Can Color Tell? Smartphone LED Notification Color and Users' Perception of the Situation

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Abstract. In this study, we investigated whether the use of LED colors that are cognitively congruent with the notification situations can help smartphone users to intuitively understand the situation. We examined whether cognitive loads placed on smartphone users differ between when single color is used and when RGB colors are jointly used to better match the situations. We predicted that participants will more quickly and correctly understand the situations when RGB colors are used than when single color is used because the use of RGB colors will improve their memory (i.e., the process of encoding and retrieval) due to the high cognitive congruency between LED colors and situations. In an experiment, we randomly assigned participants to single-color LED notification groups (i.e., red color group and white color group) and RGB color notification group and measured their cognitive loads by assessing their task performance (e.g., response time and error rate) and subjective ratings. We found no overall difference in participants' cognitive loads between groups. However, in an additional analysis, we found a significant difference exists in early rounds of experiment although the difference disappeared as participants accumulate more rounds of experiences. Our results suggest that the use of proper LED colors can help smartphone users to more effectively and efficiently understand the situations; however, the positive effect will be low for those who have more experiences of LED notification lights. We believe our study provides important implications to the study on the design of LED notification lights.

Keywords: LED notification lights · Notification situation · Cognitive load · Cognitive congruency · LED color

1 Introduction

Since smartphones provide more and more functions and information, it becomes increasingly important to design smartphone functions more effective in delivering important information to smartphone users so that they can easily and efficiently understand the situations.

LED notification lights of smartphones are a useful function which can deliver a variety of information to smartphone users, such as missed calls, incoming calls, new

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text messages, and low battery. Thus, it is highly possible that smartphone users can correctly recognize the situations by glancing at the LED notification lights without necessarily activating the display. LED notification lights use different movement patterns (i.e., blink frequency) and colors to deliver different information to users. Prior research has endeavored to identify the optimal design of the movement patterns of LED lights (e.g., Chris Harrison 2012); however, relatively little research attention has been paid to how to optimize the use of colors in designing the LED notification lights.

We believe the use of color is important because people tend to have preconceived images specific to particular colors. Therefore, when a color is used in a way that does not match users' preconceived image of the color, intended information cannot be effectively delivered (Kang, 2006). Given the scant attention to the design of LED colors, however, more work is needed to know how to optimally design the colors as well as the movement patterns of the LED lights that match smartphone users' mental model.

This study aims to examine whether the cognitive loads that smartphone users experience decrease when LED notification lights match the mental model of smartphone users, i.e., high cognitive congruence between LED colors and the situations. We expect that participants will more quickly and correctly understand the situations when RGB colors are used than when single color is used because the use of RGB colors helps participants more effectively and efficiently understand the situations due to the high cognitive congruency between LED colors and situations.

2 Method

2.1 Participants

30 undergraduate students volunteered to participate in this study. All participants had normal vision and were smartphone users.

2.2 Stimuli

In a pre-test, we assessed whether it is necessary to provide LED notification lights for various situations. On the basis of the pre-test results, we identified five situations as cognitive tasks that require immediate attention from smartphone users and thus need the use of LED lights most, including missed calls/messages, *urgent* missed calls/messages, battery charging, *urgent* incoming call, and recording.

We then examined which LED color is cognitively congruent with and emotionally satisfying for each situation. Selected colors are used in RGB color condition. In single color condition, we decided to use Red color because it was most widely selected in various situations and White color because it was least widely selected.

Experimental stimuli were made by using Flash program and they were shown on monitor.

2.3 Design and Procedures

Participants were randomly assigned to three color conditions—Red, White, and RGB. We used different LED movement patterns for different cognitive tasks. Experiments consisted of learning phase and test phase.

In the learning phase, situation and corresponding LED light appeared on the screen at the same time so that participants can learn what information the LED light intends to deliver. Participants were asked to press the spacebar on keyboard to see the next screen. Learning phase was repeated twice.

