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Intelligent Lighting System for Health

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Master of Fine Art in Industrial Design
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Intelligent Lighting System for Health

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Abstract

Lighting affects not only the way people seeing things, but also the way they feel. This thesis project surveys people’s health problems and needs related to environmental lighting changes, and aims to explore a product design solution to these problems. The outcomes of the project are a residential lighting system called INSIGHT, a mobile app interface and a key product as an example of a smart lighting system. INSIGHT helps users to control, interact with and program their home lighting in an easy way to meet their own daily needs as well as improve their visual health and emotional health. The user-friendly mobile app collects user activity data and learns about users’ preferences and schedules, so it automatically adjusts the illumination intensity and color temperature. The results indicate that today’s Internet of Things could help users to control and program lighting to provide better visual and emotional health more intelligently.
**Introduction**

Lighting is much more than something that simply lets you see. It affects the way people feel and directly influences moods. This project studies how lighting affects users visually, biologically and emotionally in residential environments, and then explores solutions for better user experience of using, controlling and interacting with lights. The design focus will be how the system reacts to users’ behavioral patterns and environmental changes. In the end, it should provide a residential lighting system design that includes the interface design for the system and one of the products working for the system.

**Challenge and Opportunity**

The U.S. National Library of Medicine notes that “some people experience a serious mood change when the seasons change. They may sleep too much, have little energy, and may also feel depressed.”¹ Most people experience some seasonal changes in terms of feelings of well-being.

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and states and behaviors such as energy level, sleep, eating patterns and mood, to greater or lesser degrees. People with Seasonal Affective Disorder have changes in mood and behavior that are so powerful that they produce significant problems in their lives. The length of daytime and the amount of sunlight are the main factors for these series of changes.

With the trending technology of the Internet of Things nowadays, there’s a great opportunity to design a lighting system that could be controlled easily by users, programmed to meet user needs in various circumstances, and mostly automated to help users make the healthiest choices based on seasonal changes and users’ life patterns.

Seasonal Affective Disorder

Seasonal Affective Disorder (SAD), also known as winter depression, winter blues, summer depression, summer blues or seasonal depression, is a mood disorder in which people who have normal mental health throughout most of the year experience depressive symptoms in the winter or summer. Symptoms of SAD may consist of difficulty waking up in the morning, nausea, tendency to oversleep and overeat, and experiencing a craving for carbohydrates, which leads to weight gain. Other symptoms include a lack of energy, difficulty concentrating on or completing
tasks; withdrawal from friends, family and social activities; and decreased sex drive. All of this leads to depression, pessimistic feelings of hopelessness and lack of pleasure, which characterizes people suffering from this disorder. People who experience spring and summer depression show symptoms of classic depression including insomnia, anxiety, irritability, decreased appetite, weight gain or loss, social withdrawal, and decreased sex drive.

Target users: people living at high latitude

Figure 1 Cities in high latitude
The target users for this project are people living in high latitudes where the weather has significant seasonal differences. People living in high-latitude area are more common to have seasonal affective disorder (See Figure 1 and 2). They have large concerns about emotional and biological health related to lighting. Some of the richer families are interested in new, emerging technologies and have the financial ability to obtain higher-end products.
For instance, Oslo is about 60° N. In June, the daytime can be as long as 18 hours while in
winter the shortest day length is only 6 hours. Sunset time moves from 3 pm to 11 pm, which is a
dramatic change and could make a large difference to people’s emotions. People in Oslo tend to
sleep two and half more hours per night in deep winter than in summer. Research has shown that
the female population affected by the winter blues is twice that of the male population in Oslo
(See Figure 3).
Research

Lighting and Health

Figure 4 Light affects melatonin production
Light is the most powerful cue for shifting human being’s circadian clock. It suppresses melatonin’s production (See Figure 4). Melatonin is a natural hormone produced in the brain’s pineal gland. It is responsible for the regulation of the body clock in each individual. According to Harvard researchers, blue wavelengths—which are beneficial during daylight hours because they boost attention, reaction times, and mood—seem to be the most disruptive at night.² As shown in Figure 5, exposure to light above a color temperature of 6500 K (cool daylight or

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² “Blue light has a dark side”, last modified September 2, 2015, http://www.health.harvard.edu/staying-healthy/blue-light-has-a-dark-side
compact fluorescent light source) induces great melatonin suppression, and thus significantly impacts on circadian physiology and cognitive performance.  

Benchmarking Research for Lighting Products

Figure 6 Benchmarking research

Lighting therapy

A low-cost and widely used way of manipulating melatonin levels is lighting boxes. They have been successfully tested in peer-reviewed clinical trials. The standard output of a light box is between 2,500 and 10,000 lux. From the lighting currently available, blue-white light (5,500 K-10,000 K) is known to be the best in managing depressive symptoms and sleep disorder, according to the article “Blue light is the light that matters” from psycheduction.org. However, desktop lighting boxes are all huge and obviously alien to certain area. Other negative aspects of lighting therapy are the side effects and complications that could occur. A more critical problem with lighting therapy is that people with minor problems or even severe emotional disorders might not be aware of their problems and thus never approach a professional for advice on getting lighting therapy.

