Out on the Town: A Socio-Physical Approach to the Design of a Context-Aware Urban Guide

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As urban environments become increasingly hybridized, mixing the social, built, and digital in interesting ways, designing for computing in the city presents new challenges—how do we understand such hybridization, and then respond to it as designers? Here we synthesize earlier work in human-computer interaction, sociology and architecture in order to deliberately influence the design of digital systems with an understanding of their built and social context of use. We propose, illustrate, and evaluate a multidisciplinary approach combining rapid ethnography, architectural analysis, design sketching, and paper prototyping. Following the approach we are able to provide empirically grounded representations of the socio-physical context of use, in this case people socializing in urban spaces. We then use this understanding to influence the design of a context aware system to be used while out on the town. We believe that the approach is of value more generally, particularly when achieving powerfully situated interactions is the design ambition.

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1. INTRODUCTION

1.1 The Emergence of Hybrid Environments

Pervasive computing is increasingly becoming a part of our everyday lives: at work, at home, and out on the town. It is blurring the boundary between physical, social and digital layers of our inhabited spaces, providing users with highly localized contextual information. Our physical, virtual, and social worlds are colliding, merging, and coordinating [Rheingold 2003]. We operate in the built environment using a combination of fixed devices, such as digital information screens embedded in the fabric of the environment, and handheld personal mobile devices, such as mobile phones. These digital devices provide both communication and computation capabilities, and therefore offer an exciting opportunity for computing to augment and enhance the way that we socialize.

Pervasive computing exploits our familiarity with the everyday environment [Dourish 2001] and breaks down the traditional mapping between activities and places, allowing people to be continually present in every place [Agre 2001]. For example, cafes become corporate meeting rooms as users deal with business calls over lunch, corporate meeting rooms become social arenas while participants text loved ones unobtrusively, streets become guided walks, and plazas become information kiosks, all without any changes to the built fabric.

As our lived world becomes increasingly hybrid physical, social, and digital spaces [Graham and Marvin 1996; Mitchell 1995], the intersecting issues of spatial context, sociality, and pervasive digital technologies need to be understood in order to design for their inhabitants' interactions [Agre 2001]. This introduces a new set of issues for analysis, including studies of the connections between physical and social space, reconsideration of existing design practices, and extension and enhancement of current HCI and CSCW methodologies [Ciolfi 2004]. By understanding the influences of both the physical environment and the human activities that unfold in that context, designers will be better equipped to provide specialized computation to support likely situated interaction [Ciolfi 2004; Dourish 2001; Erickson and Kellogg 2000].

1.2 The Notion of "Layered" Space

There are three distinct layers of space in this approach: physical, social, and digital. In the physical, architectural design has traditionally taken place within the context of an explicit set of physical and social issues in respect of anticipated activities and historical expectations of certain building types [Agre 2001; Mitchell 1995]. In architecturally designed environments people make assumptions about the kinds of activities and social interactions that

are supported there. This is partly determined by the physical affordances of the environment and partly determined by people's prior experiences. Physical spaces are formed to support the way that people do activities, and similarly, people's situated interactions in an architecturally designed space are shaped by cues in the physical environment about what is possible there.

In the social, our shared understanding of the physical world and the presence and activity of others helps people interpret activity and behavior [Harrison and Dourish 1996]. Traditionally, the opportunities of the social layer of space have been determined by qualities of the architectural design of the physical layer. Today this configuration also includes digital elements, which by their ephemeral nature facilitate fluidity, serendipity, and presence that takes us beyond the limitations of a physically built environment. In the design of hybrid spaces, architecture has acquired a new, digital layer of expression and design extending its capabilities to facilitate and organize social interactions [McCullough 2004].

In the digital, pervasive computing is a relatively new phenomenon strongly influenced by the uptake of mobile computing technologies facilitating people's social life outside the work domain [Rheingold 2003]. By extending what the built environment offers its inhabitants, pervasive computing provides new opportunities for sociality [Jensen and Lenskjold 2004]. People who are digitally connected to each other, and to the elements of the city, are now less reliant on fixed signage. They use technology to deliver relevant information just in time and just in place, guiding them to where they want to go and what they want to do. By allowing people to make inferences about the activities of others, digital systems create environments in which new social forms can evolve [Erickson and Kellogg 2000]. This digital layer not only helps structure our social interactions, but also provides a medium for facilitating and enriching everyday interactions between individuals [Erickson 1993].

In this study, the built environment is viewed as comprising these three interrelated layers: (1) the physical (material) layer comprising the architecturally designed buildings, structures, paths, signage, and spaces; (2) the social layer comprising social interaction between people moving around that space, queuing, gathering, meeting, etc; and (3) a digital, context-aware layer. We advocate that the digital layer should be designed based on a rich understanding of the physical and social layers of a space. Only through this will it form a direct relationship with the existing social and physical context of use.

1.3 Context Awareness

Design is about creating a fit between form and context [Alexander 1964]. One way of creating such a fit is to make systems context-aware, automatically adapting to the setting in which they are being used. This could be a mobile phone that automatically switches itself to silent when the user is in a meeting, or a laptop that automatically adjusts to local time. Within pervasive computing context awareness is an area of research that has received a great deal of attention. Many prototype systems have been developed and evaluated, and it has been demonstrated that value can be added to the user experience by

adapting information to contextual factors such as people's location. However, a context-aware device situated in an environment should be aware, not only of its location, but also of factors like the physical and social context of that location [Agre 2001; Bell and Dourish 2004; Bradley and Dunlop 2002; Dourish 2004; Cheverst et al. 2001; Goodman and Gray 2003; McCullough 2004; Schmidt et al. 1999; Tamminen et al. 2003].

The details of what constitutes physical and social contexts of use are not well understood, at least not in a way that provides design traction. Technology rather than user studies is currently driving the development of computation and communication systems pervading our physical and social worlds [Mitchell 1999]. Current software development methods and design techniques could be augmented with methods that provide detail and thoroughness in terms of understanding human experience of physical space and of the situated social interactions taking place there.

When dealing with context-awareness for mobile and pervasive computing systems, design should be based on field studies of existing situations of use, as done by, for example, Ciolfi [2004], Cheverst et al. [2000b], Paulos and Goodman [2004], and Tamminen et al. [2003]. If we want a system to fit well to its physical and social context, we need to understand these contexts and their interrelationships better, and explore how such understanding can be represented in ways that are useful in informing the design.

In response to this, the research presented in this article is grounded in a human-centered empirical study of physical and social context. We demonstrate how understandings of the user's physical and social context can be achieved and represented through a structured socio-physical approach, and how such understandings can then inform interaction design. This is relevant if you are building, for example, situated display or mobile device systems with content that is indexing strongly to static and dynamic elements in users' physical surroundings including buildings and people. This could be, for example, an information system in a train station or airport, a mobile tourist guide for an historic town, or a social networking system for a new housing development.

If the factors we are going to present in this article are not taken into consideration in the design of such systems, there is a risk of ending up with designs that, at best, do not fit well with their physical and social context of use. Worse, they may simply not get used because they get in the way of people going about their business. They could even impact people negatively by, for example, not giving them necessary information about the socio-physical character of a particular place of interest.

1.4 A Multidisciplinary Approach

Despite many projects looking at issues associated with designing context aware computing [Borntrager et al. 2003; Bradley and Dunlop 2002; Cheverst et al. 2002; Iacucci et al. 2004; Paulos and Goodman 2004; Randell and Muller 2000; Tamminen et al. 2003], only a few projects have explored the orchestrated use of information presented across multiple sources in the user's surroundings including nondigital ones, that is, digital, physical, and social information

[Cheverst et al. 2000a; Kulju and Kaasinen 2002; Laakso et al. 2003; Vainio et al. 2002]. To do this, we need to learn how to create relationships between the user's physical and social surroundings and the information presented digitally [Dix et al. 2000; Dourish 2004; Persson et al. 2003].

The study presented in this article adapted and combined qualitative research methods to analyze and represent people's understanding of existing physical and social contexts in urban environments. This was then used to derive "design ideas" for the incorporation of physical and social context into interaction design. This approach adapted existing research methods from architecture and sociology to provide an understanding of physical and social contexts and representations for use in interaction design.

