Ubiquitous Computing: By the People, For the People

Ali Ndiwalana, C. M. Chewar, Jacob Somervell, D. Scott McCrickard
Department of Computer Science
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0106 USA
{andiwala, cchewar, jsomerve, mccricks}@cs.vt.edu

ABSTRACT
One of the challenges in building and evaluating ubiquitous computing systems emanates from the fact that they generally have been built to showcase technological innovation without considering how to foretell whether and how people will eventually accept them in their lives. In this study, participants are introduced to the notion of ubiquitous computing via a scenario-centric presentation including basic everyday objects imbued with some computational power to convey information. Through a detailed survey, participants provide feedback relating to their impressions, rating the performance of each interface on a number of metrics and making comparisons between the ubiquitous and desktop interfaces. We inspire them to think of new ways to use existing ubiquitous interfaces to support their current and possible information needs, as well as better interfaces that can convey this information.

Keywords
Invisible computing, user preferences, attitude survey

INTRODUCTION
With the common proliferation of smaller and low bandwidth computing devices coupled with advances in wireless communications, Weiser's vision [4] of calm and ubiquitous computing (ubicomp) is gradually being realized. However, while researchers push the technology envelope with novel systems not ready for the general public, prototypes often stop in the research lab [1]. Similarly, ubiquitous systems are usually not built to address specific human needs, but are touted for providing more ephemeral benefits such as peripheral awareness. These factors make it difficult to understand the motivations behind their use as well as presence in people's lives [2]. This compounds the challenges of evaluating systems in their proper context and understanding their impact [1]—a prerequisite for progress in any research area. Our survey is an initial step in a requirements analysis process that probes issues impacting the use and acceptance of ubicomp systems in people's everyday lives.

THE STUDY
In conducting this study, we chose to focus on a population familiar with emerging technology that will more likely be at the forefront of ubicomp early adoption. Participants are 50 undergraduate computer science students who received class credit. There are 5 females and 45 males, ranging in age from 19 to 31, expressing familiarity with computers, and owning a range of mobile computing devices from laptops to miniature MP3 players.

The study's methodology introduced participants to the notion of ubiquitous computing with the help of basic everyday objects imbued with the ability to convey information. They are X10 devices controlled by the Real World Interface (RWI) toolkit [3]; including the *infoLAMP*, the *dataFAN* and a vibrating seat—*hapticCHAIR*. These interfaces are compared with two desktop interfaces that display the same information: a simple number display *counter* and a progress *indicator* bar.

During an experimental session, participants are introduced to all of the interfaces. Information is conveyed to the participants within the context of a scenario, to help situate the interaction. The scenarios are selected to reflect the variety of information needs, including monitoring of three different types of information: 1) *outdoor temperature*, 2) *online buddy status* for instant messaging, and 3) *progress in performing a timed task*.

After each scenario demonstration, participants provide detailed feedback via a questionnaire, rating the performance of each interface and comparing them on a number of metrics; this is repeated for all three scenarios. They conclude the session with a general portion that asks for their thoughts on a variety of social aspects pertinent to ubicomp [1] and inspires them to think of new ways to use these interfaces. We were specifically interested to know how they felt their current and possible information needs should be supported, as well as better interface designs that would convey this information.

Our hypotheses for the study may seem to be obvious statements consistent with mainstream HCI thinking, however we feel that they are important to verify for the ubiquitous design paradigm:

1: *People prefer desktop over ubiquitous interfaces.*

2: *People will start using ubiquitous interfaces if they perceive them as intuitive and trustworthy.*

3: *The effort required to understand information conveyed by the ubiquitous interfaces inhibits willingness to use.*

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RESULTS

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

To probe the second hypothesis, we filtered our data to include only the 27 participants who indicated "sufficient trust to be able to use" ubicomp systems. Of these, we filtered further to identify cases where participants agreed that a ubicomp device was "easy to use with no prior explanation" (intuitiveness). Qualifying sample sizes and the percentage of these cases where the participant was willing to start using that particular device is shown in Table 1. Had hypothesis 2 held, the percentages in the table would approach 100%. Surprisingly, only the infoLAMP in scenario 2 showed a (weak) correlation between trust and intuitiveness as a predictor for willingness to adopt.

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

filtered sample size (% willing to adopt)

Table 1. *Number of participants indicating sufficient trust to use each device in each scenario. In parentheses is the percent of those participants who indicated a willingness to adopt the device.*

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

DISCUSSION

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

Although hypotheses 2 and 3 seem to be obvious extensions of HCI thought, it is most interesting that they do not hold true for predicting acceptance of ubicomp systems. While this has been noted by other researchers [1, 2], this empirically validates the notion that traditional usability metrics are insufficient for understanding user acceptance.

CONCLUSION AND FUTURE WORK

The key findings of this study are summarized as follows:

- Ubicomp systems can be preferred over desktop interfaces in certain situations.
- Predicting acceptance of ubicomp systems transcends usage characteristics.

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

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