Ubiquitous Computing: By the People, For the People

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Abstract

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Computing is moving away from the desktop, permeating into many everyday objects and the environments in which we live. Many researchers in ubiquitous computing are excited about the potential to profoundly change the way we live by revolutionizing how we interact with information. Despite the excitement, few successful applications are making the transition from the laboratories to the mass market. While this could easily be attributed to the immaturity of the research area, it is also a manifestation of a larger problem—the lack of coherent methods, processes or tools that assist designers in thinking about issues pertinent to ubiquitous computing, as they explore potential ideas and develop some of these into working prototypes. To this end, this research presents an overview of the important characteristics of ubiquitous computing systems identified by many of the leading researchers in the field. Contrasting with conventional systems, we discuss the resulting issues and challenges, and their implications on the future directions of this emerging research area. In a case study, we use scenario-based design to walkthrough the design of a community computing application. At various stages of the design process, the need to focus on more issues relevant to ubiquitous computing design became apparent, resulting in the augmentation of scenario-based design.

The augmented scenario-based design process is proposed as a tool for helping designers conceptualize user activities within given usage circumstances and at various stages of the design process. New questions help to identify the most common pitfalls, enabling designers to produce systems that are more socially acceptable and provide a higher likelihood for adoption by everyday users beyond the laboratory. In initial testing, the augmented process was shown to produce better designs.

The ultimate ambition of ubiquitous computing technology is to be able to serve users anywhere, at anytime. However, taking into account the dynamic nature of user needs and usage situations, is a novel and non trivial undertaking. In essence, it is a fundamental change that requires designers to rethink many of the conventional answers and processes that help guide the creation of interactive systems—We provide a promising approach.

Dedication

To my parents,
For teaching me what is important in life.

To my family,
For providing more meaning to my life.

To my lab-mates,
For inspiring me to want more out of life.

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Chapter 1

Introduction

1.1 The Problem

Given the proliferation of smaller and low bandwidth computing devices, advances in wireless communications, and the increasing commercial interest as industry explores better ways to turn their investments in telecommunication infrastructure into profit, Weiser's vision (Weiser, 1991; Weiser, 1993) of calm and ubiquitous computing seems attainable. When it comes to pass, computing will move beyond the confines of tool usage, leaving the largely sedentary and solitary desktop platform towards a pervasive penetration of the environment around us. Emphasis will shift from interaction between the individual and a single device to a profusion of networked mobile and embedded computing devices that individuals and groups employ across a variety of settings—creating new forms of interaction, as well as social norms.

Researchers are pushing the technology envelope to create novel systems, sometimes that address no specific human needs, although they are touted for providing more ephemeral benefits such as peripheral awareness (Ishii and Ullmer, 1997). We do not have a good understanding of why and how users would interact with ubiquitous computing technology, making it difficult to understand the motivations behind their use (Abowd and Mynatt, 2000) as well as presence in people's lives (Hallnäs and Redström, 2002).

Although social implications of these technologies are generally acknowledged, they are rarely given full consideration. Partly, this might be due to the lack significant deployments of the technology that work long enough to enable us to study some of the social, cultural and organizational changes that may arise (Norman, 1999). It could also be that the methods that we use to create these new systems are not user-centered enough to allow us to adequately engage potential end-users, enabling us to better observe and appreciate their needs.

A good perception of all the issues at play is important for two main reasons:

- Successfully deployed, ubiquitous computing technology might not only enable new ways of acting and interacting, but could also have unexpected side-effects with serious implications for the way we live in future.[1]
- Successfully deployed, ubiquitous computing technology will require such a huge infrastructural base, which will be difficult to change later, even if it becomes apparent that we made some mistakes and need to do things differently (Norman, 1999).

All these issues compound the challenge of evaluating ubiquitous computing technology in their proper context and understanding their impact—a prerequisite for progress in any research area.

1.2 A Case Study for Ubiquitous Computing

Community networks are an ideal domain area for the application of ubiquitous computing research. While on the one hand they endeavor to reach and connect as many members of the community as possible within various settings, they also provide an environment that exemplifies some of the toughest challenges, which when overcome could result in ubiquitous computing being declared a success. How do you support a varying number of users with dynamic goals, who employ an extensive range of networked fixed, mobile or embedded devices that are used in multiple ways across a variety of settings, while still taking into account the social norms[2] that they have built up over a long period of time? That is the hurdle that ubiquitous computing must overcome in order to be able to successfully support community networks.

There is a growing interest in what technology can do to help sustain communities. Whereas some of the work has focused on virtual communities and the technologies to support them (Curtis, 1996; Churchill and Snowdon, 1998; Bowman et al., 1999), more emphasis is shifting to communities situated in specific physical locations such as cities and towns. While in the former case, the community relies on the technology for its existence, in the latter case, the technology is not meant to support the existence of the community itself. Instead, research and development focuses on providing tools which can augment the existing communication channels within the community, awareness of current community activities, and supporting a collective memory (Casapulla et al., 1995; Carroll and Rosson, 1996; Agostini et al., 1998; Grasso et al., 1999;

Stathis et al., 2002), since the community already exists. It is on the latter type of communities that we place emphasis.

Some of the researchers in this area assert that the quality of community life is on the decline, pointing to the corresponding decline in social capital as evidence (Putnam, 1996; Schuler, 1996). It is hoped that in concert with other efforts, the use of community networks could help curtail this trend by improving communication, providing better economic opportunity, and encouraging more civic participation and education—all of which have the potential for increasing participation within the community.

It is believed that increasing access to local communal content can contribute to enhancement of social cohesion that may have been fragmented by the recent pace of social and technological changes (Schuler, 1994). Consequently, community networks put a high priority on having a system that is widely accessible and easy to use. Wide accessibility is meant to encourage as many people as possible to join by providing some form of free access and/or terminals in public spaces. Ease of use, on the other hand, helps lower the barrier for people to be able to participate and create more content. This results in an increased sense of belonging for the members, richer interactions, and usually a more sustainable community network (Schuler, 1994).

There is a growing realization about the current limitations (Grasso et al., 2000; Agostini et al., 2002; Stathis et al., 2002) of using desktop based computers as the primary method, and in some cases the only method, of accessing community networks. This reliance on the desktop computers creates two main problems:

- **Limited access**. The community network cannot be accessed by all the members of the community. The majority of the community members cannot afford a desktop computer, and neither can the community afford to provide a computer to every member who does not own one. The ratio of computers made available in public spaces to the number of members who do not have access is usually very low.
- **Access in isolation**. Desktop computers are inherently meant for single person use in particular locations, encouraging access of the community network in isolation. On the other hand, people tend to interact within groups in a variety of community settings.

> Therefore, relying on desktop access does not successfully support group-use in the various social interactions and settings that occur each day within the community.

Approaches are being explored to more fully integrate the community network within the community by making it more accessible within the various community spaces and settings, where most of the community interaction occurs. It is our belief that ubiquitous computing technologies hold tremendous potential in addressing some of these challenges.

Although in this study, we do analyze ubiquitous computing from the perspective of community networks or community computing in general, we believe that the challenges that we highlight in this area are representative of those that will likely appear in other domains or emerging new applications areas.

1.3 Investigating Ubiquitous Computing Design

In the context of community networks, some of the challenges of dealing with ubiquitous computing technology highlighted in section 1.1 above will be further exacerbated by social implications and group dynamics resulting from the interaction with members of the community.

For ubiquitous computing technology to succeed in the context of community networks, it will not only have to respond to our innate human capabilities and limitations, but also respect the norms that we have built up over time that successfully facilitate face-to-face interaction. This work explores how ubiquitous computing technology can be leveraged to address some of the challenges of community networks by adopting a scenario-based, user-centered design approach.

We hypothesize that scenario-based design can be successfully used to design ubiquitous computing technologies that respond to needs that users find relevant. Its power lies in the fact that *scenarios* or "descriptions of people using technology" enable the discussion and analysis of how technology could reshape people's lives (Carroll, 2000; Carroll and Rosson, 2002). Since scenarios are simple narrative descriptions of activities in their context, this design approach allows ordinary people to easily understand and participate in the design, allowing researchers to more usefully engage them about the potential technologies. Scenarios can also be created before an actual system is built, deployed and its impact felt, allowing developers to easily capture potential problems much earlier in the process.

As an interface development methodology, Scenario-Based Design holds tremendous potential for considering the key issues related to ubiquitous computing usage

In the next section, we describe the process to investigate the hypothesis stated above.

1.4 Research Approach

We carry out a thorough review of literature relating to the design community networks on the one hand, as well as ubiquitous computing systems on the other. We highlight some of the main challenges that have already been identified in both of these areas, postulating on how their interaction might influence the outcome of bringing the two domains together to create community networks that benefit from ubiquitous computing technology.

Using a walkthrough method, we utilize the scenario-based design process to come up with a simple mockup of a community network application that employs ubiquitous computing. Using this as a design problem, we draw on our earlier analysis of existing literature in combination with some studies and re-examine the utility of scenario-based design as a method for designing ubiquitous computing technologies. Although in this study, our design problem has a particular emphasis on community networks, we believe that the challenges in this problem domain are representative of many new applications areas for computer-mediated solutions that support groups.

Some of the issues addressed by this research include:

- As we transcend from the desktop-based to the ubiquitous computing paradigm, how appropriate is the Scenario-Based Design process in helping us to design "better" systems?
- As computing artifacts get embedded into everyday objects creating a new breed of interfaces, will people be able to understand the information that they convey? What are some of the factors likely to influence their adoption and use? Scenario-based design suggests a number of factors to take into consideration while designing conventional system interfaces and we are interested to see if these will still apply to this new breed of interfaces.

- Building on previous work on social interfaces, computer-supported collaborative work (CSCW) systems, community computing research as well as interpersonal psychology, we discuss some of the ideas that could potentially be used to augment scenario-based design to help us create better ubiquitous computing systems that successfully support social interaction.

1.5 Thesis Overview

This thesis is divided into seven chapters. Chapter 1 provides an overview of the whole thesis in a concise manner, stating the problem. Using community computing as a case study, we highlight the approach that we use to investigate the problem. Chapter 2 provides background information on community networks as an instance of community computing. We discuss their social foundation, introducing common terms and definitions and providing a motivation for how ubiquitous computing could be leveraged to address their limitations. Chapter 3 deals with the technology-related issues and challenges that we need to keep in mind in order to successfully use ubiquitous computing. It also covers most of the related work. Chapter 4 reports a user study that investigates the use of everyday objects as system interfaces that convey various types of information, one of the many aspects that become apparent in the previous chapter. In Chapter 5, we walk-through the design of a community computing application that utilizes ubiquitous computing technology with the help of scenario-based design. This highlights the need to better address ubiquitous computing related issues along the way, resulting in our augmenting the process. Chapter 6 reports a user study that we use to test our main hypothesis. By focusing on the information and interaction design phases, we compare an augmented version of scenario-based design to an adhoc process in helping designers to come up with conceptual designs addressing a particular problem. Finally, in chapter 7 we make concluding remarks about our findings and outline some future work.

Notes

[1] Langheinrich, M., Coroama, V., Bohn, J., and Rohs M. "As we may live – Real-world implications of ubiquitous computing. This is a good presentation meant to stimulate interdisciplinary discussion about ubiquitous computing and how it could be positively influenced by other disciplines. I have not been able to find it published anywhere, but a copy is available online at http://www.inf.ethz.ch/vs/publ/papers/implications-uc2002.pdf.
[2] Social norms are the perceived standards of acceptable attitudes and behaviors prevalent among the members of a community. This definition is from the National Social Norms Resource Center, which can be found online at http://www.socialnorm.org/.

Chapter 2

Designing Community Networks

This chapter provides the foundation for a case study that we shall use to explore the problems inherent in ubiquitous computing design that we briefly introduce in Chapter 1, but discuss in more detail in Chapter 3. We shall use it as a reference point for the rest of this discussion. Aside from general interest in community-related technologies, the community domain was selected as a case study because of the intrinsic dichotomy that arises between the typical implementation form of community networks (web-based desktop interfaces) and the user goals they support (bringing a community closer together). As we noted in the previous chapter, the desktop interface—used in a solitary setting by those that have the means—tends to impede the general effort of community-building.

In addition, the community provides us with a setting that allows us to explore the opportunities afforded by the advancements in ubiquitous computing technology. We will examine this within the constraints of the social implications as well as the group dynamics that arise from the interaction of the members within the community. Designing interfaces with these user requirements in mind is likely to result in more relevant applications with higher chances for success. The knowledge that we glean from this domain should also be relevant to many new application areas for computer-mediated solutions, especially those meant for group use.

In the rest of this chapter, we will introduce some of the common terms used in this domain. We then discuss community networks, briefly reviewing their history to show their evolution from the initial concepts to where they are today. Some of the limitations in the current implementations are highlighted, along with some possible areas for improvement, motivating our interest in ubiquitous computing technology as an optimal solution to some of these deficiencies.

2.1 What is a Community?

Many people would say that their community is the place where they reside—their neighborhood, village, town, city, or suburb. This place would usually provide most of the institutions they consider important to their daily life such as stores, schools, hospitals, churches, places of work and entertainment, among others.

The term "*community*" is defined in many ways, in general there are two main approaches: one approach associates community with the social bond (MacIver, 1970), while the other associates it to territory. In the social approach, community refers to a set of interactions and human behaviors that have meaning, and expectations between its members. It is not just about action, but actions based on shared expectations, values, beliefs and meanings between individuals, ignoring territorial connotations. Thus a community in this sense may not even have a physical location, but be demarcated by being a group of people with a common interest (MacIver, 1970).

In the territorial approach, community refers to people in a particular locale and the form of natural social bond that relates these people to the territory as well as each another.

In this study, we use *community* to refer to a community that has a number of characteristics:

- **Territorial**: the community is a place, a physical geographic location with some people living together proximately as local residents. An example is the town of Blacksburg.
- **Social**: the community is a bond of local solidarity, as residents interact and engage each other on issues of mutual concern that reflect their needs and interests.
- **Sense of community**: members in the community have a "a feeling that members have of belonging, a feeling that members matter to one another and to the group, and a shared faith the members' needs will be met through their commitment to be together (McMillian and Chavis, 1986)." This leads to satisfaction and commitment and is associated with involvement in community activities (Blanchard and Markus, 2002)[1].

While a community in this context necessarily has boundaries, those boundaries are fuzzy in many ways (Schuler, 1996). Blacksburg, for example, may be thought of as a single community, but at a smaller scale, it is composed of many neighborhoods each of which could be considered an individual community. In turn, these can be further broken down into smaller units. Virginia Tech is an excellent example—the *campus* (which defines a territory) is a community in its own right. It can be decomposed into communities on the basis of the *faculties, departments, residence halls, sororities, religion, ethnicity*, etc. with which an individual may associate. This highlights that different overlapping communities can co-exist within any geographical community, each with their own special interests. Moving upwards in scale, people can be members of “regional,” “national,” or even “global” communities (MacIver, 1970).

2.2 Social Capital on the Decline

Within a community, aspects of the social structure such as trust, values and conventions that encourage collaboration within the community determine its ability to achieve common goals. These beneficial relations among individuals within a community can be used to determine the quality of life in that community, and are generally referred to as *social capital* (Coleman, 1990; Putnam, 2000).

There is a growing view that the quality of life within communities is on the decline, as evidenced by the decline in social capital. The proponents of this view argue that it is reflected in the rampant social and civic disengagement (Putnam, 2000) and the plethora of problems besieging ever more communities—increasing poverty, violence, alcohol and drug abuse, crime, unemployment, and many other social anomalies (Schuler, 1994).

Our interest in community networks is in part fueled by the need to address many of these challenging problems. It is anticipated that since they normally start at the level of the community, they could best be addressed at this level.

Many researchers have suggested many possible causes for this decline in community life; some of these include:

- Generational changes and more time spent at home watching television (Putnam, 2000)
- Growing income, racial, and ethnic heterogeneity within communities (Dora and Matthew, 2001)
- Role of rising work hours among women and among the college-educated (Freeman, 1997)
- Disempowerment of civil and social institutions, as their burden keeps on growing while their resources keep on declining (Schuler, 1996),
- High-speed, individualized transportation that enables swift movement from one place to another (Sudia, 1976)

- Temporary or transitory residence, as people move from one place to another without settling in one place for a reasonable time, creating rapid changes in residential patterns and policies.
- Obsessive consumerism and the growth of multinational corporations (Schuler, 1996).

Computers and communication technology are touted as some of the tools that could help ameliorate this problem. The proponents of computing technology claim that it could improve community life through improved communication, providing better economic opportunity, more civic participation, as well as education (Calabrese and Borchert, 1996). Their premise is that the spread of technology creates networking infrastructure, which encourages the formation of social capital.

On the other hand, opponents point out that in accessing online services, playing computer simulation games, and exploring virtual realities, abstract communication replaces firsthand experience, devaluing ordinary human contact. For example, Slouka (1995) maintains that interaction in the physical world helps to develop judgment and teaches us to relate to one another, while in the electronic world, everything happens online, making it impossible to develop such skills that we need in real life. The argument is that the technology can also have an anonymizing, deindividuating effect which relaxes social norms and erodes social capital (Kiesler et al., 1991; Loch and Conger, 1996). Their concerns seem contingent to the current inability of the technology to match neither the information richness nor the social constraints provided by human face-to-face communications, nor substitute for the benefits that accrue from interacting with others.

One issue they might all agree on is the fact that these technologies can provide a huge potential for more participation by improving and providing alternate avenues for communication within the community. This might be especially possible if we can reinforce the positive aspects put forth by the proponents, while mitigating the negative ones highlighted by the opponents. In the next section, we will introduce the notion of community networks—systems that some expect will play a potential role in the broad effort to improve the quality of life in our communities.

2.3 Community Networks

2.3.1 What is a community network?

The Association for Community Networking[2], in its inaugural organizational publication, defined *community networking* as occurring “when people and organizations collaborate locally to solve problems and create opportunities, supported by appropriate information and communication systems. A *community network* is a locally-based, locally-driven communication and information system. ” Marc Miller[3] synthesizes the two to come up a good working definition of community networks that we will use for the purposes of our discussion, defining a *community network* as “a locally-based, locally-driven communication and information system designed to enhance community and enrich lives.”

The term “Community Networking” was initially used to refer to the various modes of interaction and communication within members of a community (Schuler, 1996). This underlies the existence of a sophisticated community information network that relies on various technologies to transfer information within a given community. Such technologies utilize various forms of communication ranging from the universal human face-to-face contact or the sounding of drums, to the written word. Today’s technologies such as telephone, television, radio, and other familiar communications tools are used to enhance this interaction and communication.

The term community network is used in different ways; some use it in the interpersonal sense referred to above, while others use it in the computer-related sense. This is probably an indication of our inability to come to a consensus on what a community really is. In the computer-related sense, it is also used to refer to different systems with regard to their organization, technology, applications and usage (Maciuszko, 1990; Cisler, 1993; Schuler, 1996; Cowan et al., 1998). Community networks are as diverse as the communities they serve, although until now, their focus has been mainly on the information and communication functions.

Based on analysis and review of a number of systems, which in some cases is supported by literature, some of the usual characteristics that may differentiate community networks from other types of networks include:

- Created by the people in a particular community to serve a clearly defined geographic region. The aim is mainly to strengthen the cohesion and vitalize the local community (Morino, 1994),
- Contain information relevant to people within the community, although they may also have links to other networks or the Internet,
- Try to improve the flow of information within the community, attempting to facilitate more engagement and discussion on local issues. Information that addresses other day-to-day needs of members is also provided,
- Tend to use information provided by the members of the community, and as such usually represent local news, culture, etc. (Agostini et al., 2002)
- Try to provide free access or access at minimal costs (Morino, 1994).

Irrespective of how we define community networks, a paramount recognition is that they consist of two fundamental parts: the physical infrastructure and the social info-structure. The physical infrastructure might be the drums, the wires, the computers and other technologies that allow us to communicate to one another, while the social info-structure refers to the ongoing processes and activities through which people put the physical infrastructure to use in order to achieve their common goals. [4]

2.3.2 Brief history of community networks

Community networks have been around for awhile, predating the Internet as we know it today. They can be traced back to the first experimental "Community Memory" project in the mid-1970s created by the University of Berkeley, California (Farrington and Pine, 1996; Levy, 2001) to help strengthen the local community. The network's strong commitment to serving those with limited skills or without access to the computing technology was demonstrated by the numerous training programs and insistence that the network be accessible only from terminals in public places (i.e. , libraries and laundromats, but not via modem or from the Internet) (Schuler, 1996).

The developers of Community Memory pioneered a lot of ideas that later influenced many of the community networks that followed (Farrington and Pine, 1996); these ideas include:

- The conscious decision to limit access to outside newsgroups or email certainly ensured that information on the community network was local, but could have resulted in less interest.
- Insistence on only public access certainly set a good precedent for overcoming economic digital divide, but the limited number of public terminals, which are said to have been less than ten, must have certainly affected the number of community members who could get involved. The terminals were coin-operated, offering free read access for the various forums, but to post an opinion required 25 cents and starting a new forum required a dollar.
- It was possible to use the system anonymously, allowing users to the freedom to contribute whatever they wanted. In addition, there was no central authority to determine the identity of the information providers.

Later, in 1984, Case Western University in Cleveland, Ohio, initiated the Cleveland Free-Net to test the effectiveness of online access to deliver health information to the general public (Beamish, 1995). Free-Nets began with the mission of providing free local dialup Internet access, and creating public forums for online discussions for those without available access. As the Internet became more accessible and more widespread, the administrators were forced to refocus their mission from merely providing Internet access, to providing more enhanced community services. It was a successful endeavor that later attracted funding, adding extra new channels of information for their community.

The Big Sky Telegraph by Frank Odasz and Western Montana University later followed in 1988, as an interest in exploring how to leverage community networks to overcome the large distances between small schools in rural Montana and providing better education by using appropriate low cost technology (Uncapher, 1997). It supported teachers by linking 1 and 2-room schools with regional libraries and providing computer support for the literary and artistic projects of Native Americans. The project was implemented on obsolete computer equipment refurbished by a local women's resource center. It connected a remote and quite dispersed community to the world; for example, students now had access via electronic bulletin boards to professors at the Massachusetts Institute of Technology (MIT). Ironically, one of its most visible impacts was to contribute to the regional outflow of talented young people (Rheingold, 1993).

Figure 2.1: The Homepage of the Blacksburg Electronic Village (BEV) online. It can be found at http://www.bev.net/ .

The Public Electronic Network (PEN), created in 1989 in Santa Monica, California, was the first government sponsored system of its kind in America. Access was free and was meant to promote community oriented participation in democracy by providing more avenues for members to engage in civic activities. It served as an early test bed, highlighting many of the issues related to "electronic democracy" (Varley, 1992; Rogers et al., 1994). Unlike most other community networks, the PEN system is not linked to the Internet and is only open to those who live and work in Santa Monica. Residents can access the system through read-only discussion boards with information provided by the city government, private e-mail between residents or between city hall and residents, or public postings in conferences on a wide range of topics. It is maintained by Santa Monica residents, rather than depending on outside Usenet newsgroups (Beamish, 1995).