Architectural and urban planning methods can be used to explore the interrelationships between physical spaces and social interaction [Erickson and Kellogg 2000]. Architectural research is concerned with the user's experience of the built form in the context of the activities that they are involved in. Representations of physical context can be used as theoretical apparatus to answer questions about the interdependence of technology, space, and society [Hillier 1996]. Hence, designers of pervasive and ubiquitous computing environments have turned to architecture and urban planning to provide a basis for devising methods for understanding physical environments. The work of architecture and urban planning involves observing how people socialize in everyday spatial environments. This has been used to draw out models and metaphors for incorporating similar combinations of physicality and sociality into digital information systems [Dieberger et al. 2000]. The design of urban environments affects the degree to which those spaces encourage social encounters between inhabitants [Ingram et al. 1996]. Buildings carry social ideas within their spatial forms; in this way, spaces link to human behavior. Their configuration creates expectations about people that guide our behavior [Hillier 1996].

Understanding the human experience of built form provides a basis for understanding the context of activities within that space and helps interaction designers to provide digital links between people's activities and their current environment.

Ethnographic methods from sociology can be used to help developers conceptualize and reveal opportunities for pervasive computing design, and suggest system requirements [Crabtree and Rodden 2004]. The study presented in this article shows that the creation of analytical and conceptual frameworks resulting from ethnographic field studies can be used to sensitize designers to the social aspects of technology use, and support the design of relevant and appropriate technologies. In terms of conceptualizing opportunities for such design, sociological research has shown that people are constantly communicating social cues. This is so that others can perceive our social networks by the patterns of activities and the affiliations that we have [Donath 1996]. As part of our social identity we have a way of aligning ourselves with particular groups [Goffman 1963]. Being aware of others and the activities that they are involved in influences the choices we make about our own activities. We are also aware that the activities that we are involved in provide information to others [Erickson 2002].

Fig. 1. Images from Federation Square, Melbourne, Australia.

By understanding how people operate socially in public places we can identify opportunities for useful digital augmentation of these spaces.

2. CASE STUDY: UNDERSTANDING PHYSICAL AND SOCIAL CONTEXT

For the purpose of understanding physical and social context, we chose a compelling urban environment, a newly opened and geographically delimited civic space in the city center of Melbourne, Australia, called Federation Square (Figure 1) [Paay 2005].

Federation Square was chosen because it was a relatively new civic structure, opened to the public in October 2002. It covers an entire city block and provides the people of Melbourne with a creative mix of attractions and public spaces for socializing, including restaurants, cafes, bars, a museum, galleries, cinemas, retail shops, and several public forums. In just a few years, Federation Square has become a highly popular place to socialize for all Melbournians. It is open from early until late, every day of the week, and it hosts a rich range of planned and ad hoc activities. Located in the center of the city, on major tram routes, and adjacent to the main train station, Federation Square is easily accessible, is considered a landmark in itself, and is a convenient place for people to arrange to meet up in the beginning of a night out on the town. One of the design intentions for the public space of Federation Square was to incorporate digital technologies into the building fabric, creating a combination of virtual information space and physical building space for people to experience.

2.1 Investigating Physical Context

Physical context, as characterized by both Agre [2001] and McCullough [2004], consists of architectural structures and elements of the built environment that people use in everyday life to orient themselves and to operate in that environment. This includes the use of landmarks as reference points, identifying legible pathways in the landscape as indication of the way to go, and reading the design of doorways as places to enter. This physical context is created in response to the situated activities that occur there [Erickson 1993], and with regard for human perception of that place. For example, a landmark only becomes one in response to use as a reference point by people inhabiting that space, or a place

description such as "the sitting steps" has meaning only through an understood activity that occurs there. The investigation of physicality of an environment, that is, our physical interactions with the world [Dix 2004], provides a practical understanding of physical context.

An investigation of physical context was conducted to understand the physicality of urban space as defined by the material elements of an urban environment that contribute to visitor experience of an urban space. It involved the identification of important characteristics of the physical context of an inhabited urban environment, and the creation of an analytical abstraction useful for informing interaction design. This is a somewhat novel approach in HCI to the problem of understanding context in urban space for interaction design of pervasive computing. Sociological observational studies have been made of people inhabiting urban spaces [Whyte 1980] and conceptual models have been developed to capture the nature of digital cities in urban planning [Graham and Marvin 1996]. An HCI methodology developed for creating an analytical representation of people's understanding of urban environments for the purpose of interaction design could be built on these studies.

Our investigation of physical context, PIA (Physical Interaction Abstraction), resulted in visual representations representing the physicality of an urban environment including a layered map diagram. PIA combines two existing methods from the disciplines of urban planning and architecture for analysis of space: (1) an environmental image map identifying landmarks, districts, nodes, edges and paths, a representation devised by Lynch [1960]; and (2) an analysis of space using the sketches and descriptions from Alexander et al.'s [1977] Pattern Language.

Lynch [1960] developed a method for visual analysis of city precincts through descriptions of key aspects of the space held by people as they navigate and orient themselves within city precincts. This was done by diagramming the interplay of visible elements in the environment that contribute to a person's environmental image of a place. From these studies grew the categories of landmarks, districts, nodes, edges, and paths as key descriptors of the image of the city held by its inhabitants. The method has proved successful at assisting in the analysis of types of elements of a city, how they are put together, and what makes for strong identity. It has also proved to be a useful technique for predicting the probable public image of that city.

Alexander et al. [1977] empirically investigated the interplay between architectural space and its inhabitants and identified architectural design problems in context and their impact on inhabitants of that environment. Drawn from observations of historical solutions to common design problems, he created a method of analyzing aspects of the built environment. This led to a collection of 253 hierarchically ordered patterns of plausible solutions making up a Pattern Language for design. Each pattern consists of photographs, sketches, descriptive explanations detailing the context for the pattern, its relationship to parent patterns, a description of the problem, the empirical background of the pattern, evidence for its validity, and the design solution.

The investigation of physical context began with an exploratory study of the physical elements of urban space at Federation Square. The analytical methods

of Lynch [1960] and Alexander et al. [1977] were combined and adapted to provide a novel method for analyzing and representing qualities of physical space to provide a story about physical context of an urban environment. Lynch's method provided guidance on techniques for conducting an audit of physical elements of a space. It defines the following classification categories for those elements: district, landmark, node, path, and edge. Alexander's patterns provided a window on recurrent and complementary "fit" between functional and spatial patterns. As Lynch and Alexander et al. both viewed their analyses of built environments from the perspective of the people who inhabit those spaces, our physical audit was undertaken from the perspective of people's perception of and interaction with the physical elements.

An observational expert audit, based on the expert audit from Lynch's [1960] method, was undertaken in single field visit to Federation Square. In Lynch's method, an architecturally trained observer maps in-situ the presence of various elements of the physical environment to create an environmental image map. In the adapted method of this investigation, the architecturally trained observer recorded through photographs and field notes the elements of the physical environment for later mapping and classification using content analysis [Neuman 2003]. A total of 124 photographs recorded the material elements (building fabric, cladding, structures, surfaces, building elements, entire buildings, public spaces, paths, entrances, media screens, etc.) of Federation Square for the purpose of documenting the physical elements in the "public" areas of the space. The location, from which each shot was taken, including direction faced, was recorded on a map of Federation Square. Human activities associated with physical spaces, and the way people were using and responding to elements, were recorded in field notes. This documented every architectural element in Federation Square and its relationship to its surrounding context, including the people who inhabited the space (see Figure 2).

2.2 Investigating Social Context

Social context, as characterized by Dourish [2001], includes interaction with and the influence and behavior of people in an environment. Dourish [2004] regards context as a central concept in social analyses of interaction and that social and cultural factors affect how the user makes decisions about actions and interprets a system. In understanding the social context of a place there needs to be a way to understand the social processes and human activities through studying everyday interactions. The sociality of a place reflects the social interactions that occur there and investigation of this sociality situated in an environment should provide a practical understanding of social context.

An investigation of social context of an urban space using the SOPHIA (SOcial PHysical Interaction Analysis) method was initiated to inquire into social interaction in that environment. It identified those aspects of a person's social environment that represent their understanding of social context [Paay and Kjeldskov 2008]. The outcome from this investigation is a conceptual framework representing situated social context in the urban environment of

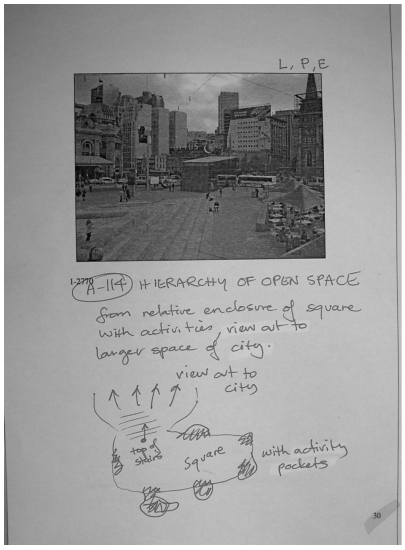


Fig. 2. One out of the 124 photographs and notes on physical elements of Federation Square.

