SA LIGHT

(SLEEP-AWAKE) LIGHT DESIGN

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Light has an important influence on the circadian rhythms of human beings. In ancient times, people’s physiological work-rest daily routine follows the law of natural light ---- sunrise and sunset. Light around us signaled to our bodies when it was time to be active, and when it was time to rest.

Nowadays, our activities are no longer limited by the setting of the sun. The artificial lighting boosted productivity by allowing us to continue to work late into the night, but simultaneously created a society that is no longer in sync with the local time. What's worse, a disrupted circadian system may lead to health and behavioral problems.

This thesis is about the relationship between light and human circadian rhythms, especially how light affects sleeps with all the consequences for the wellbeing and health of human beings. According to the preliminary conducted surveys on the sleep tracker on the market and study about the sensor, the designed system would be based on the use of piezoelectric technologies for monitoring and tracking people’s activities on the bed and their sleep stages, and the information will be transformed to the lighting device so that it can help you to fall asleep and get up more comfortable. SA (Sleep Awake) sleep light design with gestural control and automatic control on the basis of users’ sleep stages which is provided with a simple round shape which metaphorically represent an artificial sun into the domestic environment.
La luce ha un'influenza molto importante sui ritmi circadiani degli esseri umani; nell'antichità, la fisiologia data dalla routine quotidiana di lavoro-riposo delle persone si basava sulla legge della luce naturale ---- l'alba e il tramonto. La luce che ci circondava segnalava al corpo umano quando fosse il momento di essere attivi e quando il momento di riposo.

Oggi le nostre attività non sono più limitate solo dal cambiamento della luce del sole. L'illuminazione artificiale ha aumentato la produttività, permettendoci di continuare a lavorare fino a tarda notte, e allo stesso tempo ha creato una società che non è più in sintonia con l'ora locale. Ma c'è di più, un sistema circadiano interrotto e prolungato può portare a problemi di salute e comportamentali.

Questa tesi parla del rapporto tra la luce e i ritmi circadiani umani, soprattutto come la luce influenzi il sonno, con tutte le conseguenze per il benessere e la salute dell'uomo. Secondo le indagini preliminari condotte sul monitoraggio del sonno e lo studio dei sensori, il sistema progettato si baserà sull'utilizzo di sensori piezoelettrici per il monitoraggio e il controllo delle attività delle persone a riposo e le loro fasi di sonno. Le informazioni verranno trasformate e mandate nel dispositivo di illuminazione in modo che, attivandosi, possa aiutare la persona ad addormentarsi e ad alzarsi più a proprio agio e con maggiore naturalezza; Tramite il controllo gestuale e rilevamento automatico dei movimenti, SA (sleep awake) provvederà a simulare un sole artificiale in un ambiente domestico.
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1 Introduction
1.1 Project background

Light has an important influence on the circadian rhythms of human beings. In ancient times, when there was no modern artificial lighting, people's physiological work-rest daily routine followed the law of natural light ---- sunrise and sunset just as a sunflower faces and tracks the sun to maximize the amount of sunshine it receives. In the absence of artificial light sources, people woke up with the daybreak and went to sleep in the dark. Light around us signaled to their bodies when it was time to be active, and when it was time to rest. Light kept our daily lives in harmony with local time. This harmony is referred to as "entrainment": an entrained circadian system is aligned with the natural light/ dark cycle of the solar day. When we look back and think about the anthropology of luminosity, we see that the invention of artificial lighting - from firelight and candlelight to the more contemporary innovations of gaslight and, subsequently, electric lighting in the 19th century - changed all of that. Our activities are no longer limited by the setting of the sun. Nowadays we could arrive home in the dark, turn on the lights and perform additional tasks or even hang out at midnight because that, anyhow, it is artificial light everywhere. Furthermore, the use of electric lighting and electronic devices with bright screens at night from smart phones to tablets, laptops to big-screen TVs - expose us to blue light at the wrong times, which contributes to and exacerbates circadian disruption. Research now tells us that a disrupted circadian system is connected to a whole host of long-term health and behavioral problems: fatigue, cancer, obesity, diabetes, depression, mood and sleep disorders, reduced physical and mental performance, reduced productivity and irritability can be all related in some shape or form to a circadian system that isn't functioning the way it's supposed to.

The artificial lighting boosts productivity by allowing us to continue to work late into the night, but simultaneously has defined a society that is no longer in sync with the local time. What's worse, it could maybe have a terrible effect on human beings health.

The need of a better quality of life along with the development of the LED lighting technology enable the designer of today to envision new lighting landscapes through luminous systems which can simulate the sun light to make human beings back to nature. This evolution of the electrical lighting toward a good quality lighting caring the health of people is nowadays really expected and technologically possible.
After a deep analysis of the available technologies, the system will use piezoelectric sensors to monitor cardio-respiratory activities during sleep phases, and the information will be transferred to the lighting device so that it can adjust itself automatically. Thanks to the sensor technology and the dynamic features and potentials of the LED lighting technology today, we can create personalized lighting to mitigate circadian disruption, optimize mood and visual experience and improve our sense of wellbeing in better ways than ever before.

