

Is Context-Aware Computing Taking Control away from the User? Three Levels of Interactivity Examined

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Abstract. Context-aware computing promises a smooth interaction between humans and technology but few studies have been conducted with regards to how autonomously an application should perform. After defining three levels of interactivity between a mobile computing device and its user: personalization, passive context-awareness and active context-awareness, we test which approach will limit users' perceived sense of control. We also investigate users' preferences for the three approaches. We conducted an experimental case study, using mobile phone applications to exemplify the three levels of interactivity. Our study shows that users feel less in control when using either passive or active context-aware applications than when personalizing their own applications. Despite this we also find that context-aware applications are preferred over the personalization oriented ones. We conclude that people are willing to give up partial control if the reward in usefulness is great enough.

1 Introduction

While context-aware computing aims to facilitate a smooth interaction between humans and technology, few studies of how users perceive context-aware interaction have been performed. Most research focuses on the development of technologies for context-awareness as well as the design of context-aware applications. Example applications are numerous and the level of interactivity within these varies greatly, ranging from letting the user manually define parameters on how an application should behave, to automatically providing the user with services and information that the developer finds relevant. Here we present a study whose goal is to examine users' sense of control and their preference to interactivity level. Because mobile telephony is the most widely employed ubiquitous computing device, we are using this as an example of context-aware computing.

We define context-aware computing as 'an application's ability to detect and react to environment variables' [1]. Here we define three levels of interactivity for

context-aware applications: personalization, passive context-awareness and active context-awareness. *Personalization* is where applications let the user specify his own settings for how the application should behave in a given situation; *passive context-awareness* presents updated context or sensor information to the user but lets the user decide how to change the application behavior, where *active context-awareness* autonomously changes the application behavior according to the sensed information [3]. Drawing on the three types of interaction, it is our belief that users feel a loss of control when using passive or active context-aware applications but not when they personalize their mobile device, and prefer personalization despite the higher interaction cost.

We present a case study that analyzes users' attitudes towards each of the three levels of interactivity. Focusing on early stage analysis, we evaluate the services before actually implementing them; with this, we hope to gain insight into users' reactions and use-level as early in the development process as possible. We assign each participant with a specific level of interactivity and trace their user habits for five consecutive days, in order to understand their potential use habits and preferences. It is our goal to obtain results that will guide the development of future context-aware services in having an appropriate level of interactivity.

Our study found that users' sense of control decreases when autonomy of the service increases, as suggested by previous research [4]. We believed that personalization would be preferred and would be more accepted than both passive and active context-awareness, however, the results of our study do not support this. Instead we find that people prefer context-aware applications over personalization oriented ones.

In this paper we first discuss the three levels of interactivity and review relevant literature. Second we present the method used in our case study. Third, we report the results and fourth we provide a discussion of the findings. Finally, we conclude and provide suggestions for further research.

2 Three Levels of Interactivity

In this section we review related work and although we define three levels of interactivity, we review active and passive context-awareness levels together. They are closely related and, unlike personalization, are both based on sensor information.

2.1 Personalization

Personalization, sometimes also referred to as customization and tailoring, is a common feature of computing applications. Personalization of desktop applications is a widely researched area [7,8,10]. Researchers argue that the diversity and dynamics of applications call for an increased level of tailoring in software, and that this emphasis on customized functionality will add to the the user experience and smoothness of interaction [10]. Limiting the scope to mobile computing,

it is exemplified by the settings in a mobile phone, defining the user's preference for background picture and ringing profiles. One interesting finding is that, even though many desktop applications, as well as larger websites, offer personal tailoring, the majority of users use the default setting or change a small subset of the possible features [6].

No studies focus directly on personalization within mobile computing. Some studies approach the subject with respect to users' personal attachment to their mobile phone [11], but no study has looked into users' preferences or perception of tailoring their handheld device. However, because mobile devices are inherently personal, it is likely that these users, in particular, will enjoy the advantages since the tailoring will not affect other users.

2.2 Active and Passive Context-Awareness

Since the notion of context-aware computing was introduced by Schilit et al. in 1994 [9], several definitions have been offered, often describing different levels of interactivity. Cheverst et al. for example, investigate whether information should be pushed towards the user or the user should be left to pull the information on his own in context-aware systems [4], whereas other researchers consider only push based applications to be context-aware [5]. In this study we draw on Chen and Kotz's definition of active and passive context-awareness [3]. Active context-awareness describes applications that, on the basis of sensor data, change their content autonomously, where passive context-aware applications merely present the updated context to the user and let the user specify how the application should change, if at all. A simple example of an active context-aware application is the mobile phone that changes its time automatically when the phone enters a new time zone. In the corresponding passive context-aware application, the mobile phone prompts the user with information about the time zone change and lets the user choose whether the time should be updated or not.

