Context-Aware Telephony and Its Users: Methods to Improve the Accuracy of Mobile Device Interruptions

Ashraf Khalil

Submitted to the faculty of the University Graduate School

in partial fulfillment of the requirements

for the degree

Doctor of Philosophy

in the Department of Computer Science

Indiana University

April 2006

Accepted by the Graduate Faculty, Indiana University, in partial fulfillment of the requirements of the degree of Doctor of Philosophy.

Doctoral Committee

Kay Connelly, PhD
(Principal Advisor)

David Leake, PhD

Yvonne Rogers, PhD

December 6, 2005

Catharine Wyss, PhD

Dedication

To my beloved parents, wife and kids

Acknowledgment

First of all, I would like to express my sincerest gratitude and thanks to my advisor and mentor Kay Connelly who provided me with the opportunity and environment to carry out my research. Her constant support and guidance throughout the years has strengthened me as a researcher. Before gaining the chance to work with her, I had almost given up on pursuing my Ph.D, yet she helped me to make my goal realizable. I am also very grateful for the level of freedom she allowed me in conducting my research.

Second, my gratitude goes to my research committee, David Leake, Yvonne Rogers, and Catherine Wyss, for their time, support and encouragement. I am particularly thankful to Yvonne Rogers for her feedback and tips in revising my papers and suggesting ways to tackle problems. I also thank the Computer Science Department, the systems staff, and the administrative staff for creating a supportive environment.

This work was supported in part by NSF (EIA-0202048) and by a grant from the Lilly Endowment and by grant from Lilly Endowment.

On a personal note, I am much indebted to my wife, Jamie Snyder, for all the help, love, support and patience during this long time of being a student. My deepest gratitude goes to my parents for their constant and unconditional love and support. They have provided me with the support I needed to survive the darker days of research. My gratitude also goes to my brother Abedalrazq for all his constant encouragement.

I would like to thank my friends in Bloomington for many happy memories. My appreciation goes out to Yong Liu for his help and feedback regarding many research problems. I am also very thankful to my friends Wael Abu-Shammala, Karim Addas, Bassem Sayrafi, and AbdAllah Sayyed-Ahmad for all the fun times playing pool, barbequing and discussing life and politics. Special thanks to my friends Sameh Dardona, Riad Hammoud, Akshay Sharma, Amr Sabry and all of the friends I came to know through the course of my graduate studies in Bloomington for many pleasant memories.

Finally, and above all, I can never be thankful enough to God who has provided me with guidance, life, health, and a beautiful family (Jamie, Yusef and Asma). All praise, thanks, and gratitude ultimately belong to Him.

Abstract

As the number of mobile devices we carry grows, the job of managing those devices throughout the day becomes cumbersome. As a result, the many benefits that cell phones provide are at times overshadowed by the problems they create. Cell phone interruption, as when a ringing cell phone disrupts a group activity, such as a class, meeting or movie, is yet another inconvenience highlighted by the ever increasing number of mobile devices we carry. In large part, this mismatch between the user's context and the cell phone's behavior occurs because owners do not remember to frequently update their cell phone configuration according to the current context.

In this research, we present three different techniques focused on minimizing cell phone interruption: (1) Calendar-based approach, (2) Caller-based approach, and (3) Collaborative approach. The techniques capitalize on the emerging fields of ubiquitous computing, context-awareness and smart environments and are intended to function in a minimally intrusive manner. We first present a feasibility study that shows people are willing to use context-aware, automatic cell phone configuration and do not feel a loss of control. We then discuss the results of a user study that relied on mobile calendar information to infer the appropriate cell phone configuration. Next, we present the caller-based technique, which leverages the caller's judgment regarding the appropriateness of interrupting the receiver given some contextual information about him or her. We present an in-situ user study aimed at evaluating

the feasibility of that approach, the privacy concerns associated with it and the values conveyed by different types of contextual information. In addition, we present our findings that suggest surveys are unreliable tools for measuring privacy concerns. We also present a third novel approach toward automatic configuration aimed at minimizing cell phone interruption: a collaborative technique that automatically adapts its configuration according to that of the majority of the surrounding cell phones.

Finally, we present design guidelines and lessons learned based on our experience investigating the three methods. We address issues including privacy, awareness, inaccuracy and control versus convenience.

Table of Contents

List of Tables

List of Figures

1 Introduction

1.1 Cell Phone Interruptions

With the increasing number of mobile devices that seek users' attention, it is essential to minimize interruptions and distractions caused to the users and the surrounding environment. Garlan et al. notes that human attention is becoming the most precious and scarce resource, considerably more so than computational power [43]. Cell phones, with all the services they provide such as phone calls, reminders, text and instant messages, are the prime example of mobile devices that demand constant cognitive attention from the user and also serve as a frequent source of interruption and distraction. Cell phones are currently the most ubiquitous communication device the world over [85]. The tremendous growth of cell phones' usage and their location-free nature have helped to establish a new social order. This social order has been described as a shift from Place-to-Place communication to Person-to-Person communication [95].

Mobile phones offer great accessibility and flexibility. No longer do people have to remain in a fixed location to carry on conversations over the phone. Having the ability to remain in constant contact with people via the phone also gives people an additional sense of security [80]. The benefits offered by cell phones, such as flexibility and accessibility, seem to inevitably come with the cost of increased interruption and interaction demands. Interruption caused by inappropriate notification such as ringing in a meeting can cause inconvenience, disruption and embarrassment for the owner. The effect of interruptions has been shown to be disruptive to task performance even when the interruption is ignored [32]. Mobile phones create new dilemmas for users: Do they really want to be reached anywhere and anytime? What is the appropriate state for their cell phone in different places? And to whom should users give their number?

Interruption is not limited to the owner of the cell phone only but extends to the surrounding environment as well. Kern et al. [60] have introduced and validated a model for interruptability wherein they distinguish between interruption to user's environment "social interruptability" and interruption to the user him or herself "personal interruptability". The cell phone's social interruptability is further confirmed by studies that show most people consider the use of cell phones in public places to be annoying [63, 70]. Wei and Leung [93] have conducted a large study that shows that when people are asked about the contexts in which they find cell phone use irritating, 81% responded restaurants or cafes, 80% answered classes or libraries and 79% cited airport or train stations. Bautsch, et al. [15] found that most people think there should be etiquette guidelines created for public mobile phone use. Many rough attempts can be found in newspaper and magazine articles by authors fed up with rude users. Wireless World gets biblical with the "Ten Commandments" of Mobile phone Etiquette [22]. It is not uncommon anymore to see a sign saying "No Cell Phones Allowed" in some public places. An increasing number of places, such as churches, commuter trains and even parliaments, as in India, are using cell-phone jammers to restrict cell phone usage. Despite the fact that jammers are illegal in most countries, more and more countries, such as Japan and France and Mexico are approving their use in public [2, 96].

All the problems mentioned above are usually caused by the static nature of cell phone configurations and their inability to automatically change their setting according to the context of the surrounding environment. This, in turn, creates a mismatch between a phone's setting and the context of the space it occupies. Many people change their cell phone setting every time they are in a new context. This solution is both inconvenient and inadequate since in many cases the user forgets to change the setting. Other people just keep their cell phone in silent mode, but that results in their missing many important calls.

This research focuses on investigating tools aimed at minimizing inappropriate cell phone interruptions. We have extensively studied three different approaches: Calendar-based, caller-based, and collaborative. For each approach, we have conducted comprehensive user studies to examine their feasibility, limitations, and usefulness together with many other factors that are particular to each approach. We have paid particular attention to the issue of privacy and awareness trade-offs whenever relevant. In addition, we have explored the validity of using surveys as a tool for measuring privacy concerns and sharing preferences. Finally, we present the lessons we have learned and design guidelines that we have gathered through investigating various tools meant to enhance interruptions and through the user studies that we have conducted.

1.2 Related Work

Interruption has been studied extensively by researchers in the last few decades. The research has been mainly focusing on the effect of interruption, models of interruption, real-time sensing and reasoning platforms and interruption management systems. The majority of work, however, has been concentrated on stationary and office workers. The newest research studies interruption for mobile users.

1.2.1 Effect of Interruptions

A number of research efforts have been aimed at better understanding the effect of interruptions. Memory failure is often cited as one of the main consequences of interruptions. Interruptions during a primary task make that task more difficult to accomplish because of the increase in anxiety. Bailey et al. has found that "a peripheral task causes a greater increase in anxiety when it is presented during a primary task than when it is presented just after the completion of that task" [12]. Moreover, the experiment showed that interruptions have a disturbing effect on user's overall performance. Other research has shown that notification of an incoming message, even when the message is ignored, is disruptive to task performance [32]. Interruption has also been found to affect not only the current task but also future tasks. O'Connail et al. found interruptions of tasks to be the most frequent reason for failure to remember a task that needs to be preformed in the future, which has been referred to as *prospective memory* [75]. Speier et al. has found that the interruption of a complex task causes a cognitive overload, distracting the user from the original task and requiring more time to deal with the interruption, making it harder to comprehend the task at hand [90].

Interruptions for mobile users are generally more disruptive than interruptions for stationary users. Mobile users can be engaged in activities that require constant and full attention such as crossing the street or driving. Interruption while driving has been found to put the user in dangerous situations [6, 40]. Moreover, mobile users are usually surrounded by other people who can also be affected by interruptions [60].

1.2.2 Modeling Interruptions

The perceived burden or cost of an interruption is a tradeoff between the disruption to the main task and the benefit of the information it provides. The activity or the task of a user at the time of interruption has always been identified as the main factor in modeling interruptions. The more the interruption is related to the main task of the user, the less disruptive it is [44]. The disruptive effect of an interruption was found to depend on the required memory load of the main task. If the memory load of the primary task is high then it would be harder to resume it after an interruption [12]. Horvitz et al. have developed a Bayesian probabilistic system that uses sensors and schedule data to model the main task of the user and thus helps in predicating the user’s presence and availability [54, 55].

A second key factor that has been used in modeling interruption is the message utility, by which we mean the value or the benefits of the information conveyed by the interruption. For example, interruptions that are relevant to the main task are usually less disruptive to the user [32]. The *Priorities* system learns the priority of an interruption from users' behaviors or from explicit user feedback and assigns an urgency score to each interruption [54, 55]. For example, in the case of an email interruption the *Priorities* system uses information about the sender, the nature and number of recipients, the content of the header and the body of the message to assign a priority value to that email. The Scope system is an information visualization designed to minimize interruption which uses the message utility as a measure of how urgent it is [33].

In addition to the two main factors mentioned above, there are many other factors that have been found to impact the cost of interruption as well. Kern et al. identified three further factors: the user's social activity, social situation and location [60]. As an example of social situation, when the user in a restaurant, she will be less receptive to interruption than when she is in her office. Other factors such as the emotional state of the user, the frequency of interruptions and power to control interruptions were also found to affect the cost of interruptions and the user's attitude toward interruptions [56, 90]. Ho and Intille have identified a list of 11 factors that should be accounted for in order to achieve a comprehensive model of interruptions [52].

Several people have tried to address the issue of managing user interruptions and mediated notifications by using sensors data. Hudson et al. has used a Wizard of Oz technique to examine how well the interruptability of the office worker can be predicted by sensor data such as from a video camera and microphone [57]. They found that interruptability can be predicted with 75-80% accuracy. Kern et al. has addressed the issue of interruptability for mobile users by using body-worn sensors such as acceleration and audio sensors to acquire context information [60]. Different sensors provided different levels of accuracy but overall demonstrated the feasibility of their approach. Finally, Ho and Intille have shown that delivering interruptions at the transition time between activities provided an acceptable way of managing interruptions [52]. Their in-situ study found that the burden of interruptions was considerably less when interruptions are delivered at the times of the user's physical transitions between activities than when interruptions are delivered instantaneously.

1.2.3 Interruptability of Mobile Devices

Many approaches have been developed aiming to minimize interruptions caused by mobile devices. One approach is to empower the caller to make better decisions about the appropriateness of the call before making it by providing him information about the receiver's context [69, 84, 91]. The Calls.calm system uses the web to activate an interaction webpage that provides the caller with a set of available communication channels as well as information about the receiver's current situation and leaves it up to the caller to make an educated choice [84]. Milewski and Smith used the address book to display dynamic information about the recipient's availability and whereabouts [69]. The solution applies the same concepts of “Buddy list”, used in instant messengers. Users manually enter their context information and availability status and these massages automatically appear to anyone who is trying to contact them. This approach, however, raises many privacy concerns that may prevent the receivers from publishing useful information about their context. Also the approach does not address the question of what type of contextual information provides the best cues about the receiver’s availability.

Another approach is to empower cell phone owners by improving the capabilities and awareness of cell phones. Quiet Calls is a system that enables users to have a private conversation in a public place by using a quiet mode of communication such as voice mail and prerecorded messages [72]. Such a system decreases social interruption but does not affect personal interruption since the user is still expected to receive the call and act upon it. SenSay is a system that uses input from different sensors such as accelerometers, light detectors, and microphones to capture the context of the user [89]. The context is then used to adjust the modality of cell phone configuration (i.e. vibration, ringer). Schmidt et al. have introduced an adaptive cell phone that changes its profile automatically based on the recognized context [86]. The phone chooses to ring, vibrate, adjust the ring volume, or keep silent depending on whether the phone is on a table, in a suitcase, outside, or in hand. Solutions which acquire context information through augmented sensors are somewhat expensive in terms of the computational needs of inferring the context information given the scarce resources of cell phones. Moreover, usability studies have yet to be conducted to study the effect of inaccurate context prediction on users, as well as the issue of how much control users are willing to give up in exchange for convenience.

A third approach to minimizing interruption in mobile telephony was presented by Ho et al. in which interruptions are timed at transitions between physical activities [52]. Their reasoning was that change in physical activity in many cases correlates with a self-initiated mental transition which in turn make interruptions less disruptive. Their usability study showed that people are more receptive to interruptions that are triggered at an activity transition than interruptions that are triggered at random. This approach may help minimize personal interruptability but does not enhance social interruptability. Moreover, it is not clear what effect inaccuracies in predicting activity transitions will have in user's acceptance of such a technique.

Finally, Marti and Schmandt have presented a solution to social interruptability of cellphones by allowing surrounding people who are engaged in a conversation with the receiver to decide whether or not the cell phone should ring [68]. Users wear finger rings with attached sensors that vibrate when anyone in the conversation group receives a call. Any conversant has the option to veto the call anonymously by touching a small button in his or her finger ring. This solution may enhance social interruptability but does not address personal interruptability. This technique may prevent cell phones from ringing in inappropriate settings, however, interruption that is caused by the vibration of the finger ring may be as disruptive as ringing. Finally, the requirements of wearable sensors and computing infrastructure make such a solution not very practical.

1.3 Research Statement

We present three different methods aimed at minimizing cell phone inappropriate interruptions Comprehensive user studies were conducted to examine their viability, usefulness, and users' concerns. We also present general design guidelines we gathered from various user studies.

1.4 Document Overview

This chapter has explained the motivation for improving cell phone interruptions and given an overview of the problems caused by inappropriate interruptions. Chapter 2 introduces the results of a usability study that we have conducted which showed that people are willing to adopt context-aware configuration services. In that study we used information provided by the calendar book to infer users' context and configure cell phones accordingly. Chapter 3 discusses the caller-based approach and its privacy implications. This chapter consists of 2 major parts. The first part discusses a usability study that we have conducted to examine the feasibility and privacy issues of this approach. The second part discusses whether providing the caller with context information about the receiver's situation will improve cell phone interruptibility and enhance the agreement between the two parties. Chapter 4 introduces and discusses a collaborative service as another novel approach to improving cell phone interruptions. Chapter 5 discusses an experiment aimed at examining the validity of using surveys as a tool for evaluating privacy concerns as compared to using an in-situ user study. Summarized in Chapter 6 are lessons we have learned and design criteria that we have gathered from experimenting with the different tools to enhance interruptions and from conducting the user studies. Finally, Chapter 7 concludes with the contributions of this research and discusses future work.

2 Calendar-driven Approach

We predicted that context-aware configuration may contribute greatly in decreasing the mismatch and provide more socially acceptable cell phones. One approach is to identify a set of daily activities that have a consistent mapping between different activities and different configurations. We present an approach that aims to improve the awareness of cell phones by using information from the calendar book, which already exists in most cell phones and all current smart phones. The information in the calendar book is used to determine the most suitable configuration for the cell phone. In order to examine the validity and effectiveness of this solution, many questions need to be explored first. Its real value greatly depends on the accuracy of the predicted context based on the scheduled activities. Given the inevitable fact that people's actions do not always mirror their intentions, scheduling events and activities does not necessarily ensure attendance.

With this in mind, the accuracy of the information provided by the calendar must be carefully considered, along with the tendency of users to carry out their plans as written in the calendar. A related question to be asked concerns the effect of spontaneous and unscheduled activities on the predictability of calendar-based configuration. Further, can users predict the best configuration for specific activities? Is there consistent mapping between context and configuration? Given that people's sense of control decreases as a cell phone's autonomous capabilities increase [14], and given the personal connection people feel toward their cell phones, would people welcome the idea of more aware and autonomous cell phones? How much control are users willing to give up in exchange for the convenience offered by the system? Finally, how can we account for the differences in people's perception of the appropriateness of the same level of interruption?

To answer the above questions, we have conducted an in situ experiment in a dynamic campus setting. During the experiment, participants were asked to fill in their calendar information regularly in the PDA we supplied. Every PDA ran an application designed to simulate a smart cell phone. The application simulated phone calls at random times during the day, prompting participants to evaluate the appropriateness of the configuration and to specify their current activity and location. The application acquired and stored evaluation data from participants during the study. More data was collected through end-of-study interviews to examine the overall evaluation of the calendar-based solution.

2.1 Calendar as a Context Provider

All current smart phones and most other regular cell phones come equipped with a calendar book. The calendar book usually serves as a personal organizer and is a valuable resource for organizing daily activities and schedules. Naturally, calendar information provides very important and reliable cues about the availability, location, and surrounding environment of the user. For example, if the calendar has a meeting appointment from 1pm to 2 pm we know with a high degree of probability that the user is unavailable and he is in a place with at least one other person. Such information indicates that any incoming interruption should be kept minimal and only the most urgent ones should be allowed to go though with a very discreet notification mechanism. Such cues are available for free and we predict they are usually accurate.

Calendars provide simple and inexpensive contextual information. By inexpensive, we mean that no sensors or computations are needed to infer the contextual information. Furthermore we predict this information to be highly accurate since in most cases the user fills in the entries that are of high importance and that she intends to attend. This information can be used by cell phones in order to dynamically and automatically change their configuration, or settings, in a way that received calls are least disruptive to both the user and the surrounding environment.

It remains unclear, however, to what extent cell phone calendars are actually used. We have not found any studies that examine the usage pattern of a cell phone's calendar, although many studies have been conducted to examine the mobile Personal Information Management's (PIM) usage behavior, task management, and efficiency of information retrieval [17]. PIM is an essential set of tools that exists in almost all personal digital assistants (PDAs) as well as many smart phones and includes a calendar application in addition to task list, contact, and memo applications. In a recent study we conducted involving 20 cell phone users, we found that a cell phone's calendar is rarely used, or when it is used, it serves as a reminder rather than as a scheduler. However, we expect this to change in the near future as regular cell phones converge into smart phones that include many PDA-like capabilities. Smart phones usually offer better user interface and communication capabilities. Enhanced interaction capabilities such as bigger touch-screen displays and a QWERTY keyboard provide for easier user input and enable users to make better use of PIM applications, including the calendar. Moreover, the enhanced communication capabilities such as Bluetooth and infrared enable users to synchronize their calendar information and other data with their PC. Thus, even if users utilize other electronic calendars, the information can easily be transferred to and used by their smart phone.

Calendar information has long been used as a valuable resource for information in several research projects. The Coordinate system, for example, uses the calendar information and previous computer activities to predict the availability of a person on a particular computing device [55]. MyVine system uses calendar information in addition to many other cues, such as a speech detection sensor, to model a person's availability for communication [42]. The Ambush system extends the calendar via a Bayesian approach to predict the likelihood of one's attendance at the event listed in one's calendar [71]. The context-aware Office Assistant uses a person's calendar to inform a personal agent of available meeting times for visitors at the person's office door [97].

2.2 Preliminary Survey

The experiment was conducted in two stages. Preliminary data was collected in the first stage to help us better design the main part of the experiment. The benefit of a two-stage experimental approach in the context of Ubicomp was argued by Antifakos et al. [10]. The goal of the survey is to investigate how people categorize their daily activities as well as the variation of this categorization across different groups. The data was gathered by an online survey. We had a total of 72 participants divided among graduate students, undergraduates, professors and staff. The participants were distributed among 7 different majors or areas of study. The survey results show that the participants tend to do very similar activities irrespective of their major or occupation. However, we found that the frequencies of activities are different among different groups. Table 1 details the users' most frequent activities. This list of categories was used in the latter part of the experiment to ease the process for the users.

2.2.1 Participants

Table 2-1 shows the distribution of subjects across different groups. Graduate students group make up most of the participant.

Group	**Number of**
Graduate Students	49
Undergraduate	7
Professor	6
Staff	10
total	72

Table 2-1: Distribution of Participants across different groups

The distribution of participants' different majors or areas is shown in Table 2-2. More than half of the participants are from computer science and SLIS (School of Library and Information Science). The "others" field refers to the participants who are either did not fill in the major field or provided a major that has only one participant with such a major. Some participants had double majors and we counted them with the larger group.

Major/Area	**Number of Participants**
CS	21
SLIS	20
Instructional Support Technology	7
Linguistics	5
Informatics	3
information tech	2
Others	14
Total	**72**

Table 2-2: Distribution of participants' majors/areas

2.2.2 Data Analysis

In this section we look into the most common activities for different groups. The activities are divided into two main categories. The first one contains group-specific activities where activities are most likely to be specific to a certain group of the total population whereas the second category contains general activities. The general activities are all the activities that are shared by all the population in general (campus people). This section only tries to categorize the group-specific activities and in the next section we list the most common activities for the general category. Table 2-3 shows the summery of the four or five most frequent activities for each group. All other activities beyond that are found to be of the general nature and did not add any useful information.

2.2.2.1 CS graduate Students

The most common activities for CS graduate student are researching, email and planning, classes, teaching, and office hours. This is in addition to other common activities that are shared with all other different groups and discussed later. Some of these activities can be categorized as uninterruptible activities such as teaching, and classes and the rest can be categorized as interruptible with discretion such as office hours and researching.

2.2.2.2 CS undergrads

The most common activities for CS undergraduate population are classes, working, homework and recreational activities. Recreational activities include activities such as relaxing, watching TV, walking the dog, etc. People in this group are either highly uninterruptible (classes, working) or very interruptible (recreational activities).

2.2.2.3 SLIS (School of Library and Information Science) Students

All the participants in this group are graduate students and the most common activities found among them are classes, meetings, homework, and recreational activities.

2.2.2.4 Linguistics Students

We had 5 participants majoring in linguistics and all of them are graduate students. The most frequent activities among this group were found to be classes, meeting, research and teaching. People in this group share many similar activities with other groups in different fields.

2.2.2.5 Instructional Support Technology Students

We had a total of 7 graduate students in this group. The group most common activities are very consistent with other graduate groups. Common activities are teaching, classes, meetings, and working.

2.2.2.6 Staff

We had a total of 10 staff members who participated in the survey. The staff most frequent activities were found to be emailing, answering and receiving phone calls, meetings, customer service. It is hard to assess the interruptability level of staff member due to nature of their work which entails constant interruption.

2.2.2.7 Professors

A Total of 6 professors participated in the activity survey. The most common activities among this group are teaching, working (research, writing, preparing, grading), meeting, and office hours.

Group/Activities	***Most frequent activities in no particular order***			
CS graduate Student	Research	Email & Planning	Classes	teaching
CS Undergrad	Classes	Work	HW	Recreational activities
SLIS	Classes	Meetings	HW	Recreational Activities
Linguistics	Classes	Meetings	Research	Teaching
IST	Classes	Teaching	Work	Meetings
Professor	Teaching	Meeting	OH	Work (research, preparing, writing, etc)

Table 2-3: The four most frequent activities for each group

2.2.3 Findings

2.2.3.1 General Activities

Activity	**Different Labels (given by participants)**
Meeting	Meeting with advisor, meeting students
Email	Email, checking email, read email
Food eating &	Lunch, cooking dinner, eat dinner, breakfast.
Researching and	Work on research, projects, reading papers,
In transit	On road, drive to campus, return home, travel to
Classes	Seminar, class, attend classes,
Recreational	recreational activity, work out, karate training,
Teaching	Teach,
Relaxing	Relax, watching TV, nap,
Sleeping	Sleep, nap,
Office Hour	Office hour,
Presentation	Presentation, seminar

Table 2-4. List of the most common activities

There are activities that are very general and found to be relevant for all groups. These activities are sleeping, eating (lunch, dinner, and dinner preparation), in transit to and from work, showering, working out (see Table 2-4). Mostly, such activities are of the interruptible nature though they may vary on the interpretability level. For example in transit is a more interruptible activity than working out.

2.2.3.2 Activity Mapping

We fount out that almost all activities can be mapped to four different interruptability states. Different states have different interruptability level. These stats are:

2.2.3.2.1 Off State

Off or quiet state is the state where the user should not be interrupted. Activities like classes, teaching, meetings, and seminars fit under this state. This state is probably the most critical one since interrupting a person in the middle of a class or presentation can be quite embarrassing and affects not only that user but all other people around him. It is very important to accurately capture this state for any intelligent configuration system to be useful.

2.2.3.2.2 Loud State

It is the state where the user is engaged in a recreational activity such as watching TV or working out. A person in such a state can be highly interruptible and there might be a need to increase the level of alerting in some cases (maximum volume) in order to get the attention of that person.

2.2.3.2.3 Quiet State

The quiet state is the state where the user can be interrupted but with discretion. User encaged in activities such as researching, office hours, homework, and working can fit under such state. The level of discretion can vary depending on the kind of the activity and the user's preferences. For example some people would like only to receive important calls while others may prefer the phone to be in a vibrating mode.

2.2.3.2.4 Normal State

It is the default state when the state of the user is not in any of the aforementioned states. Activities such as being in transit, lunch, and waiting for the bus can fit under this state. The device configuration for this case should be decided by the user.

