepare them for this – i.e. give an introduction how this story is to be perceived, some instructions how to discover the MR part of the experience.

Try to enhance the community building aspect with supporting acts that brings participants together for exchange, such as synchronised events occurring in time.

Giving the chance to contribute and designing a game around the experience opens back-channels, attracting to participate (see also below).

Adding content to a mixed-reality urban story universe is attractive

and could greatly be a success factor for both social networking scenarios and commercial implementations. If given the chance and the access the motivation to add arises inherently not only in the current social network affine generation of youngsters, but also in the mind of professional authors, cultural heritage preservation specialists and further groups working in the urban context.


Process from upper left to lower right (1-6): When confronted to the author one of the urban stories (Wolfgang Stindl on the right in 1), participants of the IPCity Summer School started to develop an enthusiasm for the topic, as it was clear the MR urban story-telling environment is not a finished given situation, but rather a framework that allows extension, expansion and any further detail in-between.

After laying out the situation and developing a new idea how to extend the 'story universe' (2), significant effort was taken to develop details (3), content creation including audio recordings (4) were carried out and results were integrated into the database (5). The results were investigated on site (6) creating much applause and proud. We are very convinced that such a system rolled out into the real world could easily create a community contributing based on the same empowering motivation we experienced the most during the week of the IPCity Summer School!

Design guidelines:

Starting off with less content is shameful if system allows easy contribution. Do start rather early and ignite your users imagination to add their own contribution!

Focusing the stories around a dedicated user group (by age, by interest, etc.) will help to create a stronger attraction to the 'story universe' and thus encourage better to add content!

5 Conclusions

This section synthesizes the common conclusions to be drawn from experiences with a diversity of outdoor urban Mixed Reality applications in the form of design guidelines. While design considerations concerning the more technical aspects are described in the first section this concluding synthesis reflects the key findings from all showcases.

Our findings and recommendations focus on six salient issues:

- How to design for a meshing of real and virtual – imagined – elements of a city in terms of scale, representations, and boundaries;
- What to observe when planning to provide new ways of experiencing the city;
- How to support spatial, social and material aspects of presence, as well as engagement and immersion;
- How to support participation and collaboration;
- What to observe when designing for tangible and embodied interaction;
- How to facilitate participants' engagement.

Designing for Mixed Reality experience in the city

Explore different possibilities of relating 'real' and 'virtual' in a complex interface, e.g. make use of the environment and people, augment material objects.

Provide opportunities for participants to cross MR boundaries.

Use objects (e.g. buildings) where imprecision is not harmful for their believability.

Provide dynamic, (visually) expressive and potentially controversial content for participants to express

their ideas or open a debate.

When designing for experiences on a city scale, provide a sufficient number of representations of a site in different scales to work with.

When using mobile devices, design for agile use, temporary stops, and use on the move.

Always start from the real environment and investigate it deeply for clues that help anchor the MR experience in the city.

Designing for engaging with the city

Ensure that participants are exposed to the reality and complexity of an urban site and allow for another experience of the site.

Ensure that the MR environment allows participants to interact in constructive (rather than confrontational) ways and to arrive at collective 'results'.

Provide maps (eventually of different scales) to help participants orient in the city and think of the affordances of physical maps.

When designing an outdoor game, support path-finding by using locations that fit the narrative structure of the game and that stimulate engagement with the real environment.

Reflect on where to install a public installation, depending on the issues to explore and on how this installation temporarily alters the space.

Think of how to augment participants' awareness of a place or site (e.g. with location-based information, augmentations of real objects, elements that help investigate the past or the future of a place).

When designing an outdoor game, think about relating a path to landmarks, pathways, nodes and zones.

Designing for presence

Think of MR boundaries, the visibility of action, and parameters such as screen size as critical for the mapping of events in RE and VE.

Think of multimodality as a salient element of story-telling and all forms of user experience in MR environments.

Work with sound to convey the ambience of a place or its spatial properties, as well as to increase the liveliness of a virtual character, as sound strengthens immersion in a MR environment.

Consider the importance of real sound and create surround sound.