Federation Square in Melbourne, complementing the understanding generated from the PIA analysis of physicality.

The PIA and SOPHIA approaches are different in the sense that the PIA map emphasizes the physical context for understanding socializing in an urban environment while the SOPHIA table provides an hierarchical representation of activities emphasizing the social context of being physically situated in an urban environment.

Our investigation developed an approach, including the SOPHIA and PIA methods, for gaining an understanding of the social context of an urban environment using rapid ethnographic methods [Millen 2000]. This related social interactions to the physical environment in which they were taking place. Understanding the physical aspects of human experience of spaces can best be achieved through studying people situated in place [Ciolfi 2004]. To support our approach, the work of McCullough [2001] provided insight into the situated nature of social interactions through his typology of everyday situations. This provided a framework from which to view social interactions as related to the situation in which they occur, a view in turn influenced by the physicality of the space. McCullough [2004] draws together the concerns of architects and interaction designers by acknowledging that interaction design for pervasive computing has a direct relationship with and impact on the environment and the inhabitants of a place. As an example, digital devices can give you social information you can't see physically, such as where a crowd has gathered outside or beyond your immediate field of view.

The method of investigating social context involved observation in the built environment to identify the *social affordances* of a space. This included, for example, where people tend to go, where they tend to gather, and what they

tend to do at different places, which contribute to the people's understanding of that space.

This method takes a grounded approach to understanding the existing social situation. It involved accompanying three groups each of three people (9 participants in all, mixed gender, young urban professionals aged between 20 and 35, and all familiar with the location), on a typical social visit to the Square. The aim was to observe and record the group interactions using McCullough's [2001] typology of "on the town" everyday situations as a theoretical lens through which to view and guide social interactions in the field, and as a sensitizing concept in analyzing social interactions in urban environments. The categories of interest to this investigation were: eating, drinking, talking (places for socializing); gathering (places to meet); cruising (places for seeing and being seen); belonging (places for insiders); shopping (places for recreational retailing); sporting (places for embodied play); attending (places for cultural productions); and commemorating (places for ritual).

Participants were required to be familiar with Federation Square, thereby acting as key informants [Millen 2000], capturing representative interactions of an established social group. Each field visit was used to observe the social interactions of the group, the activities they participated in and how they were affected by physical space and the presence of others. Participants were instructed to go about their usual socializing practices in Federation Square. The group determined the activities undertaken and the social interactions that they engaged in. Contextual interviews from the contextual design method [Beyer and Holtzblatt 1998] were used in the field, combined with observational ethnographic methods.

Prior to each field visit the group received a 10-minute introduction to the investigation followed by a 20-minute interview about general socializing experiences as a group. This introduction occurred at a place familiar to the group, where they might meet before socializing in the city. This encouraged them to reflect on past social interactions and to relax about the visit, and gave the interviewer insight into the situated interactions that the group typically participated in. At the start of each field visit, one member of the group was taken to Federation Square and asked to contact the others to meet them there. This was designed into the method so that their meeting-up processes could be observed. All groups used mobile phones for contacting their friends, as they usually would.

The contextual interviews and observations lasted approximately three hours for each visit, allowing the group to participate in many varied activities (or situated interactions) during the field visit. Reflection on past visits by participants gave additional data about their responses to alternative activities in that space, without taking the time to do them during the visit. This reflection also gave access to the group's history of interactions in the space. The total amount of time spent in the field with the three groups was 11 hours, which proved to be a sufficient amount of time to observe that very few novel observations were occurring with the last group. The outcome from the field visits amounted to (1) approximately eight hours of digital video (Figure 3) recording situated interactions, all questions and responses, the initiation of activities

Fig. 3. Video recording the social study in Federation Square.

and movement of the group around the square, (2) notes of ethnographic field observations, and (3) diary of reflections on visits recorded immediately after each visit.

3. REPRESENTING PHYSICAL AND SOCIAL CONTEXT

3.1 Representing Physical Context

Before content analysis of the photographs collected in the field commenced, coding of the elements of each photograph was done by assigning one or more of Lynch's [1960] five categories (landmarks, districts, nodes, edges, paths) to the focal element in each image. Using the recorded locations of the photographs, these coded elements were then used to create an environmental image map for Federation Square (see the grayed under layer of Figure 4) showing landmarks, districts, nodes, edges and paths as perceived by the architecturally trained observer.

In addition to this, one or more of Alexander's [Alexander et al. 1977] 253 patterns of the Pattern Language were associated with each photograph, which was then annotated with the pattern number and pattern title of each associated pattern. Sketches and notes showing the applicability of each pattern were appended to the existing descriptions of each image. Content analysis was then conducted on this data, involving coding it by classifying, sorting, and grouping concepts in the written descriptions, and refining the themes emerging from that process. After several iterations of grouping, regrouping, forming sets of words, and refining words, a concise set of representative terms emerged. These were influenced by the categories of Alexander et al. [1977] by virtue of the encoding schemas. Each of these representative terms was then related back to the original photographs, giving them the additional quality of locatability. The coding and content analysis was done by one architecturally trained researcher alone, and was subsequently validated by a second researcher experienced with the works and methods of Lynch and Alexander.

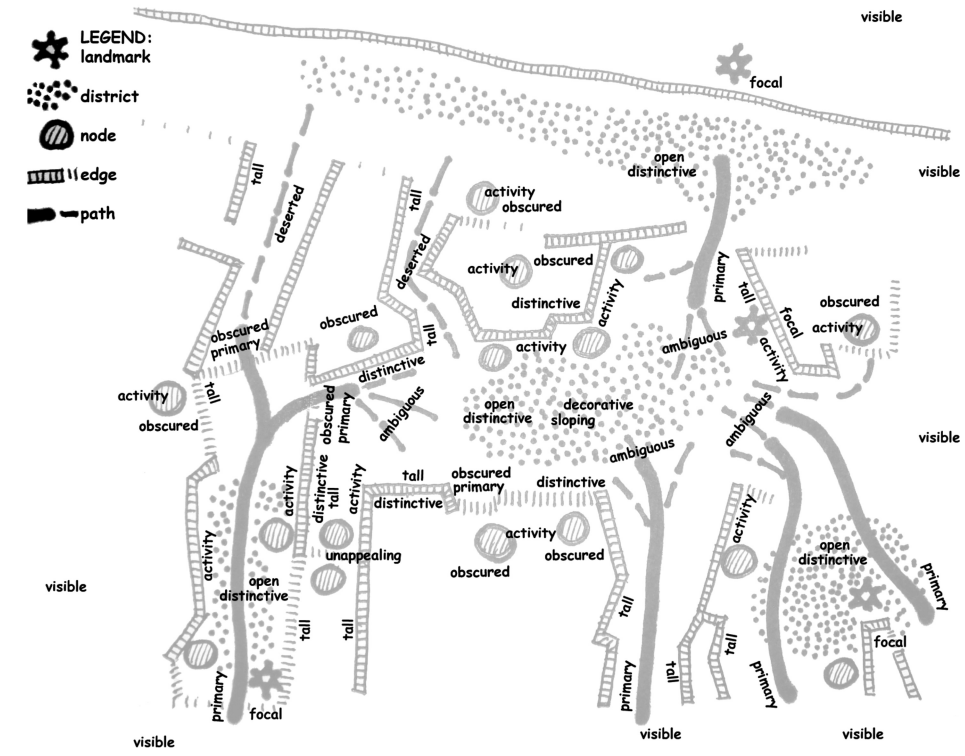


Fig. 4. Layered map of Federation Square generated from the PIA approach.

PIA Layered Map. The visual representation that came from combining these two analyses was a layered map diagram. This showed an overview of the different Lynchian-based elements evident in the space (drawn as a gray sketched "under layer") and the related, and specifically located, Alexandrian-based descriptions of the space (placed as a text over layer). This map, depicted in Figure 4, is specific to Federation Square but the method of creating it would be applicable to the analysis of other spaces in a similar way to derive a visual representation of an urban environment. The PIA layered map represents an abstraction of the physical characteristics of Federation Square. It provides a visual overview of the inhabited physical context of that space.

Surveying the layered map, it is possible to draw summary conclusions about the space, which would not be evident from viewing the original data, or from merely visiting the space. This is because it represents a composite view of that space, judiciously extracted from historical understanding of human experience of physical space through observational expert audit and analysis of urban space.

