PicLight: User-Centered Lighting Control Interface for Residential Space

Jeongmin Lee
Industrial Design, KAIST
291 Daehak-ro, Yuseong-gu,
Daejeon, Republic of Korea
jmlee_616@kaist.ac.kr

Kyungah Choi
Industrial Design, KAIST
291 Daehak-ro, Yuseong-gu,
Daejeon, Republic of Korea
cka0116@kaist.ac.kr

Hyeon-Jeong Suk
Industrial Design, KAIST
291 Daehak-ro, Yuseong-gu,
Daejeon, Republic of Korea
h.j.suk@kaist.ac.kr

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.

Copyright is held by the owner/author(s).
CHI'15 Extended Abstracts, Apr 18-23, 2015, Seoul, Republic of Korea
ACM 978-1-4503-3146-3/15/04.
http://dx.doi.org/10.1145/2702613.2732891

Abstract

This study aims to develop PicLight, a user-centered lighting control interface based on the behavior of photo editing as an analogy for controlling light. The PicLight application allows users to takes photos of a space, then uses those photos to display simulations of lighting scenarios through filter effects, providing users with guidance for easy selection of optimal lighting conditions. We formed 20 lighting presets each of that engages user activity, affection. In order to determine whether the presets were suitable, we conveyed a validation test and validated context-based presets are effective features for designing lighting control interfaces.

Author Keywords

Lighting control interface; ambient lighting; RGB LEDs; Colored lighting; affective lighting

ACM Classification Keywords

H.5.2. User Interfaces: User-centered design

Introduction

As lighting technology advances, the role of artificial lights progressively changes as well, becoming more meaningful and dependent on user context. Ambient lighting in residential space is particularly important as people may want to encounter different affective states

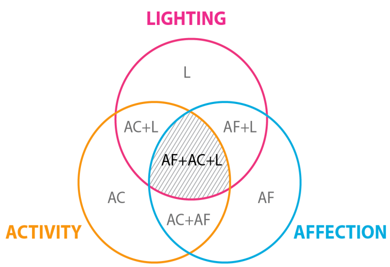

Figure 1. Relations between activity, affection and lighting. The shaded area represents a complete lighting scenario for residential space. The term "activity" refers to the action users intend to perform, such as reading; "affect" refers to behavior or mood intended by the users, such as relaxing; and "lighting" refers to the three colorific lighting components: hue, purity and illuminance.

while engaging in different activities, thereby enhancing everyday experiences. Many academic publications have shown empirical evidence that colored lighting can influence human behaviors and experiences in a positive manner [5, 9]. However, in order to successfully integrate colored lighting in everyday living, it is first essential that users feel comfortable with the lighting control system, in which they are able to generate desirable lighting with ease and fluency.

Notably in the field of Human-computer Interaction (HCI), innovative lighting concepts that engage users to interact with the light in unconventional ways have been gaining momentum as an area for exploration. Many HCI researchers have taken the metaphoric approach through which they try to invoke interaction metaphorically to disambiguate the users' interpretation of how to interact with the lighting control system. For example, "Tangible Light" is a lighting installation that acclimated the experience of walking through a corn field as a metaphor for controlling light [2]. In another publication, Mason and Engelen [6] describes a tangible user interface called "Globe UI" that incorporates an analogy between lighting and the climates around the world. It can also be noticed that many metaphoric solutions for interactive lighting control interfaces are inspired by hand and bodily movements [1, 7]. However, many of these interfaces and control methods have been designed for decorative lighting and lighting installations, and are not necessarily practical when it comes to controlling the residential lighting.

Objective

The purpose of this research is to design a practical solution for a lighting control interface for ambient lighting in residential space. To achieve this goal, a user-centered approach will be taken by exploring connections between household activities, the affective state of users while engaging in those activities, and ambient lighting conditions for the residential context (Figure 1).

