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ABSTRACT

In real world settings, mobile users are continuously bombarded by information – both solicited and unsolicited. While mobile computing increases productivity, this advantage comes with shortcomings, such as unwanted messages, distracting sounds, and cluttered menus. This research deals with notification cues that eliminate disorder and assist the user in quickly and efficiently understanding the importance of received data. This study tested the use and effectiveness of a set of user-customized visual notification cues in real-world settings. Each cue, a set of three colored lights, was sent to a mobile device which first vibrated and then displayed the cue. Different combinations of lights were mapped to different messages. The results of this work are promising. Participants made common assumptions, giving basis to possible notification standardization that would increase cognition. On the other hand, cue personalization aided learning and increased acceptance.

Keywords

Visual notification cues, tactile, mobile device testing, customization, personalization, mixed-modal.

INTRODUCTION

People often rely on technology to alert them to situations that need their attention, but many times the ways in which devices notify people are not effective. Ringing phones and car alarms all provide cues for people to act upon, regardless of the urgency of the message they carry. Cell phones can be set to ring loudly to be heard in noisy environments, but ring volume does not automatically adjust itself if the phone changes locations. Car alarms can sound when another vehicle drives by, leading to false alarms and the potential for even the car's owner to ignore the alarm.

In addition, the boundaries of mobile device use continue to stretch beyond the limits that developers first envisioned. Mobile devices are no longer the tools of high-level executives on business travel, but are available to most everyone and are used in restaurants, theaters, and even restrooms. Given this, previous notification designs may no longer be viable or appropriate for the contexts in which mobile devices are used. Auditory cues, such as a mobile phone ring, might be effective while the user is walking down a sidewalk overflowing with people, but can shatter the calm in a library. In this case, the cue can have an unintended consequence depending on the context of its execution. Notification cues need to take into account not only the possible situations in which they may be used, but also any potential social impact. The design of mobile notification cues is therefore a complex problem, requiring the selection of appropriate delivery channels based on continuously changing contexts and dynamic information needs [4].

This paper presents research-in-progress that is testing the use of pixel-based (i.e., using colored lights) notification cues in a realistic setting. The notification is also multi-level because an initial tactile cue (vibration) conveys the availability of an additional visual cue conveying more detailed information. The mapping of information to cues was first customized by each user, and then the cues were periodically sent to a device that the user carried as they went about their normal activities.

BACKGROUND

Notification cues are auditory, tactile, or visual in nature, or some combination of these modalities (mixed-modal). Mobile phones might ring or vibrate to signal an incoming call, and beep for an incoming text message. In general, auditory cues are more public and intrusive in nature while tactile and visual cues may be more subtle and private. Notification cues are an integral part of information dissemination in the mobile environment. While conveying relatively little detail, they provide meta-information, or information about information, to their intended recipients. This meta-information may be as simple as a signal indicating an incoming cell phone call, or as complex as a signal providing the priority, sender, and summary of a new email message. On ultra-small mobile devices (e.g., watches or jewelry), it may be feasible to convey certain information only in the form of notification cues. Notification cues in many cases are the precursors to fuller information retrieval on other mobile devices. For example, a cue may indicate that there is an important email message waiting. A user may then decide to access the email message on the same (or different) device.

Previous work by the authors has investigated the design of visual notification cues. Tarasewich et al. [3] conducted a study that measured the performance/size tradeoff of visual displays that ranged in size from two lights to nine lights, and used display characteristics, such as color and blinking, in various combinations. Results showed a reliable tradeoff between performance (response time and accuracy) and display size (number of lights). However, even the full set of twenty-seven messages used in the study could be conveyed with high recognition accuracy using only three lights by mapping the messages into color and position.

A follow-up study by Campbell and Tarasewich [1] measured user learning and comprehension of increasing amounts of information on a three light visual display. Each light displayed one of three colors at one of two brightness levels. Users were required to learn five sets of messages of increasing information and complexity using the small display. Results showed that micro-displays can transmit detailed, information-rich messages up to 6.75 bits in length with minimal training.

In addition to continuing the work from these previous studies, this current research expands on work done by Hansson and Ljungstrand [2], who created a “reminder bracelet” which notified a user of upcoming events (e.g., meetings). The bracelet consisted of three red LEDs that were triggered progressively as an event drew closer. However, testing showed that users found themselves frequently checking the bracelet for lit LEDs.

Our ultimate research goal is to design notification cues that allow fast, efficient, and unobtrusive information communication. The continuing trend in technology miniaturization requires exploration of optimal data delivery and display methods for small devices, taking into account factors such as usability, ease of learning, privacy, and security.

METHODOLOGY

A program was written in C# to send a notification cue, consisting of three simulated lights (colored circles of red, yellow, or green), to an HP iPaq Pocket PC handheld device over an 802.11 wireless network. When the device received a cue, it vibrated for four seconds, and then displayed the lights. The time the cue was sent to the device was automatically recorded.

The number of different cues that could be sent to the handheld device using the three colors of each light was 27 (3x3x3). Before starting the experiment, each subject was allowed to customize the meanings of the cues by selecting eight to ten color patterns and a message for each one. Subjects were encouraged to select at least two “time-based” cues (e.g., my class starts in ten minutes). Otherwise, they could choose any messages that they desired. Examples of messages chosen by subjects were “new voicemail” and “you have a meeting with a professor”. The messages were programmed into the handheld device by the authors before proceeding further with the experiment.

When a cue was received, it was acknowledged by tapping a button on the handheld. Next, a form was presented asking for the identification of the cue (from a pull-down list of the predefined messages, plus options for “no meaning” and “I do not know”), the user’s current location (from a list), the user’s current activity, and cue usefulness (from radio buttons on a 7-point Likert scale). This information, along with the time that the cue was received and acknowledged, was recorded.

