Coding Single LED Signal for Status Information Perception

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LED status indicator has commonly found on electric devices. In human-machines interface, light signals provide status, feedback and information that convey a message or meaning. Many products equipped with LED status indicator that delivers message according to its functionality. However, there are no consistent implications of light signal pattern that can cause confusions or even human casualties. Therefore, this study explored users' perception among color patterns and flickering patterns of single LED signal, in hopes of improving light signal coding in human-machine interactions.

Key words: status information;LED light characteristic

1. Introduction

Modern life, we have all kind of electric devices around us, like mobile phone, when your phone is about to run out of battery, you will connected you phone to a charger, phone screen will show current batter status in percentages, then you can estimate how long will it takes to reach full charged. Screen can show unlimited information, but most of electric devices use only LED Status indicator providing an indication of the status or activity of the electronic devices, unlike screen-based devices, LED status indicator using lights signal that indicate the status of machines operating process. LED status indicator is the most cost effective way to show machines status, therefor camera battery chargers has it, battery charger is very simple and easy to use devices, status indicator on the battery charger can deliver several statuses, like power on, charging and charged. Unlike mobile phone screen can tell you battery life in percentage, or when you copy a file on a computer, the progress bar can help you visualize the progression of an extended computer operation, so we want to find out, can we achieved this continues and progression status through a single LED status indicator.

We have investigated different brand battery chargers has different light color, light pattern, and different design philosophy (Figure. 1), left to the user in an inconsistent information, and cause confusion. Each manufacture has its own method to determine which color of the light to be used to it corresponding status, that inconsistency, may be due to brand difference, or designer personal preference. This paper will focus on how to use single LED light signal provide status, feedback and information in human-machine interface, without install multiple LEDs or put in any other display screen on the product itself.

	Light signal of charging		Light signal of full	
	Frequency	Color light	Frequency	Color light
Panasonic	permanent	green ●	permanent	black ●
SONY	permanent	orange ●	permanent	black ●
Canon	permanent	red ●	permanent	green ●
Nikon	slow	orange ●	permanent	orange ●

Figure. 1

2. Research Aims

1. Through literature review, understanding how light signal can interact with user's cognition and recollection, then constructing basic principles of light signal coding.

2. Based on existing knowledge and experiment in LED color pattern and simultaneously flickering pattern (Figure. 2), a set of light signal were defined, followed by coding a set of light signal in heating context and charging context.

3. Utilizing symbol coding criteria (Shen-Xiong HU, You Peng, Shui-Pi Wu 1991) to verify the coding light signals by conducting recognition and mapping experiment.

Breathing (0.5Hz)   Lighting gradually

Figure. 2

3. Literature review

The reason why users sometimes had problems during operation, usually caused by improper designed interface rather than the system itself (Robert & George1989). The results of improper 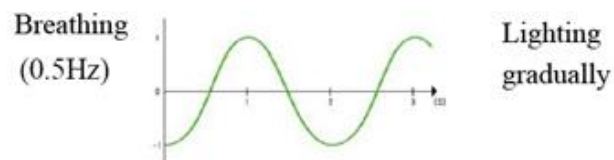interface forced users have to constantly using trial and error learning method. For example, like clothing iron with poorly designed status light signal, in this case, you may have burned yourself several times before you can remember what the light signal is trying to tell you about what the current state are, and you will probably forget about the meaning of the light signal when you are not using it often.

3.1 Information perception and process

Cognitive psychology believed, in a broad sense, cognitive psychology is process by which the sensory input is received, stored and used. In a broad sense, memory process also included the same process as cognitive psychology. N. Weiner said, "Information is a name for the content of what is exchanged with the outer world as we adjust to it, and make our adjustment felt upon it. The process of receiving and of using information is the process of our adjusting to the contingencies of the outer environment, and of our living effectively within that environment". (Hon-Sen Wei.1993) That's mean information is reflection of certain knowledge of outside world, commonly known as subjective knowledge, Therefore, the human sensory information processing and selection process, has become an important mechanism for receiving information and interpretation. This research aims to explore the impact and relationship of visual information processing model, and sorted out literature review about visual association.

