Integrated Project on Interaction and Presence in Urban Environments

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Final Environmental Awareness Demonstrator

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Author(s):	**Ann Morrison, Peter Peltonen, Toni Laitinen, Jari Kleimola, Giulio Jacucci, Saija Lemmelä, Antti Juustila**
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Abstract

This document describes redesign and evaluation for the prototypes developed in WP7 in the final year of IPCity. Both CityWall and MapLens prototypes have been developed further to support collaboration in an engaged way while users explore their urban environment through the Mixed Reality technologies.

We give a detailed overview how we have analysed the prototypes in real-life settings and what are the main findings from our trials. Many visiting researchers within and outside IPCity participated in the extensive field trials. A general overview of our analysis method is also presented in Appendix 1.

We also present how the workpackage was disseminated during the last year of the project. The emergence of *MultiTouch Ltd* was one of the big outcomes of the project, which will be discussed in the final chapter of the document.

Intended Audience

The primary audience of this deliverable is the Project consortium and the EC.

1 Workpackage Objectives

Objectives Final Phase	Objectives for the final phase is to complete the analysis of CItyWall data gathered last year, conduct further field trials with the showcase prototypes, refine aspects of the prototypes and write up our research, with the aim to publish extensively in high quality journals.
Results Final Phase	During the last year we have accomplished the following: • Further analysed our previous findings of MapLens and CityWall field trials in a chapter in the Springer series book "Shared Encounters" • Analysed the data gathered in the ECS event and submitted the findings to CHI 2010 conference • Improved and tested CityWall application based on the evaluation results • Based on last year's evaluation further developed and improved MapLens application • Presented our findings from last year's MapLens field trials in the CHI 2009 conference (receiving a best paper nomination) • Evaluated MapLens in two field trials • Analysed the data gathered in the MapLens field trials • Documented our evaluation process • The startup company based on development of the Multi-Touch Display technology has been successful and extending its business
Evaluation Final Phase	Evaluation of the both prototypes, MapLens and CityWall, has been successful.The data gathered in the ECS event was analysed and submitted to the CHI conference. The improved MapLens user interface was evaluated in two field trials in August 2009 and analysed in a thorough way. The improved Citywall *Worlds of Information* interface will be usability trialed in 2010. We have documented our analysis process for our Mixed Reality applications in urban environments and will present that work in this document.

2 Overview

As in the previous years, the demonstrator is divided into three components. The mobile component development continued with the Augmented MapLens prototype. The Public Display application called CityWall was re-designed as Worlds of Information. The Pervasive component has been integrated into Worlds of Information and MapLens applications.

2.1 Applications and Mixed Reality

The three complementaty component elements described here (Table 1) are shown at various stages of development.

Table 1. The three components in development.

Component	Mobile	Public Display	Pervasive
Application	Augmented MapLens	CityWall/Worlds of Information	Integrated into Worlds of Information and MapLens
Features	Digital overlays on physical map addressing environmental awareness theme	Collaborative and tangible exploration and manipulation of media, contextualised display	Input by users into MapLens and Worlds of Information
Platform	Mobile phone, Symbian S60 v.3 edition	Installation, public touch screen, rear projection, PC	Using existing data networks, MMS and SMS and image uploading
Development	Solid prototype with multiple field trials	Re-designed prototype, in usability testing	Integrated into Worlds of Information and MapLens
Mixed Reality	Computer vision for map tracking and overlays on video feed of map.	Multi-hand and gesture tracking, virtual 2D and 3D objects and simulated physical behaviour with tangible interface	Representing with pervasive visual cues and text

2.2 Research Questions

In this section we list the main research questions for the project and the workpackage, and list how he we have addressed them. The main IPCity research questions related to urban environment and presence are listed in Table 2.

Table 2. The main IPCity research questions.

Research Question	How the RQ has Been Addressed in WP7
1. Which design features of Outdoor Urban Mixed Reality are essential in supporting participants in engaging in novel ways with the city?	To explore these issues, the CityWall prototype has been a permanent installation in Helsinki city centre for several years now and we have organised multiple field trials in urban areas with the MapLens prototype. Robustness for outdoor conditions is essential, as is a streamlined simplicity in the tools and artifacts and conditions to enable spontaneity, intuitive uninhibited responses, as well as a sense of play with participant exploration and engagement.

2. What is the potential of the concept of presence in analyzing participant experience?	We have investigated people's feeling of presence in conjunction with two other promising scales IMI and GameFlow with questionnaires after each trial and event. We find the concept of presence to be elusive, but similarities in questions between the 3 divergent analyses (as well as with video analysis and oral interviews) makes for a more concrete understanding of the participant experience. As they are already actively present in the real environment for AR experiences (where the primary real environment is augmented by the secondary virtual one), presence or an experience *as if real*, may relate more to if the virtual feels seamless enough (or *as if real)* within the real environment.
3. What do we learn from this analysis for the design of MR applications, interfaces, as well as for how to enable participant experience?	We have done a very detailed analysis of the user experience (data collected in the multiple trials) using triangulating with multiple methods. We learnt that enabling spontaneity and supporting embodied interaction between participants is useful to support playful engagement.

In workpackage 7 we have been specifically looking at how Mixed Reality technologies are used in collaboration and how they can be used to engage people in environmental awareness, and how this can be evaluated. Our research questions for the last year of the project are listed in Table 3.

Table 3. WP7 specific research questions.

Research Question	How the RQ has Been Addressed in WP7
1. How is Mixed Reality Technology used collaboratively in urban public space?	Our focus has been on the capacity of Mixed Reality technology supporting embodied interaction, in particular via natural interfaces. The central features have been how the "public availability" of MR technology provides common stages and opportunities for performative interaction. Common stages are configured by users utilising features of ubiquitous media and provide a scene for social interaction. Performative interactions further indicate how media objects and interfaces are used as props in embodied and expressive acts.
2. How can we raise environmental awareness through use of Mixed Reality?	In both our CityWall and MapLens prototypes the content has included material on environmental awareness. The key idea has been on making the invisibile visible through the technology—making people aware of things in the environment they wouldn't have otherwise noticed. Also in allowing participants ways to easily input with comments and content.
3. How to evaluate engagement with Mixed Reality technology?	We have evaluated engagement with multiple methods, both quantitative and qualitatively and have put a lot of effort on evaluating the evalution process itself. We found rigorous cross-testing with mutiple methods and comparative conditions produced the most useful results.

To answer these research questions we set a workplan for our scientific work. This workplan had its own smaller scale more detailed research questions, which are listed in Table 4.

Table 4. Research questions from the last year's scientific workplan.

Research Question	How the RQ has Been Addressed in WP7
1. *MapLens:* Will improving performance-type issues (delay, fuzziness, difficulties reading maps, difficulties with the interface, difficulties reading the icon information, providing information on 'you are here') impact on how MapLens users collaborate, common-ground and negotiate when using the device?	Implemented Imagination's tracking improving overall performance. Also we changed to use Google satellite view maps (more user friendly and easier for tracking). Add "you are here" feature, so users can easily locate themselves on the map. Added better text support for images.Added a trace/pathway to tracking that shows where the object of the zoomed in view is, in relation to the "you are here" marker. We found significant differences in the freedom allowed to participants with using this more robust technology. They were no longer forced to collaborate, rather we could report they collaborate despite not needing to.
2. *MapLens:* What available features do our users use the most? And what do they do with them and why? How long for?	Implemented better logging. We are now able to see from the logs what thumbnails user viewed, what thumbnails were used to see the bigger pictures and what areas of the map were scanned with the MapLens most. We found all teams used required features to complete the game. The more playful or technology-competent teams (or with more devices) explored off-line browsing of other players and their own images, web browsing for clue solves, and were generally more experimental. They often engaged in conversation about the technology and explored features in a 'did you see this?" or "I found this bit" series of discussions and explorations.
3. *MapLens:* How task-orientated/ distracted/ playful are our players? How rule-bound is their play? How anarchic is their attitude to tasks and the games? (supports research we do around game tasks and kinds of behaviours they elicit).	We had plans to add to the tracking layer of paths players take on a layer that can be turned on and off, but we didn't have time to implement this feature. Instead we observed these activities live in the trials. We also had a mobbing type of activity planned to force the social presence and teamwork between the whole groups aspect. However, overly complex trials can distort rigour and complicate findings, so instead we streamlined the comparative conditions to ensure we had a more substantial narrative.
4. *MapLens:* Can users become immersed in game world (magic circle) and forget usual inhibitions?	We tried to implement the game used in our field trials as engaging and immersive as possible, following feedback from previous trials/game. We found people were openly non-self-concious later in the game and were unaware of e.g. stopping in the middle of the street etc.
5. *MapLens:* What new information can we find about mobile AR by implementing in the home with daily home-work type of use findings?	Our initial goal was to add measures for home and every-day type of use but we did not implement this largely due to time limitations. This question remains open for future research, and is a valuable future viable exploration coming out of IPCity.
6. *CityWall:* Is a multitouch system incompatible with multiple in-depth content? What are the real strengths of such a system? How to best support users intuitive responses to natural interfaces	We have optimized the system (addressing current dead spots, problems with time-stamped images where no input, bugs with, sms phone system being unstable, lag in interaction and so on). We have also worked with calibration issues the previous prototype was having. The system is now more robust and easier to maintain. We added different worlds of information to test if multiple content can be easily explored simultaneously. We found there is good potential here for more substantial content.

	As people become more familiar with multitouch technology, dealing with gestural standards and means to navigate will build on these explorations.
7. Does making ease of and multiple inputs in wide range of formats to ensure as many as public as possible can easily input into content on wall change the number and kinds of input CityWall receives.	UOulu's MMSEntrance system has been now integrated into CityWall. We have implemented a new tool for writing, a virtual keyboard (adding user input at the wall) plus implemented content world editing possibilities to the ContentManager component of CityWall. We have not solved designing an easy inerface for users to understand how to input into the system, so we can not accurately answer this question yet.

3 Related Work

3.1 CityWall/Worlds of Information

We are interested in contributing to designing applications on public multitouch screens with particular focus on engagement and group use. To this end we first review research on collocated interaction on interactive surfaces and then review work on multitouch solutions that propose widgets in support of advanced collocated interaction.

3.1.1 Collocated interaction on interactive surfaces

Many studies of collocated collaboration without computer support are relevant to our analysis and have inspired our work (e.g. Robertson 1997). As an example Isenberg et al. (2008) report on an exploratory study of individuals, pairs, and triples engaged in information analysis tasks using paper-based visualisations. They conclude that providing a flexible temporal flow of analysis actions, should possibly allow group members to be engaged in different types of processes at the same time and also allow them to work together adopting the same processes.

We concentrate here however on studies of collocated collaboration on interactive surfaces. Studies have interested the positioning and approach to public displays. Before users can start interacting with a public display, they have to withdraw from other activities they are engaged in. Brignull and Rogers (2003) have suggested positioning public displays along traffic thoroughfares and describe the ways in which the interaction principles are communicated to bystanders.

Some studies are more explorative aiming at understanding how collaboration is configured using a shared interactive surface. In their study, Russell et al. (2002) observed various aspects of group dynamics that evolved amongst participants who were using a touch-screen display designed for small-group collaboration. Observed aspects included the benefits of visible physical actions (that facilitate learning from others), difficulties in developing clear turn-taking practices, and varying emerging ways to collaborate without anyone taking a leading role.

Morris et al. (2006) reported a series of studies where various multitouch groupware prototypes were evaluated in order to find out how tabletop user interfaces might respond to, and influence a user group's social dynamics. The results of these studies indicate that aspects of group dynamics, such as conflict, awareness, participation, and communication can be influenced by interactions with a shared multitouch tabletop display.

More focused studies try to investigate specific aspects of collaboration or understand the impact of a particular set up, for example, studying pair wise work on surfaces. Tse et al. (2007) studied pairs of people who communicated and interacted in a multimodal digital table environment built on top of existing single user applications, mixing and using inter-person speech and gesture actions as commands to the system. Tang et al. (2008) carried out studies with pairs of people using an interactive table top display. Their study shows how individuals frequently and fluidly engage and disengage with group activity through several distinct, recognisable states with unique characteristics: together, kitty corner, side by side, Straight across, Angle across, End side, and Opposite ends.

Rick et al (2009) carried out studies on how for a child, the position of a tabletop (relative to their own position) affects where s/he touches the table. This study positioned three pupils at three sides of a table top studying equity of participation. A main finding was that children used the entire tabletop surface, but took more responsibility for the parts of the design closer to their relative position.

In their study of a sharing media with a public interactive screen called Dynamo, Brignull et al. (2004) witnessed the users developing ways to attract other people's attention through "upsizing" their pictures and stage video performances in the display. Dynamo also supported the use of private content through reservation of a dedicated space on the screen for personal purposes and in the high-school setting of the study, where the same people used the display for a longer period of time, this possibility for personalisation was found to be an important feature.

In their report, Scott et al. (2003) suggest particular design guidelines for digital tabletop display interfaces that aim to support effective co-located collaboration. Guidelines that relate to our work support: fluid transition between activities, interpersonal interaction, transitions between personal and group work, simultaneous user actions. These resonate with the guidelines of Tang et al 2008, that support: a flexible variety of coupling styles (i.e., manners and extent in which collaborators can be involved and occupied with each other's work); lightweight annotations and provide: fluid transitions between coupling styles, and mobile high-resolution personal territories.

Recently Hornecker et al. (2007) presents design principles for shareability. They note the central role of access and entry points for in particular tangible interaction. Entry points invite and entice people into engagement, provide an overview of the system, and draw observers into the activity. Access points are the characteristics that enable users to interact and join a group's activity. All these factors produce the shareability of the system, which refers to how a system engages a group of collocated users in shared interactions around the same content.

While guidelines and principles are useful they still need to be translated in particular solutions. Our contribution is directed to increase examples of design solution and interaction techniques for multitouch display. In the next paragraph we review a variety of related solutions.

3.1.2 Multitouch for multiple users and complex visualization

Nacenta et al. (2007) found that the choice of tabletop interaction technique does matter, and provides insight into how tabletop systems can better support group work. Techniques such as drag-and-drop reduce resource conflicts, but at the price of being much less effective when used for reaching distant artifacts. World-in-miniature views such as the radar view were surprisingly effective for a game task, although in a design task the radar did not provide enough awareness information. We found that the choice of interaction technique significantly affected coordination measures, performance measures, and preference–but that the effects were different for the two different tasks.

Some widgets have been developed that allow creating multiple simultaneous spots of interaction of the same data. The design of and experience with DTLens (Forlin and Shen, 2005), a new zoom-in-context, multiuser, two-handed, multi-lens interaction technique that enables group exploration of spatial data with multiple individual lenses on the same direct-touch interactive tabletop. DTLens provides a set of consistent interactions on lens operations, thus minimizes tool switching by users during spatial data exploration.

The concept of Interface Currents introduced by Hinrichs et al. (2005) has been utilized to address several interaction issues concerning interactive tabletop displays. Hinrichs et al. (2006) conducted a study revealing that interface currents can support the following task and group interactions: the exploration and discovery of visual information, equal access to information between group members, casual and structured information organization, both individual and collaborative work with information, and smooth and fluid transitions between individual and collaborative activities.

In order to make mode (or view) switching more convenient for large displays Everitt et al. (2005) studied a new technique, Modal Spaces, through a simple image manipulation application. In their work, Everitt et al. divided the display into four semantic workspaces (or modal regions) which each interpreted the same gestural commands differently. Switching the mode (or view) by moving workspace items to certain areas of the display eliminates the need for conventional menus and toolbars which may not be reachable from all sides of the display and which may disrupt the flow of interaction with complicated command series.

However, when utilizing Modal Spaces technique, conflict situations can arise if two people want to use the same space (or mode) simultaneously.

Tse et al. (2008) explored multi-user, multimodal interaction over a digital tabletop display. They found out four key issues regarding the behavioral factors of multi-user speech and gesture interaction. First, parallel work is affected by the design of multimodal commands. Second, individual mode switches can be confusing to collaborators, especially if speech commands are used. Third, establishing personal and group territories can hinder particular tasks that require artifact neutrality. Finally, timing needs to be considered when designing joint multimodal commands.

Tobiasz et al. (2009) presented Lark, a system that facilitates the coordination of interactions with information visualizations on shared digital workspaces. When designing Lark, Tobiasz et al. concentrated on the following criteria: scoped interaction, temporal flexibility, spatial flexibility, and changing collaboration styles. These are achieved by integrating a representation of the information visualization pipeline into the shared workspace, thus explicitly indicating coordination points on data, representation, presentation, and view levels. This integrated meta-visualization supports both the awareness of how views are linked and the freedom to work in concert or independently.

3.1.3 Designing for multiplicity and complexity of content

Images taken by one person have a limited relevance to another person unless there is a personal connection to the places or activities depicted. With the aim of getting passers-by to input into the content at CityWall, we therefore needed to generate initial content that was diverse and relevant to the many interests of a passing public with multiple interests. We decided on a pragmatic approach to include local surrounding content that may be of interest to people in the environment. We aimed to trigger passers-by to post images as a response to photos already there, in a kind of a ‘photographic conversation’. As well we assumed the participants may already be exhibiting curiosity and interest in surface-computing, so we included videos on this and other state-of-the-art multitouch systems.

We also needed to enable multiple topics, so that many conversations and themes could occur synchronously. However, as this would need to take place on the one-shared screen, this required some spatial visualization thinking on how best to divide up the space to allow for this. As well, we needed to consider that connections between multiple topics would also occur, and individual elements may fit across multiple categories. This also needed to be accommodated into the design planning.

We researched the possibility of 3D landscape visualizations but could see we would be restricting users to a one screen visual component if we moved in this direction. We then looked for existing solutions to dealing with data mapping huge amounts of content within the Information Design discipline. Information Design does not replace graphic design and other visual disciplines, but is the structure through which these capabilities are expressed (Wurman 2001). To have informational value, the data must be organized, transformed, and presented in a way that gives it meaning. Early images of displaying the internet at work, and linking large amounts of data by e.g. the opte project display these considerations well (see Figure 1, left).

Transforming data (in this case images, videos and some text) into legible information is accomplished by organizing it into meaningful forms, and presenting it in evocative and appropriate ways. In order to achieve this it is usually necessary to also communicate the context surrounding the data. We examined works such as *Valence,* the work of Ben Fry, a set of software sketches that explore the structures and relationships inside very large sets of information (Fry, 1999) (see Figure 1 right).

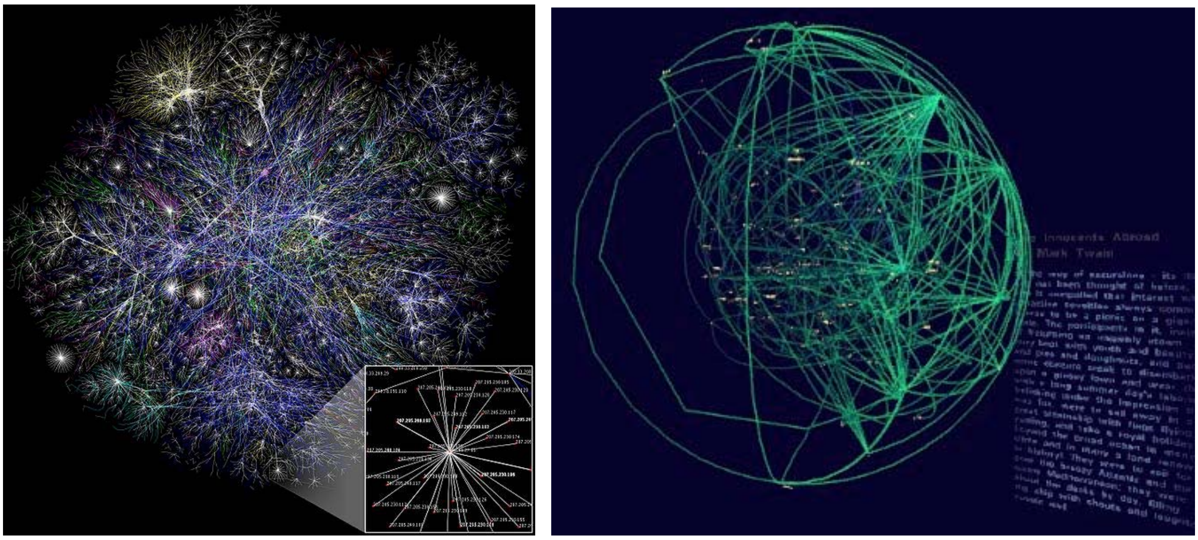

Figure 1. Left. From opte projects, http://www.opte.org/maps/Visualising Internet traffic and connections. Right. Ben Fry's Valence. 1999. Visualization of the contents of the book "The Innocents Abroad" by Mark Twain. The program reads the book in a linear fashion, dynamically adding each word into three-dimensional space.

3.2 MapLens

3.2.1 Collocated Sharing

Collocated interaction has been studied on a variety of settings. Some work looks at pair wise sharing of a computer as in Inkpen et al. (Inkpen et al., 1995) examines how two mice instead of a single mouse affects the performance of a pair of children playing on a shared computer. A vast array of studies address tabletop collaboration. As an example Scott et al. (2004) studied the collaborative use of tabletop identifying territories to help coordinate their interactions: personal, group, and storage territories. Some studies look at pair-wise collocated work with different display set ups or proximity (Hawkey et al., 2005).

Interesting for our analysis are studies where singular or multiple devices are used collectively in particular in mobile settings. Brown and Chalmers (2003) presented an ethnographic study of city tourists' practices, describing how tourists work together in groups and collaborate around maps and guidebooks, which are used in combination to plan and create a setting providing an opportunity to spend time with friends or family. The observations however do not detail aspects such the roles of tourists and the use of singular or multiple maps.

A number of studies have characterized the collocated use of mobile phones. A study by Frohlich et al. (2002) provides a useful distinction between collocated media use practices, differentiating storytelling, mostly a single-person endeavor, from reminiscing talk, which is more a collaborative project, where many people participate, sharing their experiences of the same photograph with the others. A number of studies at large scale events (Jacucci et al. 2007, Salovaara et al. 2006) show how groups of spectators share maps while navigating and planning the event. Mobile phones with cameras are used in a variety of group activities including competing, playing, storytelling, documenting and reliving previous episodes.

Collocated interaction has also been studied in the context of media sharing. Digital media archive studies on PCs have presented new collaborative methods for sharing media, such as the manipulation of content with gestures (e. g., Morris et al., 2006, Rogers et al., 2004, Wu and Balakrishnan, 2003) and the visualization of content for shared use (Shen et al., 2002).

Mandryck et al (2001) argue that students' collaborative use of handhelds might be difficult given the personal nature of these devices, and the small size of displays. These difficulties are addressed with the use of devices with larger surfaces that encourage collaboration.

3.2.2 Augmented reality

Mobile augmented reality generally refers to mobile set ups and applications whereby the real world is augmented with the perception of virtual objects. AR was already demonstrated as a tool for collocated collaboration in (Schmalstieg et al., 1996), but the practical value of such “shared space” technology was limited by its stationary nature and high cost per user.

The first standalone AR application on a mobile device was presented by (Wagner & Schmalstieg, 2003). Since then, AR on handhelds has been explored with different applications, both individual and collaborative. The sophistication of the camera-based tracking determines what kind of application can be built. Simple motion sensing (Wang et al., 2006) allows only 2D interaction, while tracking of fiducial markers or natural features allows shared space interaction.

Evaluating such user interfaces in real settings is difficult as can also be seen by the very few studies 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 [29] 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).

3.2.3 Maps and mobile devices

Our interest is in working with tangible devices and physical artifacts, and so we chose a system that combines reading paper maps from a mobile device. Our objective for future work is to include for example posters in the urban environment and eventually the architecture of the city (buildings, sculptures, features etc) as augmented objects. Combining paper maps with mobile devices has been implemented using PDA and RFID tags (Reilly et al., 2006), or using markers and dots (Rohs, 2007). Evaluation of these systems has focused on comparing the impact of the visual context in task performance (Rohs et al., 2007). Reilly et al.(2006), different tracking techniques and present exploratory studies of task performance. However, none of these works consider collaboration and device handling.

4 Presence and Experience

A core focus of IPCity is on the collaborative aspects of MR technologies. This has been also WP7's main focus during the final year: we have analysed how the multi-touch technology was used collaboratively in the European City of Sciences (ECS) event, re-designed the CityWall prototype to solve the final issues with the 3D multi-user interface, re-designed the MapLens prototype to support the collaborative elements we found in last year's trials and organised multiple field trials (see Figure 2) to explore how the final prototype is used in groups having single/multiple devices. These evaluation cases are described in the later chapters of this document.

Figure 2: The MapLens field trials

In deliverable D3.5 you can find more discussion on WP7 prototypes' relation to presence and experience.

5 Year 4 Prototypes and Demonstrators

5.1 CityWall/Worlds of Information

CityWall is a multi-touch display system developed in WP7. It has two permanent installations, one publicly available at Helsinki city centrum (Lasipalatsi) and one for internal research use at Espoo (Spektri).

Last year CityWall was redesigned for the new environmental awareness brief in WP7. In November 2008 the display was presented at the European City of Sciences (ECS) exhibition, where we also collected an extensive set of data how the display was used and how its new design worked with the system being used intensively by thousands of users.

During the fourth year, we analsysed the data collected at the ECS (video footage from two cameras and a collection of presence, IMI and flow questionnaires). Based on this analysis and additional expert evaluation, we have improved the new user interface paradigm we created that uses 3D widgets calling the new system as *Worlds of Information* (see Figure 3).

This year we have focused mostly on interaction analysis and design, the core hardware technology behind the system staying the same: 1) multiple hand tracking capable of identifying uniquely as many fingers and hands as can fit onto the screen; 2) hand posture and gesture tracking; 3) high-resolution and high-frequency camera processing up to 60 FPS, and 4) computer vision-based tracking that works in changing light conditions. The technical framework of the Multi-Touch Display is described in more depth in D4.4.

Figure 3. Worlds of Information used by three users at Spektri.