2.3 Experiment

The main goal of the experiment was to assess the likely value of the calendar-based automatic cell phone configuration approach and the various factors affecting it. We examined the accuracy of calendar information, configuration predictability, and the consistency of mapping activities to configurations for individuals and across different individuals. We examined whether automatic cell phone configuration, based on the user's calendar information, improves the overall user experience. Finally, we investigated the approach to automatic configuration and whether it should be passive, where users are aware of the change and have more control over it, or active, where the change is made without any notification and the user has less control over it.

2.3.1 Natural Setting

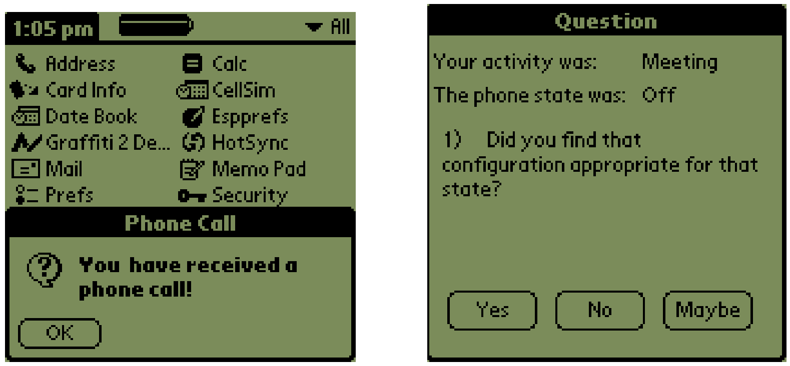
System evaluating in a natural setting is the best way to provide accurate data. This is especially true for Ubicomp systems because it is their inherent nature to interact with users in their natural environment. With that in mind, we chose to conduct our experiment in a college setting. College environments offer an ideal place for the development and testing of ubiquitous systems. They are very dynamic and active places with different groups interacting. Moreover, mobile devices and especially cell phones are extremely common on college campuses and students greatly depend on their cell phone to organize activities and keep in touch with their friends and family. In addition, campuses are highly connected environments with extensive support for mobile and wireless computing.

Many of the early ubiquitous technologies were deployed and tested in campus environments. Weiser [94] predicted that the compact nature of the campus environment will put it at the forefront of ubiquitous computing. The Active Campus project [48], designed for campus environments, is one of the largest ubiquitous computing projects in terms of its scale and the services it provides. The Aware Campus Guide [23] is another example of the early ubiquitous applications that have allowed users to annotate physical space with text notes. Several other ubiquitous applications have also been designed and deployed on campus environments to enrich students' classroom educational experiences.

2.3.2 Methodology

2.3.2.1 Design

The study consists of a context-aware cell phone configuration application. The application simulates a cell phone that changes its configuration (loud ring, quiet ring, vibrate, on, off) depending on the context of its owner. The context is derived from the calendar book. During the study, the participant carries a Palm PDA that runs the application, and during the day she receives simulated phone calls at random times (Figure 3-2). According to the context of the participant, the application notifies the user differently about the received call. The cell phone configuration can be in any of four different states: Loud, Quiet, Off, and Normal. In the loud state, the phone rings loudly when a call is received, while it vibrates in the Quiet state. Normal state is the default state that takes whichever configuration has been set up by the owner. In the Off state, the phone is off, and if a call is received then a voice mail message will be generated the next time the phone is in any other state. Moreover, if the participant misses a phone call, he will be notified of that missed call the next time he answers a phone call. The four different states were identified from the online preliminary survey mentioned in the previous section.



(a) (b)

Figure 2-1. Figure (a) shows the notification message that appears once a call is received. Figure (b) shows the question asked once the user press the "Ok" button on figure (a).

After receiving the notification of either an incoming call, missed call or a voice mail message, the participant is asked whether the configuration of the cell phone, reflected by the notification mechanism, is appropriate or not. If the answer was inappropriate, then she is asked to select the most appropriate configuration. After that, the participant is asked to select his location and activity.

We chose to use a cell phone simulator that is running on a Palm PDA instead of using a real cell phone because the PDA provided us with more programming flexibility and with greater means to collect, store and manage the data in the field. At the same time, the selected PDAs had the same notification capabilities as cell phones, such as ringing, vibrating, LED, and volume control. We were only interested in measuring the appropriateness of the configurations in terms of social ramifications of them rather than the identity of the callers or any other factors. The simulation provided us with more control over the study, which enabled us to examine only the factor of interest while eliminating others such as caller identity.

2.3.2.2 Duration

The experiment duration was chosen to be 5 working days. This period was selected because most activities are repeated in either daily or weekly intervals. In addition, we conducted the experiment only during the week rather than on the weekends because we were mostly interested in the days when the participants are busy and interactive in a campus environment. In this case, the cost of interruption or misconfiguration is rather higher for both the user and the surroundings and thus the value of the application is highlighted.

2.3.2.3 Participants

11 students both graduate and undergraduate from Indiana University participated in the study. Participants were aged 20-28 and 3 of them were males. All participants reported to have owned cell phones for more than a year and have busy daily schedules with many different activities throughout the day. 10 participants fully completed the study. One participant collected very little data due to a family emergency. This data was not considered in the evaluation process.

2.3.2.4 Equipments

The study was conducted using Tungsten T3 running Palm OS 5.2 and our cell phone simulator. The devices are equipped with ringing, vibration and volume control capabilities as well as a color display. Each participant was provided with a PDA for the duration of the study.

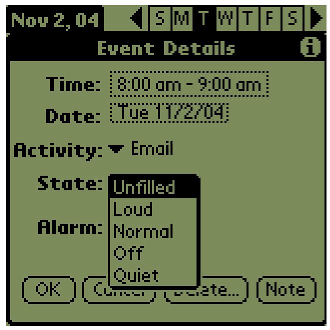


Figure 2-2. After filling in the activity in the calendar book, the participant is asked to map it to the most appropriate configuration

2.3.2.5 Procedure

Participants were individually given a brief overview on how to use the PDA and then they were introduced to the cell phone simulator and how to use it. They were asked to fill in the calendar with their activities at the beginning of every day of the study with all the activities that last at least 15 minutes. Every activity is mapped by the participant to the cell phone state that best fits that activity as shown in Figure 3-7. The participants were advised to think of the PDA as their own cell phone that is changing its configuration dynamically depending on the owner's context. After finishing with the experimental study, end-of-study interviews were conducted in one-on-one sessions that lasted approximately 40 minutes.

2.3.2.6 Design Tradeoffs

The fact that participants received simulated phone calls rather than real ones might have introduced some bias in their evaluation of the calls. In order to treat all calls with the same level of importance and factor out personal preferences, we asked participants to think of the calls as received from anonymous callers. With the simulated phone calls, participants still had to deal with social ramifications of receiving calls in public spaces and with inappropriate alerts that could have been caused by the calls. Also, in most cases, the mapping of activity to configuration should not be affected by the fact that the calls are simulated.

2.4 Results

During the study, a total of 340 calls were made, all generated by the simulator. Participants received an average of 30 calls and 4 voice mails. Even though participants missed 31% of the initial calls, they received reminders about many of the missed calls, and thus they had the chance to evaluate them. Overall participants evaluated 85% of all the calls; the rest were not evaluated due to the fact that the application only stored a partial list of missed calls and the participants were reminded only about the last three missed calls. In addition, in some cases, the Palm device had to be reset during the study, and thus a few stored reminders were lost.

2.4.1 Evaluating Calendar-Based Automatic Cell phone Configuration

During the end-of-study interview, all participants reported they were willing to use such an application if their cell phones were equipped with it. Participants were also asked to rate the usefulness of the application on a scale of 1 to 6, with 1 being the most useful and 6 being annoying. 40% of the participants rated it 1 (very useful) while the rest rated it 2 (useful). These results are particularly interesting given the fact that 9%-13% of the calls were evaluated as having an inappropriate or inexact configuration. Since these calls were received in a real-life environment, they could have caused frustration or embarrassment for the participants. The fact that evaluation occurs after notification makes the evaluation very accurate and reflects the real feelings of the participants that could not be obtained otherwise. One participant commented that: “I like how it changes state without you having to tell it to. I always forget to turn my cell [off] in class and turn it on after”.

Overall, participants rated 87% of the evaluated calls as having the appropriate configuration and 9% as having an inappropriate configuration. The rest were evaluated as having an inexact configuration but not inappropriate which was another option. Out of the missed calls that were later evaluated, 36% were missed unintentionally due to the fact that participants failed to notice the alert, usually due to low volume, and the rest were missed intentionally. We interpreted both intentionally and unintentionally missed calls as having an inappropriate configuration. In most cases participants did not mind missing the calls because they did not want to be interrupted. Only 14% of the missed calls were evaluated as having an inappropriate configuration. One participant commented that the embarrassment of having the phone ring in the middle of a meeting is worse than missing a phone call. Most of the calls with inappropriate configuration were received when the participants were either in transition between activities or dealing with unplanned activities such as ’on the phone‘, ’taking a break‘ or ’having a conversation’.

Even though this approach did not produce perfect accuracy, it did not appear to affect the participants' perception about the usefulness of the applications since any inaccuracy is a predictable one and they have total control over it. People's reaction to inaccuracies and uncertainty in context-aware applications varies from one person to another. However, if Bellotti and Edwards' [18] design principles of intelligibility and accountability are followed, which include the user in the decision making process, then we expect people will adopt context-aware applications. In our case, participants were included in the decision making process by having them initially map different states to configuration rather that using different inference techniques to map them automatically.

Our study also examined the preferred level of interactivity between the user and any potential application that could provide context-aware configuration for cell phones. This question must be dealt with for most of the context-aware applications because of the fact that they are dynamic and proactive [26].

2.4.2 Accuracy of Calendar Information

Participants were asked to fill in a more detailed account of their daily activities than they would usually do in real life. We asked them to schedule in advance all the activities that were expected to last more than 15 minutes. The purpose was to gather as much data as we could about the different activities and the way participants choose to configure these activities. Participants filled in 9 different activities on average. The most common activities were meeting, work, homework, watching TV, class, working out and eating. During the study, participants were asked to specify their current activity. Participants accurately predicted 62% of their activities and inaccurately predicted 29% of activities. 9% of participant activities were spontaneous. The relatively low value for accuracy was not unexpected given the fact that it is very hard to predict a detailed account of our daily activities in advance. The calendar is designed to function as an organizer of important, well-structured events and not activities part of one's daily routine. Not surprisingly, the activities that contributed to most of the inaccuracies in calendar predictability were the loosely structured home activities such as "food", "watching TV", "homework" and "relaxing". When such activities were ignored, a much higher accuracy rate of 93% was obtained. This result highlights the importance of using calendar information as a source of contextual cues with high level of accuracy for structured activities.

2.4.3 Mapping Activities to Configuration

One main goal of the experiment was to examine how people map their activities to different configurations and to check for consistency in the mappings. In order for the configuration to be determined automatically by the cell phone (i.e. inferring it from the description field in the calendar entry) and not as specifically directed by the owner as in our experiment, there needs to be a predictable pattern of mapping from activities to configuration.

A typical example of the mapping data that was collected is shown in Table 2-5. Upon initial observation, it appears that most activities have a dominant desired configuration, but that there exist activities that have 2 or more preferred configurations. Upon closer examination, however, we find that individuals have a predictable desired configuration for 89% of the activities. For example, the “work” activity in Table 2-5 shows two different dominant configurations. This particular case was due to the fact that the user happened to configure the “Normal” state to the same setting as the “Quiet” configuration. Thus, the “work” activity for this participant is counted as consistent. Further, configurations other than the dominant ones were usually chosen at the beginning of the study when participants were experimenting with the settings and were not yet sure which the best fit for a particular activity was. This behavior tended to diminish toward the end of the study period. This shows that the mapping process can be easily automated after the initial period where the user is more involved and she is part of the decision making.

Activity	Loud	Normal	Quiet	Off
Meeting	0	2	6	1
Work	0	6	5	1
Errands	0	1	0	0
Class	0	0	3	5
Homework	0	10	0	0
Lunch	0	3	0	0
Watching	0	1	0	0
Work Out	0	0	1	1
Walking	0	1	0	0
Shopping	2	0	0	0

Table 2-5. Activity to configuration mapping by one participant

The mapping was less consistent across different participants than for each individual participant. Table 2-6 shows the activity to configuration mapping data for the eight most common activities among participants. Even though certain activities such as “Homework” showed consistent mapping, many other activities were not as consistent. For example, many participants chose to have their cell phone “Off” during class, but others chose the “Quiet” configuration. As a result of this and in order for the automatic configuration to be useful, it should be tuned and customized to specific preferences for each user. However, results from this type of study can be used to choose intelligent default settings for different activities. For example, the default setting for “Work” could be “Quiet” because it is the most popular configuration. The users who desire “Normal” can change this default.

Kern. et al. obtained very similar results in their study of the differences between personal and social interruptability [60]. Their experiment found that there were differences among people in the way they assess personal and social interruptability and they argue for interruptability estimation systems to better adapt to individual users’ preferences. This may well be the case for all other interactive, context-aware applications. Making general conclusions about the desired behavior of context-aware applications within certain contexts is a problematic practice that many researchers have fallen into. In fact this is the same practice that Bellotti and Edwards have warned about, and they have proposed following the guidelines of intelligibility and accountability when designing context-aware systems to avoid such problems [18]. We expect that providing the capability for participants to choose their own mapping from activities to the desired configuration has had a substantial effect on the way participants perceive the application as well as on the very positive evaluation of its usefulness.

Activity	Loud	Normal	Quiet	Off
Meeting	2	25	23	6
Homework	8	57	2	0
Class	1	0	18	29
Food	1	21	9	0
Work Out	2	2	2	1
Travel	24	29	2	0
Watching	3	9	2	0
Work	0	17	38	4

Table 2-6. Activity to configuration mapping across all participants

2.4.4 Preferred Interactivity level

Context-aware applications often provide for different levels of interactivity with the users. Chen and Kotz identify two different categories for context-aware computing based on their interactivity: passive context-awareness and active context-awareness [26]. Passive context-awareness offers context information but leaves the application's action or behavior to be determined by the user. On the other hand, active context-awareness autonomously changes the application's behavior without the user's explicit approval. Barkhuus and Day have since introduced *personalization* as a third level of interactivity [14]. Personalization in applications allows the user to specify the exact application behavior or settings for a given context. In our study we examined the preferred type of interactivity for context-aware configuration. All participants have owned cell phones for more than 6 months and thus have experienced personalized interaction, while our application provided them with active context-awareness throughout the experiment period.

As discussed earlier, all participants highly ranked the usefulness of the system, and all were willing to use automatic context-aware configuration in real life if their cell phones were equipped with it. However, participants differed on the level of interactivity with the application they were willing to accept. During the interviews, participants were asked whether they would like to be notified in the case of any automatic configuration change that is trigged by a context switch. All participants reported wanting to be notified but with a varying level of frequency. Two participants wanted to be notified before any configuration change, while the rest wanted to be notified only for certain kinds of dramatic configuration changes. For example, two participants wanted to be notified when the configuration is turned to “Loud” state while 3 others wanted to know when the configuration changes to “Off” state. Thus a hybrid context-aware configuration also is preferred over a stand-alone passive or active version. These responses show that both passive and active context-awareness are preferred over personalization. Barkhuus and Day obtained the same results when they used different context-aware services for mobile telephony [14].

2.4.5 Controls versus Convenience

Naturally, any context-aware application takes some control from the user in exchange for the convenience and benefits of the services provided by the application. As a result, designers must constantly deal with the limit of control the users are willing to give up. This is directly related to the issue of interactivity level discussed in the previous section. The three levels of interactivity provide for varying levels of control and convenience; personalization offers the most control and the least convenience while the level of control decreases and that of convenience increases with passive and active context-awareness, respectively. As part of our experiment, we wanted to indirectly evaluate the willingness of participants to concede some of the control they have over their devices for future context-aware smart spaces or even smart devices that are equipped with sensors capable of providing context information. This inquiry is also relevant in the case of spaces initiating a particular device configuration [28].

Participants were asked whether they would be willing to use the service even if they could not be explicitly involved in context mapping or in deciding about the nature of the mapping from activities to configurations. 40% of the participants answered negatively while the rest answered positively. This shows the importance of the involvement of users in the decision making process of context-aware applications. One way of achieving that is to follow the accountability and intelligibility design principles proposed by Bellotti and Edwards [18].

2.5 Conclusion

Our results suggest that automatic configuration based on calendar information provides both an effective and desirable solution to the interruption problem caused by cell phones. The results show that both structured activities and appropriate configuration can be predicted with high accuracy using the calendar information. The results also show consistent mapping of activities to configuration for each individual. However there was a poor consistency of mapping activity to configuration across different participants. The results show that people are willing to accept a certain level of inaccuracy which comes as a side effect of any context-aware application in exchange for good services and convenience. Further, our results suggest that for this solution to be adopted, it is very important for the users to be involved in the process of mapping context or activity to configuration. This is especially true because the results showed that there was a poor consistency of mapping activity to configuration across different participants. This has ramifications for the broader field of context-aware applications in which designers tend to generalize the application's behavior for a given context across different users and environments. Such generalization should not be assumed without rigorous examination of variation across different users and environments.

Calendar information does not provide accurate context all of the time, and even if the context is predicted accurately, the desired configuration for a certain context is not always the same and there are many factors that might affect it. However, even with an inaccuracy rate of 9-13%, participants still liked this solution and said they are willing to adopt it in real life. We believe this inaccuracy rate can be greatly reduced if reinforcement learning tools were used over a longer period of time. Moreover, the fact that people use the calendar for important activities and appointments and not to record a detailed account of their daily activities as they were asked to do during the study, is expected to increase the accuracy of context predictability and the consistency of activity to configuration mapping.

Mobile phone calendar usage might not be very common due to the very limited inputting capabilities, but this should not undermine the importance of our results. Mobile phones are developing at a very fast pace and smartphones are gaining more and more popularity. Smartphones offer more interaction capabilities, coupling phone capabilities with the functionalities of a PDA, and short-range wireless connectivity such as Bluetooth. The PDA functionalities of the smartphones are expected to drastically increase the use of the mobile calendar application as well as other PIM applications. Moreover, the short-range connectivity is expected to further contribute to the popularity of the mobile calendar due to the fact that people can use their computers to fill in the entries and use the wireless connection to synchronize with their smartphones.

Finally, the simulated phone calls may have caused some bias in how people evaluated the appropriateness of some configurations. It is possible that people are less annoyed when they miss a simulated phone call as opposed to a real call, but this naturally depends on other factors such as the identity of the caller and the message of the call. Also, we expect people to be more accepting of interruptions made by friends or significant others as opposed to interruptions made by anonymous callers like those in our study. Even though we did not specify the identity of the callers in simulated phone calls, participants stated that they thought of the calls as having been made by anonymous callers. Still, this study serves as a starting point for evaluating the feasibility of the context-aware configuration approach. To achieve a more complete understanding of the approach, future studies with real cell phones are needed to account for roles played by other factors that could not be measured in our simulated cell phone study.

3 Caller-based Approach

3.1 Introduction

Many solutions have been proposed aiming to minimize cell phone interruptions caused by the frequent mismatch between the user's context and the cell phone behavior or settings. This mismatch is largely due to the static nature of cell phone configuration which depends on the user's memory to change the configuration every time the context changes. Context-aware mobile telephony offers a promising solution to the problem [86, 89]

Context-aware telephony has long been proposed as a way to minimize cell phone interruptions that are mostly caused by the mismatch between the user's context and the cell phone settings [69, 84, 87, 91]. This mismatch is largely due to the static nature of cell phone configuration, which depends on the user's memory to change the configuration every time the context changes. One approach to solving this problem is to empower the caller to make better, more informed decisions about the appropriateness of making a call by providing him information about the receiver's context. Context information can be any kind of information that helps in conveying the receiver's availability and circumstances, such as location, activity, ambient sound and social cues such as company.

A recent study showed that providing the caller with contextual information about the receiver indeed decreases the frequency of the mismatch and enhances the level of agreement between receivers' desires and callers' decisions [11]. The study also showed that different contextual information generates different levels of improvements.

This approach, however, raises many privacy issues that need to be answered before judging its feasibility and practicality. Moreover, the type of contextual information that provides the most information and hence the greatest improvement without compromising the receiver's privacy has not yet been investigated. For example, it remains unclear which piece of information it is most useful to publish: the receiver's location (home, office), activity (meeting, dinner, and class), speech (talking, silent), or surrounding people (surrounded by people, none). The best contextual information is that which provides the best improvement in the difference between the caller's needs and the receiver's desires and causes the fewest privacy concerns. Obviously, the more contextual details that are revealed, the more privacy concerns they will generate. Thus the question is what is the best tradeoff between contextual information value and their privacy concerns?

By addressing these issues, we are not only trying to examine the feasibility of context-aware telephony but also aim to provide valuable insight to designers of context-aware telephony applications. Only by understanding the sharing patterns of different contextual information with different social relations and user privacy preferences can designers formulate efficient, user-friendly and privacy-aware systems with improved tools for privacy management. The above issues are not unique to context-aware telephony that deals with interruptions, but are common to all context-aware telephony applications that require context sharing, such as those that support social interactions [36, 67].

We report a formative study with 20 participants in order to address the above questions. This study was conducted in-situ over a period of 10 days where participants received inquiries asking them what kind of context information they were willing to disclose to potential callers from 6 different types of social relations. Interviews were conducted at the end of the study as part of an overall evaluation.

3.2 Goals of the Study

The main goal of the study is to answer the following research questions:

1. Are people willing to disclose context information in exchange for less inappropriate interruptions? In other words, are the incentives and services offered by the context-aware telephony application good enough to overcome the privacy concerns?
2. What are the privacy concerns posed by different types of contextual information? The aim is to investigate whether participants perceive different types of contextual information with different levels of privacy concerns. If the answer is yes, which type of contextual information poses the least privacy violation or threat from the participants' perspectives? What type of context information are they willing to share? These issues are not unique to context-aware telephony that deals with interruptions, but are common to all context-

aware telephony applications that require context sharing, such as those that support social interactions [36, 67].

3. What is the effect of the caller-receiver relationship on context disclosure?
4. How do people differ, and on what do they agree?
5. What is the difference, if any, in the level of agreement between the callers and the receivers regarding the call's appropriateness provided by different types of contextual information? It is important to test whether providing the caller with contextual information about the receiver does enhance the agreement between the two parties.

By addressing these issues, we are not only trying to examine the feasibility of context-aware telephony but also aim to provide valuable insight to designers of context-aware telephony applications. Only by understanding the sharing patterns of different contextual information with different social relations and user privacy preferences can designers formulate efficient, user-friendly and privacy-aware systems with improved tools for privacy management.

3.2.1 Context Types

We identified four different types of contextual information relevant to mobile telephony: Location, Activity, Company, and Conversation. These four types were specifically chosen for the balance they provide between privacy concerns that are commonly considered high risk factors (namely, Location and Activity) and low risk factors (Company and Conversation), as well as for their relevance to context-aware telephony. In addition, capturing the contextual information of these four types of context is technically feasible, given the recent advances in context-aware computing and sensor technology. Below we describe the four contexts in more detail.

- **Location**: location is very relevant to mobile telephony. This is clear from the fact that the question of “Where are you?” is the most common and often even the first question people ask when they begin a mobile phone conversation. Depending on the location people can infer the activity of the receiver and how suitable their call is. Many location tracking systems have been developed such as GPS and GSM. Naturally, in this case, the name of the place (such as office, home, gym, in transit) is more relevant than the geographical coordinates of that location.
- **Activity:** Activity is important and relevant contextual information that could provide valuable cues regarding the appropriateness of making of a phone call. Inferring activities is a hard problem that requires the aggregation of many different information sensors plus the use of inference and machine learning techniques. Many systems have been developed in order to infer the user’s current activity and to predict future ones. These systems use cues such as calendar information, computer activities, and real-time analyses of audio and video streams to infer the current activity [42, 55, 76]. Oliver et al’s SEER system uses models to recognize a set of human activities through computer activity, ambient audio, and a video stream [76]. These activities include a phone conversation, a presentation, a face-to-face conversation, engagement in some other activity, conversation outside the field of view of

the camera, and not present. Sometimes activity and location convey the same information, e.g., classroom and lecture, office and working. Examples of relevant activities are: Meeting, Dinner, Studying, Driving, Working out.

- **Company:** This type of context information provides knowledge about the presence of surrounding people but not about the number of people or their identity. The mere fact that the receiver is surrounded by people or alone has been found to convey valuable cues about the user's availability [11]. Combining the company information with other cues, such as prior knowledge about the receiver, can only magnify the value provided by that context. For example, learning that a friend, whom you know to have his own office, has company can help one infer that he is busy, and that one should try to call at a later time.
- **Conversation:** Whether or not the receiver is talking can be a very reliable indication of her availability. Fogarty [42] found that a talking sensor can predict the interruptability of the user with high accuracy. Moreover, the fact that it is technically simple to sense talking, combined with the fact that it does not pose privacy concerns, makes it a good candidate for useful contextual information.

3.2.2 Social Relations

Based on Olson et al., we chose 6 distinct categories of social relations between caller and receiver [77]. These include Significant other, Family member, Friend, Colleague, Boss and Unknown. Even though some of the categories could be further refined (e.g. Friends could be broken down into “close friends” and “best friend”), we opted to keep these six groups in order to keep the task manageable for participants. The Unknown category is not expected to include only strangers because, in the context of cell phone communication, unknown numbers do not necessarily imply that a stranger is calling.

3.3 Experimental 1

The goal of this experiment is to assess the privacy concerns posed by different types of contextual information and to test whether or not these privacy concerns will prevent receivers from publishing such information for potential callers. People perceive privacy differently, and thus it is very hard to measure in isolation from the natural environment and the surrounding context. In order to overcome this problem, we will use the Experience Sampling Method (ESM), which is a technique used for in-situ evaluation of human subjects. Developed in the mid-70s by Csikszentmihalyi, Larson and Prescott [31]. It is now widely used in ubiquitous computing to simultaneously and systematically study people in natural environments [30]. In the simplest version of EMS, human subjects carry small computing device such as a PDA that prompts the subject for data and electronically records their responses.

Extensive research has been conducted with the aim of studying privacy issues related to context-aware computing. The study most relevant to ours is the one conducted by Consolvo et al. which explored user’s location disclosure to social relations [29]. The study also examined the decision process that determines whether and what to disclose to social relations. Our study goes beyond location information and examines the disclosure of other kinds of context information as well as the relationship between different context types.