The Blacksburg Electronic Village (BEV), whose Internet homepage is shown in Figure 2.1 above, represents the newer breed of community networks (Carroll and Rosson, 1996; Cohill and Kavanaugh, 2000) that have had to reinvent themselves in relation to the Internet. Based out of southwest Virginia, it is unique in that it is one of the first community networks that approached the issue of access by aiming to provide a network connection in every home, business and classroom. Although some of the partners have since dropped, the project was initiated as a public/private partnership between the Town of Blacksburg[5], Virginia Tech[6], and Bell Atlantic Southwest (a subsidiary of Bell Atlantic[7]). Its main purpose was to increase access to the Internet in a digital-divide-spanning effort. Started in 1993, by 2000, it had managed to connect 80% of the community residents to gain access to the Internet. Over time, as access to the Internet became universal among the residents of Blacksburg, the emphasis shifted from supporting access to enhancing use. Administrators are currently exploring new community applications like Blacksburg Nostalgia[8] for collecting local history (Carroll et al., 1999) and Moosburg,[9] which is meant to provide real-time, situated interaction, and a place-based model for accessing community information (Carroll et al., 2001).

2.3.3 Limitations of community networks

In general, community networks put a high priority on having a system that is widely accessible and easy to use. Wide accessibility is meant to encourage as many people to join by providing some form of free access and/or terminals in public spaces, while ease of use helps lower the barrier for people to be able to participate and create more content. This results in an increased "sense of community" for the members, richer interactions, and usually a sustainable community network.

Most of the community networks currently deployed revolve around the desktop platform as the main point of access. These computers are either in the users' homes or deployed in some public places for those who might not have home or workplace access. This reliance on the desktop platform creates two main limitations:

- ***Limited access*** since the community network can not reach all the members of the community. The majority of the community members can not afford a desktop computer and neither can the community afford to provide every member who does not own one with a computer. The ratio of computers made available in public spaces to the number of members who do not have access is usually very low.

- ***Access in isolation*** since desktop computers are inherently meant for single person use in particular locations; they encourage access of the community network in isolation. In reality, the bulk of community interaction occurs within various groupings of members in varied community spaces.

These are the two main limitations at the core of the case for the opponents of community networks technology. These analysts are afraid that the limited access to community networks will create a division between those who can participate in the discussion of community and governance and those who have no access to the system, further disenfranchising the "have-nots" (traditional computer users are usually more educated and have higher incomes). As they point out, access in isolation might further diminish the little face-to-face contact there now is, creating more distance between community members and encouraging more individualism. Contributors might use fake identities, with the resulting anonymity relaxing social norms and eroding social capital (Kiesler et al., 1991; Loch and Conger, 1996).

The advent of the Internet has improved the presentation and accessibility of the community network, but this has created more challenges. By making it easier for members to explore further a field, this link with the Internet has blurred the boundary between the community network and the Internet. Given that Americans already spend an average of 3-4 hours a day watching television, as the recreational and entertainment applications increase online, critics worry that there will be even greater isolation as members chose to stay indoors rather than venture out of the home (Paul and Gochenouer, 1994).

In addition, more commercial entities like on-line services such as AOL's digital cities[10] or Microsoft Network[11] have discovered the local community as a lucrative market, providing information and communications services that make it even harder to differentiate between the traditional community networks and their commercial counterparts (Carroll and Rosson, 2002). This perhaps makes it imperative for the community networks to provide easy access to and means to create local content if they are to remain relevant.

Although there are a variety of funding options, this is still another constant challenge faced by virtually every community network. Funding may come from direct users or from indirect users in almost any combination. There are as many funding approaches as there are community networks; the only common aspect seems to be the fact that there is not enough money, creating an uncertain future (Schuler, 1994). Interestingly, in the past there have been criticisms from commercial internet service providers who objected to the free or low-cost Internet access provided by the community networks and argued they were encroaching on their turf. These have lessened as providers collaborate more with the community networks and move to higher speed services.

Most architects of community networks are very much aware of these limitations and are actively trying to create or improve their systems so that they will not isolate members or inadvertently contribute to the deterioration of a community. However, though the intention and potential is positive, it remains to be seen whether community networks will actually succeed in rebuilding community life, including all residents in the system, and reaching their potential (Beamish, 1995).

2.3.4 Areas for potential improvement

There are three main areas that have been identified as being critical to producing more useful and sustainable community networks. Incidentally, these are the same areas that could easily benefit from advances in computing technology in general, they include:

- ***Better information creation***: (Carroll and Rosson, 1996; Schuler, 1996; Agostini et al., 2002) how could we enable members to create content without having to learn a lot of new skills? Can we leverage the multimodal nature in which members normally interact?
- ***Better information access***: (Schuler, 1996; Grasso et al., 2000; Agostini et al., 2002) what if users were provided with access to their community network within the community spaces where social life actually occurs? What if the community network could support a variety of devices, some of which might already be owned by community members or exist within the community?
- ***Better information navigation***: (Schuler, 1996; Grasso et al., 2000; Agostini et al., 2002) As the amounts of information on the community networks grow and it begins to support multiple devices, we will need consistent methods of interaction, as opposed to learning new methods for each device. Can we come up with universal user interfaces that apply

across the board? Will they leverage the multimodal nature in which members normally communicate as well?

One of the important ingredients in building community is a physical design that facilitates social interaction. It is difficult for people to develop the networks that are a crucial part of human social systems unless there are places for encounters to take place. Without casual regular encounters it is very difficult for all the other steps in community building to take place: discussion, organization, action, accomplishment, etc. Sociologist Ray Oldenburg refers to them as "*third places*"[12], the first two being home and the workplace. Third places are the core settings for informal public life, they are places where people can meet old friends, make new acquaintances, discuss the important issues of the day, and temporarily throw off the weight of the world that can drag them down. He claims that involvement in informal public life has important psychological, social, and political implications, and such involvement is made possible by the existence of these third places (Oldenburg, 1989).

It is our contention that ubiquitous computing technologies can be exploited in order to address some of these key limitations of community networks. They have the potential to resolve the problems of limited access by enabling members to access the community network through a diverse range of devices. The advantages of this would include the fact that community members no longer have to be restricted to using the desktop platform for accessing the community network. In addition, this provides an opportunity to use some of the other common devices that people already own and are comfortable using, like cell phones, PDAs, etc. The resulting freedom of access would certainly address some of the concerns raised by opponents of community networking; inspire new and novel community applications, in addition to making it easy to extend the community network to the third places, where the day-to-day life of the community takes place.

In the next chapter, we look at the various characteristics that differentiate the design of systems that employ ubiquitous computing from conventional computing systems. We highlight the challenges created by this difference, expounding on their implications for the design of community networks and the research questions to overcome before we can successfully leverage ubiquitous computing for community networks.

Notes

[1] Blanchard and Markus (2002) provide an extensive discussion about the "Sense of community." They compare place-based communities with those online to investigate the presence of a sense of community. Based on an empirical study, they propose a theory for developing and maintaining sense of community in virtual communities are examined in an intensive study of an established

[2] The Association For Community Networking (http://www.afcn.org/) is an educational nonprofit corporation dedicated to fostering and supporting "Community Networking" – community-based creation and provision of appropriate technology services. The definitions are found online as well as in their inaugural publication, Community Networking, Vol.1. Issue 1. January-February, 1998 p.1.

[3] Mark Miller from The Community Connector (http://www.si.umich.edu/Community/), A Project of the University of Michigan School of Information Community Networking Initiative University of Michigan.

[4] Frank Odasz (2000) The Good Neighbor's Guide to Community Networking (http://lone-eagles.com/cnguide.htm). The readings and URLs in this guide are intended to present a summative guide, and hands-on Web Tour, to the essential lessons and concepts gleaned from the experience of the early community networking pioneers who explored new methods of matching caring and connectivity to create social value for their communities. Chapter 11 is a bibliography of community networking guides, directories, and related resources.

[5] Blacksburg, found in southwest Virginia, has a population of about 39,573 (2000 estimate). It local government can be found online at http://www.blacksburg.gov/

[6] Virginia Tech is Blacksburg's major employer and university. It has a student population of about 25,000 students. It can be found online at www.vt.edu

[7] Bell Atlantic has since merged with GTE to form a new and bigger company called Verizon. You can find them online at www.verizon.com

[8] Parts of the Blacksburg Nostalgia project can be found online at http://research.cs.vt.edu/storybase/nostalgia

[9] The Moosburg project can be found online at http://moosburg.cs.vt.edu. To experience it, you will need to have an account. Make sure you read about the system requirements before to ensure that your computer has all the necessary software.

[10] AOL's Digital cities service is available online at www.digitalcity.com. A division of America Online, it provides local news, classified advertising and community resources for a good

number of the largest cities in the U.S. The company delivers its information and interactive services through its own web site.

[11] Microsoft's MSN network is available online at www.msn.com. It is currently available in 34 markets and 18 languages.

[12] Ray Oldenburg, in his book *The Great Good Place*, contends that the problem with American society and urban life is that it lacks "third places". Third places are neither home nor work, but are places where an informal public life can take place. Third places around the world share common and essential features. They are neutral ground, allowing people to converse but not become entangled in one another's lives. They are levelers in the sense that differences of the participants in class, wealth, etc. are eliminated or greatly reduced. It is inclusive rather than exclusive. Third places expand social possibilities. Conversation is the main activity in a third place. They are accessible at almost any time of the day or evening. Third places are frequented by "regulars". Physically, a third place is typically plain. The mood is playful. A third place is a home away from home. Third places play a vital role in many parts of the world and different types of third places can provide a nation with its own characteristic charm: cafes in France, beer gardens in Germany, piazzas in Italy, pubs in England and Ireland, teahouses in Japan, are some well-known examples.

Chapter 3

Issues & Challenges in Ubiquitous Computing

3.1 Introduction

Weiser articulated the notion of *ubiquitous computing* by envisioning a time in the future when people and environments would be augmented with computational resources providing appropriate information and services when and where desired (Weiser, 1991; Weiser, 1993). He predicted the large increases in the number of personal devices of varying sizes that has come to pass, with the proliferation of smaller and low bandwidth computing devices stimulated in part by advances in wireless communications. He heralded that, in order for these systems to achieve their true potential, they would have to be "*invisible*"—stay out of the way of the user's task and draw no attention to themselves. Applications are emerging that leverage these devices and infrastructure, portentous of new ways of interaction inspired by the widespread access to information and computational capabilities available (Abowd and Mynatt, 2000; Agostini et al., 2002; Stathis et al., 2002).

In this chapter, we review some of the characteristics that differentiate the design of ubiquitous computing systems from some of the conventional computer systems that we are accustomed to today. We then discuss some of the issues and challenges created as a result of these characteristics. Building conventional community networks is already fraught with challenges, some of which are described earlier in Chapter 2; we explore how integrating ubiquitous computing technology amalgamates challenges from either side, perhaps even creating in new ones. Against this milieu, we review two community networks that have attempted to include components of ubiquitous computing technology in their scheme.

3.2 Characteristics of Ubiquitous Computing

There are a number of unique inherent characteristics that differentiate ubiquitous computing from the current desktop paradigm, making the conventional human-computer interaction knowledge that we have built up overtime inadequate. There is a need to adapt or come up with new methods, theories and frameworks to guide the development of ubiquitous computing in an orderly manner. We have divided the characteristics into four categories, which are inspired by

Banavar and Bernstein, (2002). Each category brings together different viewpoints from a number of researchers on a range of related characteristics, which we highlight in the sections below.

3.2.1 Computing in a social environment

Introduction of ubiquitous computing technology within any environment will have a more significant social effect compared to conventional computing technology, changing not only our relationships with devices but other individuals as well. The embedding of computational artifacts and augmentation of common artifacts with no computational capabilities but exist within the environment, will result in new ways of acting and interacting amongst people in that environment. This will have an effect on people's existing social behavior, probably resulting in new social structures. The implication of this will be that we are not only interested in interpersonal relationships among co-located people (in the absence of the technology) or relationships between people and devices only (in the presence of the technology), but in the system mediated human-human relationships that emerge in the presence of the technology (Grudin, 1994; Banavar and Bernstein, 2002; Grudin, 2002; Jessup and Robey, 2002).

3.2.2 Dynamic goals and situations

The aim of ubiquitous computing is to be everywhere, at all times. Serving users whose task goals and situations may change dynamically requires that ubiquitous computing systems have the ability to respond adaptively. While the user might actively reconfigure the system to adapt to the new conditions, most other times the system might have to infer on its own about the changes and respond accordingly. This creates a need for the system to not only keep track of user goals, tasks and system resources over time, but environmental conditions as well. In addition, the system must be able to understand the reasoning behind those inferences in relation to the circumstances, enabling it to learn from the right and wrong inferences over time. Apart from being hard to collect all the necessary information to ensure adaptive behavior, it is challenging to do so inconspicuously, besides creating a bigger burden on system resources (Banavar and Bernstein, 2002).

3.2.3 Device heterogeneity and resource constraints

Ubiquitous computing will have to support multiple devices with varying hardware capabilities in order to be everywhere. These capabilities result in tradeoffs that inevitably influence the development of applications and their capabilities. With multiple devices at each user's disposal, there will be a need for mechanisms that help determine which tasks are appropriate for each device. As users move from one device to the next, applications with the ability to move from one device to the next will need to readjust to the uniqueness of each device, optimizing their effectiveness according to the device capabilities (Islam and Fayad, 2003).

As the devices get more mobile, more constraints arise. They have to be smaller in size to allow users to conveniently move around with them; this size constraint limits other resources like screen size, processing power, battery life, and so forth, which in turn influences other factors like connectivity and the development of services and applications (Banavar and Bernstein, 2002).

3.2.4 Network heterogeneity and coverage

In order to get more coverage, ubiquitous computing will have to be compatible with as many types of networks as possible to interconnect the many dispersed devices. Potential networks include the GSM (Global System for Mobile Communication) or CDMA (code division multiple access) networks deployed for mobile phone services, the increasingly popular 802.11x wireless network technologies, Bluetooth and IrDA, etc. These various networks have intrinsic properties that will influence the way we use them. For instance, they support different ranges of distance for connectivity. Bluetooth and IrDA support connections in a range of a few feet, while the 802.11x wireless technologies support slightly large distances, with the help of access points placed a few meters within each other. Mobile phone networks on the other hand can support distances of up to 35 km between a device and a base station.

Apart from the connection ranges, they support different throughput, implying that a connection using a particular network provides different resources to the devices and applications at the user's disposal. Switching between networks would require session management, creating networking challenges, while moving between dead spots and covered areas results in online and offline statuses. Ideally, all these changes should be transparent to the user and allow them to disconnect from the network whenever they may desire (Islam and Fayad, 2003).

3.3 Issues and Challenges

Given the above characteristics, a number of interesting issues and challenges do emerge. We have arranged these into six groups that encompass the bulk of issues that have been raised in literature and a few of which originate from our experience motivated by a keen interest to leverage ubiquitous computing technology for community computing applications.

3.3.1 Context awareness

For ubiquitous computing systems to become invisible while striving to be minimally intrusive, they have to be context-aware. They have to be cognizant of the user's state and surroundings, and have the ability to modify their behavior based on this information. This cognizance would not only help the system to sense what the user needs to do next, what they are probably going to do, and what actions can be taken to ease the task for the them, but would also need knowledge about the computational environment, what actions are possible given the computational constraints that exist at the time (e.g. how much power the device has left), whether a connection to the support infrastructure exists, and if it could support the required range of actions (Satyanarayanan, 2001).

Context-awareness is especially important because the resulting freedom created by ubiquitous computing technology affords the potential to operate devices on the move, creating changing usage situations as well as environments. Given its coverage, this in turn creates challenges for the surrounding infrastructure meant to support various applications; it might have varying capabilities to solve different tasks at various times. A good example of the coverage and limitations that could arise might be the cellular phone network.

Although numerous applications that draw context from location have already been demonstrated (Want et al., 1992; Cheverst et al., 2002) and there is no accepted formal definition of what constitutes context, it is generally agreed that it consists of more than just information about location (Abowd and Mynatt, 2000).

A user's context encompasses both human factors as well as the physical environment. Human factors may consist of attributes such as physiological state (e.g. their body temperature and hate rate), emotional state (e.g. angry, distraught, or calm), personal history, behavioral patterns and the social circumstances. The physical environment may consist of attributes like their location, environmental conditions (e.g. noise and brightness) and infrastructural surroundings.

Abowd and Mynatt (2000) put forth the "five W's" of context, providing a good starting point of how the different components could be brought together to provide context and better ubiquitous computing technologies. The "five W's" include:

- **Who**: the ability of devices to identify not only their owner, but other people and devices in its vicinity within the environment
- **What**: the ability to interpret user activity and behavior, using that information to infer what the user wants to do and provide the necessary information and help
- **Where**: the ability to interpret the location of the user and use that to tailor functionality. This one of the most explored aspects of context
- **When**: the ability to understand the passage of time, use it to understand the activities around and to make inferences
- **Why**: the ability to understand the reasons behind certain user actions. This might involve sensing the user's affective state, such as body temperature and heart rate, etc.

Key challenges are still abound in this area. High up on the list is the problem of how to collect all the information that is required to put together the whole picture, to allow the devices to operate in a context-aware manner. Although some of this information might be part of the computing space, other types of information, which might be dynamic, have to be acquired in real time from the user's environment (Satyanarayanan, 2001). Examples of such information may include position, orientation, identities of people nearby, other devices with which the user's has the ability to communicate, physiological state and so on. One solution that has been proposed is to assemble context information from a combination of related separate, but parallel services—context fusion. This would help provide reliable ubiquitous context by combining services in parallel to better eliminate noise while at the same time scaling up to sequentially cover large areas (Abowd and Mynatt, 2000).

Another challenge related to context is how to represent it internally within the system. We need to come up with methods to store this information as well as integrating it into system and application states. We will need to determine situations when the information should reside locally on the devices, in the network or both (Satyanarayanan, 2001). This is important because a good representation of context will permit “a wider range of capabilities and a true separation of sensing context from the programmable reaction to that context,” facilitating the development of context-aware applications (Abowd and Mynatt, 2000).

3.3.2 Privacy and trust

As ubiquitous computing technology matures and Weiser’s vision of invisible computing tends to resemble reality, focus will shift from the technical aspects of design to the social ones. The privacy of users and security of their information is one such social issue that has consistently been raised in literature (Abowd and Mynatt, 2000). While collecting more context information would result in more intelligent and proactive systems, it also results in the continuous monitoring of a user’s activities. As user becomes more dependent on a ubiquitous computing system, in turn, it becomes more knowledgeable about that user’s preferences, behavior patterns, movements and habits. Simple examples include my identity, which might be arrived at through the authentication of my personal mobile device, the location of different places I have been in a day etc. This raises questions of who can have access to such information and what they could use it for. Users who have a good understanding of such systems and appreciate the possible potential for the loss of privacy may opt not to use them, since in unscrupulous hands; this information might be turned into a weapon against them.

In order to get users to rely on ubiquitous computing infrastructure, we will need to get them to trust it. Conversely, the infrastructure needs to be confident of a user’s identity and authorization level in order to respond appropriately to their requests. The challenge then, is “to establish this mutual trust in a manner that is minimally intrusive and thus preserves invisibility.” (Satyanarayanan, 2001).

Research issues in this area include: various methods that could be used for user authentication in this paradigm, determining whether we could replicate methods that were developed for the desktop environment or instead focus on the newer and seemingly more accurate biometric methods (Jain et al., 2000). We will need to balance the requirement for seamless behavior and the need to alert users about potential loss of privacy while interacting with the system, deciding the frequency with which to remind them that their actions are being recorded (Satyanarayanan, 2001).

3.3.3 Infrastructure

With the multitude of interconnected and "invisible" devices required to make ubiquitous computing a reality (Weiser, 1991; Weiser, 1993), the infrastructural requirements are going to be more challenging than the current ones. Given that all these devices need to communicate with each other, the networking or communication infrastructure will dominate our infrastructural needs. This will create a numbers of issues and challenges, some of which are already being addressed, although many are still potential research areas:

- **Task-specific devices**: As we move away from technology driven general-purpose devices to ubiquitous task-specific ones, these devices will need ways to identify themselves and describe their behavior to others in the network. Apart from enabling their smooth inter-operation for the user's benefit, this will also make it easy for the user to add new devices to an already existing system (Russell and Weiser, 1998).
- **Software infrastructure**: Depending on a user's context, the "software infrastructure for running ubiquitous applications must be capable of finding, adapting and delivering the appropriate applications to the user's computing environment" (Banavar and Bernstein, 2002). Besides the user's context, other factors like their preferences or those of other users within the environment might also have to be taken into consideration. Besides supporting the large number of expected devices, the software infrastructure will also have to support many applications with various needs depending on whether it is for private or public use. It will provide support mechanisms for applications that need to move from one device or environment to another as they are required by the user, taking into account the device capabilities (like input and output modalities) and environmental conditions (like intermittent connectivity, other devices in the vicinity, user's social environment, etc.). In a sense, it will have to behave like a ubiquitous operating system (Banavar and Bernstein, 2002).
- **Information spaces**: We shall need ways to create information spaces. This may in part be a response to the need for privacy, allowing us to define boundaries between public and private information for better security. It will also help us to impose order on the

chaos created by the easy access we have to vast amounts of information available at our finger tips, enabling us to create associations over some spaces that overlap (Russell and Weiser, 1998).

- **Data-centric networking**: Given the myriad of network types available for connectivity and their varying capabilities, connections will be intermittent as applications switch from one network to another to accomplish a specific task or provide a service. Since data transfers from interfaces to applications will be invisible to the user, they will be guided by the task at hand rather than explicit commands from the user (Esler et al., 1999). There will be a need to provide a standard interface between devices and the various network types, making the infrastructure communication medium independent (Kagal et al., 2002).

Therefore, there is a need for languages and protocols that support self describing devices, make resource discovery easier, and a data-centric network architecture that addresses the challenges introduced by this ubiquitous environment.

3.3.4 User interfaces

As ubiquitous computing matures and pervades the environment, various devices and objects in our surroundings will not only be interconnected and have the ability to convey information, but they will also act as interfaces to the system. Turning a light switch in this scenario will be comparable to moving a mouse pointer in today's desktop user interfaces, only that now the user interface will be distributed, consisting of many objects that are not necessarily seen as "access points" to the system. In a distributed interface, some functions might be accessible via a range of different interface components, while a particular function might be distributed over several interface components[1]. Although many of these interfaces might be invisible in the literal sense of the word, others will be "invisible" in the sense that a user is so familiar with them (such that they do not explicitly think about how they put them to use) (Weiser, 1991).

With ubiquitous computing technology proliferating our environment, many of our artifacts will become part of its distributed interface. Unlike traditional computer interfaces, many of these artifacts will not be used to perform specific work related tasks, in a tool like sense, changing people's expectations and requirements for them. Functional aspects might be subordinated to aesthetical considerations—whether some artifact suits one's personal style of expression changing the focus from the "design for efficient use to design for meaningful presence" (Hallnäs and Redström, 2002).