Table I. Understandings from PIA Related to Design Ideas

DESIGN IDEA:		1. Location by District	2. Augmented Photos	3. Rich Descriptions	4. Use of History	5. Wayfinding	6. People and Activities	7. Meeting and Waiting
UNDERSTANDING: PIA								
Landmarks:	structures-focal	•						
Districts:	spaces-distinctive	•						
	spaces-open		•					
	surrounds-visible			•				
	ground-sloping							
	ground-decorative							
Nodes:	structures-distinctive			•				
	structures-tall			•				
	places-activity						•	
	places-obscured		•					
Edges:	edges-activity		•	•				
	entrances-obscured		•					
	entrances-primary		•					
	walls-distinctive			•				
	walls-tall			•				
Paths:	paths-primary					•		
	paths-ambiguous			•		•		
	paths-unappealing							
	paths-deserted							

The PIA layered map provides a specific representation of those key contextual factors that characterize the environment at Federation Square (see Table I), including the following key understandings of its physicality:

—Federation Square has four key districts with distinctly different characteristics, each with an associated landmark.

—Federation Square has open spaces with activity edges; distinctive and tall structures and walls; and obscured places where activities are also happening—so it is not clear from the middle of the main spaces what is around, and how to find where you want to go.

—Federation Square has visible surrounds; some primary paths that become ambiguous when they lead into open space or are deserted or unappealing when wedged between tall walls; primary entrances that are obscured; and focal structures—so people need to use the structures and surrounds in finding their way around the space.

PIA's significance lies in its ability to capture, in a readily accessible form, inhabited physical context. It makes available a visual representation describing inhabited space that can be used for identifying the key physical characteristics of any built environment. This is done in a way that is grounded in human

observation of that place and formed with reference to collected knowledge about human understanding of architectural form.

The PIA approach is novel, insofar as it is a combination of two well-respected architectural schools of thought that have both been applied in HCI before, but not in combination, and not with such adherence to their architectural origins.

3.2 Representing Social Context

The eight hours of the digital video collected during the investigation of social context at Federation Square resulted in a 60-page transcription of situated interactions "out on the town." General conversations about participant's families and work issues were not transcribed and were regarded as being outside the bounds of this investigation. The analysis of the transcript involved open and axial coding from the grounded theory methodology [Neuman 2003; Strauss and Corbin 1990] and the affinity diagramming method from the contextual design methodology [Beyer and Holtzblatt 1998].

Open coding is that part of the analysis concerned with identifying, naming, categorizing, and describing phenomena found in the text by assigning codes to them. This involved underlining key words and repeating phrases in the transcript, identifying the phenomenon that participants described, and coding that as a category-property-dimension triplet. For example, a conversation about how a group chose to meet up resulted in the code: "MEET PLACE—choice—familiar to all." These codes were then entered into a table, recording when in the transcript this phenomenon occurred, and a longer description of it, supporting the meaning behind the code. During this process, codes were modified and merged as related and similar situations were found in the remainder of the transcript. After coding of the transcripts, category names were consolidated and refined using McCullough's situated interactions as a theoretical lens. This resulted in 214 distinct codes, grouped under the following 17 descriptive categories: Contacting, Meeting, Approaching, Entering, Eating, Drinking, Sitting, Watching, Being Seen, Attending, Viewing, Shopping, Deciding, Directing, Walking, Exploring, and Locating. In the previous example, the code became: "MEETING—place—familiar," and was grouped with many other phenomenon related to people meeting up when socializing.

Axial coding is the part of the process that relates codes to each other using a combination of inductive and deductive thinking. To achieve a higher level of abstraction with our data, axial coding was used to draw a set of overarching themes from the outcomes of the open coding process. For intercoder reliability, two researchers reviewed the codes in respect to the underlined transcript to identify overarching themes emerging from the data. The two sets of themes produced were then merged and consolidated as a joint activity to produce a group of 21 agreed themes as the outcome of the fieldwork. These themes formed the starting point for the process of further abstraction, using affinity diagramming [Beyer and Holtzblatt 1998].

Affinity diagramming drew successively higher levels of abstraction from the data through a process of grouping and sorting the 21 themes until a set of three high-level key aspects emerged. These represented the essence of the data and

encompassed all lower level themes as concepts supporting these key aspects. This resulted in a conceptual framework encapsulating a structured understanding of the context of everyday social interaction providing a rich story of sociality in urban environments showing how people experience physical space and how they interact with each other while socializing in these spaces.

3.3 SOPHIA Conceptual Framework

The conceptual framework generated through the SOPHIA approach provides a hierarchical summary of key social characteristics affecting social interaction in urban space. It consists of three key aspects of social interaction in urban environments: knowledge, situation and intention. These key aspects and their related concepts tell the following story about situated social interaction.

Prior experience and expectations. When interacting in urban space people draw on their knowledge in the world. They recognize entrances, and they see large open spaces as places for people to gather. They use landmarks as reference points. People operate in public places using a set of social affordances. They look to what others are doing as cues for what to do in a place. Following crowds or people queuing is a way to decide where they might go. Places where others are sitting make them feel they can sit there too. People draw on their history with a specific urban environment. Physical familiarity with a space means that they approach familiar places using familiar paths, that is, the way that they "usually come." They use past social experience of places as a basis for selecting places to socialize with friends this time, for example "Let's eat where we ate last time," or require trusted recommendations to try a new place. Often they will have a personal preference for why they choose a particular place. People relate activities with establishments, that is, a place for drinking, based on their past experiences with it. If it is a place where they "usually sit outside" then it becomes the place to go in fine weather. If they are socializing with a particular group of friends they like to start the social outing in a place that they share a common experience of and often arrange to meet in the place where they "usually meet."

Situations, places, and spaces. Situation is an important aspect of sociality in urban space. When socializing the presence of other people influences the way that people behave and move through urban space. Friends show they are a "group" by maintaining close physically proximity, for example, walking abreast, as they move through a public place. People like to be near others but not necessarily interacting directly with them. For example, they like to share a table with others in a bar, yet not talk with them; they are "socializing by proximity." People like to watch others, especially if they feel unobserved themselves. The length of time that someone has to wait for a friend influences the choice of meeting place. The setting in which a particular activity takes place matters. The presence of others and the types of people in a place influences its acceptability. Generally, people like to socialize in places with similar types of people, that is, age, dress, intentions. Whether a place is sunny, sheltered, etc., influences the choice of location to socialize or wait. The convenience and location of a place is also important. People prefer a place to eat that is near other

places to eat. Surroundings are an important part of people's situation and are often used as reference points. They index to things around them, including buildings, for example, "the railway station," or distinctive elements, for example, "that big white umbrella." They describe a location of an unknown place to a friend by referring to the places and activities of shared experience that they hold with that person. People describe a location as "next to the place we went where we sat under those heat lamps" They might also refer to a place in terms of a past event that has happened there, that is, "where we saw the World Cup."

Sense-making. Sense-making is an important part of socializing in a place. People try to size up the situation. They like to get an overview of their environment. They strive to make sense of things and places around them. People make sense of what is happening in a place by assessing the activities of others. Before entering a place they tend to stand on the outside and familiarize themselves with the situation before committing to enter or join in. People gather information in an urban environment while socializing, and require differing levels of information for different activities. They view information/media screens as decoration, and if they have a query, they are most likely to ask a friend. They do not like to interact in places where they are unsure of how things operate. They want to know what is new and if there is something special happening in a place, especially their familiar places. Movement through an environment is part of their social activity. People explore places just for the fun of it, often wandering and browsing without a specific goal exploring both physical space through movement and shared knowledge through conversation. At other times they are trying to find their way to a specific place, involving transition through spaces preferring paths that have people and activities of interest along the way. Places are dynamic, and familiar and preferred paths are sometimes blocked or altered by the presence of ad-hoc structures or large crowds. People can get lost when taking an unknown route and get frustrated when signage is not helpful. In this situation, they look ahead for familiar objects. Friends spend time negotiating on places to go, and will make decisions by discussing options until they reach consensus, or someone leading the group.