The testing was held in a campus building with full wireless coverage. Subjects participated during a 3-hour interval in which they had continuous activities in the building (e.g., classes, meetings, or laboratory work). They chose their notifications, and were given training on how the system worked and how to respond to a cue. Subjects were then given time to memorize the notification cues they had selected (they were not allowed to write them down). Once subjects felt comfortable with their knowledge of the cues and the system, they were given the handheld and allowed to go about their activities for the rest of the time period.

Based on the notifications that the subject had selected, cues were then periodically sent to the handheld device by the authors. To test comprehension, cues from the list were mixed with nonsense cues that had no assigned meaning. At the end of the testing period, subjects were asked about their experience with the device.

RESULTS

The preliminary results reported here are based on the first five subjects tested, all of whom were graduate student volunteers. The students ranged in age from 21 to 26 years old. Four subjects were male, and one was female. None of the subjects reported themselves as being colorblind. Four out the five subjects carried a cell phone and used it at least several times a week. One subject's testing period ended unexpectedly early (after two messages) due to a power failure of the PDA.

Subjects chose eight or nine notification messages each. Of all the color patterns available, each subject chose to use the three same-color patterns (e.g., red, red, red) for three of their messages. Of the remaining color patterns, all subjects used those that had one repeating color (e.g., red, red, green). Three subjects chose patterns which used all three colors at once, but only for one message. Subjects' activities while participating in the experiment included attending class, reading books, browsing the Web, working in a computer lab, eating lunch, and studying in a student lounge.

Subject	Sent	Correct*	Incorrect*
1	8	(7) GGG, RRR, GYG, **GRR**, **GYY**, RYY, RGG,	(1) YRG
2	11	(8) GGG, GRG, RRR, RGG, YGG, RRR, YYY, GGG	(3) **RGY**, RYY, RYR,
3**	2	(2) GGY, RRR	(0)
4	9	(4) RGG, RRR, GRG, GGG	(5) YYG#, **YYR**, **RYR**, YYY, YRR
5	8	(3) YYY, RRR, GGG	(5) YYG, **YGR**, **YRR**, GGY, **RYG**
*Totals in parentheses. **Power failure of PDA early in testing. #Accidentally hit submit before selecting answer. Nonsense combinations in **bold.**			

Table 1. Cue Acknowledgements

Table 1 shows the cues that were sent to each subject, and whether the cue was identified correctly. The three-letter combinations represent the cue that was sent (R=red, Y=yellow, G=green). Nonsense cues are in bold.

All of the messages received on the handheld device were acknowledged. Of the 38 total messages sent, 24 were identified correctly. In general, subjects commented that he notification system was potentially useful, although it was difficult initially to assign messages to color combinations and learn the messages. One subject commented that some partial standardization might be useful. For example, the first light color might always mean something at a high level, and the other two lights could be customized.

Another subject commented that they selected colors for messages that matched those used on a Macintosh calendar system at home, although the color blue used on that system was not available in our experiment. The subject used three same color combinations (e.g., red, red, red) for reminders deemed most important. The system became more difficult to use, however, when more combinations of colors were used, and thus the ordering of the colors become important. The subject made a comment that such a notification system was potentially useful, and might even work on a phone to tell people apart.

DISCUSSION

This experiment demonstrated that some events users wished to be notified about can be categorized based on personal choices. For instance, continuous color patterns (i.e., RRR, YYY, GGG) were set to common events. Message grouping was also prevalent during testing. For example, one subject used "Green, Green, Green" as a notification to check voice mail, and "Green, Green, Yellow" as a notification to check email. Subjects were not told about the potential benefits of groupings such as these, but they seemed to aid comprehension of received notifications.

The use of mixed-modal cues seemed to address awareness concerns found in [2], since all of the cues were acknowledged. In addition, the ability to customize the cues was well received. Although this experiment did not determine whether customization improved performance, it is believed that the ability to personalize the cues positively influenced the use of the system. Furthermore, one could also hypothesize that user comfort level and trust in the system would be higher with customized mappings than with predetermined mappings.

While the comprehension rate was relatively low overall (24/38), the overall performance seems reasonable given the experimental conditions. Of the 14 incorrect answers, six were the result of nonsense cues purposely being sent to the subjects. Increasing the length of the test would probably facilitate better recognition as the users become more familiar with the specific cues. The cues themselves would represent a more meaningful notification of events that occur in day-to-day activities, rather than the sometimes artificial or more trivial events created for a three-hour experiment.

CONCLUSION

This experiment is a first step in investigating the uses of pixel-based visual notification cues in realistic settings. Testing in more diverse locations and over longer time periods will shed even more light on their usability. What is encouraging is the positive perception of the cues, and that the use of vibration as a preliminary cue seems to solve the awareness problem encountered with the reminder bracelet in [2]. We plan to continue testing with the current device, eventually moving toward longer-term studies and larger data sets. We also plan to create and test smaller prototypes that can be worn on the body as rings or bracelets, and to incorporate context-awareness into the prototypes.

There are many practical benefits of pixel-based visual notification cues. From a technology standpoint, cues (e.g., in the form of LEDs) can be embedded almost anywhere. This allows the display of information on very small, or *ultra-mobile*, devices. In addition, transmission of such cues requires relatively little bandwidth, and their display requires minimal power. Unlike text messages or icons, pixel-based cues can be personalized such that only the user knows what they mean, even if they are publicly displayed. For example, three green lights on a person's ring could convey a message only understood by the wearer. Thus, high levels of security and privacy can be ensured with pixel-based visual notification cues. These cues also allow for language-independent communication, aiding in the quest for universal usability.

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