The procedural flow of the user-centered approach was structured as follows: 1) derive a set of affective factors to represent key affections experienced through colored lighting; 2) empirically explore connections between household activities, affection and lighting, and derive principal lighting scenarios for the residential space represented by the shaded area in Figure 1; and 3) apply the derived lighting scenarios in a lighting control interface concept and evaluate the validity and value of the design.

Part 1: Designing Interface through Analogy

To come up with a behavioral metaphor that can be applied to the development of an intuitive lighting control interface, a workshop with six designers was conducted. Designers were asked to write down or sketch that came to mind when thinking of the word "lighting". Using the ideas generated, an affinity diagram was created. Through this exercise, it was possible to see that users easily associate lighting with behaviors related to photography.

Lighting is without a doubt a large part of photography, mainly because different light settings can change the affective responses that are captured through the images. Nowadays, all smartphones are equipped with built in cameras, allowing users to take and edit photos through editing applications. The main purpose of using filters to edit photos is to change the emotions depicted

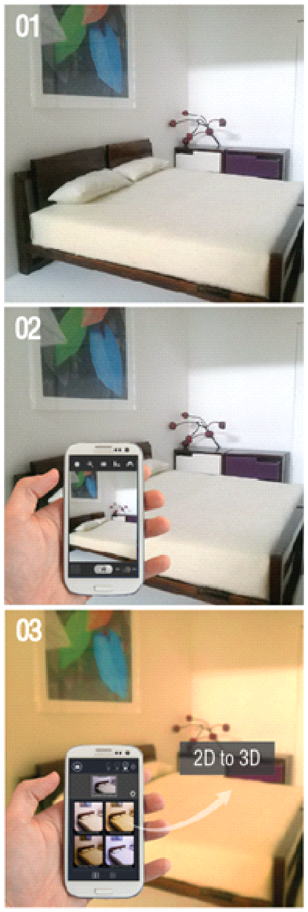

Figure 2. User scenario of PicLight: 1) want to comfortably read a book before going to bed; 2) take a photo of the space you want to preview; and 3) select optimal lighting by viewing filtered images of presets.

in them. Similarly, changing the color of ambient lighting can make the experiences of performing ordinary household activities more special. Therefore, in this study, the behavior of photo editing was adopted as the analogy for designing the lighting control interface in residential space named "PicLight".

Design of PicLight lighting control interface

PicLight is a design concept for a lighting control interface that uses the analogy of taking and editing photos to control ambient lighting (Figure 2). Using a camera function, PicLight allows users to take a photo of the area of which they want to change the lighting. The photo is then rendered using photo filters to simulate augmented realities (soft copy: 2D) of what the lit environments (hard copy: 3D) could look like under various lighting presets. The lighting presets will be labeled with terms that provides users with contextual information regarding the lighting scenario, giving users an idea of what the lighting is intentioned for intuitive selection of optimal lighting conditions. One of the main features of the presets in PicLight is that they reflect both the activity and affection, offering optimal lighting conditions for various contextual situations.

Part 2: User Study and Lighting Scenario

The user study aimed to derive appropriate lighting scenarios that would be used as PicLight presets. The lighting scenarios should reflect the context of residential environments and take into account both users' activities and affective states. The experiment was carried out in two parts. First, a preliminary study was conducted to extract emotional factors for colored lighting. The User Study was carried out to find the link between household activities and user desired affective states, and lighting conditions most optimal for those activities and affections.

Preliminary study: Extraction of affect factors

The purpose of this preliminary study was to extract affect factors of colored lighting. To extract the representative affective words, existing papers on evaluation of affective lighting were reviewed [4]. In total, 60 affective words were selected. The Korean Standards Association stipulates 12 names to describe light-source colors (KS A 0012). These 12 colors were selected to be used as hues for the lighting stimuli. The color names are as follow: red (R), orange (O), yellow (Y), yellow green (YG), green (G), blue green (bG), blue (B), bluish violet (bV), bluish purple (bP), reddish purple (rP), pink (Pk), and white (Wh). The excitation purity and illuminance were kept relatively constant between 20 ~ 30% and 500 ~ 600 lux.