This outcome of the SOPHIA analysis of social context, represented as a conceptual framework, provides a hierarchical representation of the social layer of an urban environment, and can be seen in Table II. This conceptual framework represents social influences at work at Federation Square, including the following key understandings of situated social context:

—At Federation Square people's past experience with places and people (familiar places and shared experiences) and the situation of these experiences are important in choosing places and activities to socialize;
—At Federation Square people give directions by referring to shared experiences and visible elements, and use their history and physical familiarity with a place to find their way around using familiar paths;
—At Federation Square people like getting an overview of what is happening and want to know about the presence of other people in places and what they are doing; and

Table II. Understandings from SOPHIA Related to Design Ideas

		DESIGN IDEA:	1. Location by District	2. Augmented Photos	3. Rich Descriptions	4. Use of History	5. Wayfinding	6. People and Activities	7. Meeting and Waiting
UNDERSTANDING: SOPHIA									
Knowledge: in-the-world	physical affordances	places to enter	•						
		places for gathering							
		landmarks as focal points	•						
	social affordances	cues for what to do						•	
		cues for where to go						•	
Knowledge: history	physical familiarity	familiar paths			•		•		
		familiar places				•	•		•
	social experience	past experience				•	•		•
		shared experience				•			•
		recommendations from others				•			
		personal preferences							
Situation: people	us and them	interaction by maintaining group							•
		interaction by proximity						•	
		interaction by watching						•	
		discomfort of waiting						•	•
Situation: setting	setting matters	others (social)				•			
		environment (physical)				•			
		convenience to current location				•		•	
Situation: surroundings	indexing to surroundings	index to shared knowledge				•			
		index to visible elements		•					
		index to events							•
		index to physical objects		•					
Intention: sense-making	sizing up the situation	getting an overview						•	
		pausing before committing						•	
		making sense of a place						•	
		making sense of what's happening						•	
	gathering information	different levels of information		•					
		media screens as decoration							

(*Continues*)

Table II. Understandings from SOPHIA Related to Design Ideas *Continued*

DESIGN IDEA:			1. Location by District	2. Augmented Photos	3. Rich Descriptions	4. Use of History	5. Wayfinding	6. People and Activities	7. Meeting and Waiting
UNDERSTANDING: SOPHIA									
		what's new		•					
		uncertainty (lack of info)		•					
Intention: movement	exploring	exploration for the sake of it						•	
		wandering and browsing							
	wayfinding	transition through spaces					•		
		dynamics of a place					•	•	
		getting lost (unclear signage)					•		

—At Federation Square people typically coordinate meeting up with friends in an ad-hoc manner, depending on activity and shared history with those friends.

Some of the observations we have described were surprising to us. For instance, we were surprised about the observed influence of familiar places and paths on people's socializing and navigational behavior. People would rather revisit well-known places than explore new ones, and would knowingly prefer the long way between two places to a newly found shorter path. Related to this, we were also surprised about the importance of people's history of socializing in Federation Square and how past and present interactions were not perceived as a random set of disjointed events, but rather as interwoven parts of a continuous experience over time. In terms of the way people communicated about places outside their immediate view, we were surprised with the extent of references made to activities and earlier interactions there, rather than to its physical properties. As a final example, we were surprised about the huge importance of social affordances of places when venturing into unfamiliar areas.

Many of the findings we have presented involve, and relate, social and physical aspects of context. It is our belief that these findings would not have been noticed as strongly without SOPHIA. The SOPHIA approach can be used to analyze any urban environment and provide an analytical representation of that urban space in respect to those elements of situated social contexts that are most strongly represented there. It makes available a set of concepts representing sociality in urban space that can be used to identify key social characteristics of any built environment. It describes the user's social situation in a way that is

grounded in human observation of people socially interacting in place, collected through ethnographic study of situated social interaction.

SOPHIA is unique, in so far as it represents a grounded approach to providing a widely sought representation of social context in urban environments.

4. INFORMING INTERACTION DESIGN

Using the PIA and SOPHIA methods and resulting representations of the physical and social layers of an urban environment, a pervasive computing prototype was designed for the intangible goal of "enriching people's experience of Federation Square."

The design process used in this study involved identification of a method, where no generally accepted one exists [Ciolfi and Bannon 2003], for taking knowledge gained during a grounded analysis of context of a space through to the specification of design requirements for a prototype system. The process of transition from field data to prototype design is a difficult one [Cheverst et al. 2005; Ciolfi and Bannon 2003; Kuutti 1996]. The study presented here used a method of drawing design ideas from the PIA layered map and SOPHIA conceptual framework using a technique of design sketching [Buxton 2007] to make this link between the analysis and design processes. Two researchers reflected on these field investigation outcomes and used design sketching to extract design ideas from them. This method is a combination of idea sketching as used in, for example, architectural design [Yee 1997], interaction design [Buxton 2007; Sharp et al. 2007], and software design [Checkland 1981], and empirically grounded identification of considerations relevant for design [Ciolfi and Bannon 2003].

During the design process, the PIA layered map and SOPHIA conceptual framework were continually revisited and used to inspire seven design ideas. Using the design processes of storyboarding and paper prototyping, these design ideas evolved into the design ideas that guided the creative design of an operational prototype. This prototype was then used to verify the ability of conceptual frameworks to inform the design process and also to evaluate the usefulness and understandability of references to the user's current context in the human computer interface. The following seven design ideas identify key aspects of the understandings of inhabited physical context and situated social context of the urban environment studied:

1. *Location by District*. The system responds to the users' location in terms of one of the defined districts from the PIA layered map. Importantly the understanding of location is imbued with social meaning. The information provided by the system is tailored to information needs within that specific district. To help the user relate the information in the interface to the physical surroundings, the initial screen displays the corresponding landmark for that district, using physical indexicality to align the system with the real world.
2. *Augmented Photorealistic Depictions*. Each district is represented in the system by an interactive photorealistic depiction of the physical surroundings of the user augmented with textual or symbolic information needed

to better understand the place. The outcomes from PIA tell us that the space has activity edges but primary entrances and destinations that are obscured. The interaction design matches the user's experience of this physical space and facilitates aligning the information presented in the system with the physical surroundings. The augmentation of these images helps people to know what is located behind the visible facades, and to identify primary entrances serving several different places.

3. *Rich Descriptions for Navigation*. Locations and instructions for navigation are expressed through rich descriptions derived from the distinctive characteristics of the place. Based on knowledge generated from PIA that activities are located on the edges, it follows that selected locations could be described as being "next to" or "opposite" other locations. These terms are used in the rich descriptions, thereby referring to locations relative to one another. The navigation information also indicates the path that the user should take to get to a place. The outcomes from PIA show that paths in many areas of Federation Square are ambiguous and not clearly indicated, but the space has visible surrounds. It therefore follows that descriptions, such as "away from the train station" or "towards the river," can be used to refer to visible elements of the surrounding city.
4. *Use of History*. The system keeps a record of the user's history of visits to Federation Square and visits of accompanying friends and uses this to deliver socially appropriate information about things to do and places to go. From SOPHIA we know that people use their history with a place and shared experiences with others when socializing. The past visits to places that they share with particular friends affect where they choose to socialize. Also, the current situation in a place, including environmental conditions and the presence and activity of others, affects choices of where to go and what to do. The system makes use of the social experiences and history of the user to give activity and place recommendations to them based on this database of past visits.
5. *Wayfinding*. The system supports wayfinding using people's familiar paths and indexing to their familiar places. The outcomes from SOPHIA shows that familiar places and familiar paths are important to people. Also that if signage in a place is inadequate people get lost going to new places. A system that knows a person's familiar places can present a series of them, along with key landmarks and distinctive building features as identified through PIA, to guide a person to an unknown destination. The person will use familiar paths to get to each point thereby reducing the need for detailed step-by-step movement directions. This uses people's social experience and history with a place.
6. *Representation of People and Activities*. The activity and location of others in Federation Square is represented to the user so that they can make activity choices based on assumptions that they make about this information. Representation of what is happening, including both people and activities, helps people in making sense of a space. The outcomes from SOPHIA show that interaction between the group and others by proximity and by watching

is important when socializing. There is a desire to know where other people are gathered. People are drawn to new places by the presence of others, or explore where others are out of interest. This lets users "see" important aspects of the current social context of a place that they would be otherwise unable to access from their current location.

7. *Meeting and Waiting*. The process of ad-hoc meeting up with friends is streamlined through the use of familiar places, identified groups of friends and their proximity, and information about how long a person will need to wait. This requires knowledge of the history and shared social experiences of friends. As indicated by the outcomes from SOPHIA, people coordinate meetings based on places familiar to the group, how long they will take to meet up, and what activity the group want to do. This indexes to past social interactions of a group of friends.

These design ideas were directly derived from the understandings generated through the PIA and SOPHIA methods, and can be directly traced to the outcomes from PIA and SOPHIA that inspired them as shown in Tables I and II.

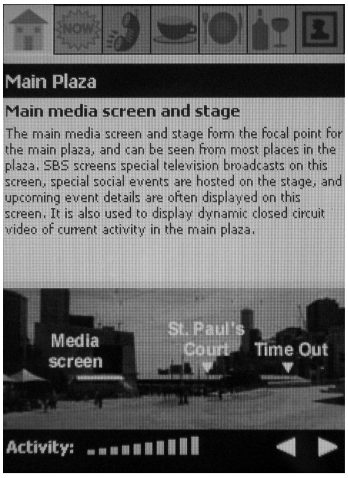
Informed by the seven design ideas, and with respect to the established functionality typically provided by, for example, mobile guides systems, a pervasive computer system prototype was developed for access through mobile devices (Figure 5).

