User Customization of Three-Pixel Displays

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Abstract

Previous research has shown that visual displays consisting of colored lights can effectively display large amounts of information in a compact footprint. This paper discusses a study-in-progress that is looking at the effects of user customization on learning and comprehension of three-light displays. Results from an initial experiment are presented, along with next steps in the study.

Keywords: Handheld Devices and Ubiquitous Computing, Visual Notification Cues, Comprehension, Customization

INTRODUCTION

This research-in-progress investigates the design and use of *pixel-based* visual notification cues, which consist of one or more individual colored lights and are used to indicate the status or availability of information. Specifically, this paper presents results of an initial experiment that tested the effects of customization on learning and comprehension of a three-light three-color cue display. Findings from this experiment are guiding additional work of a larger study.

BACKGROUND

The current study builds on our previous research on visual notification cues [3], which showed that a three-light design (compared to designs with more or fewer lights) was a good choice for conveying notifications on small devices. A follow-up study [1] measured user learning and comprehension of increasing information amounts on a three-light display. Results showed that micro-displays could convey detailed messages up to 6.75 bits in size with minimal training. Another study [2] tested a three-light cue on a wireless PDA. The cues were personalized beforehand by the device user and sent periodically as the user went about their normal activities in a building. The device also vibrated when a cue was first received. Results showed that subjects found the cues useful, and that personalization of the cues aided in the learning and acceptance process.

METHODOLOGY

We are performing a series of experiments measuring the effects of customization on learning and comprehension of linear, three-pixel cue displays. The experiments will compare the usability of customized designs (those where users choose their own mappings, cues, and/or messages) against those that are preconfigured or randomly generated.

For the experiment reported here, messages (based on the categories shown in Table 1) were mapped to three lights. Each light could show red, blue, or green, allowing 27 (3x3x3) different messages. For one experimental session, subjects worked with a predetermined mapping, where the left light indicated source (work, family, or friends), the center light type (new, reply, forwarded), and the rightmost indicated priority (high, medium, low). For example, "blue red green" indicated a new message from family with low priority. For another session, subjects assigned these mappings (i.e., messages to colored lights) as they desired. The experiment (in Java) was run on Pentium-4 Windows XP PCs with screens at 1024x768 pixels. Cues were displayed as three 20-pixel diameter circles. Status displays showed elapsed time and correct answer percentage.

Table 1. Cue categories and associated values.

Category	Possible Values
Source	work, family, friends
Type	new, reply, forwarded
Priority level	high, medium, low

Design

The design was a one-factor (i.e., mapping) repeated measures design with two levels (i.e., customized or default). The mapping presented first was balanced such that each mapping was in first and second order an equal number of times. Messages presented during the experiment were selected in random order without replacement.

Procedure

Each subject completed two task sessions that involved identifying messages given by the three-light display. One session involved default (predetermined) mappings used in a previous experiment [1], and the other user-customized mappings. At the beginning of the default mapping session, a subject was shown a list of messages, each with their three corresponding colored lights. At the beginning of the customized mapping session, subjects indicated their desired mappings using a graphical interface that listed the mappings. In both sessions, subjects could spend as much time as they wanted to learn the mappings before starting.

During the experiment, three-light cues were displayed one at a time, and subjects selected the cue's message from a list of all possible messages. The order of the messages was randomly generated each time a new cue was shown. After 20 seconds, the cues timed out and were counted as incorrect. Subjects received feedback about the correctness of the response, and moved onto another cue when ready. Subjects continued with the first session until they got 90% of their responses correct, at which time they proceeded to the next session. The percentage of correct answers was displayed after each response, but the decision on whether to proceed to the next session was not made until after the first ten answers. Thereafter, the percentage correct was calculated after every answer on a moving basis over the ten most recent responses. Subjects completing both sessions were given US$5 for their performance.