Simply shrinking computing tools from the desktop paradigm will not suffice mainly for two reasons; for one, while the miniaturization of keyboard-boards, screens and other equipment occurs, humans are not evolving by shrinking their fingers or improving the power of their sight to keep up with the miniaturization of interfaces. Human anatomy will always dictate a range of dimensions that define the shape of objects that we create, especially if they are to be manipulated with ease and convenience. The second reason stems from the need to take advantage of the new contexts of use, where interactions are dynamically defined and usage situations vary from mobile to fixed location on one dimension, as well as from the individual to the group on another (Siewiorek, 2002), rendering most traditional interfaces inadequate.

The multitude of devices that need to be supported will also create issues. Designing application interfaces to support all these devices will be very difficult, mainly because of their varying capabilities and the dynamic situations in which they might be used. Some of the issues to think about include:

- **Output**: how to render the same information on a variety of displays varying from the conventional ones that are currently in use to the new unconventional ones that are bound to emerge, from the small personal ones to the large group ones, from those that support only black and white to those that support full-color, and in some instances audio (Russell and Weiser, 1998; Siewiorek, 2002)
- **Input**: how to get input from a variety of input devices and methods, communicating the range of possible interaction types (Russell and Weiser, 1998; Siewiorek, 2002)
- **Metaphors**: The desktop metaphor created in the early 1970s at Xerox PARC, which endured extensive testing and experimentation with various applications before it became widely used, is partly responsible for the success the desktop paradigm has enjoyed to date (Siewiorek, 2002). We will need some metaphor(s) for the ubiquitous computing paradigm as well to convey to the users the possibilities inherent in our systems. What makes it more difficult, is the need to take into account consistency on multiple devices and interfaces, many of which may not even have invented right now (Russell and Weiser, 1998; Siewiorek, 2002).

All these issues and challenges require that we come up with new methods and tools to help us design new user interfaces that are appropriate and take advantage of the possibilities of the ubiquitous computing paradigm.

3.3.5 User interaction and experience

The user interface is a gateway to the user's overall experience. Although the distributed nature of the interface would allow users to interact with the system through a range of different devices as articulated in the section above, it creates a challenge for designers to ensure that the interaction experience to accomplish a particular task does not significantly vary across the range of potential devices. Otherwise users will get confused and frustrated. In the event of many co-located users simultaneously interacting with the same interface, we shall need mechanisms to capture and model such issues, to enable amicable resolution. In more instances, interaction with such intelligent interfaces would be implicit—allowing the computer to interpret the user's behavior and actions based on their context, as opposed to current explicit interaction, where the user tells the computer at a certain level of abstraction (e.g., by command-line, direct manipulation using a GUI, gesture, or speech input) what to do. We will now be concerned about people interacting with more complex environments, rather than isolated computer systems or interfaces. This signifies a radical transition from the traditional human-computer interaction knowledge that we currently employ, to implicit human-computer interaction (Schmidt, 2000). These are some of the issues that will need to be addressed, in addition to agreement on some standards, given that the different devices put together to create a coherent experience will come from different manufacturers, creating a modeling challenge (Russell and Weiser, 1998).

As computing power permeates our environment, generating tons of information all competing for the user's attention, the scarcest resource is bound to be human attention, given that our evolution is not happening fast enough to keep pace with developments of other computing resources or the amounts of information being generated. Competing demands placed on our attention will impose a larger cognitive load, in addition to being annoyingly disruptive. To overcome this, we shall need to develop a framework within which competing devices or applications might vie for our limited attention, allowing us to get the most out of our interaction with the ubiquitous computing system (Russell and Weiser, 1998). Taking into account the social environment, the framework will have to take into consideration, how we attract one user's attention, without disturbing other co-located people.

A good start in this direction is the IRC notification system framework (McCrickard and Chewar, 2003). It identifies three critical parameters: interruption or the event prompting transition and reallocation of attention focus from your current task to the interrupting event, reaction or the rapid and accurate response to important information, and comprehension or the goal of remembering and making sense of the information they convey at a later time. The design of ubiquitous computing technologies that require user attention would then be an exploration of the acceptable balance between the interruption, reaction, and comprehension design objectives of a particular device or system.

Owing to the potential tons of applications and information a fully deployed system can have, it is necessary to allow users to create preferences on the basis of which they might interact with the system. We will need to develop methods to communicate these preferences to a "distributed, intermittently communicating, heterogeneous" world of ubiquitous computing devices, so that as users can have their preferences wherever they go or whatever device they choose to use (Russell and Weiser, 1998).

In the context of community networks, it is desirable that that the system has the ability to support multiple devices for most of the services it provides. Although this might result in some limitations based on the capabilities of some of these devices, it would not only allow members to use devices that they already own, but also minimize the amount of new skills that they need to acquire before benefiting from the system.

3.3.6 Validating the user experience

As discussed in chapters 1 and 2, ubiquitous computing has the potential to fundamentally change the way people use computing devices to perform various tasks. As computing moves beyond the confines of tool usage, leaving the largely sedentary and solitary desktop platform towards a pervasive penetration of the environment around us, emphasis is shifting from interaction between the individual and a single device to a profusion of networked mobile and embedded computing devices that individuals and groups employ across a variety of settings—creating new forms of interaction, as well as social norms. The utility of the resulting computing advancements cannot be evaluated without performing significant user studies on widely deployed systems that people use for substantial periods of time.

Traditional evaluation techniques are not readily applicable to ubiquitous computing situations (Abowd and Mynatt, 2000; Banavar and Bernstein, 2002). Besides the dynamic nature of user goals and environmental situations, and the capacity to accommodate an array of devices and connectivity options, other characteristics that compound the evaluation process include:

- **Context of use**: Ubiquitous computing technology is usually novel, sometimes addressing no specific human need. This makes it harder to envisage why and how users would interact with it, eliminating the basis for evaluating the impact of the new system on the everyday life of its target population. Owing to the nature of its use, it is difficult to run lab experiments, the ideal option would be to deploy the system into an "authentic setting" and observe how it is used over a reasonable period of time, but this is not easy, because our new systems are not reliable, robust and easy to deploy over large areas (Abowd and Mynatt, 2000; Banavar and Bernstein, 2002).
- **Social Environment**: Introduction of ubiquitous computing technology within any environment is bound to have a more significant social effect, compared to conventional computing technology, possibly resulting in new ways to act and interact. What will be the effect on existing social behavior? Will we end up with new social structures? All this issues compound the evaluation, implying that we are not only interested in relationships between co-located people or relationships between people and devices only, but with the system mediated human-human relationships that emerge as well (Dryer et al., 1999; Banavar and Bernstein, 2002; Grudin, 2002; Jessup and Robey, 2002).

Consequently, there is a need to develop effective methods for testing and evaluating the wide and often unpredictable range of usage scenarios enabled by the new ubiquitous computing applications.

3.4 Implication for Community networks

In order to encourage more and better social interaction within our communities, there is a need to find more relevant and useful applications for community networks. We need to go beyond Internet access, and the conventional services that this usually entails, for example, access to email, forums, news and other online services that people generally access from their desktop computers (Carroll and Rosson, 2002). These applications may range in function from helping users to share their preferences and knowledge, provide new avenues for generating consensus, as well as directly supporting our day-to-day living within our communities.

3.4.1 Context awareness

With the help of ubiquitous computing technology, various applications provided by the community networks can be made available within specific or desired locations within the community, providing members with the right service in the right place, even on the move. Tracking and utilizing aspects of user context will certainly be difficult, but vital, if we are to provide cutting-edge applications. Besides location, which might allow us to provide location-specific applications, other aspects that we could take into consideration might relate to the user(s) and other members around them, the usage situations (e.g. on the move, walking, or in the bar, having a drink), the environment (e.g. time of day, temperature etc.), history of usage patterns and so on.

This system might determine identity through the personal mobile device carried, current location, etc. Over time this information will accumulate, and could be used to track user movements. Determining who can have access to this information and what they can use it for, inevitably leads to privacy issues.

3.4.2 Privacy and trust

As the community network supports more useful applications, it will tend more towards becoming a knowledge management system for the community; consequently issues of who can create access and manage various types of content will become important. Increasingly, members will begin to rely more on the system for their daily activities, making its availability a priority, with the accuracy of the information provided requiring constant update and verification. The need to evolve an adequate policy to address these issues will increase.

With the increased coverage and functionality, members will use many different types of devices for access. It will become increasingly difficult to draw the line between personal and public information, forcing the community to come up with strategies to protect the privacy of members and their information. The dilemma then will be to determine the amount of information that we need to provide, which is sufficient to be rightly identified by the system in order for it to respond adequately to their needs. In some cases we might permit anonymity, while in others require visibility, while managing the delicate balance of constraints on which community interaction thrives. We should design systems that are socially translucent or encourage people to act and behave in accordance with social expectations by supporting the constraints afforded by "visibility, awareness and accountability—as building blocks for social interaction" within the community (Erickson and Kellogg, 2000).

Whatever strategy we come up with, must be simple and understandable by the members in order to gain their confidence and trust. The system should be built in such a way that it provides the members as much control as possible over the information that is collected about them, allowing them to determine what is collected, how long it is kept and so on. All the decisions that we make will inevitably involve balancing the tradeoff. The first trade off is between privacy and visibility, balancing between how much personal information is available to protect members privacy on the one hand, while at the same time creating awareness and taking into account the particular kinds of accountability that exist within the community at various levels in order to enhance social interaction (Erickson et al., 2002). The second tradeoff is between privacy and automation. There is a delicate balance between how much personal information is collected to protect members' privacy on the one hand, then again, for the system to make inferences and automate some processes on behalf of the user, it requires to collecting more context information—the bulk of which could be classified as private (Abowd and Mynatt, 2000).

3.4.3 Infrastructure

As the community network grows in size and the need to support multiple devices for access is taken into consideration, we will have to provide various connectivity solutions. These must take into account the various devices and their capabilities, in addition to the applications provided and their system requirements. Applications will have to be designed with all the various devices in mind, creating issues of determining appropriate tasks on the appropriate devices amongst many others, further complicating application development (Islam and Fayad, 2003).

3.4.4 Interaction and evaluation

In the past, community networks have not been thoroughly evaluated to provide us with a good understanding of the effect of some of their properties on the actual lives of individuals or the community at large. Most evaluations focus on quantity of usage, demographic breakdown of usage or user satisfaction surveys in the context of a single network project, often by network developers themselves[2]. Carroll and Rosson (2001) identify a number of cardinal issues, which if answered, might enable us to design better community networks and provide more relevant applications, helping us build even better communities. Some of the issues they identify include:

- **Participation**: we do not know who participates in the network and who does not. Neither do we have a good understanding of the causes of unequal participation throughout the community
- **Community life**: we do not have a good understanding of the actual effect of the network on community life, to determine whether it increases or diversifies participation in community activities
- **Social networks**: we a lack a thorough understanding of the impacts of the network on the human social networks within the community

This is, perhaps, a reflection of the fact that there is no generally accepted method for evaluating community networks making the evaluation process a challenge. Even if such a methodology were in place, any evaluation effort would still have to face the complexity and uniqueness of each environment of use. Although many designers of community networks do set out some goals and objectives, these are usually not directly translatable into user needs, making it rather difficult to determine their impact on the fabric of the community.

During the literature review, we did not encounter any studies that look at the appeal or predictors for everyday people to adopt the use of these new technologies. Given that many of the current implementations of ubiquitous computing systems involve embedding computational power into everyday objects, we were inspired to explore what people thought of these new types of interfaces. We report our findings in the next chapter.

Notes

[1] Schmidt, A. 2001. Context-Awareness, Disappearing and Distributed User Interfaces - Experience, Open Issues and Research Questions. A talk presented at the Dagstuhl Seminar on Ubiquitous Computing. http://www.inf.ethz.ch/vs/events/dag2001.

[2] Gregson, K., and Ford C. 1998 Evaluation of Community Networks. In online Proceedings of the American Society for Information Science and Technology Midyear Meeting: Collaboration Across Boundaries: Theories, Strategies, and Technology. Orlando, FL. May 16-20, 1998

Chapter 4

Using Everyday Objects to Convey Information

4.1 About the Experiment

Ubiquitous computing technology is beginning to arouse commercial interest as industry explores better ways to turn its investments in telecommunication infrastructure into profit, by leveraging gadgets that provide contextual information and services. Scenario building has the potential to generate and prioritize ideas for new products and services, in addition to identifying the possible users and contexts of use.

As pointed out in section 3.3.4 above, user interfaces as we know them today will gradually disappear with ubiquitous computing, as computational devices get integrated into everyday objects and the environment around us. While this creates many opportunities for situated computing, it raises the question of whether people expect to find computational functionality in these objects or environments, let alone, be able to use them and understand the information that they convey. While it is much harder to make interfaces invisible in our environment in the literal sense of the word, researchers have had more success at embedding them into everyday objects (Want et al., 1992; Heiner et al., 1999; Beigl et al., 2001; Mynatt et al., 2001; Dietz, 2002; Mankoff et al., 2003). Most everyday objects are designed with specific functions in mind, this usually influences their design both in appearance and in the affordances that they embody. Computational power might be added in order to enhance the utility of a given object, or to give the object added functionality. In either case, we presumably would like to maintain their appearance as well as original functionality. While this provides flexibility to use the object either as a normal artifact or as an "invisible" computing interface, designers will inevitably have to contend with the tradeoffs created by this duality.

Ubiquitous computing is still cutting-edge technology that has not yet found its way into the mainstream population, who will be vital for its success. Since their awareness of its existence and potential is not well documented, we feel that it is relevant to explore this aspect, and to probe at some of the inhibitive notions that they may have towards the technology. This will not only enable us to do a better job at educating them about the possibilities, but also help researchers and designers better address people's concerns, as both sides engage in a participatory design approach, enabling us to come up with more relevant and marketable applications.

4.1.1 Purpose of experiment

It is with these concerns in mind that we designed our first study. Some of the specific questions that we hoped to answer with this study include:

- Do people expect to find computational functionality in everyday objects?
- Would they understand the information conveyed by these interfaces, given that they are accustomed to using these objects in other ways?
- Would they be interested in using such devices?
- What are some of the factors that would influence their decisions to adopt the use of some of these interfaces?

We also wanted to determine whether with the help of some examples, we could stimulate participants to generate ideas that could be further explored for potential applications.

4.1.2 Brief outline of experiment

Participants are introduced to the notion of ubiquitous computing via a scenario-centric presentation using basic everyday objects imbued with some computational power to convey various types of information. Besides determining whether they understand the information, participants also compare these ubiquitous interfaces with desktop interfaces that display the same information allowing us to glean some insight as to how the two types of interfaces might differ.

Through a detailed survey, participants provide feedback relating to their impressions, rating the performance of each interface on a number of metrics and making comparisons between the ubiquitous and desktop interfaces. We inspire them to think of new ways to use the demonstrated ubiquitous interfaces to support current information needs that they may have or come up with new and different uses for them. Additionally, we solicit for other everyday objects that they think could be successfully implanted with computational capabilities to help convey information in the real world.

4.1.3 Hypotheses

The hypotheses for our study may seem to be obvious statements consistent with mainstream human-computer interaction thinking, however, we feel that based on the concerns raised by some researchers (Abowd and Mynatt, 2000; Hallnäs and Redström, 2002), they are important to verify for the ubiquitous design paradigm:

1. People prefer desktop over ubiquitous interfaces to display everyday information.
2. People will be more willing to start using ubiquitous interfaces if they perceive them as trustworthy and intuitive.
3. The effort required to understand information conveyed by the ubiquitous interfaces inhibits willingness to use.
4. People who have never heard of ubiquitous computing before will be less trusting of and want to be less dependent on ubiquitous computing systems, impacting their willingness to adopt ubiquitous interfaces.

4.2 Related Work

The main themes within human-computer interaction that we draw upon for our study are the scenario-centric method to determine user needs and investigate predictors of user adoption of ubiquitous computing technology. Some of the work related to these themes (Kankainen, 2001; Bødker and Buur, 2002; Hallnäs and Redström, 2002; Iacucci and Kuutti, 2002; Ikonen and Rentto, 2002; Mikkonen, 2002; Strom, 2002) is discussed in sections 5.1, 5.2 and 5.5 in Chapter 5 below.

4.3 Methodology

In this study, participants are introduced to the notion of ubiquitous computing with the help of basic everyday objects imbued with the ability to convey information. We used the Real World Interface (RWI) toolkit (McCrickard et al., 2003) to extend the capabilities of three everyday objects. The *infoLAMP* uses the brightness of a light to convey information, the *dataFAN* uses wind speed from a fan, and the *hapticCHAIR* uses vibration from a cushion (please, see Figure 4.1 below).

Using the Real World Interface (RWI) toolkit, it is easy to make everyday objects to convey information. It abstracts a lot of the details allowing the designer to use the objects just as they would any typical interface widget. The X10 transmission protocol is used to control power flow to these electrical devices, connected via a serial or USB port to an information source (McCrickard et al., 2003). The protocol allows easy association of information sources with physical device properties such brightness levels, rotation speed or vibrations, which are adjusted in this case to depict varying information states.

Participants compare these ubiquitous interfaces with two desktop interfaces that display the same information: a simple number display *counter* and a progress *indicator* bar, allowing us to glean some insight as to how the two types of interfaces might differ.

Figure 4.1: Everyday objects that have been imbued with computational power to enable them to convey information using the Real World Interface Toolkit. From the left to right, they are the infoLAMP, the dataFAN and the hapticCHAIR.

4.3.1 User population

In conducting this study, we chose to focus on a population familiar with emerging technology that will more likely be at the forefront of ubiquitous computing early adoption. Therefore our participants are 50 undergraduate computer science students who received class credit for their time. There are 5 females and 45 males, who range in age from 19 to 31. Most of them reported being very familiar with computers (43/50), while the rest felt fairly familiar (7/50). They own a range of mobile computing devices that include laptops, cellular phones, Personal digital assistants (PDAs), miniature MP3 players, etc. In the pre-study questions, the majority indicated not having heard of the term "ubiquitous computing" before (34/50), while some (4/50) were not sure. Of those who had heard of the term (12/50), two were not sure of its meaning.

4.3.2 Experimental session

Participants were studied in groups of eight, although each session was conducted in identical fashion. During an experimental session, participants are introduced to all of the interfaces. Everyday information is conveyed to the participants on the various devices within the context of a scenario that helped situate the interaction. The scenarios were selected to reflect a variety of information needs, and they include monitoring of three different types of information: 1) *outdoor temperature*, 2) *online buddy status for instant messaging*, and 3) *progress in performing a timed task.*

Scenario 1. In this scenario, participants were told to imagine themselves seated before a computer, engaged in an editing task. They were then asked to monitor outdoor temperature to determine changes over time with each of the five devices being tested.

Scenario 2. Like in scenario 1, they performed a similar primary task. However, they were asked to use the devices being tested to monitor online buddy status of someone they are interested in communicating with via instant messaging.

Scenario 3. In the final scenario, the primary task changed, requiring participants to imagine themselves engaged in a timed online examination. They were then asked to monitor their progress in relation to the amount of time that had passed using each of the five devices being tested.

Detailed feedback is collected via a questionnaire, which consists of four subsections and 154 questions in total. After each scenario demonstration, participants provided feedback by completing a section of the questionnaire. This involved rating the performance of each interface, as well as comparing them on a number of metrics that include: *learnability* or ease of learning, *intuitiveness* or easy of use with no prior explanation, *interruptiveness* and simplicity of effort required to understand the information conveyed. The first three sections are similar, and are used to collect feedback for each of the scenarios, while the fourth section is more general and probes their experience in all three scenarios. Each section consists of 46 questions and is repeated for all three scenarios. Table 4.1 shows a typical beginning portion for the first three sections, with the results from scenario 2 for each of the devices that we tested. For the full list of questions, please see appendix B.2.

Participants conclude the study session with a general section consisting of 10 questions that asks for their thoughts on a variety of social aspects pertinent to ubiquitous computing (Abowd and Mynatt, 2000; Jessup and Robey, 2002) and inspires them to think of new ways to use these interfaces. We were specifically interested to know how they felt their current and possible information needs should be supported, as well as better interface designs that would convey this information. Participants were free to ask questions at any time during the session, which normally lasted for about one hour.

Table 4.1: Some of the typical questions from the beginning portion of the first three sections of the questionnaire that help rate the performance of each of the tested devices in each of the scenarios. Average results from scenario 2 are shown. For the entire questionnaire, please see appendix B.2.

	Typical question in the first part of section 1, 2 & 3	infoLAMP	dataFAN	hapticCHAIR	counter	indicator
a)	easy to learn to use *in this scenario*	4.78, +/-.65	4.38, +/-.90	4.32, +/- .91	4.52, +/- .65	4.62, +/-.67
b)	easy to understand the information conveyed *in this scenario*	4.78, +/-.68	4.28, +/-.93	4.40, +/-.86	4.56, +/-.61	4.58, +/-.73
c)	interruptive to the current task that I am doing	2.65, +/-1.25	3.20, +/-1.21	3.86, +/-1.28	2.16, +/-1.22	2.28, +/-1.34
d)	easy to use with no prior explanation	4.30, +/-1.02	3.82, +/-1.03	3.90, +/-1.18	4.20, +/-1.01	4.32, +/-.94
e)	I would use it in real life *in this scenario*	3.50, +/-1.22	2.18, +/-.86	1.94, +/-1.02	3.16, +/-1.23	3.41, +/-1.21
f)	I would you use it in the same way that it was demonstrated	4.04, +/-1.17	3.13, +/-1.31	2.69, +/-1.40	3.61, +/-1.24	3.92, +/-1.11

4.4 Results

We present our results in terms of each of the four hypotheses and elucidate some of the interesting findings in the discussion section that follows.

The first hypothesis was generally supported, although ubiquitous interfaces showed promise in specific situations. Based on the questionnaire results for all three scenarios, 63% of responses exhibited preference for desktop interfaces, while 21% showed preference for ubiquitous interfaces, and 16% were unsure, as indicated in Table 4.2. However, focusing on monitoring online buddy status (scenario 2) 22 of the 50 participants expressed preference for the infoLAMP, favoring the ubiquitous device over other interface choices. User comments elaborated on this finding, recognizing preference for peripheral information delivery: "not having to focus on the desktop," "provides information you need," "you don't have to read it or look at it." Preference for ubiquitous interfaces was weak in all of the other scenarios.

Table 4.2: Number of participants indicating preference for each device type in each scenario. The totals and overall percentages in parentheses for all the participants are shown at the bottom.

Scenario \ response	infoLAMP	dataFAN	hapticCHAIR
1	9	36	5
2	16	24	10
3	6	35	9
totals	31 (21%)	95 (63%)	24 (16%)

responses for each (% total of whole group)

To probe the second hypothesis, we filtered our data to include only the 27 participants who indicated "sufficient trust to be able to use" ubiquitous computing systems. Of these, we filtered further to identify cases where participants agreed that a ubiquitous computing device was "easy to use with no prior explanation." This sample consisted of trusting participants that found the particular ubiquitous computing device to be intuitive in use. Qualifying sample sizes and the percentage of these cases where the participant was willing to start using that particular device is shown in Table 4.3. Had hypothesis 2 held, the percentages in the table would approach 100%.

Surprisingly, only the infoLAMP in scenario 2 showed a (weak) correlation between trust and intuitiveness as a predictor for willingness to adopt.

Table 4.3: Number of participants indicating sufficient trust to use each device in each scenario. In parentheses is the percent of those participants who indicated a willingness to adopt the device.