5.1.1 Re-design and development

Design Challenges and Goals

Multi-touch interfaces are a new solution for walk-up-and-use displays. According to our experience with passersby, local institutions and stakeholders, it is important to allow for a variety of content, themes, and categories within the display. Multi-touch can potentially provide intuitive interaction capabilities and create a playful environment that engages users. However the challenge is to move beyond ephemeral interactions, driven by the playfulness of the interface, and to encourage users to pay attention to the content also exploring more complex functionality. Multi-touch is groundbreaking because it affords multiple hands and users to manipulate the same surface. Parallel interaction is beneficial in the way that it fosters social learning, social experience and creates the attractive honey pot effect (Hornecker et al., 2007).

In our previous evaluation of Multi-Touch Display (see D7.2 and Peltonen et al. 2008) we detailed the social usage of an interactive public installation. We described how passers by approach and form crowds, engage in parallel and collaborative interaction, social learning, conflict management, negotiations of transitions and handovers, playful, and performative interaction. We resolved that the interaction could be improved as the use was characterized by being ephemeral, driven by the playfulness of the interface, and permeated by unnecessary conflicts. We aimed at improving upon the existing two-dimensional version of Multi-Touch Display, with its singular timeline and therefore no possibility for multiple content categories. In particular, we wanted to keep the possibility for several people to interact simultaneously at the display as a central aspect of fostering engagement through socially experiencing and learning the installation.

Engaging experiences. A "Walk-up-and-use" system needs to be so self-explanatory that first-time or one-time users need no prior introduction or training (Elrod et al., 1992). We saw that by implementing our design changes we would disrupt this ease of use, and while we also aimed to extend the scope of the interactions beyond this early learning curve, we looked for a balance, with the aim of extending the depth of the experience. The engaged experience we were after can be thought to involve aspects of presence, flow and intrinsic motivation (Benyon et al., 2006; Deci et al., 2000; Jackson & Marsh 1996; Vorderer et al. 2007; Tang et al. 2006). We wished to retain ease of first use, and structure complexity in a scaffolded way, unpacking the functionality and content gradually as one mean of enabling sustained interaction (Jacucci et al., 2009). Our aim was to immerse our participants in both solo and joint activities, enabling social and spatial immersion in a mixed reality environment, where participants could act with the contents 'as if it was real' (as we see with presence research). We see similar phenomena in accounts of flow (Csikszentmihalyi, 1990)—optimal experiences in which 'attention can be freely invested to achieve a person's goals,' which results in the merging of action and awareness, as well as a consequent lack of self awareness and distortion of sense of time. When participants are engaged with both the product at hand and with others in the collaboration, we can characterise this as group flow [24], similar to what is investigated with social and spatial presence research. Similarly, we wanted the user and group experience to be intrinsically motivated, or inherent, for its own sake and an end-in-itself. John T. Guthrie (2001) makes a case for connection between high levels of engagement and intrinsic motivation, with the promotion of goal-orientated activities that involve understanding content, using effective strategies, and making links between old and new knowledge (in opposition to performance-related activities).

Multiplicity of Content. According to our experience with passersby, local institutions and stakeholders, it is important to allow for a variety of content themes or categories. The aim is to be able to attract passing public with multiple relevant topics to foster and support conversations.

Multiplicity of Users. In our earlier 2D interface implementation, we treated the entire display as a single interaction space, meaning that one user's actions often had effects on the actions of another user. For example, resizing an image to a very large size might overlap another user's focus of interaction, and moving the single timeline means disruptions for others because all the photos in the content then start moving left or right accordingly. Our goal was to allow individuals and groups to be engaged in different types of processes at the same time (or to work together using the same processes).

Gradual Discovery. The aim in designing CityWall was to have an intuitive interface where novice users could easily approach and easily use the interaction techniques. Such a "Walk-up-and-use" system needs to be so self-explanatory that first-time or one-time users need no prior introduction or training. We saw that by implementing our design changes we could disrupt this ease of use, and while we also aimed to extend the scope of the interactions beyond this early learning curve, we looked for a balance. We wished to retain ease of first use, and structure complexity in a scaffolded way, unpacking the functionality and content gradually as one means of enabling sustained interaction.

Design Solution

Worlds of Information

Working towards these design goals, we sought to develop an interface that would allow us to present large amounts of multi-themed content – originating from a multiplicity of content sources – in a way that also affords parallel interaction. We investigated several solutions as to how these views could be presented in the interface, including (i) dividing the screen into vertical panes, (ii) using overlapping transparent layers and manipulation handles, and (iii) using timelines in either x or z-axis dimensions. Because these solutions did not work well in practice, we settled for an alternative that shares the entire interaction space between interacting users. We found that using multiple virtual 3D container objects (spheres or widgets), sitting on the display side by side, would offer a feasible solution. Each virtual 3D sphere could provide an individual interaction access point, with an independent timeline, and a collection of these 3D spheres would then enable parallel interaction within a shared display space.

As the overlying theme of the work was environmental awareness, worlds proved appropriate conceptual and functional 3D metaphors for the containers, and were shapes that could readily expand to add more layers of information. The envisaged two-meter screen could easily accommodate multiple spinning spheres, or as we now came to think of them, *Worlds of Information*, each with its own theme (see Figure 4). We used six individual globes that contained themed information, in the form of images, videos and text. These worlds housed images of Helsinki since 2007; images of the venue of the installation; videos of state of the art multi-touch systems; SMS, MMS, and email messages sent to the system; help animations; and images from participants of a nearby installation. The hardware of the installation is built similarly to CityWall (Peltonen et al., 2008), with its framework and application running on top of .Net 3.5 and Windows Presentation Foundation (WPF) frame-works, using a combination of object oriented and declarative languages (C# and XAML).

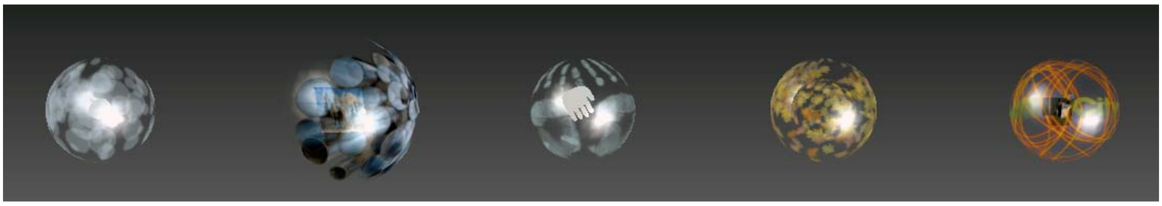

Figure 4. Different worlds with different themes fit side by side on the display. The worlds are shown here in their collapsed state, hinting the themes with distinct wrapping textures, while hiding actual contents.

Stretching the sphere over a certain threshold size opens the world, while resizing to the opposite direction will shrink the world back to the collapsed state (see Figure 5). In the opened state, the container sphere is coated with 2D plates, each holding an information item belonging to the themed timeline. An opened world can be further enlarged, moved along and spun around the x- and y-axis, in order to browse the photo, video and text items attached to the sphere.

Figure 5. A. Closed world. B. World opening, animated using fade ins and radial beams. C. Opened world.

Re-design of the nanigation system

With the old navigation system (Figure 5) spinning the world rapidly around its y-axis (i.e., to the left or right) allows navigating back and forth through time to view older and newer content according to the theme of the world: the current layer of coated items is replaced with another layer of items from preceding or succeeding dates. To this end, the sphere consists of multiple stacked layers of content, which can be exposed by peeling or spinning actions (see Figure 6A). It is also possible to jump directly to a specific date by activating the navigator menu (see Figure 6B). The menu items in the equatorial circle represent days of a month, while the items in the longitudinal circle denote months and years. Both circles can be spun around to make a selection of the date that is presented with the larger frontal item.

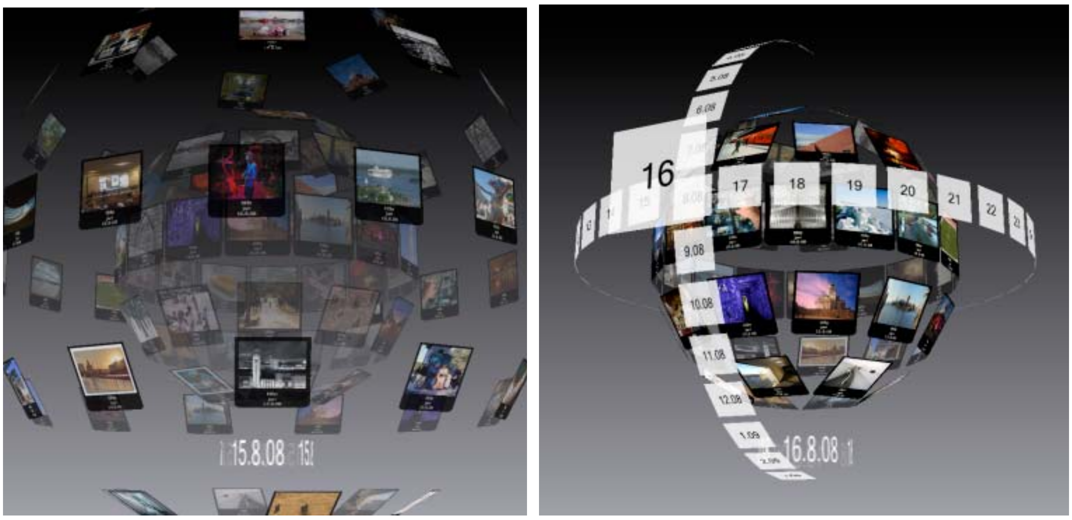

Figure 6. A. Navigating backwards in time, current layer is exploded out while a new layer is faded in. B. Navigator menu, date label at the bottom of the sphere.

Our field trials revealed that this system was not ideal and not supporting our design principle of gradual discovery. The date label at the bottom of the sphere was not noticeable enough and when the navigator menu appeared, users seemed confused with what to do with it. Therefore a new solution was designed.

Content and New Input Methods

The content displayed on the wall contains images, videos and text items that are tagged with title, author and timestamp metadata. They are visualized using 2D plates that are inclined in 3D to cover the spherical surface of a world. A single content item can be selected for closer inspection: this action rotates the world to an angle which brings the item to the front of the sphere, where it appears larger that the other items (see **Error! Reference source not found.**B). This close-up position allows them to be resized and flipped around to read the associated comments (see **Error! Reference source not found.**C). It is also possible to make copies of the close-up item, and add these to the communal 2D front plane of the interface. To support co-operative interaction further, we overlaid the entire display space with a virtual transparent interaction area (see **Error! Reference source not found.**A).

Figure 7. A. 2D front plane and 3D worlds co-exist. B. Content selected and enlarged. C. Flipped around to read associated comments

The content is mainly downloaded from Internet searching by certain tags. At our Lasipalatsi solution we have had four worlds in use, which are listed in **Table 5**.

Table 5. Content displayed in the Worlds of Information.

World of Information	Content displayed
1. Helsinki	Images of Helsinki downloaded from Flickr.
2. Nature	Into this world we download images of nature that can be seen either as nuisance or nice things for the city environment. For this world we also fetch the description and comments from the web interface and from tagged mobile communication.
3. MultiTouch	In this world we show videos of different MultiTouch solutions.
4. Communication	This worlds holds the content created at the wall (SMS and MMS messages sent, pictures drawn and text typed with the virtual keyboard)

In addition to the copied content, the front plane holds recent text messages, which can be moved, resized, rotated, played and dismissed by any user. This horizontally scrollable layer corresponds to the 2D content area of our earlier implementation. Consequently, the ability to enlarge the items and the worlds, and to overtake the whole display area, ensured we maintained the accidental parallel and associative interactions that had enabled sociability between relative strangers at our previous implementation.

To support the active role of the users we re-added some input possibilities for the users: a virtual keyboard and the possibility to hand draw on the display. As well we added more information clues on dates to enable a better understanding of the role of time in the interaction (see Figure 8).

Figure 8. Left and Middle. New Multi-Touch Display features: drawing and keyboard. Right. Added date information to assist users with navigating time.

The help system, gesture language and specific list of improvements for the Multi-Touch Display component are detailed in D4.4. The prototype's content is managed and moderated with web based ContentManager software, which is discussed in D5.4.

5.1.2 Specification

Hardware and OS	Data Projector, Camera, Infrared lenses and filters, Infrared emitters, Multiple cameras and projectors are supported to handle larger screen (so far 2 IEEE 1394 cameras with 60fps and VGA resolution have been used with maximum of 4 projectors), PC Hardware, Windows XP
Software	The software consists of two parts: 1) touch-display manager (written in C++) and 2) application layer. (written in C#) A high definition IEEE 1394 (FireWire / i.Link) camera with IR lens is used to track objects near the screen. The computer runs touch-display manager software that • captures images from the camera (platform-specific) • calculates touch-points from the images using computer vision methods (platform independent). Image processing is done in the background at a fixed rate (regardless of the application). The application sees the touch-screen as providing new fully-processed input samples at fixed rate. Support for multiple screens and cameras Separate, dynamic calibration for each camera is implemented (a calibration application for setting up the projection parameters interactively has been developed) and information is merged at the edge of the camera images. Each camera image is processed in a separate thread. Multi-head key-stoning is handled with OpenGL transformation matrix. A separate, stable API layer provides all the important information from the computer vision.

Core Features	Multiple point touch-screen interaction Detecting points of contact, tracking of fingers at 60 FPS Operation in day and night mode Multiple interfaces for the application layer
Intended users	Citizens and visitors

5.1.3 Addressing Environmental Awareness

Worlds of Information prototype has been designed to address the brief of environmental awareness by disseminating information of the nuisances and nice things found from the urban environment, such as city rabbits which are cute to watch in the city parks but cause a lot of damage to the vegetation. As well we had discussions around using video footage of a long term study looking at a comparative study of foresting processes, combined with long term measurements of climate and forest ecosystem processes, process based models of tree and stand growth, optimization models of forest productivity and forest management models with climate change scenarios. A video of this and a local study can be made available for WP7 and CityWall for future use.

The content at CityWall on urban nature deals with local urban issues of environmental awareness relevant to the regular community who pass by CityWall. The navigational interface mimics the interlinked global nature of these issues. The information—in the form of text, images and videos from Finnish Environment Institute SYKE shows examples of the benefits and nuisances of urban nature. CityWall presents images, videos, descriptions and discussions on how nature in Helsinki benefits and disturbs dwellers. A single tree, for instance, can be both a useful physical shelter, an appreciated element in the urban landscape, a source for an irritating pollinosis and a danger for traffic. Many of the changes in the benefits and nuisances of nature are, at least partly, dependent on human activities. The settling of rabbits as permanent residents to Helsinki, for instance, follows partly from global warming that allows released pet rabbits to survive winters in urban green areas. Examples of *nature as nice* and *nature as nuisance* can be seen in Figure 9 and Figure 10 respectively.

Figure 9. Nature as nuisance information dsiplayed at CityWall.

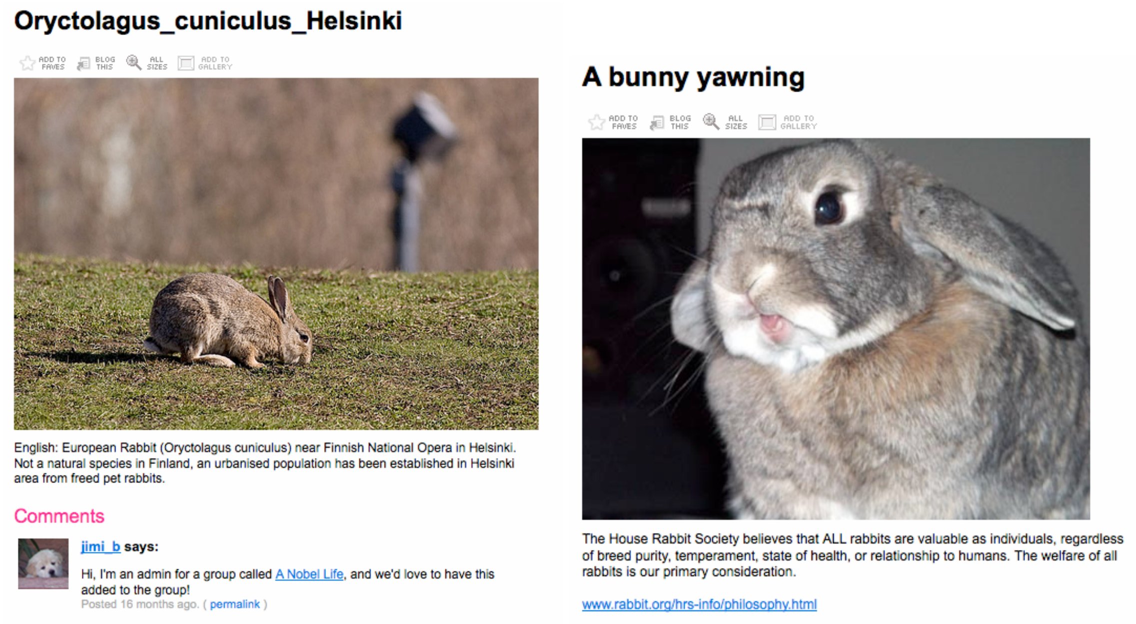

Figure 10. Nature as nice information dsiplayed at CityWall.

Urban Mediator with rabbit feed is a project that also looked at the rabbit problem in Helsinki. We also have ongoing discussions with the project manager of this project to show this feed on CityWall in future iterations. Urban Mediator is a platform that provides the possibility to create, obtain, and share location-based information that is organized according to topics of interests set up and maintained by the users themselves. UM uses a map-portrayal service as means for representing location-based information and complements it with a set of tools for users to process, share and organize this information. Urban Mediator can also connect to other systems such as city customer services or community portals. UM uses a map-portrayal service as means for representing location-based information and complements it with a set of tools for users to process, share and organize this information. The software and related web-based services, enable users (e.g. citizens and city administration) to obtain and share information about a city / neighborhood or any other place represented in the map.

The rabbit information on Urban Mediator Helsinki can be found here: http://um.uiah.fi/hel/topic/24, with geofeed here: http://um.uiah.fi/hel/feed/topic/24/points

Urban Mediator is developed at the ARKI research group, Media Lab, University of Art and Design in Helsinki.

Currently involved:

Joanna Saad-Sulonen - joanna.saad-sulonen(at)taik.fi - researcher, designer, project manager, Andrea Botero Cabrera, designer, researcher, project manager, Roman Susi, software designer, Eirik Fatland, user interface designer, Mark van der Putten, web design, Abhi Singh, usability and mobile application, Joonas Juutilainen, graphic and interface design, Tuomo Tarkkianen, map search module, Anne Naukkarinen, um visual image, Kari-Hans Kommonen, research group director

Previously involved:

Iina Oilinki, project manager (2006) - currently ICING project manager at City of Helsinki, Taina Rajanti, senior researcher (2006), Tommi Raivio, softaware designers, ui (2006-June 2007), Mika Myller, software designer (2007)

The rabbit information from UM was gathered as part of a case study with City of Helsinki's Public Works department, who asked people to report on the places they have seen rabbits inhabiting, or places where there was damage done by rabbits (see Figure 11).

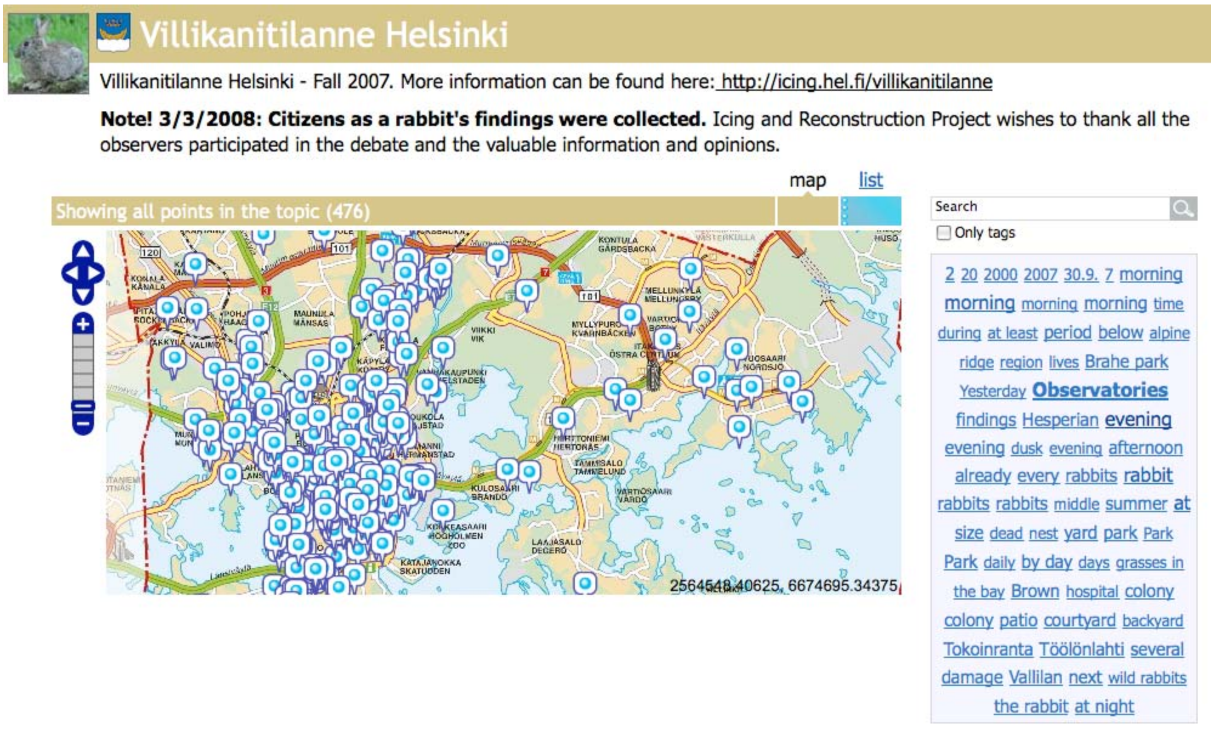

Figure 11. Map showing people's reports on the rabbit situation.

Acknowledgements:

Urban Mediator development has been possible thanks to ICING project (Funded is provided by European Commission through FP6 contract number FP6-IST-2004-4 26665).

Collaboration with other members of the Icing project has been part of Urban Mediator development, who are particularly grateful to the City of Helsinki Survey and Urban Facts

Departments; eSpatial and City Councils in Barcelona and Dublin. Many communities and people have participated in workshops, design sessions, and trials including Art and Design City oy, Arabianrata e-moderators, Media Lab TAIK and Arcada students.

5.1.4 Testing / Evaluation

We iteratively improved our evaluation processes this year, analyzing comparative testing and follow-on studies to ensure we had improved our technologies, our use scenarios, our field trials and our evaluation methods. We then instigated a small usability trial to ensure we trialed our technology with expert users before testing in the wild. The evaluation of the prototype is discussed in more depth in the chapter 6 of this deliverable.

5.2 MapLens

MapLens is an application that allows investigating physical maps through the mobile phone's camera with digital information overlaid on top of the view. Through MapLens one can see for example photos that are connected to certain location on the map or one's own location. MapLens can be used to upload new geo referenced content to the map.

The application for Symbian OS S60 on Nokia N95 phones with camera and GPS. When a paper map is viewed through the phone camera, the system analyses and identifies the GPS coordinates of the map area visible on the phone screen. Based on these coordinates, location based media (photos and their metadata) is fetched from Imagination's server. Markers to access the media by clicking the selected marker showing the thumbnail of the photo are then provided on top of the map image on the phone screen (see **Error! Reference source not found.**).

Figure 12 - MapLens in use with a paper map showing multiple thumbnails.

The paper map used with MapLens is an unmodified satellite image (with street overlay) from Google Maps. The phone camera and display are used as a viewer on top of the paper map, which is then augmented with location based data.

Users browse the augmented map by physically panning the phone's camera over it. MapLens overlays the real map with icons that identify the game clues and the users' photos. Users select icons via an on-screen viewfinder frame. One click provides a list of thumbnails for all selected icons, while a further click zooms any desired image to full-screen for closer inspection.

A "you are here" icon shows the position of the user in the map, helping the user to orientate herself against the locative media visible on the augmented paper map. One keyboard shortcut is used to remove excessive data off the screen.

MapLens runs at interactive frame rates of 16-20Hz on the N95. It uses the 3D tracking method described in detail in D5.4 and in Wagner et al. (2009b). It is important to note that once the map is detected, the tracking is extremely robust, even to strong changes in illumination (sunlight) blur, and strong tilts of up to 90°. The tracking supports camera distances from the map between 10cm and 2m, accommodating almost every physical use case.

While the 3D tracking and image augmentation execute directly on the phone for minimal latency, the MapLens system relies on client/server architecture for storing and retrieving the media data. The server provides mobile clients with HTTP access to a geographic information system (GIS), allowing for location-based queries to media and associated metadata (location, date/time, user name, etc.). As the user launches MapLens, a connection to the server is made to download data related to the area on the paper map. The place marks found within are drawn on top of the paper map in correct places. Clients are also able to upload GPS tagged photos to the server using the standard newsfeed (ATOM) protocol.

5.2.1 Re-design and development

Based on last year's evaluation we decided to improve the MapLens prototype in multiple ways. To ease navigation, a green circle indicating the current location of the user on the map was added. The interface was designed to give more feedback when taking a photo, so user has a cliear understanding when photo is taken and uploaded. Taking of photos was redesigned to use the phone's photo capture button instead of the button 0 that was previously used and was reported difficult to use by the users. Also, when taking a photo the user is presented a countdown from 3 to 0. At 0 the photo is uploaded. This gives the user the possibility to abort photo uploading and minimizes the risk of accidental photo uploading. While showing the photo countdown, user is presented a preview of the photo so she can evaluate if the photo is worth of uploading

Viewing multiple thumbnails online was totally redesigned: to make it more easier for the users selecting an image from a cluttered view: when a lot of icons are stacked together, clicking a thumbnail does not enlarge the thumbnail right away, but opens a horizontal list of thumbnails of pictures from the same area showing also a line connected to the icon, so user is really aware which icon belongs to what photo. Clicking the thumbnail enlarges the photo. Also, the multiple thumbnail view can be also used in offline mode: the thumbnails stay on the screen and can be interacted with even if you take away the paper map.