While many researchers differentiate between the levels of interactivity, they rarely agree on where to separate them. Cheverst et al.'s 'push' approach is described in the same terms as our definition of passive context-awareness, while their pull approach falls in a category between personalization and passive context-awareness [4]. Another distinction is provided by Brown and Jones, who define the levels of 'interactive' and 'proactive' [2]. Interactive applications cover our definitions of both personalization and passive context-awareness where proactive is defined almost identically to active context-awareness. None of this research however, considers the difference in users' perception of the different levels. The three levels of interactivity presented here serve as the basis for our case study, which we will describe in the next section.

3 Case Study

Our study is conducted as an experimental case study comparing users' responses towards applications, representing our three levels of interactivity. It is based on a five-day fill-in diary, which are supplemented with qualitative interviews with

Table 1. The three levels of services presented to participants.

Service	Personalization	Passive Context-Awareness	Active Context-Awareness
A: Private ringing profiles	Different ringing profiles that are set manually	The phone prompts the user to adjust the profile when sensing it is in a meeting or class	The phone automatically changes profile when sensing the user is at a meeting or in class
B: Public ringing profiles	Different ringing profiles that are set manually	The phone prompts the user to adjust the profile when sensing it is in a movie theater or at a restaurant	The phone automatically changes profile when sensing the user is at a movie theater or at a restaurant
C: Lunch service	Manual search for appropriate lunch place	Single alert around noon for lunch place according to users' preferences	Alerts the user when passing by a lunch place of relevance and suggests places at noon
D: Class slides	Manual search to see if class slides are available online	If signed up, the phone alerts user of available slides for class	Automatic alert every time the teacher updates class slide website
E: Location tracking	Manually location tracking of predefined friends	Locations tracking of friends and setting to alert when they are within a certain range	Location detection of friends that alerts when they are within 300 feet of user
F: Activity tracking	Display of potential call-receiver's social situation (e.g. meeting, home, out)	In a new context, the phone prompts the user to display the user's situation to possible callers	Automatic switch to display of social situation when entering a new context

a subset of the participants. By studying participants' reactions and attitudes towards context-aware applications, it is our goal to obtain results that will guide the development of future context-aware services in having an appropriate level of interactivity.

3.1 Research Method

The study is designed as a between-subjects study, where each participant is assigned to a group within one of the three levels of interactivity. Because it was

Table 2. General participant demographics.

N=23	Personalization	Passive Context-Awareness	Active Context-Awareness
N	8	8	7
Average age	23.7	22.9	25
Average mobile phone ownership	2.2 years	2.6 years	2.7 years
Average user level (a scale from 1–6)	3.1	3.8	3.4

not possible to implement all the services within each interaction level, we introduced participants to new services that they were to ‘pretend’ were available on their mobile phones. The applications are described in table 1. At the end of each day (for 5 days), the 23 participants filled in a journal of how many times they would have used the services and to what degree they thought the services would have been useful. The services’ usefulness and level of intrusion were evaluated on a scale from 1-5 and the journal form left room for additional comments. To supplement the journal, qualitative interviews were conducted with 6 of the participants to elaborate on their reactions to the interactive services and their overall perception of context-awareness within mobile computing.

Six different services were proposed and each was described in terms of personalization, passive context-awareness as well as active context-awareness. The participants were presented with services that belonged to one level of interactivity and not informed that there were different groups. The journals were filled out over the same 5-day period.

3.2 Participants

23 participants were selected using the criteria that they should have a mobile phone and use it frequently, at least three times a day on average. Both students and non-students were recruited with an age range from 19 to 35 and average age being 23.7. 10 out of the 23 were students and their mobile phone ownership ranged between 1/2 and 6 years, with an average of 2.5 years. The participants were randomly assigned to the groups, resulting in a slight difference in average age and use level among the groups. However, the values are fairly close and this difference is therefore not considered in our analysis; see details of each group in table 2. We now present the findings of the case study and conclude on the participants’ sense of control and preferences.