Device / Scenario	infoLAMP	dataFAN	hapticCHAIR
1	16 (19%)	14 (36%)	10 (0%)
2	24 (75%)	17 (12%)	20 (10%)
3	19 (16%)	12 (0%)	16 (50%)

filtered sample size (% willing to adopt)

For the third hypothesis, we assessed the effort required to understand the information conveyed in terms of three factors—responses on questions related to learnability, intuitiveness, and interruptiveness. With each device, we looked for patterns related to these responses and the outcome of the willingness-to-adopt question. For instance, in 62 of the 68 occurrences that participants indicated negative responses to both learnability and intuitiveness, they were also unwilling to adopt. Likewise, two or more unfavorable responses in the effort-required factors are a strong predictor of not being willing to adopt (108/114 occurrences). However, it is surprising that when we compare the predicted unwillingness to adopt versus the actual unwillingness to adopt, we find that the third hypothesis is a weak predictor and dependent on the scenarios. In scenarios 1 and 3, the factors predicted 57/123 and 54/130 cases of unwillingness to adopt, while scenario 2 predicted only 6/108 cases. The results are depicted in Table 4.4 below.

Table 4.4: Ratio of predicted unwillingness to adopt based on hypothesis 3 criteria versus actual unwillingness to adopt. Note that Scenarios 1 and 3 exhibit much better prediction success, although this hypothesis is not supported by any scenarios.

Scenario \ Device	infoLAMP	dataFAN	hapticCHAIR	Total
1	12/40	14/36	31/47	57/123 (46%)
2	1/18	3/46	2/44	6/108 (6%)
3	17/42	24/50	13/38	54/130 (42%)

For the fourth hypothesis, we filtered our data to include only the 34 participants who indicated having not "heard of the term ubiquitous computing." From the sample, 28 did "sufficiently trust" ubiquitous computing systems to be able to use them and 6 did not exhibit agreement that they trust these systems. Of the 28 who sufficiently trusted ubiquitous computing systems to be able to use them, 17 were worried about becoming fully dependent on the reliable operation of ubiquitous computing technology and 11 were not. Of the 6 who did not "sufficiently trust," 4 did not mind dependency, while 2 did. Figure 4.2 depicts how our user samples are distributed between these hypothesis' conditions. The only group that directly meets the conditions of hypothesis 4 is indicated with a dashed outline. If Hypothesis 4 had been supported, both of these participants would not have indicated willingness to any of the ubiquitous computing devices demonstrated in the study. However, both of these participants agreed that they would want to use multiple ubiquitous computing devices in their daily lives, providing evidence that is contrary to hypothesis 4. It is interesting that the other subgroups had lower percentages of willingness to adopt at least one of the three devices.

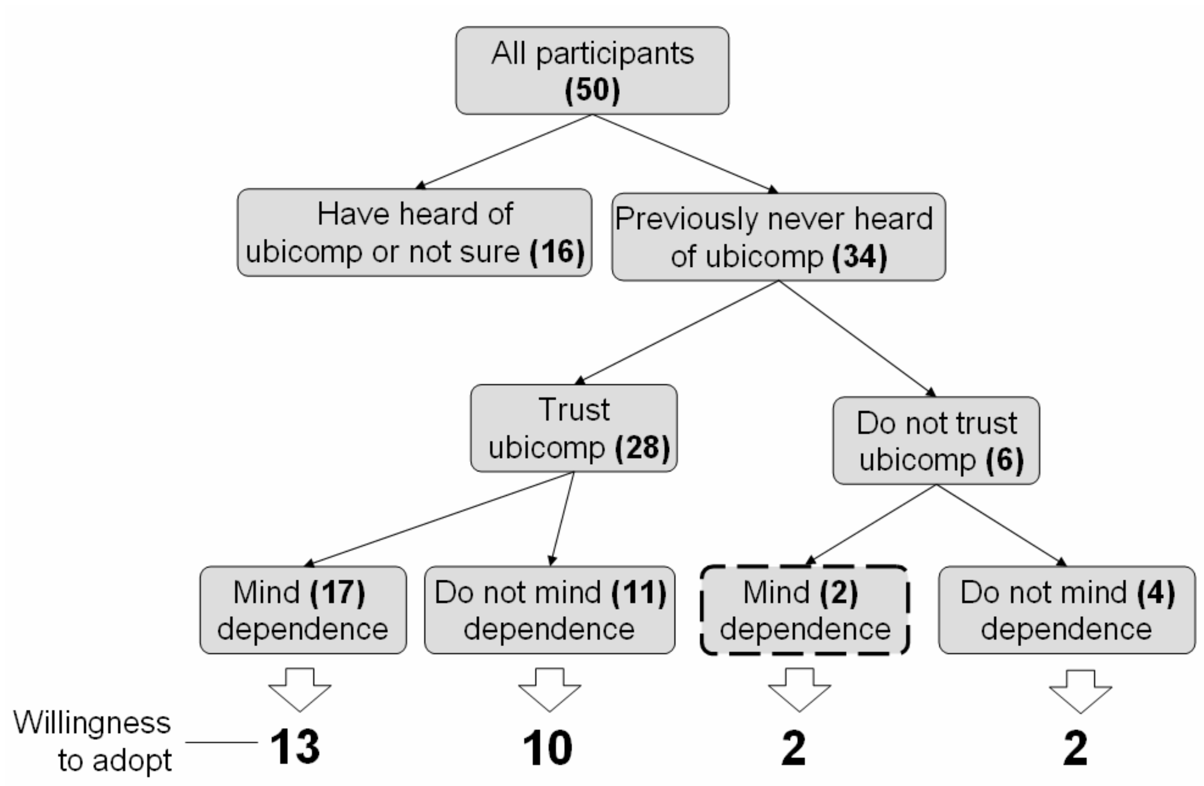

Figure 4.2: User samples distributed between hypothesis 4 conditions. The group with the dashed outline indicates the only participants who met the hypothesis conditions. The hypothesis implies that these participants would not have been willing to adopt any of the ubiquitous computing devices.

4.5 Discussion

Our user survey provided some much needed introspection into the attitudes and tendencies of our target population. We were quite surprised at many of the results despite the suggestions of these trends within existing literature. We expected that many of the usability notions from mainstream human-computer interaction will be reflected more in the participant responses. However, this was not the case.

The preference for desktop interfaces over ubiquitous devices in hypothesis 1 might be explained by the fact that most participants have previously used desktop interfaces to keep track of similar information. However, this does not explain the unexpectedly strong preference for the infoLAMP in scenario 2. We suspect this may relate to the kind of information being conveyed in that scenario—unlike the ratio values conveyed in the other two scenarios, scenario 2 depicted binary categorical buddy statuses. While this implies successful information mapping for the infoLAMP, we feel the result has deeper implications due to the lack of preference for the counter interface (similar information mapping). Factoring in the participant comments, the infoLAMP was truly appreciated for its ability to liberate information delivery from the desktop platform and blend in with the user's environment—this exemplifies success of a ubiquitous computing system.

Although hypotheses 2, 3 and 4 seem to be obvious extensions of human-computer interaction thought, it is most interesting that they do not hold true for predicting acceptance of ubiquitous computing systems. In other words, trustworthy, intuitive, easy to use devices were not readily accepted by users that frequently use computers, personal digital assistants, and other electronic gadgets. Perhaps this finding highlights the importance of identifying good application areas for ubiquitous computing systems, understandable given their potentially intrusive nature (particularly the haptic devices). This suggests the ubiquitous computing paradigm must not be measured in terms of the traditional; usability metrics, but must focus on other features of use as well. While this has been noted by other researchers (Abowd and Mynatt, 2000; Hallnäs and Redström, 2002), this study empirically validates this critical notion.

4.6 Conclusions

Based on our experience in conducting this user survey we found that using scenarios to get feedback from potential users is an excellent and inexpensive way that can be used to generate and prioritize conceptual ideas for new products and services, in addition to focusing the actual contexts of use. While the existing literature we discussed suggested benefits of this approach, we were uncertain from these accounts whether it would be suitable for probing barriers to ubiquitous computing adoption. Likewise, we were initially hesitant with using the prototypes to demonstrate features, fearing that users would not be able to fully appreciate the potential of computationally enhanced everyday objects integrated within the actual context of use. Neither of these initial apprehensions materialized in the study. Realizing this provides excitement about the rapid prototyping features of systems such as the Real World Interfaces (RWI) toolkit described by McCrickard (2003) and their potential to augment textual scenario descriptions as tools for use in the scenario-based design of ubiquitous computing systems and applications. The combination will enable designers to develop functional models of real-life use of new products and to present design ideas to the users, which could otherwise be difficult or expensive to prototype or simulate.

While many people might not have heard of ubiquitous computing before, they do not seem to have a hard time transitioning from the traditional user interface to ubiquitous interfaces, at least those embedded in everyday objects like the ones used in this experiment. While this is encouraging, it is worthwhile to note that people did not use these interfaces for more than an hour in the context of this study.

Owing to the nature for ubiquitous computing, using different objects within the environment to present the same kind of information is going to be unavoidable, in fact it is one of the ideals. In this study, it is clearly apparent that different objects are only good at conveying certain types of information, given their properties. This creates a need to study how different kinds of information should be presented taking into consideration the presentation medium as well as the usage situation. This is especially important in the case of ubiquitous computing because we do not yet have any universal metaphor or framework within which interface or interaction decisions can be made, just as the current computing paradigm has the desktop metaphor and its embodiment in GUIs and WIMP (Hong et al., 2002)[1].

The key findings of this study are summarized as follows:

- *Ubiquitous computing interfaces can be preferred over desktop interfaces in certain situations*. Although this might sound trivial, it is at least an indication that people are willing to make the transition from the currently predominate desktop computing paradigm to the ubiquitous computing paradigm.
- *Predicting people's acceptance of ubiquitous computing systems transcends usage characteristics*. This is important given that people will be interacting with more complex environments than the isolated computer systems or interfaces that we are used to today. While we have not yet mastered how to create usable computer systems, we will soon need to add even more factors into the quagmire.

The performance of the infoLAMP is an outlier in all three hypotheses, raising questions about its differences from the other ubiquitous interfaces and providing a strong foundation for further inquiry. Participants provided many new ideas for alternate ubiquitous computing interfaces, some of which can be further validated using a similar process in future testing. Since learnability, intuitiveness, interruptiveness, or trust are not predictors of user acceptance, we must use successful systems such as the infoLAMP to determine better predictors.

It will be very interesting to see how results from this same study conducted in future years with similar populations will change over time. We predict that future of these young participants will be increasingly more familiar with ubiquitous computing systems and have stronger predispositions that impact willingness to adopt them in their daily lives.

It is already common to see people walking around with wearable computing and communication devices that allow ubiquitous access to information—many of which are context-aware or allow capture of daily experiences. It would be interesting to know, how a user's perception of these devices differs from the natural, embedded interfaces that we targeted in this study. While we have already recognized that traditional measures of usability can not readily be applied to real world interfaces, we suspect that metrics for systems within these other two classes would need even more revision, considering the social implications that surround their use and interaction. It will be exciting to see how the opportunities, created by understanding user expectations better, are harnessed by system designers for the betterment of humanity.

Notes

[1] A copy of the workshop position and presentation given at Ubicomp 2002, workshop on Concepts and Models for Ubiquitous Computing is available with other workshop proceedings here or from the main author's publication section of his website (http://www.cs.berkeley.edu/~jasonh/research/research-publications.html).

Chapter 5

Augmenting Scenario-Based Design

In this chapter we employ scenario-based design to walkthrough the design of a community network application that leverages ubiquitous computing technology to allow shared access for community members in their "third places" or on the move (excerpts appear within the chapter, for more details, please see Appendix A). Drawing heavily on the background from Chapter 2 and Chapter 3, we analyze the utility of scenario-based design as a method for the design of ubiquitous computing applications and systems. We discuss potential aspects of scenario-based design that could be augmented with work from other areas to create a process that helps designers create better ubiquitous computing systems more successfully.

Scenario-based design (Carroll, 2000; Rosson and Carroll, 2002) is an iterative approach that can be used for interactive systems design and analysis. It is comparable to other usability engineering methodologies, in that it encompasses requirements analysis, design, prototyping, evaluation, and documentation. What sets it apart is the reliance on user interaction scenarios as a tool to highlight users' needs and experiences in relation to technology, providing a mechanism to identify and balance tradeoffs that may arise in the process of development.

"*Scenarios* are stories—stories about people (sometimes called actors) and their activities." (Carroll, 2000, p.46) They talk about people with specific behavior, goals and experiences, carrying out a sequence of activities with the help of an interactive system to achieve a specific goal. This makes explicit the user's expectations, enabling the system designer to respond to them without speculation. Scenarios are complimented by claims analysis, where important features of the situation are identified to help generate design reasoning. Besides grounding the design process in the situated tasks of users, scenarios allow designers to make assumptions explicit as they balance the tradeoffs that arise in the claims.

5.1 Requirements Analysis

This process usually starts with a root concept, which helps outline the project's high level goals. It may include "a project vision and rationale, an analysis of project stakeholders, and an acknowledgement of starting assumptions that will constrain or guide the development process."

It is developed to summarize the key aspects of the planned application or system and helps guide the field studies that ensue. The field studies are carried out to acquire a better understanding of the stakeholders, their environment, and the actions in which they engage to achieve their intended goals. The collected information and artifacts help in the creation of problem scenarios, which put the tasks learned from the field studies into context and their claims, identifying interesting features or those with important effects on the actors (Rosson and Carroll, 2002, p.37-47). Our root concept appears in Table 5.5 below.

Table 5.5: Our root concept and some of its constituent components.

Component	Contributions to the Root Concept
High-level vision	To allow Blacksburg residents to participate more in the issues that relate to the way their community is governed by making it easier for them to access community related information at any time, in a variety of places, using a variety of devices
Basic rationale	By enabling easier shared-access in community "third places," this will provide a framework for discussion to reflect on the most current issues of interest within the community. Feedback can be directly incorporated into the system helping to enhance social interaction and making the community network more relevant
Stakeholders	
Local authorities	Provides them with a mechanism to communicate to members about intended actions in order to get feedback, enabling them act in the interests of the community
Community members	Provides them with convenient access to local government plans, allowing them to provide feedback to guide them
Starting Assumptions	A range of wireless networks already exist within the town of Blacksburg. They are interconnected to cater for various connectivity requirements Users already own a variety of handheld devices that they are already comfortable using. These range from cell phones to PDAs

	Owing to the success of the BEV project, the use of computers and the Internet is pervasive. Most people have the necessary basic computer skills

For a discussion about some of the considerations that motivated us to come up with the starting assumptions above, please see appendix A.1.1, while for some of the artifacts that we collected, please see appendix A.1.2.

5.1.1 Problem scenarios and claims

Problem scenarios are stories of current practice, carefully crafted to reveal aspects of the stakeholders and their activities with implications for design in the current problem domain (Rosson and Carroll, 2002, p.64). Scenario generation is combined with claims analysis, which enables the investigator to identify features that are interesting or have important effects on the actors (Rosson and Carroll, 2002, p.73).

Our problem scenario responds to the familiar challenge of community advocacy. While this is one of the services that most community networks do provide, the way it is discharged is constrained by their limitations, which are discussed in section 2.3.3. In our case study, we look at the problem from two perspectives; the first perspective is that of John, a local community member who is concerned about the impending rezoning of a popular community nature park—the Brown farm park[1]. His concern is to raise the awareness of other community members about the implications of that action and to get them to put pressure on the local government to reverse the decision. The second perspective is that of James, a local council employee, whose concern is to disseminate information pertaining to zoning and other land use policies to members of the community, to allow them to provide feedback and ensure that the planning commission, in its duties, responds to their needs.

For the full problem scenarios and claims that we came up with, see appendices A.1.1 and A.1.4.

5.1.2 Generating scenarios

Scenarios are usually generated from materials collected from observations or field studies, by system designers brainstorming ideas together, or involving prospective users in the process to create written or visual narratives. While the scenarios enable the designers to respond to user's expectations, they might be limiting as we transcend from the conventional interfaces and technologies into the realm of ubiquitous computing. On one hand, we will experience new technologies in a more intimate and physical way, as they follow wherever we go, compared to most current technologies that we experience in a more sedentary manner. In addition, new technologies will not only affect the individual or their performance, but their relationships with others both proximately and remotely.

While in some situations the problem in need of a solution might be more evident, in most cases designers are pushing the envelope, trying to create novel technologies and "invisibly enhancing the world that already exists" (Weiser, 1991). Hence, there is need for some coherent method to generate new ideas and test their feasibility whenever possible, before designers invest a lot of resources in ideas that could end up going no where.

Motivated by these realizations and a better understanding of some of the limitations of current usability work in HCI for ubiquitous computing design, new types of conceptual design activities, where scenarios are created and performed, are emerging (Kankainen, 2001; Bødker and Buur, 2002; Iacucci and Kuutti, 2002; Ikonen and Rentto, 2002; Mikkonen, 2002; Strom, 2002).

A common approach in ubiquitous computing research is to build and deploy working systems and then observe them in use to generate ideas for iterative deployment. This has produced numerous insights on how the systems could be improved, as well as their affects on users and social interactions. A good example is the Classroom 2000 (Abowd, 1999), an instrumented classroom environment that captures live lectures in a form that can be accessed later. An iterative design process involving users in an actual classroom was used to generate progressive refinements. Qualitative data was collected from surveys and quantitative data from usage logs. Comparative studies were done to determine the impact of the system on student performance, but they exhibited only marginal improvement despite the costly iterative re-engineering process.

User-centered scenarios, on the other hand, have been used in a variety of ways to generate design ideas for new products and services (Ikonen and Rentto, 2002; Mikkonen, 2002), in addition to validating and prioritizing user needs (Kankainen, 2001). The scenarios are stories about situations involving actors or users and their interaction with the environment to satisfy specific information needs (Carroll, 2000; Rosson and Carroll, 2002). They enable researchers and designers to develop functional models of real-life use of new products and to present design ideas to the users, which could be difficult or expensive to prototype or simulate otherwise.

Motivated by the growing aging population worldwide, Mikkonen et al (2002) investigate the needs of the elderly, particularly in regard to independent living. Using a group of experts and some end users, they generate ideas on how wireless devices and services can be used to facilitate independent living. These ideas are then used to evolve usage scenarios to reflect the potential services and utility, and tested using a group of elderly users. The feedback generated is used to determine the feasibility of some of these ideas as well as prioritize them. They are pleasantly surprised that the elderly are willing to use some of these services because they are perceived to be easy to use and to facilitate independent living.

Similarly, Ikonen & Rentto (2002)[2] report some experiences with scenario evaluations of ubiquitous applications with potential users. Using different user groups, they try to identify needs that could be supported by ubiquitous computing applications. They also use the groups to validate the feasibility of future technologies, aided by different techniques of enacting scenarios, which vary from written text to acted and filmed videos. Some of the technologies they explore include, a personal navigation system, where they are interested in identifying potential users and their usage cultures and a future home network concept, where domestic appliances are interconnected on short range wireless technologies to provide various services. Interestingly, they found that a substantial number of users wanted to use the technology in ways different from those enacted in the scenarios and had some problems with some of the terminology used. Overall, they learned that scenario-based evaluation can be used to provide valuable clues for how novel technologies could be developed for different kinds of user groups.

Kankainen (2001) uses scenarios for two purposes that support the goal of determining ubiquitous computing product and service concepts. The first purpose is to validate user needs derived from user research results before they are used as a basis for actual design work. The second purpose is to prioritize these users needs, determining which are the most important to fulfill first, as a strategy to pursue concepts with the most potential. Using a multi-level scenario-based process that gets feedback from not only end users, but also experts in other domains like technology and business, they come up with a set of products and services that are likely to succeed commercially.

While some of these studies (Kankainen, 2001; Ikonen and Rentto, 2002) are reports presented at workshops that have not yet been followed up with published literature, they nonetheless provide a good picture of how scenario-based design can be used to generate design ideas for new ubiquitous computing systems and applications, help test their feasibility, and prioritize them, long before any actual prototypes are built.

5.2 Activity Design

In scenario-based design, activity design is the first phase of design, and the "emphasis is on the basic concepts and services of the new system" that address the needs expressed in the problem scenario. It is influenced by the consideration of some of the existing technologies and how these could be leveraged to come up with a solution to the problem scenario. Existing metaphors and interaction modalities are used partly to inspire non-obvious reasoning as well as to ensure that users do not have to learn many new skills in order to interact with the resulting solution. The activity scenarios direct attention to the system's core functionality, by allowing the designer to envision new ways to meet the needs of the stakeholders in the problem scenarios, while taking into account the affordances provided by the various interaction contexts. This phase helps identify some of the potential features, basic services, and raises issues for the information and interaction design phases that follow (Rosson and Carroll, 2002, p.79-94).

Three design concerns highlighted for the activity design phase include designing effective, comprehensible and satisfying activities. Effectiveness deals with identifying the right services and may not necessarily relate to efficiency. Comprehension deals with the ability of users to determine the action possibilities offered by a system and enabling them to get feedback on their progress in performing these actions. Interaction between the designer's model of the system and the user's mental model plays an important role here. On the other hand, satisfaction refers to making use of the system a pleasurable experience by incorporating some form of reward structure commensurate with the type of work involved (Rosson and Carroll, 2002, p.81).

5.2.1 Enacting scenarios

For ubiquitous computing design, activity design can occur simultaneously with the requirements analysis process. As we generate scenarios, they could also be enacted wherever possible. Enacting scenarios provides a rich framework within which to not only test potential ideas that might be way ahead of their time, but to also discern important "contextual information" that may relate to desired functionality, system inputs and outputs, as well as the various types of possible interaction (normal human-human interaction in the absence of technology, human-technology interaction, and the mediated human-human interaction that emerges in the presence of the technology). All this happens within the constraints afforded by the social situation in a given usage context, before any actual prototypes are created (Iacucci and Kuutti, 2002).

Iacucci and Kuutti (2002) report on their situated and participative enactment of scenarios (SPES), where a participant is given a simple mockup of a future device, referred to as the "magic thing" to help stimulate their imagination to determine new service ideas or features for the device. The designer then "shadows" the participant around as they go on with their daily life. Although the designer may interrupt the user now and then to seek explanations for their behavior, it is interesting to note that every once in a while, they both engage in acting out interesting usage situations as they arise, switching between being an actor and a spectator. This in essence allows one to see the technology from another's point of view, which in part might result in more socially acceptable technologies.

Continuing our case study, we had a few users enact the problem scenarios as a way to explore the activity design space. During the process, we asked them to comment on the various challenges that they encountered and how they thought these should be resolved. We used the feedback to improve on some of the ideas that we were already considering for a potential solution.

5.2.2 Conceptual metaphors and system technology options

A metaphor is a known concept used to understand a new concept by analogy. They are often used when learning to interact with systems, since it is easier to understand new ideas when they are similar to familiar concepts. For example, a user may rely on portions of the writing metaphor to understand how to use a stylus or how to use graffiti on a PDA. Metaphors not only simplify initial comprehension and use, but can also be useful in design brainstorming, when people seek to generate completely novel ideas. Different metaphors can often be mixed or composed into a single coherent concept. Many of the conceptual metaphors that helped us to brainstorm the core functionality of the potential solution come from real world activities and are shown in Table 5.6 below.