The biggest change with the system was with tracking: The tracking was reimplemented to provide a more robust and stable user experience. The newly developed tracker is 1-2 orders of magnitude faster than naïve approaches towards natural-feature tracking used in earlier system. The system feels now more robust and accurate—augmenting information from the map is now effortless and smooth.

At the server-side the biggest change was moving from using HMDB to use Imagination's CityTales2 server implementation, which enabled creation of the game area through web interface and improved the performance of the overall system. Using Imagination's system also allowed us to free us from using third party applications shuch as ShoZu and Flickr.

For a full list of changes in the technology see the deliverable D4.4.

5.2.2 Specification

Hardware and OS	Nokia N95, Symbian OS v 9, S60 UI 3rd Edition
Software	C++
Core Features	Grabs mobile phone camera image, extracts features from the image, showing a map. Defines the area of the map visible on screen, gets location based media from remote database and displays media, icons on top of map. Enables also content production by uploading geotagged images to Imagination's CityTales2 server.
Status	Second prototype finished in June 2009.
Intended users	Users interested in location based media, events.
Showcases	WP7, others.
Relevance beyond project	Would be usable and extensible over many usage scenarios.

5.2.3 Addressing Environmental Awareness

One of the design goals for MapLens was to create a system that would make people aware of their physical environment, to pay attention to things they normally wouldn't. From technology view point the system can be viewed only as an information retrieval system, but when used in the right context, it can work as a tool to connect the user to the environment in a new way, mixing the digital and physical worlds together. The game we used in our trials tried to accomplish this in various ways: the phone and map system invited the user to explore urban nature by testing the water, taking sunlight photos and photographing your bare feet in the grass with others. The purpose of the game was to activate thinking of issues related to the urban environment. The participant interviews revealed that this goal was achieved and people enjoyed the various tasks located in the streets and parks in Helsinki, even when facing some rough weather.

The IPCity project organised a summer school during the final year in Vienna, where also a workshop on environmental awareness was held. In this workshop a group of PhD students were introduced to MapLens and then asked to design a game of environmental awareness located in Stadtpark in Vienna city centrum (see Figure **13**).

Figure 13. Summerschool participants creating an environmental awareness game.

5.2.4 Testing / Evaluation

We iteratively improved our evaluation processes with comparative testing and follow-on studies to ensure we had improved our technologies, our use scenarios, our field trials and our evaluation methods. The evaluation of the prototype is discussed in more depth in the chapter 7 of this report.

6 Evaluation: CityWall / Worlds of Information

The 3D user interface of the Worlds of Information porototyep was tested in public in the European City of Sciences (ECS) exhibition in Paris (10/2008) with WP6 Urban Renewal. After ECS, we have set up new display at HIIT as a demonstrator to our visitors and passing public.

An extensive analysis of the data gathered at during the ECS exhibition was conducted in 2009. Both video data and surveys were collected as part of the field evaluation. The video data provided observations of participants in-situ across three days of the exhibition. The researchers worked with a visiting researcher to complete the video analysis in an effort to reduce bias. The surveys were not compulsory and a convenience sample of 101 users completed them.

For each of the three days of the exhibition several hours of video were recorded. All the three days of video data was analysed using the third day of the exhibit as a purposive sample for more in-depth analysis. In addition, two hours of continuous video footage was analysed using Erickson's (1992) method of "microanalysis." This technique is particularly useful when trying to understand the common and distinct elements of events that occur. The video data was examined to understand how individuals, groups and pairs configured themselves around the system; what system states occurred as a result of the interaction; how users worked together or separately; what sort of interaction techniques users employed; how users learned how to use the system; and how the interaction sessions were structured.

For the participants we video taped and observed using the system, the ages ranged from infants (with families) to people in their 80s. An exact number of participants and their demographic information was not obtained, but the surveys were used to obtain descriptive information of a subset of the sample.

6.1 Supporting Multiple Configurations and Parallel Interaction

We observed 20 configurations of use around the system, which are illustrated in detail in Figure 15. While each of these observations were unique instances of use, they often involved the same participants reconfiguring themselves around the system based on changes in the system, or their engagement. Often the configurations would perform like a dance, with users working alone, then collaborating and then working alone again, or vice versa. A configuration was labelled as individual if one person engaged in focused manipulation of one object or area of the screen without interacting with or avoiding interaction with other users. It was labelled as pair if 2 users began to manipulate an object or objects together or talk and interact with each other while manipulating objects. It was labelled as group if 3 or more users engaged in the same manner as a pair. Results are depicted in Figure 14.

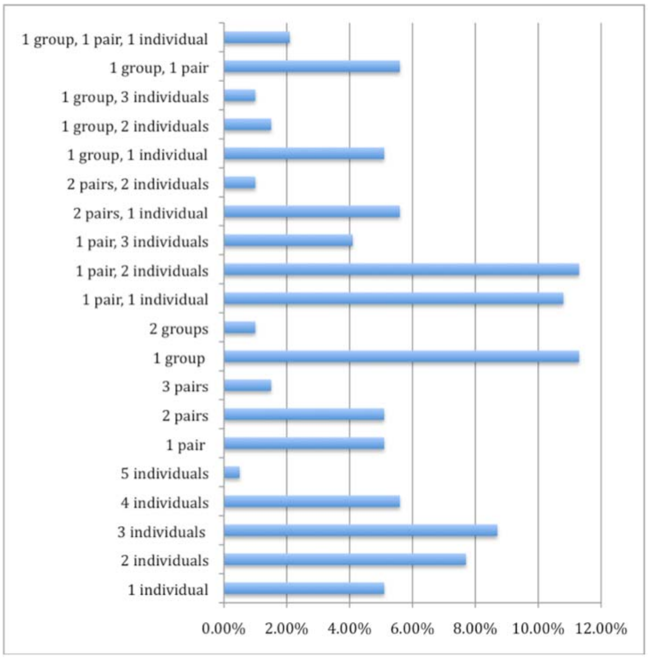

Figure 14. User Configurations around the Wall, with a total of 195 occurrences.

We also analysed the overall individual use, pair wise use and group use, finding that the most frequent use was individual (47%), followed by pair wise (35%) and group (18%). Figure 16 shows the distribution of occurrences for different configurations. We can analyse the support for multiple use by grouping the above as interaction spots. Following this we group as 1 interaction spot occurrences of 1 pair, 1 individual and 1 group, 2 interaction spots combinations or two of the latter, and so on. As can be seen from the Figure 14 and Figure 15 interaction spots account for most occurrences with 4 and more still having a sizeable portion.

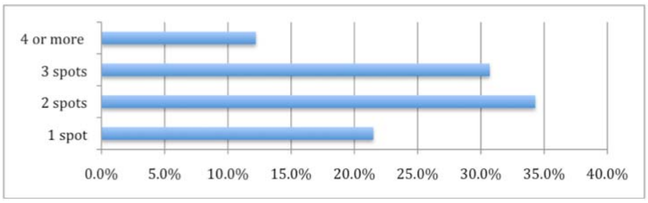

Figure 15. Configurations into number of interaction spots.

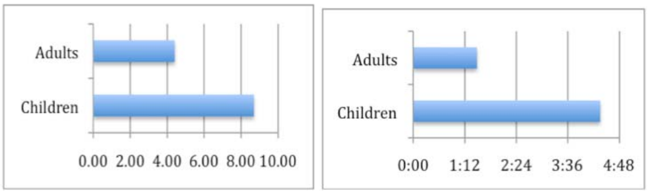

Figure 16. Average number of configurations and length of time of use by an individual at the wall.

Coupled with understanding of the most common configurations of users around the system and how the users would configure themselves, we also were interested in understanding the average length of time that a user would interact with the wall and the average number of configurations they would take on. Analysis revealed that, on average, an individual would stay at the wall for 2 minutes and 33 seconds, and be part of 6 configurations.

However, analysis also revealed that there were distinct differences between adults and children. Once the two groups were analysed separately, we found that children tended to interact with the wall much longer than adults. Children, on average, interacted with the wall for 4 minutes and 21 seconds, while adults on average stayed for 1 minute and 29 seconds. As a result, children tended to take on 8.7 configurations, while adults took on 4.4 (See Figure 16).

6.2 Gradual Engagement

We identified five distinct system states that influenced interaction and configuration by users. The states of the system are not linear, and the system can go back and forth (depending on use) through any of the states, with the exception of the first. During state 1, the system is at its initial state with the worlds closed and discrete interaction zones. During state 2, one or more of the worlds are open, but the interaction zones are still discrete. During state 3, the interaction zones are mostly separate but partially overlapping, meaning that one or more worlds or objects partly intersects another initially distinct space. During state 4, at least one world or object is overtaking one-third or one-half of the space but there is still at least one separate interaction zone. During state 5, one or more worlds or objects completely takes over the space.

Everything starts with one finger. Users were most likely to attempt to manipulate objects with one finger initially (see Figure 17), especially when not influenced by other users' of the wall. One-finger interaction was often not a problem for users who would start interaction when trying to manipulate an open world or a picture. During those times, users would often be able to rotate a world or pull out a picture, which was most amenable to one-finger interaction. *Difficulties opening the worlds*. One-finger interaction didn't lend itself well to opening a world. In the cases where someone was successful, it was often by accident (i.e., pressing on the world for a long period of time or moving a finger around the world, hoping to spin it but instead opening it), or by observing someone else.

Figure 17. Left: One-finger interaction; Center: one-handed interaction; Right: two-handed, one-finger interaction.

From one finger to two handed interaction. Often, one-finger interaction would become partial or full one-handed interaction or two-handed, one-finger interaction as users would attempt to enlarge or compress pictures or worlds. Often full one-handed interaction or two-handed, one-finger interaction starts accidentally (unless the user had observed someone else successfully using the technique) and becomes a more and more refined intentional manipulation. Intermittently, users would start with one full or partial hand interaction, but this typically happened in cases where they encountered the screen at state 3 or 4 and attempted to move an object or picture already situated on the screen.

Figure 18. Interaction with two full hands was the most effective for enlarging objects, especially the worlds.

The use of two full hands for manipulating objects was a less intuitive response by users (unless they had observed someone else using the technique) but it was the most effective for enlarging objects, especially the worlds (see). Users who stayed at the wall longer than average usually ended their session with two full-handed interaction, and influenced other users to do the same. A typical user would not start with two-full-handed interaction unless influenced by another user. One of the cases we observed involved a woman who attempted to open a world in the same way that she enlarged a picture (see Figure 19). She initially started with one finger interaction, flicking pictures around on the screen. Then she decided to open and close her hand on one of the pictures and discovered that it opened in response. She decided to try that interaction technique on a closed world. Unfortunately, she wasn't successful in doing so. As a result, she adjusted to two-handed, one-finger interaction, which resulted in successfully opening the world. A second case studied involved a pair (see Figure 20). Two men were working together, manipulating objects with one full hand and talking. They accidentally started working with the same picture and realized that by having each of their hands on the screen, they were able to make a picture larger. One man learns, as a result, that he could use two full hands to make that same picture smaller.

Figure 19. Case 1: A woman learning two-handed interaction.

Figure 20. Case 2: Pair learning two-handed interaction.

6.3 Social Learning

There were four types of techniques that users employed to understand the system: *individual exploration, cooperative exploration, passive observation then attempt* and *imitation.* Individual exploration is defined as one user testing out techniques with the system independently without observing or working with others. Cooperative exploration defines users who work together in pairs or groups to understand the system. Passive observation and attempt is defined when users watch others using the wall and attempt to imitate their use or try out their own strategies. Imitation is defined when users go directly to the wall (without observing others initially) and imitate how other users work with the wall while they are there. Most users would use a combination of two or more of these techniques when using the wall. The most frequently cited learning techniques were cooperative exploration and passive observation followed by attempt, which often worked in tandem.

Figure 21. Case 3: An example of passive observation followed by attempt and cooperative learning.

Case study 3 (see Figure 21) illustrates how users learned both through passive observation followed by attempt and cooperative learning. A man observes others using the wall but starts his interaction with one finger. A young boy at the wall starts talking with him about the wall and shows him a technique he has used. As a result, he starts to successfully work on his own section of the wall. A woman comes to the wall and starts to work with him. In the process, he learns a new technique (how to turn a picture around to view comments) and shows her what he has learned. Imitation and individual exploration were less frequently cited, probably due to the nature of use at the wall, which was often continuous. Imitation worked successfully when employed in a similar vein to passive observation and attempt because users could learn from others around them. Individual exploration varied in success depending upon the interaction techniques users employed. For example, in the first case study (Figure 20), the user had observed several users successfully opening and closing worlds with two full hands, but she decided to start with one finger interaction. However, having watched others in their attempts may have helped her determine that two-handed, one-finger interaction would later be a better choice for opening the worlds. This may have been an attempt by her to understand if the system would be amenable to another interaction technique.

6.4 User Experience and Impressions from the Survey Data: Presesence, Instrinsic Motivation and Flow

We received 101 filled in surveys, of which 64% of respondents were males, and 37% were females. Ages of respondents ranging from eleven to sixty seven years. The average age of individuals who completed the questionnaire was 29. Overall, the user population that completed the surveys would be considered frequent ICT users. In response to expertise in ICT, 54.5% reported having average expertise, 25.7% reported having expert knowledge and 18.8% reported having basic knowledge. Respondents spent, on average, 32 hours with ICT though individual use, ranging from 0-80 hours (Median=30, Mode=60). Of those who responded to educational background (81%), almost all had received or were receiving post-secondary education (83%) with the exception of secondary school student respondents (15%) and 2 adults. The majority of respondents claimed frequent use of the web (95%) and mobile phones (91%).

Eighty-nine percent of users responded to what they liked about the system. The most cited reasons for liking the system were its simplicity/ease of use (12.9%), interactivity (12.4%), tactility or multi-touch (10.1%), fun or playful nature (7.3%), novelty (6.7%), technology (6.2%) and intuitiveness (5.1%). Other responses cited its versatility, futuristic nature, fluidity, social capacity, and multi-user compatibility. Seventy percent of users responded to what they didn't like about the system, of which 22% stated they didn't dislike anything. The most cited reasons for disliking the system included multi-touch feedback or reactivity problems (16.3%), poor definition of images (13.5%), incomprehension of the system (10.8%) and problems with the interface (6.8%). In response to presence, the most cited words or feelings conveyed by users were fun/play/amusement (13.4%), amazement (7.6%), innovative (6.7%), high tech (6.1%), interactive (5.5%), simplicity/ease of use (5.2%), fascinating/involving (4.9%), tactile (4.7%) and interesting (4.4%).

Likert-type scales measured IMI, GameFlow and social presence. Thirteen statements were adapted from the IMI and GameFlow scales as well as the IPCity forging new territory questionnaire (see Table 2). Items 5, 7, 8 and 9 were adopted from the flow scale; items 10, 11, 12 and 13 were adopted form the IMI scale and items 1, 2, 3, 4 and 6 were inspired by Presence questionnaires. An additional five statements were adopted from the presence scale (see Table 3). One sample t-tests with an assumed mean of 4 (the midpoint of the Likert scales) were used to analyse the items to understand the significance of the responses to the users' experiences with the system. Most of the responses for the IMI, GameFlow and social experience items were statistically significant, demonstrating that, on average, users found the system fun, easy-to-use and understandable, and that they were relaxed using it. Further, they felt their skills increased over time. Similarly, four of the five items on the presence and user experience items were statistically significant. In general, users felt that they didn't experience technical issues, that they concentrated on the tasks and that the system activated their thinking. We compared answers to all of the Likert-scale responses through 3 different sets of analysis. We first ran t-tests comparing professions to see whether there was a difference between responses for people who worked or studied in the technology field (engineers, computer scientists and designers) versus those who indicated they did not. Then we ran one-way ANOVAs comparing individuals who labelled themselves as basic, average or expert ICT users.

Table 6. IMI, GameFlow and Social Presence Questions. (*)= p<.05. (**)= p<.01.

Item	M	Mean Diff	SD	t	df
1. I felt I was sharing the same inside-the screen space (virtual) with others.	5.28	1,277 (**)	1.931	6.41	93
2. I often changed by actions in response to those of others.	3.89	-.110	2.030	-.516	90
3. I felt I could move objects and images around in the virtual space freely.	5.91	1.909 (**)	1.487	12.38	92
4. I felt there was a shared experience between the people I was with.	4.99	.989 (**)	1.925	4.96	92
5. I found the system fun.	6.28	2.277 (**)	1.195	18.47	93
6. I understood the spatial relationships between the objects in the environment.	4.79	.793 (**)	1.992	3.82	91
7. My skill level increased as I progressed.	4.82	.815 (**)	1.809	4.32	91
8. I understood what the immediate tasks were and what I needed to do to achieve them.	5.10	1.098 (**)	1.729	6.089	91
9. I lost all sense of time while doing things.	4.26	.261	2.132	1.17	91

10. I felt relaxed while doing the tasks.	4.95	.945 (**)	1.797	5.016	90
11. I thought the tasks were very interesting.	5.12	1.123 (**)	1.798	5.96	90
12. It was important to me to do well at this task.	4.02	.022	1.803	.116	91
13. By the end, I felt competent using the system.	4.81	.811 (**)	1.890	4.07	89

Finally, we ran t-tests comparing males and females in their responses. For the profession comparison, there was a statistically significant difference between those who worked in the field and those who did not (see Table 4), with those in the field finding it less interesting and those outside the field feeling less competent using the system. There were no statistically significant differences for the other analyses. We were also interested in understanding whether there was a difference in experience between those who would use the system in the future (N=75) and those who would not or weren't sure (N=12). There were statistically significant differences in responses with the following items: "I understood what the immediate tasks were and what I needed to do to achieve them" (t(82)= -3.03, p=.003), "I felt relaxed while doing the tasks" (t(81)= -2.325, p=.023), "I thought the tasks were very interesting" (t(81)= -2.89, p=.006), and "by the end I felt I competent using *CityWall*" (t(80)= -4.098, p<.0005), with those who would not return responding statistically significantly lower than those who would.

Table 7. Other Presence Questions. (*)= p<.05. (**)= p<.01.

Item	M	M Diff	SD	t	df
1. I concentrated on the tasks and/or technology	4.97	.966 (**)	1.835	4.938	87
2. I did not experience technical problems when using the system	4.96	.956 (**)	2.076	4.393	90
3. The system activated my thinking	5.16	1.165 (**)	1.740	6.386	90
4. When someone shows me a floor plan, I am able to imagine the space easily	5.39	1.393 (**)	1.850	7.104	88
5. I concentrated on the content	4.04	.044	2.098	.201	89

7 Evaluation: MapLens

Following previous studies on collaborative use in mobile Augmented Reality, we set up a field experiment to better understand differences in collaboration and tangible Mobile AR device use in urban environment in August 2009. In this field trial participants used MapLens (see ***Figure 22***), an application on a mobile phone that works like a magic lens over a paper map, which provides an additional layer of digital information to the view seen hrough the mobile phone's camera.

Figure 22: The MapLens application showing a live video of the paper map underneath, augmented with icons and labels registered to map locations.

Our study was the first study of its kind to synchronously trial multiple, single and shared users and mobile devices in the field. The three configurations were: solo users with one device; a team of three sharing one device; a team of three with each one device. Each configuration completed the same game tasks in the same given time. We found that solo users could complete the game tasks in the given time therefore shared use as not required. However, in teams with more devices, the devices were used in a more expansive way. We observed divergent roles emerging and that the teams still decided to share only one paper map. We also noted that teams largely stayed together to complete tasks, despite it was not essential to complete the game. In teams sharing the device, looking at and pointing at each other's screens and the map beneath, occurred more than in the teams where everyone had their own device. The findings of this study have been reported in more depth in a paper submitted to CHI2010 and Mobile HCI 2010 (Morrison et al., 2009b).

In this section we will look into more depth how the evaluation of the field trial was done using multiple and both quantitative and qualitative methods following the procedures and methods described in earlier sections. This section's purpose is to show how these methods can be triangulated in practice and what kind things has to be considered especially when evaluating Mobile AR applications.

7.1 The trial

7.1.1 Research Questions

Before the trial we held long discussions and brainstorming events with TKK researchers and visiting researchers from HitLabNZ, UOtago and TUG, how we could extend our evaluation of the *MapLens* system from last year's trial and how the new AR features would be best trialled. We discussed many things, some of them were as follow ups from mapLens1 trial August 2009 to prove the findings we found there without limitation. These possibilities included questions listed in Table 8.

Table 8. Research question options.

Research question / Option
• Changing the role of the physical objects—take away/ add objects • Using a non-AR game as a comparative—just using a paper map with the same game • Comparing different map sizes between groups (see also Rohs, 2009) • Comparing size of the groups • Adding one extra play component to test for anarchic play state and radical behaviour • Analysis could look at Suchman's notion of situated action for the interaction work between team players Other considerations included: • One digimap session with equal gender mix • Ensuring devices swapped between users equally as part of the game tasks • Comparative testing of tracking with new and old system—lab or in field, located but without tasks • Using more experienced researchers to ensure accuracy/ even-ness of the reporting As addendum and background related material that contributed to the research questions we considered the following issues • Will improving performance-type issues (delay, fuzziness, difficulties reading maps, difficulties with the interface, difficulties reading the icon information, providing information on 'you are here') impact on how MapLens users collaborate, common-ground and negotiate when using the device? Tested with condition Group 1, 3 and

4a

- What available features do our users use the most? And what do they do with them and why? How long for? (Improved logging shows this)
- How task-orientated/ distracted/ playful are our players? How rule-bound is their play? How anarchic is their attitude to tasks and the games? (Supports research we do around game tasks and kinds of behaviours they elicit)
- How liberating can games be for users? Can users become immersed in game world (magic circle) and forget usual inhibitions?
- Situated action: unpack what it is we call interaction activity/ interaction work. Devise a common-ground language to discuss this interaction work and embodied activity
- Prove collaboration and embodied interaction happen (or not) regardless of number of devices or regardless of AR

As reported in Morrison et al. (2009b) in this experiment we decided to test three conditions:

1. Three devices and three maps in a team of three people, denoted as multi-lens
2. One device and one map shared in a team of three people, denoted as single-lens
3. One device and one map for one person solo, denoted as solo

See Figure 23 for a graphical representation of what conditions were trialed which day. We decided to print the map larger on paper (not foam core) like a usual paper map that folds up, so we can run single use, multiple use and shared use according to the numbers at each trial.

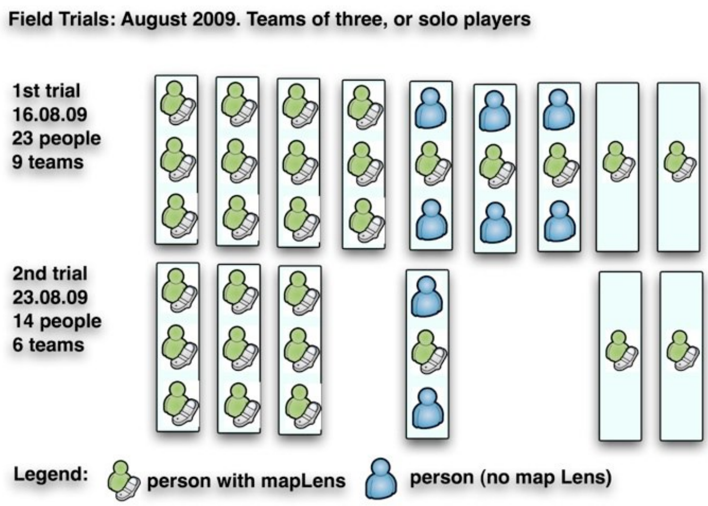

Figure 23. Configurations of players on the 2 trials days.

7.1.2 Design of the trial

The trials were designed as location-based treasure hunt games in the Museum of Natural History and the green areas of the city. Unlike in earlier work in which environmental games have been largely narrative-based (Klopfer, 2008) the goal of our game was to connect players with urban nature by giving them a new kind of experience of the city. The goal was to make their connection to urban nature and place to endure beyond the more artificial environment of the game. As such, our aim was to re-position physicality at the core of our players' AR experience by including many artifacts, and designing the game and tasks to remind the participants of their own selves, interacting within the physical world (Merleau-Ponty, 1968).

7.1.3 Briefing the researchers

Each team had a researcher video-record and observe them in the field. As there was 15 teams in total, we needed to brief all the researchers before the trials so they would know what to look for. The researchers were briefed with the following topics:

- How to work with the video camera (and prepare ahead)
- How to work with *MapLens* (what to do if it crashes, battery runs out etc.)
- What are our research questions
- What to focus on when videoing the participants

The instructions for our research team is listed in Table 9.

Table 9. Instructions for researchers.