30 college students made up of 16 females and 14 males were recruited in the preliminary study and their averaged age was 21.93 (SD = 2.33). The experiment was conducted in a room installed with a LED ceiling (Figure 3). A uniform illumination environment was realized in the room, ensuring that the participants fully adapted to the surrounding environment (Figure 4). During the experiment, the 12 lighting conditions were exposed to the participants in random order. For each lighting, participants evaluated the 60 affective keywords in terms of how appropriate they were in expressing the affective state that they experienced using a 7 point-Likert scale.

A factor analysis was performed to extract the affect factors (KMO > 0.80, Bartlett's significant value < 0.05). Seven affect factors were identified that gave a

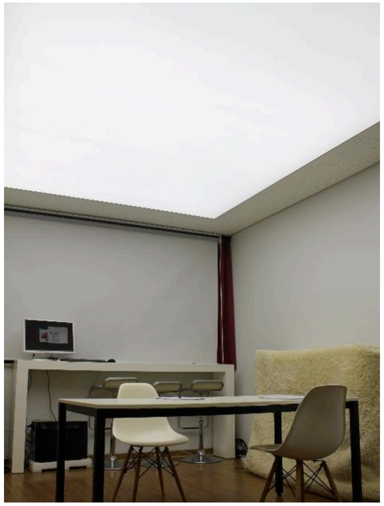

Figure 3. Experimental room equipped with LED ceiling.

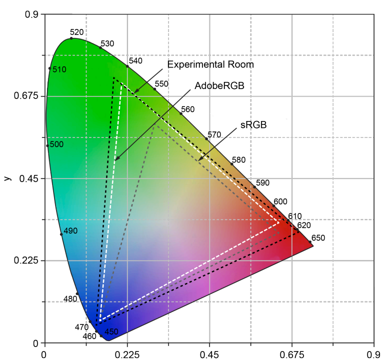

Figure 4. The color gamut of the experimental room is compared with AdobeRGB and sRGB. The area of each triangle is the entire range of possible chromaticities.

cumulative variance above 56.97%. The seven factors were labelled as ‘gentle’, ‘affectionate’, ‘inspiring’, ‘entertaining’, ‘alert’, ‘elegant’, and ‘nostalgic’.

User study: Deriving lighting scenario presets
The purpose of the user study was to establish relationships between household activities and affective states, and determine the most appropriate lighting conditions that can be used to enhance the desired affective states. The activities evaluated during the user study were extracted through literature reviews on daily life activities in homes [3, 8]. A total of 30 different household activities were extracted.

Each lighting stimulus was created using three parameters that make up the colorific components of light sources: hue, purity and illuminance. 12 hues, 3 purity levels, and 6 illuminance levels were used to make combinations of the lighting stimuli. The hues were derived from the KS A 0012 standard. The purity was divided to represent three saturation levels; low (L), medium (M), and high (H). The illuminance was divided into six levels (30, 300, 600, 900, 1200, and 1500 lux). A total of 147 different lighting stimuli were extracted for the experiment.

210 college students (113 males and 97 females) were recruited so that each lighting stimuli could be evaluated at least 30 times. The average age of the sample group was 22.95 (SD= 2.15). During the experiments, each experimental group was exposed to 20 to 25 lighting stimuli in random order. Participants were asked to complete two types of evaluation for each lighting stimuli: 1) affective and 2) activity evaluation. With regard to the affective evaluation, we facilitated the seven affect factors such as gentle, affectionate, inspiring, entertaining, alert, elegant, and nostalgic. Related to the activity evaluation, we presented the 30 activities. For evaluation of both affect and activity, we offered three options, such as ‘yes’, ‘maybe’, or ‘no’ which were later coded with +1, 0, and -1 respectively.

Based on the rating on activity, we filtered out best matches between affect types and activities with highest mean scores. We clustered up to 5 activities as far as their scores did not show any statistical difference from One-way ANOVA at an alpha level of 0.05. In this way, the activities were further divided into 20 groups based on the similarity of the top five lightings conditions as presented in Table 1. The 20 groups are then considered as 20 lighting scenarios.