The "Just-for-Us" prototype was created as a proof of concept, to evaluate the usefulness of the design ideas emerging from PIA and SOPHIA in situ. The four example screens shown in Figure 5 have design elements that can be directly linked to the design ideas detailed above. For example, the *NOW* screen was inspired by design idea 6, *Representation of People and Activities,* where the location and activities of other people within proximity are visually represented on a dynamically updated map. This represents the current situation, allowing people to make sense of a place through the social affordances provided by the presence of other people.

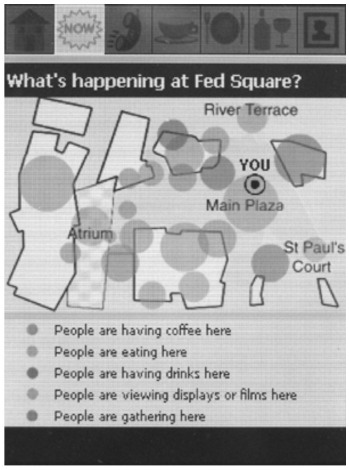
When a user enters one of the square's four districts, the system pushes data about that district, including a panoramic photograph, to the mobile device (the Home screen). Clicking on an annotation brings up a brief description of the item. By clicking on the arrow icons at the bottom of the screen the user can rotate the view and learn about other locations in the area. When the user enters a new district the corresponding panoramic photograph is automatically pushed to the device.

Clicking on the Now icon at the top of the home screen brings up a small map showing the user's approximate location and dynamically updated colored circles. The radius of each circle indicates the number of people present, while the color represents their prevalent activity—for example, having coffee, eating, having drinks, or attending a cultural event. Clicking on a circle calls up detailed descriptions and images of the place, for example, a particular restaurant, along with information such as wayfinding directions and menus.

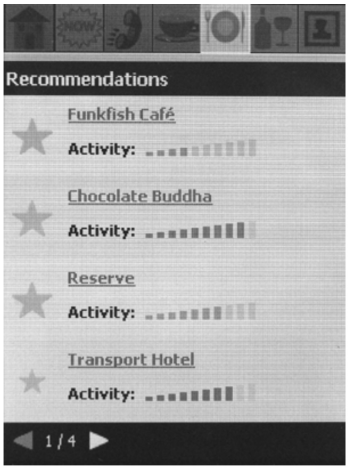
Just-for-Us was implemented as a server-side Web application that can be accessed through a mobile Web browser. For the first prototype, we used a



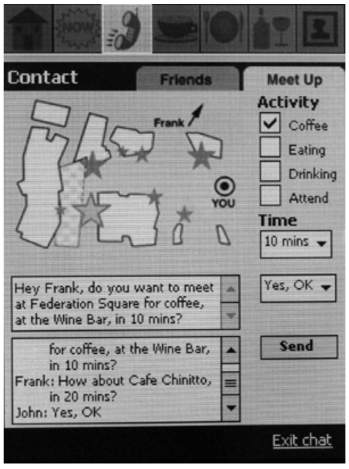
HOME screen



NOW screen



RECOMMENDATIONS screen



CONTACT screen

Fig. 5. The "Just-for-Us" prototype system—four example screens.

series of HP iPAQ h5550's connected to the Internet through WLAN or a GPRS connection. The content of Just-for-Us is generated from a mySQL database containing information about the physical layout of Federation Square (derived from the architectural field study). It also holds descriptions and photographs of landmarks and transition points, and information about the different establishments and businesses in the precinct. Additionally, the database is continuously updated with information about people's current context (location, activity, social group, etc.) and keeps a history of their interactions in Federation Square. PHP is used to generate web pages on the basis of the information in the database, and JavaScript is used for handling client-side interaction and information push. Supporting the Web application, a number of server-side programs perform specific subtasks such as pushing information

to the user when appropriate and dynamically generating maps and annotated photographs. The system scans for other Bluetooth-enabled mobile devices to identify nearby friends, and uses Bluetooth beacons in the built environment for positioning. Hence, it does not know people's exact geographical coordinates but only their approximated location, for example if they are in a specific café or in the main square. The location of people appears anonymous. For full details of the prototype design and implementation of Just-for-Us, see Kjeldskov and Paay [2005].

5. EVALUATING JUST-FOR-US

To investigate the usefulness and understandability of the prototype system, and to extend our understanding of physical and social context in urban environments, an empirical user-based evaluation was conducted. Unlike many other mobile information systems, the proposed design is built on insights into user perceptions of the built environment gained from empirical fieldwork. This facilitate presentation of information in the interface that refers to elements of the user's physical and social contexts.

The evaluations of the Just-for-Us prototype involved 20 participant pairs of mixed gender, with a history of socializing in Federation Square. Ten evaluations took place in the field at Federation Square, and ten in a laboratory. Using a mixture of field and laboratory evaluations made it possible for us to powerfully introduce the situation of use into the assessment (in the field) whilst allowing for a degree of control (in the laboratory); in doing so we asked questions of use in the field, and questions of usability in the laboratory, integrating our insights as we went. As previous research has stressed the value of researcher control in field evaluations [Kjeldskov et al. 2004], users were given a number of overall tasks to prompt use of specific parts of the system that related to the users physical context and social context, in respect to the six design ideas that were implemented in the operational prototype. A set of tasks and field questions were devised to ensure that these parts of the system were evaluated. Supporting this approach, users were asked to validate the relevance and realism of these tasks in relation to the activity of socializing out on the town. Before taking part in a visit, each participant pair jointly completed a history survey of their previous visits to Federation Square to simulate history data that the real system would have collected automatically. For the purpose of the field evaluation, the user's position, people and friends in the vicinity, etc. were "Wizard of Oz'ed" [Dahlbäck et al. 1993; Buxton 2007] with data being entered manually behind the scenes without the knowledge of the test subjects.

The investigation was an evaluation of use borrowing techniques from traditional usability studies such as specific tasks, think aloud protocol, and the data collection methods of video and audio recording. Inspired by the codiscovery testing approach to thinking-aloud studies with more than one user [Snyder 2003], pairs were asked to discuss their perception of and interaction with the system with each other. The researcher read the tasks and asked questions about participant's interactions for clarification. Each evaluation took

approximately 1.5 hours. The evaluation was documented on digital video both in the laboratory and in the field.

Due to the fact that this was not a theory building exercise but an exploration of the use of the PIA and SOPHIA understandings in the design of Just-for-Us, a detailed grounded analysis of this data was deemed unnecessary. Instead the rapid ethnography method of collaborative data analysis [Millen 2000] with two researchers provided the level of feedback sought from the use evaluations. The collaborative data analysis approach was combined with the analytical technique of identifying critical incidents to produce a list of observations [Sharp et al. 2007] with each observation associated with one of the five major tasks.

The outcome of this analysis was a list of 74 issues related to user experience and comprehension of the system, for example, "People want to use the map representation overview to make activity choices." These issues were then associated with specific outcome elements of the PIA and SOPHIA tables to extend the understanding represented by these frameworks.

In terms of inter-coder reliability, a total of 1390 instances of the 74 issues were coded across the 20 participant pairs. Out of these, the two researchers independently identified and coded 1318 matching instances of these issues, which shows a high level of reliability (94.9%).

6. FINDINGS

The user study provided rich data on the use of a public pervasive information system within an urban context. On a general level, the study showed that people could easily operate the system, find what they were looking for, and understand the presented information and functionality. They found the design of the system attractive, streamlined, and professional looking, and trusted its content to be true. On a more specific level, most users reported that providing a public digital layer of information augmenting the city on their mobile device was "very cool," "useful," and "fun." In particular, people were fascinated that the system knew their current physical location, whom they were with, and where other people in the civic space were currently gathering. They were also fascinated by the ability to access information about the places around them from both businesses and other people, and they perceived the service as a credible source of information augmenting their surroundings.

The user study also provided us with the following detailed findings that can be tied to specific themes captured in the understandings generated through PIA and SOPHIA.

Informed by the empirical findings of the evaluation, we can confirm that *landmarks*, that is, features that are distinct from their environment, worked well as anchor points for matching information in the system with information in the real world. Landmarks are an important focal point for people operating in urban environments.