Olson et al. studied the sharing of private information with the purpose of identifying clusters of information and recipients in order to create a simple and efficient privacy management system [77]. The study focused on personal information rather than dynamic context information. Patil and Lai investigated sharing preferences for location, availability, calendar information and messaging activities for a collaborative application called MySpace [81]. The study explored how people control their privacy permission for social relations. They found that grouping mechanisms offer a balance between privacy control and configuration burden. The study is mostly relevant, however, to CSCW applications.

Lederer et al. presented a mechanism to allow people to control the disclosure of their context information [66]. They introduced the "face" concept as a metaphor to what the user is willing to show others in a certain situation. Their user study found that the inquirer plays a larger factor than the situation when people decide what to disclose.

Several studies have aimed at exploring the privacy requirements in context-aware applications. Lederer et. al have identified five pitfalls that designers should avoid when designing interactive systems [65]. These pitfalls include obscuring potential information flow and lacking coarse-grained control. Reciprocity was introduced by Bellotti et al as an important privacy control feature in context-aware applications [19].

3.3.1 Methodology

At the beginning of the study, participants were familiarized with the purpose of the study and answered a P&AB-Harris Interactive privacy classification survey so they could be grouped according to their level of privacy concern [78]. Demographic data was also collected. Participants were each given a Palm PDA that ran a general purpose ESM application partially developed at Intel research labs named iESP [30]. They were given a brief introduction on how to use the PDA with a walk-through scenario similar to the ones they were expected to encounter in the real study.

During the study, each participant carried a PDA. Throughout the day, every participant received inquiries prompting her to choose what context she would like to disclose to a potential caller (Figure 3-1). Participants were asked to assume the role of the receivers of a cell phone call. The caller assumed one randomly chosen role out of the 6 social relations. In addition to inquiring about participants' willingness to disclose different types of context information, every questionnaire included a list of questions about the current location, activity, number of surrounding people, and the social relationship to the surrounding people, as well as the participant's availability under those circumstances to receive a phone call from that particular caller. These questions allowed us to examine the effect of the environmental conditions on participants' pattern of context disclosure.

Figure 3-1. ESM question asking about the kind of context information the participant would be willing to disclose to the caller (a friend in this case).

The questionnaires were triggered randomly throughout the day in order to maximize the chances of capturing a variety of different situations and also to minimize their predictability and thus decrease any potential bias in the answers. The questionnaires were triggered during the day from 10 am to 10 pm, unless the participant requested different times at the beginning of the study. The questionnaires were also equally distributed as to the roles of the callers. The study lasted for 10 days during which participants were prompted to answer the questionnaire 13 times a day. The 10-day period was chosen so as to elicit a representative sample from participants without overwhelming them with too many questionnaires per day. In addition, by conducting the in-situ study over 10 days, we were likely to capture participants’ responses throughout a wide range of usual and unusual daily activities. Each questionnaire took approximately 1-2 minutes to complete.

At the end of the study, semi-structured interviews were conducted with participants in order to obtain their overall feedback about the usage, acceptability and concerns of context-aware telephony. The interviews lasted approximately 20 minutes each. The list of all in-situ questionnaires and the end of the study interview are listed in Appendix A.

3.3.2 Participants

We recruited 20 participants equally divided between males and females. Participants were ages 18-51 (average 24), were mostly students and all had either a full-time or part-time job. All participants had owned cell phones for more than a year (4.4 years on average) and regularly used their cell phones (daily average: made 5 calls and received 4).

Using the P&AB-Harris Interactive privacy survey, we found that twelve participants were privacy fundamentalists, six were pragmatists, and two were unconcerned (see Figure 3-2). The P&AB-Harris study reported similar rates [78].

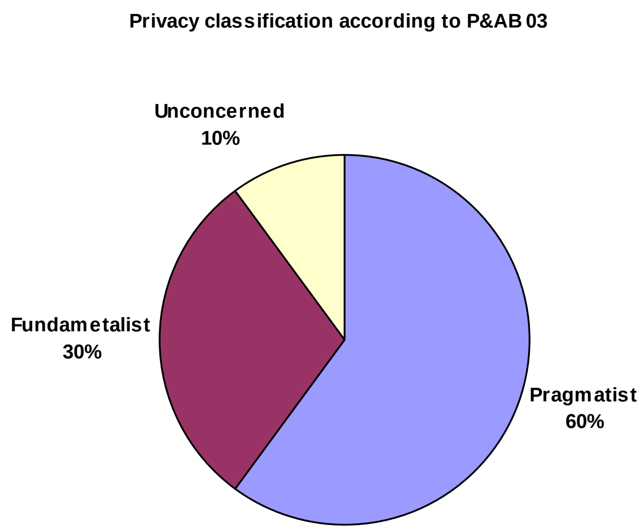


Figure 3-2: Participants distribution according to P&AB 03 privacy classification. The distribution is very similar to the one reported by P&AB from 2003.

3.3.3 Design Tradeoffs

Since the study involved hypothetical context disclosure, and no real context was actually disclosed, this may have caused the participants to be less concerned about their privacy and thus disclose more context information than they would disclose in a real application. However, employing the in-situ technique to capture people's responses in real life is expected to minimize such bias.

The goal of the study was not to provide a comprehensive account of the details of privacy preferences for context-aware telephony, but rather to provide designers with high-level guidelines about user privacy preferences and sharing patterns.

3.3.4 Findings

The overall participation rate was around 80%, which means participants answered 80% of the total questionnaires and missed 20%. After removing the partially answered questionnaires, a total of 2422 questionnaires were considered for the analysis.

In this section, we report the main findings of the study. We begin by examining overall context disclosure rates, the correlations between the examined contexts that emerge, and how we classify the contexts according to their perceived privacy risk. We then analyze the effect of the social relationship between the caller and receiver on context disclosure rates and caller availability, identifying distinct patterns. We also look at how the current physical and social contexts (as reported by the participant) affect both context disclosure rates and availability. We present a discussion of how we can classify the participants in terms of their privacy concerns as gleaned from their in-situ answers, and how that compares to the P&AB-Harris survey. We end with a discussion of the effect of gender.

3.3.4.1 Context Classification

For every questionnaire, participants selected any combination of the four different types of context information they were willing to disclose, including “none”. In most cases, participants opted to either reveal all context information or none at all. Participants revealed all the information (location, activity, company, and conversation) 41% (992 responses) of the time whereas they chose to reveal nothing

19.1% (463 responses) of the time. The third most frequent selection was Company and Conversation (18.7%, 452 responses), followed by Company in the fourth place (8.1%., 195 responses) and then Conversation in the fifth (3.6%, 88 responses).

This data suggests that users are more sensitive to the release of Location and Activity, rising to an initial classification of these contexts as *high privacy risk*, and Company and Conversation as *low privacy risk*. The data also show that users tend to share as much information as possible, removing contexts from their disclosure lists selectively based on their specific situation.

3.3.4.1.1 Context Disclosure Rates

Table 3-1 shows the frequency with which participants chose to release each type of context information. Company was the most frequently released context type, closely followed by Conversation, then Location, and then Activity. We believe the frequency of releasing a specific type of contextual information is directly related to its perceived level of privacy risk. So, the more a certain type of context is perceived to threaten privacy, the less frequently participants choose to disclose that information.

Contextual info	Frequency	Percentage
Company	1799	74.3
Conversation	1681	69.4
Location	1148	47.4
Activity	1123	46.4

Table 3-1. The disclosure frequency and percentage for each type of context information for all participants out of a total of 2422 questionnaires

The Conversation context appears to spark a slightly higher level of privacy concern than Company. This may be because Conversation indirectly suggests the existence of Company either physically, in the case of a person-to-person conversation, or virtually, in the case of a phone conversation. The opposite is not necessarily true however.

Location and Activity information were disclosed at virtually identical rates with Activity disclosed slightly less than Location. Even though the Activity and Location can convey the same information in many cases, Activity may convey more information than Location in some cases. For example, often one can infer other context information such as location, company and availability from Activity.

Participant	Location	Activity	Company	Conversation	None
1	93.3	79.8	100.0	94.2	0.0
2	89.6	55.7	100.0	100.0	0.0
3	79.2	79.2	79.2	79.2	20.8
4	79.7	79.2	67.0	82.2	17.3
5	72.6	76.0	76.0	74.7	21.2
6	47.0	77.8	84.6	72.6	0.0
7	57.4	57.4	63.5	65.2	33.9
8	46.4	45.6	80.8	65.6	19.2
9	55.6	53.8	64.1	60.7	35.9
10	53.6	52.7	61.3	58.6	33.8
11	41.5	44.9	72.9	66.1	22.0
12	48.5	48.5	74.2	48.5	25.8
13	56.9	54.9	54.9	42.2	41.2
14	26.8	22.7	78.4	78.4	0.0
15	11.0	14.5	82.0	95.9	2.9
16	18.3	19.5	82.9	74.4	8.5
17	0.0	1.1	94.7	66.0	3.2
18	18.4	18.4	65.3	49.0	34.7
19	14.6	5.1	73.4	57.6	12.0
20	0.0	2.0	41.4	31.3	54.5
Average	***45.5***	***44.4***	***74.8***	***68.1***	***19.4***

Table 3-2: The rate of context disclosure across different context types for each participant

The percentage at which a participant chooses to disclose a particular type of context information relative to the total number of requests for that disclosure is called the *disclosure* or *sharing* rate. As shown by Table 3-2, the average disclosure rate is relatively high in general with the least rate is for Activity information at a value of 44.4%. Overall, this high rate of context disclosure indicates that solutions which aim to enhance cell phone interruptions based on the receiver's context are both feasible and practical.

3.3.4.1.2 Grouping of Context Information

After examining the four different context disclosure rates for each participant, we observed that Location and Activity have a very similar trend while Company and Conversation share a different trend. We found a strong correlation between disclosing Location and disclosing Activity of 0.92 (significant at 0.001 level). This high correlation rate indicates that, in addition to the fact that the disclosure rates for Location and Activity are very close to each other across all participants, people perceive both activity and location information to carry almost the same weight in terms of their privacy concern level. Another statistically significant correlation is found between Company and Conversation (the correlation value is 0.78, significant at 0.001 level). Again, the high correlation between Company and Conversation and the similar values for their disclosure rates across the participants means that people tend to categorize them in the same level on the scale of privacy concern.

We also found a strong and statistically significant negative correlation between disclosing no context information and disclosing company and conversation contexts (correlation with company context is -0.91 and correlation with conversation context is -0.81, both significant at 0.001 level). There was no such correlation between choosing not to disclose any context information and disclosing Location and Activity. Thus, for certain situations, participants appeared to make a choice between disclosing Company/Conversation information and disclosing no information at all. This further validates that Company and Conversation are perceived to have a lower privacy risk than Location and Activity.

As a result, we categorize the four types of context information into two groups: *high privacy risk*, and *low privacy risk*. The high privacy risk group includes Location and Activity where as the low privacy risk group includes Company and Conversation. The different context types within the same group are almost equivalent in terms of their privacy concern level, allowing designers to choose the best context for their context-aware application from the desired privacy risk group.

3.3.4.2 Social Relationship of Caller and Receiver

The number of questionnaires per social relation or caller role is shown in Table 3-3. Ideally, the number of questionnaires would be equal across the types of social relations in order for any comparison across social relations to be precise and unbiased. However, this was not possible in our study since the social relation associated with each questionnaire was randomly selected and 20% of the questionnaires were not answered.

	Significant Others	Friend	Boss	Colleague	Family	Unknown
#	374	427	380	395	416	430
%	15.4	17.6	15.7	16.3	17.2	17.8

Table 3-3. The # and % of questionnaires per social relation

3.3.4.2.1 Context Disclosure and Social Relations

Figure 3-3 shows the average disclosure rates across all participants for the four different types of contextual information for different social relations. The rate of context disclosure decreases as the strength of social relationship between the caller and the receiver becomes weaker. For example, participants disclose their locations around 76% of the time to their significant others, 60% of the time to their family members, 61% of the time to their friends, 39% for their colleagues, 24% for their boss and 19% for anonymous or unknown callers. Interestingly, the rate of context disclosure is slightly higher for friends than family members. Even though the difference is not significant, the trend is consistent across all four context types, which suggests that people are in general more open to sharing private information with their friends (whom they choose) than with their family members.

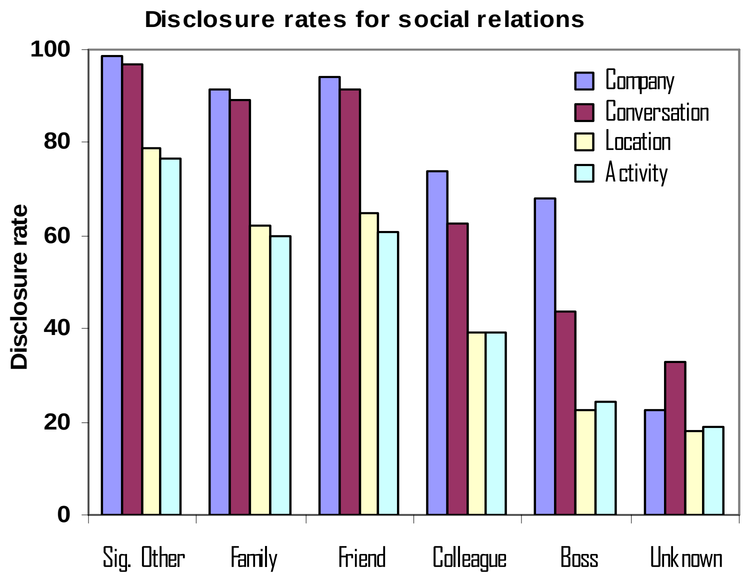


Figure 3-3. Average disclosure rate for different types of context information across different social relations

The rate of sharing decreases drastically when moving from high privacy risk group to low privacy risk group. This pattern is consistent across all social relationships. Participants shared Company more with Boss and Colleague than Conversation, (68%, 74%) and (44%, 63%), respectively, pointing to a higher level of privacy concern for Conversation than for Company. This may be because both Boss and Colleague already know the company information when participants are at work, but this is not the case for the conversation information. However, participants disclosed Conversation more than Company (33% and 22.6% respectively) when the caller was Unknown. The change in the rank order of disclosure rates for Company and Conversation moving from Boss and Colleague on one side to Unknown on the other side indicates that the ranking of different types of context information according to their privacy risk is dynamic and can change from one role to another.

The disclosure rates for every participant for the four type of context information across all social relation are shown in Appendix B.

3.3.4.2.2 Grouping of Social Relations

The six groups of social relations were found to be a good fit for clustering different social relations. In order to study the sharing pattern of different types of contextual information amongst different social relations, we employed a hierarchical cluster analysis technique. The dendrograms shown in Figure 3-4 depict the different clusters for different social relationships. Each dendrogram shows the clusters for one type of contextual information using the disclosure rate by each one of the 20 participants for that particular type of context. We used a between-group linkage as a clustering method and Squared Euclidean Distance as a clustering measure. From the dendrograms we can see that there are 3 different main clusters. The first cluster contains the Significant other, Friend and Family member relationships while the second cluster contains Colleague and Boss, and the third cluster contains the Unknown category. The same clustering pattern was obtained when using the disclosure rates for the four different types of contextual information. However, the distances between clusters when they are joined vary from one type of context to another.

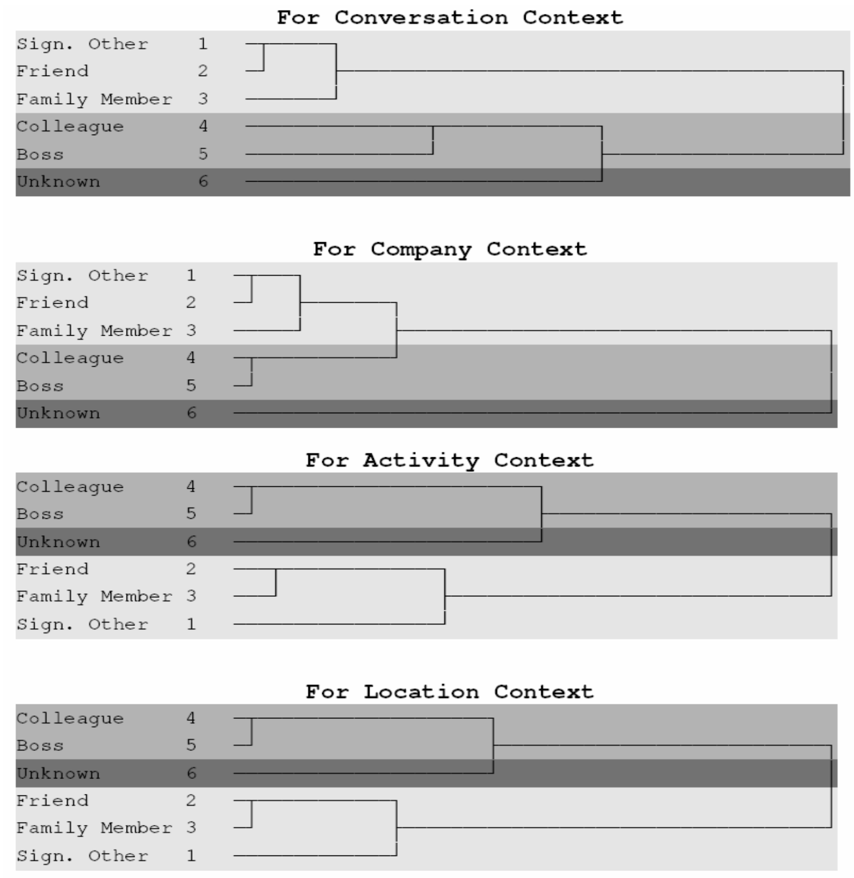


Figure 3-4. Dendrograms showing the clustering pattern of caller roles for each type of context information.

The three different clusters correspond to three levels of sharing: high, medium, and low. The high sharing group corresponds to the first cluster that contains social relations with whom participants are less concerned about sharing context information. On the opposite extreme, the low sharing group corresponds to the third cluster which only contains the Unknown social category. The medium sharing group corresponds to the second cluster and so contains the Boss and Colleague relationships in which participants share information only on an as-needed basis.

Having the same clustering pattern of social relations across different types of context (high privacy risk and low privacy risk contexts) suggests a pattern of sharing contextual information among different social relations. This common pattern of sharing can help designers of context-aware telephony applications in particular and privacy-aware systems in general to build simpler systems either by using an access control approach or a learning and recommending approach. These results are in agreement with the work of Olson, who obtained similar results investigating sharing patterns of 40 different types of personal data across different social relations [77].

3.3.4.2.3 Availability and Social Relations

During the in-situ study, participants were asked at the end of each questionnaire whether it is an appropriate time for the caller to call. Our results show that the availability rate (the percentage of the appropriate calls) does not only depend on the context of the receiver but also on the relationship between the caller and the receiver. In fact, the social relation was found to have a main effect ($F(5,114)=10.7$, $p< 0.001$). The availability rate for Significant Others is the highest (75%), followed by Friends (68%), Family members (63%), Boss (50%), Colleagues (47%), and Unknown (39%). This shows that designers of context-aware telephony applications that aim to minimize unwanted interruptions should take into consideration the social relation between the parties in addition to the receiver’s context.

The average availability over all different social relations and for all participants is around 57%. This means that a little less than half of the calls are not received at appropriate times. This high rate of unwanted incoming calls stresses the importance and the need for solutions to minimize cell phone interruptions. It is worth mentioning that the rate for inappropriately received calls may be lower in real life than the one obtained from our study due to the familiarity of friends, family members, and significant others with the work pattern of the receiver.

The availability rate across different social relations for any specific participant seems to be independent from each other for the most part. Table 3-4 presents the correlation matrix of the availability rate for different social relations. We can see that other than there is a weak correlations in the availability rate of the different social relations. An exception of that behavior is the strong correlation between Family and Significant others. The weak correlation behavior means that a high (low) level of availability for a certain social relation does not necessarily mean a high (low) level of the availability for other social relations. This emphasizes the high dependency of the availability on social relation and not on other factors such as whether or not the person likes to talk on the phone.

	Significant others	Friends	Family	Boss	Colleague	Unknown
Significant others	1.00					
Friends	0.48	1.00				
Family	0.77	0.52	1.00			
Boss	0.17	-0.04	0.27	1.00		
Colleague	0.55	0.14	0.30	0.43	1.00	
Unknown	-0.07	-0.17	-0.12	0.45	0.57	1.00

Table 3-4: Correlation matrix between the availability rates for different social relations

3.3.4.3 Effects of Physical/Social Context of Receiver

3.3.4.3.1 Location and Sharing Rates

Figure 3-5 shows the distribution of location information, or where participants spent most of their time, as reported by the participants during the in-situ study. When participants optionally chose to specify their exact meaning of “elsewhere”, the most popular entries were ‘at gym’, ‘office hour’, ‘park’ and ‘concert’. To explore the effect of location on disclosure rates, we examine the two most frequent locations: home and work.

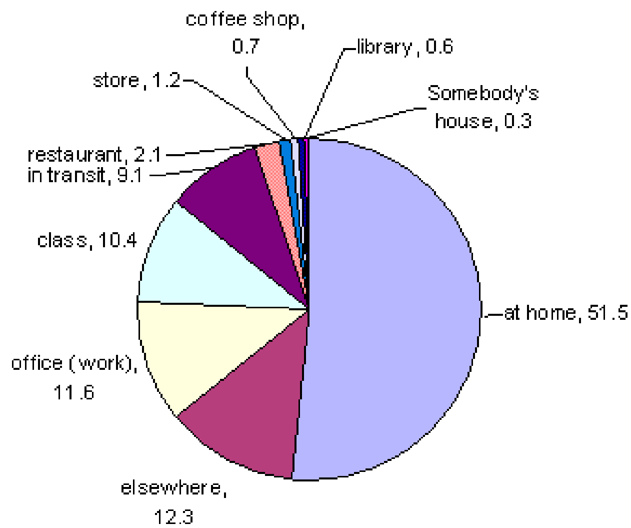


Figure 3-5. Distribution of locations as reported by the participants during the in-situ study.

Figure 3-6 compares the sharing rate for location information when participants reported being ‘at work’ and ‘at home’. As expected, more privacy is desired when at home than at work. One can see a steady decease in sharing rates going from Significant Other to Unknown. One interesting observation is that participants disclosed location information at a considerably higher rate for Significant Other when at work than when at home. However, this is not the case for Friend and Family member.

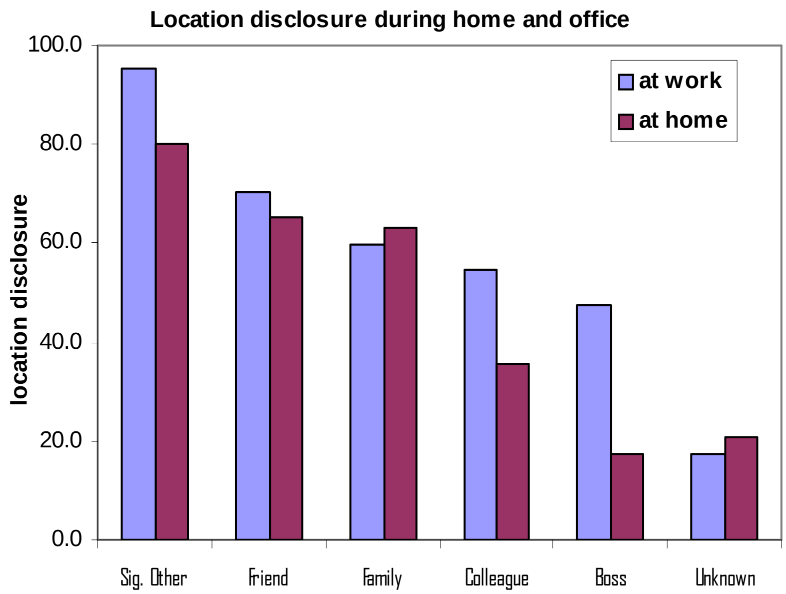


Figure 3-6. Comparison of sharing rate for location information across different social relations during home and work times

Colleague and Boss social relations appeared to be affected the most where participants disclosed a significantly higher rate of location information when at work than when at home. Similar patterns were observed for the other types of context information.

3.3.4.4 Location and Availability

Table 3-5 shows the availability (the situations where participants answered "yes" for being available to receive a call) as a function of location. We can see participants are mostly available in the 'restaurant', 'at home', 'in transit' and 'store'. The table shows many unexpected results. For example, participants are almost as equally available being at home as being at a restaurant, or in transit. Surprisingly, people do not seem to mind receiving calls in restaurants. Another one is that in almost 5% of the times, participants showed willingness to receive calls while in the class. But after following up with these cases, we found that people were waiting for the class to start and not during the class. The availability number given for the gym might be unreliable due to very few data points that were collected there.

Location	Total Requests	Availability (YES)	Availability rate
restaurant	51	36	70.6
at home	1248	875	70.1
in transit	220	154	70.0
store	29	19	65.5
coffee shop	18	9	50.0
elsewhere	314	149	47.5
office (work)	282	129	45.7
gym	7	2	28.6
class	253	12	4.7

Table 3-5. Availability rate as a function of location across all participants.

From the fist glance, it seems people have relatively high availability being at office/work. However, upon further examination, we found that, most contributions came from the fact that participants were being available to calls from boss and colleagues. Table 3-6 shows the detailed distribution of participants' availability when at work/office across different social relations. We can see that, participants when at 'office/work' were mostly available for boss and colleagues. Yet, upon further examining the availability for Boss we found that most participants were always available to receive calls from Boss, and the non-availability contributions came from only 2 participants which may indicate they are special cases. In conclusion, information about both the location and the social relations of the callers are needed in order to accurately determine the availability of the receiver. Depending on the location information by itself to decide about the user availability will not yield accurate results.

	Total	Available	Percentage
Boss	42	29	69.0
Colleague	53	32	60.4
Significant others	42	19	45.2
Friends	47	21	44.7
Family	52	18	34.6
Unknown	46	10	21.7

Table 3-6. Availability distribution across social relations when participants reported to be at 'office (work)'

3.3.4.4.1 Availability and Surrounding People

Participants were asked to report the number of surrounding people in order to study its effect on their availability to receive calls. We found that participants were alone for 38% of the times and were surrounded by more than 4 people 23% of the time (see Figure 3-7). Figure 3-8 shows the distribution of social relationships between the participants and the surrounding people. Participants were surrounded by friends for 23% of the times, while they were surrounded by classmates for about 2% of the times.