Instructions for researchers
* Synchronize ALL clocks: personal, those in the mobile device/server that logs interactions, videocameras, and audiotapes. **What are we looking for?** 1. Player-Player Interaction 2. Player-devices Interaction 3. Player-Environment Interaction 4. Player-spectator Interaction 5. Player-Game Management Interaction
What else do we focus on? **1. Gestures** we observe: Iconic gestures represent something, such as motion, the size or shape of an object, Deictic gestures point to an object or place or in a direction. To space: immediate- close/ far Between the players (interactional space) **2. Gaze** we observe: Follow a gesture Direct attention Body follows gaze (move towards what looking at)
3. Body Posture and Movement we observe: Orientation within space: e.g. around card map, a device, towards real environment, other artifacts Orientation towards each other Orientation towards the environment
4. Object Handling we observe: Attending to and acting to the thing-focus Acting through the thing (extension of ourselves, unaware) Thing as Mediator—use it, aware but not focus (like common ground) (Wagner, 2009, *IPCity Guidelines for the set up and analysis of trials*. pp. 7-9)
PRINCIPLES VIDEO Capture: 1. THE CAMERA AS A SPOTLIGHT. Think your video camera as a spotlight. Although you're there, witnessing

with your all your senses and wide field of vision what's happening, your video camera picks up only a tiny part of that. Camera is a sampling device, you're the sampler. 2. CAPTURING HCI. We are studying human-computer *interaction*, which means that we have to capture the user and the device. However, this is a special case: there may be more than one user AND the device has a referential relationship with the surrounding environment (because it's a map!). The moral is: 3. BE PERSISTENT. Aim at 100% quality. You have to stay sharp all the time. Do not give in and think that there's enough data already.
GUIDELINES A) PRIORITIZE THE USER(S). Often when the subjects are talking about or pointing at or orienting to some STATIC object in the built environment, as they will be doing many times, it may not be THAT important to keep the video on that object for a LONG time. Rather, prioritize the users. In many cases it's obvious from what we know about the task and the spot the users are what they are talking about. Try to capture what the users are doing together and keep in mind what they pointed at. If the situation is brief, you can capture that object after the users have stopped talking. B) *NO* TALKING WITH THE USERS. Your task is to record the interactions AS if you were not there. You are not supposed to talk with the users or answer their questions. However, if the software crashes, your duty is to fix the problem. Intervene, don't leave them struggling with it. Remember they have to learn a lot in their briefing session so they may forget some things. ALSO if you see that the participants are under-using or incorrectly using the application, PLEASE assist them. For example: "do you remember you can use 1 to stop seeing all the uploaded photos and press 1 again to turn them on?" This is the only interaction that is allowed with the users. The participants usually react to your presence (being videoed) by making remarks/jokes about the camera or "acting" for the camera. You should not care about that but stay neutral, eventually this will all relax. Film them in the museum so they get used to this (and used to searching). C) YOU FOLLOW THE USERS, NOT THE OTHER WAY AROUND. You should not imply or hint where to walk. You should not hint what the correct answer is. If you don't believe, read the classic story of the Clever Hans: http://en.wikipedia.org/wiki/Clever_Hans :) D) EFFICIENT SHOOTING DISTANCE IS 1-2 METERS. The only way to make sure that you can fully capture interactions is to stand close. E) DON'T RECORD THE BACKS OF THE USERS. It's important to see where they're looking at and what they're pointing at. The optimal angle is a little bit to the side of the user. F) DON'T BLOCK THE VIEW OF THE USERS. Don't stand in front of the users. Remember: You're not there. G) MAKE THE USERS COMFORTABLE. This is not ethnography. We don't have the luxury of spending years with the participants and make them comfortable with your presence and the camera. Therefore it is necessary that you spend some time in the *beginning* introducing yourself, maybe even cracking a joke / ice breaker. But only in the beginning when you meet, not when the action is on. H) CHECK YOUR CAMERA. Your responsibility is to collect data. Sometimes technology disagrees with. If you notice that too late, then we lose a whole session. So, just before embarking, check your camera. And do it again when it's safe. I) YOU MAY HAVE TO RUN. If the participants are walking and doing something with the materials during walking, you may have to run, especially at corners. (You may think yourself as a satellite on the sky: your path is always longer than that of the planet's). J) BE CAREFUL WITH THE SUN. You must know this, but just to remind you. L) FAMILIARIZE YOURSELF WITH THE CAMERA. How does it operate? How do you change the tape/battery? Can you index events (useful!)? M) KEEP AN EXTRA BATTERY + TAPE WITH YOU. N) ENTERING A SCENE. When the users enter a new scene, you may take a "panoramic view", but ONLY if they are not interacting with each other. Remember that you can also do this later on. Otherwise, keep the focus on the users.

This time we decided ahead of four places we would ensure that the researchers videoed with close attention the participants—four places where we knew that would need to orientate to the environment, to each other and through the device find their current location and where to go next. This was to ensure we got the footage we needed.

7.1.4 Briefing the participants

We had a total of 37 users, 19 females and 18 males between the ages of 14 and 44. The user group consisted mostly of expert users. Before the game the users went through a briefing session, where each team was handed their MapLens devices and a kit bag that contained a clue booklet and material needed during the game. The participants also were introduced to the researcher that was going to observe their team and who then showed the team members how to work with the technology.

The purpose of the briefing session was to make the participants

- understand how the game worked
- understand how the technology worked
- understand the role of the researcher and the video observations

The participants viewed a presentation, which explained 1) configurations of teams and which teams were with which researcher (see Figure 24 left), 2) the purpose of the game and how to approach it 3) the clue booklet (Figure 24 right), 4) how to boot the application and work GPS, 5) how to use the interface (see Figure 25) and how different MapLens features worked (see Figure 26), as well as 6) the general running order of events, handing out of prizes etc.

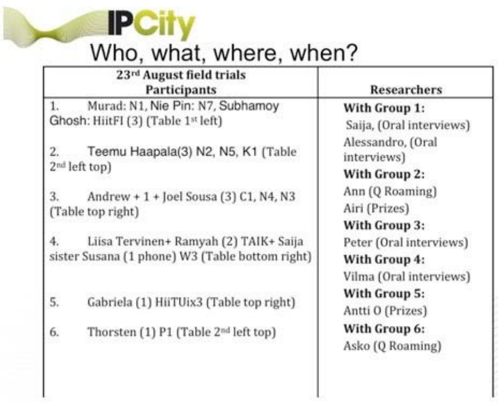

Figure 24. Left: MapLens introduction slide 1. Right: MapLens introduction slide explaining the clue booklet.

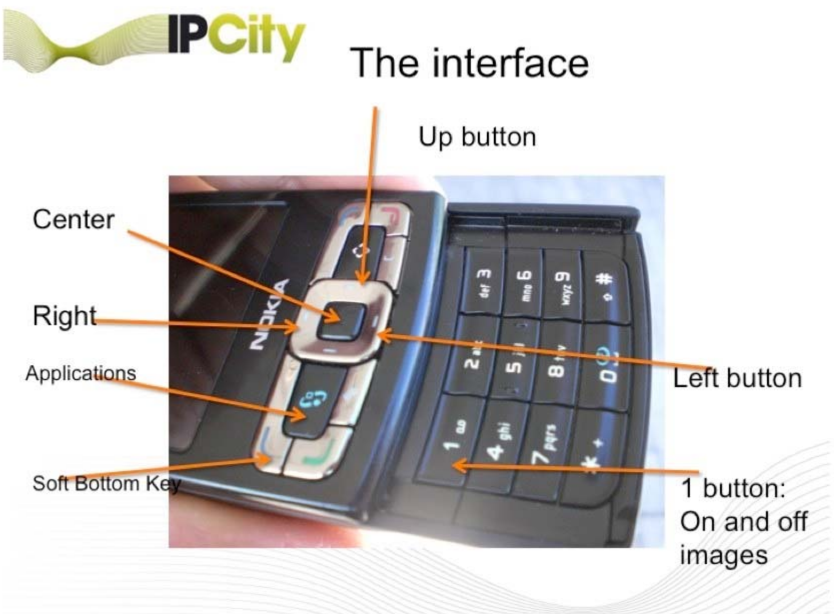

Figure 25. MapLens introduction slide explaining how to use the device.

Figure 26. MapLens introduction slides explaining how different features work.

At the end of the intrudction session the participants they received final instructions how to start playing the game (see Figure 27).

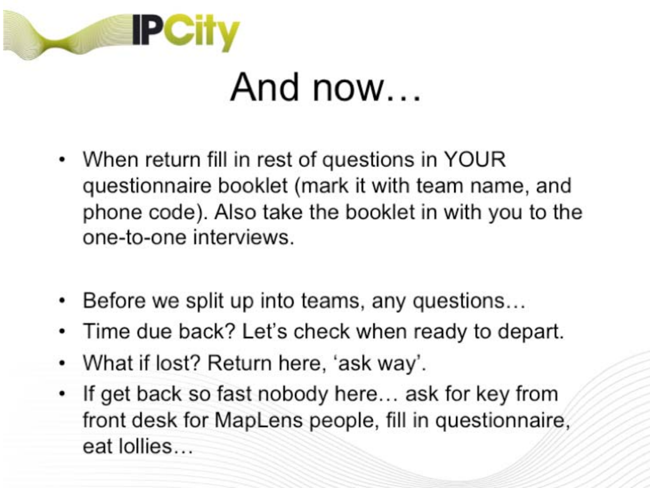

Figure 27. The final MapLens introduction slide.

7.1.5 The game

The game began after a training and introduction session at the museum. The teams completed six tasks at the museum without any assisting technology, but when planning their outdoor activities and routes, MapLens supported them. MapLens showed images as clues, like an image of a recycling point or a statue, which guided players to locations, where the tasks could be conducted. Not all outdoor tasks necessarily required MapLens use for successful completion, as we wanted to direct attention to physical aspects of the environment. Many tasks included photographing, and all the photographs taken during the game were shared through MapLens between all the players, providing the players a feeling of stronger social presence with the other groups.

The experiment lasted for an hour and a half. The weather was roughly the same for both days, cloudy and windy.

7.1.6 Data collection

Before the game, participants filled out forms including questions on demographics and experience with technology, use of maps, knowledge of environmental issues and Helsinki centre. Throughout the game, one or two researchers taking video accompanied each team, having been instructed to focus on particular instances of use and types of interactions.

After the game, participants completed shortened versions of a MEC Spatial Presence Questionnaire (MEC-SPQ), GameFlow questionnaire and an Intrinsic Motivation Inventory (IMI) to gauge reactions to the game. Participants were also interviewed with in a semi-structured interview, where they were also asked to show how they had used *MapLens*, which was then videoed.

After the trials, videos were cut into manageable chunks focusing on activity around the MapLens system and tasks. The footage from two teams, a shared device team (single-lens) and a solo team (solo) was excluded from the analysis due to technical failure. Then each researcher that had observed the teams in the field participated in a 30-40 minute semi-structured interview with the core team of researchers. Next, we will describe the analysis process of the data in more detail.

7.2 The Analysis Process

After the trial, the data we had collected included:

1. Demographic questionnaire data
2. MEC-SPQ questionnaire data
3. GameFlow questionnaire data
4. Intrinsic Motivation Inventory questionnaire data
5. Game team video observation data
6. Participant interview data
7. Participant *MapLens* video demonstration data
8. Researcher interview data

Post-processing tasks for all this data included entering the questionnaire data into spreadsheets and cutting the videos into episodes that could be analysed. The analysis process in whole included the following steps:

1. Post-processing the questionnaire and video data
2. Game team video analysis pass 1: First pass with the videos, formulation of initial categories
3. Researcher interviews with videos as cues

4. Game team video analysis pass 2: formulation of 52 item code list
5. Game team video analysis pass 3: coding the instances of the activities in the 52 item code list into spreadsheet
6. Game team video analysis pass 4: drilling down with the video analysis, focusing on things revealed by the coding (team roles for e.g.)
7. Questionnaire analysis with SPSS
8. Participant interview analysis (coding into spreadsheet, creating categories, counting instances)
9. Participant MapLens video demonstration analysis (coding into spreadsheet, creating categories, counting instances)
10. System Log analysis
11. Triangulation of data: mapping the results from the different analysis steps together to find and make sense of patterns that cross match results.

In the following subchapters we will go through the analysis steps by method used.

7.2.1 Questionnaires

Before the game, participants filled out forms including questions on demographics and experience with technology, use of maps, knowledge of environmental issues and Helsinki centre. After the game, 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 game (Vorderer et al., 2004), (Sweetser & Wyeth, 2005), (Deci & Ryan, 2000). For Presence questionnaires we measured concentration, errors, activated thinking, and imagining space. For IMI questionnaires we measured interest/enjoyment, perceived competence, pressure/tension, and effort/importance. For Flow questionnaires we measured challenge-skills balance, clear goals, concentration on task at hand, and sense of control. For social presence we added questions under development and validation through the EU funded IPCity consortium that investigates presence and interaction in urban environments. These provided us with quantitative data about the user experience, as did the in one-to-one semi-structured interviews that followed and are discussed in the next sub-chapter.

We looked at the questionnaire analysis results as an additional resource that was used as support for the video analysis. In our opinion 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 how they are used. We translated them to a ‘common-sense’ language, still retaining the original meaning and with consistent meaning for their translation into Finnish (and making sense in that culture). We did this with four researchers: one presence questionnaire expert, one evaluation expert, one mobile technology expert and one ‘using mixed methods for evaluation’ researcher. This process forced lively debate and took the most part of one day, with further follow-on conversations over email and in the translation process with other evaluation experts.

The English version of the questionnaire can be found from Appendix 1.

7.2.2 Interviews

User Interviews

In the semi-structured oral interviews after the finishing the game, the participants described their experience, highlighting aspects that had caught their attention in the game. These are the example questions asked from the participants:

Q1. How did you use the MapLens, can you show with a phone and a map?
Q2. Did you know beforehand your team members? What relationship—friend, colleague, boss etc?
Q3. Did pointing help you complete the map+phone tasks?
Q4. Did talking with the others help you complete the map+phone tasks?
Q5. How was the experience?
Q6. Which parts did you take more time with? Which did you enjoy most? Which things related to game or technology, were you thinking more about /played more with / returned to or engaged most with.(Choose which part of the question is appropriate to your interviewee)
Q7. And then if the user said something interesting I would ask more about it, but letting the user speak as freely as possibly.

All answers were recorded with a digital sound recorder, except Q1, which was also recorded with a video camera: participants were asked to show with MapLens how they had used the device and this was then videoed, allowing us to see them using the device in the more controlled environment of the museum (even lighting, no wind etc.) Also this session acted as a cue for the user to go back to the experiences she had encountered in the trial with the technology. The participants were asked to think aloud when doing this, so that the researcher could pinpoint important points that might have been otherwise missed in the interview.

Data post-processing tasks included transcribing these user interviews and translating them into English for further analysis. Also, data from the pre-phase forms and the post-trial questionnaires were entered into spreadsheets, and videos were cut into pieces where activity around MapLens tasks occurred.

The actual interview analysis included coding the interviews into a spreadsheet. In addition to the questions listed earlier and demographic information such as gender and education level, we also coded things related to categories listed in Table 10.

Table 10. Categories coded.

Categories	
• Map	• Roles
• Multiple thumbnails	• Pointing
• Enlarging pics	• The experience in general
• On the move	• Most time consuming
• You are here	• Most enjoyable
• System in general	• Most engaged with
• Talking with others	

The interview coding data can be found from Figure 28 (Sheet1: Data): double click the figure to see the whole table.

This coding then could be then analysed by counting the instances of occurrences in each category for each three condition. The occurrences could be then categorised further. For example for the category “the experience in general” we counted:

- 10 occurrences for the shared condition, of which 8 was positive, 2 neutral and 0 negative

- 3 occurrences for the solo condition, of which 2 was positive, 1 neutral and 0 negative
- 13 occurrences for the three devices condition, of which 13 was positive, 1 neutral and 2 negative

From this we could conclude that mostly users gave positive feedback about the experience in general while only the three devices group had something negative to say. Then we could drill down what negative things the three devices group encountered and start thinking why it was like this for this condition? You can find the counting results from Figure 28, Sheet2-5.

#	Trial	Condition	Questionnaire language	Team name	Phone	Corner note	Age Groups	Gender:	Education Level	Interviewer	Interview order	you use the MapLens, can you show with a phone and a	know beforehand your team members? What relationship-	How was the experience?
	2=23.8.2009	1=1user	en/fi				1: <18	m/f						
	1=16.8.2009	2=1shared phone, 3users					2: 18-24							
		3=3phones, 3users					3: 25-34							
							4: 35-44							
							5: 45-54							
							6: 55-64							
36	1	1	en	Highway to Helsinki / Christian's solo	Ht13	99	3	m	master	alessandro	2	99	99	fun, tasks w
33	1	1	en	Perrine / solo	nameless	99	2	f	bac+2	antti	0	She showed	[illegible]	[illegible]
9	2	1	en	Nomands/solo	HiltUix3	nomads	3	f	doctoral candidate (Masters undergrad degree)	peter	3	99	solo	enjoyed doin
8	2	1	en	Tf6/solo	P1	tf6	3	m	PhD	peter	4	99	solo	certainly eng
19	1	2	en	CHC	N5	n5	3	m	bachelor of engineering	peter	7	99	didn't know beforehand	it was new,
20	1	2	en	CHC	N5	n5 holgers wife	4	f	post???	peter	6	99	daughter and [illegible]	[illegible]
18	1	2	en	CHC	N5	N5 lost B, holgers daughter	1	f	intermediate school	saija	4	could use [illegible]	[illegible]	interesting [illegible]
34	1	2	en	Gruppo	G1	99	3	m	engineering degree	alessandro	1	99	99	interesting
31	1	2	fi	Gruppo	G1	99	3	f	kuvataiteilija AMK	antti	2	99	jenny 1 kerta	99
32	1	2	fi	Gruppo	G1	99	3	f	ktm			99	99	it was ok wi
35	1	2	en	Mammut	K1	k1	3	m	master of computer sciences	alessandro	4	99	99	fun, worki
24	1	2	fi	Mammut	K1	k1	2	f	liikunnanohjaaja (AMK)	peter		99	99	fun and differ
25	1	2	en	Mammut	K1	k1! Timo	3	m	BBA	peter		99	99	idea was re

Figure 28. Interview data coded in an embedded Excel spreadsheet.

The videos from the interviews (question Q1) were analysed separately by one researcher.

Researcher interviews

In the week following the trial each researcher, participated in a 30-40 minute semi-structured interview with the team of 3-4 core researchers, to obtain a richer overview of how teams interacted, e.g., how roles were formed, when discussions happened, how map and device shared, typical ways to gesture and point, and ways teams interacted with other teams, spectators and researchers. We also wanted to allow time for the researchers to reflect on what they had witnessed, as we had the immediate responses of the participants, as well as immediate footage at the trials.

To help recalling the important events, we watched together the video footage of the group the researcher was observing in the trial, adapting a video-based recall technique standardly used with participants (Costello & Edmonds, 2007). These videos acted as cues for the researchers to explain the interaction and events she had witnessed during the trial. This video based interview technique is discussed in the following chapter on video analysis.

Our process in research interviews was this:

1. We interview researcher with grabbed footage and get most information
2. Stay as a group with the video footage straight after the researcher interview and revisit for the last three stages of the process.
3. Collate what we find on the spot

4. At various stages in the process we need to total the similarities and differences in what we are finding, so remember this advice: “One way, start with characterization of typical and marginal use types *per group*. This is where we aim for in first pass.”
5. We can then plumb these more with in-depth of a sample, e.g. a group of 3 devices, a group of shared device users and a solo user gropu doing same task or where lots of activity for each group.

This way we focus our coding when we do the interviews. In Table 11 you can find a list of examples we asked from the participants.

Table 11. Examples asked from participants.

Interview questions for the participants and example notes
1. How roles formed? Who did what? phone-map-cluebook-bag. When did they switch roles? At what stage roles defined? System in place?
Example note: “Two lead roles, girl passive as late call in, guy in black took first leading and expert role, then two boys co-lead or battled for leadership. Both used maplens concurrently on map. Roles defined from museum outwards, used on ground when started, rolling map and dropping down, rolled map inwards system. Used ad hoc and on the move batteries, then it went awry because they separated and there on in stayed together. Grey guy used pen for clue book.”
2. Main person using *MapLens*? (in what circumstances did they switch?)
Example note: “Two leads, who got there first began it, and then e.g. taking photo”
3. Pointing gestures (on map and environment, screen, clue book; with pen and finger?)
Example response: “on screen many, on map many, not with pen, phone to point and phone to circle iconic gestures.”
4. When and what kinds of gesturing happened? Over map? At environment? When difficult?
Example response: “Some gesturing to the environment, and gestures with map rolled to the environment.”
5. Sharing device?
Example note: “All 3 person users using simultaneously on two occasions. Sharing, and looked through others, pointing on the others device, parallel use—are you getting this? Communicating while use in parallel.”
6. Other use of the device?
Example response: “Only for photographing, pointing iconic circular gestures No browsing, not great use of other photos (check)”
7. Map/s, Switching? (Whose map using)
Grey guys map used mainly. But black guys also. First all maps out., and then who has the map out first, although she never puts
Example response: “Girl when solo, black guy when couple, grey guy when all. Leadership and map related. People augmenting and map gets taken away by map owner (just like phone)”
8. Use while walking?
Example response: “Tried to use, and she tried a few times---map in held bag and tried to use it. Up and again and down again with girl trying to use in parked mode, not able to use while standing as not steady enough? (wind) map itself.”
9. Two-handed or one-handed use of the device (change over time?)
Example response: “Two-handed for clicking through images, enlarging etc. and one handed for roving the map, standardly in one hand horizontal use”
10. What was the alignment of the phone (e.g. vertical/horizontal, near/far from the body, can others see the screen etc.)

Example response: "Vertical or other while walking and horizontal on top of map"

11. Did they switch attention between the map and the mobile device? (Between phone+map and environment / From map to environment)

Example response: "When searching something from environment looking around, she going from mapLens to environment, often from all perspectives."

12. Did they interact with spectators? With you as a researcher? With other teams?

Example response: "Interacted with researchers, reverse roles and took photos, interact slightly to Thorsten, did not interact with spectators and were self-sufficient"

13. Other comments?

Example response: "When split and did ad hoc activity at batteries, did not work out. Everybody carrying map and phone out all the time. Mediated image through feet in grass, looking through all cameras."

Rationale

We reasoned that after going through this interview process we would have much information and should only need to revisit the videos for the following topics::

1. Object handling
2. Body Gaze (body follows gaze) (BG)
3. Gestures: Iconic and Diectic (or may be covered 4 + 5)

We were completely incorrect with this. We had a general impression of differences, but we did not really get enough information on how people used devices differently until we began actually counting specific instances of different types of activities. It was very hard to get beyond the personalities driving the teams and we knew we needed to do some analysis specifically with this. Who uses the phones and how (nature of the collaboration) depends on team composition and personalities. With MapLens1, we saw team personalities impacted use but had no evidence, so for MapLens2 we ensured we could prove impact, adding to an understanding of situated collaboration around mobile devices.

7.2.3 Video

Data collection, post-processing and preliminary analysis

Throughout the game one or two researchers taking video accompanied each team. Our researchers were briefed to record for the entire 90 minutes, but to focus on sharing, turn taking and object handling of the device, and instances where

1. The participants used *MapLen*s in the museum
2. The participants used *MapLens* outdoors
3. The participants were developing or changing strategy
4. The participants were working on a pre-selected task that required extensive *MapLens* use.

After the trials the video data was uploaded to a shared server, from where each researcher could access the files. The videos were then encoded into format that all researchers could access.

At this point the lead researcher went first time through all the video material and did a preliminary summary of observations of each team. An example of this kind of summary can be found from Appendix 2. Each summary contained only new kinds of activities found from the group observed.

Watching the videos with the researchers

After the preliminary analysis of the video material the core researcher team (four people) negotiated what they thought that was the relevant material in the video data. The summaries done by the lead researcher acted as the starting point for this work.

Each group's video footage was watched by the core researcher team together so, that the researcher who was with the group was also present and explaining what in her opinion happened in the video. This part acted at the same time as the video based research interview and the first pass of the video analysis.

At this point the researchers started forming the initial codes, mainly based on the multimodal dimensions discussed in chapter 2 and 7, but also on gaming related categories highlighted by the IPerg (2005) project. The coding system is discussed in the next subchapter.

Coding system

In our video analysis process we focused especially in the dimensions related to embodied interaction (Dourish 2001) and how players focus on, act though or use artifacts as mediators (Norris, 2004, iPerg, 2005, Wagner 2009). This focus originated from our research questions and the theoretical framework discussed in chapter **Error! Reference source not found.**. Based on that, we created initial categories (codes) of things we were looking from the video (see Table 12).

Table 12. Initial categories for coding.

Initial categores formed for coding
Game Date: Team: Number of Devices:
1. Player-spectator Interaction (PS)
2. Player-researcher Interaction (PR)
3. Teams to other teams (TT)
4. Map use only one at a time? Record switching+map activity (MU)
5. Object handling: where the thing is LARGELY the mapLens in tandem with the map PLUS occasionally aspects of the kit.
• Attending to and acting to the thing-focus (TF)
• Acting through the thing—unaware of it in hand (extension of ourselves) (TA)
• Thing as Mediator—use it, aware but not the focus (TM)
6. Pointing:
Map (PM) Environment (PE) Screen (PS) Clue book (PC) Pen (PP)
7. Body Gaze (body follows gaze) (BG)
8. Gestures:
• Iconic Gestures (e.g. motion, size or shape of obect))IG)
• Deictic Gestures point to an object (DGN)Near or (DGF)Far or between players—interactional space (DGI)
Be aware we may need to include observations (MapLens1) For example:
- Pointing gestures (on map and environment) - Two-handed or one-handed use of the device
- Alignment of the phone (e.g. vertical/horizontal, near/far from the body, can others see the screen etc.) - Role switching and negotiations - Body postures and attention switches between the map and the mobile device

After the interview session and initial coding, the core researchers discussed their observations. These observations were mapped to the AR features of the system, listed in Table 13.

Table 13. AR Features of *MapLens*

A: Features Used	B: Improvements and new features
Green circle (you are here)	Taking images offline and browsing while walking
Selection viewfinder (red square)	Stability of use, so no issues with hand shake
Icon information (clues)	System more robust, so ease of use with ML system
Camera information (photos)	Interface gives more feedback
Thumbnail online	Researcher intervention on using device
Multiple thumbnails online	
Multiple thumbnails offline	
Enlarged image (full-screen)	
Photo countdown	
Photo upload (preview)	

This discussion resulted in the creation of the actual list of codes, which is presented in Table 14. This 52 item list of activities (actual codes) included ways the devices and maps were held, different pointing gestures, means of sharing a screen and a device, frequency of stopping or parking for the system use, and effects of a map or phone ownership on a balance of power in each team. At this point the two key researchers watched through the videos again, coding the activities of players observed on the video using the codes created in this phase. The two key researchers had been involved in the planning and implementation of all stages of August 2008 and August 2009 trials so were considerably more involved from the project's inception and particularly at this stage than the rest of the core group.

Table 14. List of activities (codes) searched from the video data.