Even though the accuracy of the system's positioning was limited to only knowing what district or place a user was at, rather than knowing their precise geographical coordinates, this proved to be specific enough and matched with

people's perception of their current location. Within each district it was quite natural for people to use the visible surroundings for aligning the system with the real world by matching the outline of buildings and distant skylines with images on the screen. In situating themselves people would use distinctive elements and structures to make quick confirmations that they were in the right place using images on their screen to index to their surroundings. We were surprised that while doing this many users stated that they did not need such a detailed image and would be capable of using, would even prefer, a line drawing or an outline with a few detailed features. In doing this matching, however, it did surprise us that even though people seemed perfectly capable of identifying and matching on a more abstract level than we had designed for, they wanted the virtual world to automatically correspond and align with their exact orientation in the real world—they expected the system to "know which way I'm facing" and would even relocate themselves a few meters to one side so that this alignment was achieved.

We found that people did treat the space as a series of interconnected *nodes*, that is, places of activity and interest, which they were keen to know more about. Given the distinctive structures of places, we found that using a physical quality of a place as a descriptor in instructions worked very well, for example, telling users to "walk toward the black building" negated the need for detailed distance and vector-based wayfinding instructions. Surprisingly the same success was not achieved using activity as a descriptor, for example, "walk past the sitting steps." Although all participants said they were well aware which steps we meant, they were worried that activity was transient, and not necessarily happening at all times of the day.

Generally people navigated and oriented themselves using the perceived *edges* of the space. Although we understood people to use physical affordances to determine places to enter, we also knew that the space had primary entrances that were often obscured. We found these transition points were vital to people finding their way in the space, and that augmenting an image of the activity edges of the space with text indicating the location of entrances and places supported improved wayfinding in the space.

As noted in the analysis, *paths* in the space were both very large and generally lead into the square and were not clearly indicated inside the space. This did not prove to be something that needed to be augmented by the system because, as expected, people used their familiar paths, and therefore only needed fragmented detail to get to the vicinity of a new place, with more specific detail when up close.

In terms of *prior experience* used when socializing with the system, it was confirmed that people do navigate very successfully using physical familiarity. They adapt to fragmented wayfinding descriptions finding their own path as far as possible by navigating to places that the system knows are familiar to the user. However, in giving these instructions we found that users often did not know the formal name for their familiar places, and in this case resorted to viewing and recognizing a picture of their destination. In our evaluation we confirmed that it made sense to people to know about the activity and number of people at places nearby, and influenced their decision to go there. The system

provided the kinds of cues or social affordances needed for deciding what to do and where to go, but for places beyond the users current visual range. Many parts of the system relied on knowledge of the user's past social experience with the space to give directions and recommendations on places to go. Although this was successful in most cases, and people do generally favor returning to familiar places, we found that frequency of visits to a place is not a universal indicator that people want to go there this time. The system would give recommendations based on familiarity and current social situation, and it would surprise users when the system adapted to their history—most users expressed uncertainty about how to control this ability and a desire to do so. In our design we had overlooked that fact that when places are being recommended by a system, people want to know the factors influencing that recommendation. We did, however, have it confirmed that people regard the favorite place of a friend as a form of recommendation.

The *situation* for socializing was also confirmed as important. Knowing about the activity of people in a place influenced the decision to go there. It was interesting to note that for some individuals a busy area made them want to go there and "check it out," showing an interest in interacting by proximity,with users stating that the presence of others is a sign that a place is good. For others large numbers of people clearly indicated a place to be avoided, although some clarified this choice by telling us that it depended on the mood they were in. It was our understanding from the social study that spatial convenience was also important, but in the evaluation users said that this did not matter—this may have simply been a factor of the small-scale testing space.

People's *sense-making* when socializing was the most difficult to confirm. It was evident in our use study that people do spend a significant amount of their socializing time on making sense of their surroundings and sizing up the situation. People really loved getting an overview of other people and their activities in their surrounding environment. They appreciated having information presented to them about events that were about to happen at places around them—suiting the serendipitous form of socializing that most users engaged in. People also really liked it when the system automatically gave them relevant information about the activity they were about to do at a place. For example, having menu information pushed to their device when in proximity of a café gave them the opportunity to pause before committing to the place, which was perceived as less of a commitment than going inside to read the menu. However, what we did not foresee was that at this point users wanted to make a quick comparison between this place and others nearby without moving. Nor did we predict the level of detail that they required, including food type, price, genre, ambience, outdoor spaces, and type of people there. Generally, we found that people exploring and making sense of an urban space wanted to be able to access differing levels of informational detail, in sequences that was difficult to predict, constantly changing, and not simply related to their current location. When delivering specific information adapted to their locational context we found that people still wanted to be able to access non-context-specific information relatively easily. We also found that people required quite different information about their favorite places, such as "what is new since the last time

I was there," but more general information about new places. In the wayfinding sections of the system we found that the dynamic nature of urban spaces presented a problem when using detailed photographs for matching between virtual and real world. The presence of new or temporary structures changed the look of the physical environment (and the social interactions that occurred there) to such an extent that people found it difficult to make the match. Perhaps the more abstract line-drawing-type representation, that users suggested would be acceptable, could help alleviate this problem.

7. DISCUSSION: THE VALUE OF A MULTIDISCIPLINARY APPROACH

7.1 Understanding the Socio-Physical Context of Urban Environments

One of the guiding questions of the study presented in this article was how we could understand and represent the socio-physical context of urban environments. In response to this question, we have proposed a multidisciplinary approach combining empirical and analytical methods and techniques from the fields of human-computer interaction, sociology, and architecture. The result is a rich understanding of the social and physical properties of an inhabited urban environment, and the interplay between the two.

It is extremely difficult to separate the physical context of a space from the people inhabiting that environment. Physical context is more complex than a mere catalogue of physical elements in a specific environment, and in analyzing a built environment it is important to regard responses of the inhabitants of that space to the physical elements around them. Likewise, social context in urban spaces is more than just the existence of people and their immediate interactions with each other. Interactions occur in place and are influenced by the configuration of physical spaces. The situation of these interactions, the history of interactions in that place and experience of similar situations all influence people's understanding of social as well as physical affordances of a space. The dynamics of an interaction are very much influenced by the configuration and population of the urban environment in which they are taking place. This interrelationship between physical and social aspects of an environment is an important part of the understanding of socio-physical context of urban environments we have presented in this article.

In informing our understanding of the socio-physical context of Federation Square, the investigation of both physical and social context produced holistic representations of the interrelationship between physical and social aspects of an urban environment. By making one part of the investigation focus primarily on the physical context of socializing in an urban environment, represented as a map, and the other part primarily on the social context of being physical situated there, represented as a table of activities, the overall investigation of the urban environment of Federation Square captures not only the unique properties of physical and social context but also the interplay between the two. The PIA layered map and hierarchy of architectural features provides an understanding of the physical context of an inhabited urban environment in the

form of a graphical, people centered, representation. It highlights key properties of a particular space in an understandable and easily extractable way. The SOPHIA conceptual framework provides an understanding of the social context of a built urban environment in the form of a hierarchy of themes. It describes key properties of situated social interactions and through a qualitative, but structured, story about how people experience physical space and how they interact with each other while socializing in these spaces. Combined, PIA and SOPHIA provides a method for understanding of the socio-physical context of an urban environment.

7.2 Informing Interaction Design for a Socio-Physical Context

The second guiding question for the research presented in this article was how understanding the user's socio-physical context could inform design of a digital layer of pervasive computing for urban environments. In response to this question we have proposed an iterative, creative process as a way for interaction designers to incorporate this knowledge into their design. This process is based on design sketching in combination with systematic development of design ideas from PIA- and SOPHIA-type representations of socio-physical context. Through the development and evaluation of our prototype application, Just-for-Us, we have reflected on the value of this approach.

The design of the Just-for-Us prototype is very tightly coupled the understanding of the socio-physical context of the urban environment it was intended for. As illustrated in Tables I and II, each of the seven design ideas making up the basics of the Just-for-Us system can be traced back to specific elements of the understanding generated through PIA and SOPHIA. Five of the seven design ideas were developed on the basis of the combined architecturally and sociologically derived understanding of the socio-physical context of the urban environment of Federation Square. Location by district (1) and the use of augmented photorealistic depictions (2) both respond to the combined socio-physical understanding of the space. They do so by utilizing, for example, the presence of distinctive and focal structures, districts, obscured places and entrances, open spaces with visible surroundings and activities around the edges *as well as* the way people use physical affordances, past experiences with a space. They index to visible elements and objects to collectively deal with uncertainty and gather information about the environment around them. Without the combined understanding represented in the outcomes from PIA and SOPHIA, these two design ideas, and their specific implementation in the Just-for-Us prototype system, would not have had the same depth and richness. Only from the combined qualitative understanding of people's use of the physical space, and the quantitative understanding of the actual properties of that physical space was it possible to develop these ideas.