Figure 3-9 shows the average availability rate for different numbers of surrounding people. The availability rate decreases linearly as the number of surrounding people increases. This suggests that the number of surrounding people is a good indicator of the user's availability. Number of surrounding people provides information about user availability that could not be achieved by company information (whether a participant has a company or not) by itself. Company information only provides a binary value of whether the user has company or not regardless the number of people.

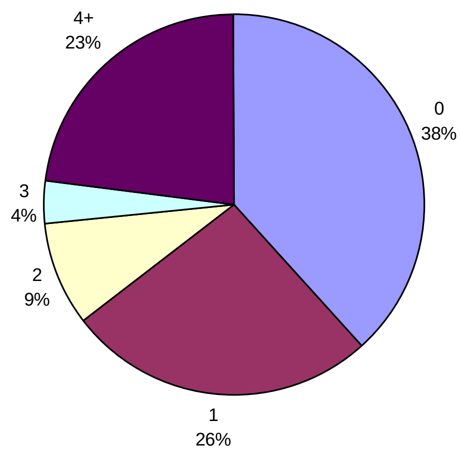


Figure 3-7: Distribution of the number of surrounding people as reported by participants during the in-situ study

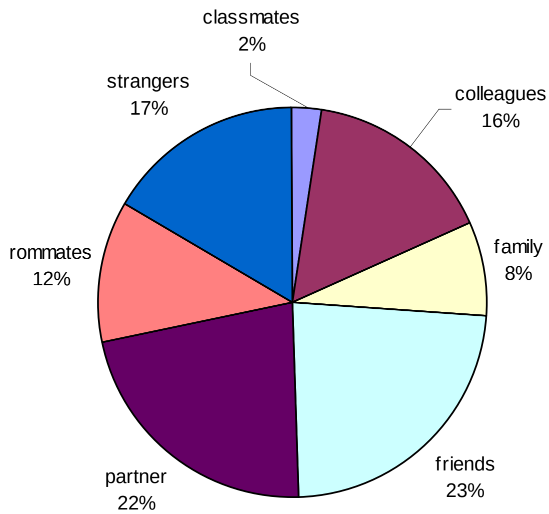


Figure 3-8: Distribution of social relationships between the participants and the surrounding people as reported by participants during the in-situ study

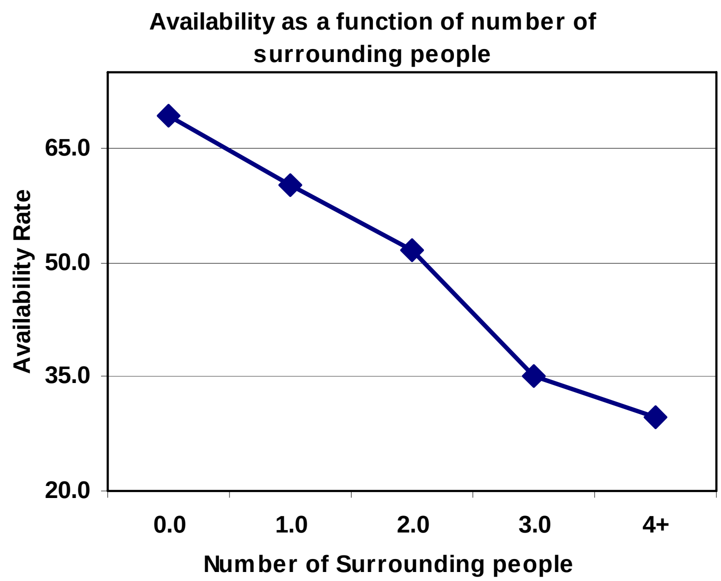


Figure 3-9. The average availability rate for different number of surrounding people

3.3.4.5 Participants' Privacy Classifications

Previous research in consumer privacy [77, 78, 88] has shown that one fourth of consumers are "privacy unconcerned", having little to no concern about their privacy, one fourth are highly concerned "privacy fundamentalists", and around half fit in between those extremes as "privacy pragmatists". To test whether our results reflect that breakdown and to examine the differences in participants' privacy classifications, we categorized the participants according to their willingness to share context information with others. We chose the average disclosure rate for location information across all social relations to represent the privacy index for each user because Location and Activity were responsible for most of the variation in sharing rates among participants. The privacy index ranged from 0 to 100.

Figure 3-10 shows a histogram of participants' average rate of sharing location information. From the figure we can see that 4 participants can be considered "privacy fundamentalists", having sharing rates between 0-20%, 12 can be considered "privacy pragmatists" with sharing rates between 20% and 80%, and another 4 participants can be considered "unconcerned" due to their sharing rate between 80% and 100%. The overall average location sharing was 6.3% for privacy fundamentalists, 94% for privacy unconcerned, and 54.5% for privacy pragmatists. Clearly, "privacy pragmatics" make up the largest group, a fact which agrees to a large extent with the results obtained in consumer research [78, 88]. However, participants were located in different categories from those in the P&AB survey. The same observation was cited by Consolvo et al.: the P&AB privacy index is not a suitable measure for privacy concerns in context-aware computing [29].

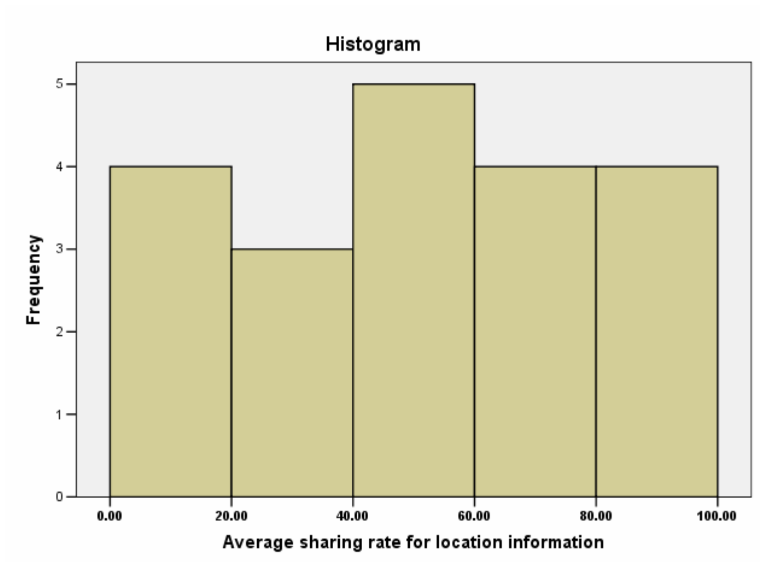


Figure 3-10. Histogram of average location disclosure rate across all social relations. There are 4 "privacy fundamentalists" (at left) and 4 "privacy unconcerned" (at the right).

3.3.4.6 Gender Effect

Gender was found to have a significant effect on the sharing rate across the four context types. Figure 3-11 shows the difference in location sharing between the male and female groups across different social relations. One can see that males shared significantly more location information than females for each one of the social relations. We performed an independent sample t-test (single-tailed) for every female-male pair's rate of disclosure for each social relation. We obtained a statistically significant difference (at 0.05 level) for Friend, Family, Colleague, Boss, and Unknown (values for t(18) are 2.27, 1.80, 2.75, 2.07, 1.90 respectively), and near statistical significance for Significant Other (t(18)=1.71, p=0.052).

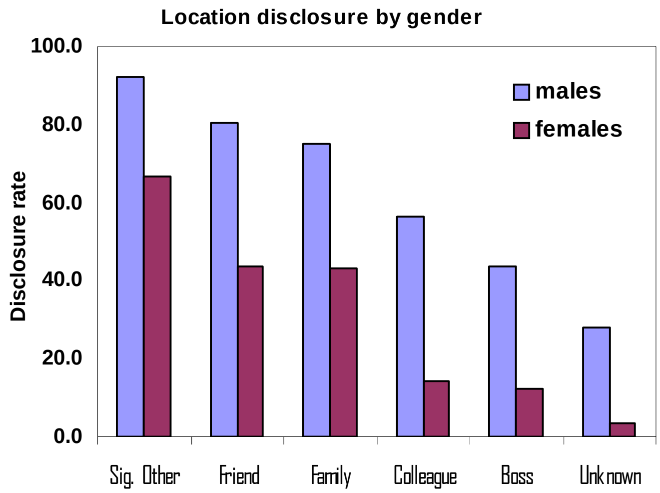


Figure 3-11. Comparison between males and females in location sharing across different social relations

The same behavior was found for the disclosure of Activity. However, even though males shared Company and Conversation at a higher rate, the differences in averages were not significant. Looking back at the 'privacy fundamentalists' group, we found that 3 out of the 4 members were females and only one female was found to be a member of the 'privacy unconcerned' group. Such results imply that females, in general, are more sensitive or cautious in sharing their location and activity information than males.

3.3.4.7 Qualitative Results

During the end-of-study interview, 70% of participants reported they were willing to use a service that publishes their context information comparable to the one used in our study if their cell phones were equipped with it and if they were provided with a tool to manage their privacy preferences. Twenty percent of the participants answered that they would possibly use the service, while the remaining 10% would avoid the service due to privacy concerns. Participants were also asked to rate the usefulness of the service on a scale of 1 to 5, with 5 being the most useful. Fifty-five percent of the participants rated it 4, 30% rated it 3, 10% rated it 2, and 5% rated it 1.

We also found that participants frequently changed their cell phones' profiles, an average of 4 to 5 times per day. One participant reported keeping his cell phone in vibrate mode all the time, despite the risk of missing some calls, rather than changing the profile back and forth. Another participant reported that she stopped carrying her cell phone around because of the inconvenience of untimely interruptions.

3.3.5 Discussion

The low availability rate of our participants to receive cell phone calls (only 53% of the time) highlights the usefulness of such a service and may explain the high acceptability rate. Privacy preferences and disclosure patterns discussed in the paper should provide guidance for the designers of context-aware telephony, as it is essential that designers provide users with an easy and efficient way to control their information disclosure.

People perceive different kinds of personal information with varying degrees of sensitivity or privacy comfort [45]. Patil and Lai attribute the difference in the rate of context disclosure to the level of privacy comfort associated with a particular type of context information [81]. The higher the disclosure rate for a certain type of context information, the less sensitive the person is and the higher the level of privacy comfort regarding this context. Looking back at our results, we can see that both

Location and Activity information were disclosed less frequently than Company and Conversation. This suggests that Location and Activity triggered lower privacy comfort levels while Company and Conversation triggered higher levels of privacy comfort. This is not surprising given that in many cases learning the activity or the location of a close friend automatically conveys substantial information about the friend's company and conversation status. For example, finding out that a friend is at a movie theater indirectly suggests with high probability that she has company and is not engaged in a conversation. However, this ability to infer information does not work reciprocally, i.e., knowing Company or Conversation status does not generally lend information about Location and Activity.

The association of the different types of context information to varying levels of privacy comfort is not only evident from the disclosure rate but also from the negative correlation between disclosing Company and Conversation and disclosing nothing. This means that, in many cases, participants choose to disclose Company and Conversation over not disclosing anything, suggesting that people disclose less sensitive context information when they are concerned about their privacy

Moreover, even though our study predicted similar ratios of the three different groups of privacy classifications to those found by P&AB, some participants were categorized differently. This suggests that the P&AB privacy index does not serve as a global measure of privacy concerns, and different privacy indexes are needed for different areas such as context-aware telephony.

3.4 Experiment 2

This experiment assesses the differing value of different types of contextual information users can provide. The value of a given type of contextual information is measured by the level of agreement between the caller and the receiver as to their evaluation of appropriateness of different calls. The greater the agreement, the better a cue it is for the caller. We expect that the more information provided to the caller about the context of the receiver and his surrounding environment, the better the decision he can make regarding the appropriateness of a call. This is best achieved if the caller has access to a live stream of audio and video coverage of the receiver's environment. However such a solution is not feasible or realistic given privacy concerns as well as the technical difficulties of providing live audio and video coverage of mobile users.

The best contextual information is that which (a) provides cues about the receiver that are relevant enough to help the caller make good decisions whether or not to call and (b) causes the fewest privacy concerns for the receiver. Another factor that contributes to the overall value of a certain type of contextual information is the technical feasibility of capturing and providing such information for the caller. When we chose the different types of contextual information we made sure that they are all technically feasible given the current technology though they vary in their cost and difficulty level. Given that technology is improving rapidly and continually decreasing the problems of cost and technical difficulty, we are not going consider these factors in the evaluation at hand. We will only consider the level of agreement and the level of privacy.

3.4.1 Methodology

Twenty participants were randomly divided into 2 equal groups: callers and receivers. The caller group was provided with hypothetical messages to deliver to the receivers as well as different kinds of contextual information about the receivers. Callers were asked whether they think it is appropriate to call given the context of the receiver and the message to be delivered. Participants within each group where further divided into two separate and equal subgroup and participants in each subgroup (5 participants) evaluated half of the 10 messages combined with all different contextual conditions (60 combinations).

We used four different types of context information: Location, Activity, Company, and Talking. Since the Location and Activity context information can have countless values, we limited our experiment to the three of what we think are the most common of each type. Location values included: Office, Home, and in Transit. Whereas Activity values included: Meeting, Driving, and Dinner. As for the Company context, receivers are either were surrounded by (a) one person (b) two or more people or (c) no one. Finally, for the Talking context the receiver were described as either talking or not. The messages combined with context information were randomly displayed to participants but with equal distribution.

The relationship between the callers and the receivers was that of colleagues, and that it stayed the same throughout the experiment. This relationship was chosen in order to eliminate any bias for the value provided by different contextual information, which is the main purpose of this experiment. The experiment used between-subject design where participants were divided into two groups and thus were subjected to different experimental conditions.

The experiment will be conducted in-lab at the end of the in-situ study. We collected data using java desktop application (see Figure 3-12).

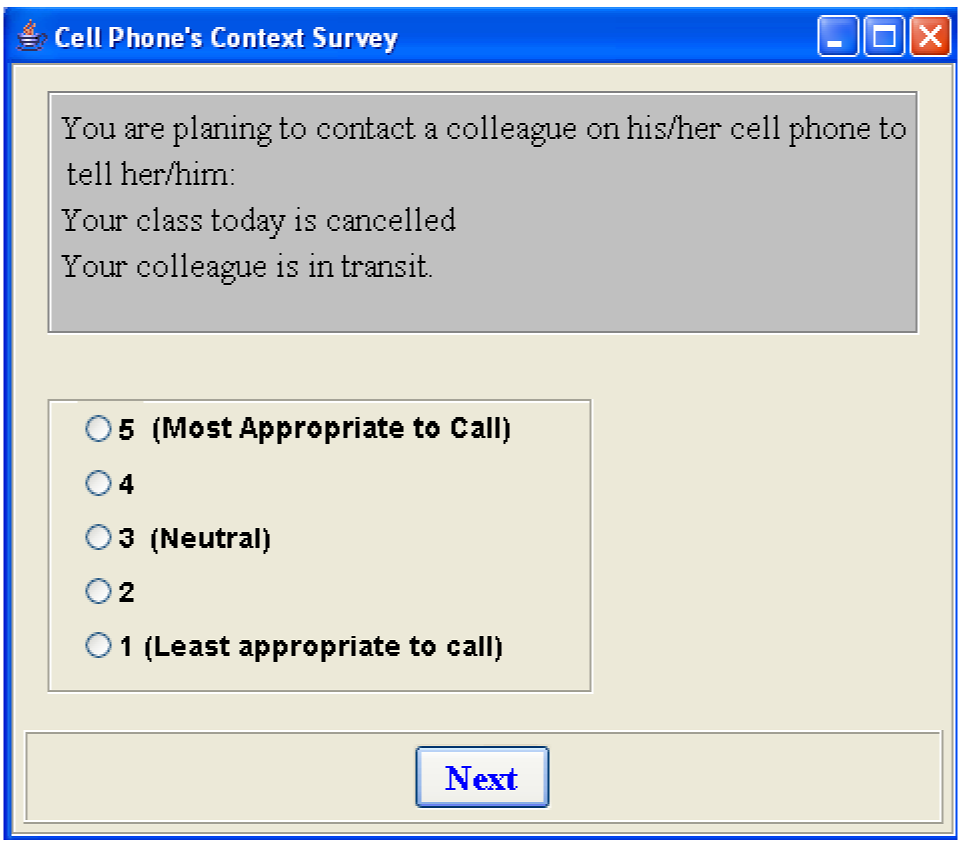


Figure 3-12. The desktop application used to evaluate the receiver-caller agreement given a certain message and context information

3.4.1.1 Messages

The messages contain the information that needs to be conveyed by the callers to the receivers. Our messages are mostly inspired by those used by Avrahmi et al. [11] which were chosen to equally cover good and bad news as well as different levels of urgency. Moreover, the messages include information related to work, family, friends, and school. Below is the list of 10 messages we used in our study.

1. Your class today is cancelled
2. Your final exam date is changed
3. Circuit City has a clearance sale today
4. IU basketball team lost
5. Would you like to join our BBQ party this weekend?
6. Your boss wants to talk to you
7. Can I borrow your Java book?
8. I will be late for our meeting
9. Would you like to join us for coffee?
10. I just sent you email with the document you requested

3.4.1.2 Participants

The participants were the same 20 individuals who were recruited for experiment 1. The participants were given instructions that pertained to their condition (Receiver or Caller) and how to navigate through the application. The task took approximately 5 to 10 minutes.

3.4.1.3 Design Tradeoffs

The hypothetical nature of the study where participants have to imagine the scenarios will inevitably introduce a certain amount of bias in our findings. However, this bias effect will be minimal due to the fast that all participants were subjected to the same experiment conditions (same message, context info, the relationship between the caller and the receivers).

3.4.2 Findings

3.4.2.1 Message Evaluation

Table 3-7 shows the rating for all the messages by both the receivers and the callers. The rating of a particular message represents the appropriateness of that message from both the receivers' and callers' perspective, i.e. how appropriate it is for the caller to make a call regarding that message and how appropriate the receiver judges that call to be. The scale used ranges from1 to 5 where 1 is the least appropriate and 5 is the most appropriate. Every message was evaluated by 5 callers and 5 receivers. The appropriateness of calling to convey a particular message is a direct measure of the urgency of that message. The average rating by the receivers was 3.92 (SD=0.78) and by the callers was 3.16 (SD=0.72) (see Figure 3-13). The two-tailed t-test showed that the difference between the receiver's and the caller's rating is significant ($t(18)=2.27$, $p<0.035$). This shows that the callers are more conservative than the receivers when evaluating the message's urgency. This means that there is a higher tendency for the receivers to accept the call than for the caller to make the call.

message	Receiver Average Rating	Caller Average Rating
Your class today is cancelled	5	2.4
Your final exam date is changed	5	2.6
Circuit City has a clearance sale today	3.2	2.2
IU basketball team lost	3.8	2.6
Would you like to join our BBQ party this weekend?	4.8	2.8
Your boss wants to talk to you	3.8	4
Can I borrow your Java book?	3	3.4
I will be late for our meeting	4	4
Would you like to join us for coffee?	3	3.6
I just sent you email with the document you requested	3.6	4

Table 3-7. The average rating per message by the callers and the receivers (every message rated by 5 callers and 5 receivers)

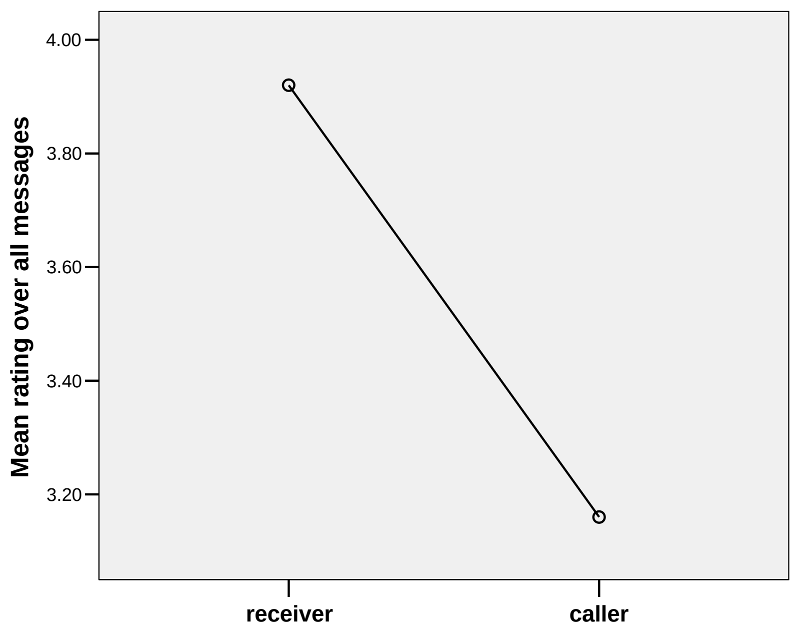


Figure 3-13. The mean ratings by receivers and callers for all messages without context info

Table 3-8 shows the average rating by each caller and receiver over all 60 questionnaires answered. The 60 questionnaires are the results of 5 different messages combined with 12 different contextual types, including an instance of no context information. Once again the average for callers is less than that for the receivers, but this time the t-test shows that the difference is not significant at the 0.05 level (the receivers' average is 3.50 while the callers' average is 3.14 ($t(18)=1.10$ and $p<0.14$). This is an indication that context information increases the agreement level between the callers and the receivers.

Receiver Average Rating	**Caller Average Rating**
3.1	3.6
3.7	2.5
3.8	1.7
3.3	3.9
3.6	2.3
3.2	3.4
3.6	3.5
3.3	3.5
3.1	3.8
3.9	3.9

Table 3-8. The average rating by each caller and receiver over all 60 questionnaires (5 messages combined with 12 different types of contextual information)

3.4.2.2 Receivers' Behavior

Figure 3-13 shows the rating assigned by each receiver for messages with and without context information. Each rating is averaged over 5 different messages with the same context information. Every message combined with context information was evaluated by 5 receivers from a total of 10 receivers.

Receiver Number	Location			Activity			Company			Conversation		None
	office	home	in transit	shopping	working	class	alone	1	>=2	no	yes	None
1	3.4	4	3	2.4	3.2	1	4.2	3.2	3.2	4.2	2.4	3.4
2	3.4	4.6	3	4.2	3.2	1	4.6	4	4.2	4.4	3.8	4.4
3	4	5	4.2	4.6	4	1	5	3	2.8	4.2	2.6	4.6
4	1.6	5	3.8	4.2	1.8	1.4	5	3.2	2.4	5	2	4.6
5	2.8	5	3.6	4	2.4	1.4	4.8	4.2	3.6	4.4	2	4.8
6	4	3.4	3	2.6	3.8	1.2	4.2	3.2	3	3.6	3	3.4
7	4.4	4.2	3.8	4	3.2	2.2	4	3.8	3	4	3.2	3.2
8	3.8	4.2	3.2	3.4	3	1.4	4.4	3.2	2.8	3.6	3.2	3.6
9	4	4	1.4	3.2	3.8	1.8	3.4	3.4	3.2	3.2	3	3.2
10	4	5	4	3.8	3.8	2	5	3.4	3.4	4.8	3	4

Table 3-9. The average rating by each receiver for different messages with context information. Every rating was averaged over 5 different messages with the same context information.

3.4.2.2.1 Location Effect

Looking at receivers' rating of the appropriateness of the message with the context of being "home" versus being at the "office", we found that people are more available to receive messages when at home (average message appropriateness is 4.4) than when at the office (average of 3.5). The availability is directly related to the appropriateness level. The higher the appropriateness level, the higher the availability of the user to receive phone calls. Using a paired-sample t-test we found that the difference in the availability between being at home and being at the office is significant ($t(9) = 2.4$, $p < 0.02$).

3.4.2.2.2 Activity Effect

The effect of the activity of the receiver on his or her availability was analyzed in the same way as for the location effect. Comparing the receivers' availability for the two activities "having class" and "shopping" shows that the type of the activity has a significant effect on the user's availability to receive phone calls. Receivers were much more available to receive calls when they were shopping (average of 3.6) than when at class (average of 1.4). A paired-sample t-test showed that the difference is significant ($t(9) = 10.2$, $p < 0.001$).

3.4.2.2.3 Company Effect

Company was found to have a primary effect on the receivers' availability to receive phone calls. Receivers who were alone were found to be significantly more available (average = 4.5) than receivers surrounded by 1 person (average = 3.5) ($t(9) = 4.7$, $p < 0.001$) or 2 or more people (average =3.2) ($t(9) = 5.6$, $p < 0.001$). We also found that receivers who are surrounded by one person are significantly more available than people who are surrounded by 2 or more people ($t(9) = 2.8$, $p < 0.02$).

3.4.2.2.4 Conversation Effect

Whether the receiver is engaged in a conversation was also found to have a significant effect on his or her availability to receive a call. Receivers who are having conversation averaged 2.8 on their evaluation of call appropriateness whereas people engaged in no conversation averaged 4.1 ($t(9) = 4.4$, $p < 0.001$).

The significant effects of different types of context information on the receiver's availability illustrate how the dependence of the receiver's availability on his or her current situation. Thus, it is essential to take context information into consideration when assessing the receiver's availability for cell phone interruption.

3.4.2.3 Value of contextual information

In this section we discuss the likely value of context information. The value of context information is measured through the difference in the level of agreement between callers and receivers before and after adding context information to the messages. We define the level of agreement as the difference between the caller's and receiver's evaluation of the appropriateness of exchanging messages given a certain context for the receiver. This level of agreement reflects the degree to which the caller was able to predict the receiver's availability to receive a phone call under various conditions of contextual information.

To compute the agreement level, we first calculated the average rating of 5 ratings for each message combined with the 12 different types of context information. The agreement scores are the absolute value, achieved by subtracting from every caller's rating for each message the corresponding average rating given by the receivers for the same message in a matching situation. For example, the rating by a caller as to the appropriateness of making a call to convey message #2 when the receiver was shopping was compared to the average rating by the receiver for the same message when they were shopping. We used the absolute value because both negative and positive values should be taken into consideration, and they should not cancel each other out since the negative values result from under-calling while the positive values result from over-calling.

Table 3-10 showed the agreement scores generated by different types of context information for each individual message. Next we examined the statistical significance of different agreement scores generated by each type of context information compared to the scores obtained in the "None" condition (no context information). For that analysis we used repeated-measure ANOVA which examines whether the averages of two or more trials significantly differ from each other and that the difference is not caused by chance. Repeated-measure ANOVA is a generalized form of the t-test.