Make use of the material aspects of presence by design possibilities to touch, feel and hold objects of various materials and forms.

Support social presence by allowing learning by observation and collaboration.

Increase participants' engagement (e.g. with a game) by integrating time critical tasks, by using elements of drama, and by focusing on specific user groups.

Designing for Collaboration

Design for equal accessibility of content and interface for all participants.

Provide shareable surfaces, screens to share through, as well as collaborative tasks.

When designing a tangible user interface, provide multiple physical handles to support collaborative interactions.

Design with synchronous use in mind.

Enable more devices where team composition will impact on user experience.

Think of the size of the interface with respect to collaborating in a task.

When designing a multitouch application, manage territoriality to support parallel interaction and allow overlapping content.

Ensure that the design affords ease of place-making and establishing of common grounds.

Where narrative or story elements are used provide clearly important decisions, which can be taken by at least two of the users.

Designing for tangible and embodied interaction

Use various forms, materials and colours to awake multiple senses (visual, acoustic, haptic) and creative uses.

Work with familiar interaction modes from everyday life and favour simple and consistent interactions, simple to learn and clear to perform.

Provide multiple small, light-weight artefacts for easy manoeuvring.

When designing a complex interface, think of a clear workspace design with tools and objects easy to find.

Add complex functionality gradually with appropriate interaction and cues

Provide space for movement and the gathering around of people

Design tasks that require physical proximity between participants

Allow for a diversity of interactions and combinations of interaction including those which encourage different paced behaviour e.g. rapid movements or running.

Designing for enabling the user experience

Think about how to motivate participants and facilitate their engagement.

Help participants familiarize themselves with the tools and think of creating technical aids where breakdowns are to be expected..

When engaging participants in issues of urban renewal aim at participants arriving with their own vision of the kind of interventions they would like to explore and ensure that they find the content they need for entering the debate of an urban project. Also design for openness and freedom of expression.

When designing an outdoor game, scout out your locations in advance and make sure you are aware of real life obstacles, such as seasonal changes and temporal events.

If planning to scale MR experiences on mobile devices to large user bases follow industry standards, use widely available hardware, and plan the effort to support multiple platforms.

6 References

Alexander, C. et al., Pattern Language, Cambridge, Mass, MIT Press, 1977.

Amphoux P., Thibaud, J.-P., CVhelkoff, G., Ambiances en débats, A la croisée, Bernin, 2004.

Augé, M. “Non places”, Paris, Le Seuil, 1992.

Benford S, C Greenhalgh, G Reynard, C Brown, B Koleva. Understanding and Constructing Shared Spaces with Mixed Reality Boundaries. ACM Transactions on Computer-Human Interaction, vol. 5, no. 3, pp. 185-223, Sep. 1998.

Benyon, D., Smyth, M., O’Neill, S., McCall, R. and Caroll, F. (2006). The Place Probe: Exploring a Sense of Place in Real and Virtual Environments. *Presence*, 15, 6, 668–687.

Billinghurst Mark, Hirokazu Kato, Ivan Poupyrev: The MagicBook: a transitional AR interface. Computers & Graphics 25(5): 745-753 (2001)

Bimber Oliver, Ramesh Raskar: Spatial Augmented Reality – Merging Real and Virtual Worlds. AK Peters, 2005.

Biocca, F. (1997) The cyborg's dilemma: embodiment in virtual environments. In: Proceedings of the Second International Conference on Cognitive Technology 'Humanizing the Information Age', Aug 25-28, 1997.

Bowker, G. & Star, S. L. (1999). *Sorting Things Out: Classification and Its Consequences.* Cambridge, MA: The MIT Press.

Callon, M., Lascoumes, P. et Barte, Y., Agir dans un monde incertain, essai sur la démocratie technique, Paris, Le Seuil, 2001.

Castells, M., The Rise of the Network Society, The Information Age: Economy, Society and Culture Vol. I. Cambridge, MA, 1996.

Chang, A., Gouldstone, J., Zigelbaum, J., and Ishii, H. 2007. Simplicity in interaction design. In *Proceedings of TEI* (Baton Rouge, Louisiana, February 15 - 17, 2007). TEI '07. ACM, New York, NY, 135-138.