In the test phase, LED light was shown on the screen for 700 ms and a situation (e.g., missed calls) was presented. For each test, we measured participants' cognitive loads by assessing their task performances (i.e., response time and error rate) and their subjective ratings. Participants were asked to answer as quickly and correctly as possible whether the situation matches the LED light by pressing "yes" key or "no" key on keyboard. We then asked participants how hard it was to answer. Participants' subjective ratings were measured using seven-point Likert scale. Tests repeated fifty times for each participant (i.e., five situations x matched/mismatched x five phases) in random order.

3 Results

We analyzed participants' response time using ANOVA, Average response times in Red color condition (M = 1.38) and RGB color condition (M = 1.36) are shorter than that in White color condition (M = 1.44). However, the differences are not statistically significant (Fig. 1).

Analysis by phases shows that average response times significantly decreased as the number of phases increases, $F(4,768) = 20.711$, $p < .05$. However, no statistically significant differences between LED stimuli were observed beyond phase 2, where the response time of RGB substantially decreases (Fig. 2).

We found the same results when we analyzed error rates and subjective ratings.

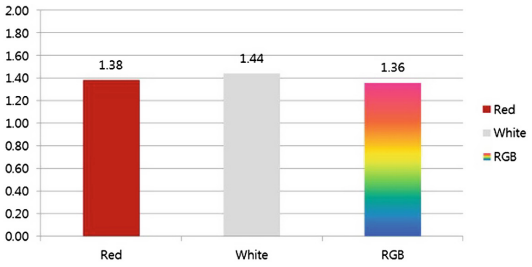

Fig. 1. Response time (sec.) of each LED color stimulus

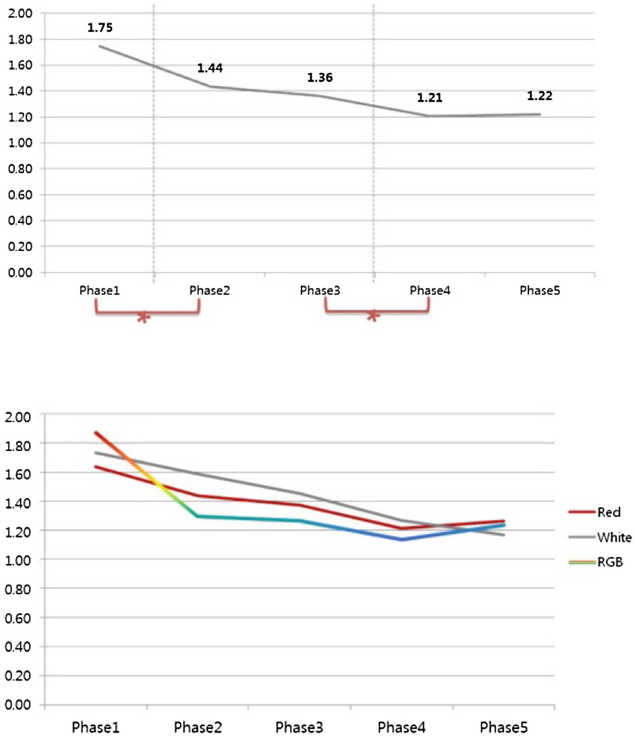

Fig. 2. Response time

4 Conclusion

This study examines how much of cognitive loads can be reduced when LED notification lights use such colors that are cognitively congruent with situations by enabling smartphone users to more intuitively understand situations. Our results suggests that, although not statistically significant, smartphone users will perceive lower cognitive loads when RGB colors—which are congruent with situations—and Red color—which has high coverage of various situations—are used than when White color—which doesn't have enough information—is used. The lack of statistical significance might be due to the fact that the number of tasks is limited to five.

Also, a phase-by-phase analysis, which is conducted to further explore the impact of learning, shows that the differences in the effects of three color conditions decrease as participants accumulate more experiences. The amount of cognitive loads that smartphone users experience in understanding situations from LED lights varies when different colors are used. However, our result suggests that the difference will start to decrease as smartphone users are exposed to LED lights.

In addition, we develop a novel evaluation method in our study which uses a series of cognitive tasks to properly measure the amount of cognitive loads reduced when colors congruent with situations are used for smartphone's LED notification lights. We

believe our method can be used in future studies that concern the role of cognitive congruence. Finally, our study provides an important practical implication regarding how we can design LED notifications more effective and intuitive.

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