Chapter 12

Designing the Expressiveness of Point Lights for Bridging Human-IoT System Communications

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Abstract

In the last decade, the digital devices and intelligent systems are becoming popular in people's everyday lives. Many machines could communicate and collaborate as a system to provide various services. However, they seldom provide sufficient feed forwards or feedbacks to help users understand current states and aware what it is about to act. In this study, we explored the possibilities of expressiveness with the point lights embedded on ubiquitous devices. By applying the findings from related works and animation principles, we created nine basic individual patterns and composed 12 designs of group behaviors. We then conducted a survey with 69 participants to rate their expressiveness regarding nine vocabularies of the human-system communication. The results show that single light behavior and the performative group light behavior could help to convey specific state information for intuitive communication. At the individual light level, for instance, the *fade in* light behavior can indicate changes in status; *rapid blinking* can indicate important information. At the group level, the two designs developed in this study, *leading* and *simultaneous* type also can initiate human interactions and represent the machine-to-machine conversations taken place in the system, respectively.

Keywords: feedback, communication, understanding, vocabulary, LED lights, Internet of things (IoT)

1. Introduction

In the recent decade, the connected products and services are emerging and becoming more and more popular. It is estimated that by 2020, everyone would have more than 20 devices worn on the body or used in the environments [1]. When the systems run well, they can provide users smooth experiences. However, when something unexpected happens, users usually feel frustrated because they do not know how the problem occurred [2, 3]. Even when everything runs smoothly, feedbacks are also essential to reassure that this is the case. To increase users' awareness, the small light emitting diodes (LEDs) were embedded in most devices for providing information and feedbacks. However, the lighting behaviors are either ambiguous or unintuitive for understanding [4]. As a result, users are unable to obtain useful feedbacks to create the appropriate conceptual model and do not know what actions they could take.

Recently, several researchers have investigated the design of good feedbacks with lights or sounds. However, most of the studies were focusing on the interactions with a single device, for example in [4, 5], how to assist the communications between a user and system is seldom investigated. Our research aims to explore the expressiveness of light behaviors that could enhance users' awareness and understanding on the systems of smart things in the smart environments. In the study presented in this manuscript, we reported the preliminary results that focused on the expressiveness of the individual and group behaviors through the point light embedded on simple devices. Through a user survey with 69 participants, it was found that the combination of light behaviors could sufficiently convey eight of the nine vocabularies investigated in this study. The contribution of this study is a set of light pattern that could be used to provide informative clues of the Internet of things (IoT) system and facilitate the user-system interactions.

2. Related works

In an interactive system, visible lights are commonly treated as versatile mediums to grab user's attentions or provide feedbacks on their interactions. For instance, [6] installed ring lights to a flying drone and designed the light behaviors to let users understand its intentions. Although the usage of LED is a common paradigm in designing electronic devices, Harrison et al. [4] found that the expressiveness of light behaviors was either limited or ambiguous. By using the smartphone as an example, they proposed eight light designs that might provide strong and iconic indications of a particular informational state. In addition, Pintus [5] created six light behaviors to express the status that two devices were connected for transmitting the data to each other. Extending from those studies, we aimed to investigate the design of light behaviors to create sufficient feedbacks of a system with multiple simple devices.

Because the point lights are both sequential and nonpersistent [7], it needs thoughtful designs in composing multiple lights to deliver coherent messages. It is similar to the directing of actors' movements in a movie or animation. Among the well-known 12 principles of animation [8], we thought the *staging* and *timing* could be two proper strategies in designing the system feedbacks. It could direct the user's attentions facilitate him/her to perceive the smart things' states, functions, and reactions.

Finally, Deckers et al. [9] applied the concept of perceptual crossing to show the acknowledgment of a smart thing to a user's approach. With perceptual crossing, he/she not only can recognize the possibility to initiate interactions with the system but also is invited to engage in a more continuous way with something akin to an artificial living creature. In this study, the analogy of "I see you seeing me" in their study was chosen as the semantic term for evaluating the alternative light behaviors developed.