Cao X., Li J., Balakrishnan R. (2008) Peephole pointing: modeling acquisition of dynamically revealed targets. In: Proceedings of the SIGCHI Conference on Human Factors In Computing Systems (CHI'08). ACM, New York, pp 1699–1708.

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*. Harper and Row, New York.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. (1994). Facilitating internalization: The self-determination theory perspective. *Journal of Personality*, 62, 119–142.

Deci, E. L., Ryan, R. M. The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. (2000). *Psychological Inquiry* 11, 227–268. Questionnaires: http://www.psych.rochester.edu/SDT/measures/IMI_scales.php

Deleuze, G. et Guattari, F., Mille Plateaux, Paris, Éditions de Minuit, 1980.

Denzin, N. (2006). *Sociological Methods: A Sourcebook*. Aldine Transaction.

Derrida J., Peter Eisenman, Chora L Works, ed. Jeffrey Kipnis and Thomas Leeser, New York, The Monacelli Press, 1997.

Djajadiningrat T., Wensveen S., Frens J. and Overbeeke K. (2004): Tangible Products: redressing the balance between appearance and action. In Personal and Ubiquitous Computing, 8 (5) pp. 294-309

Dourish, P. (2001) Where the Action is: the Foundations of Embodied Interaction. London, MIT Pres.

Erickson, F. (1992). The interface between ethnography and microanalysis. In LeCompte, M.D., Millroy, W.L. and Preissle, J. (Eds.). *The handbook of qualitative research in education*. Academic Press, San Diego, CA, 201–225.

Fitzmaurice George W.. Graspable User Interfaces. PhD thesis, University of Toronto, 1996.

Floridi, L(2007) The Philsophy of Presence: From Epistemic Failure to Successful Observation. Journal of Presence: Tele-operators and Virtual Environments 14:6 p656-667

Gaver, B. (2002). Provocative awareness. *Computer Supported Cooperative Work* 11, 475-493.

Gerhard M., Moore D., Hobbs D. *Embodiment and copresence in collaborative interfaces;* International Journal of Human-Computer Studies; Volume 61, Issue 4, Pages 453-480; Elsevier Science Ltd 2004.

Gibson, J.J. The Ecological Approach to Visual Perception(1986). Erlbaum, Hilldale, NJ.

Goldiez, B., Dawson, J., W. Is Presence present in Augmented Reality systems? In proceedings of Presence 2004. VII. International Workshop on Presence - “Presence 2004”, October 13.-15. 2004, Valencia, Spain, 294-297.

Goodwin, Charles (1998). Pointing as Situated Practice. In S. Kita (Ed) *Where Language, Culture and Cognition Meet*. Lawrence Erlbaum Associates.

Halliday, M.A.K. (1978) *Language as a Social Semiotic: The Social Interpretation of Language and Meaning.* Edward Arnold, London.

Haviland, John B. (2000). Pointing, gesture spaces, and mental maps. In D. McNeill (Ed) *Language and Gesture*. Cambridge UK, Cambridge University Press: 13-46.

Healey, P.T.G., Leach, J., Bryan-Kinns, N. (2000).Inter-Play: Understanding Group Music Improvisation as a Form of Everyday Interaction. http://scholar.google.at/scholar?cluster=5567332340511431994&hl=de&as_sdt=2000

Heath, C. and P. Luff (1992): Collaboration and Control: Crisis Management and Multimedia Technology in London Underground Line Control Rooms. *Computer-Supported Cooperative Work*1 (1–2), 69–94.

Heeter, C (1992) Being There: The subjective experience of Presence. Presence 1(2): 262-271.

Henrysson A., Billinghurst M., Ollila M. (2005) Virtual object manipulation using a mobile phone. In: Proceedings of the International Conference on Augmented Tele-Existence (ICAT), pp 164–171.

Herbst I., Braun A.-K., McCall R., Broll W. (2008) TimeWarp: interactive time travel with a mobile mixed reality game. Proc. ACM MobileHCI, pp. 235-244.