Table 5.6: Conceptual metaphors for the activities and objects in the petition application.

Activity	Real-World Metaphor	Implications for Petition Application Activities
Subscribing to an information channel is like…	Using an automated telephone service	Dial a number, follow voice prompts and use the phone keypad or voice to navigate menu
	Subscribing to a magazine	Provide personal contact details, indicate how often and the form (hardcopy or electronic) in which you want to receive the magazine
Accessing the petition system is like …	Entering a secured building	Personal identification is required
	Using a debit card	Swipe it through a card reader and provide enter your PIN
Using you voice as input is like speaking to…	Someone	Audible, clear voice, distinct from the background noise, get feedback
Editing text is like writing a…	letter	Use of your hand, require something to use to write (pen, pencil…) and something to write on, usually paper

System technology options are familiar or innovative information technologies that can serve as a type of metaphor for how a user may think about using the interactive system being designed. In our case, examples include using a mailing list, stylus, word processor, or login into a computer. An exploration of system technology options can lead to specific ideas about the content and structure of various elements of the interactive system. Some of the technology metaphors that we used are shown in Table 5.7 below.

Table 5.7: System technology options for the petition application system.

Activity	Information Technology	Implications for Petition Application Activities
Subscribing to an information channel is like using a…	Mailing list	Send a subscribe command to the list you are interested in
Receiving information from an information channel is like using a…	Mailing list	Information goes out to everybody on the list
Accessing the petition system is like…	Login to a computer	User ID and password are required
	Using a debit card	Swipe it through a card reader and provide enter your PIN
Using you voice as input is like speaking through a …	Microphone	
Editing text is like using a…	Stylus	
	Word processor	

The success of the personal computing era is usually attributed to the use of the desktop metaphor as an overall guiding concept that helps tie together various components of the WIMP (windows, menus, icons and pointers) interface. Most of the systems that leverage this metaphor were initially intended for general use in a fixed location, usually an office. The affordances provided by a desk to organize documents are leveraged to help people understand the hierarchical file system of organizing their files and folders, those that we do not need any more are deleted by putting them in the trash can. It is evident that the desktop metaphor will not be of much help for ubiquitous computing design, given the need to support varied and dynamic goals as well as usage situations. While it maybe difficult to come up with one all encompassing metaphor, there may be a set of metaphors tailored to a specific application or a specific information type that emerge (Siewiorek, 2002). Researchers are beginning to explore more appropriate metaphors and interaction frameworks (Hong et al., 2002)[3] in anticipation that ubiquitous computing is going to be the next computing paradigm.

5.2.3 Activity scenarios and claims

Just like before, scenario generation is interspersed with identifying and analyzing claims. The activity scenarios respond to the needs identified in the problem scenario. For John, the community member, besides extending the community network out to the space where he normally interacts with his friends, the scenarios portray how the community network could be enhanced for community advocacy. For James, the community employee, the scenarios respond to his need to disseminate more information to more community members in a more efficient manner.

The activity scenarios are influenced by the various metaphors, with feedback from discussions with various stakeholders helping to fine tune them. Enacting the scenarios made apparent some non-salient aspects that we had initially ignored. For the full activity scenarios and claims that we came up with, please see appendices A.2.2 and A.2.3 respectively.

5.3 Information Design

While activity design deals with the functionality of the proposed application in the context of specific use, the objective of information design is to "specify representations of a task's objects and actions that will help users perceive, interpret, and make sense of what is happening" (Rosson and Carroll, 2002, p.110). In this phase, activity design scenarios are elaborated with presentation details, to ensure that users can determine the status of their current activity and what they need to do achieve their goals. This design phase deals with the "gulf of evaluation," while interaction design will deal with the "gulf of execution" (Norman, 1986; Rosson and Carroll, 2002, p.110).

Although the theoretical foundations of Norman's stages of action framework (Norman, 1986) were conceived when design mainly dealt with the visual sense, they can be easily re-interpreted to cater for the other faculties with which human beings are endowed, some of which ubiquitous computing seeks to exploit. Interactive systems have been dominated by the graphical user interface (GUI) paradigm for a long time (at least in the context of developments in computing). Over time, designers have built up a vocabulary to deal with most of the common problems that users normally encounter, creating what Bellotti et al. (2002) refer to as a "genre." They are multitudes of methods and guidelines that provide designers with "generalizations relating to the parts, rules and meanings constituting human-system dialog" to help users circumvent Norman's famous gulfs of evaluation and execution (Bellotti et al., 2002).

Bellotti et al. (2002) highlight the limitations of the current "genres" and rightly point out why they can not successfully be applied to other emerging areas such as ubiquitous computing. They go ahead to propose an approach that emphasizes the "communicative" rather than the "cognitive" aspects of the interaction inherent in Norman's approach, and put this forth as a substitute. While we do recognize the utility and potential of their approach, we do not necessarily see it as a substitute for Norman's stages of action, but rather as a complement. This is in part influenced by our expectations that as we move towards truly ubiquitous computing applications or systems, interaction would involve a delicate balance between both explicit and implicit interaction, with the initiative also having the ability to either be with the user or with the system.

While in conventional system design, exchanges between the user and various components of the system rely on the user's initiative and input to drive the interaction; in ubiquitous computing design, this does not have to be the case. The onus might instead be with the system to collect the necessary input from the environment, process it and interpret the results, then determine how to convey them to the user in an ideal manner given the circumstances. This implies that not only users have the problem of bridging the gulfs of evaluation and execution, but in certain situations (which will probably be more prevalent in future), the system may also have the same problem (Schmidt, 2000).

In this section, we look at how work from related literature could complement the "gulf of evaluation," while in the section 5.4, dealing with interaction design, we use it to compliment the "gulf of execution." The quest is to help us to create better ubiquitous computing technologies using scenario-based design.

5.3.1 Perception

Supporting perception is the first step in the gulf of evaluation, and the goal is to encode information being conveyed to the user in such a way that we enable them to quickly see some structure and relationships within this information. Some of the mechanisms at the designer's disposal to help them achieve this include the Gestalt principles (Rosson and Carroll, 2002, p.111).

Moving beyond conventional design and starting to think about ubiquitous computing related issues, additional questions that designers should think about at this stage include:

How does the system direct information (or feedback) to user attention, given that the usage situation and/or goals are dynamic? Or conversely how does the user direct information to the system's attention? Given that multiple interfaces might be competing for the user's attention, on what basis is this attention being allocated?

In the desktop computing paradigm, the concept of a system is very clear; "it is the box sitting on your desk" (Bellotti et al., 2002), while in mobile computing the focus is on having a portable computing device loaded with applications on it to effect user mobility. However, using the ubiquitous computing model, instead of carrying a portable device that contains all your applications, the goal is to have the applications come to the user on whichever device they might have, prefer or be more appropriate under the circumstances. Given that the environment will be permeated with computing power, the possibility of having applications follow the user around is not far-fetched, but will require mechanisms to help detect the location of users as well as those that help migrate running applications from one device to another (Banavar and Bernstein, 2002). In situations where the user initiates and delegates multiple tasks to different applications, they may want to be notified about the outcome "while engaged in other tasks." The system will need to take into consideration a variety of factors to determine how to appropriately provide such feedback (McCrickard and Chewar, 2003).

How does the user know that they have got the system's attention or conversely how does the system know that it has got theirs?

With graphical user interfaces, "mechanisms such as flashing cursors and watch icons" are used to alert the user that the system is responding to their requests and to discern what is going on, all they have to do is to look at the display (Bellotti et al., 2002). It is not too apparent how to handle such issues when dealing with "invisible" interfaces.

Are the various states of information provided distinctive and timely?

Users should be able to easily tell one information state from another to help them quickly perceive changes. With many interfaces competing for the user's attention, care should be taken to draw attention to the most important information under the prevailing circumstances. The ability of information to smoothly transition from the user's periphery to the center of attention when needed and fade back when not in use will be paramount (McCrickard and Chewar, 2003).

Is the system state perceivable at various times during its operation?
Is it easy to recognize when user interaction starts and ends?

Graphical user interfaces communicate system state in a variety of ways that include, "input text and formatting, rubber-banding, wire-frame outlines, progress bars, highlighting changes in a document, listing sent messages and so on" (Bellotti et al., 2002). Interaction is usually user driven with the help of some external device connected to the system like a keyboard or mouse, helping to make the interaction state more apparent at any given time.

5.3.2 Interpretation

Interpreting what has been perceived is the next step in the "gulf of evaluation." Designers usually help users do this by leveraging what the users already know or "familiarity," abstracting information to remove unnecessary details, and providing affordances within the user interfaces (Rosson and Carroll, 2002, p.119).

Questions that will help designers focus on some of the ubiquitous computing related issues include:

Is the system state persistent?

Designers need to take into consideration that users may want some information about events that might have happened over a period of time, probably in the past and provide for information persistence (Bellotti et al., 2002).

Does the system interface provide the necessary affordances? If the interface is embedded into an everyday object, does the new set of affordances cloud those of the *everyday object in its original use? If the interface is invisible, how do we embody its affordances?*

Designers of every day objects use affordances to provide clues on how they could be used. In graphical user interfaces, the visual elements are used to achieve this, suggesting to users various ways that interface components might be manipulated (Norman, 1990, p.9). Embedding interfaces within everyday objects subordinates them to the objects' affordances, making it hard to suggest the new possibilities inherent in these enhanced objects, especially if designers do not want to change their appearances. When interfaces are made to vanish, then embodying the interaction possibilities becomes even harder.

Do the objects (interfaces, artifacts, etc.) leveraged in the system behave in a way that the user is already familiar with?

Rosson and Carroll (2002, p.119) point out the drawbacks in designing for familiarity. While the discussion is related to conventional graphical display interfaces, it can also be applied to ubiquitous computing ones. This is a concept with which designers shall have to push the envelope given the novel nature of ubiquitous computing and the fact that it will inevitably affect more people in the long run.

How do users control or cancel system action in progress?

Users perform actions by manipulating graphical user interfaces with the help of some device like a keyboard or mouse, while getting feedback via dialogue boxes, animated cursors, audio alerts or seeing the results of their actions. Besides providing feedback on the progress of various user actions, these afford the user the possibility to monitor, control, cancel or correct their actions usually through an "undo" function (Bellotti et al., 2002). This visibility helps to inform the user of what is going on, allowing them to control the behavior of the system. Allowing users to control systems with invisible interfaces or those with which they interact in an implicit manner is going to be challenging and will require some tradeoffs.

5.3.3 Making sense

In the final stage of the "gulf of evaluation," the aim is to enable the user to understand what has been perceived and interpreted by relating the information at hand to what they understand about their task, and determining how all this relates to their goals. Designers achieve this by using consistency (both internal to a given application or system and external or across different applications or systems), visual metaphors (when elements look like things in the real world, people expect them to behave in the same way as their real world counterparts) and information models (ways to organize relationships in information to enable users to quickly make sense of large amounts of information) (Rosson and Carroll, 2002, p.125).

5.3.4 Information scenarios and claims

The information scenarios expound on the activity scenarios conveying an information model that is presented to the user. They were influenced by many of the preceding issues discussed within this section. Similar to the earlier design phases, the pros and cons of each information design feature are considered and documented through claim analysis. For the full information scenarios and claims that we came up with, please see appendices A.3.1 and A.3.2 respectively.

5.4 Interaction Design

During information design, design issues revolve around how users would perceive, interpret and make sense of what they see. In this phase, emphasis shifts to action, specifying mechanisms for accessing and manipulating task information to enable people to do the right thing at the right time, with minimal cognitive effort, as they bridge the "gulf of execution" (Rosson and Carroll, 2002, p.159).

5.4.1 Selecting goals

The first step in the "gulf of execution," involves the goal of enabling the user to easily translate their real world goal into something that the system can do. Here, designers have leveraged direct manipulation as the interaction style of choice, mapping interface objects and actions to equivalents in the real world to simplify this process whenever possible (Rosson and Carroll, 2002, p.161).

5.4.2 Planning actions

The second step in the "gulf of execution" entails helping users create a plan to achieve the system goals identified in the previous step. Conventional ways that designers do this is to make actions obvious by emulating real world tasks wherever possible, breaking down complex actions into smaller and simpler pieces, while remembering that people have a limited memory capacity (Hrair's limit), and allowing users the flexibility of pursuing multiple impromptu goals (Rosson and Carroll, 2002, p.164).

In a truly ubiquitous environment, there might be multiple interfaces that allow a user to achieve a goal, as well as multiple ways of interacting with any given interface. Many of these interfaces might be invisible to the user in the literal sense. In addition, embedding user interfaces into other everyday objects with other functions inherits their affordances, which may not necessarily match with those that you would want to provide or portray for the embedded user interface. All these issues make this a critical step in the cycle, where we shall have to come up with more appropriate techniques to help support the user.

Ubiquitous computing related issues that designers should think about during this stage include:

If there are multiple interfaces that can accomplish a user's goal, is this apparent? Are these interfaces visible or invisible to the user? How do they select between them? Is this done for them automatically by the system? If so, on what basis?
If there are multiple ways to input/communicate information to the system, is this apparent? How does user select between them? Is this done for them automatically by the system? If so, on what basis?

Direct manipulation enables system objects that are represented visually in graphical user interfaces to be manipulated in ways that are very similar to how objects are manipulated in the real world (Shneiderman, 1997). While this might be helpful for ubiquitous computing, we have to make sure that users do not run into trouble with computationally enhanced objects because manipulating them to interact with the system conflicts with their normal functional utilization. In situations where interfaces or input modalities are selected automatically for the user, probably taking into account existing conditions, the user should be aware of this and have the means with which to override the selection should the need arise.

If there are multiple actions possible with a given interface, is this apparent? If not, how does user tell which actions are possible with a particular interface? How do they identify and select between potential actions?
How does the user handle complex operations that involve multiple actions across multiple interfaces?

In graphical user interfaces, possible actions are externalized in the form of commands accessible from a drop-down menu or list. This easily allows the user to determine how to instantiate given actions. For ubiquitous computing, explicit interaction requires that we have some methods that convey to the user the action possibilities, how these could be effected and their scope controlled (Bellotti et al., 2002).

5.4.3 Execution

In the final step of the "gulf of execution," the user performs the plan conceived in the previous step to achieve the system goal. Given that the system goal may essentially be just one step in the user's overall goal, providing feedback to the user is paramount. Feedback might just let them know how they are progressing, or it might indicate the success or failure of their last actions, helping them understand what actions they need to do next to achieve their overall goal.

In conventional design, we allow for users to undo their actions. This inevitably will also be expected of ubiquitous computing systems as well, although balancing the tradeoffs will be more arduous. Although interacting with systems in an implicit manner might be more efficient, we will undoubtedly have to figure out ways to inform the user of what is going on, allowing them to control the behavior of these systems. Otherwise, how will the user know that the intermediate actions taken by an invisible interface of a system, with which they are interacting in an implicit manner, has performed the wrong action, so that they could correct it? Do they have to wait for the result of a whole sequence of actions to manifest itself in their environment before they can tell that something went awry? How should they determine which of the intermediate actions went wrong? These are some of the issues which we have to grapple with as ubiquitous computing moves into the mainstream (Rosson and Carroll, 2002, p.171).

Designers should think about several points in order to help users through some of these issues:

Is the execution explicit or implicit? If it is implicit, how can designers avoid the system misunderstanding user behavior? Does the environment or the act of interaction generate noise? How does the system disambiguate between noise and actual input?

Explicit interaction has the advantage that it is user driven, helping to reduce misunderstandings between the user and the system. Implicit interaction, on the other hand, has more potential and the ability to free up the user for more important tasks. While many applications will combine both types of interaction to help balance their limitations in the interim, the balance should shift more towards implicit interaction as our environments become more computationally complex (Schmidt, 2000). Despite the promise inherent in implicit interaction, system resources have to be expended to collect the necessary information from the environment using a variety of sensors, interpret the collected information so that the system or various applications can make of use it. Owing to the ambiguity that usually accompanies people's actions, care should be taken to mitigate failures that may arise out of the system being unable to pick up the necessary input either as a result of signal noise or failure of some of its components (Satyanarayanan, 2001; Bellotti et al., 2002).

How does the system intervene when the user makes obvious execution errors?
How does the user control or cancel system action in progress?
Does the system provide for users to undo their actions? At what level of granularity?
Does it determine the scope or extent of undoing an action the system state?

With graphical user interfaces, the result of user actions is usually displayed. When errors occur that are not easily corrected during execution, they are easily apparent, enabling the user to correct them usually through an "undo" function (Bellotti et al., 2002). Given that a complex task is usually divided into smaller sub-tasks, with the output of one used as input for the next, it is easy to control the process and determine when errors occur. This allows the user to know where the error occurred and to easily correct it. Compare this to a ubiquitous computing situation, where the user makes a request using a particular interface, then moves on. The system processes the request then tailors and forwards the output to their new location and a different device. If the user were to determine that an error occurred, it is much harder to know exactly where it happened and presumably may be harder to solve (Siewiorek, 2002).

5.4.4 Interaction scenarios and claims

The interaction scenarios provide user interaction details, describing system inputs and outputs. Similar to the earlier design phases, the pros and cons of each information design feature are considered and documented through claim analysis. For the full interaction scenarios and claims that we came up with, please see appendices A.4.1 and A.4.2 respectively.

5.5 Discussion

Like other user-centered design approaches (Norman and Draper, 1986), scenario-based design places the design focus on the end user rather than the technological aspects of the system. Scenarios aid the designers in conceptualizing activities through their interpretation, enhancing design and evaluation decisions, and providing a foundation for design rationale (Carroll, 2000).

As ubiquitous computing permeates our environment and becomes the norm, there are bound to be more significant social effects, compared to the spread of the now conventional desktop computing paradigm. Researchers postulate that new ways of action and interaction will emerge (Dryer et al., 1999; Banavar and Bernstein, 2002; Grudin, 2002; Jessup and Robey, 2002). Scenario-based design can enlighten us on how relationships between people and devices might evolve by focusing on the goals they pursue with the help of these devices. It has the capability to give us insight into the resulting relationships between co-located people or system mediated human-human relationships that emerge, providing us with some mechanism with which to better understand the effect of our proposed systems on existing social behavior. This understanding of the impact on social behavior will be an important component for success of ubiquitous computing.

By focusing on tasks that the user performs to achieve their goal, scenario-based design enables us to create more usable systems. But as more everyday objects within our environment are imbued with computational power, researchers are beginning to look beyond usability. Hallnäs and Redström (2002) poignantly argue that, designers of these systems will need to look beyond mere "*use*"—functional aspects of their systems. Instead, they implore consideration of "*presence*," which they define as the "existential definitions of a thing" based how we invite and accept it into our lives. They make strong arguments for rethinking traditional human-computer design and evaluation as "computer systems change from being tools for specific use to everyday things present in our lives," and the need to "change focus from design for efficient use to design for meaningful presence."

Besides usability and presence, there is a need to investigate other factors that could be incorporated into the scenario-based design process to enable creation of better ubiquitous computing systems.

Drawing on the background that we laid in Chapter 2 and Chapter 3, and the various studies that we have compiled together all through this chapter from various disciplines, we propose an augmented scenario-based design process that is more suited to the design of ubiquitous computing systems. We hypothesize that it will lead to more successful ubiquitous computing designs because it facilitates designers to consider issues relevant to ubiquitous computing during the various design stages. We setup a study to test this hypothesis and the results are reported in Chapter 6. For a summarized version of the augmented scenario-based process, please see appendix C.4.

The user interface as we know it will disappear, becoming more intelligent and distributed, made up of many objects that are not necessarily seen as "access points" to the system by the user. Interaction with such interfaces will tend to be implicit—allowing the system to interpret the user's behavior and actions based on their context, as opposed to current explicit interaction, where the user tells the computer what to do. With more computing power spread within our environment through the interconnection of various devices and objects, there are bound to be many processes or applications competing for the user's limited attention. Various components of the system will behave like notification systems, providing the user with multiple sources of information while they are engaged in other tasks. Awareness of the user's situation and ability to "adapt information delivery to avoid overloading the user" could determine which systems succeed on the market (McCrickard and Chewar, 2003).

As we pursue the notion of invisible interfaces and the benefits inherent in implicit interaction, we should remember that users need to be aware of what is going on in the background and possess the means to influence system action should the need arise.

Notes

[1] Community members interested in conserving the Brown farm park have got an organization—Friends of the Brown Farm Nature Park to protect and guide the development of what they refer to as a "valuable community resource." Their website is online here.

[2] A copy of the workshop position and presentation given at Ubicomp 2002, workshop on User-Centered Evaluation of Ubiquitous Computing Applications is available with other workshop proceedings here.

[3] A workshop on Concepts and models for Ubiquitous Computing was held at ubicomp 2002, in Göteborg, Sweden. Although the results have not yet been published, position papers and presentations are available online here.

Chapter 6

Generating Conceptual Prototypes

6.1 About the Experiment

As outlined in section 1.3, we hypothesize that scenario-based design has got the potential to respond to the challenge of designing successful ubiquitous computing technologies. Although we do not know of any designers that have put it to such use yet, we think that this should be possible given its nature and some of the advantages that it provides (Carroll, 2000; Carroll and Rosson, 2002). By focusing the design process on the end user and their needs rather than the technology, the process allows designers to envision user activities and appreciate their usage context. This will result in not only more usable systems, but systems that support and conform to people's natural social behaviors and are thus more socially acceptable.

6.1.1 Purpose of experiment

This experiment is a pilot meant to validate our hypothesis that scenario-based design can be used to successfully design ubiquitous computing technologies. In the study, we compare scenario-based design to an adhoc process, where designers are provided no particular instructions on how to come up with a conceptual design prototype for a given problem. To put things in perspective, we also compare the conventional version of scenario-based design to the augmented version described in Chapter 4 to determine if there is any added utility when designers think about the problem, taking into account issues specific to ubiquitous computing design.

6.1.2 Brief outline of experiment

Using different methods, participants were given a similar design problem to solve. They were required to come up with a conceptual design idea addressing the needs reflected in the problem. They were asked to communicate their idea in the form of a narrative describing how potential users would interact with their solution, in addition to simple paper mockups about their concepts and ideas wherever possible. With the help of a questionnaire, we collected some feedback from the participants about their particular process, in helping them to come up with a solution.

The designs from all the participants were then collected together and given to reviewers who were asked to determine how well they addressed the design problem and their potential for success. The solutions were blinded, such that the reviewer would not have any clue as to the process used in coming up with the design. The review process was based on a grading mechanism designed by the experimenters.

6.2 Methodology

6.2.1 Participants

For the study, we sought participants who had some system/interface design experience , so we concentrated on senior undergraduate and graduate level students. 15 senior level or graduate computer science students voluntarily participated in the study for free. Of these, 5 were female and 10 males, ranging in age from 20 to 38. They were all familiar with computers and reported owning a variety of computing devices that include cellular phones, video cameras, personal digital assistants (PDAs), MP3 players and discmen, as well as personal computers at home. They all reported having heard about ubiquitous computing before and rightly defined what they understand by the term, although, two thirds of them knew about and rightly described community computing. About half of them (7/15) reported that they frequently eat out at local restaurants, some did occasionally (4/15) and others seldom (3/15). Only one participant reported that they almost never eat out. This question was included, since the design problem pertained to helping a potential user in determining the ideal place to eat out given a set of circumstances. We wanted to see if any correlation would emerge between those who eat out frequently and the score of the resulting solution.