Message Number	Location			Activity			Company			Conversation		None
	office	home	in transit	shopping	working	class	Alone	1	>=2	no	Yes	None
0	1.4	2	2	1.75	1.65	1.25	1.5	1.6	0.85	1.5	1.2	2.25
1	0.9	1.75	1.75	1.3	1.55	1.25	1.5	1.3	1.25	0.75	0.7	2
2	0.5	2	1.75	1.5	0.75	0.75	1.25	1.25	0.95	1.75	1	1.6
3	0	2	2	1	1	0.75	1.5	0.6	0.7	1.75	1.35	1.5
4	0.75	2	2	1.5	0.6	0.5	0.75	0.9	1.15	1	0.8	1.75
5	0.8	1.2	0.92	1.44	0.84	1.24	0.8	0.4	1.04	1	0.92	0.84
6	0.52	0.76	1.6	1.48	0.8	0.2	1	0.72	0.96	0.84	0.64	0.8
7	0.72	0.72	1.24	1.12	0.52	0.56	0.6	0.56	0.68	0.8	0.72	0.4
8	1.24	0.8	0.96	1.16	0.88	0.68	1	0.52	0.64	1.2	0.68	1
9	1.24	0.64	1.32	1.2	1.8	0.8	0.56	0.52	0.76	0.6	0.2	0.88
Ave	**0.81**	**1.40**	**1.55**	**1.35**	**1.04**	**0.80**	**1.05**	**0.84**	**0.90**	**1.12**	**0.82**	**1.30**

Table 3-10. The average rating by each receiver for different messages with context information. Every rating was averaged over 5 different messages with the same context information.

Location was found to have a main effect on enhancing the caller-receiver agreement ($F(3, 147)= 5.64$, $p < 0.01$). The Office condition generated more agreement and thus more accuracy than Home or Transit conditions, due to lower difference scores. The differences between Home and Office, Office and Transit, and Office and None were significant, whereas the rest of the combinations did not yield a significant difference. One explanation for the significant difference between the

Home and Office conditions could be that being at the office is perceived as making one unavailable for calls; however, the conditions of being at home or in transit do not imply such information. One interesting result is that the None condition generated a better agreement than the Transit condition even though the difference was not significant. This indicates that when people are provided with less ambiguous context information they can make a better decision that can significantly enhance the agreement between the caller and receiver and thus result in less interruption. Moreover, providing ambiguous context information such as home and transit may not enhance the caller-receiver agreement.

For the activity context, we also found activity plays a main effect on enhancing the agreement between the two parties ($F(3, 147) = 2.7$, $p < 0.05$). We found that the Work condition generates significantly better agreement than the Shopping condition. The same effect was observed for the shopping-work, work-none, and class-none combinations, whereas the remaining combinations did not generate any significant difference in enhancing the agreement. Similar to the Location condition, but unlike the Shopping and None conditions, the Work and Class conditions were perceived as uninterruptible.

Company context is additionally found to have a main effect on improving caller-receiver agreement ($F(3,147) = 6.35$, $p < 0.0001$). The context of being alone generated significantly less caller-receiver agreement than when receivers were surrounded by one person (One condition) or by 2 or more people (Two condition).

This may be because being alone is not a good indicator of one's availability but being surrounded by one or 2 people conveys a stronger possibility that the user is socially engaged. Moreover, the condition of being alone generated better agreement than the None condition; however, the difference was not statistically significant. Finally, users in the None condition generated significantly less agreement than users in One or Two conditions. The results indicate that providing context information about whether there are people around the receiver will help people to make better decisions about the appropriateness of interruption.

Finally, the Conversation (Talking) condition is also found to have a main effect on improving the agreement between the two parties ($F(2, 98)= 9.16$), $p < 0.001$). We found that providing the caller with information about the receiver's conversation status, i.e. whether he or she is engaged in conversation, significantly improves the caller-receiver agreement, as compared to the None condition. The context condition of "Not Talking" was found to be redundant piece of information since it did not contribute significantly in enhancing the agreement between the two parties when compared to the None condition.

3.4.3 Discussion

The main goal of this experiment was to investigate whether providing context information for cellphone communication would decrease interruptions that result from receiving calls at inappropriate times. The results of the experiment qualitatively show that context information indeed reflects the availability of the receiver to accept phone calls.

The number of people surrounding the receiver (company) and whether the receiver is engaged in a conversation (talking) proved to be good indictors of the receiver's availability. In addition, they proved to enhance the caller-receiver agreement though increasing caller accuracy. Such context information has also been found to generate less privacy concerns, as showed in the previous experiment. This combination, in addition to their being technically simple to sense, makes them ideal candidates for sharing in context-aware telephony. However, in order to convey more information about the receiver's context and improve accuracy, different context information needs to be combined together.

3.5 Implications for designers

3.5.1 Implications from Experiment 1

The findings of experiment 1 suggest that people are willing to share personal information in exchange for useful services. Enhancing the agreement between the caller and the receiver in the context of cell phone communication such that inappropriate calls are minimized was found to offer a good incentive for participants to share their context information.

The results showed significant differences in the disclosure rates for different types of context information. For the four contexts we examined, two distinct groups emerged which we classified as low privacy risk and high privacy risk. Designers of context-aware telephony applications can use this classification to decide to use any contextual type within the same group depending on design requirements other than the privacy risk. For example, a designer can choose to enable sharing of conversation or company information depending on the presence of sufficient audio or video infrastructure, respectively.

Focusing too much on location information, as is common practice, prevents systems from making use of other types of context information that could convey valuable details about the situation while simultaneously being sensitive to users' privacy concerns. For example, information about the number of surrounding people was found to be a good indicator of participants' availability.

By classifying participants' privacy sensitivity in terms of the frequency in which they disclosed Location, we found that users showed varying degrees of willingness to share information. Designers should take this into consideration when devising context-aware telephony and avoid rigid rules, allowing for flexibility to accommodate individual differences. Indeed, it would behoove designers to provide users with options for sharing context from both low and high privacy risk groups in order to accommodate the privacy fundamentalists and the privacy unconcerned.

Finally, the findings also demonstrate the important role of social relations on the rate of disclosure for different contexts. For the 6 social relations we examined, we found 3 clusters with distinct sharing patterns. By using both the clustering of context information and the clustering of social relations, designers can create efficient and user-friendly privacy management tools. The inclusion of an efficient privacy management tool that provides users with full control over their privacy preferences without the burden of complex configuration may be critical to the acceptance and adoption of such a service.

3.5.2 Implications from Experiment 2

These findings emphasize the important role played by context information in minimizing interruptions through enhancing caller-receiver agreement on the appropriateness of making a phone call. The findings also show that different types of context information generate different improvements in the caller-receiver agreement.

The significant effects of different types of context information on the receiver’s availability illustrate the dependence of the receiver’s availability on his or her current situation. Therefore, it is essential to take context information into consideration when assessing the receiver’s availability for cell phone interruption.

The level of agreement was found to depend less on the specific value of context information and more on the type of context itself. For example, some values for location context such as “home” and “in transit” did not have any positive effect on enhancing the agreement values. Interestingly, values for company context and conversation contexts enhanced the agreement significantly. We believe if the context information is unambiguous then it will enhance the agreement between the caller and the receiver regardless of the type of the context information. In order to achieve that, we believe combining different types of context information would minimize any ambiguity and greatly enhance the agreement between the two parties. These findings highlight the importance of not depending solely on location information but rather trying to integrate different context types such as company and conversation for context-aware services. People were found not to be highly concerned about sharing such context information and the information was found to provide a good value toward enhancing the agreement between the two communicating parties.

An interesting finding was the difference between the callers' and the receivers' evaluations of the urgency of the messages. Receivers consistently evaluated the messages with higher importance than the callers did, as reflected in their willingness to accept the calls more often than the callers were willing to make the calls to convey particular messages. This confirms the discrepancy in preference for calls that was suggested by O'Conaill and Frohlich [74]. The reason for this asymmetry is not totally clear, but it should be taken into account when designing such services. One way to account for the discrepancy is by assigning higher availability values for the receivers than their actual availability values.

3.6 Conclusion

We have presented a study investigating privacy preferences and sharing patterns for context-aware telephony with the aim of decreasing interruptions and enhancing agreement between callers and receivers. Moreover, we examined the role played by different types of context information in minimizing interruptions through enhancing caller-receiver agreement on the appropriateness of making a phone call. Finally, we looked at the differences in user’s privacy concerns gathered by using survey compared to the concerns gathered by using in-situ study. The aim was to examine the validity of using surveys as tools to study privacy in context-ware services.

Our most prominent findings are:

- Context-aware telephony is not only feasible but also desirable, as is reflected by the high level of acceptance and the high rate of context disclosure.
- When people are concerned about privacy, they will selectively remove contexts from their disclosure list instead of disclosing no context at all. This indicates that people want to share as much information as possible without compromising their privacy in return for useful services.
- The clustering of context information into two groups of high privacy risk and low privacy risk, as well as the clustering of social relations, indicates a pattern of privacy preferences. These patterns can be used to guide designers of context-aware applications.
- Context information reflects the availability of the receiver to accept phone calls.
- Providing the caller with context information about the receiver contributes significantly to enhancing the agreement between the too sides.

4 Collaborative approach

In this chapter, we present a collaborative approach to minimizing inappropriate cellphone interruptions. The approach uses Bluetooth technology to discover and communicate with the surrounding cell phones in order to read their notification profiles. The profile of the majority is assumed to be the most suitable setting for the current social environment. Cellphones running the collaborative service can automatically update their profile according to the majority profile or at least alert the user to do so. We have conducted a user study to examine the acceptability and the usefulness of the collaborative service and to incorporate users' feedback into the early design process.

4.1 Introduction

Mobile phones offer great accessibility and flexibility. No longer do people have to remain in a fixed location to carry on conversations over the phone. The benefits offered by cell phones, such as flexibility and accessibility, seem to inevitably come with the cost of increased interruption and interaction demands. Examples of inappropriate cell phone interruptions are when a cell phone ring disrupts a group activity, such as a class, meeting or movie. In large part, this mismatch between the user's context and the cell phone's behavior occurs because owners do not remember to frequently update their cell phone configuration according to the current context.

The tremendous growth of cell phones' usage and their location-free nature have only magnified this problem

Interruption caused by inappropriate notification such as ringing in a meeting can cause inconvenience, disruption and embarrassment for the owner. The effect of interruptions has been shown to be disruptive to task performance even when the interruption is ignored [32]. Interruption is not limited to the owner of the cell phone only but extends to the surrounding environment as well. Kern et al. have introduced and validated a model for interruptability wherein they distinguish between interruption of a user's environment (social interruptability) and interruption of a user him or herself (personal interruptability) [60].

4.2 Bluetooth Background

Bluetooth is a short-range radio standard that was created mainly to connect devices and gadgets together without cables or cords. Bluetooth was first introduced in 1994 by Ericsson Mobile Communications and was designed from the beginning to be both a low-power-consumption and low-cost system as a cable replacement technology. Bluetooth has gained popularity within a very short time. Ericsson was joined by Motorola, Nokia, Microsoft, IBM, and Toshiba to form a Bluetooth Special Interest Group (SIG) in order to standardized Bluetooth technology. Since then, almost all of the biggest companies in the telecommunications business have joined the Bluetooth SIG and the number of the participating companies is now over 1,500. The first Bluetooth protocol was released in 1999. Bluetooth specification defines two radio choices: a low-power level with a range of 10 meters for most of the client devices and a high-power level with a range of 100 meters for public access points. A maximum of 8 devices may work together to form a Piconet, which is the simplest configuration for a Bluetooth network. Bluetooth is not only a network protocol, but a whole communication stack that enables devices to discover, advertise their services, and connect to each other in ad-hoc environments.

Bluetooth offers data transfer rates up to 1 Mbps, while a next-generation version offers up to 3 Mbps. Bluetooth operates in the unlicensed 2.4 GHz frequency band ensuring communication compatibility worldwide. These radios use a spread spectrum, frequency hopping, and full-duplex signal for up to 1600 hops/sec. The signal hops among 79 frequencies at 1 MHz intervals to give a high degree of interference immunity.

4.3 Motivation

In this chapter we describe an approach aimed at minimizing cell phone interruption: a collaborative technique that accepts the configuration of the majority of the surrounding cell phones as the appropriate configuration and adapts accordingly. The collaborative approach uses Bluetooth technology for discovering and communicating with the surrounding cell phones. The main idea behind this approach is the observation that most people in any given situation have their cell phones configured to the correct setting, or profile, for that situation. The collaborative approach capitalizes on the explosion of cell phones that are equipped with short-range Bluetooth capability, which enables them to communicate with other cell phones in the vicinity. For instance if a user in a meeting has forgotten to turn his cell phone ringer off, his cell phone can contact other cell phones in the same room and learn that most of them have their ringer off. Consequently, the cell phone can safely assume that it should also have its ringer off, and when the meeting is over the cell phone can return to its default state (ringer on) without the user having to take action. Cell phones that are equipped with Bluetooth connectivity can use that observation to automatically set their profile to fit the majority profile without user’s explicit intervention or at least to remind the owner to manually switch to the right setting.

Bluetooth has many properties than make it ideal for collaborative configuration. In general, Bluetooth technology fits social interactions well and many applications and tools have been developed for social purposes [16]. Serendipity is a tool developed by the MIT Media lab that allows two different devices within the range of Bluetooth to communicate with each other if their personal profiles match [36]. Serendipity can be used for dating, introductions, collaboration and social networks. Yet Bluetooth serves diverse uses beyond matchmaking and friend-finder applications. Jabberwocky, for instance, is a project developed by Intel research labs at Berkeley that targets people in urban environments and uses Bluetooth to provide visualization of strangers that we encounter in our daily life [83]. The service reports the number of strangers and the number and history (place and duration) of the user’s encounters with each stranger. Mobile gaming is yet another growing market for Bluetooth enabled devices.

In this section we discuss the various features of Bluetooth technology that make it ideal for our approach.

4.3.1 Short range

The short-range radio capability of Bluetooth technology is the main feature that enables and motivates our collaborative configuration services as well as other Bluetooth social services. Short-range radio means only devices in the physical proximity of each other, usually within the same room, can communicate and share information. Bluetooth works over a range of about 10 meters (30 feet).The close proximity is ideal for our system, since people within the same physical space usually share the same context, social norms, and constraints. We can assume that people who share the same social and physical place are likely to agree on what counts as an acceptable interruption and what does not. For instance, people in a meeting or a place of worship usually turn their cell phone ringers off and expect others to do so, too. Bluetooth works over a range of about 10 meters (30 feet) and in some cases it can reach a 100-meters range with special Bluetooth devices.

4.3.1.1 Automatic Discovery

Bluetooth protocol, unlike many other wireless standards, defines both link and application layers. Bluetooth provides service discovery and advertisement. It is an almost effortless process for anybody to use Bluetooth technology and services.

Bluetooth service discovery protocol includes three essential components: search by service class, search by service attribute, and service browsing. Service browsing is used when there is no prior knowledge about the environment and other devices. Service discovery application profile is used to discover applications and services in other devices. Bluetooth service discovery protocol, however, does not support features like event notifications, service brokering or service registration.

However, in order for any Bluetooth-enabled device to discover other new devices in the vicinity, these devices have to be in a discoverable mode. All Bluetooth devices come with this mode turned off for security and privacy concerns. Devices in the non-discoverable mode only respond to other already known devices, e.g. devices with whom it has already set up communication before. Furthermore, Bluetooth devices can be in a connectable or non-connectable mode. A connectable device is one that is prepared to accept connections and it frequently listens for connection requests. A device has to be discovered before other devices can connect to it.

4.3.2 Market Share

For the collaborative service to work, it is essential that most cell phones be equipped with Bluetooth. Bluetooth is quickly becoming mainstream technology as more and more people are buying notebooks, cell phones, MP3 players, home electronics, and PDAs. Bluetooth is the glue that connects these devices together and enables them to communicate with each other seamlessly. Cell phones are the most popular market for Bluetooth, and according to IDC approximately 13% of the cell phones that were sold in 2004 are Bluetooth-enabled. IDC also reported that sales of Bluetooth chips increased by 34% in 2004 from the previous year and the number is expected to double in 2005 [46]. Three million Bluetooth devices are shipped every week, according to Bluetooth's official Web site [1]. All current cell phone handset manufacturers are marketing different models of Bluetooth-enabled cell phones. Moreover, the remarkable increase in smart phone popularity is only going to increase Bluetooth popularity. Usually all smart phones come equipped with Bluetooth capabilities.

4.3.3 Automatic Discovery

Bluetooth's protocol, unlike many other wireless standards, defines both link and application layers. Bluetooth provides service discovery and advertisement. It is an almost effortless process for anybody to use Bluetooth technology and services. Bluetooth's discovery protocol involves three essential components: search by service class, search by service attribute, and service browsing. Service browsing is used when there is no prior knowledge about the environment and other devices. The service discovery application profile is used to discover applications and services in other devices.

4.3.4 Efficient Power Consumption

Power consumption is a major concern for both mobile manufacturers and users. Given the battery limitation, power consumption is one of the main factors affecting decisions about whether a particular mobile technology will be largely adopted.

Bluetooth technology was designed from the beginning to be energy-aware and that is one of its main advantages. In addition to the low power radio waves, the Bluetooth protocol enables devices to automatically modify their power consumption based on signal strength and traffic volume.

The low power consumption of Bluetooth technology will only encourage people to use the collaborative configuration service. However, the exact effect of the service on the power consumption depends largely on the way it is configured, (e.g., how often and for how long the service goes into the discovery mode). This is one of the main issues we will explore in order to reach the best trade-off between limited battery life and maximum utilization of the collaborative service.

4.3.5 Mature and Cheap technology

Bluetooth was first proposed almost 11 years ago and, after years of designing, testing and implementation, it is now a mature technology that enjoys industry-wide support. The market penetration rate and the vast number of companies that are part of the Bluetooth SIG are indications of its maturity. Finally, another important advantage of Bluetooth technology is its cheap cost. Bluetooth chips cost less that $10 a piece which make them easily placed on any device.

4.4 Usability Study

Before going through the user study, we conducted a pilot study to obtain information to validate our assumption that the majority of people usually have the correct notification setting for a given social situation. We surveyed 2 classes and 4 different group meetings (presentations). The result of the survey showed that in most cases more than 90% of the attendants have the correct cellphone notification setting (silent, vibrate or off), while the rest forgot to change their setting from the loud setting. The lowest rate we obtained for the majority was 70%. These results confirm the fact that the majority of people remember to configure their cellphone to the right setting in a given social situation.

4.4.1 Methodology

A user study was then conducted in order to examine the acceptability and usefulness of the collaborative service and to incorporate users' feedback into the early design process. Due to the futuristic nature of the collaborative service, 10 participants were introduced to the service and were asked to 'pretend' it exists on their mobile phones. The participants, 2 of whom were males, were ages 19-30, were mostly students and all had either a full-time or part-time job. All participants had owned cell phones over a year.

The study was based on a five-day diary in which participants were asked to record relevant activities they engaged in each day, specifically those involving surrounding people, and describe those situations in which they think the collaborative service would be useful. The descriptions were to include the activity, location, number of surrounding people, their relationship with those people, and any other relevant context information. Semi-structured interviews were conducted at the end of the study in order to get their overall feedback, reactions and attitude towards the collaborative service.

4.5 Findings

4.5.1 Acceptability and Usefulness

On average participants reported 1 to 5 different situations per day, with an average of 3, in which they could envision using the collaborative service. The diverse situations included official meetings, work, family gatherings, dinner, class, and exhibits. This indicates that participants considered the usefulness of the collaborative service in many situations both formal and informal. In the end-of-study interview, participants were also asked to rate the usefulness of the service on a scale of 1 to 5, with 5 being the most useful. All participants rated the service 3 or higher with an overall average of 4. This high level of perceived usefulness is translated as a high level of usability, supported by the fact that all participants reported that they would use the service if their cell phones came equipped with it.

4.5.2 User control

During the interview, we asked participants which if any specific features of the collaborative service they would like to have control over so they could personalize the service according to their particular needs. Participants reported a desire to control the following features:

- Turning the service on and off whenever they wish to.

- Controlling the frequency of scanning for new surrounding cellphones so that new situations can be discovered whenever possible. This parameter is a trade-off between conserving the battery power and discovering new social environments that require different cell phone configurations. Naturally, this will be different from one user to another depending on their lifestyle. For example, a student with a busy class schedule might need to set the discovery frequency higher than would an IT consultant who spends most of his day in the office with some sporadic meetings. The perceived cost of inappropriate interruption also plays an important role in deciding on the value for this parameter. Cell phone interruptions that might disturb a large group of people during an important meeting, such as in a classroom or a movie theater, are essential to avoid. Thus, a user might decide to increase the discovery frequency more than he or she would normally. Sixty percent of participants reported that they would choose 5 minutes as the default value between scans with an overall average of 30 minutes.

- Controlling the parameter that controls the majority value. Eighty percent of participants reported that they would consider 60% and above as a majority. This means that in the case that 60% or more of the surrounding cellphones agree on a certain configuration, the service should consider this the majority configuration. A related parameter that participants reported desire to control is the minimum number of surrounding cellphones that should exist before the service majority profile can be considered reliable. One participant commented, “What if I am meeting with only one person. Then his profile can be as reliable as mine.” On average, participants chose 5 to 6 surrounding cellphones as a minimum value.

- Controlling the configuration transitions and notifications. Seventy percent of the participants reported that they would only use the service for a profile change going from loud (ringing) to quiet (vibration) but not the other way around. They reported that avoiding inappropriate interruption is their priority. One participant reported that she would use the service for both transitions while the rest reported that it would depend on the situation. As for the style of profile transition and whether it should be automatic or should notify the user and let her decide how to proceed, half of the participants reported that they would like to be notified of the profile change. They also reported desire to control the notification mechanism, i.e. vibrate, ring and volume. The remaining half of the participants opted for automatic transition.

4.5.3 Privacy and trust

Participants were asked during the interview whether they mind sharing their cellphone notification profile with the surrounding people. All but one answered negatively. The participant who reported some privacy concerns commented that “It is a bit disconcerting. It makes me think of conspiracy theory”. All participants reported that they would trust the profiles of the surrounding people in the same way regardless of their social relations to them. One participant commented that “I would have the same level of trust regardless, because your friend could have the wrong setting”.

4.6 Limitations

There are many potential limitations that should be pointed out in order to fully understand the capabilities of the collaborative solution and it is underlying Bluetooth technology.

4.6.1 Incomplete Solution

The inherent nature of this collaborative solution that makes it very attractive is also responsible for one of its biggest limitations. The fact that the collaborative service depends on the majority of the surrounding devices to reach the right configuration, means no more than a minority of the surrounding devices can expect to depend on the service to reach the right configuration. The collaborative service should not be introduced or used as an alterative solution for other solutions, whether manual or automatic. Ideally, the collaborative service should be used together with other techniques such as the calendar, manual, or caller-based approaches. The collaborative service is best used as the last resort in the case that one forgets to manually change the configuration of his or her phone or in the case that other configuration techniques fail to produce the expected behaviors.

4.6.2 Bluetooth Security

Even though Bluetooth provides a strong security protocol, its security has been compromised on many occasions. There are three types of common attaches on Bluetooth devices: Bluejacking, Bluesnarfing, and Bluebugging.

4.6.2.1 Bluejacking:

Bluejacking involves sending unsolicited text messages to other Bluetooth users. The technique abuses the “pairing” protocol, which is the system that enables Bluetooth devices to authenticate each other and pass messages during the initial handshake. In most cases, the mere annoyance of receiving messages from anonymous surrounding people is the biggest harm of Bluejacking. However, the more such a practice grows it could be leveraged as a marketing tool by vendors. Bluejacking can be thought of as equivalent to spam emails and raises many ethical issues [5].

4.6.2.2 Bluesnarfing:

Bluesnarfing is another security vulnerability that allows the attacker to steal the phone book along with other information from the victim without leaving a trace. Bluesnarfing is possible because some devices allow an incoming connection without alerting the owner of the request and thereby allow access to restricted data. This vulnerability, however, is not inherent in Bluetooth protocol but rather is a result of poor design of Bluetooth applications on some mobile phones.

4.6.2.3 Bluebugging:

This vulnerability is similar to Bluesnarfing in allowing other devices to make an unauthorized connection to the target device, but it is more dangerous than Bluesnarfing in that it allows the attacker access to the phone functionality. Once the attacker Bluebugs the target device, he can then divert or initiate calls, send and receive SMS messages and connect to data services such as the Internet The Bluebugging vulnerability only affects certain makes of cell phones and is not inherent in Bluetooth's security protocol.

The above security threats, in addition to many other less frequent ones such as backdoor attack, may discourage people from carrying or using Bluetooth-equipped devices. However, as has been pointed out, most vulnerabilities are either harmless in nature or not inherent in the Bluetooth protocol and thus easy to fix. Indeed, Bluejacking and Bluebugging vulnerabilities were quickly identified and fixed by manufacturers. There are no indications that Bluetooth's wide adoption was hindered due to security vulnerabilities.

4.6.2.4 Bluetooth Tracking

Every Bluetooth device broadcasts a 48-bit address that can uniquely identify the device and therefore the owner. This unique identification makes it possible to track the movement of Bluetooth user (Bluetracking). There are many possible scenarios for location tracking attacks such as stalking and blackmailing. The risks of Bluetooth location tracking are minimal due to Bluetooth's short-range radio signals. However, BlueSniper, a Bluetooth tracking device developed by a Flexilis team, increases Bluetooth’s tracking range to approximately half a mile [3]. Movement tracking also can raise serious concerns about privacy. However, since the collaborative service is a distributed one and there is no central repository for information from different devices, it will be extremely hard to generate detailed movement tracking for a particular device.

4.6.3 Collaborative Attack

It is possible for people to come together and conspire a collaborative attack against somebody whom they know uses the collaborative service, in order to fool his cell phone into assuming a different configuration than the appropriate one. This scenario however, is very unlikely, given that these people would have to change their phone configuration to an inappropriate one, which in turn may subject them to the same harm as the victim. Moreover, the harm that can result from having a wrong configuration may not provide enough incentive for a collaborative attack.

4.7 Related Work

Schmidt et al. have introduced an adaptive cell phone that changes its profile automatically based on the recognized context [86]. The phone chooses to ring, vibrate, adjust the ring volume, or keep silent depending on whether the phone is on a table, in a suitcase, outside, or in hand. However, solutions which acquire context information through augmented sensors are somewhat expensive in terms of the computational needs of inferring the context information given the scarce resources of cell phones.