Part 3: Implementation and Validation

In Part 3, PicLight was developed as a mobile application (Figure 5). The validation test was intended to determine if the lighting scenarios derived from the user study are valid and applicable for implementation in the context of residential environments. PicLight was programmed to control three Philips Hue LED light bulbs that were installed in a miniature model house, approximately 1:10 in scale, so that users may experience the intended context of a residential home while evaluating the interface. To accommodate the different household activities, the model house had three main areas: kitchen and dining room, living room, and bedroom, each area installed with a Hue bulb.

Validation test
16 college students consisted of 8 females and 8 males were recruited for the experiment. Their averaged age was 24.06(SD = 1.73). Participants were given a set of

Preset Name	Lighting
Mindful Reading	YG/L/1500
Cozy Reading	O/M/900
Food Centric	Wh/900
Gentle Meal	YG/L/300
Wakeful Morning	O/L/1500
Cognizant Tasking	bV/L/900
Focused Cleaning	Wh/1500
Warming Rest	Y/M/900
Nostalgic Rhythm	Y/M/300
Easy Listening	G/L/600
Hypnotic Sleep	R/L/30
Reflective Meditation	YG/L/600
Elegant Cinema	bP/L/600
Chillin' TV	bV/M/30
Tech Alert	bV/M/900
Friendly Company	Pk/L/600
Graceful Discussion	O/L/900
Passionate Musician	Y/L/900
Romantic Dining	R/L/600
Luxurious Dining	Y/M/1200

Table 1. 20 lighting scenarios derived as PicLight presets. Lighting is defined by hue, purity, and illuminance.

lighting context cards, which were titled with 20 lighting scenarios and provided information about the activities and affective state associated with each scenario. Participants were first instructed to select a space in the model house where they want to conduct the activity written on the card, and control the ambient lighting of the space that best satisfies the user context using 20 lighting presets.

From the results of the validation test, it was possible to see if the lighting scenarios and presets derived from the main user study were acceptable, especially when experienced in the residential environment. The lighting scenarios were considered valid when the frequency count of participants choosing the intended lighting presets was greater than or equal to 50%. The results indicated that the internal relationship among activity, affect, and lighting for eight lighting scenarios - Chilling TV, Cognizant Tasking, Focused Cleaning, Food Centric, Graceful Discussion, Luxurious Dining, Nostalgic Rhythm, and Wakeful Morning - were valid. However, three lighting scenarios - Easy Listening, Mindful Reading, and Passionate Musician - did not have any lighting presets with frequency counts greater than 50%.

Usability interview

Interviews were made to compensate for the absence of a comparative usability evaluation with other lighting control interfaces. The user interviews proved that PicLight has a lot of potential to be employed as a lighting control interface as it gives users intuitive information about optimal lighting conditions. Users indicated that being able to create an augmented reality (2D) by taking photographs of the space (3D) allowed them to feel like they had more control over the lighting system. However, there are some implementation issues that can be improved through further studies. Users indicated that they would like some degree of freedom with controlling the brightness. Additionally, the graphics of PicLight can be further improved in order to maximize visual feedback given to users about the colored lights.

Conclusion

The main purpose of this study was to develop a lighting control interface for ambient lighting in residential space by deriving the most optimal lighting presets using a user-centered approach that involved empirical evaluations of user activities and affections in relation to colored lighting conditions. Through experimentation, four main findings were derived, which provides support that a preset-based lighting control interface inspired from the analogy of photo-editing is highly appropriate for controlling future LED lighting systems. The main findings of this research are described in the following:

First, there are seven factors – gentle, affectionate, inspiring, entertaining, alert/attentive, elegant, and nostalgic – that can be used to describe the affective experiences of users in colored lighting. Second, there are multilateral relationships between activities, affection, and lighting that can represent lighting scenarios for ambient lighting in residential space. This user-centered approach can also be applied to deriving lighting scenarios and creating lighting presets for other user contexts as well. Third, simulation of lighting environments through preset filters can create an augmented reality for intuitive lighting control. Fourth, the role of colored lighting shows potential for growth in everyday activities. Although only eight lighting presets