For the review process, participants are PhD students in computer science. They all specialize in human-computer interaction and have significant experience building and evaluating user interfaces. 2 of them are male and one is female.

6.2.2 Study session

Sessions were run with an individual participant at a time, although each session was conducted in an identical manner. During an experimental session, after having completed the informed consent form and pre-test questionnaire that was available online (see appendix C.1), a participant is taken through a brief introduction to ubiquitous computing using a power point presentation. They are then given a problem scenario (see appendix C.2) and asked to come up with a potential prototype solution that leverages ubiquitous computing technology using a particular design process.

The problem scenario (see appendix C.2) was specifically selected to include a range of issues that would best be addressed by a ubiquitous computing solution. These include dynamic goals and usage situations in addition to a combination of static and dynamic information that is available in specific locations. The participants were encouraged to think about and support the kind of social interaction that normally occurs within the given situations even without the help of technology.

Three different design processes were used in the study, these included:

- *SBD*—the conventional scenario based design process, with an emphasis on the information and interaction design stages. For the summary provided to guide participants, see appendix C.3.
- *Augmented SBD (SBD+)*—the version of scenario-based design augmented with ideas from other places to make it easier to identify ubiquitous computing related issues. For the summary provided to guide participants, see appendix C.4.
- *Adhoc*—here participants were given no particular guidance on how to come up with a solution.

All the participants that used either the SBD or the augmented SBD process had taken at least one course in scenario-based design for class credit and were randomly assigned, while those that used the adhoc process had taken no scenario-based design courses, although they had adequate system design experience. To facilitate participants that were not familiar with scenario-based design, some of the important issues that needed to be addressed were extricated from the problem scenario and presented as a design problem alongside (see appendix C.2).

The output from each participant session was a narrative (or interaction scenario) describing how potential users would interact with their prototype solution. They were encouraged to include simple paper mockups as well as sketches to show their concepts and other interesting aspects about their solutions like the exchange of information between the users and the system. The participants were provided with lots of plain paper, a set of highlighter markers and pencils, and encouraged to mark up the problem scenario or design problem as they read it. They were free to write out or type their narrative using a word processor on the computer before them, as long as they referenced whatever sketches they made to allow the reviewers to easily relate them to their narrative.

Participants concluded the session by answering a post-test questionnaire online (see appendix C.5) that was designed to collect some feedback on how useful or relevant they had found the particular design process they used in coming up with a solution prototype. We were also interested in how confident they were about their potential solution to the problem. They were encouraged to ask questions or seek clarification at any time during the session, which on average went on for about an hour and fifteen minutes.

6.3 Review Session

All the solutions were then put together and given to three independent reviewers, who then ranked them by answering a series of the same questions about each of the designs using a 5-point likert scale (1-5). The scale ranged from strongly disagree (score of 1), disagree (score of 2) through neutral (score of 3) to agree (score of 4) and strongly agree (score of 5). The grading mechanism (see appendix C.6) was designed such that each solution got a score from each question depending on how positive the reviewer answered any particular question, but the reviewers were unaware of this. In the end, a score is generated automatically that indicates how appropriate a given solution matches the design problem according to the reviewer. Scores from the three reviewers were averaged to determine the final score for each solution. The higher the score, the more appropriate the design was found to respond to the design problem by the reviewers as a team.

The grading mechanism is a modification of the social computing checklist proposed by Dryer et al. (1999). The modifications are made to reflect the issues deemed important by many of the researchers in the ubiquitous computing area. These are discussed in sections 3.2 and 3.3 above. The checklist is put forth as a tool to assist designers in coming up with successful social computing technologies, to which we think ubiquitous computing duly belongs. In their studies, they seek to understand the mechanisms through which mobile devices can affect social relationships. Although it focuses on the interaction between two people, one using a mobile device and another who is not, with the user of the mobile device being the primary focus of these mechanisms. We think, this can be easily applied to help us understand some of the desirable characteristics of successful ubiquitous computing technology.

6.4 Results

In general, the results of the study support our hypothesis. Participants using the augmented SBD process had an average score per question of 3.51, with standard deviation +/– .91, performing better than those using the adhoc or conventional SBD processes. The participants using the adhoc process had an average score per question of 3.30, with standard deviation +/– 1.04 while those using conventional SBD had an average score per question of 3.12, with standard deviation +/– .94. The difference among the processes was significant based on a single factor ANOVA ($F(2,446) = 5.84$, $MSE = 5.61$, $p < 0.05$) between the three groups of review scores.

Despite the significant difference between the three processes, we are discouraged by the fact that the average scores for all the processes are barely above neutral (score of 3). We decided to investigate further to try and get a better picture, comparing the augmented SBD process directly to each of the other two processes.

Comparing the augmented SBD to the adhoc process, participants using the augmented SBD process performed better than those using the adhoc process. They had an average score per question of 3.51, with standard deviation +/- .91 verses an average score per question of 3.30, with standard deviation +/- 1.04 achieved by those using the adhoc process. This is only a marginally significant difference based on a single factor ANOVA ($F(1,297)= 3.218$, $MSE = 3.131$, $p = 0.074$) between the two groups.

On the other hand, participants using the augmented SBD process performed better than those using the conventional SBD process. They had an average score per question of 3.51, with standard deviation +/- .91 compared to an average score per question of 3.12, with standard deviation +/- .94, achieved with SBD. The difference is significant based on a single factor ANOVA ($F(1,297)= 12.136$, $MSE = 11.213$, $p < 0.05$) between the groups.

Analyzing the individual questions, augmented SBD performed better than the other two processes on six out of the ten questions and tied for the best with another process on two questions. A complete picture of how each of the processes performed with a given question is summarized in Table 6.1 below.

Table 6.1: Average responses from the reviewers for each of the questions along with the standard deviation are shown for each of the processes. The highlighted cells indicate which process performed better of the three, for a particular question. For the actual questions, please see appendix C.6.

Question	SBD+	SBD	Adhoc
Q1	3.60, +/- .83	3.20, +/-1.32	3.20, +/-1.08
Q2	3.47, +/- .83	2.73, +/- .88	3.13, +/-1.06
Q3	3.80, +/- .56	3.60, +/- .74	3.47, +/-1.06
Q4	3.47, +/- .83	3.07, +/- .88	3.57, +/- .85
Q5	3.33, +/-1.05	3.53, +/- .83	3.40, +/-1.06
Q6	3.47, +/- .99	3.47, +/- .74	3.33, +/- .98
Q7	3.80, +/-1.08	2.87, +/- .99	3.27, +/-1.16
Q8	3.40, +/-1.12	3.07, +/- .88	3.27, +/-1.10
Q9	3.00, +/-1.07	2.33, +/- .82	3.00, +/-1.00
Q10	3.73, +/-1.03	3.33, +/- .98	3.40, +/- .99

6.5 Discussion

While the pilot study has provided some indication that we are on the right track, we noted that the average scores for all the processes are just above the neutral score (3), despite the significant difference between them. A look at the individual scores emphasizes this point as well, in the two questions (Q3 & Q7, see Table 6.1 above) where augmented SBD performed the best, it achieved a score of 3.8 out of a possible 5 points. This all points to the reality that while this is a good beginning, there is still plenty of work that still needs to get done. The average scores could also be a result of the short length of time that was used by the participants to come up with the concepts

Looking at the overall picture, the augmented SBD process did not perform well in the areas addressed by questions 4 and 5. Question 4 probes whether the proposed system leverages artifacts/objects/interaction modalities that are appropriate for proposed system's context of use, while question 5 addresses the proposed system's ability to provide easy and natural information input without undue effort from the user. The capability of the process to address such issues will need to be enhanced.

Running subsequent review sessions with a 7-point likert scale is a logical progression that might help clearly highlight the differences between the processes, isolating the specific areas that need more work.

An aspect of our study that perplexed us was the fact that participants using the adhoc process seemed to perform better than those using SBD. One explanation could be the fact that in the latter case, participants are constrained to follow a process that in no specific way aids them to think about the issues relevant to ubiquitous computing as opposed the former case, where they have a free reign.

Chapter 7

Conclusions

Many researchers point to the trend towards ubiquitous computing as one of the next big steps in computing. They agree that it has the potential to profoundly change the way we live by revolutionizing how we interact with information. Despite all this optimism, there are barely any successful applications that have made the transition from the laboratories to the mass market. While this could easily be attributed to the immaturity of the research area, it is also a manifestation of a big problem—the lack of a coherent process that allows designers to think about the issues pertinent to ubiquitous computing, as they explore and develop potential ideas into working prototypes.

Research in ubiquitous computing presents a whole new set of challenges that differentiate it from most of the other computing challenges that we have had to deal with. Eminent among these, is the need to support dynamic user goals as well as usage situations, which are entwined in a complex social environment. Besides compelling us to rethink many of the basic things that we currently take for granted, like how users should interact with a system, we have to contend with how to design new systems and user interfaces that support mobility, as opposed to sedentary use. These systems are "invisible" as opposed to being in users' faces all the time, supporting multiple devices as opposed to a single device. They allow multimodal interaction verses one or two modalities, and implicit interaction, as opposed to always having to wait for or rely on the user to directly provide input. Many of these challenges are elaborated in Chapter 3.

The ultimate ambition of ubiquitous computing technology is to be able to serve users anywhere, at anytime. However, taking into account the dynamic nature of user needs and usage situations, is a novel and non trivial undertaking. In essence, it is a fundamental change that requires designers to rethink many of the conventional answers and processes that help guide the creation of interactive systems.

7.1 Our Contributions

The main contribution of this work is in two areas. First, we provide a compilation and categorization of the characteristics that differentiate ubiquitous computing from the norm, and illustrate through a case study how these manifest themselves in issues and challenges that need to be addressed. Secondly, we provide a process—an augmentation of scenario-based design, that promises to help designers create more successful systems by enabling them to thing about the issues that are pertinent to ubiquitous computing.

7.1.1 Issues and challenges of ubiquitous computing

In Chapter 3, we present a collection of important characteristics of ubiquitous computing as identified by the leading researchers in the area. We discuss the resulting issues and challenges, putting together various viewpoints published in literature and speculating on their implications on the future directions of this emerging research area. Implications of some of these issues on the perspective of community computing is highlighted.

In Chapter 4, we carry out a study to better understand how computationally enhanced everyday objects can double as user interfaces and how conventional HCI usability notions might impact their use and adoption. Our emphasis is on how these are employed to convey different types of information, given that people might not expect to find computational functionality in these objects or be able to understand the conveyed information. While we found that many users will not find it hard to transition from the standard use of some these everyday objects to using them as computational displays, we could not readily predict their adoption based on the conventional usability notions. This empirically validates research that suggests other non-functional related aspects might have a role to play here.

7.1.2 Augmented scenario-based design

In Chapter 5, an augmented scenario-based design process is presented. Besides helping the designers conceptualize user activities within given usage circumstances, it can enlighten us on how relationships between people and devices might evolve. In addition, designers are able to think about aspects relating to ubiquitous computing at various stages of the design process, ensuring identification of the most common pitfalls. This enables production of systems that are more socially acceptable, perhaps providing a higher likelihood of adoption by everyday users beyond the laboratory. The process is used to walkthrough the design of a community network application prototype that leverages ubiquitous computing technology to allow shared access for community members in their "third places" or on the move (see Appendix A for details).

In Chapter 6, a pilot study provides some insight on how the augmented scenario-based design process compares to an adhoc process, where users are given no particular guidance on how to come up with a conceptual design to the same problem. The augmented process is also compared to conventional scenario-based design for the same problem scenario to determine whether there is any added benefit from augmenting the process. While the results show that augmented scenario-based design produced significantly better designs than the other processes, it is worthwhile to note that the average per question scores for all three design processes compared average barely above neutral (a score 3 out of a possible 5) on the social computing checklist. We have interpreted this to mean that, while this is a good beginning, there are still many aspects of the process that can be further improved.

7.2 Future Work

In the first study, we looked at the use of computationally enhanced everyday objects to convey different types of information and the ability of users to understand it. A natural progression would be to look at how people could actually use some of these objects to interact with a system, particularly given that they might already have a prior use function. For example, I normally use a chair for sitting, how could I use it to interact with a system? Should we restrict the use of these objects to aspects that relate directly to their function? (For example, should only the act of sitting have a meaning in the case of chair) Or can we come up with a set of interaction modalities that relate to a given group of objects? While the former is already being explored because of its inherent naturalness, it could prove limiting in future.

Another aspect that emerged in the first study and is beginning to receive attention in HCI literature is the notion that successful design of everyday objects used as computational interfaces requires designers to think beyond the common notion of HCI usability. Although this is a complex area, which we might not be able to understand until much more research, researchers are already scratching the surface by to exploring aspects like presence (Hallnäs and Redström, 2002), pleasure (Jordan, 2000), emotion (Lisetti and Nasoz, 2002; Norman, 2002; Battarbee, 2003), and other facets of human nature. Aspects to keep in mind here include the fact that either the interface or the user could be the channel of these phenomena, and the presence of co-users or co-present people might have a role to play too.

To assist further development of the augmented scenario-based design process, we need to take it through the rigors of developing an actual working system prototype. This will provide first hand experience of its adequacy as an aid to the design process. The evaluation challenge of ubiquitous computing systems still persists, mainly because the effect of actual use situations is very difficult to recreate in lab settings. Researchers are exploring various ways to overcome this (Bødker and Buur, 2002). When fully developed, augmented scenario-based design might have a role to play here, since potential problem areas could become apparent or be identified through the enactment of scenarios. This might highlight areas that need more scrutiny, helping the designer with some clues about what to look for when they go out into the real world.

These ubiquitous computing issues and others that will emerge as the research area matures could be compiled into a checklist, which can be used as aid to whatever design process that is employed. Such a checklist could further be used to develop heuristics that are valuable to designers in the formative evaluation stages of an iterative design process.

The desktop metaphor (despite its short comings) and the creation of consistent rules and operating systems for applications have helped drive the fast development of applications on PCs. People find it easier to apply knowledge learned from one application to a new one because of this. Interaction is more or less standard using a mouse and keyboard.

In the ubiquitous computing world, we envision multiple different types of devices that do all sorts of things. Are we ever going to have some form of convention regarding interaction or application development, so the knowledge that people learn from using some devices can be carried to others? If so, what will it be? Will we ever have some form of metaphor to guide designers?

Appendices

Appendix A

A Conventional Scenario-Based Design Prototype

In this appendix, we employ scenario-based design to walkthrough the design of a community network application that leverages ubiquitous computing technology to allow shared access for community members in their "third places" or on the move. Various portions of this appendix appear in Chapter 5, but have been repeated here for the sake of completeness to allow the reader to go through the whole process without having to switch between sections.

A.1 Requirements Analysis

This process usually starts with a root concept, which usually helps outline the project's high level goals. It may include "a project vision and rationale, an analysis of project stakeholders, and an acknowledgement of starting assumptions that will constrain or guide the development process.". It is developed to summarize the key aspects of the planned application or system and helps guide the field studies that ensue. The field studies are carried out to acquire a better understanding of the stakeholders, their environment, and the actions in which they engage to achieve their intended goals. The collected information and artifacts help in the creation of problem scenarios, which put the tasks learned from the field studies into context and their claims, which identify interesting features or those with important effects on the actors (Rosson and Carroll, 2002, p.37-47).

A.1.1. Root concept

This is developed to summarize the key aspects of our planned application.

Table A.1: Our root concept and some of its constituent components.

Component	Contributions to the Root Concept
High-level vision	To allow Blacksburg residents to participate more in the issues that relate to the way their community is governed by making it easier for them to access community related information at any time, in a variety of places, using a variety of devices
Basic rationale	By enabling easier shared-access in community "third places," this

	will provide a framework for discussion to reflect on the most current issues of interest within the community. Feedback can be directly incorporated into the system helping to enhance social interaction and making the community network more relevant
Stakeholders	
Local authorities	Provides them with a mechanism to communicate to members about intended actions in order to get feedback, enabling them act in the interests of the community
Community members	Provides them with convenient access to local government plans, allowing them to provide feedback to guide them
Starting Assumptions	A range of wireless networks already exist within the town of Blacksburg. They are interconnected to cater for various connectivity requirements Users already own a variety of handheld devices that they are already comfortable using. These range from cell phones to PDAs Owing to the success of the BEV project, the use of computers and the Internet is pervasive. Most people have the necessary basic computer skills

The list of stake holders identified above is pertinent to our scenario, and is not intended to be exhaustive. It is only a typical cross-section of the potential users of our envisaged application in the town of Blacksburg.

The assumption of the existence of a wireless network within the town of Blacksburg is not such a big stretch of imagination. There is a growing “not-for-profit” movement to create community–owned wireless networks in many towns and cities across the world. They are generally free and locally owned, operating in an unlicensed portion of the wireless spectrum on standards-based radio frequency technology and driven mainly by volunteers. They do not currently have any business model and seem to be motivated by people eager to exercise their telecommunications freedom.

Some of the famous ones include the Seattle Wireless Network[1], NYCWireless[2] in the New York City metro area, and Mesh Madison[3] in downtown areas of Madison, Wisconsin. While some of these like the Seattle Wireless Network and Mesh Madison are interested in connecting people within their locality by encouraging members to purchase the necessary equipment to join the network, others like NYCWireless are more philanthropic in the sense that they provide open wireless hotspots in public spaces with free internet access for anybody who has the proper equipment. They manage to do this by generating funding from both public and non profit organizations. Despite the differences, their goals are similar; they are all intent on building a "free" wireless network to cover their communities in a decentralized and distributed manner with individuals providing and caring for their "own parts." This is stimulating the creation and distribution of content and services local and pertinent to their communities.

A.1.2. Artifacts

These are some of the pieces of information that are used or created in the process of performing work activities as well as some of the tools that used. Various artifacts used in the zoning and sub-division of land as well as its development in the town of Blacksburg were collected. Some of these are shown in the figures below.

Figure A.1: The Town Council homepage of the town of Blacksburg. It provides an agenda for the upcoming meeting, minutes of previous meetings, information on council members along with their contacts.

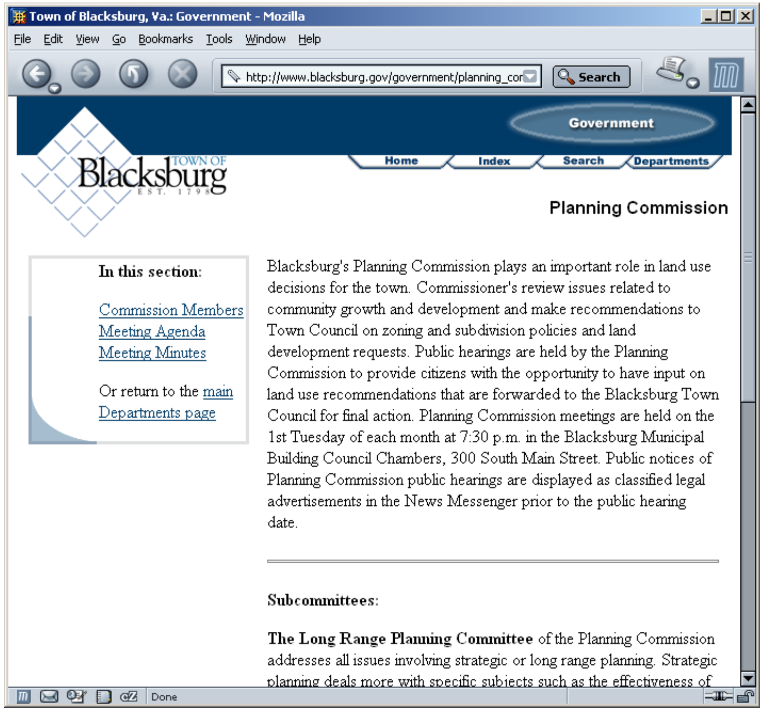

Figure A.2: The Planning Commission's [homepage](). They are responsible for liaising with the community about land use and development related issues, and make recommendations to the Council on land development requests. It also provides an agenda for the upcoming meeting, minutes of previous meetings, and information on council members.

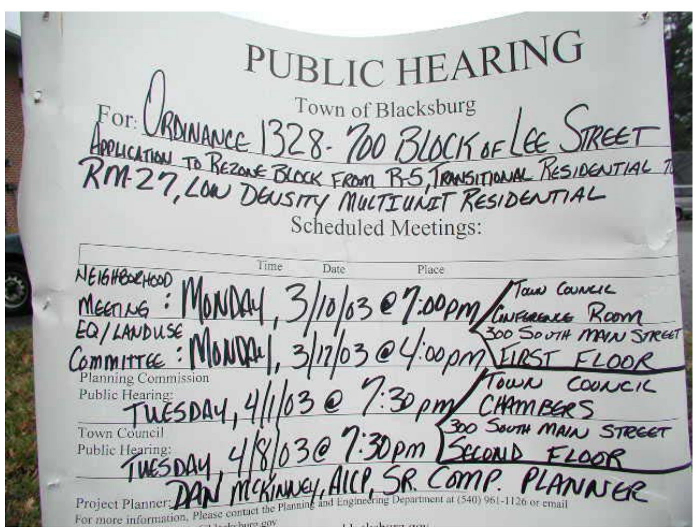

Figure A.3: A typical poster usually placed by the roadside in a community to announce upcoming public hearings on various land related rezoning or development issues.

A.1.3. Problem scenarios

These are stories of current practice, carefully crafted to reveal aspects of the stakeholders and their activities with implications for design in the current problem domain (Rosson and Carroll, 2002, p.64). The actors and situations in the scenarios that follow are entirely fictional.

John – the community member

John and his friends usually meet down at the *local bar* for an evening drink at the end of each week. They use this time to catch up on things that have happened in each other's lives as well as to discuss interesting developments within the community. He is an avid conservationist at heart and enjoys hiking out in the woods and biking along the scenic trails.

While he is driving home from work, he sees a *poster by the road side*, in the neighborhood. It is *announcing a public hearing* about the *impending rezoning of part of Brown Farm Park* by the *local council*. He notices the *date* and makes a *mental note* to attend, having heard that the planning commission is considering rezoning part of the park from a recreational zone to a commercial one. He is worried that this could be the beginning of the end of his beloved park. Unfortunately, he *forgets to add it to his schedule* and never attends the hearing because of his busy schedule.

A few days later, on his way from work that Friday, he learned about what transpired in the public hearing on the *impending rezoning* by the local authorities over the local *radio station Q99*. From the *broadcast* it seems that the majority of the people who were present seemed to favor the rezoning of the park in order to allow commercial development. He *resolves to do something about it*, deciding to later bring up the issue with his friends later that evening at the bar.

At the bar, he raises the issue with his friends, most of whom share his interest for the outdoors, pointing out the negative aspects of rezoning the park. He *described what had happened to other parks that had been partially rezoned in other neighboring places*. An enlightening discussion then ensued, drawing in other people at the bar. In the end, they were all convinced that this might not be a good idea after all, they resolved to petition their local representatives by *writing letters and making phone calls* to air their views in the hope that they can influence the imminent decision by the *local council*.