Vertegaal et al. used eye-contact sensors and speech recognition to determine whether or not the cell phone owner is engaged in face-to-face conversation [92]. This information was used to set a default notification level of the user's cell phone and to communicate back to any callers the status of the receiver (having a conversation). Chen et al. have suggested regulating cell phone interruptions and other notifications from mobile devices depending on the user's mental load [25]. The mental load was measured using heart rate and motor activity. Notification channels can be customized by the user depending on the particular attentive state.

Finally, Marti and Schmandt recently presented a system in which a cell phone decides whether to ring by accepting votes from the others in a conversation with the called party [68]. The system uses body-worn sensors to detect the group of people who are engaged in a conversation in addition to a finger ring with vibration capability and a button to collect users' input wirelessly. This approach is closest to our solution in terms of its use of the collaborative approach through engaging surrounding entities in deciding whether or not to allow cell phone interruptions. However, our approach does not require an extensive set of sensors and extra computations to detect conversations. Also, it is still unknown whether such a system may in fact increase rather than decrease interruption since it involves action by all members of a given group. Our approach, on the contrary, does not require the attention of the surrounding people as the devices alone communicate with each other to reach the most socially accepted setting. Finally, we believe our approach of collecting the majority vote is more suitable than the veto approach, which is more susceptible to abuse by group members.

4.8 Conclusion

We have introduced a novel collaborative approach that aims at improving the awareness of cellphones to the social context by minimizing inappropriate interruptions. Our approach is most useful in cases where a user forgets to change the notification profile of his or her cellphone. The diverse usage scenarios, together with the high acceptability rate reported by the users during the usability study, reflect that our proposed collaborative approach is both feasible and desirable.

It is essential to incorporate the above mentioned personalization features into the design of the collaborative service since different people are subjected to different social interactions and environments. Personalization provides them with the tools to customize the service according to their specific needs. Another important advantage of personalization is that it provides users with a sense of control over their devices and hence makes them more comfortable in using the collaborative service.

It is important to indicate that the collaborative approach is basically independent of the underlying communication technology as long as it supports the same features that are supported by Bluetooth, including short-range, automatic discovery, low power consumption and widespread adoption. However, from the current market share and the market trend over the last couple of years, it is very reasonable to assume that the majority of cell phones will be equipped with Bluetooth capability within the coming few years.

The fact that the collaborative service depends on the majority of the surrounding devices to reach the right configuration, means no more than a minority of the surrounding devices can expect to depend on the service to reach the right configuration. The collaborative service should not be introduced or used as an alterative solution for other solutions. Ideally, the collaborative service should be used together with other techniques such as the calendar, manual, or caller-based approaches [61, 69].

5 Measuring Privacy Preferences in Context-Aware Services

With the increasing popularity of ubiquitous computing and context-aware services, the privacy challenges posed by such technologies remain one of the biggest concerns. Several research efforts have been aimed at better understanding the privacy concerns, preferences, and management systems in the context of ubiquitous computing [19, 62, 64, 81]. Most research on privacy in general and on ubiquitous computing in particular depends, however, on surveys and polls as the main tools of data collection [13, 66]. Context-aware services are very intertwined in our daily lives, they have access to sensitive and private information, and they are in most cases proactive services, (i.e. they can function without explicit and full awareness of the user). These unique characteristics of context-aware services and ubiquitous computing in general only highlight the privacy issues and introduce many challenges that make it difficult for surveys and polls to capture the full picture of user privacy concerns and preferences.

In this chapter we discuss an experiment that examines the validity of using surveys as tools to study privacy in ubiquitous computing. We aim to measure whether or not there is a difference in the level of privacy concern between survey and in-situ studies. We used an in-situ user study form experiment 1 in chapter 3 to evaluate privacy preferences because we believed it offers a reliable tool. However, there is no study that quantitively examines whether there is a considerable difference in the privacy concerns data evaluated by the two different techniques. For example if the techniques generate similar results then we would rely on surveys more in the future because they are much cheaper to conduct in terms of money and effort compared to in-situ studies. However, if the difference is considerable then there is no choice but to use the more reliable in-situ approach. To explore this question, we have designed an experiment that measures users' privacy concerns with respect to a context-aware service using in-situ and survey techniques.

In the next section we discuss the use and shortcomings of surveys for measuring privacy concerns regarding context-aware services

5.1 Problems with Surveys

Harper and Singleton have questioned the validity of using surveys and polls in measuring privacy concerns and preferences and have consequently advocated for more objective ways of measuring the cost and benefit of privacy for the consumer market [51]. They listed many problems with using surveys to measure privacy concerns, among which are: 1) surveys can be designed in a way that manipulates and causes bias in the results, 2) privacy surveys tend to combine multiple privacy issues together in such a way that makes it hard to identify specific concerns precisely, 3) surveys suffer from the "talk is cheap" problem in which it does not cost consumers anything to be very stringent and unrealistic at times and, 4) polls and surveys can not replicate the different factors that are considered by consumers when making decisions in real life. The study, which examined 24 surveys, concluded that surveys are unlikely to accurately reflect the consumers' true privacy preferences and concerns.

The discrepancy between privacy concerns measured by surveys or self-reports and the actual concerns observed in real-life is widely acknowledged in the field of consumer market and online commerce [8, 20, 59]. Jensen et. al. examined privacy practices of internet users and found that users' behaviors did not match their survey statements [58]. The authors conclude that surveys are best suited to study attitudes and opinion rather than behaviors or experience and they called for a reevaluation of the role of surveys in studying Internet behavior. Bettman, Luce, and Payne attributed this discrepancy to the fact that decisions are based on heuristics rather than rational consideration of all possible factors at play due to limited processing capacity (bounded rationality) [21]. Acquisti discussed different hypotheses beyond bounded rationality that could explain the dichotomous privacy preferences and concerns between reported and actual behaviors [8].

Even though the privacy issues pertaining to these fields are somewhat different than those related to ubiquitous computing, the two domains share many common problems that are inherent to using surveys in general. Consolvo et al. have examined the privacy issues associated with disclosing location information for location-aware services [29]. They used an in-situ technique whereby participants received hypothetical requests for disclosure of their location from people they knew. They compared the average location disclosure for the three different groups categorized by using the Westin/Harris privacy classification survey. According to this survey, one fourth of consumers are "privacy unconcerned", having little to no concern about their privacy, one fourth are highly concerned "privacy fundamentalists", and around half fit in between those extremes as "privacy pragmatists". The location disclosure rate by the three groups was not found to be consistent with the expected behavior of each group (e.g. fundamentalists disclosed more location information than unconcerned). This indicates that the Westin/Harris privacy survey is not a good predictor of how participants would respond to requests for their location information [79]. This study examined the Westin/Harris survey as a tool to classify people depending on the level of their concerns about privacy and did not study surveys in general. However, their results further support the argument that surveys may not be the right tools to study privacy in general and privacy concerns related to context-aware services in particular.

We believe that in-situ studies are the best approach to accurately evaluate factors that are of a subjective nature and depend on many hidden and unclear conditions. It is reasonable to expect that the ESM approach may fare better than survey questionnaires since it provides real-time data that is inherently affected by the situation of the participant which can not be predicted in advance. Moreover, the ESM approach does not suffer from most of the aforementioned drawbacks identified by Harper and Singleton.

5.2 Experiment Design

The goal of this experiment is to assess the privacy concerns posed by different types of contextual information and to test whether or not these privacy concerns will prevent receivers from publishing such information for potential callers. These concerns are measured through two different techniques (survey and ESM) and the results were compared to study the consistency between them. We used the same participants from chapter 3, and we compare the results of the surveys to the results of the in-situ study discussed in chapter 3.

	Options
Context	location, activity, talking, company
Location	home, office, class, coffee shop, gym, restaurant, store, in-transit.
Activity	working, conversation, driving, studying, leisure, meeting, on the phone, surfing the Web, working out
Roles of caller	boss, colleague, friend, family, significant other, somebody unknown

Table 5-1. Experiment settings for the survey evaluation user study

First, each of the 20 participants was given a survey that asked them to fill in what kind of contextual information they would disclose to a given caller in each of a set of different situations. Each situation referred to in the survey was a combination of a location, an activity, and a specified relationship between the caller and the participant. The options for location, activity, and role of caller are shown in **Error! Reference source not found.**. Participants could choose from four types of context information to disclose to particular callers: their *location*, their current *activity*, whether they were *talking*, and whether they were in the company of others. Table 5-2 shows an example of the tables used in the survey.

Role/Activity	Dinning	Watching TV	On the Phone	Showering	HW/Studying
Significant other					
Family member					
Friend					
Colleague					
Boss/Employer					
Unknown					

Table 5-2. One of the tables used in the survey. The participants filled in each cell the type of the context information (out of the four type of context) that they do not mind to share with the corresponding social relation (the columns) and the corresponding activity (rows) and the corresponding location (home)

5.3 Findings

In the experiment, each participant selected context to share in 126 different scenarios in the survey and an average of 121 questionnaires in the in-situ study (for a total of 2520 and 2422 entries respectively). The number of points that had the same conditions (i.e. participant ID, location, activity, and caller) in both studies was 422.

We calculated the number of mismatches between answers given in the survey and the in-situ study for the same conditions. Out of the 422 answer pairs, only 31% of the answers from the two studies were identical. Each of the remaining answers contained at least one type of contextual information (i.e. location, activity, talking, or company) that a participant disclosed in the survey but did not disclose in the in-situ, or vice versa, given the same conditions. The maximum number of mismatched contexts was 4, which means the participant incorrectly predicted what she or he would be willing to share for all four types of context in that situation in the survey.

A one-sample t-test on the number of mismatched contexts per participant shows that the difference between the answers from the two studies was statically significant (mean = 1.59, $t_{19} = 24.51$, $p < 0.001$). This means participants gave different answers to the same questions using the two different evaluation techniques. We also classified the participants using the P&AB Harris Interactive privacy classification survey and analyzed the disclosure of context by each group of participants in the in-situ study. We found, on average, privacy pragmatists revealed more context information than privacy unconcerned did in-situ. The finding suggests this standard survey did not reflect our in-situ study results, which verifies Consolvo's earlier results.

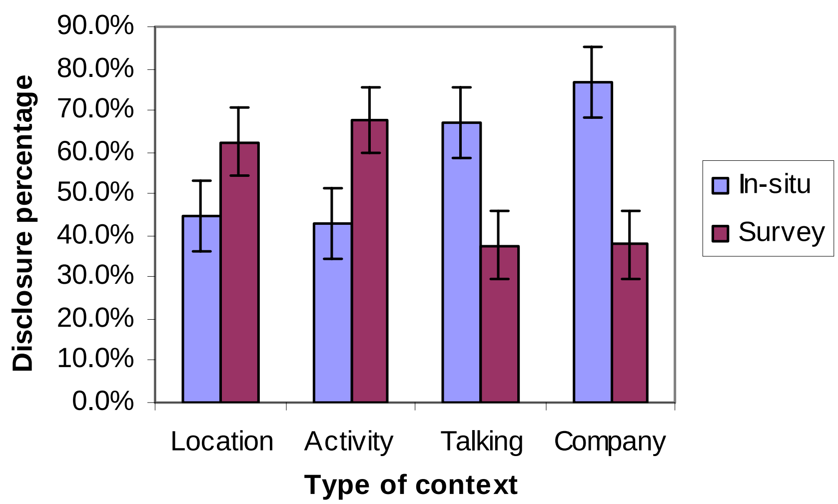


Figure 5-1. Disclosure rates for the four types of context using the two different evaluation techniques

5.3.1 Participants' Prediction

A paired-sample t-test shows that the difference between the percentage of the contextual information the participants predicted they would reveal in the survey and the percentage of information they actually disclosed in the in-situ study was not statistically significant.

However, for each particular type of context, we found that participants' answers to the survey questions were significantly different from their answers in the in-situ study. Participants were much more willing to reveal their company ($Mi = 76.8\%$, $Ms = 37.8\%$, $t_{19} = 5.74$, $p < 0.001$) and talking ($Mi = 67.1\%$, $Ms = 37.7\%$, $t_{19} = 4.34$, $p < 0.001$) in the in-situ study than they had predicted in the survey. However, they expected to reveal more information in the survey than they actually did in the in-situ study for activity. ($Mi = 42.7\%$, $Ms = 67.7\%$, $t_{19} = 4.91$, $p < 0.001$) and location ($Mi = 44.6\%$, $Ms = 62.5\%$, $t_{19} = 3.05$, $p < 0.01$).

The results, shown in Figure 5-1, indicate that the four types of context fall into two groups – the location-activity group and the talking-company group. Predictions for the disclosure of location and activity information are very close. We believe this is because a participant's location usually determines his or her current activity. Similarly for talking and company, talking was a strong indicator that the participant was with other people.

Our results suggest that, in the survey, participants tended to overestimate the privacy concerns associated with disclosing Company and Talking contexts and underestimate the privacy concerns associated with disclosing Location and Activity contexts. Since participants were both more and less conservative in their responses on the survey as compared to in the in-situ study, the survey results cannot be used by designers as a conservative estimate (or upper bound).

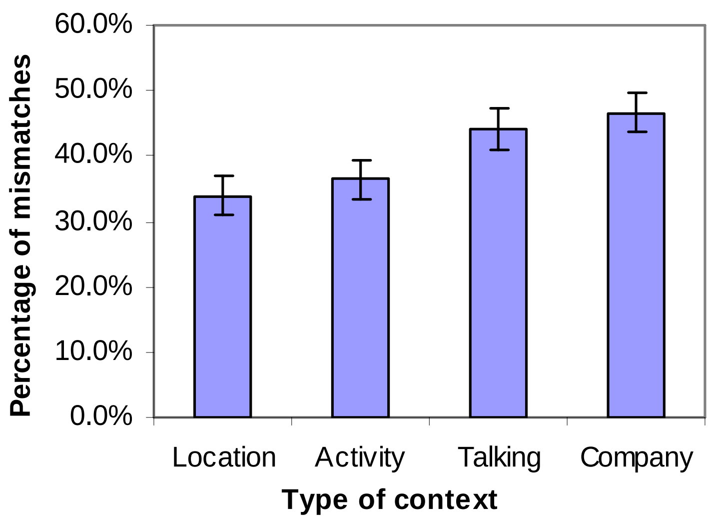


Figure 5-2. Mismatches of certain context type in two studies

5.3.2 Accuracy of Prediction for Four Types of Context

Figure 5-2 shows the prediction accuracy for each type of context by comparing the number of mismatches between the in-situ and survey answers for each type of context across all participants. A paired-sample t-test for each pair of types of context shows that company (M = 46.7%) was changed significantly more often than activity (M = 36.4%) ($t_{19} = 2.1$, $p < 0.05$) and location (M = 34%) ($t_{19} = 2.2$, $p < 0.05$). Talking (M = 44.2%) was also changed significantly more often than location (M = 34%) ($t_{19} = 2.16$, $p < 0.05$). However, the differences between company and talking, talking and activity, and activity and location were not statistically significant. This result shows again that the four types of context fall into two groups. It also suggests participants' predictions were more accurate for the location-activity group than for the talking-company group.

5.3.3 Predictions in different situations

We analyzed how the context itself affected participants' predictions on the disclosure of the contextual information. We examined the effect of the participants' location and activity and the role of the caller.

5.3.3.1 Location

In 69% of all the analyzed situations, the participant indicated that his or her location was *home*, while the remaining 31% of the time he or she was at the *office*. A paired-sample t-test shows that participants made better predictions in disclosing the four types of context information in situations when they were at home (M =35.2%, where M is the percentage of mismatches) than in situations when they were at the office (M =46.3%) ($t_{15} = -3.88$, $p < 0.01$). Figure 5-3 shows the results.

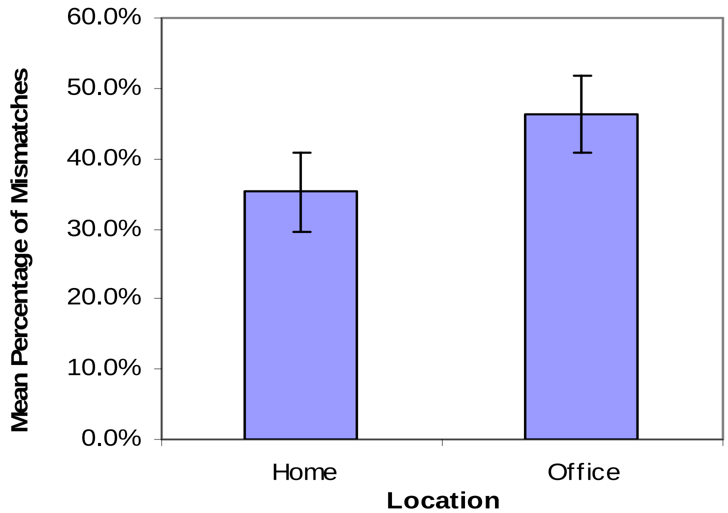


Figure 5-3. Mean percentage mismatches by location

That participants made better predictions in situations when they were home indicates that they were more certain about what would happen in such situations. When the location was *office*, greater uncertainties could be involved, and that led to less accurate predictions.

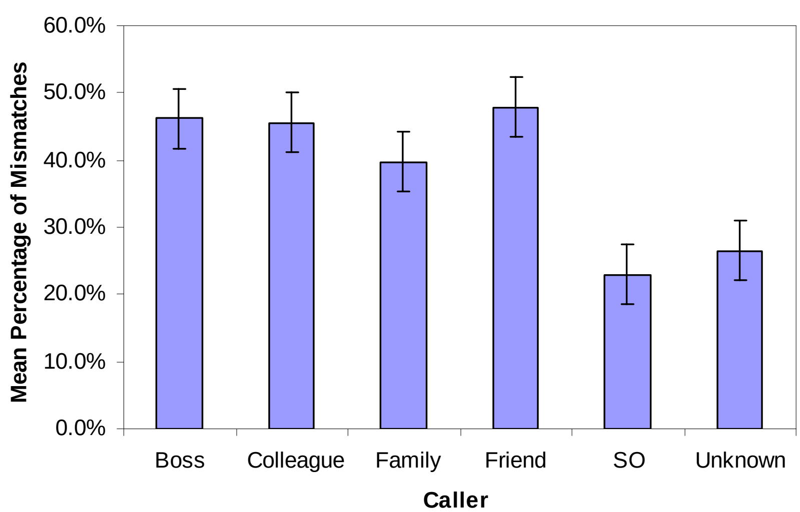


Figure 5-4. Mean percentage mismatches by caller

5.3.3.2 Activity

We analyzed the three most frequently occurring activities, which accounted for 92.4% of our sample set. Activities involved in this analysis included studying (25.6%), leisure (43.8%), and working (30.5%), which had mismatch rates of 39.1%, 36.3% and 46.3% respectively. A one-way ANOVA shows that activity had no significant effect on the percentage of mismatches ($F(2, 42) = 1.235$, $p > 0.05$).

5.3.3.3 Caller

We analyzed all of the roles of callers, as they all had a close representation in our dataset: boss (17.5%), colleague (19.2%), family (15.4%), friend (16.1%), significant other (12.8%) and somebody unknown (19.0%). The one-way ANOVA showed that the roles of callers had a statistically significant effect on the percentage of mismatches ($F(5, 114) = 2.925$, $p < 0.05$).

Figure 5-4 shows that participants tended to make better predictions in situations in which the caller was their significant other or somebody unknown. Participants tended to reveal all information to their significant others and nothing to unknown callers, and that helped them make more accurate predictions (22.9% and 26.5%, respectively). For other relationships to the caller, the percentage of mis-predictions ranged from just 39.8% to 47.9%.

5.4 Implications for Designers

Our aim was to contribute to the understanding of using surveys as tools for studying privacy concerns. Our findings empirically demonstrate that surveys are unable to accurately reflect participants' true privacy concerns with regard to the use of context-aware services. The in-situ technique may not be the ideal tool for measuring privacy preferences either, but we expect it to generally fare better when compared to the survey tool. Surveys suffer from many drawbacks such as not being able to replicate the different factors that are considered by participants when making decisions in real life [51]. Drawing on our findings on how certain situations and types of context can affect the reliability of surveys in predicting privacy concerns, context-aware service designers and can make better decisions in designing proper user studies.

5.5 Conclusion

By comparing results of a survey to an in-situ study, we found that:

- There is a significant difference in the disclosure pattern of context information using the two different evaluation techniques.
- Participants were both more and less conservative in their survey responses depending on the context, indicating that survey results cannot be used as an upper or lower bound by designers.
- Participants' predictions were significantly more accurate on the disclosure of certain types of context (i.e. location and company) and for certain situations (i.e. when their location was home or when the caller was a significant other or unknown). This suggests that a survey may be appropriate for providing a rough estimate of privacy preferences for context-aware applications.

However, surveys may not serve as a reliable tool when a thorough and precise evaluation is needed.

6 Lessons Learned and Design Issues

The three different approaches for context-aware telephony which we have presented and extensively studied have provided us an ideal opportunity to extract important lessons so they can be used as design criteria for other designers and future approaches. We have discussed many design issues for every approach in its corresponding chapter. In this chapter we describe general and important lessons we have learned and the subsequent design criteria to be considered when developing context-aware telephony intended to minimize cellphone interruptability depending on user context and thus on availability.

6.1 Control versus convenience

There is always a trade-off between control and convenience. The more control the user has, the less convenient the system is, and the less control the user has over the system, the more convenient it is for him or her. This question arises in most computer applications but more so in context-aware applications. The proactive nature of context-aware services makes the process of controlling them a very costly one, and thus users are always driven to relax their control over such services in return for convenience. However, context-aware services are usually available anytime and anywhere as they are intertwined with our life and usually have access to sensitive information. This in turn drives users to be sensitive about losing control over such services, hence the conflict between control and convenience.

Our user studies have touched on this issue so we can understand its effect on context-aware telephony. In three different user studies, we asked participants whether they want the device to act automatically or want to be notified before each action. For example, for the calendar application, participants were asked whether they would like to be notified in the case of any automatic configuration change trigged by a context switch. All participants reported wanting to be notified but with a varying level of frequency. Two participants wanted to be notified before any configuration change, while the rest wanted to be notified only for certain kinds of dramatic configuration changes. For the collaborative service, most participants mentioned that that they would like to have the capability of turning the service on and off whenever they want to. They expressed desire to control many other parameters as well. When participants were asked whether they want to be notified when the service discovers a new configuration, 50% replied positively while the rest wanted this to happen automatically.

Design Recommendation

Personalization offers an ideal way to establish the best trade-off between control and convenience. It lets users decide which aspects of the service should be automated as well as when and where. Personalizing context-aware services does not make them less proactive or useful, but different users have different needs and preferences, and context-ware services should account for that. By doing so, users can still feel they are in control of context-aware services without restricting the services' proactive nature. We believe personalization will increase user acceptance and adoption for context-aware services.

6.2 Awareness

According to Dourish et al. awareness is “an understanding of the activities of others, which provides a context for your own activity” [35]. In our case, we refer to the awareness of a user’s current setting, or context, which is relevant to inferring the social context and user availability and thus the appropriateness of cellphone interruption. Social context usually conveys information about the immediate circumstances, such as whether others are present, whether there is a conversation or gathering going on, what kind of gathering it is, whether it is formal or informal, who is speaking, etc.

Awareness in the context of telephone communication can be achieved mainly in two ways. The first way is to make cell phones themselves smarter and more aware through inferring the context of the user and thus his or her availability by using sensors or calendar information. This approach provides more privacy for the user since the availability information is self-contained. However, inferring activity is a complicated process that may produce many inaccurate predictions of availability. The alternative route to increasing awareness is by having the caller reason about the receiver’s availability through access to some of her contextual information such as location or activity. This method however, can compromise the privacy of the user since he has to disclose some potentially private context information. Also, having the caller make decisions about the receiver's availability may not produce the best results, since deciding about one's availability is a complicated process that depends on many factors that can not be conveyed by context information alone.

This research has explored using different ways of enhancing awareness in cellphone communication with the purpose of minimizing inappropriate interruptions. Our experience shows that in many cases context-awareness can be achieved through technically simple tools and methods such as calendar information and a collaborative approach. The emphasis of this research, however, is not on how to capture social context but rather on how people interact with it, how useful it is, whether it will enhance interruptability, whether people will use it and like it, and what its privacy implications are. In general our user studies show that people are willing to use context-aware telephony services as long as they feel they have control over them. This was clear from the high demands on personalizing the services to fit specific user's preferences.

The three context-aware services presented in this research are designed to work best when used together. To achieve optimal results in minimizing interruption and enhancing the overall user experience, the three services are best considered complimentary to each other, even though they can be used independently. For example, the calendar service yields best results if used for well-structured and repeated activities such as meetings and classes. The caller-based approach is expected to yield best results in situations that are subtle and too complex to be understood by computers. After all, computers are effective in collecting data and detecting patterns, however they are less effective in reasoning about subtle and complex activities in our daily lives. Humans are better equipped to understand such subtleties, and the caller-based approach enables them to negotiate availability and interruption appropriateness. The caller-based service is even more effective in communicating availability within closely-knit groups since they are more familiar with each other's habits and preferences and small pieces of relevant context information such as whether company is present. Finally, the collaborative service works the best in minimizing social but not personal interruptability since it can only function when there are many people around whose phones have the correct profile settings.

Context-aware telephony can be used for more than interruption minimization. In fact many awareness systems have been developed for the field of Computer Supported Collaborative Work (CSCW) and they remain a topic of active research. Awareness has been found to be productive in collaborative work and people prefer being aware of others within a shared space [39]. Moreover, telephony awareness has been used to maintain and strengthen the existing sense of connectedness and to support the feeling of being in touch within members of a closely-knit group [67].

Design Recommendation

Our user study showed that different context-information provides different level of awareness, as reflected by having different accuracy for the agreement in the level of call urgency between the caller and the receiver. However, the awareness value should not be the only factor for designers when deciding about different types of context to support. For example, our data showed that people sharing of context information significantly varies from one type of context information to another depending on their privacy risks. People were found to share information about whether they have company and whether they are talking very generously. However this was not the case for sharing location and activity information since they may provide too much sensitive information. Therefore, factors such as privacy risk, ease of context capturing and publishing, and accuracy should be taken into account when deciding about context-aware services.

6.3 Alerting

It is very important that context-aware services not be constantly intrusive or attention demanding. However, they must be able to alert the user. Hansson et al. suggested that alerts can range from private to public and from subtle to intrusive and have argued for combining the properties of subtlety and publicity when designing notification cues [50].Toward that end, they developed the Reminder Bracelet which is connected to a PDA’s calendar and conveys visual notification when there is an event reminder [49]. Sawhney and Schmandt explored using wearable audio messaging as an alternative way of notification.