Hindmarsh, J. and Heath, C. (2000) Embodied reference: A study of deixis in workplace interaction. *Journal of Pragmatics* 32, 1855-1878.

Hindmarsh, J. and Pilnick. A. (2002) The Tacit Order of Teamwork: Collaboration and Embodied Conduct in Anesthesia . The Sociological Quarterly, Vol. 43, No. 2 (Spring, 2002), pp. 139-164

Hirose M., Y. Ohta, S. Feiner, Guest Editors’ Introduction Special Issue on Mixed Reality, Presence 11(2), 2002.

Hollan J., Hutchins E., Kirsh D. *Distributed cognition: toward a new foundation for human-computer interaction research*; Transactions on Computer-Human Interaction (TOCHI) Volume 7 , Issue 2; Special issue on human-computer interaction in the new millennium, Pages: 174 – 196; ACM 2000.

Hornecker, E., Buur, J. (2006): Getting a Grip on Tangible Interaction: A Framework on Physical Space and Social Interaction. Proc. of CHI 2006. Montreal, Canada (full paper). ACM, pp.437-446.

Hummels C., Overbeeke K. C. J. and Klooster S. (2007): Move to get moved: a search for methods, tools and knowledge to design for expressive and rich movement-based interaction. In Personal and Ubiquitous Computing, 11 (8) pp. 677-690

Ijsselstein, W. & Riva, G. (2003) Being there: The experience of Presence in mediated environments. In Riva, G., Davide, F. & Ijsselstein, W.A. (eds.) Being there: Concepts, effects and measurements of user Presence in synthetic environments, pp. 3-16, IOS Press, Amsterdam.

IPerg (2005). The official IPerG (Integrated Project on Pervasive Gaming) web site available online: http://iperg.sics.se/

Jacob, R. J., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T., and Zigelbaum, J. (2007). Reality-based interaction: unifying the new generation of interaction styles. In CHI '07 Extended Abstracts on Human Factors in Computing Systems (San Jose, CA, USA, April 28 - May 03, 2007). CHI '07. ACM, New York, NY, 2465–2470.

Jacob, R. J., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T., and Zigelbaum, J. (2008). Reality-based interaction: a framework for post-WIMP interfaces. In Proceeding of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems (Florence, Italy, April 05 - 10, 2008). CHI '08. ACM, New York, NY, 201–210.

Jackson, S.A., and Marsh, H.W. (1996). Development and validation of a scale to measure optimal experience: The Flow State Scale. *Journal of Sport and Exercise Psychology*, 18, 17–35.

Jegers, K. Pervasive game flow: understanding player enjoyment in pervasive gaming. Proc CIE 5, 1 ACM Press (2007), Article 9.

Jewitt, C. (2009). What is Multimodality? In Jewitt, C., et al. (Eds) *The Routledge Handbook of Multimodal Analysis.* Routledge.

Jones, Stuart (2006). "space-dis-place: How Sound and Interactivity Can Reconfigure Our Apprehension of Space." Leonardo Music Journal 16: 20-27.

Kendon, A.: Conducting Interaction: Patterns of Behaviour in Focused Encounters. Cambridge University Press (1996)

Kirsh D. *The intelligent use of space;* Journal of Artificial Intelligence; Volume 73 , Issue 1-2 ; Special volume on computational research on interaction and agency, Pages: 31 – 68; ACM, Elsevier Science Ltd. 1995.

Kristoffersen, S., Jungberg, F. L. “Making place” to make IT work: empirical explorations of HCI for mobile CSCW. In Proc. International ACM SIGGROUP 1999, ACM Press (1999), 276-285

Klopfer, E. (2008). Augmented Learning Research and Design of Mobile Educational Games. MIT Press, Cambridge, MA, USA.

Knoblauch H. et al. Visual Analysis. New Developments in the Interpretative Analysis of Video and Photography. *Forum: Qualitative Social Research* 9, 3, Art. 14 (2008).