4 Perception of Control

Our hypothesis that people felt less in control when using context-aware services, than when personalizing applications, was found to be true. Users' perception of control was measured in three ways. First, the participants were asked directly if they felt a loss of control over their mobile phone when 'using' the services; second each of the services were evaluated according to this perception at the end of each day, and finally the interviews were analyzed.

From the direct questions we found a correlation between the given level of interactivity and the participants perception of control of -0.26, meaning that the more autonomous the service is, the less users felt in control. This is not statistically significant at the .025 level. However, when considering the two levels of context-awareness as one category, the correlation is -0.31, which is statistically significant at the level of .025. When evaluating each of the services in relation to sense of control, the participants' results indicate that the personalization group felt more in control than both other groups of context-awareness for services A, B and D, but the opposite was true for service E. The latter result is perhaps due to the rather controversial nature of tracking the user's location; it does not matter if display of location information can be controlled, since for some people it is an uncomfortable feature. The last two services did not show any difference in perception of control. Finally the interviews indicated that most of the participants feel they have control of their mobile phone with their currently available personalization-based applications, but several of them worried about this control when they were introduced to context-aware features.

5 Preference for Active and Passive Context-Awareness

We found that preference for interactivity level actually contradicted our initial hypothesis. Participants preferred active context-awareness and passive context-awareness over personalization.

The preference for different levels of interactivity was measured in two ways. First each of the services was assessed according to how many times the participant would have used it on a specific day, and, second, the participants were asked to rate the services for their usefulness.

We found an unexpected statistically significant correlation between the levels of interactivity and use for two of the services (B with a correlation of 0.29 and E with a correlation of 0.31, both significant at the .025 level), meaning that the higher level of interaction resulted in higher level of preference. Personalization-based services were used the least, whereas active context-aware services were used much more. Service F on the other hand had a statistically significant correlation of -0.32 (significant at the .025 level); the most popular version of this service was the personalization oriented and the least preferred was the active context-aware one. The rest of the services did not show any correlation between preference for interactivity level at all.

An interesting result is that preference for interaction level did not vary across individuals, but varied across service. Hence, some services were very popular

(A, B, E), where other services were regarded as fairly irrelevant (service D¹ and F), meaning that they were used rarely, and overall were too intrusive (service C). As a general finding the active context-awareness approach was preferred. Even when taking into account the fact that some participants are high level users, defined as 7 calls a day or more, and some are low level users, defined as 4 calls a day or less, the finding that active context-awareness is slightly preferred is still consistent.

Although some of the results were not what we expected, they provide interesting insight into users' perception of control and preference for interactivity levels, which we will elaborate on in the discussion.

6 Discussion

The finding that participants felt they had less control in the context-aware groups but still preferred the context-aware approaches, might at first seem contradictory. However, it should be considered that owning a mobile phone in itself constitutes some lack of control since the user can be reached anywhere at anytime; the user might have less control, but are aware that this is the cost of becoming more interactive and in achieving a smoother everyday experience.

Although our study results provide support for highly interactive applications for mobile computing, by indicating that people would use them to a fairly high degree, the applications should still be developed with caution. The incurred cost due to loss of control can result in users turning off a service. While the participants initially liked many of the active context-aware services, they might become frustrated by their perceived lack of control and eventually turn the service off.

Lastly it should be noted that even though participants were 'equipped' with a highly interactive mobile phone for the duration of the study, imaginary approaches like this are not always sufficient to tell if users would actually behave as they self-reported. One commonly observed factor is that even though potential users may disregard a technology a priori, they may adopt it anyway for various reasons. Examples include text messages over the phone where reasons to adopt this communication form can be peer pressure or change of attitude due to a realization of the value it provides.

7 Conclusions and Further Work

In this study, we have examined peoples' sense of control and preference for three levels of interactivity within mobile computing. The study shows that participants feel a lack of control when using the more autonomous interactivity approaches but that they still prefer active and passive context-aware features over personalization oriented applications in most cases. Our conclusion is that

¹ The results from the class slide service were adjusted to account for the participants who are not students.

users are willing to accept a large degree of autonomy from applications as long as the application's usefulness is greater than the cost of limited control.

Because our study is a theoretical evaluation of three levels of interactivity, the logical next step is to develop actual context-aware and personalization oriented services. They should be user tested for the same parameters as this study and compared to how people rated the virtual services. To complement our diary and interviews, observational methods should be used to more accurately determine how users handle highly interactive applications. Finally, it should be noted that for rigor, future studies should account for participants' mobile phone experience and use level.

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