

Context-aware configuration: A study on improving cell phone awareness

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Abstract. As the number of mobile devices we carry grows, the job of managing those devices throughout the day becomes cumbersome. This is especially true for cell phones. Despite the many benefits they provide, cell phones create problems that arise from a mismatch between the user's context and the cell phone's behavior. In large part, the mismatch occurs because owners do not remember to frequently update their cell phone configuration according to the current context. It is desirable for mobile devices to automatically configure themselves based on the context of the environment and user preferences.

Given the personal attachment between people and their mobile devices such as cell phones, context-aware automatic configuration may not be the preferred solution for users. We have conducted an in situ experiment to examine the feasibility, effectiveness and people's reactions to such a solution. Our results show that people prefer automatic configuration over configuring their devices by hand, and they are willing to adopt it in real life. The results also suggest that a hybrid, passive-active, context-aware configuration approach is preferred over a purely passive or active one.

1 Introduction

Cell phones are currently the most ubiquitous communication device the world over [1]. The mobile nature of cell phones is changing the way people have traditionally mapped activities to places [2]. Places usually dictate the structure of the activities that take place within, but cell phones are, to a large extent, loosening or dissolving that relationship. Wellman has described this as a shift from Place-to-Place communication to Person-to-Person communication [3]. This new social order has created both opportunities and problems for mobile phone owners and for society in general.

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 [4]. However, most people already consider cell phone use in public places to be annoying [5-7]. Wei and Leung [8] 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 [9] 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 [10]. 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 [11, 12].

In addition to annoying surrounding people, inappropriate calls can cause inconvenience, disruption and embarrassment for the owner. Such calls can also lead to an increased level of stress and errors, or even put the owner in a dangerous situation, as in the case of receiving calls while driving [13, 14]. The effect of interruptions has been shown to be disruptive to task performance even when the interruption is ignored [15]. 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?

Most of the problems mentioned above can be reduced or eliminated by reducing the mismatch between the cell phone state and the context of the owner and the surrounding space. In other words, it is important to make cell phones more aware of their context and surroundings.

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 conducted an experimental study to examine the viability of such a solution. We report the findings of our study examining people’s reactions to cell phones that are more aware and can change their configuration automatically.

Section 2 examines the existing solutions to this problem and describes how they fail. We briefly describe a preliminary study we performed on workday context in Section 3, and give the details of our in-situ study in Section 4. Section 5 goes over our results, including the accuracy of the context input we used, the consistency of the mappings between context and configuration in our user population, and overall user feedback. We conclude in Section 6.

2 Existing Solutions

Many solutions have been proposed to address the social disturbance caused by cell phone interruptions. We categorize these solutions as follows:

2.1 Human Intervention

One proposed solution is to have the government and policy makers formulate regulations concerning cell phone use in public places [8]. Another one is by educating the

public about cell phone use etiquette. This may reduce the problem but will not likely resolve it since cell phone interruptions often occur simply because the owner has forgotten to switch his cell phone to the correct configuration. Another proposed solution is to provide callers with contextual information about the receiver to help them make more educated decisions about the appropriateness of the call before making it [16-18]. The contextual information can be entered explicitly by the phone owner or automatically by other means such as sensors. This type of solution, however, leaves many questions unanswered:

- What type of information should the receiver publish?
- How often should information be published/updated?
- Will people adopt a manual solutions that requires extra effort and time?
- Would context information improve the match between the caller's and receiver's expectations?
- In terms of privacy, will receiver's be willing to publish information, and to whom?

We believe the caller-based approach is somewhat orthogonal to our work, in that the context information could be published automatically. However, there are so many privacy issues involved with publishing one's context that it could interfere with our test results, so we decided not to pursue this approach at this time.

Another proposed solution provides cell phone owners with more configuration options and thus more control over their devices. Quiet Calls is a system that uses pre-recorded messages to carry on a conversation discreetly without the need to talk [19]. Additionally, Calls.calm uses web pages to provide information about the receiver's context and enables the caller and the receiver to interact to determine whether or not to continue with the call [16]. Such a system enables the recipient to determine the context to send to the caller in real-time. This kind of solution may decrease the level of the interruption for people around the receiver, but does not eliminate it for the receiver, as she is still expected to receive the call and act upon it. Additionally, it is expected that the caller will respond appropriately to the receiver's preferences.

2.2 Automatic Intervention

It is clear that the solutions cited above solve part of the problem. One main drawback is the need for the receiver to frequently update his published information to reflect the current context. This overhead has been stated as one of the main drawbacks in most collaborative systems [20]. The other main drawback of publishing one's context or information is the privacy violation. As a result, most systems have decreased the details of published personal information to overcome the privacy concerns, but this has not allowed callers sufficient information to make accurate judgments. We propose instead to empower cell phones with more capabilities and options so that they are more autonomous and flexible to adapt their state (i.e. on, off, loud, vibrate, quiet) dynamically according to the owner's context. This, together with having more informed callers, can provide a better solution to the problem.

The awareness of cell phones can be greatly improved by augmenting them with the capabilities of gathering information about the owner (receiver) and inferring the appropriate state or behavior. Contextual information can be gathered by sensors or from other cues such as the calendar book. As part of the SenSay project [21] researchers at CMU have augmented the cell phone with many different sensors to capture the context of the owner. The cell phone's behavior is changed dynamically depending on the owner's context. Schmidt et. al. introduced an adaptive cell phone that changes its profile automatically based on the recognized context [22]. The phone chooses to ring, vibrate, adjust the ring volume, or keep silent depending on whether or not the phone is on a table, in a suitcase, outdoors, or in hand.