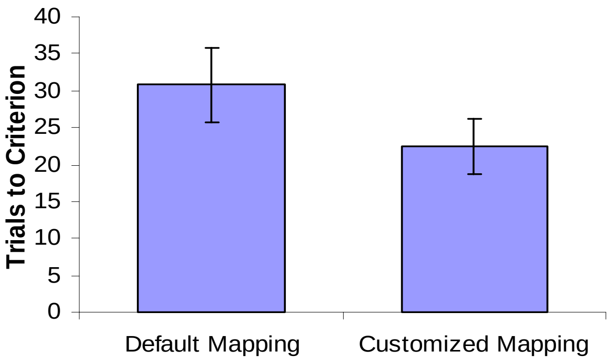

Figure 1. Number of trials to criterion for customized versus default mappings (±SE).

RESULTS

Eleven undergraduate and graduate students (nine male and two female) participated in this study. The average age was twenty-five, and no one reported being colorblind. Of the five subjects that customized mappings before experiencing the default mappings, all but one structured the mappings according to category and color (e.g., always assigned red as the color of the first light when a message concerned friends). The one subject that did not do this did not complete the trails for that session to criterion. Four of the six subjects that performed the experiment with the default mapping first used the same mapping for the customization session. The other two subjects interchanged colors for two values in the Source or Type categories.

Results were analyzed by calculating the number of trials and time to reach criterion. The number of trials was simply a count of trials in each condition that were performed before the running average reached 90% correct or greater. Four subjects failed to complete one of the mapping conditions (two in the default and two in the customized) and these data-points were removed from analysis.

As Figure 1 shows, the number of trials to criterion was somewhat higher for the default mapping than the customized mapping ($t(16) = 1.32$, $p = .10$). It required, on average, 31 trials to reach criterion with the default mapping but only 22 trials with the customized. Analysis of time to criterion also showed that subjects took longer, on average, to reach criterion for the default mapping (405 seconds) than the customized (287 seconds). This difference was marginally reliable ($t(16) = 1.45$, $p = .08$).

DISCUSSION

The results show a trend towards better memory for customized mappings instead of a well-designed default mapping. Although this experiment has limitations in terms of its design, and relatively few subjects were tested, subjects appear to be fairly skillful at creating memorable cues to aid them in recalling brief messages. The colors assigned to the customized cues often followed the same structure of the graphical customization interface; i.e., one color was used consistently for each message value and one light position was used for each message category. Additional experiments will reduce structure by giving subjects more cue options (e.g., light intensity and whether the light is on or off) forcing subjects to create a design that is more their own. Experiments will also be conducted using randomly generated cues and mappings rather than default values.

Unlike our previous experiments [1, 3] stimulus-response compatibility was removed by putting each message on its own button and presenting the buttons in random order on every trial. This appears to have added considerably to the difficulty of the experiment as trials to criterion more than doubled (i.e., from 11 in the previous experiment [1] to 22) from previous experiments with the same number of messages. In addition, the response search time required to find answers was observed to be quite long, and many subjects commented on the added difficultly of locating the correct answer in time. In future experiments, we will try variations of response interfaces, perhaps just alphabetizing the answers or moving to voice response. Finally, the screen size of each light was meant to approximate the size of an LED to realistically model the size factor that would be used in small devices. This seemed to work well, although our work will eventually move to actual LEDs and mobile devices.

CONCLUSIONS AND FUTURE WORK

Pixel-based notification cues (e.g., using LEDs) eliminate the need for output screens and allow the display of information on very small, or *ultra-mobile*, devices. Personalization of pixel-based cues can create a situation where only the user knows what they mean, even if they are publicly displayed. For example, three blinking green lights on a person's ring, even when noticed by other people, could convey a message only the wearer understands. Thus, high levels of security and privacy can be ensured with pixel-based cues. Pixel-based cues also allow for language-independent communication, aiding universal usability.

This experiment has shown that cue customization supports increased performance with pixel-based notification cues. Additional experiments will look not only at user customization of mappings, but at customization of messages and cues as well. We will investigate these issues with varying amounts of information, and move towards testing cues in realistic situations and settings in support of decision making.

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