Attentional demands required by context-aware telephony services play a major role in shaping the user experience and ultimately in the level of acceptance and adoption of the services. Context-aware telephony services interact with users while they are going about their daily lives and involved in other tasks. This makes it essential to design services that demand minimal attention from the user. Context-aware services must have a low level of intrusiveness that is subtle and efficient but at the same time noticeable enough to catch users' attention. The right balance between the need for user attention and subtleness varies from one system to another. Different notifications are appropriate for different situations. We believe subtle and private alerts are more appropriate for context-aware telephony since the main purpose of such services is to minimize interruptions and not to contribute to them. User's preferences vary significantly in this regard as shown by our user studies. Many users want context-aware telephony services to change profile automatically while others want to be notified. Users vary on when and how they should be notified.

Design Recommendation

Users should be left to decide on their own notification mechanisms; the system should provide different options so users can customize according to their preferences.

6.4 Privacy

Privacy has been identified as one of the main challenges that faces the emerging field of context-aware applications and ubiquitous computing in general. Context-aware services magnify the tracking and profiling capabilities of personal information. Tension and trade-offs between awareness and privacy are inevitable [7].

In context-aware telephony some of the information can cause privacy concerns for some people at least part of the time. For the three different services we propose, privacy is relevant to only two of them: caller-based service and collaborative service.

For the caller-based approach, the privacy issue is fundamental. In fact, our main contribution to that particular approach was the exploration of people's privacy preferences and sharing patterns with different social relations in different contexts. The plausibility and practicality of the approach is not in its technical feasibility but rather in whether people perceive its benefits to outweigh its privacy concerns. Our in-situ user study showed that people are willing to generously share their context information with people whom they trust in return for less interruption. Our study explored the complicated details of sharing and social relations and identified emerging patterns: what and how much people are willing to disclose, who has access to the information, and what patterns emerge from this information.

In the collaborative approach, people might be wary of sharing their profile information with strangers. Cell phone profile information (notification mechanisms) is not very sensitive information which is why most participants did not show any concerns sharing their profile information during the user study. However, the mere fact of sharing information with strangers regardless of the type of information could cause some people to be concerned about their privacy. One participant in our user study expressed some privacy concerns even though she acknowledged the information she is sharing are not very sensitive.

Privacy is a complicated and dynamic construct. It is not clear how accurate our user studies reflect privacy concerns in real life with a full-functioning application rather than with the hypothetical ones we have used. Conducting in-situ studies should minimize such bias since they capture people's responses regarding privacy in their natural settings. In addition, our user studies were not supposed to provide a comprehensive account of privacy preferences but rather were meant to provide general understanding and guidelines for privacy concerns that could be caused by such services. Another issue that may not have been fully explored is whether using context-aware services in real life would cause some privacy-threatening scenarios to emerge. For example, is it possible to use the collaborative service for movement tracking? Every Bluetooth device has a unique address, which makes it theoretically possible to track people. However the short-range of Bluetooth signals make such threats very minimal and not practical. We expect deploying a service in the real environment over a long period of time will give rise to new privacy threats that could not be anticipated in advance to be examined during the user study.

Design Recommendation

It is very important for designers to consider privacy implications when providing context-aware services. People vary significantly on their perceived level of privacy risk of a given context-aware service. However, we found that in general people generously share what they perceived as private information in order to get services in return.

6.5 Inaccuracy

As context-aware technologies start moving from the laboratory setting into the real-world, accounting for uncertainty and inaccuracy is key in achieving public acceptance of context-aware applications, which of course include context-aware telephony. Inaccuracy is an inevitable part of context-awareness due to the inherent inaccuracy and ambiguity of the sensors, context providers, human errors, inference mechanism, and unpredictable behavior [27, 37, 47]. Bellotti and Edwards [18] have even argued that in some situations, it is impossible to capture some human aspects of context by means of sensors or inference. However, the effect of such inaccuracy on context-aware telephony in particular and on context-aware applications in general has been largely ignored. Context-aware applications are very pervasive and interact with their users throughout the day in different situations and places such as home, office and car. In addition, they are fundamentally proactive, responsive, and dynamic in nature in that they usually change their behavior and adapt depending on the context. Their nature highlights the question of how inaccuracy affects the way people will perceive their usefulness. This will eventually reflect on the level of adoption and acceptance of the solutions and services offered by context-aware applications. This in turn will reflect on the acceptance of the field of ubiquitous computing as a whole since context-awareness is a key ingredient.

Many solutions have been developed to deal with inherent uncertainty and inaccuracy in context information. Systems such as Coordinate project [53] and Activity Campus [82] explicitly model and use uncertainty during inference and decision making. Newberger and Dey [73] have extended Context Toolkit to support context monitoring and control by using a component that encapsulates application state. Chalmers [24] urges the use of seamful rather than seamless design to reveal the uncertainty in sensing and ambiguity in representations. Greenberg [47] also argues the importance to clearly link actions automatically taken by systems to their respective context through feedback. Bellotti and Edwards take a similar approach in their presentation of design principles which support intelligibility of system behavior and accountability of human users [18]. More recently Antifakos et al. have proposed the idea of explicitly displaying the uncertainty and leveraging human's ability to deal well with it [9]. They conducted an experiment that showed the effectiveness of such a solution by the increase in human performance in a memory task.

We attempted to evaluate the effect of inaccuracy on the user's perception of the usefulness of context-aware telephony and hence the level of acceptance whenever possible. For example, we found that people are willing to use the calendar-based application even with an inaccuracy rate of 10 to 15%. Even though this approach does not produce perfect accuracy, that did not affect the participants' perception of the usefulness of the application, since all inaccuracies are predictable, and users have total control over them. For the collaborative approach, users expressed the concern of not acquiring an accurate estimate of the appropriate profile from the surrounding environments for reasons such as having a small number of people, being in a dynamic environment, or simply other surrounding people having a wrong profile. That prompted users to suggest ways that enable users to customize or fine-tune the behavior of the collaborative application in such a way as to account for the unique environment for each user.

People’s reaction to inaccuracies and uncertainty in context-aware applications varies from one person to another. However, we expect that if Bellotti and Edwards’ [18] design principles of intelligibility and accountability, which include the user in the decision making process, are followed then we expect people will adopt context-aware telephony and context-aware applications in general. For example, we included the users of calendar application in the decision making process by having them initially mapping different states to configuration rather that using different inference techniques to map them automatically.

Little work has been done to explore how users conceive uncertainty and inaccuracy in context information and more research is needed in that respect. For example, it remains unclear whether inaccuracy will change their attitudes on the usefulness of context-aware applications, whether they will still be willing to use the applications after producing inaccurate behaviors, and the extent to which this inaccuracy will frustrate them. Answering such questions could positively influence the design of context-aware applications and services and inspire better design.

Design Recommendation

Inaccuracy is an inherent side effect of context-aware services. Designers have to account for it by including the user in the decision making process. This can be achieved by providing the user with the capability of correcting the behavior of the service in case of uncertainty or inaccuracy, as well as with the source of inaccuracy.

7 Conclusions

The main goal of context-aware telephony, and of the solutions we have proposed toward that end, is to enhance people's experience throughout their interaction with cellphones in particular and mobile devices in general. By minimizing personal and social interruptions we contribute to a better user experience. Thus the human-centric approach has been the main guiding principle that we have followed in order to evaluate the success and usefulness of the three proposed solutions.

For every approach we have studied, we have conducted a user-study to examine how users like the system, whether they are willing to use it, and what aspects of it they like or dislike. We conducted user studies in-situ for over a week period to get accurate data. In so doing, we were able to minimize any influence of the wow factor in people's acceptance of new technology. By conducting user studies we wanted to make sure that our proposed solutions do indeed enhance interruptions and do not contribute to more interruptions themselves. User studies have provided us with much feedback with many subtle details that could not be obtained otherwise and which could prove to be essential to enhancing overall user experience and acceptability related, for instance, to personalization, control and level of interactivity.

Table 7-1 summarizes the main features of the three different approaches discussed in the previous chapters to address cell phones' inappropriate interruptions.

	Calendar-based	**Caller-Based**	**Collaborative**
Control	User has full control	User can only control what type of context to publish and can not control caller behavior	User has no control over cellphone profile, but controlling the application preferences can greatly reduce the uncertainty
Intervention	User sets cellphone profile when adding entries to the calendar, requiring minimum intervention from the user	User needs to regularly update her profile, but this process can be easily automated by augmenting cellphones with sensors such as GPS, and microphone. However capturing user's activity is more complicated	User only needs to customize the application preferences once
Complexity	Very simple	Simple	Trickier to set up the right preferences
Accuracy	Highly accurate	Context is accurate if published by users, otherwise the automation process would introduce some inaccuracy	Largely depends on how well the preferences of the application match the user's desire. Some unexpected situations can give rise to unpredictable profiles

Privacy	No loss of privacy	Varying degree of privacy risks depending on the published context and the receivers of the context	Minimum privacy risk that could arise from sharing profile. Location tracking could be a potential risk
Usefulness	Best if used for structured, well-defined, repetitive activities	Can be used for a diverse set of scenarios but preferably for the cases that do not require frequent update of contextual information	Best if used in combination with other techniques

Table 7-1. Table comparing the different features of the three different approaches to address the problem of inappropriate cellphone interruptions

7.1 Contributions

This research presents several contributions aimed towards minimizing inappropriate cell phone interruptions through making cell phones more aware of the user's current situation and adapting their configuration accordingly.

The main research questions included whether people would like context-aware telephony and interact positively with it, whether context-aware telephony would decrease inappropriate interruptions and contribute to more socially intelligent mobile devices, how context-aware telephony can be achieved, and what implications they may have for the users regarding privacy, loss of control, and acceptability.

First, we have shown that people are willing to adopt context-aware telephony services, which requires a sacrifice of some control in exchange for convenience. This was achieved by conducting a user study that used the Experience Sampling Method to study peoples' reactions in real life. We then presented three different approaches to minimizing cell phone inappropriate Interruptibility: Calendar-based, caller-based and collaborative. We were the first to employ the calendar-based and collaborative approaches in enhancing cell phone awareness with the aim of minimizing disruptions and were also the first to examine the feasibility of the caller-based approach from the user's perspective. In addition, we have conducted usability studies to examine the feasibility, acceptability, limitations, and privacy issues of each of the approaches. For the calendar-based and caller-based approaches, we used the Experience Sampling Method to examine the users in the field and to capture subtle factors that influence people's concerns and reactions which could not be captured otherwise. The user study for the collaborative approach employed the fill-in diary method.

Another important contribution involves the design issues and lessons learned from the various user studies, which are essential for designers to consider when building context-aware telephony services. Finally, we have quantitatively shown the limitation of using surveys to measure privacy concerns for context-aware services.

7.2 Future Work

A recommended approach to future work on this topic has been to integrate the approach of empowering cell phones to be more context-aware (by using calendar information and collaborative applications) with the approach of empowering the caller to be aware of the receiver's context. We believe this method offers the most promising solution provided that the right balance between the two approaches can be established. After all, interruption appropriateness can only be determined in the context of both the initiator and the receiver [34]. For example, a receiver who is busy at a meeting might nonetheless be awaiting a call from somebody regarding updates related to the meeting. Interruption in such a situation is appropriate even if it may seem otherwise from an outsider's perspective. A challenging research issue is to examine how combining the different approaches presented here can contribute to better awareness and less inappropriate interruptions and would not place extra burden on the users.

Our user study for the calendar-based approach showed that calendar information is not always accurate, and, even if the context is predicted accurately, the desired configuration for a certain context is not always the same and there are many factors that might affect it. However, even with an inaccuracy rate of 9-13%, participants still liked this solution and said they are willing to adopt it in real life. An interesting research problem is to study whether reinforcement learning tools would enhance the accuracy of inferring the context and the right configuration by only using calendar information (event description, time, location, duration).

The success of the caller-based approach depends on providing an efficient way of capturing, managing, and presenting users' context information. The challenge is to capture user context automatically without the need for user intervention but, at the same time, to give him control of what is presented and to whom it is presented. This is a particularly challenging problem, and some researchers even doubt that intelligent systems are capable of inferring our context from sensor data as well as humans do [38]. However, previous research by Hudson, Fogarty, and Horvitz has shown that intelligent systems using sensor data are capable of inferring and reasoning about human interruptibility as well as, and in some cases better than, humans [41, 55, 57]. Yet, even if intelligent systems were capable of inferring users' context, we do not expect such systems to be capable of reasoning about sharing patterns and privacy preferences of users, and we believe the right approach is in the middle where people are kept in the decision-making cycle as we discussed earlier.

An interesting type of future work will be to implement the collaborative approach and study it in real life. The feasibility of this depends on how fast the cellphone industry adopts Bluetooth on a wide scale. The collaborative application can be used as a test bed in which to examine energy consumption, user interface, feature set, and default settings. One issue that is worth exploring is the effect of incorporating the history of encountered devices within the collaborative service so different weights can be assigned to them according to the level of trust between users and the frequency of encounters.

The collaborative model described in this research is not limited to minimizing disruption and has the potential to be generalized to provide a variety of services. As mobile devices become cheaper, smaller, faster and more pervasive, there will be a potential for many collaborative paradigms to emerge. For example, cell phones may carry their users' preferences for room temperature, and smart places could customize the room temperature according to the majority's preference. Certainly, future work must also include attempts to identify interesting services and their feasibility based on the collaborative model.

Finally, we also plan to repeat some of our experiments using real cell phones in order to validate the results and avoid any biases that could be introduced by the simulation. It is also important to examine the preferred direction of error in a context-aware configuration. The error of such an application can be of two sorts: fewer missed calls but higher probability of inappropriate interruption or fewer inappropriate interruptions but higher probability of missed calls. In our experiment, most participants were not annoyed by missing calls since the caller was assumed to be anonymous. That the calls were not real may have contributed to this factor; therefore the results may be skewed and inapplicable to real life. It would be interesting to investigate whether it is more important for people not to be interrupted inappropriately or not to miss certain calls. It is also important to study sharing patterns and privacy preferences using real life data and real situations and compare the results with those obtained in our ESM study.

Appendix A - Experiment Details

Questionnaires used during the in-situ study for the caller-based approach

1. **So-and-so** is going to call. What information would you like to disclose to him/her?
    - Where you are
    - What you are doing
    - Whether or not you are in a conversation
    - Whether or not you have a company
2. Where are you?
    - at home;
    - office; (work)
    - class;
    - in transit;
    - coffee shop;
    - gym;
    - restaurant;
    - store;
    - elsewhere.
3. What are you doing?
    - sitting in class;
    - working;
    - preparing food or eating;
    - working out;
    - homework or studying;
    - shopping;
    - driving a car;

  - leisure, TV;
  - other

4. How many people are around you?

  - 0
  - 1
  - 2
  - 3
  - 4+

5. In whose company are you?

  - Nobody
  - Friends
  - Colleagues
  - Partner
  - Family
  - Classmates
  - Boss/Employer
  - Stranger

6. Is it an appropriate time for him/her to call?

The caller in question 1 who is referred to as “so-and-so” was replaced by one of the roles that was randomly but equally selected from the following list of social relations:

- Significant others (spouses)
- Family members
- Friends
- Coworkers (colleagues)
- Boss/Employer

- Unknown

Questions 3 and 4 were customized depending on the answer for question 2. For example, if the answer for question 2 was "class", then the next three (two?) questions were not asked because their answers are obvious, and we did not want to bother participants unnecessarily.

iESP questionnaires

In order to use the iESP application [4], which is the free source experience sampling application from Intel research labs that we used in our in-situ study, we needed to write the questionnaires in the section above in a specific format that is understood by the application. The iESP-formatted questionnaires include tags to specify transitions between questions, dependency among questions according to answers for each, and the probability that each question can be triggered. Following is how the above questionnaires are written in the iESP format.

100|Your significant other is going to call. What information would you like to disclose to him/her?%TYPE checkboxes %PROB 16 %NEXT 1000 %SNEXT 110|Where you are|What you are doing|Whether or not u r in a conversation|Whether or not u have company

110|Your friend is going to call. What information would you like to disclose to him/her? %TYPE checkboxes %PROB 20 %NEXT 1000 %SNEXT 120|Where you are|What you are doing|Whether or not u r in a conversation|Whether or not u have company

120|Your employer/advisor is going to call. What information would you like to disclose to him/her? %TYPE checkboxes %PROB 25 %NEXT 1000 %SNEXT 130|Where you are|What you are doing|Whether or not u r in a conversation|Whether or not u have company

130|Your colleague is going to call. What information would you like to disclose to him/her? %TYPE checkboxes %PROB 33 %NEXT 1000 %SNEXT 140|Where you are|What you are doing|Whether or not u r in a conversation|Whether or not u have company

140|A family member is going to call. What information would you like to disclose to him/her? %TYPE checkboxes %PROB 50 %NEXT 1000 %SNEXT 150|Where you are|What you are doing|Whether or not u r in a conversation|Whether or not u have company

150|Somebody (unknown) is going to call. What information would you like to disclose to him/her? %TYPE checkboxes %NEXT 1000|Where you are|What you are doing|Whether or not u r in a conversation|Whether or not u have company

1000|Where are you? %TYPE popup %NEXT 2000|at home %NEXT 2010|office (work) %NEXT 2020|class %NEXT 5000|in transit %NEXT 3000|coffee shop %NEXT 2030|gym %NEXT 3000|restaurant %NEXT 3000|store %NEXT 3000|elsewhere

2000|What are you doing? %TYPE popup %NEXT 3000|working|preparing food or eating|working out|homework or studying|shopping|driving|leisure, TV|other

2010|What are you doing? %TYPE popup %NEXT 3000|conversation|on the phone|working|preparing food or eating|working out|homework or studying|leisure, TV|surfing the web|other

2020|What are you doing? %TYPE popup %NEXT 3000|conversation|on the phone|working|taking a break|meeting|office hour|surfing the web|other

2030|What are you doing? %TYPE popup %NEXT 3000|conversation|on the phone|Studing/HW|taking a break|meeting|surfing the web|other

3000|how many people are around you? %TYPE list|0 %NEXT 5000|1|2|3|4+

4000|Who are you in accompany of? %TYPE popup %NEXT 5000|partner|rommates|friends|family|colleagues|classmates|boss/employer|strangers

5000|Is it appropriate time for him/her to call?%TYPE buttons %NEXT 6000|yes|no

6000|Would you like to add any comments? %TYPE buttons|yes%NEXT 7000|no%NEXT 8000

7000|Thank you, please type your comments %TYPE text

End of the Study Interview

1. How old are you?
2. How long you have been using a cell phone?
3. Gender?
4. On average, how many times a day you receive cell phone calls?
5. On average, how many times a day you make cell phone calls?
6. When you agreed to disclose your location to the receiver, what kind of location did you have in mind? (home, exact address, town, country)
7. Would you like to approve the disclosure of contextual information every time you release it or would you prefer this to occur automatically?
8. Were there any specific activities you did not feel like disclosing?
9. Were there any specific locations you did not feel like disclosing?
10. Does disclosing information about whether you are talking or not pose any privacy concerns to you?
11. If the answer for the question above is “yes” please specify “Why”
12. Would you like to use such a service for your cell phone?
13. What cues do you use to decide whether or not it is appropriate to call somebody?
14. What places you find using cell phone most annoying?
15. How often do you find your cell phone with the wrong settings?

Appendix B – Results from the Caller-based User Study

Sharing (disclose) rate for each participant for four types of context information (location, activity, conversation, company) across six different social relations obtained.

Participant ID	***Sig. Other***	***Friend***	***Family***	***Colleague***	***Boss***	***Unknown***
1	100.0	92.0	95.0	92.0	90.9	0.0
2	80.0	42.1	30.0	18.2	5.0	5.3
3	100.0	100.0	100.0	44.0	83.3	0.0
4	95.7	89.7	84.0	36.0	30.3	13.0
5	100.0	100.0	96.0	14.3	16.7	0.0
6	100.0	62.5	100.0	70.0	22.2	0.0
7	100.0	100.0	100.0	36.8	62.5	14.3
8	93.8	86.4	95.0	50.0	44.4	31.6
9	100.0	95.2	92.6	91.7	25.0	33.3
10	100.0	92.1	96.0	22.6	9.1	10.8
11	100.0	95.5	100.0	100.0	100.0	81.8
12	63.6	77.8	100.0	65.0	21.4	62.5
13	100.0	100.0	100.0	100.0	100.0	4.8
14	100.0	87.5	95.0	95.0	100.0	91.3
15	100.0	100.0	9.5	42.1	41.7	0.0
16	92.9	80.0	70.6	88.9	69.6	78.6
17	100.0	100.0	100.0	87.1	8.8	100.0
18	100.0	100.0	100.0	100.0	100.0	100.0
19	93.8	100.0	92.3	0.0	0.0	0.0
20	100.0	100.0	100.0	90.5	21.7	0.0
average	***96.0***	***90.0***	***87.8***	***62.2***	***47.6***	***31.4***

Table B-7-2: Disclosure rate for Conversation information by each participant across different social relations

Participant ID	***Significant Other***	***Friend***	***Family Member***	***Colleague***	***Boss***	***Unknown***
1	100.0	100.0	100.0	88.0	90.9	0.0
2	90.0	63.2	30.0	36.4	15.0	5.3
3	100.0	100.0	100.0	40.0	66.7	4.2
4	95.7	93.1	92.0	72.0	78.8	0.0
5	100.0	100.0	96.0	23.8	16.7	11.8
6	100.0	75.0	100.0	80.0	88.9	0.0
7	100.0	100.0	95.7	73.7	75.0	14.3
8	100.0	77.3	95.0	71.4	74.1	21.1
9	100.0	100.0	100.0	100.0	81.3	37.5
10	100.0	84.2	100.0	29.0	15.2	18.9
11	100.0	100.0	100.0	100.0	100.0	6.1
12	100.0	100.0	100.0	100.0	92.9	75.0
13	100.0	100.0	100.0	100.0	100.0	4.8
14	100.0	100.0	100.0	100.0	100.0	100.0
15	100.0	100.0	0.0	84.2	100.0	0.0
16	92.9	85.0	88.2	88.9	87.0	21.4
17	100.0	100.0	100.0	58.1	8.8	36.4
18	100.0	100.0	100.0	100.0	100.0	100.0
19	93.8	100.0	100.0	66.7	68.8	17.6
20	100.0	100.0	100.0	100.0	95.7	0.0
average	***98.6***	***93.9***	***89.8***	***75.6***	***72.8***	***23.7***

Table B-7-3: Disclosure rate for Company information by each participant across different social relations

Participant ID	***Significant Other***	***Friend***	***Family Member***	***Colleague***	***Boss***	***Unknown***
1	100.0	96.0	90.0	96.0	95.5	0.0
2	0.0	5.3	10.0	0.0	0.0	0.0
3	100.0	90.0	100.0	32.0	50.0	0.0
4	8.7	3.4	4.0	0.0	3.0	13.0
5	100.0	90.9	80.0	14.3	0.0	0.0
6	100.0	25.0	33.3	0.0	11.1	0.0
7	100.0	0.0	17.4	0.0	0.0	0.0
8	81.3	54.5	50.0	35.7	37.0	15.8
9	82.4	76.2	81.5	75.0	68.8	79.2
10	97.0	73.7	88.0	22.6	6.1	10.8
11	51.6	4.5	13.8	10.7	0.0	3.0
12	0.0	0.0	6.7	0.0	0.0	0.0
13	100.0	100.0	100.0	100.0	100.0	4.8
14	100.0	87.5	90.0	80.0	58.3	65.2
15	100.0	100.0	4.8	89.5	83.3	0.0
16	78.6	20.0	23.5	11.1	8.7	0.0
17	100.0	97.6	96.6	83.9	8.8	90.9
18	54.5	52.2	56.3	68.2	62.5	37.5
19	93.8	100.0	92.3	0.0	0.0	0.0
20	100.0	84.0	100.0	14.3	0.0	0.0
average	***77.4***	***58.0***	***56.9***	***36.7***	***29.7***	***16.0***

Table B-7-4: Disclosure rate for Activity information by each participant across different social relations

Participant ID	Significant Other	Friend	Family Member	Colleague	Boss	Unknown
1	100.0	92.0	90.0	84.0	90.9	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	100.0	90.0	100.0	32.0	50.0	0.0
4	13.0	20.7	12.0	16.0	0.0	30.4
5	100.0	90.9	88.0	14.3	0.0	0.0
6	100.0	25.0	33.3	0.0	11.1	0.0
7	100.0	0.0	13.0	0.0	0.0	0.0
8	87.5	54.5	50.0	14.3	33.3	10.5
9	82.4	71.4	81.5	16.7	6.3	4.2
10	97.0	73.7	88.0	25.8	9.1	10.8
11	48.4	4.5	10.3	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0
13	100.0	100.0	100.0	100.0	100.0	4.8
14	92.3	100.0	100.0	100.0	66.7	91.3
15	100.0	100.0	4.8	94.7	91.7	0.0
16	78.6	35.0	23.5	11.1	13.0	0.0
17	100.0	100.0	96.6	87.1	5.9	90.9
18	95.5	95.7	100.0	90.9	81.3	68.8
19	93.8	100.0	92.3	0.0	0.0	0.0
20	100.0	84.0	100.0	19.0	0.0	0.0
average	***79.4***	***61.9***	***59.2***	***35.3***	***28.0***	***15.6***

Table B-7-5: Disclosure rate for location information by each participant across different social relations

Bibliography

1. Bluetooth Market Share, http://www.bluetooth.com/news/sigreleases.asp?A=2&PID=1352&ARC=1&ofs=

2. Cell-phone jammers answer prayers of some., http://www.jsonline.com/bym/tech/news/nov04/271384.asp

3. http://www.flexilis.com/

4. iESP application, http://seattleweb.intel-research.net/projects/esm/iESP.html

5. New mobile message craze spreads, http://news.bbc.co.uk/1/hi/technology/3237755.stm

6. Study: All cell phones distract drivers, http://archives.cnn.com/2001/US/08/16/cell.phone.driving/

7. Ackerman, M., *The Intellectual Challenge of CSCW: The Gap Between Social Requirements and Technical Feasibility*. Human-Computer Interaction, 2000. **15**(2-3): p. 181-205.

8. Acquisti, A. and J. Grossklags, *Privacy Attitudes and Privacy Behaviour: Losses, Gains and Hyperbolic Discounting.* The Economics of Information Security, 2004.