However, given the personal connections people feel toward their cell phones, more aware and autonomous cell phones may not be a welcomed idea for many people. Moreover, people's sense of control decreases as a cell phone's autonomous capabilities increases [23]. This study is set to examine the validity of such a solution. We have designed an experiment that allows us to measure people's reaction to having more autonomous cell phones.

3 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. [24]. 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.

4 Experiment

The main goal of the experiment was to assess the likely value of the automatic device configuration approach. We examined whether automatic cell phone configuration, based on the user's context, improves the overall user experience. We also investigated the approach for 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.

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

Table 1. List of the most common activities

4.1 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 [25] predicted that the compact nature of the campus environment will put it at the forefront of ubiquitous computing. The Active Campus project [26], 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 [27] 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.

4.2 Method

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 1). 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.

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.

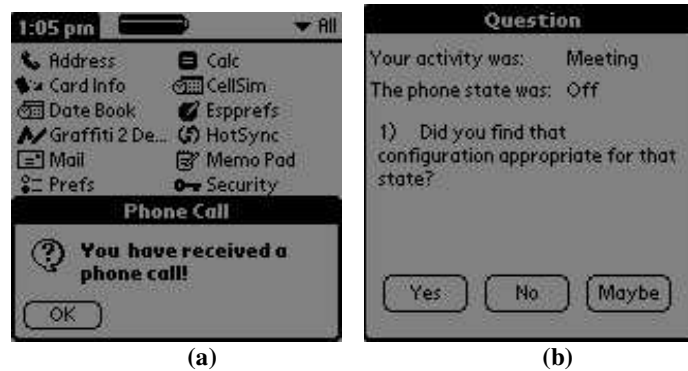


Fig. 1. Figure (a) shows the notification message that appears once a call is received. Figure (b) shows the question asked once the user presses the “Ok” button on figure (a).

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 pro-

vided us with more control over the study, which enabled us to examine only the factor of interest while eliminating others such as caller identity.

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.

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.

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.



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

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 2. 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.

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.

5 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.

5.1 Evaluating Context-aware cell phone configuration

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 not having the exact configuration, as in the case where “Maybe” was selected to answer the question in Figure 1.b. 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. Neither intentionally or unintentionally missed calls were directly interpreted as having an inappropriate configuration, and 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 it is worse to get embarrassed from having the phone ring in the middle of a meeting than to miss a phone a 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’.

During the end of the study interview, participants were 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 as very useful while the rest rated it as useful. These results are particularly interesting given the fact that 9%-13% of the calls were evaluated as having inappropriate or inexact configuration and that these were received in a real-life environment that 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 feeling of the participant that could not be obtained otherwise.

This shows that the positive value of the context-aware configuration is strong to the extent that people are willing to accept a certain level of inaccuracy in return. All participants were willing to use such an application in real life if their cell phones were equipped with it. All participants expressed a liking for the fact that configuration changed automatically depending on the context. Comments included:

I did not have to worry about forgetting to set the ringer to the appropriate setting when entering a certain situation.

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.

When the participants were asked about whether inaccuracies in the system frustrated them, all of them answered negatively. However, two of the participants said it was inconvenient at some times.

5.2 Consistency of Mapping Activities to Configurations

One important 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 a context-aware configuration to be determined automatically by the cell phone 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. Such consistency has ramifications in the broader field of context-awareness in the sense of whether a given context provides data reliable enough to generate the same behavior every time it occurs.

Our results showed that, for each individual, mapping from activities to configurations is consistent, i.e. each activity very frequently mapped to the same configuration. The results showed that 89% of activities have a predictable desired configuration for an individual. This consistency, however, did not hold across participants. This means that for the same activity people map configurations differently. This could be caused by the fact that activities are not the only factors that dictate the appropriateness of public interruption and other personal factors come to play. As a consequence, mapping can not be generalized across participants, and personalization is needed to reach the best daily configurations for each individual. A more detailed discussion can be found in [28].

5.3 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

[29]. 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 [23]. 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 triggered 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 [23].

5.4 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 [30].

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 [31].

6 Conclusion

We have presented a study to evaluate the feasibility and the effectiveness of context-aware configuration for cell phones. We first introduced the problems caused by the wide-spread usage of cell phones and then the different types of solutions that have been proposed to solve them. The main goal of all the solutions is to create more socially acceptable cell phones by decreasing their disruption, embarrassment, and annoyance for both the user and the surrounding environment. We tested for context-aware configuration as a viable solution for the problem. Though different projects [21] have explored the idea of context-aware configuration for cell phones, we are the first to study its viability and effectiveness from the user's perspective. Toward that, we conducted an experiment to examine the solution in a natural university setting.

Our results suggest that context-aware configuration provide a very desirable solution that is found to be preferred over the personalization approach. 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.

Moreover, our results suggest that a hybrid approach of both active and passive context-aware configuration is preferred over either individual solution, as a hybrid approach appears to provide the right balance of convenience and control. This was the case for our application, though further examination is needed to make more conclusive results.

The fact that the study uses 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.

A recommended approach to future work is to integrate the approach of empowering cell phones to be more context-aware with the approach of empowering the caller to be aware of the receiver's context. We believe a promising solution is the one that offers the right balance between the two approaches. This is due to the fact that interruption appropriateness can only be determined in the context of both the initiator and the receiver [32]. For example even if the receiver is in a meeting, he still might be awaiting a call from somebody regarding updates related to the meeting. Interruption in such situations is appropriate even if it may seem otherwise from an outsider's perspective. It is also important, and it is in our plan, to extend our results to non-college settings and include weekend days in future studies.

7 References

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