3. Methodology

To understand possible communications that will be needed between human and intelligent systems, in a previous study [10], we chose and analyze nine concept videos produced by leading companies, research institutes, and independent designers. Through the semantic analysis of the interactions between the user and a system of smart things demonstrated in the films, we extracted 43 design vocabularies and clustered them into 11 categories. Among those vocabularies, some of them were extracted from complex interactions, such as the *emotional* or *social reactions* with robots or anthropomorphic devices. For exploring the possible expressions of the simple devices with point lights, we reviewed the video clips and selected nine vocabularies that were essential for creating users' awareness of the system of smart things. This set (shown in **Table 1**) covers the basic communications between a user and a system of simple smart devices.

No.	Categories	Vocabularies included
1	Active	Booting, sleeping, join, broadcasting
2	Exchange info	Synchronizing
3	Notify	Alerting
4	Show problems	Detecting errors
5	Socialize	I see you seeing me
6	Trigger functions	Waking up everyone

Table 1. The vocabularies selected for investigation in the study presented in this manuscript.

4. Designing the individual and group light behaviors

We first explored the different behaviors of single point light based on [4] and created nine basic patterns (shown in **Figure 1**) with variations in the changes of intensity and velocity. Those designs include the two lights that gradually fade in or out, two static designs (on/off) that maintain the intensity as 100% or zero, one breathing light, two designs (blink twice/thrice) that embedded blinking two or three times, one random brightness, and one (dark flash) that quickly blinks once when it stays as the brightest state.

For the group behaviors, we utilized the animation principles of staging and timing [8] to create six types of arrangements for a system with five devices. In the first three types, all the devices had the same individual behaviors but would light up with different time settings,

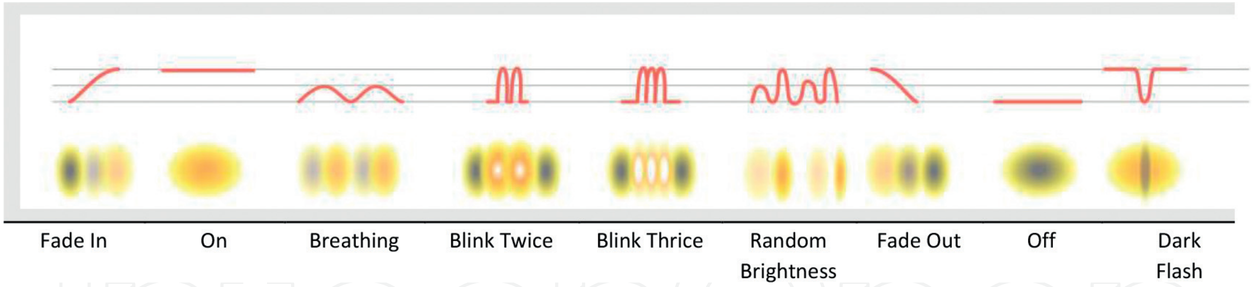

Figure 1. The nine behaviors of point light.

including *simultaneous*, *sequential*, or *random*. In the other two types, there was a device dressed with different light behavior to grab users' attentions on it, such as *leading* and *emphasizing* type. Finally, there is a *counting off* type that simulates the machine-to-machine conversations by aligning the pairing responses in the same time or with a short delay in time. Through compositing the individual light behaviors with those group patterns, we generated 12 designs with the video editing software. The illustration of the light behaviors was shown in **Figure 2**.