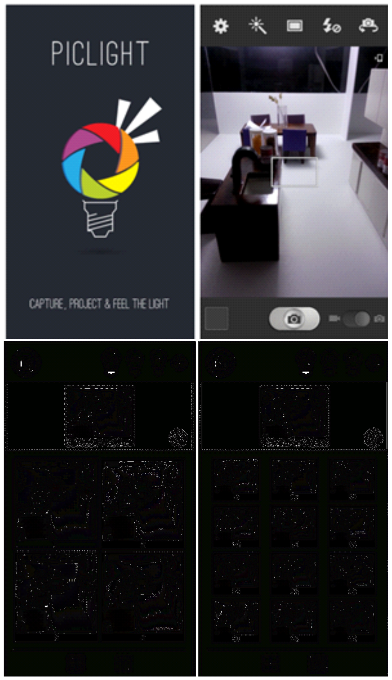

Figure 5. Operational flow of PicLight and outlines basic structure and features of the PicLight interface.

were derived from the final validation test, participants indicated that when using PicLight for the second time, they were tempted to try new lighting options that were more dynamic, such as red or green hues.

Moreover, the concept of applying colored lighting to everyday living is not yet widely accepted by the general public. However, this study demonstrates that an intuitive lighting control interface can help users progressively explore the effects of colored lighting in creating a diverse range of user experiences and gradually develop an interest towards integrating colored lighting into their lives.

Limitations and Next Steps

In this study, a miniature model house and Philips Hue light bulbs were used to represent the general ambient lighting in residential area. Unfortunately, because of the scale, there was a chance that the colored lightings with higher purity felt more saturated and unusual by participants. Hence, there is a need to conduct the validation test in a real 1:1 scale residential lighting environment. Moreover, during the validation test, several participants indicated that there were perceptual differences between the 2D display and the actual 3D lit space. To close this gap of perceptual difference, it would be fitting to review researches in realistic lighting rendering and conduct further research on determining the threshold for colors observed in soft-copy 2D displays and 3D hard-copy objects.

Finally, the interface of PicLight should be improved in future works. Because the main focus of this study was on deriving the user-centered lighting scenarios for ambient lighting in residential space, the method of selecting the presets from the PicLight interface was not as innovative as it could have been. To make the PicLight more novel and creative, other methods of displaying the lighting presets should be explored.

References

[1] Alaoui, S.F., et al. Movement qualities as interaction modality. In *Proc. DIS 2012*, ACM Press (2012), 761-769.

[2] Du, W. *Informatics and Management Science III*. Springer, New York City, NY, USA, 2013.

[3] Lee, Y.S., et al. Behavioral patterns and conflicts in multifamily residential space. *Journal of the Architectural Institute of Korea 6*, 3 (1990), 21-33.

[4] Lee, J.S., Kim, B.H., and Kim, W.D. Emotional evaluation of lighting design through case study of apartment housing exterior lightings. *Journal of the Architectural Institute of Korea 25*, 3 (2009), 291-298.

[5] Lee, E.S. and Suk, H.J. The emotional response to hue of lighting focusing on relaxation and attention, *Korean Journal of Design Studies 25*, 2 (2012), 27-40.

[6] Mason, J. and Engelen, D. Beyond the switch: Can lighting control provide more than illumination? In *Proc. Design & Emotion 2010*, Design and Emotion Society (2010).

[7] Mrazovac, B., et al. Gesture based hardware interface for RF lighting control. In *Proc. SISY*, IEEE (2011), 309-314.

[8] Naeem, U. and Bigham, J. Activity recognition in the home using a hierarchical framework with object usage data. *Journal of Ambient Intelligence and Smart Environments 1*, 4 (2009), 335-350.

[9] Suk, H.J., Park, G., and Kim, Y.S. Bon appetit! An investigation about color combination between food and lighting, *Journal of Literature and Art Studies 2*, 5 (2012), 559-566.