Activities searched from the video data		
1. One-handed panning 2. Two-handed panning 3. Short-distance panning 4. Middle-distance panning 5. Long-distance panning 6. Pointing on map 7. Pointing mid-air 8. Marking map 9. Pointing on screen 10. Pointing to environment 11. One-handed hovering 12. Two-handed hovering 13. One-handed selecting 14. Two-handed selecting 15. Checking clue thumbnails 16. Checking thumbnails taken by others	21. Sharing the device 22. Sharing the screen 23. Standing 24. Squatting 25. Moving closer to map 26. Moving further from map 27. Use non-Maplens functionalities e.g browsing, sending SMS messages 28. Use offline functionality (multiple photos offline) 29. Use online multiple images 30. Used another phone for other functions 31. Use while walking 32. Use parked 33. Use stopped (things down) 34. Vertical use of device	39. Switch phone/environment 40. Interact with researcher 41. Interact with other teams 42. Interact with spectators 43. Vertical map 44. Horizontal map 45. Map on the ground / tabletop 46. Folded map 47. Rolled map 48. Map owner main augmenter 49. Map owner not map augmenter 50. Leadership for phone holder

17. Checking enlarged images taken by others 18. Checking own gallery 19. Take photos 20. Checking own locations	35. Horizontal use of device 36. Skewed use of device (between H+V) 37. Switch phone/map 38. Switch map/environment	51. Leadership for map holder 52. Swap roles

While going through the list (coding the video data) researchers marked the frequency of each action by using a 4-point scale:

- Did not occur (not marked),
- Less (L=<3, occurred less than three times)
- Average (X=3-5, occurred 3-5 times)
- More (M=>5, occurred more than 5 times)

In unclear situations questionnaires filled by players were consulted for background information. We then looked through this list to see what commonalities or patterns were emerging between the three conditions: solo, solo user; single-lens shared device; multi-lens device each.

During the interviews and the different passes of the video analysis the core researchers sought new phenomena not already identified. The questions and the list of actions were updated continually, when new phenomenon were identified researchers returned to previous videos and interviews to check and update the findings. This provided us the coding result that was inserted in a spreadsheet, which is here embedded in Figure 29 **Figure 29. Coding of our 52 item list.**(double click the figure to access the whole spreadsheet).

Date	16.08	16.08	16.08	16.08	23.08	23.08	23.08	16..08	16.08	23.08	23.08
researcher	Peter	Ann	Saija	Holger	Saija+Aless	Ann+Airi	Peter	Mikael	Antti J	Asko	Antti O
Team	KateGroup	Joanna Taik	C/S Hanne+	Didn't work	Murad + 2	Teemu + 2	Andrew+2	Christian	Didn't work	Thorsten	Gabriela
Phone/s	N1, N4, C4	N2, DCC2, I	N7, HiitFI, V	Redundant	N1, N7, Hii	N2, N5, K1	C1, N4, N3	Hiit3	redundant:	P1	Uix3
Legend:	**L=<3; X=3-5; M=>5**										**no cross-**
Action	**3 devices**	**3 devices**	**3 devices**	**3 devices**	**3 devices**	**3 devices**	**3 devices**	**solo user**	**solo user**	**solo user**	**solo user**
Onc-handcd panning	M	M	X		X	M	X	M			X
Two-handcd panning	L	X	X		X	X	X	M			X
Short-distance panning	X	M	X		M	X	X	M			X
Middle-distance panning	X	M	X		M	M	X	X			X
Long-distance panning	X		L			X					
Pointing on map	M	M	M		M	M	X	M			X

cannotbe

Figure 29. Coding of our 52 item list.

These results were then used to identify differences between the conditions (for example in “holding maps”). In Figure 30 is a scanned image of our coding process, which how we worked with the data marking the differences between conditions and highlighting important items. This lead us to “drilling down” deeper in the data and counting results, which is discussed in the next subchapter. At this stage we were still looking for patterns or any unusual occurrences of significant difference to emerge. The videos from each team were gone through several times and each occurrence of the activity was marked in the excel sheet.

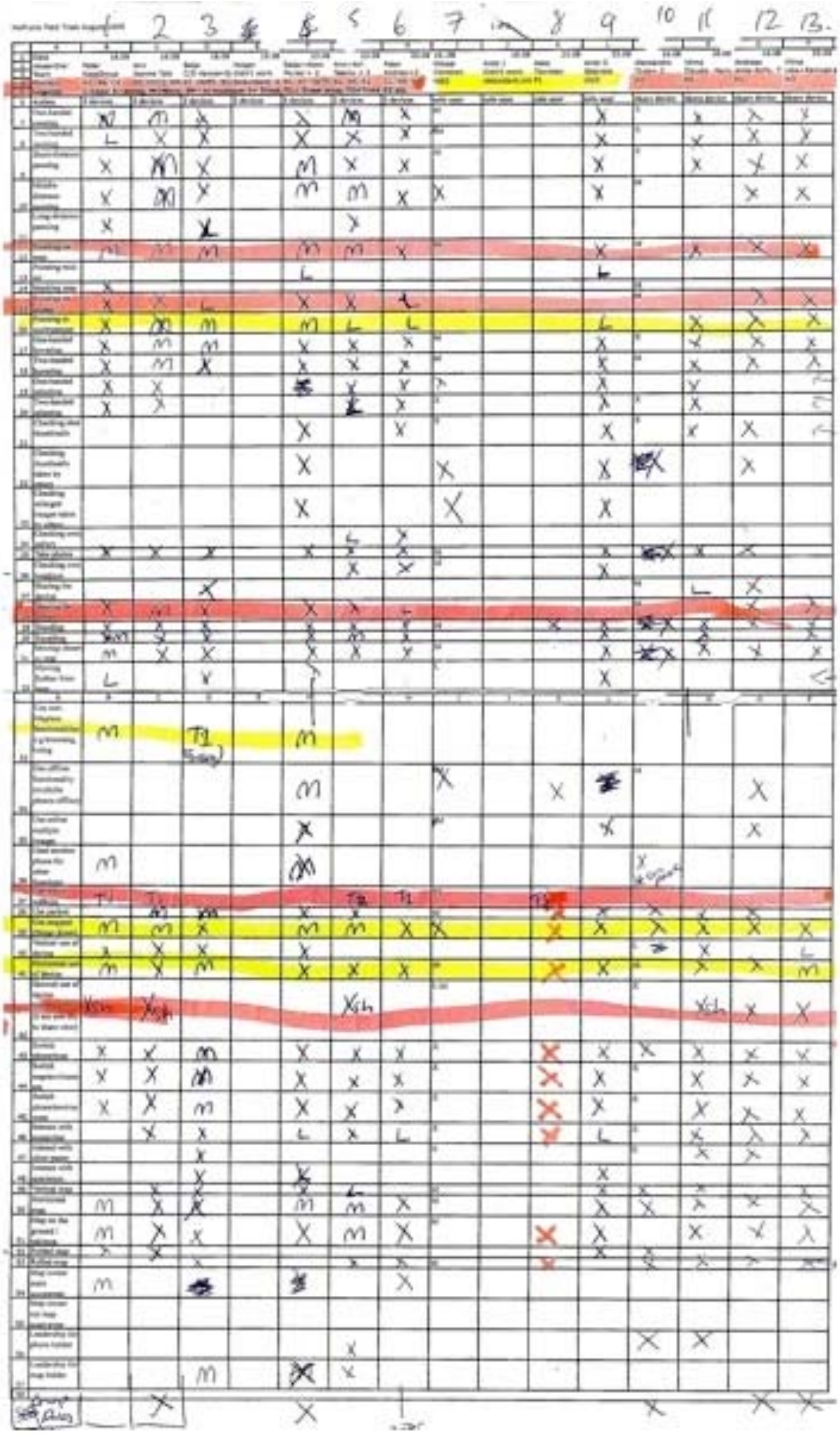

Figure 30. Scanned image of our coding process.

Drilling down

A smaller list relating to specific AR sharing, screen sharing and pointing to screens, map and environment was then compiled and all the footage was gone through to count instances of these activities that are listed in Table 15.

Table 15. List of sharing and pointing related activities

Activities related to sharing and pointing	
Non map lens user points the map	Phone screen shared with X people
ML user points it's screen	Screen shared: horizontal
Other person points device screen	Screen shared: vertical
ML user points the map	Screen shared: tilted
ML user Quiet when point	Phone moved because of colliding
Other person points the map, while ML used	Phone kept further away to avoid collisions
ML user points environment	Phone used for something else (time)
ML user looks environment	Phone not used (time)
Other person points environment	Changing user (mid.session)
	Using another phone

We decided to put more effort into clarifying the typical ways the device was used during the game, the length of the use sessions and if all the devices were used equally. We also recorded, when the devices were shared between the users, and when they were used simultaneously with other devices, and clarified how this affected how and what they were used and also how that effected the communication around them.

While watching videos :

- We recorded the length of each usage session, where it occurred (indoors/outdoors), and if a map was hold on a hand or put on a bench or ground.
- For each device we recorded/counted:
    - how long it was used during each use session,
    - how long it was used simultaneously with other devices, (see Figure 32)
    - if a phone was moved during a session because it was about to collide with another phone, or if it was purposefully kept further away from other phones ,
    - if it's screen was shared during the use session
        - how many people it was shared with,
        - if it was kept horizontal, vertical or tilted,
        - how many times device user and other persons pointed it's screen,
    - how many times device user and other persons pointed to a map to identify or suggest a place of interest ,
        - and if this was done for communication, or to keep the place on mind, when simultaneously trying to identify it by watching around ,
    - how many times device user and other persons looked at environment to identify the place,
    - if a user of the device changed during the usage session,
    - how long a device was used for something else than augmenting (e.g. browsing),
- Were other phones (the personal ones) used during the session and how long

In addition to this we identifed the typical 'patterns' of use, especially

- how user's attention switched between the device screen, the map and the environment,
- how the device, the map and other items were held, and
- how users were aligned during each usage session.

We compiled the average amount of pointing in the three different team conditions (see Figure 31)

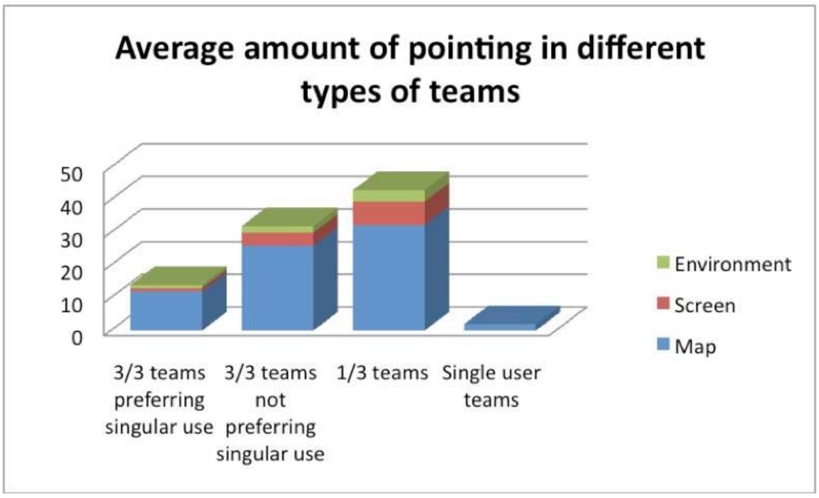

Figure 31. Average amount of pointing per condition

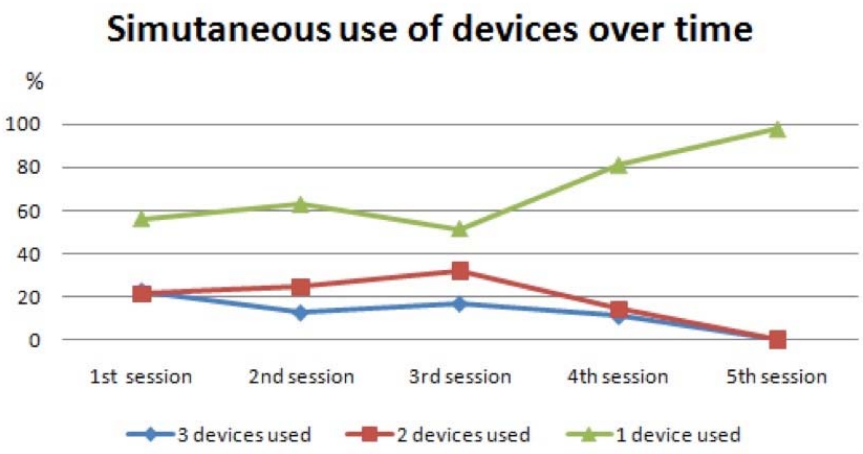

Figure 32. Simultaneous use of devices

We then ascertained the average number of times the main and auxiliary phones were used in multi-lens teams (see Figure 33).

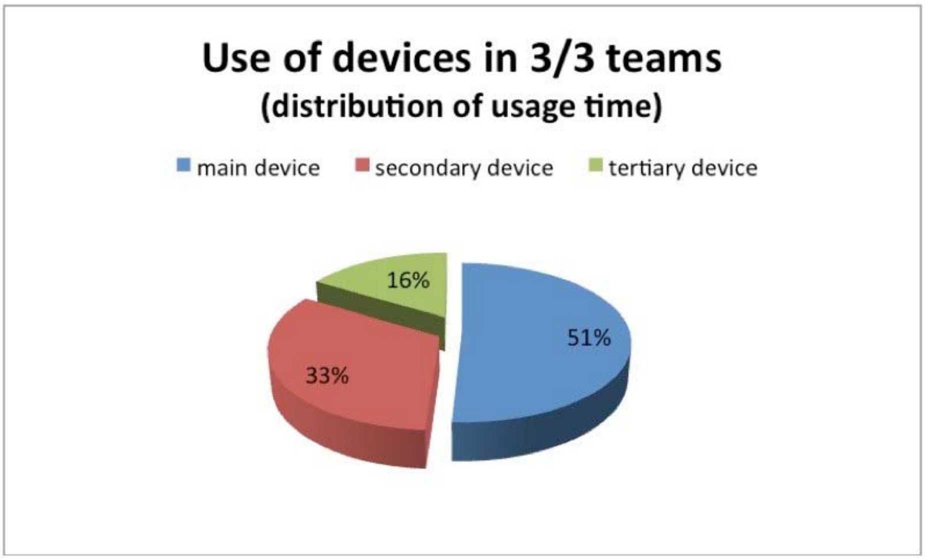

Figure 33. Use of devices in multi-lens teams

Division of Labour and Team Roles

Also, lists for coding of team roles was compiled to capture the essence of how the groups worked and who was in control the group (= who was the alpha user). This coding system can be seen in Table 16, how the division of labour was achieved, what teams were more active (see Figure 34) what configurations of teams spent most time on which activities etc. The researcher marked an instance of each activity for each team (noting there was usually one most active and decision-making (alpha) phone on the map at any one time. The compiled results of these are discussed in the findings section.

Table 16. Coding system for team roles.

Coding system for team roles
Alpha user dominant phone
Auxiliary supporting phone 1
Auxiliary supporting phone 2 / other use (e.g browsing)
Manage map (opens, carries or takes away)
Person who choreographs and makes decision on where to go next in the game
Person who scouts or does other supportive tasks to AR Phone use, for e.g. decides on where to go next.

3 DEVICES			SHARE DEVICES	
R1 Totals	21		P1 Totals	13
R2 totals	23		P2 Totals	12
R3 Totals	13		P3 Totals	26
3 Devices	57		Share Devices	51
K1 Totals	24		A1 Totals	22
K2 Totals	28		A2 Totals	18
K3 Totals	33		A3 Totals	23
3 Devices	82		Share Device	63
M1 Totals	23		C1 Totals	37
M2 Totals	14		C2 Totals	34
M3 Totals	20		C3 Totals	35
3Device	59		Share Device	106
P1 Totals	14			
P2 Totals	9		D1 Totals	5
P3 Totals	18		D2 Totals	3
			D3 Totals	12
3Device	41			
			Share Device	20
N1 Totals	27			
N2 Totals	24			
N3 Totals	25			
3 Devices	72			
Q1 Totals	16			
Q2 Totals	7			
Q3 Totals	11			
3 Devices	35			

Figure 34. Activity levels in each group, to determine dominance or equity in distribution of tasks

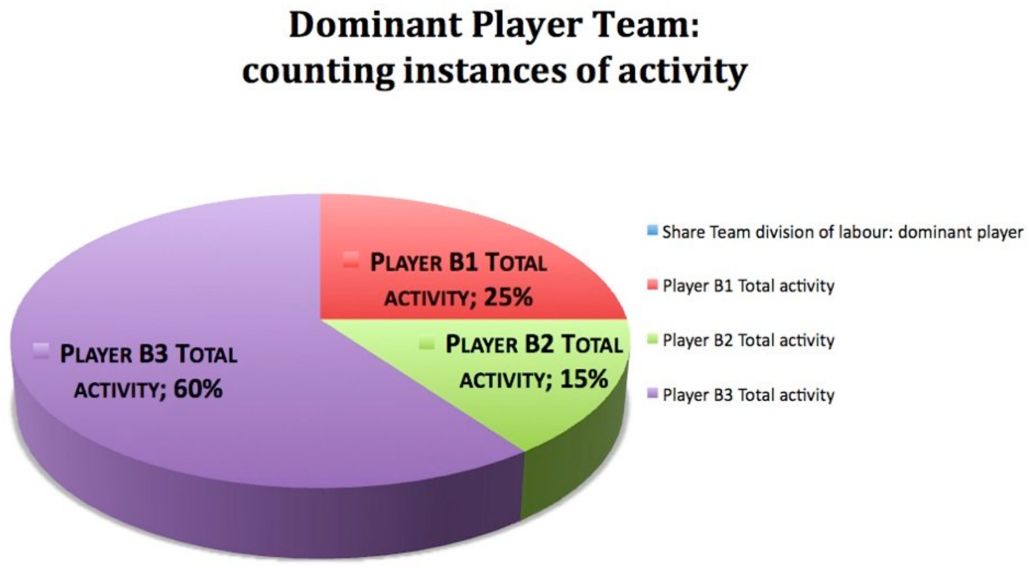

Figure 35. Instances of activity.

Coding MapLens demo use episodes

In the user interviews we had asked the users to show with *MapLens* how they used the system and talk aloud while demonstrating their use. These demo episodes were also analysed by one researcher who coded from the videos the occurrences of how many times users used the old and improved features (see Table 13). We added this information to the spreadsheets with a column for each feature and demographic information such as gender and education level.

7.2.4 System logs

MapLens logging was verbose and produced a lot of information of every system. These logs were then parsed to see how many times certain features were used, as this could not be observed from the video all the time, and to cross check and support findings.

Table 17. Averages of features used by different teams.

Condition	N	Uploads	Enlarged	Enlarged Clues	Enlarged User Photos	Thumbs Viewed Total	Thumbs viewed in normal view	Thumbs viewed in multiple thumbnail view	Entered Multi-Thumbnail View	AR Features used in total
solo	3	13,33	24,00	6,75	17,25	374,25	269,50	104,75	8,00	460,00
single-lens	3	20,33	18,00	8,00	10,00	344,00	275,33	68,67	7,33	389,67
multi-lens separately	18	15,39	14,50	4,72	9,78	242,39	202,17	40,22	4,89	277,17
multi-lens together	6	35,67	50,17	16,83	29,33	544,50	629,33	260,33	34,17	664,50

Table 17 shows the differences in averages of features used by different teams. Solo users (11) and shared device users (single-lens) used the different features approximately the same amount and differences found were not statistically significant.

Although the averages between single-lens and both multi-lens conditions are different, these differences are not statistically significant. Statistical comparison in general with such small N values is not feasible. For more in depth analysis we would have needed more cases to compare.

Finding no differences in log analysis 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.

7.3 Findings

In this subchapter we review our findings from the analysis process presented in earlier subchapters. Most of these results were written in a publication submitted to CHI2010 conference.

7.3.1 Questionnaires

Thirty-seven questionnaires were filled-out and entered into Excel/SPSS, with one dataset excluded due to missing data. We looked at pairwise comparisons of the three conditions. As shown in Table 18, the data suggest significant differences between single and multiple user conditions (conditions solo vs. single-lens vs. multi-lens) in experience of the game only (not for technology use). In terms of attention (A2), activity in the environment (A8, A10) and the challenge-skills balance items (B10 to B20) the group configurations (multi-lens, single-lens) scored higher than single users (solo). The reported ratings for the enjoyment or loss of self-consciousness (B21, B23) are generally high for all conditions, but group conditions had the highest scores with these items as well. Also, group configurations also reported higher scores in the Intrinsic Motivation Inventory (IMI) part of the questionnaire (C1, C10) than single users.

Table 18. Questionnaire items showing significant differences between the conditions

General Linear Model Pairwise comparisons	Conditions compared	Mean Diff.	Std. Error
A2: The game took most of my attention	single-lens vs. solo	2.167*	.992
A8: I felt I could be active in my surrounding environment	solo vs. multi-lens	1.833*	.843
A10: I thought about whether this map & phone system could be of use to me	single-lens vs. solo	3.000*	.998
	multi-lens vs. solo	2.833*	.962
B8: How to play the game was easy	multi-lens vs. single-lens	.833*	.293
B10: I understood how to play the game when I left the meeting room	single-lens vs. solo	1.167*	.523
	multi-lens vs. solo	1.417*	.504
B19: I understood what the immediate tasks were and what I needed to do to achieve them	single-lens vs. solo	2.167*	.814
	multi-lens vs. solo	2.250*	.784
B20: I knew how I was progressing in the game as I was proceeding	single-lens vs. solo	2.000*	.643
	multi-lens vs. solo	2.167*	.619
B21: I was not as aware of time passing or of other people outside of the game as I feel I would usually be	single-lens vs. solo	2.667*	.995

B23: I enjoyed putting my feet in the grass, looking at the leaves, testing the pond water and similar tasks	single-lens vs. solo	2.333*	.675
	multi-lens vs. solo	2.417*	.651
C1: I enjoyed doing the game tasks	single-lens vs. solo	2.333*	.540
	multi-lens vs. solo	2.333*	.520
C10: I felt pretty skilled at the game tasks	single-lens vs. solo	2.000*	.776

Notes:
*. The mean difference is significant at the .05 level.
All items 1-5 scale; Ax: presence, Bx: Flow; Cx: IMI

Differences between the group conditions (single-lens and multi-lens) were not as strong as one would expect. The only significant difference between the group conditions was how easy they found the game (B8), with multi-lens teams scoring higher than single-lens teams. All significant responses (significant at the .05 level) were found with game experience. For technology, only thinking about future use (A10) revealed any significant differences (multi-lens, single-lens scored higher than solo), despite the same questions being asked about the technology and the game. For groups (single-lens and multi-lens) we found higher levels of attention, activity in the environment, challenge-skills balance, enjoyment or loss of self-consciousness and intrinsic motivation than solo users. It seems that the sharing tasks, meant there was not such a large workload and more opportunities for discussion and playful kinds of activity: 'feel-good factor'.

7.3.2 Interviews

People reported being very engaged and involved with the game, although for multi-lens, half of the users reported the most engaging single thing in the experience was the technology. Almost all users reported having used pointing to the map as a means of communication between team members, and half of them reported pointing being very helpful to refer to items seen through *MapLens*.

7.3.3 Video analysis

Most teams left the briefing room in the museum and completed museum tasks before venturing outside. Some teams were more systematic, planning their route by utilising *MapLens* before heading outside, while others traveled from clue to clue. The first sessions of MapLens use were longer than the later sessions.

Duration of Map Usage Session

Overall the durations were similar in the two teamwork conditions: the durations were slightly longer and sessions more frequent in single-lens teams (mean 1:36 min, 7 times, σ =2.9) than in multi-lens teams (mean 1:26min, 6 times, σ =1.4). However, the contrast to solo users is larger. The solo users used MapLens slightly more frequently, but had almost half-a-minute shorter sessions (mean 1:06min, 8 times, σ =1.0). We can surmise multi-lens use enabled faster common ground understandings between players to reach a decision while the device was over the map, than for single-lens teams. While solo users were more efficient, it seems their cognitive load was higher, (as shown in Questionnaires) needing to re-access information more frequently, perhaps because joint problem-solving was not possible.

Sharing of Devices in Multi-Lens Teams

Devices could be shared in the multi-lens teams, so we analyse this condition separately.

When starting the game, multi-lens teams typically used two or three devices simultaneously, but once familiar with the game and the system, largely just one device was used. Four of the teams continued to use two or three devices simultaneously over half of the time that the devices were in use (mean use time 2 devices 33%, 3 devices 20%) but two teams consistently used only one device throughout the game (mean use time 2 or 3 devices 4%). Even with the teams that used two or three devices, there was still clearly one ‘main device’ (mean total use 51%) and more ‘secondary or tertiary device/s’ that were used less (mean use 33% and 16%).

As well, two phones seemed to be the maximum amount of devices that could easily fit at one time on the map surface, and here again, one was always a ‘main device’ with one or two ‘secondary or tertiary devices’ used to support or assist the alpha device (see Figure 4 a). We also observed decreasing multiple phone use over the span of the game. Devices were used in a panning motion over the map and needed space around them in order to move freely. In some teams where devices collided, one user would move their device to a different height above the map, moved alongside the other device on the map, or withdrew their device and looked through the other device or sideways under the device with the naked eye to avoid reoccurence(see Figure 36a). To avoid collisions some players also explored different areas of the map (see Figure 36b). However, players grouped together to work on the same MapLens task, rather than delegating out tasks and working solo. Because of space around the map, and teams discussing and solving the same problem together, we surmise that over time more efficient use emerged with one alpha device over the map, and that the peak use was for two devices, given the amount of space working around the map provided.

Figure 36. (a) 3 devices used simultaneously (fitting better, when on different heights) (b) 2 devices used simultaneously. (c) Using just one device was often more effortless.

Embodied interaction

We refer here to the way in which the game threw players in multi-lens and single-lens teams into close physical proximity, forcing them to draw close together (into a cluster) around the small devices’ screens. Players used their bodies; their hands, their gaze, their gestures, and tangible artifacts; their phones, pens, whatever was at-hand in order to communicate and reach decisions together.

Looking

When using MapLens to identify a location, MapLens users in all teams typically switched their attention between the device screen, the map and the environment. Typically, (1) a player first identified a location on a device screen, (2) after that the player checked where the location exactly was on the map, and finally (3) the player looked to the environment to decide where to head next. In addition, all teams also used the shortened version of the method by switching attention just between a device screen and a map, and/or a device screen and the environment. Switching attention between a map and the environment was naturally more typical for non-*MapLens* users than *MapLens* users (see Figure 37).