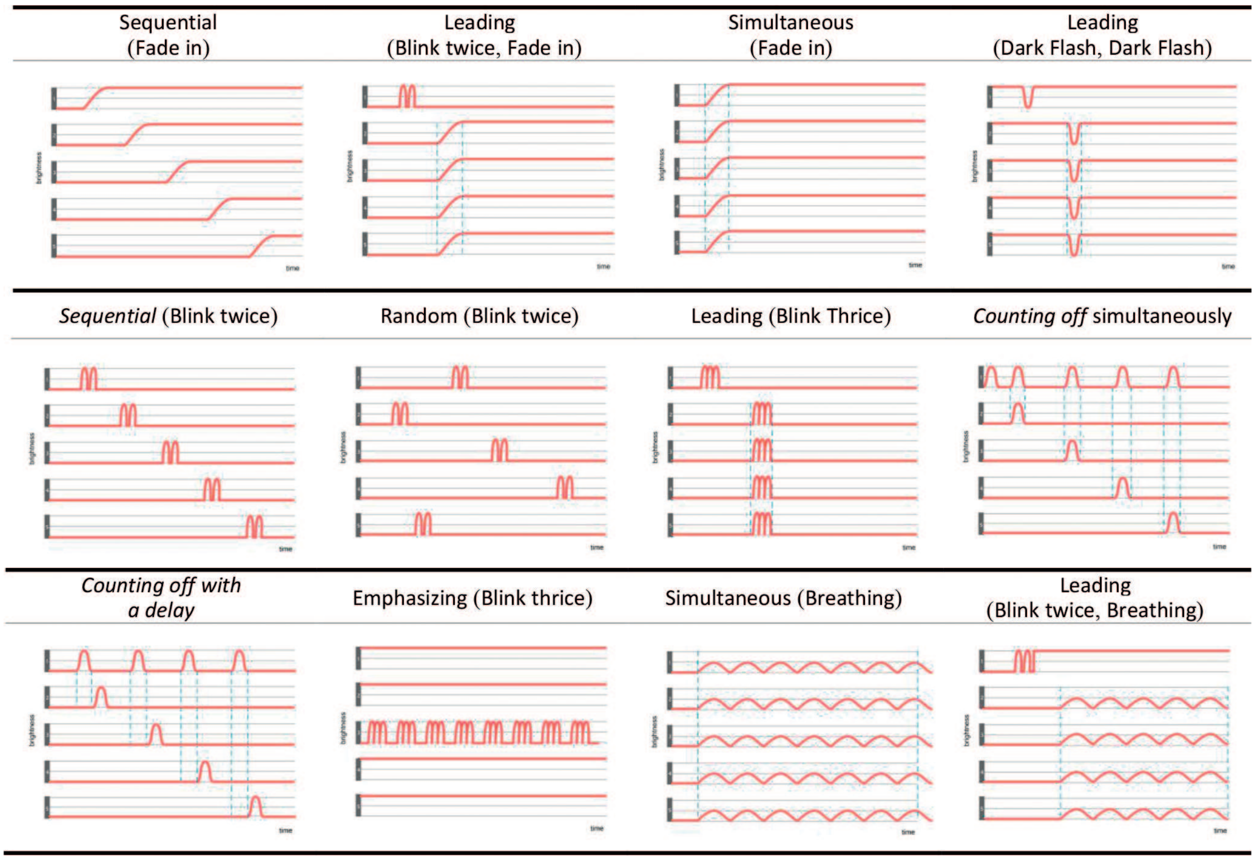

Figure 2. The 12 lighting patterns for group communications. The settings in brackets refer to the individual point light behavior on the device.

5. Experiment

5.1. Setting and procedure

An interactive survey was developed for evaluating the expressiveness of light behaviors in random order. In each round, a participant would see one of the 12 video clips (that would automatically replay) and rate the degree of their perceptions regarding the nine vocabularies shown in **Table 1**. A five-point Likert scale was provided next to each of the scale (ranging