3.2 Strength of association

In this section, we will discuss the association between, light color, frequency and flicking pattern. The whole concept of strength of association based on pervious living experiences, people can perceive objective things, recollection experience, and can forming new images that you have never experienced before. In your brain, forming those new images activity we called it association (Huai-Seng Chang, 1995). Light color and it association meaning has common emotion feeling and psychology symbol with in a range of common characteristics (Figure. 3).
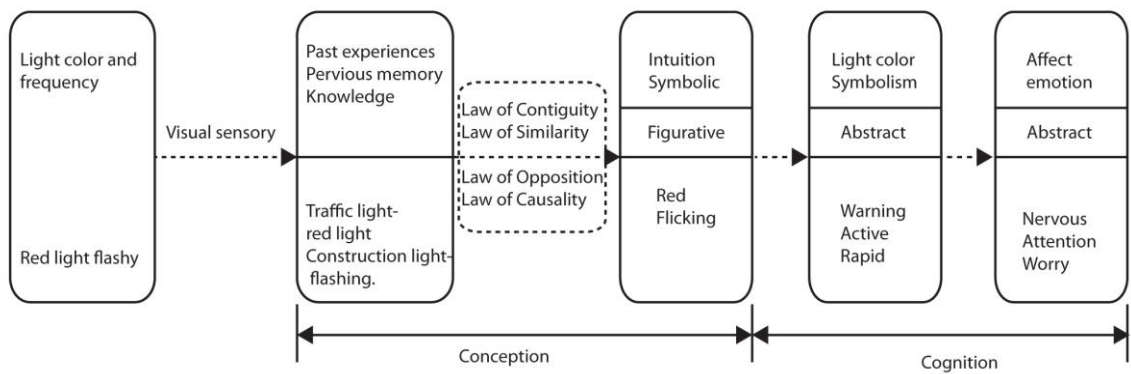

Figure. 3

3.3 Affordance

Norman (1999) incorporated affordance into product design, a situation where an object's sensory characteristics intuitively imply its functionality and use, light signal in product application has relation to sensory affordance. Through human- machine interface, light signals or any other interfaces design with affordance in mind; users will no longer need to read users' instruction first to understand how product works. Designer should emphasis product affordance, let users to perceive products color, shape and texture that also included light color, frequency and flickering patterns, through those methods.

3.4 Compatibility

Stimulus-response compatibility is one of the key principles in the human factors design of human-machine interfaces. The Compatibility principle can help users do effective cognitive judgments in search task. Interface must be able to meet the human perception, memory, and problem solving, action and communication performance. Compatibility has four main categories 1.conceptual compatibility 2.movement compatibility 3.spatial compatibility 4.modality compatibility (Sander & McCormick, 1993). The most important reference factor of coding light signal is conceptual compatibility, using light color, frequency and flicker patter to formation lights meaning.

3.5 Colored light

Color is the most commonly used symbols of the code (Table 1), colored light is often used to express the dynamic changes in environmental conditions, for example for equipment of different status information, color light most often match symbols to brightness and the flicker rate.

Some colors and the meaning that it represents have already formed rather strong the majority stereotype or stereotyped response. Design of display equipment it should be taken into account, such a strong association can help users perform their interpretation job and avoid identification errors occur.

Table 1

Association of meaning and color（Warren, 1980）

color	meaning
red	alarm
	emergency
	critical
	disable
	power
	failure
	major
	stop
yellow	minor

	stand by	
green	active	
	normal	
	on	
	enable	
	run	
	on line	
white	clear	
black	off	

3.6 Frequency and flickering

Different blink rates to represent different deceleration rates, subject to human perceptual skills that cannot use more than three different frequencies (Mortimer &Kupec 1983; Tolin 1984). If there is more than three and above, people cannot clearly identify any difference between a blink rate and other flashing rate.