Figure 37. Attention switching (a-c) from a device to a map and then to environment, (d-f) between a device and environment, (g-i) from a map to environment

Sharing

In single-lens teams players communicated more around the system by sharing information on the map, screen and environment (means 32, 7, 4 compared to multi-lens 22, 3, 2), while in multi-lens teams players shared information while looking through their own devices. In single-lens teams the players shared the device screen largely throughout all sessions (mean total 89%), by tilting their screen for others to see, pushing the device closer to others, handing the device over or standing closer together.

In single-lens teams the players shared the device screen practically throughout all sessions (mean total 89%). Players tilted their screen for others to see it better, pushed the device closer to their teammates, handed it over or stood closer together (see Figure 38). Pointing to the screen used by another team member was more common in single-lens teams. In multi-lens teams, the intentional sharing of screens happened less, typically only a couple of times during the game, and then only for a few seconds (see Figure 38).

In single-lens teams, all three players typically shared the screen almost continuously (79% of the shared cases), while in multi-lens teams, it was most typical that two people shared a screen (71% of the shared cases). Also, pointing to another person's screen was more typical in single-lens teams than in multi-lens teams (see Figure 38). Also, single-lens teams shared information on a map and environment more frequently, while multi-lens teams shared it (whenever they shared) through their own device. All players in the sigle-lens teams, both *MapLens* users and non-users, were looking and pointing to the environment more frequently than in multi-lens teams.

Figure 38. (a,b) Sharing a screen and a device in a single-lens team (c) sharing a screen in multi-lens team

Pointing

Pointing to the screen of another team member was more common in single-lens teams, as was looking and pointing to the environment and the map. In multi-lens teams, the intentional sharing of screens happened less, typically only a couple of times during the game, and then only for a few seconds.

While solo users pointed to a map typically a couple of times during the game to support their own use and thinking, MapLens users in all multi-user teams pointed to the map on average 12 times throughout the game, usually to communicate locations to their team members.

Non-*MapLens* users pointed to a map more in single-lens teams (mean 14.5 times) than in multi-lens teams (mean 10 times). We surmise that these players were not able to augment the location themselves, and needed to inform or query the *MapLens* user about information. As well, these non-*MapLens* users had their hands and eyes free to look around, whereas people in multi-lens teams were more focused on using and looking through the device. All players in the single-lens teams were pointing to a map, a screen and an environment more frequently (means respectively 26, 7, 3) than in multi-lens teams (means 22, 3, 2). We observed that for multi-lens teams, pointing on the screen could often be replaced by looking through *MapLens(es)* screens to *e.g.,* augmented information or a finger pointing on a map (see Figure 36a).

Differences in multi-lens teams

The two multi-lens teams, who mainly used just one device for the entire game (at least 92% of the time), also pointed to the map, device screen and the environment notably less (mean 11) than the members of other multi-lens teams (mean 29). The difference was especially clear with the non-*MapLens* users of these teams, who pointed to the map only couple of times (mean 4) compared to the other multi-lens teams, where the mean count was 15. These teams acted differently to the single-lens device teams.

One multi-lens team used just one device 92% of the total time they used the system. The team had one main augmenter, who knew the city well, but all the team members took turns and used the system actively (see Figure 39a,b). While one team member was using the system, others were browsing, working with a clue booklet and kit, exploring the environment, taking photos and browsing offline the photos taken by other players. Despite clear roles and a singular use of the system, team members often agreed on a next destination by pointing to it on a physical map before moving ahead.

Figure 39. (a,b) multi-lens team members using the system by turns, (c) multi-lens team members preferring simultaneous use

Another multi-lens team used two or three phones simultaneously relatively often (28% and 22% respectively) (see Figure 39c). The team actively discussed and planned their activities and pointed to a map, a device screen and their environment while using the system. This team used two maps simultaneously while inside museum, but switched to one map use when outdoors. They also folded the map outdoors, used *MapLens* parked, and attempted use while walking.

Teamwork

We identified occurrences of predominant recurrent tasks that team players took charge of. We then compiled this information adding device use time, activity levels and division of tasks. As game strategy, most teams completed museum tasks before venturing outside. Some teams systematically planned their route, while others traveled from clue to clue. The first sessions of MapLens use were longer than the later sessions, as participants became more adept with using the device in tandem with the map.

We identified occurrences of predominant recurrent tasks that team players took on. We then compiled this information adding device use time, activity levels and division of tasks.

Division of Labor

We found there were five main tasks, three of which included responsible decision-making for the team (agency), and two more general support tasks. We surmise the division of labour occurred as a form of natural social organisation, in order that people were not continuously attempting the same task. These tasks were categorised as:

(1) Alpha device use: dominant device used by the team to view and make agreements through;

(2) Map use: carrying, orienting, holding out. No hands free for a device. Having a map available for use (or not) begins and ends MapLens use; directs game play and time management (see Figures 4a, 6a)

(3) Navigation: decision on where to go next, often several occurrences for each MapLens use; route and overall strategy for whole game;

(4) Secondary or tertiary phone use: supporting lens(es) in relationship to alpha device on map, browsing internet or photos taken by other players for clue solves;

(5) Scouting: exploring environment, looking, marking, pointing paper map, using clue booklet and kit, taking photos, discussion etc. Does not occur while holding MapLens, map or navigation decision.

We found in multi-lens teams, the average for division of labour for instances of use was: 37% phones (with 20% alpha phone, 7% auxiliary 2nd phone, 6% auxiliary 3rd phone); 27% managing map, 26% scouting and other tasks and 14% deciding where to go next. The average amount of time all phones were used across all multi-lens teams was 920 seconds.

We found in single-lens teams, the average for division of labour for instances of use was: 36% scouting and other tasks, 27% first phone use, 24% managing map and 13% deciding where to go next. The average amount of time phones were used across all share-device teams was 647 seconds.

In descending order of activity we found values for multi-lens teams/single-lens teams for device use 37%/27%, for map use 27%/24%, for scouting 26%/36% and for navigating 14%/14%. The average time for all device use for multi-lens teams was 15.3 minutes (920 sec), compared to 10.7 minutes (647 sec) for single-lens teams. Therefore, we found our multi-lens teams averaged 10% more device use, and 4.5 minutes more phone time compared to the single-lens teams, who engaged in 10% more scouting activities. Again we found that multi-lens teams worked more through MapLens, and single-lens teams performed more activities outside of the device.

Therefore, we found our multi-lens teams averaged 10% more phone use, and 4.5 minutes more phone time compared to the single-lens teams, who engaged in 10% more scouting activities and other tasks (including pointing and looking to map and environment etc.), and 3 % more map use.

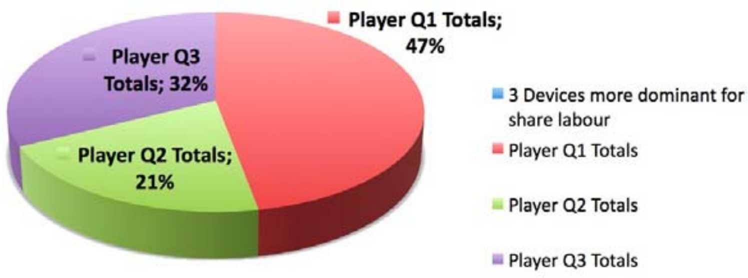

Figure 40. Case example: activity counts multi-lens team with dominant player taking up 47% of the activity

Types of teams

By counting the numbers of activity per player, and then comparing teams, we classified the teams according to the number of "active user/s" combinations possible in teams of three at any given time: 1 = controller, 2 = 2-share, 3 = agile.

(1) Agile: equal counts of activity per member. We also observed in these teams that roles flowed from one to the other almost seamlessly (see Figure 39).

(2) 2-share predominant: two players had larger activity counts, and one player was less active in the game. However, all took turns at tasks and entered the spirit of team play. (see Figure 42.

(3) Controller: one player with much higher activity counts than other two. Roles were often fixed from game start, with the controller being reluctant to share agency **(**see Figure 42b,c)

We found that the multi-lens teams consisted of two agile, two 2-share predominant and one controller types. In single-lens teams, there was one agile, two 2-share predominant and one controller type. In the two controller teams, the dominant player often put the device back in the pocket, or while using it, hid the screen from team view. We rule out shading from direct sun, as we saw no other instances of this kind of use in other teams (Figure 42b).

In the two controller teams, we surmise either players did not intervene as they were too polite, happy to take a lesser role or unfamiliar with outdoor use of the device. In 2-share predominant teams, the predominant two players either knew each other beforehand or connected while playing the game, but also made sure they included the third person. In agile teams, players did not necessarily know each other beforehand, but managed the sharing of tasks in an equitable manner.

Obviously a controller in a single-lens team impacts the general team experience more heavily than in a multi-lens team, where the other devices can be used. For playing the game, team type was not determined by the number of devices, but rather by the personality make-up of teams, with no obvious correlation of team type to condition (multi or single-lens) across this size sample. We can see clearly that the team personalities impacted on how the device and tasks were shared (or not) and how collaboration occurred. Multi-lens supports more independent and flexible use of the technology, so as a way to circumvent e.g., controller behaviour, having multiple phones can be useful.

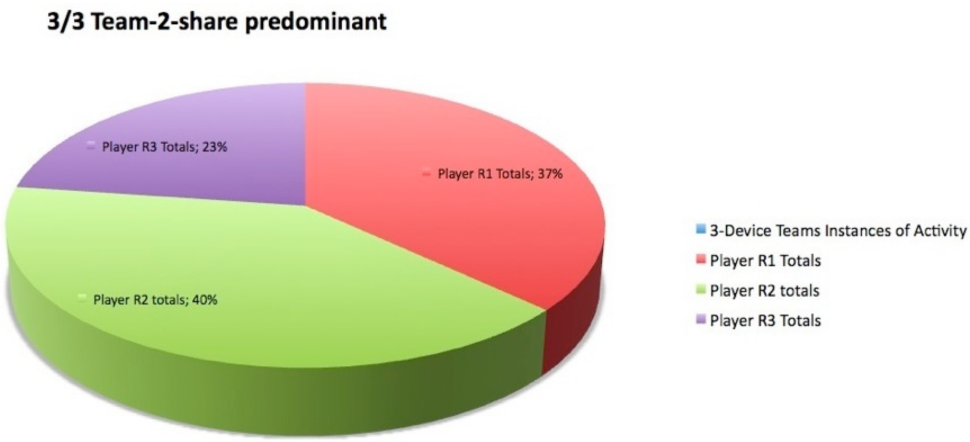

Figure 41. Shared labour in 2-share predominant team

Figure 42. (a) She is still using map but the map carrier pulls map away and team moves on. (b) Controller: he even hides the screen view from his team, (c) and puts device in pocket so he is always in control.

Impact of new AR features on use

We logged MapLens activity on the devices to see how many times certain features were used, as this could not be observed from the video all the time, as well as to cross check peaks of activity and support other findings. When looking at the average use of AR features across all conditions, we found no significant difference between the three conditions. Video observation allowed us to better understand the situated context of use, and included all the non-AR physical types of activities, including pointing, looking and discussion.

Some players also browsed photos while on-the-move, as this was now possible without constantly needing to access the map (a new AR feature). The device over the map allowed defining an interest area, connection to the content server to download, and 'caching' all images within the selected area, which were then available for offline non-AR browsing. This version of 'Take-away Interface' was perceived as most useful by those who employed the technique as it allows a more in-depth or a re-checking of information on-the-fly, without the need to continually stop to access information.

Compared to the previous version (Morrison et al., 2009), technical improvements in *MapLens2* provided users with more flexibility of use and a larger range of functionalities, which were used extensively during the game. The use of the new features meant:

Almost every user browsed the map for clue images (94% multi-lens, 100% single-lens, 75% solo), and many browsed for their own and other team's photos (47% multi-lens, 70% single-lens 50% solo), even though they considered it a side-activity not connected to the game. Most users browsed photos on a scrollable overlay view developed for the system to support the viewing of dense image areas (70% multi-lens, 70% single-lens and 50% solo). Some players also browsed photos while walking, because this was now possible without constantly needing to access the map. The device over the map allowed defining an interest area, connection to the content server to download, and 'caching' all images within the selected area, which were then available for offline non-AR browsing. This version of '*Take-away Interface'* was perceived as most useful by those who employed this technique. Most users also found the "you are here" icon showing a live GPS position of their position helpful (70% multi-lens, 58% single-lens and 75% solo).

Use outdoors

The teams either used the system while standing and holding a map, or they put a map on a supporting surface (see Figure 44). When comparing *MapLens2* with *MapLens1* (Morrison et al., 2009), users no longer needed to stabilise either the map or their hands when augmenting. The system also worked well for a wide variety of angles distances between map and device. While there was increased capacity to use the device while walking, we found only four multi-lens teams, and two solo teams attempted to do this, but did not continue use while walking outside the museum.

Figure 43. a,b) Different ways to use MapLens: players either stand and hold a map or lay a map on a supporting surface like ground, table or a bench c) using while walking d) a team struggling with 3 maps at the beginning of the game.

Outside use with wind, direct sunlight and obstacles, such as people passing, uneven pavements, moving traffic, as well as wind and direct sunlight impacted on *MapLens* use. We observed constant negotiation with wind and large maps. Despite the fact that the map was an inexpensive item and could obviously be stressed without consequences, only two multi-lens, one single-lens, and one solo team folded the map, making it easier to use.

More temporary stopping and more mobility

Just as 'no parking' zones are used for temporary parking, all our players exhibited more 'park type' activity (stopping briefly to check a detail) and continued to stand while using *MapLens* (see Figure 38c, Figure 37d-f). Two of the single-lens and one solo users only used *MapLens* while standing. All teams also made longer stops, using the device for extended periods and putting down items (see Figure 39a-c, Figure 43b). However, the recurring temporary stopping for quickly checking a detail was a phenomenon not found in our last trial, where more *place-making* was the common practice. We believe the ability for quick stops is a result of the technical improvements of our system.

8 Key Evaluation Results and Conclusions

8.1 CityWall/Worlds of Information

We set out to develop a multi-touch display for a walk-up-and-use interaction. We have identified challenges for designing for engagement and for parallel interaction. Supporting multiple users and multiple content has been addressed concurrently by providing several separate worlds. Engagement was addressed through gradual discovery of content and functionality, which is particularly challenging in a public display due to the short character of sessions.

8.1.1 Information Worlds as Multi-touch 3D widgets

Our solution adds a 3rd dimension to multi-touch interfaces that are generally 2D and applies the metaphor of Worlds, which is different from other metaphors used for similar purposes (Forlines et al., 2008; Hinrichs et al., 2005; Everitt et al., 2005). The interface solution we proposed worked but uncovered four problems and implications in particular for this type of display. (1) Users should be accompanied through the exploration of the functionality, for example, through the help spheres, which can be brought contextually to the attention of the user at the right moment or made more intuitive in design. (2) Gradual unfolding and discovering means that the interface should be adaptive to the situation and be able to provide a similar starting phase to all users. For example, the *Worlds* could be animated to go back more promptly to the starting collapsed state to be able to offer people exploration from the beginning (Forlines et al., 2008). Additionally, the starting collapsed state should be made more intuitive to open. (3) Advanced functionality should be brought to users' attentions intervening in the interaction. Spinning and Timeline navigation, which was not found intuitive to users most of the time, should be made more visible and easier to understand. Similarly, the methods for uploading and sending content should be more obvious. (4) Finally, the display should provide support for managing territoriality in parallel interaction, controlling size and position of worlds. This could be used to better support stability of some of the configurations of people at the display by limiting the behaviour of the *Worlds*.

8.1.2 The Worlds Inviting Multiple Users

We have shown how the multi-touch 3D widget supported parallel interactions. The observational data demonstrated that the most frequent configurations of users involved multiple individuals working in groups or pairs, and the instances of individual use that were highest were in tandem with another individual, pair or group. This demonstrates that the system frequently accommodated multiple users, and different coupling styles (Forlines et al., 2008, Gutwin et al., 2002). Another finding was that users were influenced by others, both through observation and collaborative exploration, as pairs and groups often influenced each other on the wall. Further, survey data indicated that users felt that they engaged in shared experience with others, but did not change their actions in response to them, indicating that they could share the space without compromising individual exploration.

Designing for the walk-up-and-use experience

The responses to the survey data indicate that, overall, users responded positively to the system, finding it engaging, interesting and understandable. Engagement with the content was not significantly reported, indicating that further attention should be paid to the information users interact with. Users started with one-handed or one-finger interaction and were less likely to engage in two-handed interaction without observing or interacting with others. Overall, the analysis supports *Worlds of Information* as a system that enabled different levels of use where users could explore the functionality individually or socially.

Even though the system was found to be engaging and easy-to-use, on average, different groups of users (for example, people working in ICT) found the system less interesting and non-ICT professionals felt less competent, showing that supporting different levels of competence did not work perfectly. However, users, on average, found the interface intuitive and playful, which has also been found in former studies (Peltonen et al., 2008). Further, users responded that motivation to play was intrinsic (without external reward). The 3D Spheres and the metaphor of the 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. By adding another layer of complexity with gestures that move beyond the now familiar pinch, expand and rotate movements, we hoped to entice our participants to become more immersed in uncovering interaction techniques by pursuing varied options. By allowing worlds to overlap, participants were required to be aware of each others activity, and we looked to initiate forms of mutual engagement (Everitt et al., 2005), where individuals can spark their curiosity together, and can lose themselves in a joint activity. Walk-up-and-use display can greatly benefit from multi-touch. However we found that not all users fully exploit the multi-finger and multi-hand features. The challenges ahead include providing easy access to relevant content through effective navigation mechanisms. The gradual discovery of more complex functionality should be supported adopting adaptive interface strategies.

8.2 MapLens

8.2.1 Trickle Down Effect of Robustness

We return now to the central tenet of our previous study, where we found teams positioned themselves in close bodily proximity around the device and map (a phenomenon we label as clustering), in order to render AR information visible to all, and so enabling collaboration. The key questions left unanswered [16] were:

(1) How does group use change if the technology is more flexible?

(2) And how does it further change if users have access to multiple mobile AR devices (and no real necessity to collaborate)?

With MapLens2, our design included improvements in flexibility, stability and range of the technology, hugely improving the team's freedom when using the device. Users no longer needed to cluster so closely to the map, the device could be tilted in order to more easily share screen view up to 90°, and use at a greater distance from the map was now possible (up to 2 meters). As well, there was no need to shade the display in order for tracking to work, or to keep a steady hand while standing still.

We identified four key factors—the technology factor, the people in teams factor, the shared artifact factor and the shared lens factor—that may have contributed as extenuating factors forcing collaboration from our MapLens1 study, and ensured that we directly account for these factors in this study. We found that MapLens2 technology does impact on freedom of use and supports a more rapid form of place-making on the move. From testing solo users, we found that not only can the game be completed solo, so too can the MapLens system be successfully used solo, so there is no imperative to collaborate. We also found that while personalities do impact on the experience, this is not caused by whether people needed to share devices. However, having individual devices available, allows more flexibility and agency for individuals. While people do not use multiple maps beyond early training stages, having individual devices reveals a difference in how those devices are used. For multi-lens teams, there is less need for direct communication and devices are used more as a common-ground form of sharing with understandings more easily reached by sharing information via the device screen. As well, regardless of no longer needing to collaborate, we found:

1. People worked on the same problem together. Dividing up and distributing tasks and working alone did not occur. Rather 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 mores—it is 'usual' to work together when placed in a team, as well as it being more fun to work with others. Bearing this in mind, it would be sensible when designing future AR applications to ensure the design affords ease of place-making, and establishment of common-ground.

2. More agile use extends ad-hoc place-making. We see that the more robust system enables more transient forms of place-making and ad-hoc collaboration, facilitating more temporary stops, and adds parking and stopping as forms of place-making to the more traditional setting-down. We found the 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, adding to topical work on situated use, mobility and place-making [5]. Features such as 'Take-away Interface' decrease the need to stop and enhance the potential for use-on-the-move. The design of improved AR and technology factors did positively affect team configuration and usage patterns, extending the range of collaboration styles available.

We also now know more pragmatic details, such as for future game trials we could dispense 8-10 phones for 5 teams of 3 players, whereas 15 phones is over-kill as not all players used their phones equally. As AR research is an emerging area with scope for speculation, this seemingly trivial information is useful for eradicating guesswork in logistical planning and future design for both this game, and other pervasive mobile game and Mobile AR experiences.

8.2.2 Multi-lens and Single-Use: how the teams AR'd

When we look at the differences between multi-lens use and single-lens use, five main conclusions on situated use of the devices can be drawn:

1. Teamwork is more enjoyable. AR on mobile phones is easily used in multi-user situations. Multiuser teamwork has more 'feel-good' factor than solo use.

2. Sharing of artifacts. Single physical frame of reference is preferred for teamwork over multiple frames.

3. Economical sharing through displays. Collaboration in the multi-lens situation is characterised by sharing of AR information among the members through their displays. This decreases the amount of communication work necessary.

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

5. One alpha lens. Even when multiple lenses are simultaneously used, one lens emerges as dominant.

First, the general finding is the confirmation and extension of our previous result [16] that AR on mobile phones is a natural platform for collaboration. The presence and experience questionnaires show single and multi-lens groups scored higher on attention, activity in the environment, challenge-skills balance, enjoyment or loss of self-consciousness and intrinsic motivation. Solo users reported enjoying the game less than the multi-user teams. Team-sharing increases enjoyment and offers more opportunities for 'feel-good' experiences.

Second, we found that the greater freedom of use provided does not mean teams will not collaborate. Despite the availability of multiple maps, multi-lens teams still shared one map and gathered around it. Our observations show that in this situated use, the option of having multiple individual frames of reference was not relevant. Users, in particular those who clustered together for collaboration, preferred a single physical frame of reference.

Third, we witnessed the multi-lens teams created a common-ground method for co-operation via their lenses over the map (regardless that there was not a ready-made system of use designed for them). It seems for multi-lens use, sharing via a screen and holding one's own personal device heightened efficiency in collaboration. Less pointing and looking to the environment was needed, with use of the system less frequent and for shorter periods of time, and players looked through their own lens to AR together. By looking through their multiple devices simultaneously, players could synchronously experience the same view of the information, with less need for overt pointing and discussion, and as a result establishing multi-lens common ground procedures on-the-fly. They shared differently than the single-lens teams, as they shared more through the device screen, and consequently needed to point less to the map, the screen and the environment. This was the more efficient way of sharing with the most information at hand, and in view; lightening the communication workload by using the devices to establish a multi-lens common-ground system of use. Two phones seemed to be the maximum amount of devices easily fitting simultaneously on a map of this size; additional phones were frequently moved up or to the side. The personal device was literally at hand (not put away) for use when needed. We speculate the peak use of two phones is dependent on the size of the shared space, the distance to the augmented object (consider augmenting the façade of a historical building) and the information density in this space.

Fourth, multi-lens use provides more flexibility for use to teams and more opportunity to overcome problems of team composition, such as overly dominant users. The use of multiple devices expands individual agency and collaboration possibilities by extending the range of interactions possible for the ways in which groups can collaborate. Individuals were enabled more agency in completing additional tasks such as web browsing for information, asynchronous use, and less need for co-location. It is therefore worthwhile supporting multiple AR devices.

Fifth, regardless of the number of phones available to a team, there was one dominant phone that facilitated the viewing and the decisions. While this phone could change depending on, e.g., through which device the latest clue was found, it was consistently found that there was one alpha phone on the map surface that all other phones acquiesced to at any given time.

8.2.3 Summary and future work

This study opens up a new domain of investigation, because it extends the study of collaboration on mobile phone based AR to a multi-AR and multi-FoR (frame of reference) situation. Having multiple phones and multiple maps in teams created a novel situation not studied in the context of AR before. Normally, AR displays content on a unique object that can be shared by a group. Today's mobile phones allow a wider approach. Not only can each user have her own device and frame of reference (*e.g.*, the world or the map), but there could also be as many FoRs and lenses available, as there are users simultaneously using the system. While FoRs were not useful in this instance, we see these have potential for future work, *e.g.,* with remote collaboration for multiple users, or for training with placing different posters in an environment and adding extra information at each new location to support incremental learning processes. As we progress to 'serious' outdoor AR use, we will note subtle but important changes of use. From the perspective of serious application development, the AR design space is hardly known, so these findings on multi-lens sharing are important particularly in the context of the recent popular uptake of AR for product advertising, business cards, *etc*. Notable works suggesting directions of future use include research using maps/frames of various sizes [23] and application ideas exploring playful interactive environments [18].

The study lends evidence that mobile phones are easily adopted as collaborative tools for small groups, despite expectations around their use as a small personal device. We find having multiple lenses useful in expanding collaboration possibilities. While the use of multiple lenses is not linear with the number of users (*i.e.*, not all users use their phones equally all the time), the quantity and quality of collaboration is changed in a number of ways, making it worthwhile to leverage the ubiquity of phones for more collaborative interaction design.

This study also suggests a number of further questions to be examined. One such question concerns the relationship of multiple devices to the size and structure of the shared space. Another important question, not considered in this paper is how showing customised augmentation content on the individual phones—*subjective views*—would affect simultaneous use. This is particularly interesting if users are able to create or manipulate virtual content in the environment, only available in this study via photo taking. The very positive results of spontaneous, voluntary, expanded and agile place-making within intense collaboration suggest that there would be more interaction designs that evoke these properties with AR interfaces.

9 Dissemination

9.1 Publications

WP7 presented a paper on *MapLens* field studies in CHI2009, which received a best paper award nomination:

1. Morrison, A., Oulasvirta, A., Peltonen, P., Lemmela, S., Jacucci, G., Regenbrecht, H. 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 (CHI '09) pp. 1889–1898.

This year WP7 has submitted two conference papers to the CHI2010 conference:

2. Morrison, A., Lemmela, S., Oulasvirta, Schmalstieg, D., Peltonen, P., Mulloni, A., Regenbrecht, H., Jacucci, G. and Juustila, A. Sharing through the lens: Collaborative Augmented Reality on Mobile Phones. Submitted to CHI2010.
3. Jacucci, G., Morrison, A., Richardson, G., Kleimola, J., Laitinen, T. and Peltonen, P. Worlds of Information: Supporting multiplicity at a public multitouch display. Submitted to CHI2010.