Design/factor analysis	Factor 1: active				Factor 2: interaction			Factor 3	Factor 4
	Booting	Waking up everyone	Detecting problems[#]	Synchro-nizing	Broad-casting	I see you seeing me	Joining the system	Sleeping	Alerting
1. *Sequential* (fade in)	**	***					***		
2. Leading (blink twice, fade in)	*	*			*	*	**		
3. Simultaneous (fade in)	***	**		***					
4. Leading (dark flash)				*	**	***			
5. Sequential (blink twice)					***		*		
6. Random (blink twice)			*						*
7. Leading (blink thrice)			**		*	**			***
8. *Counting off* simultaneously				*					
9. *Counting off with a delay*								*	
10. Emphasizing (blink thrice)			***						**
11. Simultaneous (breathing)				**				***	
12. Leading (blink twice and breathing)								**	

Note: more * indicates the mean is larger; the settings in brackets refer to the individual point light behavior on the device; #, in the repeated measures ANOVA analysis, the data of "Detecting Problems" vocabulary is the only one that the light behaviors were not significant (Mauchly's Test of Sphericity, df = 65, $p = 0.175$); and the data of the other eight vocabularies are all significant ($p < 0.05$).

Table 2. The top three light behaviors the participants thought are relevant to the specific vocabulary.

from 1, strongly disagree, up to 5, strongly agree). There were 69 participants (52% male and 48% female, 88% aged between 21 and 30) recruited and completed the survey. A total of 70% participants have expertise related to interaction design.

5.2. Results

The statistical analysis shows that for eight of the nine vocabularies (excepting "Detecting problems"), there were several designs of the group light behaviors perceived with higher correlations to particular terms than the others (repeated measures ANOVA, $p < 0.05$). **Table 2** provides an overview of the matching. Together with the *factor analysis*, it was found that the nine vocabularies could be clustered into four groups (with 93.91% of variance explained). Regarding the first *active* factor, the *sequential* (fade in), *simultaneous* (fade in), and *leading* (blink twice, fade in) light behaviors are the three ideal designs that can express the system's working state. For the second *interaction* factor, the *sequential* (blink twice) and *leading* (dark flash) are perceived to convey the machine-to-machine communications and human-system interactions, respectively. In addition, because the *breathing* light pattern was widely used in many electronic devices, the participants could easily perceive the system in sleeping or standby status with the pattern. Finally, for the *alerting* vocabulary, the most correlated designs are *leading* (blink thrice) and *emphasizing* (blink thrice). Similar to the first *active* factor, the individual light pattern articulates to alter or notify the users an important message. Besides, the group behavior provides additional information to help him/her aware of the different levels of the communication. Based on those findings, currently, we are implementing those light behaviors with tangible prototypes. We plan to conduct contextual experience experiments to investigate how will people interpret the light behaviors in the physical world. This will help us to understand how to design intuitive feedbacks to bridge the human-IoT system communications and create natural and seamless interactions.

6. Limitations

In this study, we mainly focused on the design of light behaviors and their semantic expressions. Therefore, we chose the video simulations to explore alternative design ideas. This helped us to investigate the subtle changes of single point light and the compositions of multiple lights. In our survey, the text descriptions were presented to help users imagine the context and rate the degree of correlations between the designs and vocabularies. The preliminary results could provide designers an initial set of individual and group light behaviors for conveying specific feedbacks.

7. Conclusion

As the IoT technology is maturing, many designers are focusing on creating smart products to improve customers' living experiences. There have been many devices installed and used in many people's daily lives. However, due to the lack of communications, users often encountered frustrations to the system's unexpected behaviors. This study is aimed to explore how to design the expressiveness of point light to improve users' situated awareness to the smart things in the surrounding space. Based on related studies of the point light design and the animation principles [8] of staging and timing, we composed 24 group light behaviors for a local system that consists of five virtual devices. After evaluating the esthetic quality and the consistency of message conveyed, we chose 12 designs and conducted a survey with 69 participants. The results show that the point light behaviors and the composition of grouping performance could create implicit and sufficient communications. As a result, we recommend a collection of design strategies. With this new knowledge, designers could successfully provide useful clues for users to have the natural and seamless experience while interacting with a system of smart things in a smart environment.

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