The value of the combined socio-physical understanding of the context of Federation Square also comes to show in relation to the development of the idea of using rich descriptions for navigation (3). This idea can be quantitatively strongly traced back to understandings about nodes, edges and

paths originating from the architectural part of the investigation as generated through the PIA method (see Tables I and II). The understanding of people's use of familiar paths, as a part of their physical familiarity with a place, was derived from the sociological part of the investigation. Both played equally important roles in the development of a design that takes into consideration people's actual use of a space over time. Not only could our rich descriptions for navigation refer to the prominent physical properties of a space, they could also refer to well-known interactions there in terms of places and paths that people are familiar with. Similarly, the idea of representation of people and activities (6) can be traced back most strongly to understandings originating from the sociological part of the investigation generated through the SOPHIA method. However, the development of this design idea was as strongly influenced by one of the observations captured by PIA highlighting a major presence of "activity places" at Federation Square. Again, in informing the design of a pervasive computing system, the strength of the proposed approach lies in the richness of the combined, socio-physical understanding of the urban environment context being designed for.

Only two of the seven design ideas, use of history (4) and meeting and waiting (7), were not derived from a combination of outcomes from PIA and SOPHIA. These two ideas respond to understanding captured in the SOPHIA framework dealing largely with experience *over time* and of *other people* in an urban environment rather than with the physical space itself. Naturally, these highly human-centered factors are hard to capture with pure architectural methods and techniques. This emphasizes the importance of a combined socio-physical approach sensitive to both aspects of context when designing pervasive computer systems for urban environments.

Based on the findings from our user-based evaluation of the Just-for-Us prototype system, we found that the design ideas developed on the basis of our socio-physical understanding of context at Federation Square were, indeed, successful at delivering the user experiences aimed for. The implemented design successfully created a pervasive digital layer of information for an urban environment that tied directly into the existing physical and social layers of that space, acknowledging and reinforcing the interrelationship between the three. Positive user experiences of the prototype system could be traced back to elements in the interaction design of Just-for-Us that were informed directly by our understanding of both physical and social context as represented in the outcomes from PIA and SOPHIA. When given access to the described digital layer of pervasive computing at Federation Square, people were able to overcome some of the limitations of the physical layer of the environment. At the same time they used elements of this layer as anchor points for the social and digital layers. They were able to access otherwise invisible information about places and people around them and obtain an overview of what was happening and where people were gathering. They were also able to string together their situated interactions at Federation Square over time, and share this with their friends. The socio-physical understanding of urban environment context provided by the PIA and SOPHIA methods was necessary for creating these user experiences.

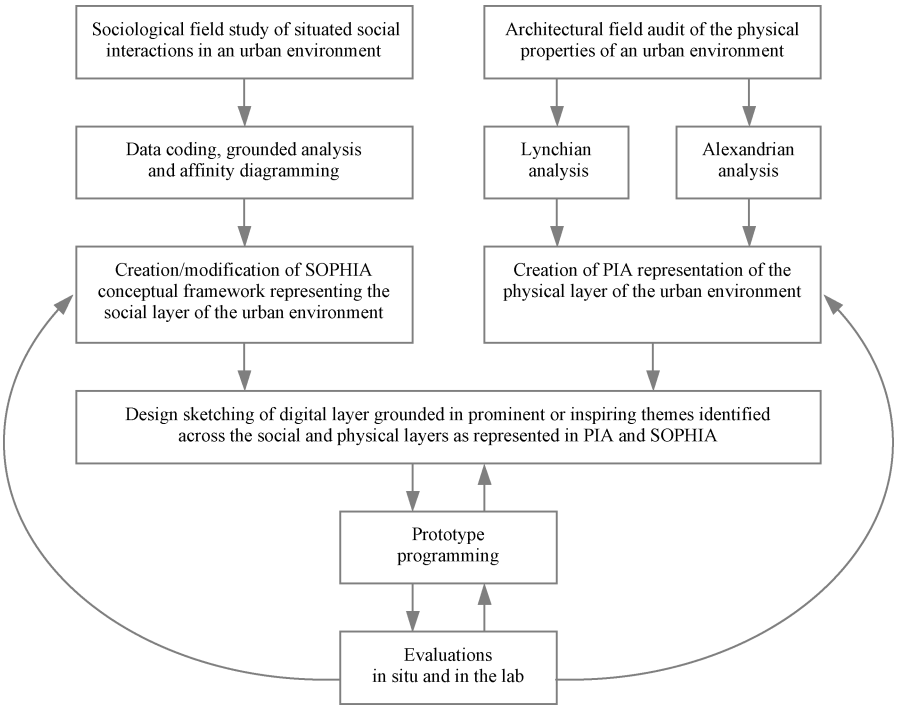


Fig. 6. Socio-physical development process for pervasive computing in urban environments.

7.3 A Socio-Physically Informed Development Process

Based on our experiences, we propose a socio-physically informed approach to pervasive computing interaction design for urban environments (Figure 6).

The process depicted in Figure 6 combines architectural and sociological streams of field studies and analysis towards the creation of PIA- and SOPHIA-type representations of the socio-physical context of an urban environment. The architectural stream involves field audits and analysis guided by the techniques of Lynch and Alexander. The sociological stream involves field observations and contextual interviews. This activity could be guided by, for example, the SOPHIA conceptual framework presented in this article, McCullough's [2001] typology of "on the town," or it could be open-ended in its focus. The data collection activity leads to an activity of grounded data analysis and affinity diagramming. The two streams of research then feed understanding of the socio-physical context of the urban environment into a creative process of grounded design sketching of a digital layer of pervasive computing. Following on from this activity, the process takes the shape of a traditional prototyping process through which design ideas are iteratively implemented, evaluated, and refined until a satisfactory product outcome has been reached. However, as illustrated in Figure 3, and described in the findings section above, studying the user experience of a pervasive computing prototype system in situ often leads to more knowledge about the socio-physical context for which it was designed. This means that additional understanding may have to be fed back into the PIA and

SOPHIA conceptual frameworks, which again may lead to the emergence of new design ideas or refinement of existing ones.

7.4 The Open-Endedness of PIA, SOPHIA, and the Seven Design Ideas

It is important to notice that PIA and SOPHIA are not complete methods and have not generated complete frameworks and representations. Neither is the list of design ideas, which emerged from these frameworks, a complete collection of design outcomes possible to derive from the understanding encapsulated herein.

PIA and SOPHIA have both generated specific summaries of the context of Federation Square, and we do not claim that their outcomes are generally valid for all urban environments. The level of generalizability of the PIA and SOPHIA methods and their outcomes can only be determined through repeated studies in similar as well as different types of urban environments. In terms of the outcome, repeating the described socio-physical investigation in other urban environments would possibly confirm aspects of the presented conceptual frameworks, but would most likely also extend them with further concepts and categories. In terms of the methods, it is our belief that the two approaches would be able to capture the essence of the socio-physical context of sites other than Federation Square.

In terms of generalizability, however, it is also important to notice that PIA and SOPHIA differ fundamentally in what they are capturing. PIA provides understanding that is very specific to a certain physical environment being designed for. The combination of Lynch's and Alexander's approaches to architectural analysis supports this by providing a set of physical features to look for and PIA provides a combined way to represent the outcome of such analysis. In contrast, SOPHIA provides understanding that is potentially more generally applicable to situated interactions in urban environments. This is the case because the SOPHIA empirical study is based on a broader empirical foundation, and because the data analysis process was grounded towards the creation of general concepts rather than top-down from a set of predetermined ones. The value of combining this top-down architectural and bottom-up sociological approach lies in the potential to provide focus as well as scope. The architectural part of the investigation adds focus on the physicality of situated interactions to the sociological analysis. In return, the sociological part of the investigation broadens the scope of the architectural analysis by highlighting the role of sociality.

The seven design ideas presented are, in a similar way, specific to the particular team of designers working on the Just-for-Us prototype and their creativity at the time. Other designers, or even repeated design sessions with the same designers, would most likely generate more ideas. Hence, the design-idea dimensions of Tables I and II are not complete, and can never be. Adding to this open-endedness, extending the outcomes provided from PIA and SOPHIA with additional understanding through further investigations of socio-physical context of urban environments would undoubtedly expand the design-space with more ideas.

8. CONCLUSIONS

Hybridized spaces, in that they blend the physical digital and social, challenge our current conceptions of technology, and our approaches to understanding and designing. As we learn from our reference disciplines, sociology and architecture for example, we can return the favor with our own insights and collectively strengthen our response to a significant digital challenge; the "turn to the social" and indeed physical that is implicit in the pervasive agenda. Later work should examine the value of our approach more generally, and contribute to our collective ability to compellingly situate interaction in the built, the social, and the increasingly occupied digital space.

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