Human breathing frequency

Human breath is a deep progressive frequency of changes, rather than a rapid frequency changes, such as lights of airplane plane wing, flashing rate is very slow, but flicker variety bright with off rapidly.

3.7 Concept of Time and continuous

There are two types of status information, which are continuous and non-continuous for the information disclosure of light signal, such as heating water from cold to boiling, getting full of battery charging, etc. For battery charging, there are three status information which are charging-on, charging, and charged. these status could be defined as the steps of the linear feature of the time which in the condition of succession. Equal to the all status of the process of a matter in the time series, each of them constructed in the relationship of sequence with each other.

It can be categorized to dynamic and Static for the information of the display device. Light signal is feasible in the communication of dynamic information, which change continuously with time goes by. The types of the information of light signal are as below (Shen-Xiong HU, You Peng, Shui-Pi Wu, 1991):

1. Status Information: To describe the specific situation or status, such as ON/OFF of device, STOP/GO of traffic light

2. Warning and Signal Information: Described for emergency or dangerous scenario, or the existence of object and condition, such as the light signal of airplane and lighthouse.

3. Time-Phased Information: This type of signal shows with pulse feature or regular temple in the section of the time unit, such as Morse code, which was coding in advance to be a meaningful signal.

3.8 Instant Message, IM

Instant message used in the communication of internet which in P2P (point-to-point) mode, the content could be text, image, and in multimedia which could show the personal online status. In the point of view of HCI, product shows its live status to users via various of medias, display by light signal is a way to let people know what the product status is.

3.9 Information and Visual Coding

Light signals to be able to communicate status information to users successfully, it must be through rigorous process of encoding, and the light signals encoding process is also visual coding transmission of status information.

Whether the symbol code is existing or developed, it's assured to use. If there is doubt about its applicability, it must be examined by experimental procedure. (Shen-Xiong HU, 1991) :

1. Recognition : Presents the experimental symbols and ask subjects to write or say the meaning of the symbols were represent.

2. Mapping : Give the symbols and the list of all possible indicators to the subjects, and ask the subjects to pair the items. In addition to calculate the quantity of right and wrong pairs, sometimes also measure the time.

From Sanders and McCormick's (1987) experiments on visual codes, this study singled out the lights-related visual coding material and summarized in the following table (Table 2):

Table 2

Visual Coding	Notice
Color (light)	Less than ten, no more than three is preferred. Subject to space and environmental constrain. Applicable to the property interpretation.
flickering pattern	It is better within two kinds. If the recipients must distinguish between various of flickering frequency, than it is limited to use. Flash duration in a regular pattern combination is available for the lighthouse signal or the communications at sea to attract attention.

4. Method

This chapter contains two stages, in the first stage focused on how to coding product with continues status information, based on pervious analyzed and categorized to determined what kind of signals should be displayed on product with continues status, and coding light patterns to help improved users' perception and reduced cognitive load. The second stage is the validation phase. Validate users' recognition and matching effect of status indictor signal sets.

First, summarizing literature review to analysis status indicator, coding continues status signal sets, based on products properties then dived into charging and heating context (Figure. 4). Second stage was using matching