Wakeup lamp

During an early stage of my research, I came up with the idea of using gentle lights to wake up people gradually. There are already some products on the market using this concept. Philips, as the leading company in the lighting industry, also leads the market for wake-up lamps. The wake-up lamps start glowing 30 minutes before the alarm time that users set.

These existing products provide some early approaches to stimulating sunrise as a process to wake up people. However, there’s still a lot of room for exploration around the interactive experience and the lighting effect.

Wireless lighting system

Following the trend of the internet of things, several products on the market provide wireless lighting systems to residential areas including Philips Hue, LIFX, Belkin(WEMO), and Emverlight. The major concept is controlling your home lighting easily through a mobile app. Users get more options around lighting effects and interactions including colorful lighting, a morning alarm and remote control.
While the smart lighting system brings the benefit of more user-friendly control, there’s still a lack of understanding around how a system could help with adjusting people’s emotional feeling and regulate biological clocks in an intelligent way.

User Interviews

‘Do you think you are affected by the seasonal change?’ - ‘Yes!’

‘What do you do to improve the situation?’ ‘Nothing.’

In order to validate the online research and get a vivid picture of how people are affected by day-length changes, I interviewed several people in person including 12 students (4 female, 8
male) from RIT and two local families. The surveys and interviews mainly focused on people’s daily activity shift and emotional feelings in different seasons.

Almost everyone said “Yes” when being asked “Do you think you are affected by the seasonal changes?” All female interviewees described themselves as experiencing depression in long winter weeks without sunshine to differing degrees. Most of the male interviewees had similar feelings but usually to a much more lower degree. Everyone considers the struggle of getting up in the darkness of winter to be natural. Even though some people were aware of their mood disorder, they usually didn’t associate it with weather or the length of the daytime. Instead, they connected it more with their daily events. Not surprising at all, one key takeaway from the interview is that most people don’t do anything about their winter depression or know about lighting therapy.

One student who was interviewed used to have a lighting box at home. According to him, after he experienced severe SAD, his doctor suggested he use a lighting box. When moving to Rochester to study, he left it at home because he didn’t want to carry it around and now no longer uses it.
I interviewed a family living in Rochester, New York. They are a family of four, including parents and two young kids. Studying their daily life routine was very helpful to learn what kinds of lights are needed at different times during a day. The mother mentioned a very interesting use case of adjusting lighting intensity. When their infant could not yet move by himself, they used paper to cover the floor lamps and ceiling lamps, so when the infant stared at the ceiling, the lights would not hurt his eyes. Similar needs of changing lights during different time periods of kids’ growth were validated during that interview.

**Design Process**

The user interviews and online research validate the problem of some people in area with distinguished seasonal changes suffering from emotional change and low energy especially in long winter weeks. Exposing to a right amount of lighting during the right time period is an effective way to adjust people’s melatonin level and improve sleeping quality and emotional health. This design project aims to develop lighting design solutions that provide lights at right intensity and color temperature and adjust them based on users behavior pattern intelligently.
Concept Development

At the early design phase, I developed some concepts around end products. One direction is to design lights of which users can adjust the intensity easily through physical interactions. Some ideas were about adjusting lighting intensity by changing the physical volume of a product (Figure 8) and customizing the forms through certain connections (Figure 9), so users can get both the shape and the lighting they want.
Figure 9 Sketches
Figure 10 Lighting system concept
However, users usually don’t know what’s the right illumination of best intensity and color temperature to adjust their biological clocks. Even those who know it don’t have time to customize their home lighting to meet the needs. Therefore, the other direction that I worked toward was to design a systematic solution providing lighting intelligently based on live environment illumination and the daily schedule that users expect to have.

![Diagram](image1)

**Figure 11**

The initial concept is developing a system that senses the indoor lighting intensity, gets weather information from the Internet, and reacts to users’ activity. For instance, when users...
wake up at midnight to go to the bathroom, the hallway and bathroom should light up with a very dim and yellow light, to provide enough illumination but keep users’ melatonin at a high level.

When it is a rainy and cloudy afternoon, and a user is reading in her home office, the ambient lights will be brighter and cover a larger area than on a sunny afternoon, but the task lighting auto adjusts to provide the most comfortable illumination for reading.

Figure 12
Part of the concept is to have a mobile application. Users can use it to set up their expected sleeping and waking up time. Also, they can use it to select different activity modes to customize the environment lighting atmosphere quickly. In this way, the system learns about users activity during a day and generates behavior patterns for future analysis.