The MapLens paper was not accepted and has been now submitted with changes to the MobileHCI conference. The CityWall paper was accepted for CHI2010.

A journal article was accepted in the PRESENCE special issue:

4. Wagner, I., Broll, W., Jacucci, G., Kuutti, K., McCall, R., Morrison, A., Schmalstieg, D., Terrin, J-J. (2009). On the Role of Presence in Mixed Reality, PRESENCE special issue from RAVE'09, MIT Press. Accepted for Publication.

A journal article was submitted to the Personal and Ubiquitous Computing journal, which was not accepted and will be resubmitted with changes in the HCI journal:

5. Morrison, A., Lemmela, S., Peltonen, P. and Jacucci, G. Methods to Evaluate Pervasive Technologies: Games and Patterns of Play. Submitted to PUC.

A journal article has been submitted to International Journal of Human-Computer Studies (its acceptance status still unknown):

6. Peltonen, P., Kurvinen, K., Morrison, A., Jacucci, G. and Lemmelä, S. Studying Collaborative Embodied Interaction. Submitted to IHJCS.

Also WP7 was invited to write a book chapter about CityWall and MapLens in the Springer Series on CSCW, published Jan 2010:

7. Jacucci, G., Peltonen, P., Morrison, A., Salovaara, A.,Kurvinen, E., & Oulasvirta, A. (2009). Ubiquitous media for collocated interaction. In Willis, K. (Ed.), Shared Encounters. Springer Series on CSCW.

9.2 Events, workshops and field trials

During 2009 we have organised multiple events and field trials around the showcase prototypes. Our evaluation was organised so, that different members of the IPCity project could participate in organising the trials, guaranteeing us as wide group of professionals from different fields as possible. Visiting researchers from FIT, TUG, UOulu, Nokia Research, New York University, University of Otago and HitLabNZ participated in planning and organising our field trials during the summer.

Table 19. Visiting foreign researchers during the final year.

Visitng international researchers at HIIT
Alessandro Mulloni from TUGraz arrives 10 August - September 6. (IPCity and MARCUS partner) Andreas Deunser from HitLabNZ 6 July - 17 August. (IPCity and MARCUS partner) Gabriela Richards from University of New York, 1 June – 1 September (participated in Worlds of data analysis) Holger Regebrecht from Univ. Otago, NZ arrives August 1st - 20 August (MARCUS partner) Hyowon Lee from Dublin City University, UK, 27 November, 2009 (participated in multi-touch workshop and evaluating Worlds of Information interaction desgin) Thorston Froehlich, FIT, Germany arrives for 23rd August trials (IPCity and MARCUS partner)

Figure 44. Hyowon Lee (Dublin City University)and Tatu Harviainen (University of Helsinki) trying out *Worlds of Information* (CityWall) at Spektri as part of a Multitouch Workshop organized by WP7.

The showcase organised several workshops on evaluation with international participants. The showcase also succeeded in carrying out two field trials for the *MapLens* prototype with international visiting researchers from IPCity and MARCUS projects. In addition the showcase had and is having a permanent installation for the Multi-Touch Display in Lasipalatsi, Helsinki.

Events and trials organised during the last year of the project are listed Table 20

Table 20. Events, workshops and trials organised 2009.

Prototype	Date	Event/trial	More information available at	Participa nts
CityWall	Jan 1- Dec 31	City installation in cooperation with Cultural Office	http://citywall.org	Average 20-400 per

				week
CityWall	Apr	Multitouch and Surface Computing Workshop CHI 2009 oragnisers of workshop. With Steven C Seow, Microsoft Corporation, Dennis Wixon, Microsoft Corporation, Giulio Jacucci, HIIT, Ann Morrison, HIIT, Scott MacKenzie, York University	http://www.stevenseow.com/chi09/	12
-	Feb	Attended MARCUS meeting and presented IPCity WP7 and WP6 showcases to UOtago, HitLab and companies Boffa Miskell (Urban Planning) and GRC		20
MapLens	Mar 27	A presentation of MapLens study results was given at Tampere, Finland for Nokia NRC		50
MapLens	Apr 21-23	MapLens presented at FET2009 exhibition	http://ec.europa.eu/information_society/ events/fet/2009/	800
CityWall MapLens	May-Jun	3 seminar series on evaluation with Andreas Duenser at HitLabNZ		20
CityWall	May-Aug	CityWall analysis from Lorenza Parizi (summer intern from Facoltà di Scienze della Comunicazione) for ECS. Continuing discussions on comparative ECS and Hki video analysis.		1
MapLens	Aug 6	Workshop on MR/AR examples and evaluation styles		15
MapLens	Sep 9	Workshop on interactional techniques in mobile virtual and augmented reality applications		15
MapLens	Jul-Aug	Visiting Researchers HitLabNZ, UOtago, TUGraz (1 month), FIT, UOulu, NRC (2 months) at TKK for MapLens field trials		6
MapLens	Aug 6	Workshop on MR/AR examples and evaluation styles with Holger	http://www.hiit.fi/~morrison/workshop6	15

		Regenbrecht (Uotago), Saija Lemmela (Nokia), Andreas Duenser (HitLabNZ), Gabriela Richard (NYU), Mikael Wahlström (HIIT)	August.html	
MapLens	Aug 16	1st Field Trial		23
MapLens	Aug 23	2nd Field Trial		14
MapLens	Sep 2	Workshop on interactional techniques in mobile virtual and augmented reality applications with Alessandro Mulloni (TUGraz), Antti Nurminen (HIIT), Ville Lehtinen (HIIT)		15
MapLens	Sep 22-25	Workshop on Environmental Awareness	http://ipcity.imagination.at/summerschool/	9
CityWall	Nov 18	CityWall presented in a workshop at Mobile Life center, Stockholm		25
CityWall	Nov 27	Workshop on Multitouch: Design Issues and Knowledges: Limitiations and Affordances with Hyowon Lee (UDublin), Tatu Harviainen (VTT), Mika Nieminen (TKK), Tommi Ilmonen (Multitouch Ltd), Celine Coutrix, Ivan Avdouvevski and Toni Laitinen from HIIT.	See Figure 45 http://www.hiit.fi/~morrison/workshop27November.html	15
CityWall	April 10-15, 2010	Natural User Interfaces workshop at CHI2010, organisers of workshop Giulio Jacucci, HIIT, Ann Morrison, HIIT, Steve Seow, Microsoft Surface, Dennis Wixon, Microsoft Surface	http://www.stevenseow.com/chi10/	12

9.3 Workpackage visibility in Internet

Like previous years, the workpackage 7 prototyes have had a good coverage in the Internet and in the news. MapLens interview was presented in local University of Helsinki newspaper (http://www.helsinki.fi/news/archive/3-2009/3-14-12-51, see Figure 45).

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Helsinki University Bulletin

A tiny bottled creature

Without cyanobacteria, natural history wouldn't be much to talk about. Now these billions of years old microbes help the development of bioenergy and medicines.

- Read more >>
- HUB's frontpage >>

HIIT researchers enhance maps with mobile phones

In the MapLens service, a mobile phone will compare a paper map to maps in its database, adding digital information to the area shown on the screen.

Have you ever looked at a bus stop map and wished it told you more? It may do just that in the future; even though the map on the wall will remain as silent as ever, you can get more information by photographing it with your mobile phone.

The Helsinki Institute for Information Technology (HIIT) researchers and their partners have developed the MapLens service where a mobile phone compares a map on paper to maps in its database and then adding digital information to the area shown on screen.

"The real time information may consist of images, text and video", says Project Leader **Ann Morrison** of HIIT.

Figure 45. MapLens in University of Helsinki news.

The video of MapLens on Youtube (Figure 46, http://www.youtube.com/watch?v=00hiRuCTBOQ) has so far received 825 views.

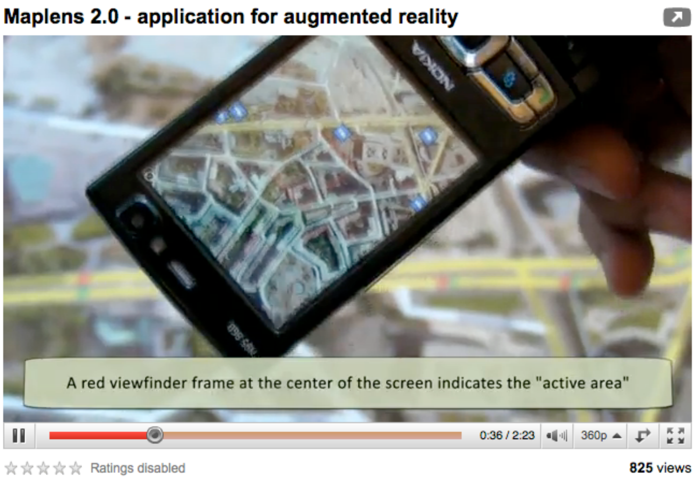
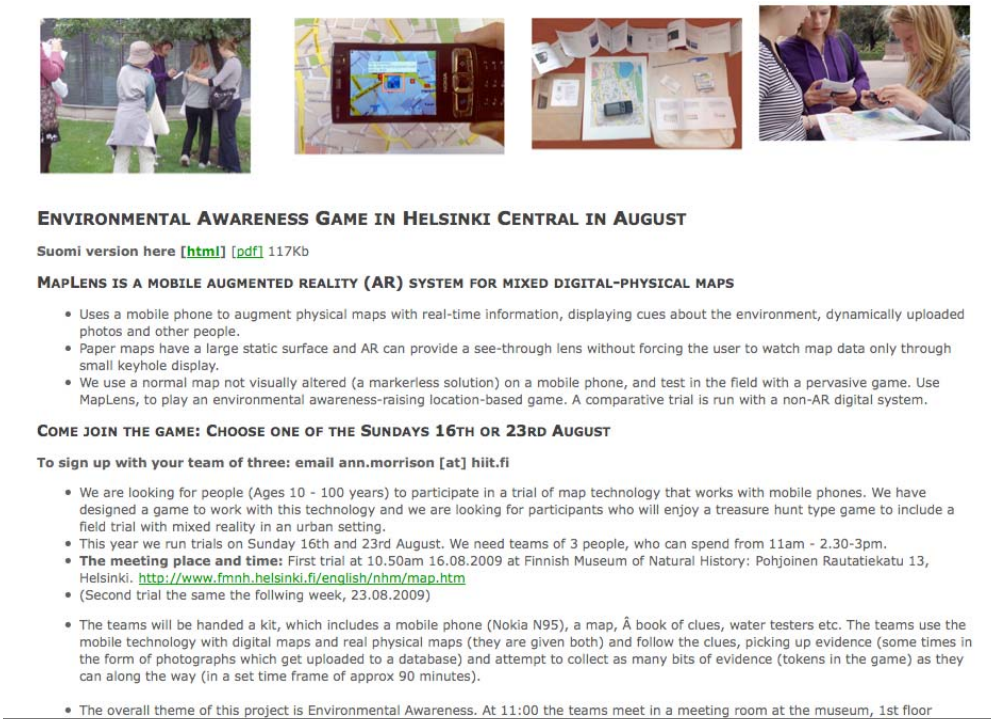


Figure 46. MapLens video on YouTube.

The MapLens HiitTV video on YouTube (see Figure 47, http://www.youtube.com/user/HIITTV) has received 286 views.

Figure 47. MapLens HIITTV video on YouTube.

We also published a call for MapLens game applicants in our web pages (see Figure 48, http://www.hiit.fi/~morrison/maplens.html). Our environmental awareness theme was also presented in our web pages (see http://www.hiit.fi/node/507).



Environmental Awareness Game in Helsinki Central in August

Suomi version here [html] [pdf] 117Kb

MapLens is a mobile augmented reality (AR) system for mixed digital-physical maps

- Uses a mobile phone to augment physical maps with real-time information, displaying cues about the environment, dynamically uploaded photos and other people.
- Paper maps have a large static surface and AR can provide a see-through lens without forcing the user to watch map data only through small keyhole display.
- We use a normal map not visually altered (a markerless solution) on a mobile phone, and test in the field with a pervasive game. Use MapLens, to play an environmental awareness-raising location-based game. A comparative trial is run with a non-AR digital system.

Come join the game: Choose one of the Sundays 16th or 23rd August

To sign up with your team of three: email ann.morrison [at] hiit.fi

- We are looking for people (Ages 10 - 100 years) to participate in a trial of map technology that works with mobile phones. We have designed a game to work with this technology and we are looking for participants who will enjoy a treasure hunt type game to include a field trial with mixed reality in an urban setting.
- This year we run trials on Sunday 16th and 23rd August. We need teams of 3 people, who can spend from 11am - 2.30-3pm.
- **The meeting place and time:** First trial at 10.50am 16.08.2009 at Finnish Museum of Natural History: Pohjoinen Rautatiekatu 13, Helsinki. http://www.fmnh.helsinki.fi/english/nhm/map.htm
- (Second trial the same the follwing week, 23.08.2009)
- The teams will be handed a kit, which includes a mobile phone (Nokia N95), a map, Â book of clues, water testers etc. The teams use the mobile technology with digital maps and real physical maps (they are given both) and follow the clues, picking up evidence (some times in the form of photographs which get uploaded to a database) and attempt to collect as many bits of evidence (tokens in the game) as they can along the way (in a set time frame of approx 90 minutes).
- The overall theme of this project is Environmental Awareness. At 11:00 the teams meet in a meeting room at the museum, 1st floor

Figure 48. A call for MapLens game applicants.

Workpackage 7 work was also visible on Twitter (see http://twitter.com/HIIT/status/4498452803) and Uoulu have blogged about MapLens actively (see http://www.tol.oulu.fi/users/antti.juustila/?s=maplens).

CityWall has been advertised in the Internet (see Figure 49, http://www.citywall.org), where it has received also a lot of attention: the CityWall Hki YouTube video (see Figure 50, http://www.youtube.com/watch?v=IldDrCcZkZY) has had 286 925 viewers and the very first

CityWall video (see http://www.youtube.com/watch?v=WkNq3cYGTPE) has had 35,882 viewers.

Figure 49. Screenshot from CityWall website.

Figure 50. CityWall Hki video on YouTube.

The popularity of the CityWall video has been noted in the news of University of Helsinki (see Figure 51, http://www.helsinki.fi/ajankohtaista/uutisarkisto/10-2008/20-15-04-37) and naturally also in the HIIT news (http://www.hiit.fi/node/735).

Figure 51. CityWall in the University news.

9.4 Commercialisation

Multitouch Ltd, the spin-off company created by the original development team of the WP7 CityWall prototype, has been growing and receiving attention from both the media and the scientific community: one of the success stories was winning the MindTrek Launchpad 2009 competition (see Figure 52).

Multitouch Wins The MindTrek Launchpad

by **Ville Vesterinen** on October 2, 2009 — **2 Comments**

The winner of the MindTrek Launchpad 2009, a pitching competition for statups at MindTrek, has just been announced on stage. This year's winner is Multitouch, a Finnish table- and wall-sized multitouch display manufacturer.

The winner receives € 20,009 and of course a major publicity boost. Congratulations to Multitouch!

This year, just as last year, the short list included some promising companies and some complete misses. Also they were from a broad variety of industries, ranging from hardware manufacturer (Multitouch) to a Facebook game (Kamu World).

Compared to the quality of last year's startup pitches at Mindtrek Launchpad, this year saw a big improvement. The pitches were better structured and more coherent. A good pitch does not equal a successful company, but it's part of it.

Compared to many other web conferences, Mindtrek is positively different since it brings together people not only from the startup scene but across the digital field, including academia and and BigCo. I enjoyed this as I saw what is happening across the field and I also think it helps the startups to understand what is happening beyond their immediate industry niche.

Figure 52. A story of MultiTouch's MindTrek win.

Currently, MultiTouch offers three products: The MultiTouch Box, MultiTouch Cell and CornerStone. The Box uses the same back projection technology as CityWall/Worlds of Information. The Cell is implemented using a different technology: LCD panels. The CornerStone is a software product (SDK) for developing applications for the MultiTouch hardware. See Figure 53 for further details of the products.

/// MultiTouch Cell

Multitouch LCD for modular display arrays
MultiTouch Cell is the first and only multitouch LCD display for scalable display arrays. The Cell:

- units can be combined into one large display array
- is stackable and movable
- is inclinable into any position
- Full HD, 1920-by-1080p-pixel resolution (2,1 MP)
- normal and high brightness LCD models available
- 50 000+ hours expected life-time
- low maintenance, scratch-resistant front glass
- automatic self-calibration

Download the Product Brochure for MultiTouch Cell >>
Learn more about MultiTouch Cell >>

/// MultiTouch Box

Multitouch projection box for large seamless displays
MultiTouch Box is a scalable projection box for large seamless displays. The Box:

- can be used to build a seamless display of any size
- several preconfigured sizes available
- cost effective solution for customized sizes
- possible to use rear or front projector technology
- single or multiprojector installations supported
- scratch-resistant front glass available

Download the Product Brochure for MultiTouch Box >>
Learn more about MultiTouch Box >>

/// MultiTouch Cornerstone

MultiTouch CornerStone Software Development Kit
The CornerStone SDK is used to create new applications that rely on multitouch interaction. It includes:

- MultiTouch CornerStone run-time libraries
- C++ header files for compiling against libraries
- Libraries and header files of relevant third-party libraries
- API documentation in HTML format
- Example applications as source code
- Documentation for building projector- or LCD-based displays

Learn more about MultiTouch CornerStone SDK >>
Go to MultiTouch CornerStone developer site >>

Figure 53. The three MultiTouch products.

MultiTouch has also succeeded internationally—they have partners all over the world, in Swizerland, Norway, Germany, France, Italy, Australia, New Zealand, Mexico, Russia and Chile. See http://multitouch.fi/ website for further details on the company’s activities and partners.The company has been actively demonstrating its products in various venues. In 2009, MultiTouch vsited IBC and Viscom fairs (see Figure 54 and Figure 55).

Figure 54. MultiTouch fair acitivities in 2009.

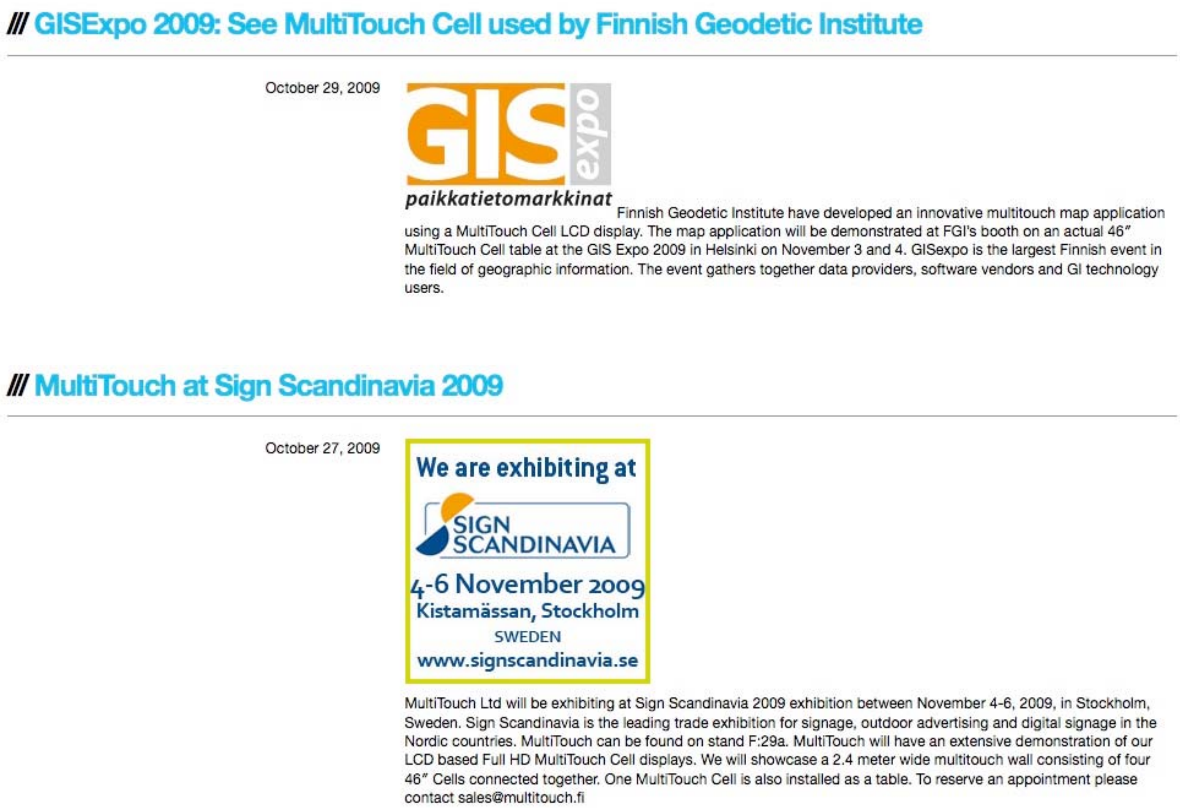


Figure 55. MultiTouch news in 2009.

In 2010 MultiTouch has been visible in ISE 2010 (see Figure 56). It also announced supporting Windows 7 multitouch applications (see Figure 56).

/// MultiTouch at ISE 2010

January 18, 2010

Integrated Systems Europe

MultiTouch will be exhibiting at the Integrated Systems Europe 2010 in Amsterdam, the Netherlands, on February 2-4. ISE 2010 is the most important Audio Video (AV) Integration show in Europe for the home, professional and commercial markets. MultiTouch will be showcasing our modular 46" LCD-based MultiTouch Cells in various table and wall configurations. MultiTouch is located in Hall 4 at the RAI Centre on stand 4P20. For an appointment, please contact sales@multitouch.fi.

/// CES 2010: MultiTouch Supports Windows 7

December 10, 2009

International CES

New feature released at CES: you can run Windows 7 multitouch applications on MultiTouch LCDs. Come and try the multitouch LCDs at CES, Las Vegas on 7-10 January. Please agree the appointment by e-mail: sales(a)multitouch.fi. Please read the full Press Release here.

Figure 56. MultiTouch activities in 2010.

The durability, scalabilty and robustness of the technology in action can be seen in figures 58 and 59.

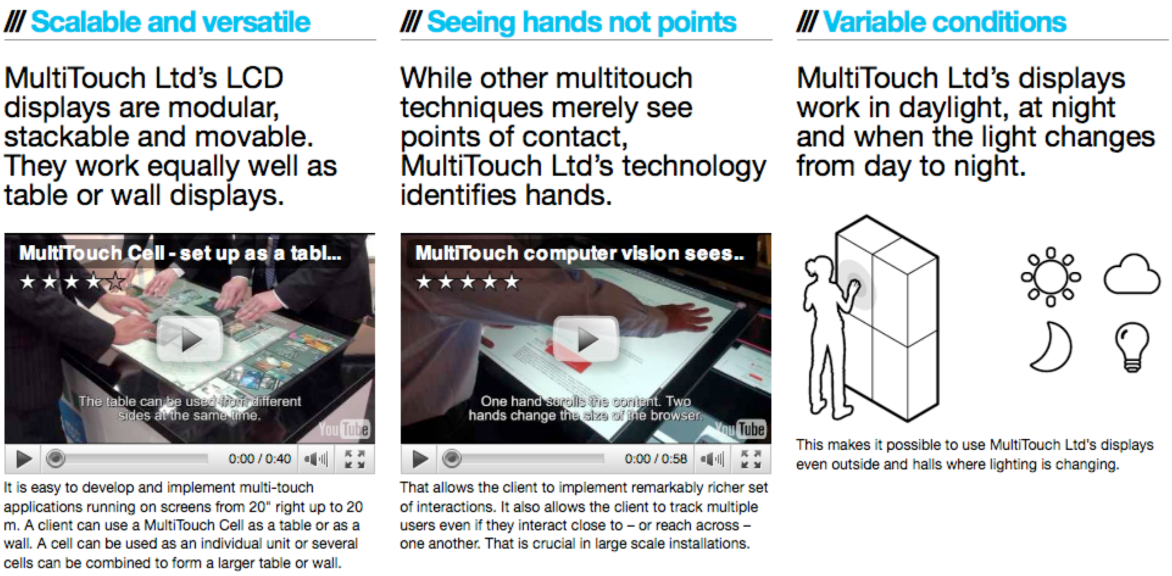


Figure 58. Aspects of MultiTouch technology, as can be seen on multitouch.fi.

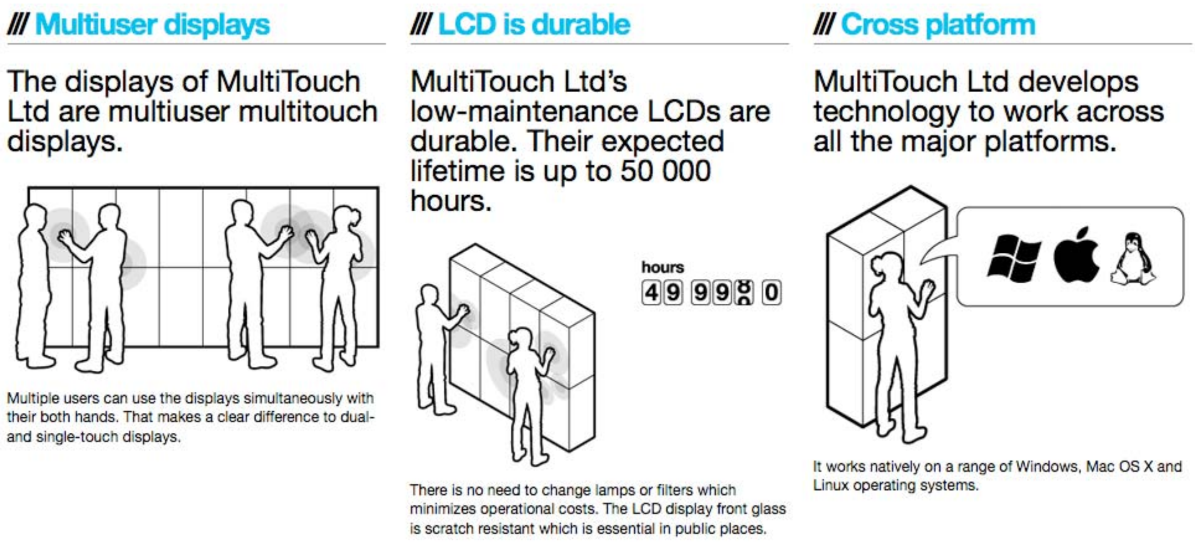
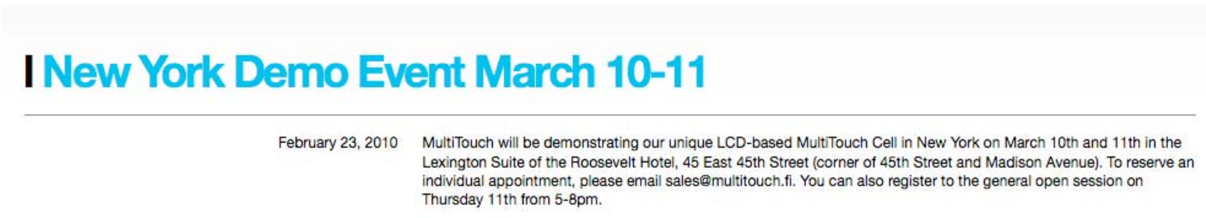


Figure 59. Aspects of MultiTouch technology, as can be seen on multitouch.fi.