effect to validate coding light signal appropriateness by percentage of correct answer. Third stage was single status indicator recognition experiment (Figure. 5), by recording subjects correct answer rate and recognizing tasks time. Recognizing tasks divided into two subcategories. First, read users' instruction: provided correct and incorrect users instruction to subject, this experiment designed to testing new light pattern whether can help users to learn and memorize. Second, without reading users' instruction and conduct the experiment directly: preset correct and incorrect light patter, the subject needs to answer by its stereotype and cognition.
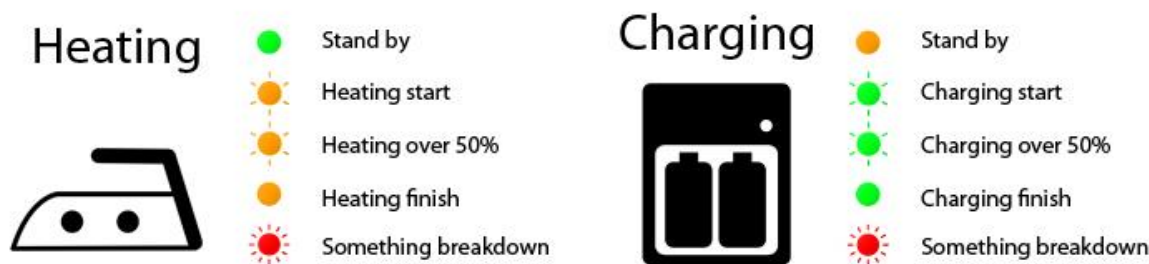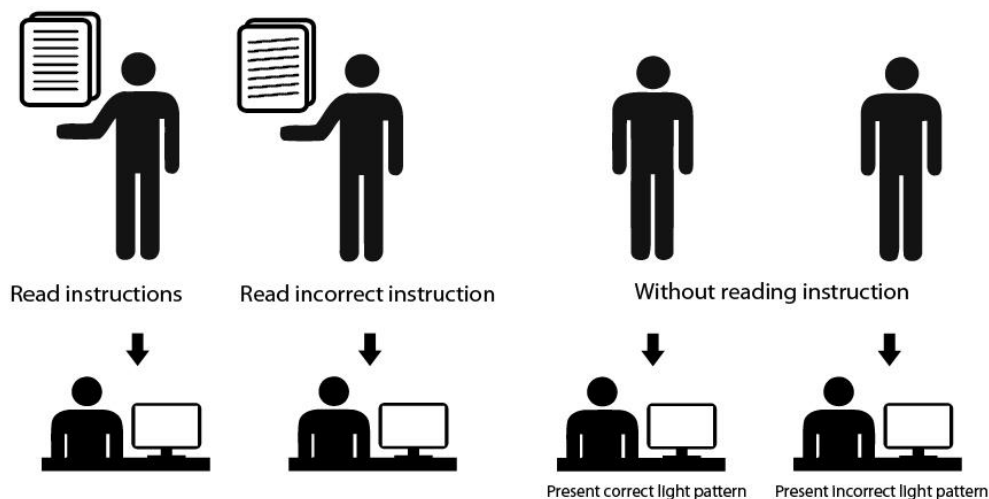

Figure. 4

Figure. 5

5. Conclusion

This study explored status information transfer and user perception of single LED status indicator. Through literature review and the discussion of this study, we generalize and verify the light signal coding that is applicable for heating context and charging context. Here is the result of this study：

5.1. Patterns of light signal in both charging context and heating context presented high matching effect.

In this study, we examined and set the status information, and divided the heating and charging succession state into 3 status: starting heating or charging、achieving 50% of the goal of heating or charging、completing of

heating context or charging context. Than we paired the status information and the light signal patterns. The experiment result shows the subjects can understand the status information that the product light indicator represent in the task. Breathing light flickering pattern can effective express the continuous status of heating process. With different frequency and color, light signals can support user's perception of product status information.

5.2 Those did not read users' instructions were not inferior to those who did in completing the recognizing tasks, which indicated the intuitive perceptibility of the proposed light signal sets.

In the recognition experiment, whether reading the correct instructions of light indicator before testing or not, the correct rate are 91% and 85%, respectively. It represents appropriate light signal can be directly perceived by users.

5.3 Coding heating context light signals must be more careful.

Users took longer time to complete the light signal sets recognizing tasks in heating context than in charging context. The light signal design for heating product or products require security concern are encouraged to employ multimodal interface (combining voice or symbols) for message assuredness..

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