James – the local council employee

James works with the local council. He is in charge of community public relations for the Blacksburg Planning Commission. It is his responsibility to disseminate information relating to zoning and other land use policies to members of the community.

Currently before the planning commission is the issue of *rezoning of part of Brown Farm Park* into a commercial area, which seems to have galvanized the members of the community. There seems to be as many people for as there are against the idea. As usual, a public hearing has been organized to take place in the next few weeks. He put up the announcement for this meeting on the departmental website, earlier than he usually does, so that community members can schedule time to come and air their views on this contentious issue. To get more representation, he decides to print more *posters and newspaper notices* than usual and makes a decision to put more announcements on the local *radio*.

On the day of the public hearing, fewer people turn up, than he had expected. At the end of the hearing, he updates the *departmental website* with the minutes of the meeting.

A.1.4. Problem claims

Scenario writing is combined with claims analysis, this enables the investigator to identify features that are interesting or have important effects on the actors. The potential good or “desirable consequences” and bad effects or “undesirable consequences” are identified (Rosson and Carroll, 2002, p.73).

Table A.2: Claims analyzed in the development of the problem scenario. The plus signs (+) are the “pros” or “upsides” of a feature, while the minus signs (–) are the “cons” or “downsides.” Together they highlight the tradeoffs associated with each feature.

Situation Feature	Possible Pros (+) or Cons (–) of the feature
Meeting at the local bar at the end of each week	+ enables members to catch up on what is happening in each others’ lives + enables members to learn about other things happening in the community that they may be unaware of + provides an excellent opportunity to engage members together on communal issues, which they could discuss to reach some

	consensus
Use of posters by the roadside to announce public hearings	+ allows local authorities to get information about upcoming public hearings to more members – but they are easy to miss, since many members just drive around in vehicles – but it is easy to forget, since members who see them can not easily jot it down anywhere
Use of the radio or newspaper notices to inform members about upcoming meetings and a summary of the proceedings of completed ones	+ allows members to learn about upcoming meetings in advance so that they can include them in their schedule, if they want to attend + allows members who were unable to attend the public hearing to learn about what transpired – but not all members listen to the radio or read newspapers – but none provides an interactive medium, information flow is usually moves in one direction only, to the listener or reader
Bringing up the issue of rezoning at the bar	+ allows members who might be unaware of it to learn about it – but it might be heard to convince skeptics, since you really don't have evidence
Petitioning local representatives by writing letters and making phone calls	+ helps to get the views of the community to their local representative so that they may be taken into account + since action is taken by individual alone, later on, it eliminates undue influence form other members who might be over bearing – is an involved process that may need someone to set aside extra time to write, call or visit the local representative or office – people may forget about it or never find the time to act later on, even if they were seriously concerned about the issue in the bar
Using the departmental website to announce upcoming meetings and proceedings of past ones	+ allows members who visit the website to learn about upcoming meetings + allows members who miss meetings to follow proceedings by looking through the archived minutes – but not all community members have access to the internet – but to get information requires a community member to go out

	actively seeking information

A.2 Activity Design

In this phase of the project, the system was influenced by the consideration of some of the existing technology like cellular phones, so that people do not have to entirely invest in new technology. Existing metaphors and interaction modalities are used to inspire non-obvious reasoning and to ensure that users do not have to learn many new skills in order to interact with the system.

A.2.1. Conceptual Metaphors and System Technology Options

A metaphor is a known concept used to understand a new concept by analogy. They are often used when learning to interact with systems, since it is easier to understand new ideas when they are similar to familiar concepts. For example, a user may rely on pieces of a store metaphor (cashier, shopping cart) to understand online shopping or writing metaphor to understand how to use a stylus. Metaphors not only simplify initial comprehension and use, but can also be useful in design brainstorming, when people seek to generate completely novel ideas. Different metaphors can often be mixed or composed into a single coherent concept. Many of the conceptual metaphors that helped us to brainstorm the core functionality of the petition application come from real world activities.

Table A.3: Conceptual metaphors for the activities and objects in the petition application.

Activity	Real-World Metaphor	Implications for Petition Application Activities
Subscribing to an information channel is like…	Using an automated telephone service	Dial a number, follow voice prompts and use the phone keypad or voice to navigate menu
	Subscribing to a magazine	Provide personal contact details, indicate how often and the form (hardcopy or electronic) in which you want to receive the magazine

Receiving information from an information channel is like…		
Accessing the petition system is like …	Entering a secured building	Personal identification is required
	Using a debit card	Swipe it through a card reader and provide enter your PIN
Creating a petition is like …		
Using you voice as input is like speaking to…	Someone	Audible, clear voice, distinct from the background noise, get feedback
	Microphone	
Editing text is like writing a…	letter	Use of your hand, require something to use to write (pen, pencil…) and something to write on, usually paper

System technology options are familiar or innovative information technologies that can serve as a type of metaphor for how a user may think about using the interactive system being designed. In our case, examples include using a mailing list, stylus, word processor, or login into a computer. An exploration of system technology options can lead to specific ideas about the content and structure of various elements of the interactive system.

Table A.4: System technology options for the petition application system.

Activity	Information Technology	Implications for Petition Application Activities
Subscribing to an information channel is like using a…	Mailing list	Send a subscribe command to the list you are interested in
Receiving information from	Mailing list	Information goes out to everybody on the

an information channel is using a…		list
Accessing the petition system is like…	Login to a computer	User ID and password are required
	Using a debit card	Swipe it through a card reader and provide enter your PIN
Using you voice as input is like speaking through a …	Microphone	
Editing text is like using a…	Stylus	
	Word processor	

A.2.2. Activity Scenarios

John – the community member

Background on John and his motivations….

While he is driving home from work, he sees a *poster by the road side*, in the neighborhood. It is announcing a public hearing about the impending rezoning of part of Brown Farm Park by the local council. He looks for the *date* and a *phone number to their information channel.* He *dials the number from his cell phone and follows the voice prompts to subscribe to the Planning Commission's Information Channel.* He requests to receive *regular email updates about the issue and sets up an SMS*[4] *(Short Message Service) alert* to later remind him about attending the meeting. Having heard that the planning commission is considering rezoning part of the park from a recreational zone to a commercial one, he is worried that this could be the beginning of the end of his beloved park.

A few days later, while he is away from his office, he receives an *SMS reminder* to attend the public hearing, but unfortunately he can not go to the meeting due to a busy schedule. Later when he returns to his computer, he finds an *email update* with the minutes of the meeting. From the minutes, it appears that the bulk of the people present supported the rezoning. Knowing that there were many more people out there in the community, who felt like him, he resolved to do something about it, and promised himself to bring up the issue with his friends later that evening at the bar.

At the bar, he raises the issue with his friends, most of whom share his interest for the outdoors, pointing out the potential negative aspects of rezoning the park. Seated around the *large interactive touch-screen display* in the corner of the bar that usually displays current information from the community network that is new or of interest to many members, he brings up the Planning Commission's website to show his friends what transpired at the meeting. He describes what has happened to other parks that had been partially rezoned in other neighboring places, some of which have had to be fully rezoned eventually because of the arising challenges. He shows them a number of *reports online from some of these other places* to prove his point. An enlightening discussion then ensues, drawing in other people at the bar. In the end, they are all convinced that this is certainly not a good idea after all, they resolve to create a *public petition and to get as many local members to sign it* to get their views to the town council members to reverse the imminent decision.

John *uses his driver's license to authenticate himself* in order to get access to the public petition system provided by the community network. He quickly creates the petition by *dictating into a microphone on one side of the display*. His colleagues suggest changes and corrections, which he makes *using a stylus*. Satisfied with everything, most people in the bar start to sign the petition in a variety of methods, *some sign up on the interactive large screen display, others just send SMS to the system, while others use their cell phones.*

When he gets home that night, John logs into the community network using his home desktop personal computer and requests the petition system to disseminate the petition to other people that he knows in a bid to get more signatures.

James – the local council employee

Background on James and his motivations….

Currently before the planning commission is the issue of rezoning of part of Brown Farm Park into a commercial area, which seems to have galvanized the members of the community. There seems to be as many people for as there are against the idea. As usual, a public hearing has been organized to take place in the next few weeks. He put up the announcement for this meeting on the departmental website, earlier than he usually does, so that community members can schedule time to come and air their views on this contentious issue. To enable the commission to get even more feedback, he decides to setup an information channel for the rezoning of Brown Farm Park. This will allow the local council to *push new information, updates and reminders to interested subscribers via a variety of other media besides the usual ones that include email as well as WAP*[5] *(Wireless Application Protocol) and SMS updates*. Information about the new information channel goes out on the posters and newspaper notices and is also incorporated into the radio announcements.

On the day of the public hearing, fewer people turn up, than he had expected. At the end of the hearing, he updates the departmental website and the *information channel* with the minutes of the meeting.

A.2.3. Activity Claims

Just like before the scenarios are interspersed with claims.

Table A.5: Claims analyzing the key features of the activity design scenarios.

Situation Feature	Possible Pros (+) or Cons (–) of the feature
Using an Information Channel that pushes information to subscribers	+ enables subscribers to receive more information about specific aspects that they might be interested in without expending much effort after initial subscription + enables the local council to disseminate more information to community members in a timely manner as and when it comes up – but it may overwhelm subscribers with too much information – but it may make the members lazy, since they no longer have to actively seek out new information – but may result in some members of the local council involved in having to performing more work
Using a large interactive display in the bar to	+ allows members to keep track of what is happening in their community in a leisurely manner and atmosphere

access community information from the community network and the Internet	+ provides members with shared-access to the community network in a “third” place + provides members with shared-access to the Internet in a “third” place should the need arise + the large size of the display discourages members from accessing private content in a public setting, unless it is for the benefit of others or a group – but not all members in the “third” place might be interested in whatever is shown on the large display – but some members might feel that providing a large display is an intrusion on their peace of mind
Using a community petition application	+ provides members with a platform to articulate their stand on issues that might be contentious and to get others to consider it for support or rejection – but might be misused by members on issues that may not necessarily enjoy community-wide support – but might be misused by members to object to all sorts of issues in the community, since it is easy to create petitions
Using the sponsor’s address book to spread the petition	+ allows petition sponsor to access more of their friends or other people they might know – but other people might not be interested in the petition issues – but other people do not get a chance to say whether they want to receive the petition or not

A.3 Information Design

While activity design deals with the functionality of the proposed application in the context of specific use. The objective of information design is to “specify representations of a task’s objects and actions that will help users perceive, interpret, and make sense of what is happening.” In this phase, activity design scenarios are elaborated with presentation details, to ensure that users can determine the status of their current activity and what they need to do achieve their goals. (Norman, 1986; Rosson and Carroll, 2002, p.110). Like earlier phases, the pros and cons of information design feature are considered and documented through claim analysis, and are shown in Table A.6 below.

A.3.1. Information Scenarios

John – the community member

John dials the number of the information channel from his cell phone, following *voice prompts through a hierarchy of menus*, he enters the necessary options using his phone keypad to receive email updates and an SMS reminder to attend the public hearing.

From the *community network website*, John selects the *applications tab*. Under the applications tab, he selects Community Petition and a *login screen* comes up. It contains entry fields for a community account ID and password and a login button. It also mentions that you can use your driving license to login, and he decides to *use his driver's license* to see whether he would still need to enter a password.

He is presented with a *welcome screen* and is pleasantly surprised that it also has his *name*. After reading the instructions, he clicks the *forward arrow* which takes him to the petition creation screen. At the bottom there are two arrows, the one pointing to the left has text that says "back one step," he knows that can take him back to the welcome screen, while for the one pointing to the right, it says "forward one step." Between the two arrows is text that says "*1/5*," he understands that this is the first step out of five, that he needs to go through to create a petition.

He notices the three icons on the right side of the screen, they have icons that look like a *stylus, a keyboard and a microphone.* To create the petition text, he clicks on the *microphone icon*, which becomes depressed. A *microphone on one side of the display* makes a *startling sound* as it becomes active, he *dictates into* the microphone and is surprised to see the *bands similar to the graphic equalizer* on his music system move at the bottom of the window as he speaks. He figures that this indicates that the microphone is recording his voice, since when he keeps quiet, they disappear. Text generated from his speech appears in a window in the center of the large display confirming to confirm his suspicion. He is surprised that things he said earlier are now appearing in text form, although some of them words seem different from what he said.

His colleagues suggest some changes and corrections, he clicks on the *stylus icon* and a working area appears beneath the text window. uses *a stylus* to make them. Satisfied with everything, he clicks the forward arrow and proceeds to complete the petition signatures and background information. Using the forward arrow he gets to the petition author's information, he is surprised to find that his name and contact details are already filled, he guesses that these could have been extracted from his driving license. After reading a *reminder that he will not be able to edit the petition* again once he completes the process by submitting it, he clicks the *submit button* to submit the petition to the system.

When he gets home that night, John logins to the community network using his community account ID and password on his home desktop personal computer in order to disseminate their petition to other people. On the petition distribution page, he selects that the petition system should *send an email message, SMS summary or voice transcript to everyone in his address book*, depending on whether the entry is an email, cellular phone or fixed phone. Instead of creating an address book from scratch, he uploads his personal address book to the system and selects an option to ensure that it sends *only one message to a person*, irrespective of whether they have multiple entries or all three types of contacts in his address book.

James – the local council employee

To enable the commission to get even more feedback, he decides to setup an information channel for the rezoning of Brown Farm Park. He logins to the information channel system and creates one for the rezoning of Brown Farm Park and gets back an *automatically generated phone number*.

For the methods of information dissemination to be supported by the channel, he selects *email, WAP and SMS*.

Finally he *connects the information channel to the database from which the dynamically generated information for the news section of the website is derived*

On the day of the public hearing, fewer people turn up, than he had expected, he wonders whether he set up the information channel. To verify, he decides to check the channel logs to see whether some people had used it and is surprised to find that a good number of people had actually done so.

A.3.2. Information claims

Some of these raise general information design issues like login screens, progress indicators and so no.

Table A.6: Claims analyzing the Pros and Cons of some of the information design features in the information design scenarios.

Situation Feature	Possible Pros (+) or Cons (–) of the feature
Logging in to the petition application	+ allows the system to identify the member interested in creating a petition, a useful aspect for accountability within the community + can be used to ensure that the system is available to only members served by the community network – but a user who has no way to authenticate themselves might be irritated – but it might discourage others who are interested in creating anonymous petitions
Using a driver's license for logging in to petition application	+ provides an alternative method for logging in to the petition application, besides the community account ID and password + leverages our knowledge of using the driver's license to identify ourselves in other situations – but it might discourage those who do not trust the system well enough to use their driver's license or are concerned for the privacy of their personal information – but not all members own a driver's license – but members might think that they need a password or PIN to use a driver's license
Providing a welcome screen that has a user name and instructions	+ lets the user know that authentication was successful + including the user's name lets them know that the system is aware of their identity + the instructions are helpful for the novice user – but including the user's name might scare some users into thinking that the system knows much more about them than just their names

	–but an experts or regular users may be irritated by the instruction message
Using forward and backward arrows (with text below them that says what they do) to move between various screens	+ lets the user know that the use of the arrows, if they don't already know + lets the user know that they have the ability to move forward or backward freely while using the application – but might encourage users to move from one screen to the next without entering all the necessary information for that screen
Showing the progress of the user through the process by using text like "1/5"	+ makes the user aware of their progress through the process +leverages our natural tendency to speak or dictate information – but the user may worry that they have a long way to go at the beginning – but might encourage users to move from one screen to another
Using icons with pictures to show possible ways of entering petition text	+ lets user know that there are different ways that they could enter petition text into the application – but not everyone might understand what the pictures on the icons mean
Microphone makes startling sound when the speech icon is selected	+ lets user know that the microphone is ready to record their voice + shows the user where the microphone is located if they don't already know – but not everyone might understand what the startling sound means – but some might find the startling sound disturbing
Using bands similar to the graphic equalizer	+ lets the user know that the microphone is recording their voice – but not everyone might understand what the bands

A.4 Interaction Design

While in information design, design issues revolve around how users would perceive, interpret and make sense of what they saw. In this phase, emphasis shifts to action, specifying mechanisms for accessing and manipulating task information, to enable people to do the right thing at the right time (Rosson and Carroll, 2002, p.159). We attempt to create a step-by-step exchange between users and the various components of the system. Claims analyzing important interaction features are shown in Table A.7 below.

A.4.1. Interaction Scenarios

John – the community member

Background on John and his motivations….

While he is driving home from work, he sees a *poster* by the road side, in the neighborhood. It is announcing a public hearing about the impending rezoning of part of Brown Farm Park by the local council. He looks for the date and a *phone number to their information channel (IC).* He dials the number from his cell phone and follows the voice prompts

<IC> Thank you for calling the information channel on the rezoning of Brown Park. The public hearing on the issues will be held on <date> and you are warmly welcome to attend

To sign up for news updates, please press 1

To setup a reminder to attend the public hearing, please press 2

To hear the menu options again, please press 9

<John> "1"

<IC>

To hear a voice transcript of the latest news right now, please press 1

To receive news updates via your email, please press 2

To receive news updates via SMS, please press 3

To hear the menu options again, please press 9

To go back to the beginning, please press 0

<John> "2"

<IC>

To use the email address in your community profile, please press 1

To enter a new email address, please press 2

To hear the menu options again, please press 9

To go back to the beginning, please press 0

<John> "1"

<IC> Thank you for signing up for email news updates

To go back to the beginning, please press 0 otherwise just hang up

<John> "0"

<IC>

To sign up for news updates, please press 1

To setup a reminder to attend the public hearing, please press 2

To hear the menu options again, please press 9

<John> "2"

<IC>

To set up an email reminder, please press 1

To setup an SMS reminder, please press 2

To hear the menu options again, please press 9

To go back to the beginning, please press 0

<John> "2"

<IC>

To send a reminder to phone you are calling from, please press 1

To send a reminder to another phone, please press 2

To hear the menu options again, please press 9

To go back to the beginning, please press 0

<John> "1"

<IC> There are 14 days left before the public hearing

To send a reminder a day before the hearing, please press 1

To send a reminder any number of days before the hearing, please press the key representing the number of days followed by the # sign

To hear the menu options again, please press 9

To go back to the beginning, please press 0

<John> "1"

<IC> Thank you for setting up an SMS reminder

To go back to the beginning, please press 0 otherwise just hang up

<John> Hangs up

Having heard that the planning commission is considering rezoning part of the park from a recreational zone to a commercial one, he is worried that this could be the beginning of the end of his beloved park.

A day before the hearing, while he is away from his office, he receives an *SMS reminder* to attend the public hearing, but unfortunately he can not go to the meeting due to a busy schedule. Later when he returns to his computer, he finds an *email update* with the minutes of the meeting. From the minutes, it appears that the bulk of the people present supported the rezoning. Knowing that there were many more people out there in the community, who felt like him, he resolved to do something about it, and promised himself to bring up the issue with his friends later that evening at the bar.

At the bar, he raises the issue with his friends, most of whom share his interest for the outdoors, pointing out the potential negative aspects of rezoning the park. Seated around the *large interactive touch-screen display* in the corner of the bar that usually displays current information from the community network that is new or of interest to many members. He *switches to application mode and starts the browser*, bringing up the Planning Commission's website to show his friends what transpired at the meeting. He describes what has happened to other parks that had been partially rezoned in other neighboring places, some of which have had to be fully rezoned eventually because of the arising challenges. He shows them a number of reports online from some of these other places to prove his point. An enlightening discussion then ensues, drawing in other people at the bar. In the end, they are all convinced that this is certainly not a good idea after all, they resolve to create a *public petition and to get as many local members to sign it* to get their views to the town council members to reverse the imminent decision.

From the *community network website*, John selects the *applications tab*. Under the applications tab, he selects Community Petition and a *login screen* comes up. It contains entry fields for a community account ID and password and a login button. It also mentions that you can use your driving license to login, and he decides to *use his driver's license* to see whether he would still need to enter a password. He is presented with a *welcome screen* and is pleasantly surprised that it also has his *name*. After reading the instructions, he clicks the *forward arrow* which takes him to the petition creation screen. At the bottom there are two arrows, the one pointing to the left has text that says "back one step," he knows that can take him back to the welcome screen, while for the one pointing to the right, it says "forward one step." Between the two arrows is text that says "*1/5*," he understands that this is the first step out of five, that he needs to go through to create a petition. To create the petition text, he clicks on the *microphone icon* found on the right side of the screen between the *stylus and keyboard icon*. A *microphone on one side of the display* makes a *startling sound* as it becomes active, he *dictates into* the microphone and is surprised to see the *bands similar to the graphic equalizer* on his music system move at the bottom of the window as he speaks. He figures that this indicates that the microphone is recording his voice, since when he keeps quiet, they disappear. Text generated from his speech appears in a window in the center of the large display. His colleagues suggest some changes and corrections, he clicks on the *stylus icon* and uses *a stylus* to make them. Satisfied with everything, he clicks the forward arrow and proceeds to complete the petition signatures and background information. Using the forward arrow he gets to the petition author's information, he is surprised to find that his name and contact details are already filled, he guesses that these could have been extracted from his driving license. After reading a *reminder that he will not be able to edit the petition* again once he completes the process by submitting it, he clicks the *submit button* to submit the petition to the system. A number of people in the bar sign the petition right from the bar. They use a variety of methods, some *use the large interactive screen display, others just send SMS to the system, while others use their cell phones to call into the system.*

When he gets home that night, John logins to the community network using his community account ID and password on his home desktop personal computer in order to disseminate their petition to other people. On the petition distribution page, he selects that the petition system should *send an email message, SMS summary or voice transcript to everyone in his address book*, depending on whether the entry is an email, cellular phone or fixed phone. Instead of creating an address book from scratch, he uploads his personal address book to the system and selects an option to ensure that it sends *only one message to a person*, irrespective of whether they have multiple entries or all three types of contacts in his address book. Depending on the device on which you receive the message, it provides instructions on how to support or reject the petition.

James – the local council employee

Background on James and his motivations….

Currently before the planning commission is the issue of rezoning of part of Brown Farm Park into a commercial area, which seems to have galvanized the members of the community. There seems to be as many people for as there are against the idea. As usual, a public hearing has been organized to take place in the next few weeks. He put up the announcement for this meeting on the departmental website, earlier than he usually does, so that community members can schedule time to come and air their views on this contentious issue. To enable the commission to get even more feedback, he decides to setup an information channel for the rezoning of Brown Farm Park.

He logins to the information channel system and creates one for the rezoning of Brown Farm Park and gets back an *automatically generated phone number*. For the methods of information dissemination supported by the channel, he selects *email, WAP and SMS*. The phone number for the information channel is added to the posters and newspaper notices and is also incorporated into the radio announcements. Finally he *connects the information channel to the database from which the dynamically generated information for the news section of the website is derived*

On the day of the public hearing, fewer people turn up, than he had expected, he wonders whether he set up the information channel. To verify, he decides to check the channel logs to see whether some people had used it and is surprised to find that a good number of people had actually done so. At the end of the day, he *updates the news database with the minutes of the meeting*.