Other upcoming events include a demonstration in New York on March 10th and 11th in the Lexington Suite of the Roosevelt Hotel, 45 East 45th Street (corner of 45th Street and Madison Avenue), see Figure 60.



New York Demo Event March 10-11

February 23, 2010

MultiTouch will be demonstrating our unique LCD-based MultiTouch Cell in New York on March 10th and 11th in the Lexington Suite of the Roosevelt Hotel, 45 East 45th Street (corner of 45th Street and Madison Avenue). To reserve an individual appointment, please email sales@multitouch.fi. You can also register to the general open session on Thursday 11th from 5-8pm.

Figure 60. Upcoming event in New York City, 2010.

10 References

1. 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.
2. Brignull, H., Izadi, S., Fitzpatrick, G., Rogers, Y., and Rodden, T. (2004). The introduction of a shared interactive surface into a communal space. In Proc. CSCW 2004, ACM Press, New York, 49–58.
3. Brown B., Chalmers M. (2003). Tourism and mobile technology. In Proc. Conference on European Conference on Computer Supported Cooperative Work (ECSCW 2003, pp. 335–355). Norwell, MA: Kluwer Academic Publishers.
4. 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.
5. Csikszentmihalyi, M. (1990). Flow: The psychology of optimal experience. Harper & Row, New York.
6. Deci, E., Ryan, R. (2008). The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry,* 11 (2008), 227–268.
7. Elrod, S. Bruce, R., Gold, R., Goldberg, D., Halasz, F., Janssen, W., Lee, D., McCall, K., Pedersen, E., Pier, K., Tang, J. and Welch, B. (1992). Liveboard: a large interactive display supporting group meetings, presentations, and remote collaboration. In *Proc. CHI 1992*, ACM Press (1992), 599–607.
8. Erickson, F. The interface between ethnography and microanalysis. (1992). 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.
9. Everitt, K., Shen, C., Ryall, K., and Forlines, C. (2005). Modal spaces: spatial multiplexing to mediate direct-touch input on large displays. In CHI 2005 Extended Abstracts, ACM Press, New York, 1359–1362.
10. Forlines, C. and Shen, C. (2008). DTLens: multi-user tabletop spatial data exploration. In Proc. UIST 2005, ACM Press, New York, 119–122.
11. Frohlich D., Kuchinsky A., Pering C., Don A., Ariss S. (2002). Re-quirements for photoware. In Proceedings of the 2002 ACM Conference on Computer Supported Cooperative Work (CSCW'02, pp. 166–175). New York: ACM Press.
12. Fry, B. Valence. http://benfry.com/valence/index.html (last accessed 01.09.2009)
13. Guthrie, J.T. (2001). Contexts for engagement and motivation in reading. Reading Online, 4, 8.
14. Hawkey K., Kellar M., Reilly D., Whalen T., Inkpen K. (2005) The proximity factor: impact of distance on co-located collaboration, Proceedings of the 2005 international ACM SIGGROUP conference on Supporting group work.
15. 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.
16. 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.
17. Hinrichs, U., Carpendale, S., Scott, S.D. and Pattison, E. Interface Currents: Supporting fluent collaboration on tabletop displays. In Proc. SG 2005, Springer (2005), Berlin, 185–197.
18. Hornecker, E., Marshall, P. and Rogers, Y. From entry to access: how shareability comes about. In Proc. DPPI 2007, ACM Press (2007), New York, 328–342.
19. Inkpen K., Kellogg S., Booth K., Gribble S., Klawe M. (1995) Give and take: children collaborating on one computer, ACM Conference companion on Human factors in computing systems, pp. 258–259.
20. Isenberg, P., Tang, A. and Carpendale, S. An Exploratory Study of Visual Information Analysis. . In Proc. CHI2008, ACM Press (2008), New York, 1217–1226.
21. 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.
22. Jacucci, G., Oulasvirta, A., Ilmonen, T., Evans, J. & Salovaara, A. (2007). CoMedia: mobile group media for active spectatorship. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'07, pp. 1273–1282). New York: ACM Press
23. Jacucci, G., Spagnolli, A., Chalambalakis, A., Morrison, A., Liikkanen, L., Roveda S., Bertoncini, M. (2009). Bodily Explorations in Space: Social Experience of a Multimodal Art Installation. In: Interact 2009, Springer, 62–75.

24. Mandryk, R. L., Inkpen, K. M., Bilezikjian, M., Klemmer, S. R., & Landay, J. A. (2001). Supporting children's collaboration across handheld computers. In Extended Abstracts of CHI, Conference on Human Factors in ComputingSystems. Seattle, USA.
25. 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.
26. Morris, M.R., Huang, A., Paepcke, A. & Winograd, T. (2006). Cooperative gestures: multi-user gestural interactions for colocated groupware. In Procceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'06, 1201–1210). New York: ACM Press.
27. Morrison A., Oulasvirta A., Peltonen P., Lemmelä S., Jacucci G., Reitmayr G.,, Näsänen J., Juustila A. (2009) Like bees around the hive: A comparative study of a mobile augmented reality map. In Proc CHI 2009.
28. Nacenta M.A., Pinelle D., Stuckel D., Gutwin, C. (2007). The effects of interaction technique on coordination in tabletop groupware, Proceedings of Graphics Interface 2007, Montreal, Canada.
29. Reilly D., Rodgers M., Argue R., Nunes M., Inkpen K. (2006) Marked-up maps: combining paper maps and electronic information resources. Personal Ubiquitous Computing 10(4):215–226
30. Rick, J., Harris, A., Marshall, P., Fleck, R., Yuill, N., and Rogers, Y. 2009. Children designing together on a multi-touch tabletop: an analysis of spatial orientation and user interactions. In Proc. IDC 2009, ACM Press (2006), New York, 106–114
31. Rogers, Y., Hazlewood, W., Blevis, E. & Lim, Y.-K. (2004). Finger talk: collaborative decision-making using talk and fingertip interaction around a tabletop display. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'04, 1271–1274). New York: ACM Press.
32. Robertson, T. (1997). Cooperative Work and Lived Cognition: A Taxonomy of Embodied Actions. In Proc. ECSCW 1997, K Kluwer Academic Publishers (1997), Dordrecht, 205–220.
33. 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
34. 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.
35. Rohs M., Schöning J., Raubal M., Essl G., Kruger A. (2007) Map navigation with mobile devices: virtual versus physical movement with and without visual context. In: Proceedings of the International Conference on Multimodal Interfaces (ICMI'07), pp 146–153.
36. Russell, M., Drews, D. Sue, A. (2002). Social Aspects of Using Large Public Interactive Displays for Collaboration. In UbiComp 2002, LNCS 2498, Springer (2002), Berlin, 229–236.
37. Salovaara, A., Jacucci, G., Oulasvirta, A., Kanerva, P., Kurvinen, E. & Tiitta, S. (2006). Collective creation and sense-making of mobile media. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'06, 1211–1220). New York: ACM Press.
38. Schmalstieg D., Fuhrmann A., Szalavári Zs., Gervautz M. (1996). Studierstube - An Environment for Collaboration in Augmented Reality. Proc. Collaborative Virtual Environments '96. Republished in Virtual Reality 3(1):37-49.
39. Scott, S.D., Sheelagh, M., Carpendale, T. and Inkpen, K.M. (2004). Territoriality in collaborative tabletop workspaces. In Proc. CSCW 2004, ACM Press, New York, 294–303.
40. Tang, A., Tory, M., Po, B., Neumann, P. and Carpendale, S. (2006). Collaborative coupling over tabletop displays. In Proc. CHI 2006, ACM Press, New York, 1181–1190.
41. Tobiasz, M., Isenberg, P., Carpendale, and Lark, S. (2009). Coordinating Co-located Collaboration with Information Visualization. In Proc. InfoVis 2009, IEEE.
42. Tse, E., Greenberg, S., Shen, C., Forlines, C. and Kodama, R. 2008. Exploring true multi-user multimodal interaction over a digital table. In Proc. DIS 2008, ACM Press (2008), New York, 109–118.
43. Wagner D., Schmalstieg D. (2003). First Steps Towards Handheld Augmented Reality. Proc. IEEE International Symposium on Wearable Computers, pp. 127-135.
44. Wagner D., Schmalstieg D., Bischof H. (2009). Multiple target detection and tracking with guaranteed framerates on mobile phones. To appear in: IEEE International Symposium on Mixed and Augmented Reality, ISMAR 2009.8, 15-18 Sept 2008, Cambridge, UK.

45. Wang J., Zhai S., Canny J. (2006). Camera phone based motion sensing: interaction techniques, applications and performance study. In: Proceedings of the Symposium on User Interface Software and Technology (UIST'06), pp 101–110.

46. Wu, M., Balakrishnan, R. (2003). Multi-finger and whole hand gestural interaction techniques for multi-user tabletop displays. In Proceedings of the 16th Annual ACM Symposium on User interface Software and Technology (UIST’03, 193–202). New York: ACM Press.

47. Wurman, R. (2001). Information Anxiety 2 New York: New Riders Publishers.

Appendix 1: Overview of General Analysis Procedure

Questionnaire Analysis

Immersion in virtual realities has bee traditionally researched through use of presence questionnaires. Lombard and Ditton (1997) have defined the feeling of presence as the perceptual illusion of non-mediation, which has three dimensions: spatial (the feeling of "being there" in a mediated environment), social ("being together with another") and co-presence ("being socially present with another person"). Traditionally, to study the different aspects of presence, presence questionnaires have been used for this. We selected to use the MEC-SPQ (Vorderer et al., 2004) presence questionnaire to investigate the spatial presence experienced by the participants in our trials.

As reported earlier by Morrison et al. (2008), we have looked to the work of Csikszentmihalyi (1990) on flow and optimal engagement to extend our evaluation methods. Flow is described as an auto telic state, where people lose track of time and any self-consciousness surrounding their activity, as they become so involved in an activity that nothing else matters. When people complete the kind of activity which has put them into the flow state, they feel much better about themselves and life generally. Activities may range from e.g. mountain climbing to painting. There are a multitude of activities that the work of Csikszentmihalyi (1990) has shown can produce this state in individuals.

The original concept of Csikszentmihalyi (1990) has been adapted to understanding flow in gaming by Sweetser et al. (2005), who have developed a questionnaire to measure the flow experienced in game like situations. In our work, we are using a similar approach to improve user experience on large touch displays and to investigate the user experience afterwards in our trials

A third questionnaire that we have been using to gather feedback from our field trials is the Intrinsic Motivation Inventory (IMI), which is a multidimensional measurement device intended to assess participants' subjective experience related to a target activity: interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice while performing a given activity. The interest/enjoyment subscale is considered the self-report measure of intrinsic motivation. The device has been used in several experiments related to intrinsic motivation and self-regulation (e.g., Ryan, 1982, Deci et Ryan 2000) and was originally designed by Deci and Ryan, 1994.

The questionnaires are available at:
http://www.psych.rochester.edu/SDT/measures/IMI_scales.php

The three different questionnaire models have been used in combination to get a better understanding of the audience experience and how they engage.

The questionnaire data is analysed statistically, for example using software such as SPSS. When combined with demographic information, valuable observations can be made such as "females reported experiencing more spatial presence than males". These kinds of subjective measurements offer interesting insight how users experienced the tasks and technology they were trying out.

Questionnaires can provide the researchers with interesting information, but one has to remember that these are subjective and retrospective measurements: what users report afterwards might not be the whole truth what happened in the field from the beginning to the end of the trial: the actual questionnaires might be interpreted differently by each participant: for example, the word "often" might have a different meaning for user A than for user B. Also, especially the presence questionnaires can contain very abstract terms and concepts that users might understand differently, depending on their age and educational level for example. Slater et al. (2007) have argue that in general presence questionnaire data is treated far too seriously, and that a different paradigm is needed for presence research–one where multivariate physiological and behavioral data is used alongside subjective and questionnaire data, with the latter not having any specially privileged role.

System Log Analysis

In the first field research manual for IPCity, Oulasvirta et al. (2006) highlight the importance of gathering system logs to get an understanding how the system was used, which will provide context for making interpretations of the presence measurements and other observations. For a communication based application Oulasvirta et al. (2006) give an example what should be logged (presented in Table 21).

Table 21. What to log from a communication based application.

Items to be logged	
• Average # of packets sent per day • What time of day was the system accessed • How active were different users in accessing the system • What is the average amount of packets per day • Distribution of media taken by the different phones • How many replies and how are they distributed among different users • When were replies made, time of day • How long time after a piece of media was uploaded was it commented • Average # of packets sent per day • What time of day was the system accessed • How active were different users in accessing the system • What is the average amount of packets per day	• Distribution of media taken by the different phones • How many replies and how are they distributed among different users • When were replies made, time of day • How long time after a piece of media was uploaded was it commented • Who replied/viewed a message, the author vs others • What is the average length of discussions (number of comments, length of an individual comment) • Distribution of different media (audio, video, photo) • Turn-taking length: how long between replies to a comment • Calling others before or after using the system. This is important for understanding the role of the system for coordination. • How many times were messages created/viewed when others were present vs. not?

The logging needs depend heavily on what kind of system one is evaluating. When evaluating a multi-touch screen for example, the first three items on the list are important, but others are probably not: in this case one would need to focus on how many users are at a time at the display, how many hands they use, what kind of gestures are being used and so on.

Good logging can reveal not only interesting patterns of use and give perspective to the questionnaire analysis, but also act as a filter for the qualitative analysis process: with good logging we can identify the most interesting sessions of use for more in-depth qualitative analysis. This is very useful, if we have hundreds of hours of video data gathered and only limited time to analyse all this material.

Video Analysis

As noted by Pink (2007; Ref. Wagner 2009) 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. Video analysis is a good tool for catching the different aspects of embodied interaction that other methods cannot capture, but it is also challenging to do reliably and quite time consuming.

Data collection

Collecting data by video recording in field trials is harder than it sounds. It is very easy to get distracted and target to wrong things, it is impossible to get everything on tape. If video recordings are the only form of data gathered and one is shooting subjects on the move, doing bottom up grounded theory (Glaser & Strauss, 1967) based analysis comes quite hard, as one has to decide beforehand in what to focus: the more clearer and focused the research questions are in the beginning, the easier it is to do the actual recording (and the analysis in the later stages). With static installations where the subjects don't move as much and you can cover the whole "interaction area" with cameras, you can do more explorative type of research to just see what happens when people encounter the new technology.

Another difficulty in video data collection is when to record: if you record an installation 24/7 you will end up with hundreds hours of data. With careful planning and doing demos of the actual trials one can save hours and hours of time in the analysis phase. Also proper logging of the system can prove extremely useful in this sense as discussed in chapter 0. And when on the move, one has to consider the battery life of the cameras. What could be more disappointing for a researcher than to find out that you have recorded hours of meaningless chitchat which have eaten all your camera batteries when something actually interesting starts to happen? And while the researcher is changing the battery she might also miss something essential that the users do.

The selecting and cutting of video material is done in what Laurier et al. (2008; Ref. Wagner 2009) 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 we think are relevant instantiations of participants' co-constructing the experience. This cutting process is already part of the analysis process, which general guidelines will be described next.

General video analysis process

In this chapter we describe a general video analysis process, which is suitable for most purposes when evaluating use of Mixed Reality technologies.

We have used successfully an analysis process based on "constant comparison analysis" (Glaser & Strauss, 1967), where codes emerge inductively, or through the data directly. In this process, at least 2 researchers go through the analysis process together. This way interrater reliability can be achieved, which is the extent to which two or more individuals (coders) agree while doing the analysis. Interrater reliability addresses the consistency of the rating system, which can be ensured if multiple people code the same data and agree with each other's codings.

The steps in the video analysis process are described in Table 22.

Table 22. Video analysis process steps.

Video analysis process
1. Initial research questions are formulated by the researchers 2. The researchers watch the entire video first separately, and make field notes of interesting points segments (relevant clips) that they would like to explore further. 3. The researchers meet with their notes and negotiate which of the selected clips are the most relevant for the research questions. Then these relevant clips are sorted and uploaded to a shared folder from where all persons involved in the analysis can access them. 4. The researchers watch each clip separately and come up with a list of codes associated with each clip.

5. Achieving interrater reliability: The researchers come together again and compare the codes assigned to random selection of the video clips. If differences are found between the researchers' coding, these are discussed and the coding scheme is modified if necessary. The researchers repeat this step until no differences between the coding results are found. When resolving differences between coding schemes, think about the following: What are the relationships between the codes? Do the codes really capture what's happening here?
6. After researchers have agreed with a common coding scheme, the researchers will then recode the videos together based on this new scheme.
7. Finally, they work together to integrate the themes that emerge and finalize or refine theory based on the final coding and analysis.

Tools for video analysis

There can be found numerous commercial and free transcription systems to help in the video analysis process. Two simple freeware programs can be found from these websites:

http://videonotetaker.sourceforge.net

http://www.dvcreators.net/qt-movie-notetaker/

A suggestion for a commercial solution could be ATLAS.ti for example, which allows an easy way to manage the codes you have created and build diagrams etc. based on them. But most of the video analysis tasks can be easily done also with regular video playing software such as VLC or mplayer and using a spreadsheet program for the codes on the side.

Interviews

All the earlier methods of gathering and analysing data rely heavily on the researcher's interpretations of why the users used the system under evaluation the way they did. This kind of analysis has always the risk that user's own intentions and meanings for their actions do not get exposed, and something valuable might be missed in the analysis process. Therefore it is a good to hear the users to explain their experiences in their own words. This way the Mixed Reality experience can be framed yet from another angle.

Interview techniques: semi-structured, cue based and researcher interviews

In *semi-structured interviews* the users are asked a set of predefined questions in a flexible way, allowing new questions to arise in the interview as a result of what the interviewee says. This way all the users are given the option to describe freely their experience related to the topics that interests the researchers.

Sometimes the interview questions can be too abstract or complicated for the interviewee, or she can feel pressure to give what she feels is the “right” answer for the question. A good tool to overcome these problems, and to make the interviewee have more freedom to explain her experience, is to have also cue-based parts in the interview. This kind of *cue-based narrative interview*'s aim is to get the informant to recall *real, actual episodes that happened and to tell them in her own words*. In the interview the interviewee is presented with cues such as video footage from the trial that helps her to recall the experience. Oulasvirta et al. (2006) describe the general approach of this technique as follows:

> Using a (color) print with one screenshot of the technology in question on each page, point a feature/data item/object and ask the interviewee to explain what aspects s/he used, what it means and then to tell 1-3 episodes for that. Because the use of these cues might have been quite uncommon, it is even more important not to give up as an

interviewer but to pressure even more to find out even the rarest and most marginal use cases.

Another technique is to give the actual technology back to the user and ask her to show how she used it for different tasks. Researchers can also this way capture some of the embodied interaction and compare that to the ones they have observed on the field.

When dealing with data gathered from multiple sources, it might be sometimes also useful to interview not just the users but the also the researchers that were observing them on the field. This way it is possible to get a wider perspective of the user's actions in the field than can be witnessed from video recordings, which can focus only on a single thing at a time.

To increase recall, during these interviews one can also make the interviewee watch video footage captured during the trial. For more information about this video (cue) based recall technique see Costello et al. (2008).

Interview data analysis

In the actual analysis part, the interviews are first transcribed into textual format. The amount of detail in the transcription can vary based on what one is looking from the data.

After the interviews have been transcribed, the data is content analysed in a similar way that as with the videos (see chapter 0 in this document). The idea is to come up with a list of codes that describe the experience. The abstraction level of the code is also dependent on what one is trying to dig up from the data. This excerpt from our MapLens 2009 study (Morrison et al., 2009), which presents an coding system that focused on how users described their experience with the mobile AR system (M) in comparison to digital only system (D):

In the transcriptions of our interviews, we searched for recurrent adjectives in the participants' descriptions of their experiences. We found M users made 11 mentions of the word *stability* (and 0 with D). For example, "You need to be quite accurate; you need to be *stable* and you need to get the camera into the right position." Six M users described the trial as *easy* compared to 25 instances of *easy* being used by D players. Here too, we find M teams more challenged by the technology: "At first it was difficult to find these dots. Maybe it was because we were not able to keep our hands stable enough. But after that we catch the red dots by using the square."

In some cases it might be useful to lift the abstraction level of the coding, for example one might create codes labelled "it might be just enough to code "positive experiences" and "negative experiences". Of course the same data can be analysed at multiple levels at the same time.

To achieve interrater reliability, it is wise to follow the same guidelines as in video analysis: multiple researchers code the same episodes and then compare their results, after which the coding scheme is modified if necessary. These steps are repeated until researchers agree that they are coding in the same way and reliability has been achieved.

Conclusions

In this appendix we have described the general analysis process for evaluating Mixed reality applications, which was used while evaluating the MapLens and CityWall/Worlds of Information prototypes. The user experience of Mixed reality technologies consists of many parts including the technology itself, the physical surroundings it is used, the people it is used with and the experience created when the technology is used to mix the physical world with virtual elements. Therefore we cannot rely only on one specific method for evaluating this experience–multiple methods triangulated together are also needed.

Our *MapLens* trials have revealed us that video analysis can be a valuable tool for obtaining information from real life like use of mobile AR. It allows drilling down to even the smallest nuances of the use of the technology including the social and physical aspects of the environment, revealing phenomena, which might have not been otherwise found. In our case the questionnaires were not found to be that useful when evaluating the technology, as the answers reflected more the whole experience than use of the technology.

Looking back at our analysis process, next time we would probably do things a bit differently: the heavy use of video cameras is not always a good thing as it forces the researchers to observe everything “behind the lens”, narrowing the scope of perception for them. For our next trials, the ratio of video cameras and still cameras could be 60% video/40% still cameras, which would allow the core researchers to observe the teams in a more holistic way without having to hassle with the video cameras.

For future work and next trials we would also do more rigorous usability testing before the trials. Finding out limitations in the UI or the system crashing because of heavy load should be found and resolved well before the field trials. Arranging large trials with teams of participants, researchers, phones, arranging museum open, game tasks etc. is complex enough without the technology failing to work at the critical times. This is crucial otherwise this lengthy ground work is wasted, as trials are often temporal events, so organising teams of people with approx. correct demographic balance, booking museum, permission to film with café and internet passes, buying food etc cannot just be postponed and reinstated on short notice. The logistics escalate with the complexity of the study and the number of users and locations etc involved.

We propose *a three-step approach*, customisable on a case-by case basis. We propose that by integrating these three stages into the evaluation process/es, we can progressively implement iterative changes more thoroughly with technology use over time, in real conditions and with multiple users. As a result for future trials we will adopt this three-step approach, which will include:

1) A series of iterative informal lab testing of devices with set tasks that replicate game tasks with a small set of participants. Correction of perceived faults. Small test trial run synchronously on several devices at the one time (e.g. with 5 participants and 5 devices simultaneously). Makes sure that the technology is usable in general.

2) Usability study in outdoor conditions with simple tasks that replicate real use, stressing the use with a worse-case scenario. For example, if the field trial will have 20 participants using the system at the one time, then 20 researchers should use the system at the same time with tasks that replicate game functions. Further, if we expect that 20 phones will take 10–50 photos each during the trial, then set this taking number of photos as a task (and stress the condition, i.e. use worse case scenario where all players take photos in a 10 minute period—as this also tests the upload, GPS locating upload etc.). Other tasks for *MapLens* use would include browsing for locations, looking at photos, looking at multiple photos (online and offline), trying to use map in windy conditions (choose a windy corner for one task), browsing on web browser etc) and for the same set period of time as the trial will take place. Essentially the aim is to force the circumstances so that any breaks in the system occur now. If the system fails, then time is taken to fix the problems and again the system and how it is tested in this stage 2 is replicated until there are no breakage problems. We estimate that depending on the complexity, this stage adds at least two to four weeks to the implementation cycle (depends on complexity and robustness of the prototype).

3) Field trials (as done) with amendments to percentage ratios of video/ still cameras. As well we would look to do a shorter game that tests and expands the capacities of the technology more. The last game was designed to compensate for initial unstable prototypes. As the prototype has become more robust, we can now include and more accurately directly test specific aspects of the technology.

The three step approach for evaluation process is summarised in Table 23.

Table 23. Three Step Approach for evaluating technology prototypes..

Step	Description
1. Informal Lab test	Check that things are working.
2. Usability test to check robustness	Task orientated approach with single aspects checked for robustness at one time (emulate real world use for each aspect, one thing at a time—include e.g., battery life, number of users at one time etc.).
3. Field test to emulate real world use	Multi-tasking with multiple distractions and activities occurring at the same time. Impossible to relate task to outcome, and care taken to ensure use happens while distracted or among other activities including e.g., social interaction.

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ipcity.eu