Kress, G., and Van Leeuwen, T. (1996) *Reading Images. The Grammar of Visual Design. Routledge, London.*

Lainer, R. und Wagner, Ina (1998). Connecting Qualities of Social Use with Spatial Qualities. In Streitz, N., et al. (Eds) *Cooperative Buildings - Integrating Information, Organization, and Architecture*. Lecture Notes in Computer Science. Springer: Heidelberg, 191-203.

Larssen, A. T., Robertson, T., and Edwards, J. (2007) The Feel Dimension of Technology Interaction: Exploring Tangibles through Movement and Touch. *Proceedings of TEI'07* (Baton Rouge, LA, Feb 2007), 271-278.

Latour, B., La Science en action, Paris, Gallimard, 1995.

Laurier, E., Strebel, I., and Brown, B. (2008) Video Analysis: Lessons from Professional Video Editing Practice. *Forum: Qualitative Social Research* 9, 3, Art. 37.

Lee, C. (2007). Boundary negotiating artifacts: unbinding the routine of boundary objects and embracing chaos in collaborative work. *Computer Supported Cooperative Work* 16 (3), 307-339.

Loke, Lian, Astrid T. Larssen, et al. (2005). Labanotation for Design of Movement-Based Interaction. *Proceedings of Second Australasian Conference on Interactive Entertainment*, Sydney, Australia.

Lombard, M. and Ditton, T(1997) At the heart of it all: The concept of Presence. Journal of Computer Mediated Communication, 3 (2).

Lynch, K., The image of the City, Massachusetts, The MIT Press, 1960.

MacIntyre, B., Bolter J. D., Gandy, M. (2004) Presence and the Aura of Meaningful Places. Presence 6/2, 197-206.

Mantovani, G. and Riva, G(1999) "Real" Presence: How different ontologies generate different criteria for Presence, telePresence, and virtual Presence. Presence: Teleoperators and Virtual environments no. 8 vol 5, 538-548.

Mehra S., Werkhoven P., Worring M. (2006) Navigating on handheld displays: Dynamic versus static peephole navigation. ACM Transactions on Computer-Human Interaction (TOCHI) 13(4):448–457.

Milgram, P. and Kishino, F. A taxonomy of Mixed Reality visual displays. IEICE Transactions on Information Systems 77, (1994), 1321-1329.

Mitchell, W., City of Bits, Cambridge, Mass, MIT Press, 1996.

Mondada, L. Using Video for a Sequential and Multimodal Analysis of Social Interaction: Videotaping Institutional Telephone Calls. Forum: Qualitative Social Research 9, 3, Art. 39 (2008)

Morrison, A., Jacucci, G., Peltonen, P. (2008). CityWall: Limitations of a Multi-Touch Environment. Public and Private Displays workshop (PPD'08), AVI 2008: the International Working Conference on Advanced Visual Interfaces. Naples, May, 2008.

Morrison, A., Oulasvirta, A., Peltonen, P., Lemmela, S., Jacucci, G., Reitmayr, G., Näsänen, J., and Juustila, A. 2009. Like bees around the hive: a comparative study of a mobile augmented reality map. In *Proceedings of the 27th international Conference on Human Factors in Computing Systems* (Boston, MA, USA, April 04 - 09, 2009). CHI '09.

Norbert-Schulz, C., Intentions in Architecture, Universitets Forlaget, Oslo, 1962.

Norris, Sigrid (2004) *Analyzing Multmodal Interaction*. Routledge, London.

Novak, M., Next Babylon : Algorithm To Play, In "The Art of the Accident", Rotterdam, NAI Publishers/V2 Organization, 1998

O'Donoghue, T., Punch K. (2003). Qualitative Educational Research in Action: Doing and Reflecting. Routledge.

O'Halloran, Kay L. (2008). Systemic functional-multimodal discourse analysis (SF-MDA): constructing ideational meaning using language and visual imagery. *Visual Communication* 7(4), 443-475.

O'Neill, S.J. Presence, Place and the Virtual Spectacle. PsychNology 3, 2 (2005), 149-161.

O'Toole, M. Opera Ludentes: The Sydney Opera House at work and play. In K. O'Halloran (ed) *Multimodal discourse analysis: Systemic functional perspectives*. Continuum, London 1994, 11-27.