A.4.2. Interaction claims

Table A.7: Claims analyzing the important interaction design features.

Situation Feature	Possible Pros (+) or Cons (–) of the feature
Allowing the information channel to support a variety of devices and methods of access	+ allows the local council to reach even more members, who may each own different devices + allows subscribers to get access to the information channel without having to invest in a new device, since there is a good chance that they already own at least one supported device – but it might require that the same information is prepared in different formats in order to be accessed by multiple devices

	– but it might have implications for the interaction model, since we would not like the interaction experience to be very different on the various supported devices despite their varying capabilities
Providing a variety of methods to input petition text	+ provides options to the user – but they all have a different interaction experience, which might be confusing the user
Using a touch sensitive screen	+ allows users to use their hands to access menus and buttons by just touching them – but not everyone knows how to use one – but using touch along other input devices like the stylus or voice input might further confuse users
Dictating into a microphone to create petition text	+ user does not require to type in the petition +leverages our natural tendency to speak or dictate information – but system will need ways to filter out other background noise in the bar – but people have different accents, tones, pronunciation and so no that differentiate the way they speak
Using a stylus to edit petition text	+ leverages user's knowledge of writing with pens or pencils + is more appropriate for people working in groups – but requires knowledge of graffiti or some other form hand writing abstraction – but not everyone knows how to use hand writing abstraction technologies like graffiti
Using a virtual keyboard to enter or edit petition text	+ leverages user's knowledge using physical keyboards + does not require extra space, since it occupies part of the screen – but requires knowledge of how to use an actual keyboard – but the keys are much larger than on an actual keyboard making it harder for experienced typists in terms of finger movements
Providing various methods to support or reject a petition	+ allows petition sponsor to get more participation from more community members + can allow members to reflect on issues before taking action

	+ allows individuals to make up their decisions alone without undue influence form other members in a group like in the bar + allows members who were not part of the petition sponsors to support or reject petitions based on their relevance – but it might be confusing since support or rejection is expressed in different ways using different devices – people may forget about it or never find the time to act later on, even if they are seriously concerned about the issue in the bar

Notes

[1] To learn more about the Seattle wireless project, you can visit them online at http://www.seattlewireless.net

[2] To learn more about NYC wireless, you can visit them online at http://www.nycwireless.net

[3] To learn more about the Mesh Madison wireless project, you can visit them online at http://www.meshmadison.org

[4] SMS (Short Message Service) is a service for sending messages of up to 160 characters (224 characters if using a 5-bit mode) to cellular phones. It is very similar to paging. However, SMS messages do not require the cellular phone to be active and within range and will be held for a number of days until the phone is active and within range. Besides being transmitted within the same cell or to anyone with roaming service capability, they can also be sent to digital phones from a website or from one cellular phone to another. A variety of cellular network operators and affiliates have come up with a variety of novel value-added services that include creating information channels, bulk SMS delivery, reverse billing applications and so no. For a good overview about SMS, this is a good article.

[5] WAP (the Wireless Application Protocol) is an open, global specification that empowers mobile users with wireless devices to easily access and interact with information and services instantly. It supports a variety of handheld digital wireless devices such as mobile phones, pagers, two-way radios, smartphones and communicators—from low-end to high-end. WAP is designed to work with most wireless networks as well a operating systems, providing service interoperability even between different device families. It is defined and coordinated by the WAP Forum, a consortium of industry players who have an interest in extending the kind of information and services that we have become used to accessing over the Internet, to users of mobile devices, including mobile phones. Founded by Openwave, Ericsson, Nokia and Motorola, the members of the WAP Forum now include most of the leading corporations in the industry, including all the major handset manufacturers, network operators, and software companies.

Appendix B

Experiment 1

B.1 Pre-Experiment Questionnaire

Subject #:
Please help us to categorize our user population by completing the following items.

Rate your familiarity with computers:
<not at all familiar>
<not very familiar>
<somewhat familiar>
<fairly familiar>
<very familiar>

Major Area of study:
Gender:
<Male > <Female>
Age:

Do you own any of the devices listed below (tick all that apply)?
<Desktop computer>
<Laptop computer>
<Cellular phone>
<Personal Digital Assistant (PDA) like a Palm, Visor etc.>
<Handheld computer like an Ipaq, a Journada etc.>
<A portable MP3 player, Discman, Walkman etc.>

Check any of these terms below that you have heard of before:
<pervasive computing>
<mobile computing>
<wearable computing>
<tangible interfaces>
<roomware>
<attentive interfaces>

Have you heard of the term "real world interfaces"?
<Yes> <No> <Not sure>
Please explain what you understand by this term

Have you heard of the term "ubiquitous computing"?
<Yes> <No> <Not sure>
Please explain what you understand by this term

B.2 Main Questionnaire

Subject #:
Please Help give us some feedback on the various interfaces in each of the following scenarios.

Task 1: Monitoring outdoor temperature
Various interfaces are used to monitor the price of a stock. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree), the aspects below:

Using the lamp interface to monitor outdoor temperature
a) It is easy to learn to use to monitor temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand the current temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor outdoor temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would like to use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the fan interface to monitor outdoor temperature
a) It is easy to learn to use to monitor temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to learn to understand the current temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor outdoor temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would like to use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the Cushion interface to monitor outdoor temperature
a) It is easy to learn to use to monitor the temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand the current temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor outdoor temperature

<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would like to use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the counter interface to monitor outdoor temperature
a) It is easy to learn to use to monitor the temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand the current temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor outdoor temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would like to use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the indicator interface to monitor outdoor temperature
a) It is easy to learn to use to monitor the temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand the current temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor outdoor temperature
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would like to use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Summary
1) Which interface was easiest to learn to use in monitoring outdoor temperature?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
1b) Which interface was hardest to learn to use in monitoring outdoor temperature?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
2) Which interface was easiest to understand in monitoring outdoor temperature?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
2b) Which interface was hardest to understand in monitoring outdoor temperature?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
3) Which interface was the most interruptive to the current task you were doing?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
3b) Which interface was the least interruptive to the current task you were doing?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
4) Which interface was the easiest to use with no prior explanation?

<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
4b) Which interface was the hardest to use with no prior explanation?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
5) Which interface did you trust the most in monitoring outdoor temperature?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
Please elaborate on your answer above
6) Which interface did you prefer the most in monitoring outdoor temperature?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
Please elaborate on your answer above
7) Of the two categories desktop based and Real World Interfaces, Which do you prefer the most for monitoring outdoor temperature
<Desktop> <RWIs> <Not Sure>
Please elaborate on your answer above

STOP

Task 2: Monitoring online presence
Various interfaces are used to monitor online presence. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree), the aspects below:

Using the lamp interface to monitor online presence
a) It is easy to learn to use to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the fan interface to monitor online presence
a) It is easy to learn to use to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the cushion interface to monitor online presence
a) It is easy to learn to use to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the counter interface to monitor online presence
a) It is easy to learn to use to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the indicator interface to monitor online presence
a) It is easy to learn to use to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor online presence
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Summary
1) Which interface was easiest to learn to use in monitoring online presence?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>

1b) Which interface was hardest to learn to use in monitoring online presence?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
2) Which interface was easiest to understand in monitoring online presence?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
2b) Which interface was hardest to understand in monitoring online presence?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
3) Which interface was the most interruptive to the current task you were doing?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
3b) Which interface was the least interruptive to the current task you were doing?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
4) Which interface was the easiest to use with no prior explanation?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
4b) Which interface was the hardest to use with no prior explanation?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
5) Which interface did you trust the most in monitoring online presence?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
Please elaborate on your answer above
6) Which interface did you prefer the most in monitoring online presence?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
Please elaborate on your answer above
7) Of the two categories, desktop based and Real World Interfaces, Which do you prefer the most for monitoring online presence
<Desktop> <RWIs> <Not Sure>
Please elaborate on your answer above

STOP

Task 3: Monitoring progress while performing a task (pacing yourself)
Various interfaces are used to monitor online presence. Please rate on a scale of 1 (strongly disagree) to 5 (strongly agree), the aspects below:

Using the lamp to monitor task progress
a) It is easy to learn to use to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the fan interface to monitor task progress (pace yourself)
a) It is easy to learn to use to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>

b) It is easy to understand task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the cushion interface to monitor task progress (pace yourself)
a) It is easy to learn to use to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the counter interface to monitor task progress (pace yourself)
a) It is easy to learn to use to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Using the indicator interface to monitor task progress (pace yourself)
a) It is easy to learn to use to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
b) It is easy to understand task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
c) It is interruptive to the current task that I am doing
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>

d) It is easy to use with no prior explanation
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
e) I would like to use it in real life to monitor task progress
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
f) I would use it in the same way that it was demonstrated
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>
g) Please elaborate on your answer above

Summary
1) Which interface was easiest to learn to use in monitoring task progress?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
1b) Which interface was hardest to learn to use in monitoring task progress?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
2) Which interface was easiest to understand in monitoring task progress?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
2b) Which interface was hardest to understand in monitoring task progress?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
3) Which interface was the most interruptive to the current task you were doing?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
3b) Which interface was the least interruptive to the current task you were doing?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
4) Which interface was the easiest to use with no prior explanation?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
4b) Which interface was the hardest to use with no prior explanation?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
5) Which interface did you trust the most in monitoring task progress?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
Please elaborate on your answer above
6) Which interface did you prefer the most in monitoring task progress?
<Lamp> <Fan> <Cushion> <Counter> <Indicator> <Not Sure>
Please elaborate on your answer above
7) Of the two categories desktop based and Real World Interfaces, Which do you prefer the most for monitoring task progress?
<Desktop> <RWIs> <Not sure>
Please elaborate on your answer above

General
1) What other everyday devices or objects can you think of or imagine yourself using to monitor any information (assume they can be easily fitted with the required computational intelligence)?

2) What other types of information or data that you encounter or keep track of on a regular basis would you want to monitor using RWIs?

3) To build better RWIs, we will need to add more intelligent sensors capable of understanding and reacting to phenomena in the real world, allowing them to pick up more information about our activities in order for them to respond appropriately.
a) I would mind that such systems monitor my daily activities?
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>

b) I am worried that such systems might be abused to spy on me?
<Strongly disagree><Somewhat disagree><Neutral><Somewhat agree><Strongly agree><not sure>

4) An important feature of this type of research is the attempt to merge computational objects smoothly with the world of physical objects.
a) Do you think that using them to keep track of information will be confusing since you are already using the same objects in a different way?
<Yes> <No> <Not sure>
b) Do you think that you will sufficiently trust them to be able to use them?
<Yes> <No> <Not sure>

5) As more electronic devices, processors and micro-controllers getting embedded in everyday objects, we will inevitably become more dependent on the proper operation of such technologically enhanced artifacts or environments.
a) Are you bothered by the fact that you may become fully dependent on the proper operation of these electronic devices in your daily life?
<Yes> <No> <Not sure>
b) Are you bothered that you might not even have the means to avoid such an ever increasing dependency?
<Yes> <No> <Not sure>

6) The goal of this area of research is to make this technology "invisible in use". This can be achieved in many ways, they could be:

- Wearable—the technology becomes just another piece of your clothing
- Pervasive—the technology is built into the environment around you in an invisible manner but is still available wherever you go
- Objects—the technology is built into objects in your environment that are visible but they may not necessarily be different from other ordinary objects

a) Can you think of any advantages/disadvantages of any of these?
b) Please rank them in the order of your preference starting with the most preferred to the least preferred.

Thank you for helping us with this rather long survey!

Appendix C

Experiment 2

C.1 Pre-Experiment Questionnaire

Describe Yourself
Please enter your participant ID number (found on your informed consent form)
What is your current age?

What is your gender?
<Female> <Male>

If you are a student, what is your major area of study?

What is your academic level?
<Freshman> <Sophomore> <Junior> <Senior> <Graduate>

How often do you eat out at local restaurants?
<Almost never> <Seldom> <Occasionally> <Frequently>

Technology
How would you rate your familiarity with computers?
<Not at all familiar><Not very familiar><Somewhat familiar><Fairly familiar><Very familiar>

Do you own any of the devices listed below (select all that apply)
<Desktop computer>
<Laptop computer>
<Cellular phone>
<Personal Digital Assistant (PDA) like a Palm, Visor etc.>
<Handheld computer like an Ipaq, a Journada etc.>
<A portable MP3 player, Discman, Walkman etc.>

How many years of system design experience do you have?
<Less than one year> <About one year> <About two years> <More than two years>

Have you heard of the term "ubiquitous computing" before?
<Yes> <No>
If you answered "Yes" above, please briefly explain what you understand by this term

Have you heard of the term "community computing" before?
<Yes> <No>
If you answered "Yes" above, please briefly explain what you understand by this term

C.2 Problem Scenario and Design Problem

Problem scenario

Ali, his wife and 3 year old son live in Blacksburg. Ali is a graduate student in computer science at Virginia Tech. The family would like to have a decent meal, so they decide to drive down to Christiansburg, where there is a wider variety of restaurants. The family likes steak a lot, so they decide to head to Outback Steakhouse. They have heard from friends that this is one of the places with the best steak around, although it is always crowded. When they get there, they are pleased to see people leaving, as this will increase their chances of getting a table. Once inside, they survey the menu to make sure there is something they can eat and to determine how much that will cost them. They are surprised to be told that there are no tables and that the waiting lines ahead of them that will last hours. Disappointed, they move onto Applebee's, where they encounter the same problem. They move onto a few other restaurants and the cycle is repeated. Finally they figure out that the people who they usually see moving out might be others like them looking for places to eat too. They give up and drive back home, disappointed at having missed the opportunity to have a juicy steak, after driving around like that.

Design Problem

Your team has been asked to design a system that would assist Ali's family to determine some of the potential restaurants that they should visit. You will need to take taking into account their meal preferences, their price range and the waiting times. Since their meal preferences and price ranges are relatively static pieces of information, they can discuss and agree on these while still at home. The waiting times at various potential restaurants on the other hand are dynamic and will certainly change as they drive from Blacksburg to Christiansburg.

Once at the restaurant, the pieces of information that they need to make a decision include, which meals on the day's menu meet their preferences, their price range and how long they would have to wait before they could get a table. It would even be nice to know how long the meals would take to prepare, to give them an idea of how long they would wait once they got a table. Assume that they do not necessarily have to walk into the restaurant to acquire such information, but need to be in its vicinity (for example in the parking lot).

The system should be able to support the dynamic goals and usage situations of the family in the context of its use. Including support for or designing to encourage the kind of social interaction that usually occurs or can occur in this context would be an added bonus.

C.3 Summary of Scenario-Based Design Given to Subjects

The Scenario-Based Design (SBD) is an iterative approach to interactive systems design and analysis. It is comparable to other usability engineering approaches, with its key distinction being the reliance on user interaction scenarios as an ongoing source of insight and reasoning about users' needs and experiences.
For this Experiment we are going to focus on the Information and Interaction design phases.

Information Design

- "…specify a task's objects and actions possible in a system in such a way that that users perceive, interpret and make sense of what is happening."
- Ensure that users can determine the status of their current activity and what they need to do achieve their goals
- Gulf of Evaluation

Perception
Goal: encode the information being conveyed to enable the user to quickly see some structure and relationships
\+ Gestalt principles (proximity, similarity, closure, area, symmetry, continuity)
\+ Squint test

Interpretation
Goal: interpret what has been perceived
\+ Familiarity (leverage what the users' already know)
\+ Abstraction vs. Realism (when to abstract information, how?)
\+ Affordances (aspect of an object that makes it obvious how that object is used)

Making Sense
Goal: understand what has been perceived and interpreted by relating the information at hand to what they understand about their task, and determining how that relates to their goals
\+ Consistency (similar elements are presented the same way across displays)
  o Internal vs. external consistency
\+ Use of visual metaphors (when elements look like things in the real world, people expect them to behave in the same way as their real world counterparts)
\+ Information models (ways to organize relationships in information to enable users to quickly make sense of large amounts of information)

Interaction Design

- Specify mechanisms to access and manipulate information, to enable users (or the system) to do the right thing at the right time, with minimal cognitive effort.
- Gulf of Execution

Selecting System Goals
Goal: user translates real world goal into something that system can do
\+ Interaction style
  o Direct manipulation, command language prompts
\+ Supporting opportunistic behavior

Action Planning
Goal: user creates a plan to achieve the system goal
\+ Make actions obvious
\+ Break down complex actions into smaller and simpler pieces
  o Remember people have limited memory (7±2 Hrair's limit)
\+ Allow people to pursue multiple goals at once

Execution
Goal: user performs plan to achieve the system goal
\+ Choice of input device vs. task's performance requirements
\+ Provide users with feedback about their actions
  o Allow users to undo their actions
\+ Optimize execution efficiency
  o Keyboard shortcuts, macros, default selections

C.4 Summary of Augmented Scenario-Based Design Given to Subjects

The Scenario-Based Design (SBD) is an iterative approach to interactive systems design and analysis. It is comparable to other usability engineering approaches, with its key distinction being the reliance on user interaction scenarios as an ongoing source of insight and reasoning about users' needs and experiences.
For this Experiment we are going to focus on the Information and Interaction design phases.

Remember in ubicomp systems, interaction maybe explicit (user tells system what to do at a certain level of abstraction e.g. by command-line, direct manipulation using a GUI, gesture, or speech input), implicit (action performed by the user not primarily aimed to interact with system but which such a system understands as input) or a combination of the two. During the various design stages, this should be taken into account and design can be from either the user's perspective or the system's perspective.

Information Design

- "…specify a task's objects and actions possible in a system in such a way that that users perceive, interpret and make sense of what is happening."
- Ensure that users can determine the status of their current activity and what they need to do achieve their goals
- Gulf of Evaluation

Perception
Goal: encode the information being conveyed to enable the user to quickly see some structure and relationships
\+ Gestalt principles (proximity, similarity, closure, area, symmetry, continuity)
\+ Squint test
Ubicomp related issues
- How does the system direct information (or feedback) to user attention, given that usage situation and/or goals are dynamic? Or conversely how does the user direct information to the system's attention?
  - Given that multiple interfaces might be competing for the user's attention, on what basis is this attention being allocated?
- How does the user know that they have got the system's attention or conversely how does the system know that it has got theirs?
- Are the various states of information provided distinctive (can user tell one information state from another easily)? Timely (available when user needs it)?
- Is the system state perceivable at various times during its operation?
- Is it easy to recognize when user interaction starts and ends?

Interpretation
Goal: interpret what has been perceived
\+ Familiarity (leverage what the users' already know)
\+ Abstraction vs. Realism (when to abstract information, how?)
\+ Affordances (aspect of an object that makes it obvious how that object is used)
Ubicomp related issues
- Is the system state persistent (user can find out what happened over a period of time)?
- Does the system interface provide affordances? If the interface is embedded into an everyday object, does the new set of affordances cloud those of the everyday object in its original use? If the interface is invisible, how do we embody its affordances?
- Do the objects (interface/artifacts) leveraged in the system behave in a way that the user is already familiar with?
- How does the system intervene when user makes obvious errors?
- How does user control or cancel system action in progress?

Making Sense
Goal: understand what has been perceived and interpreted by relating the information at hand to what they understand about their task, and determining how that relates to their goals
\+ Consistency (similar elements are presented the same way across displays)
  - Internal vs. external consistency

+ Use of visual metaphors (when elements look like things in the real world, people expect them to behave in the same way as their real world counterparts)
+ Information models (ways to organize relationships in information to enable users to quickly make sense of large amounts of information)

Interaction Design

- Specify mechanisms to access and manipulate information, to enable users or the system to do the right thing at the right time, with minimal cognitive effort.
- Gulf of Execution

Selecting System Goals

Goal: user translates real world goal into something that system can do

+ Interaction style
    - Direct manipulation, command language prompts
+ Supporting opportunistic behavior

Action Planning

Goal: user creates a plan to achieve the system goal

+ Make actions obvious
+ Break down complex actions into smaller and simpler pieces
    - Remember people have limited memory (7±2 Hrair's limit)
+ Allow people to pursue multiple goals at once

Ubicomp related issues

- If there are multiple interfaces that can accomplish my goal, is this apparent? Are these interfaces visible or invisible to the user? How do they select between them? Is this done for them automatically by the system? If so, on what basis?
- If there are multiple ways to input/communicate information to the system, is this apparent? How does user select between them? Is this done for them automatically by the system? If so, on what basis?
- If there are multiple actions possible with a given interface, is this apparent? If not, how does user tell which actions are possible with a particular interface? How do they identify and select between potential actions?
- How does user handle complex operations that involve multiple actions across multiple interfaces?

Execution

Goal: user performs plan to achieve the system goal

+ Choice of input device vs. task's performance requirements
+ Provide users with feedback about their actions
    - Allow users to undo their actions
+ Optimize execution efficiency
    - Keyboard shortcuts, macros, default selections

Ubicomp related issues

- Is the execution explicit or implicit? If it is implicit, how does user avoid the system misunderstanding their behavior (i.e. it thinks they are addressing it, when they aren't)? Does the environment or the act of interaction generate noise? How does the system disambiguate between noise and actual input?

Some simple rules of thumb

Preserve the original functionality of an everyday object

When we embed computational power into an everyday object, we should strive to neither change its appearance, original functionality nor the way it is used. Remember the user may put it to use as a computing interface or as it was originally intended.

Awareness and accountability

In systems meant for community computing, we should design to create awareness *(how members in a setting accomplish coordination of action through knowledge about others' actions.)* and accountability *(make sense of action in the context in which it arises)* by making users' actions visible to help provide social affordances.

C.5 Post-Experiment Questionnaire

Please enter your participant ID number (found on your informed consent form)

How easy was it to come up with a design?
<Not easy at all>
<Somewhat easy>
<Very easy>

Was the process helpful in identifying some of the potential problems with your design?
<Not helpful at all>
<Somewhat helpful>
<Very helpful>
Comments:

In general, how would you rate the process in terms of helping you to come up with a design to address the problem?
<Not helpful at all>
<Somewhat helpful>
<Very helpful>
Comments:

In general, how confident are you about the utility of your design in solving the problem?
<Not confident at all>
<Somewhat confident>
<Very confident>

Please provide any comments about your whole experience below:

C.6 Grading Questionnaire Used By Reviewers

1. I believe that users can easily understand how this system works (accessibility)
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>
2. The system does not disrupt the users' natural social behaviors in the context of its use (i.e. it does not make them behave in a way that is different than they would have otherwise)
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>
3. The system leverages artifacts(objects??) and/or interaction modalities with which users are already familiar (familiarity)
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>
4. The system leverages artifacts(objects??) and/or interaction modalities which are appropriate for its context of use (appropriateness)
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>
5. The system allows information input easily and naturally or has mechanisms that allow it to collect the necessary information without undue effort from the users (input)
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>
6. The system outputs information in such a way that it is easy for the users to perceive and understand what to do (output)
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>
7. Using this system would not create a distraction for nonusers in the context of its use (perceiver distraction)
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>
8. Using the system does not in any way change the status quo that naturally exist in the given situation (power)
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>
9. The system is designed to enrich the social interaction that occurs in the context of its use (social application)
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>
10. I would use this system and be comfortable being seen by others using it in the given context
<Strongly Disagree> <Disagree> <Neutral> <Agree> <Strongly Agree>

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