**INSIGHT Lighting System**

INSIGHT is a lighting system linking home lights and sensors with a mobile app through the internet. Users can turn the lights on and off, and adjust the lighting intensity and colors through physical controls on the wall and on the mobile app. In the meantime, INSIGHT adjusts...
the lighting intensity and color based on sensing the environmental natural lighting and the time of the day.

Figure 14 How the system is connected

Figure 15 How INSIGHT works
Mobile interface design

The mobile app INSIGHT has four main interfaces that can be navigated through a side-bar navigation. The home/primary interface offers a quick selection between different scenes. Users could select from sleeping, partying, reading, meditation and away mode. They could also tap the three-dot button to download more customized modes from the internet. By setting up your own floor plan during the on-boarding process and through GPS, INSIGHT learns in which room the
user is located, and controls related lights depending on the mode. For example, the away mode turns off all lights and the reading mode adjusts the ambient and task lights around users to provide a comfortable and healthy lighting environment to help users be more focused.
From the sidebar navigation, the last screen that users can go to is Data. Nowadays users can easily get a lot of health data from smart devices. For example, if you turn on the bedtime function in iPhone’s native app Clock, you can easily get your health data about your sleep quality and length. INSIGHT can link this data from a health and fitness app. By connecting the daily weather and daytime length data, it analyzes and adjusts home lighting as well as giving users actionable tips about keeping a good mood and energy level.

Figure 17
The nightstand lamp

Figure 18 Digital model

Figure 19 Digital model
This nightstand lamp is one product of the INSIGHT lighting system. It provides different color and intensity depending on the time of the day. Users can interact easily with the lamp by tapping or touching it. The uses of this product will be explained more in the next section on scenarios.

In the model-making process of the nightstand lamp, I made 3 physical models. First, I built a foam model to test how it holds various types of mobile phones and what might be the best curves for the shape. After that, I made a 3D model using Rhino and 3D printed a physical model that was close to my concept in detail. The last model I made was a functional prototype with
programmed and adjustable lights inside the model.
Scenarios

In order to explain how the INSIGHT system works, a video of different scenarios was shot and posted online. The URL is https://vimeo.com/139659164. Here are some examples of how INSIGHT helps users to improve their comfort and health intelligently.
In an afternoon, when the contrast between a user’s task light and the natural environment light becomes too strong, the system will also provide more ambient lighting by using a combination of all the lights in a room.
Figure 24 Going to bed

At night, provide a dim and warm light

Turn off all the lights

Figure 25 Waking up at midnight

Gently light up the way

Just enough for seeing
At night, the nightstand lamp will provide a dim and warm light to help increase a user’s melatonin level. If a user keeps working or playing mobile devices late, it will flash three times to remind them that it’s time to go to bed. When a user falls asleep, the control center will make sure to turn off all the lights in the house to be energy efficient, unless the user is using special settings for certain lamps.

If a user wakes up and gets out of bed at midnight, the lamp will provide a very dim and yellow illumination (20lux, 3000K). In this case, a sensor sends a signal to other lights in a user’s home, so the lights along the user’s path to bathroom or kitchen will also give a low-intensity lighting.
If the user sets up an alarm in the morning, it will light up gradually with a bright blue to white light (6500 lux at 7000K). By tapping the lighting surface or the mobile interface, the user can turn off the alarm sound.

The combination of a nightstand lamp and a general ceiling lighting would meet the needs of multiple users. It could also be used as a secondary alarm to make sure users totally wake up.

User feedback

The criteria for this project are around the end product design and the mobile interface. Do
users find the nightstand lamp useful and effective? Do users think the mobile app provides the features valuable to them? Is it easy to use? After finishing the design, I interviewed a family of a couple in Rochester, NY and 3 people in Boston, MA for feedback. It was also demoed to public in thesis exhibition at RIT.

People being interviewed thought the overall concept of this lighting system was very smart. Some use cases of the mobile app were more validated than others such as turning off all lights when leaving a room, tracking sleeping data and giving tips on health. Most people liked the nightstand lamp, because it holds phones in a stylish way, and is useful for charging mobile phones and displaying the time. People liked the gradually changing process of the lighting alarm. The interaction at night and morning with the nightstand lamp was considered very user-friendly and fun.

On the other hand, some people had concerns about the difficulty of the implementation process of the system, which was the major uncertain part of this project that remained from the design end and one that needs more exploration.
Conclusion

In the market, there are a lot of lighting products aiming to solve similar problems. A lot of those products have technology-centric interface. No matter how complicated the algorithm behind a screen is or how advanced the technology is, product design should always be user-centric and easy to understand. For most times, invisible and natural experience means a good experience. INSIGHT helps users reduce the effects of seasonal affective disorder or winter blue in a tangible but less visible way by providing user-friendly interface and physical products.

On the other hand, as a conceptual system design, some key hypotheses around this project need future exploration to launch a real product in market. Most of the illumination set-ups of light bulbs are designed based online research and tested by several friends and myself in a short time period mainly around the waking up function. More research is needed on long-term health effect.
Bibliography