Pierce, J. S., Forsberg, A. S., Conway, M. J., Hong, S., Zeleznik, R. C., and Mine, M. R. 1997. Image plane interaction techniques in 3D immersive environments. In Proceedings of the 1997 Symposium on interactive 3D Graphics, ACM, New York, NY, 39-ff.

Pink, S. (2007) *Doing visual ethnography*. Sage, London.

Rossi, A., The Architecture of the City. New York City: Opposition Books, 1982. Pg. 130

Rohs M. (2007) Using Visual Markers for Embodied Interaction in Handheld Augmented Reality Games. In: Magerkurth, C, Röcker, C (eds) Concepts and Technologies for Pervasive Games. Shaker Verlag, Aachen, pp 207–230

Rohs M., Oulasvirta A. (2008) Target acquisition with camera phones when used as magic lenses. In: Proceedings of the SIGCHI Conference on Human Factors In Computing Systems (CHI'08), pp 1409-1418.

Schmidt, Kjeld & Wagner, Ina (2004) Ordering systems. Coordinative practices and artifacts in architectural design and planning. *Computer Supported Cooperative Work* 13, 349-408, 2004.

Schmalstieg, D., Wagner, D. 2007. Experiences with Handheld Augmented Reality. In Proc. IEEE International Symposium on Mixed and Augmented Reality, ACM Press, 3–18.Handheld AR for Collaborative Edutainment. In Proc. ICAT 2006, Springer.

Scollon and Scollon 2003

Stenglin, Maree Kristen (2009). Space odyssey: towards a social semiotic model of three-dimensional space. *Visual Communication* 8(1), 35-64.

Suchman, L. (1994). Plans and situated actions: The problem of human-machine communication: Cambridge University Press.

Suchman, L. (1995). Making work visible. Paper presented at the Commun. ACM.

Suchman, L. (2006). Human-Machine Reconfigurations: Plans and Situated Actions (2nd ed.). USA: Cambridge University Press.

Tang J.C., Minneman S.L. *VideoDraw: A Video Interface for Collaborative Drawing;* Transactions on Information Systems (TOIS); Volume 9, Issue 2; ACM 1991.

Turner, P. (2007). The Intentional Basis of Presence. In the Proceedings of the 10th International Workshop on Presence, Barcelona, Spain. P127-134

Turner, P. & Turner, S. (2002) Embedded Context of Use in CVE Design. Presence vol. 11, no. 6, pp. 665-676.

Ullmer Brygg and Ishii. Hiroshi Emerging frameworks for tangible user interfaces. IBM Syst. J., 39(3-4):915_931, 2000.

Ullmer, Brygg Ishii, Hiroshi and Jacob Robert J. K.. Token+constraint systems for tangible interaction with digital information. ACM Trans.Comput.-Hum. Interact., 12(1):81□118, 2005.

Van Leeuwen, T. & Jewitt, C. (2001). (Eds). Handbook of Visual Analysis. Sage, London.

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

Wagner, Ina, Basile, M., Ehrenstrasser, L. Maquil, V., Terrn, J.-J., Wagner, M. (2009) Supporting Community Engagement in the City: Urban Planning in the MR-Tent. *Proceedings of C&T (Communities & Technologies) 2009*, Penn State University, University Park, PA, USA.

Wensveen, S. A., Djajadiningrat, J. P., and Overbeeke, C. J. 2004. Interaction frogger: a design framework to couple action and function through feedback and feedforward. In *Proceedings of the 5th Conference on Designing interactive Systems: Processes, Practices, Methods, and Techniques* (Cambridge, MA, USA, August 01 - 04, 2004). DIS '04. ACM, New York, NY, 177-184.

Zahorik, P. & Jenison, R.L. (1998) Presence as Being-in-the-World. Presence vol. 7 no. 1, 78-89.

Acknowledgements and Further Information

IPCity is partially funded by the European Commission as part of the sixth framework (FP6-2004-IST-4-27571

For further information regarding the IPCity project please visit the project web site at:

ipcity.eu