9. Antifakos, S., A. Schwaninger, and B. Schiele. *Evaluating the effects of displaying uncertainty in context-aware applications*. In Proceedings of *International Conference on Ubiquitous Computing (UbiComp)*. 2004. Nottingham, England.

10. Antifakos, S., A. Schwaninger, and B. Schiele. *Evaluating the Effects of Displaying Uncertainty in Context-Aware Applications*. In Proceedings of *Ubicomp'04. 6th International Conference on Ubiquitous Computing.* 2004. Nottingham, UK.

11. Avrahami, D., D. Gergle, S.E. Hudson, and S. Kiesler, *Improving the Accuracy of Cell Phone Interruptions: A Study on the Effect of Contextual Information on the Behaviour of Callers.* Behaviour & Information Technology.

12. Bailey, B., J. Konstan, and J.V. Carlis. *Measuring the Effects of Interruptions on Task Performance in the User Interface*. In Proceedings of *IEEE Conference on Systems, Man, and Cybernetics (SMC 2000)*. 2000.

13. Barkhuus, L. and A. Dey. *Location-Based Services for Mobile Telephony: a study of users privacy concerns*. In Proceedings of *Interact 2003*. 2003.

14. Barkhuus, L. and A.K. Dey. *Is context-aware computing taking control away from the user? Three levels of interactivity examined*. In Proceedings of *UBICOMP 2003, 5th International Symposium on Ubiquitous Computing*. 2003.

15. Bautsch, H., J. Granger, T. Karnjate, F. Khan, Z. Leveston, G. Niehus, and T. Ward, *An investigation of mobile phone use: a socio-technical approach*. 2001

16. Beale, R., *Supporting social interaction with the smartphone - designing pervasive systems.* IEEE Pervasive Computing,, 2005. **4**(2).

17. Bellotti, V., B. Dalal, N. Good, P. Flynn, and D.G. Bobrow. *What a to-do: Studies of task management towards the design of a personal task list manager*. In Proceedings of *CHI 2004*. 2004: ACM Press (2004).

18. Bellotti, V. and W.K. Edwards, *Intelligibility and accountability: human considerations in context aware systems.* Human Computer Interaction, 2001. **16**(2-4).

19. Bellotti, V. and A. Sellen. *Design for privacy in ubiquitous computing environments*. In Proceedings of *Third European Conference on Computer Supported Cooperative Work (ECSCW'93)*. 1993.

20. Berendt, B., O. Günther, and S. Spiekermann, *Privacy in E-Commerce:Stated Preferences vs. Actual Behavior.* Communications of the ACM, 2005. **48**(4).

21. Bettman, J., M.F. Luce, and J.W. Payne, *Constructive Consumer Choice Processes.* Journal of Consumer Research, 1998. **25**: p. 187-217.

22. Briody, D., *Thou shalt learn and abide by the ten commandments of cell phone etiquette*, in *InfoWorld*. 2000. p. p.59B.

23. Burrell, J., G.K. Gay, K. Kubo, and N. Farina. *Context-Aware Computing: a test case*. In Proceedings of *Ubiquitous Computing*. 2002. Gothenburg, Sweden.

24. Chalmers, M. and I. MacColl. *Seamful and seamless design in ubiquitous computing*. In Proceedings of *Workshop At the Crossroads: The Interaction of HCI and Systems Issues in UbiComp*. 2003.

25. Chen, D. and R. Vertegaal. *Using mental load for managing interruptions in a physiologically attentive user interface*. In Proceedings of *CHI'04: Extended Abstracts*. 2004.

26. Chen, G. and D. Kotz, *A survey of context-aware mobile computing research*. 2000, Department of Computer Science, Darthmouth CollegeTR2000-381.

27. Cheverst, K., N. Davies, K. Mitchell, and C. Efstratiou, *Using context as a crystal ball: Rewards and pitfalls.* Personal Technologies, 2001. **3**.

28. Connelly, K. and A. Khalil. *Towards Automatic Device Configuration in Smart Environments*. In Proceedings of *UbiSys Workshop*. 2003.

29. Consolvo, S., Smith I., Mathews T., and L. A. *Location Disclosure To Social Relations: Why, When, & What People Want To Share*. In Proceedings of *ACM Conference On Human Factors In Computing Systems*. 2005. Portland, Oregon.

30. Consolvo, S. and M. Walker, *Using the Experience Sampling Method to Evaluate Ubicomp Applications: The Human Experience.* IEEE Pervasive Computing Mobile and Ubiquitous Systems, 2003. **2**(2): p. 24-31.

31. Csikszentmihalyi, M., R. Larson, and S. Prescott, *The ecology of adolescent activity and experience.* Journal of Youth and Adolescence, 1977. **6**: p. 281-94.

32. Cutrell, E., M. Czerwinski, and E. Horvitz. *Notification, Disruption, and Memory: Effects of Messaging Interruptions on Memory and Performance*. In Proceedings of *Interact 2001*. 2001. Tokyo, Japan.

33. Dantzich, M.v., D. Robbins, E. Horvitz, and M. Czerwinski. *Scope: Providing awareness of multiple notifications at a glance*. In Proceedings of *AVI 2002, ACM Conference on Advanced Visual Interfaces*. 2002.

34. Dourish, P. and V. Bellotti. *Awareness and Coordination in Shared Workspaces*. In Proceedings of *ACM Conference on Computer Supported Cooperative Work (CSCW)*. 1992.

35. Dourish, P. and S. Bly. *Portholes: Supporting Awareness in a Distributed Work Group*. In Proceedings of *CHI '92 Conference on Human Factors in Computing Systems*. 1992.

36. Eagle, N. and A. Pentland, *Social Serendipity: Mobilizing Social Software.* EEE Pervasive Computing, 2005. **4**(2): p. 28-34.

37. Edwards, W.K. and R.E. Grinter. *At home with ubiquitous computing: Seven challenges*. In Proceedings of *Conference on Ubiquitous and Handheld Computing (UbiComp)*. 2001.

38. Erickson, T., *Ask not for whom the cell phone tolls: Some problems with the notion of context-aware computing.* Communications of the ACM, 2001.

39. Erickson, T., D.N. Smith, W.A. Kellogg, M. Laff, J.T. Richards, and E. Bradner. *Socially Translucent Systems: Social Proxies, Persistent Conversation and the Design of "Babble"*. In Proceedings of *CHI '99*. 1999.

40. Eyrolle, H. and J. Cellier, *The effects of interruptions in work activity: Field and laboratory results.* Applied Ergonomics, 2000. **31**: p. 537-543.

41. Fogarty, J., S. Hudson, C. Atkeson, D. Avrahami, J. Forlizzi, S. Kiesler, J. Lee, and J. Yang, *Predicting Human Interruptibility with Sensors.* ACM Transactions on CHI, 2004.

42. Fogarty, J., J. Lai, and J. Christensen, *Presence versus Availability: The Design and Evaluation of a Context-Aware Communication Client.* International Journal of Human-Computer Studies (IJHCS), 2004. **61**(3): p. 299-317.

43. Garlan, D., D. Siewiorek, A. Smailagic, and P. Steenkiste, *Project Aura: Toward Distraction-Free Pervasive Computing.* IEEE Pervasive Computing, 2002(April-June).

44. Gillie, T. and D. Broadbent, *What makes interruptions disruptive? A study of length, similarity and complexity.* Psychological Research, 1989. **50**: p. 243-250.

45. Goffman, E., *The Presentation of Self in Everyday Life*. 1959, Garden City, NY.

46. Goldfayn, A., *After years of promise, Bluetooth hits its stride*, in *Chicago Tribune*. 2005.

47. Greenberg, S., *Context as a dynamic construct.* Human-Computer Interaction, 2001. **16**: p. 257-268.

48. Griswold, W.G., P. Shanahan, S.W. Brown, R. Boyer, M. Ratto, R.B. Shapiro, and T.M. Truong, *ActiveCampus - Experiments in Community-Oriented Ubiquitous Computing.* IEEE Computer, 2004. **37**(10): p. 73-81.

49. Hansson, R. and P. Ljungstrand. *The Reminder Bracelet: Subtle Notification Cues for Mobile Devices*. In Proceedings of *Extended Abstracts of CHI 2000*. 2000.

50. Hansson, R., P. Ljungstrand, and J. Redstrm. *Subtle and Public Notification Cues for Mobile Devices*. In Proceedings of *UbiComp 2001*. 2001.

51. Harper, J. and S. Singleton, *With a Grain of Salt: What Consumer Privacy Surveys Don't Tell Us.* 2001.

52. Ho, J. and S. Intille. *Using context-aware computing to reduce the perceived burden of interruptions from mobile devices*. In Proceedings of *Conference on Human Factors in Computing Systems (CHI 2005)*. 2005: ACM Press.

53. Horvitz, E., J. Breese, D. Heckerman, D. Hovel, and K. Rommelse. *The lumiere project: Bayesian user modeling for inferring the goals and needs of software users*. In Proceedings of *Fourteenth Conference on Uncertainty in Artificial Intelligence*. 1998.

54. Horvitz, E., A. Jacobs, and D. Hovel. *Attention-sensitive alerting*. In Proceedings of *Conference on Uncertainty and Artificial Intelligence (UAI ’99)*. 1999.

55. Horvitz, E., P. Koch, C.M. Kadie, and A. Jacobs. *Coordinate: Probabilistic Forecasting of Presence and Availability.* In Proceedings of *National Conference on Uncertainty and Artificial Intelligence (UAI 2002).* 2002.

56. Hudson, J.M., J. Christensen, W.A. Kellogg, and T. Erickson. *”I’d be overwhelmed, but it’s just one more thing to do”: Availability and interruption in research management*. In Proceedings of *Conference on Human Factors in Computing Systems (CHI 2002)*. 2002.

57. Hudson, S., J. Fogarty, C. Atkeson, D. Avrahami, J. Forlizzi, S. Kiesler, J. Lee, and J. Yang. *Predicting human interruptibility with sensors: a wizard of oz feasibility study*. In Proceedings of *Human factors in computing systems*. 2003: ACM Press.

58. Jensen, C. and C. Potts, *Privacy Practices of Internet Users: Self-report versus Observed Behavior.* To appear in International Journal of Human Computer Studies special issue on HCI Research in Privacy and Security.

59. Junglas, I.A. and C. Spitzmueller. *A Research Model for Studying Privacy Concerns Pertaining to Location-Based Services*. In Proceedings of *38th Hawaii International Conference on System Sciences*. 2005.

60. Kern, N., S. Antifakos, B. Schiele, and A. Schwaninger. *A model for human interruptability: experimental evaluation and automatic estimation from wearable sensors.* In Proceedings of *IEEE International Symposium on Wearable Computers*. 2004.

61. Khalil, A. and K. Connelly. *Improving cell phone awareness by using calendar information*. In Proceedings of *INTERACT 05*. 2005. Rome, Italy.

62. Langheinrich, M. *Privacy by Design - Principles of Privacy-Aware Ubiquitous Systems*. In Proceedings of *Third International Conference on Ubiquitous Computing (UbiComp 2001)*. Atlanta, USA.

63. Lasen, A., *A comparative Study of Mobile Phone Use in London, Madrid and Paris*. 2002

64. Lederer, S. *Everyday Privacy in Ubiquitous Computing Environments*. In Proceedings of *Ubicomp 2002 Workshop on Socially-informed Design of Privacy-enhancing Solutions in Ubiquitous Computing*.

65. Lederer, S., J.I. Hong, A. Dey, and J.A. Landay, *Personal Privacy through Understanding and Action: Five Pitfalls for Designers.* Personal and Ubiquitous Computing, 2004. **8**(6).

66. Lederer, S., J. Mankoff, and A.K. Dey. *Who Wants to Know What When? Privacy Preference Determinants in Ubiquitous Computing*. In Proceedings of *Short Talk in the Extended Abstracts of CHI 2003, ACM Conference on Human Factors in Computing Systems*. 2003.

67. Marmasse, N., C. Schmandt, and D. Spectre. *Watchme: Communication and Awareness between Members of a Closely-Knit Group.* In Proceedings of *UbiComp*. 2004. Nottingham, UK.

68. Marti, S. and C. Schmandt. *Giving the caller the finger: collaborative responsibility for cellphone interruptions*. In Proceedings of *CHI Extended Abstracts 2005*.

69. Milewshi, A.E. and T.M. Smith. *Providing Presence Cues to Telephone Users*. In Proceedings of *CSCW 2000*. 2000. Philadelphia, PA.

70. Monk, A., J. Carroll, S. Parker, and M. Blythe, *Why are Mobile Phones Annoying?* Behaviour and Information Technology, 2004. **31**(1): p. 33-41.

71. Mynatt, E. and J. Tullio. *Inferring Calendar Event Attendance*. In Proceedings of *the International Conference on Intelligent User Interfaces (IUI 2001)*. 2001.

72. Nelson, L., S. Bly, and T. Sokoler. *Quiet Calls: Talking Silently on Mobile Phones*. In Proceedings of *CHI 2001 Conference on Human Factors in Computing Systems*. 2001.

73. Newberger, A. and A. Dey. *System support for context monitoring and control*. In Proceedings of *Workshop At the Crossroads: The Interaction of HCI and Systems Issues in Ubi-Comp.* 2003.

74. O'conaill, B. and D. Frohlich. *Timespace in the workplace: dealing with*

75. *interruptions*. In Proceedings of *Conference companion on Human factors in computing systems*. 1995: ACM Press.

76. O'Connail, B. and D. Frohlich. *Timespace in the workplace: Dealing with interruptions*. In Proceedings of *CHI '95 Conference on Human Factors in Computing Systems. Extended Abstracts*. 1995: ACM Press.

77. Oliver, N., E. Horvitz, and A. Garg. *Layered Representations for Recognizing Office Activity*. In Proceedings of *International Conference on Multimodal Interaction (ICMI 2002)*. 2002.

78. Olson, J., J. Grudin, and E. Horvitz. *A study of preferences for sharing and privacy*. In Proceedings of *CHI 05*. 2005.

79. P&AB, *Consumer Privacy Attitudes: A Major Shift since 2000 and Why.* Privacy & American Business Newsletter, 2003. **10**(6).

80. P&AB, *Consumer Privacy Attitudes: A Major Shift since 2000 and Why*. Privacy & American Business Newsletter. **10**(6).

81. Palen, L., M. Salzman, and E. Youngs. *Going Wireless: Behavior & Practice of New Mobile Phone Users*. In Proceedings of *ACM 2000 Conference on Computer supported cooperative work (CSCW '00)*. 2000. Philadelphia, PA.

82. Patil, S. and J. Lai. *Who Gets to Know What When: Configuring Privacy Preferences in an Awareness Application*. In Proceedings of *CHI 2005*. 2005. Portland, OR.

83. Patterson, D.J., L. Liao, D. Fox, and H. Kautz. *Inferring high-level behavior from low-level sensors.* In Proceedings of *International Conference on Ubiquitous Computing (UbiComp)*. 2003.

84. Paulos, E. and E. Goodman. *The familiar stranger: anxiety, comfort, and play in public places*. In Proceedings of *CHI 2004*. 2004. Vienna, Austria.

85. Pedersen, E.R. *Calls.calm: Enabling Caller and Callee to Collaborate*. In Proceedings of *CHI 2001*. 2001.

86. REUTERS, Mobile phone users double since 2000, http://www.computerworld.com/mobiletopics/mobile/story/0%2C10801%2C98142%2C00.html

87. Schmidt, A., K.A. Aidoo, A. Takaluoma, U. Tuomela, K.V. Laerhoven, and W.V.d. Velde. *Advanced interaction in context*. In Proceedings of *First International Symposium on Handheld and Ubiquitous Computing (HUC'99)*. 1999. Karlsruhe, Germany.

88. Schmidt, A., A. Takaluoma, and J. Mantyjarvi, *Context-Aware Telephony Over WAP*. Personal and Ubiquitous Computing, 2000. **4**(4): p. 225-229.

89. Sheehan, K., *Toward a Typology of Internet Users and Online Privacy Concerns.* The Information Society, 2002. **18**(1): p. 21-32.

90. Siewiorek, D., A. Smailagic, J. Furukawa, N. Moraveji, K. Reiger, and J. Shaffer. *SenSay: A Context-Aware Mobile Phone*. In Proceedings of *IEEE International Symposium on Wearable Computers (ISWC)*. 2003. New York, NY.

91. Speier, C., J.S. Valacich, and I. Vessey. *The effects of task interruption and information presentation on individual decision making*. In Proceedings of *Eighteenth International Conference on Information Systems*. 1997.

92. TANG, J.C., N. YANKELOVICH, J. BEGOLE, M. VAN KLEEK, F. LI, and J. BHALODIA. *ConNexus to awarenex: extending awareness to mobile users*. In Proceedings of *CHI 2001*. 2001.

93. Vertegaal, R., C. Dickie, C. Sohn, and M. Flickner. *Designing Attentive Cell Phones Using Wearable EyeContact Sensors*. In Proceedings of *CHI 2002*. 2002.

94. Wei, R. and L. Leung, *Blurring public and private behaviors in public space: policy challenges in the use and improper use of the cell phone.* Telematics and Informatics, 1999. **16**(1-2): p. 11-26.

95. Weiser, M., *The Future of Ubiquitous Computing on Campus.* Communications of ACM, 1996. **41**(1): p. 41-42.

96. Wellman, B., *Physical Place and Cyber Place: The Rise of Personalized Networking.* International Journal of Urban and Regional Research, 2001. **25**(2): p. 227-52.

97. Wylie, M., *Cell-phone jammers enforce quiet, but illegally*, in *Cleveland Plain Dealer*. 2000.

98. Yan, H. and T. Selker. *Context-aware office assistant*. In Proceedings of *International Conference on Intelligent User Interfaces*. 2000. New Orleans, LA.

ASHRAF KHALIL
Department of Computer Science
Indiana University, Bloomington
Email: akhalil@indiana.edu
http://www.cs.indiana.edu/~akhalil

EDUCATION

Indiana University, Department of Computer Science, Bloomington, IN

PhD (Expected 12/2005)
Dissertation: Context-aware Telephony and Its Users: Methods to Improve the Accuracy of Mobile Device Interruptions

M.S 2004. GPA:3.9

Indiana University, Department of Chemistry, Bloomington, IN

M.S. May 2001
Dissertation: Predicting Reservoir Geometry and Internal Characteristics: An Integrated Data and Modeling Approach

Birzeit University, Palestine

B.S (Honors) Physics July 1998
Minor Computer Science

AREAS OF INTEREST

I aim to pursue further study on various aspects of Human-Computer Interaction, Ubiquitous and Mobile Computing, Context-Awareness, Interruptions, Social Computing, and Privacy. I am particularly interested in user acceptance of ubiquitous computing technologies, and how acceptance is affected by such issues as control, convenience, personal motivation and privacy. I also hope to discover new interaction paradigms between users and their cell phones to provide users with computing services other than voice communications and text messaging.

PROFESSIONAL EXPERIENCE

Research Assistant for Prof. Kay Connelly at SURG Lab: 2003-current

Working on Automatic Device Configuration (ADC) which automatically changes the configuration of mobile devices depending on the social context. The purpose is to minimize inappropriate cellphone interruptions and to create more socially-aware cell phones. Part of the research is to develop a user study to examine the feasibility of the project and analyze the requirements. Another part is to investigate users' privacy preferences and concerns when using different types of context information for context-aware telephony.

Research Assistant for Prof. Beth Plale at DDE Lab: 05/2001-05/2002

Worked on developing a benchmark for evaluating the performance of different platforms for grid resource information managements. The work compared results obtained from three different platforms (relational database, XML database, and LDAP database). Tasks ranged from developing the benchmark, installing servers, writing queries, and analyzing performance.

Research Intern, Adaptive Technology Center at IUB: Summer 2002

Tested and evaluated different computer software for students with disabilities. Part of the work was designing and conducting user studies as well as developing software training guides for students with visual and mobility impairments.

Research Assistant for Prof. Peter Ortoleva at LCG Lab: 08/1998-01/2000

The **EQM** project, an earthquake modeling that is based on incremental stress rheology and rock texture dynamics. The model used state of the art scientific computing and visualization techniques to solve the highly dynamic equations and visualize the 3D results in real-time.

Summer Internship at Jefferson Lab, Newport News, VA, summer 1998.

Developed computer applications which analyzed and visualized real-time and large-scale data generated from a high-energy particle accelerator.

TEACHING EXPERIENCE

Associate Instructor for Department of Computer Science, Indiana University for Computer networks (graduate level), Operating Systems (senior undergraduate), Introduction to Programming (sophomore undergrad), Network Technology and Administration (non-major graduate), Introduction of Computers and Computing (freshman non-major). Responsibilities included leading laboratory discussions, designing and grading assignments and exams, and occasional classroom teaching.

Associate Instructor, Indiana University Chemistry Dept., 01/2000-12/2000

Calm Project, a dynamic and interactive web-based educational system through which students evaluate their problem-solving skills. Responsibilities included design and implementation of an early version of the system, plus management and maintenance. URL: http://calm.indiana.edu/

PROJECTS

- Conducted computational experiments to identify PageRank (used by search engines to determine the global importance of web pages) properties. The experiments examined the PageRank dependency on the net size, degree distribution, stability, and convergence using different numerical solvers.

- Managed a team of 4 graduate students to develop a 3D wireless location tracking infrastructure for the computer science building. The project used Wi-Fi single strength measurements to build a radio map that was later used for location prediction of mobile users.
- Worked on ‘NACHOS’, an instructional Operating System as part of the Advanced Operating Systems course. The projects involved implementation of Multitasking, basic System Calls and Demand Paged Virtual memory. Involved extensive programming in C++. Fall 2001
- With a team, developed and implemented an inventory management software system for a client, as part of a year-long project for a Software Engineering class. The software includes web based catalog, real time inventory updates and order handling. The project involved extensive coding using ASP, MS-SQL and Visual Basic. Also prepared professional documentation in the form of user and programmer guides. Aug 2000-May 2001
- Built an Instant Messenger Service based on simple distributed event model. It uses a federated server model with LDAP directory services for registration and SOAP for messaging. Involved extensive programming in C++ and Java. Fall 2002

PUBLICATIONS

JOURNALS:

- **Failure, Memory and Cyclic fault Movement,** K. Tuncay, A. Khalil, and P. Ortoleva June 2001; Bulletin of Seismological Society of America.

CONFERENCES:

- **Improving Cell Phone Awareness by Using Calendar Information.** Ashraf Khalil and Kay Connelly. In the Proceedings of International Conference on Human-Computer Interaction (INTERACT 2005), 2005. Rome, Italy.
- **Context-aware configuration: A study on improving cell phone awareness**. Ashraf Khalil and Kay Connelly. In the Proceedings of Fifth International and International Conference on Modeling and Using Context (CONTEXT 2005), 2005. Paris, France.
- **The Internet Hunt Revisited: Personal Information Accessible via the Web**, Kay H. Connelly, Tom Jagatic, Ashraf Khalil, Yong Liu, Katie A. Siek, and Sid Stamm. In the Proceedings of www@10, Paper, Terre Haute, IN, September 30-October 1, 2004.
- **A Comparative Study of Web Language Support for Mobile Web Browsers,** Katie A. Siek, Ashraf Khalil, Yong Liu, Nick Edmonds, and Kay H. Connelly. In the Proceedings of www@10, Paper, Terre Haute, IN, September 30-October 1, 2004.

WORKSHOPS:

- **Exploiting Social Environment to Increase Cellphone Awareness.** Ashraf Khalil and Kay Connelly. Workshop on Mobile Social Software. (CHI 2006).
- **Examining the Use of Surveys in Measuring Privacy in Ubiquitous Computing.** Ashraf Khalil and Kay Connelly. Workshop in Appropriate Methodology for Empirical Studies of Privacy, 2005, (INTERACT 05).
- **On Negotiating Automatic Device Configuration in Smart Environments,** Kay Connelly and Ashraf Khalil. In the Proceedings of PerWare 04 Workshop, Second IEEE International Conference on Pervasive Computing and Communications, Orlando, FL, March 14-17, 2004.
- **Towards Automatic Device Configuration in Smart Environments,** Kay Connelly and Ashraf Khalil. In the Proceedings of UbiSys Workshop 2003.

TECHNICAL REPORTS:

- **Experiments with PageRank Computation,** Ashraf Khalil and Yong Liu (Dec 2004). Technical Report.
- **Development of a Wireless Location System in Lindley Hall ,** R. Doshi, T. Jagatic, A. Khalil, S. Shirasuna, and P. Venkatakrishnan (Jan 2004). Technical Report.

PAPERS UNDER REVIEW:

- **Context-aware Telephony: Privacy Preferences and Sharing Patterns.** Ashraf Khalil and Kay Connelly. (*Submitted)*
- **Majority Takes All: A Collaborative Approach to Minimize Cellphone Interruptions.** Ashraf Khalil and Kay Connelly. (*Submitted)*
- **Do I Do What I Say?: A Survey's Ability to Predict Privacy Concerns in Pervasive Computing**. Yong Liu, Ashraf Khalil, Kay Connelly. (*Submitted)*
- **Evaluating the effect of Inaccuracy in Context-aware Applications.** Ashraf Khalil and Kay Connelly. Submitted

PRESENTATIONS

- **Towards Automatic Device Configuration in Smart Environments,** UbiSys Workshop, October 2003. Seattle, Washington.
- **On Negotiating Automatic Device Configuration in Smart Environments,** PerWare 04 Workshop, March 14, 2004. Orlando, FL.
- **Examining the Use of Surveys in Measuring Privacy in Ubiquitous Computing.** Workshop in Appropriate Methodology for Empirical Studies of Privacy, 2005, (INTERACT 05), September 12, 2005. Rome Italy
- **Improving Cell Phone Awareness by Using Calendar Information.** INTERACT 2005, September 17, 2005. Rome, Italy.

- **Context-aware Telephony and Its Users: Methods to Improve the Accuracy of Mobile Device Interruptions.** Invited Speaker for Motorola Company, November 21, 2005.

HONORS/AWARDS

- Student representative for the Graduate Education Committee, Department of Computer Science, Indiana University. 2004.
- Student Recognition Award granted by Indiana University Information Technology Services (UITS) for developing “Locate Me” system. 2003
- Volunteer award granted by Office of International Services, Indiana University, for helping incoming international students discover the university resources. 2001.
- Undergraduate Study Scholarship granted by Birzeit University, 1996, 97, 98.
- Excellent Academic Achievement Award granted by the College of Science, Birzeit University, Palestine, 1995, 1996, 1997, 1998.
- Highest GPA of the Regional High School Graduation Exam, 1994.