1.2 Purpose and goal

The daylight, as the first and natural light source, serves as the benchmark for the artificial lighting to mimic in order to optimize circadian health and wellbeing. In this thesis, we would like to interpret the features of daylight in terms of lighting distribution, colours of light, intensity and lighting dynamics in order to design this luminous variability inspired by nature from the complete darkness, passing to warm dim lighting toward brighter and colder lighting to wake up the body and activate the mental alertness in the morning. Differently, at the dusk, the lighting would accompany the relaxing moment before the bedtime with a warm lighting toward the complete darkness. In addition to this natural luminous behaviours, the system would be a night-time companion by lighting subtly the environment when the user wakes up to have a view of the surrounding without disrupting the circadian system. To sum up, the designed lighting system is able to reinterpret, in the artificial and digitalized world of lighting, the sunrise and sunset in order to accompany the sleep and awake phases accordingly to the circadian rhythm.
1.3 Thesis contribution

This thesis is about the exploration of the relationship between light and human circadian rhythms through research and design of a luminous system in order to understand how light affects sleep with all the consequences for the wellbeing and health of human beings. A luminous prototype for testing the lighting conditions and a lighting product were designed in order to deeply investigate this relationship and to define a system which could be useful for the awake and sleep timing in the domestic and hospitality (e.g. hotel and hospital) indoor environment. Based on the literature review, the research about circadian lighting has not yet disruptively entered the lighting design in domestic environment. The majority of the studies has been conducted in workplace and healthcare but the domestic environment is gaining interest because it is linked to the wellbeing of all people in their domestic environment. In fact, laboratory experiments have shown that light can reduce insomnia by helping the wake up in the morning with diminished sleep latency; it can increase mood and induce positive humoral conditions by preventing depression, it can support relaxation and turn health in general. In order to have a good monitoring of the sleep, a preliminary benchmark has been conducted on sleep trackers available on the market along with a study about the sensor capabilities. From that, the use of piezoelectric technologies has been selected for monitoring and tracking people's activities on the bed and their sleep stages. This system is gathering all the information and analyzing data that would be transformed in different lighting scenarios so that it can help the user to fall asleep and get up more comfortable in the right moment (not REM phase).

In addition to the circadian lighting features, the shape of the lighting system, its lighting distribution, intensity and colours of light have been designed in order to metaphorically represent an artificial sun into the domestic environment.

Ergonomy and simplicity of use have been studied and designed: SA (Sleep Awake) lighting system is controlled through gestural sensors and capacitive touch switches which enable the user's to control.

Compared to the other products available on the market, SA light is more systematically contain sleep tracking, sleep stage signal to determine the lighting effect and sleep analysis.
2 RESEARCH & ANALYSIS
2.1 Study on sleep

2.1.1 Sleep stages and wake up

Stages of sleep
There are five stages in human sleep, including four non-REM stages and one REM stage.

Rapid eye movement (REM) sleep is marked by extensive physiological changes, for instance, respiration will be faster, brain activity will be increased, heartbeat will be irregular like in the awake phase, eyes move rapidly accompanied with muscle tone throughout the body. People usually dream during the REM sleep stage, perhaps as a result of excited brain activity and the paralysis of major voluntary muscles.

Sleep characteristic and quality change with the interim from one sleep stage to another. Although the signs for transition among the five sleep stages are mysterious, it is important to know that these stages are independent. Each transition is defined by delicate changes in body function and each one is predictable and observable. Sleep stages are monitored and examined clinically with polysomnography, which provides reliable data regarding electrical and muscular states during sleep.

The awake phase before falling asleep
The waking stage is a relaxing wakefulness, it is the preparation stage for body to go to sleep. Generally speaking, when people get into sleeping, their body internal activities get slower, muscle begins to relax and the eye movements slow down.

Stage 1 Sleep
From the result of polysomnography monitoring, the activities during the stage 1 reduce 50% compared to the awake stage. Eyes are closed in stages 1, if someone are awakened in this stage he or she will feel as if they have not slept. The stage 1 may last 5 to 10 minutes.

Stage 2 Sleep
Stage 2 is the light sleep period. Polysomongraphy shows intermittent peaks and valleys, or positive and negative waves. These waves indicate the spontaneous periods of the mixture of the muscle relaxation and tone. Muscle tone of this kind can be seen in other stages of sleep as a reaction to auditory stimuli. If any sound is heard, the sleeper is not able to understand its content at this point. The heart rate will get slow and body temperature decreases which means that the body prepares to get into deep sleep.

Stage 3 and Stage 4 Sleep
These are deep sleep stages, with Stage 4 being more intense than Stage 3. These two stages are also known as deep or delta or slow-wave sleep (SWS), and during this period the sleeper is even less responsive to the outside environment, essentially cut off from the world and unaware of any sounds or other stimuli. It is
much more difficult to wake up a person during these two stages and if awakened from them they will often feel very groggy and may need nearly 30 minutes to get normal mental performance. Children and young adults tend to have more slow-wave stage 3 sleep than adults, and the elderly may experience little or no stage 3 sleep at all.

Non-REM Sleep
The period of non-REM sleep (NREM) consist of stages 1-4 and lasts from 90 to 120 minutes, each stage lasts from 5 to 15 minutes. However, stages 2 and 3 always repeat backwards before REM sleep. So, a normal sleep cycle has this pattern: waking, stage 1, 2, 3, 4, 3, 2, REM. Usually, REM sleep occurs 90 minutes after sleep onset as visible in the Figure 1.

Graph 2.1 Brain-wave patterns during wakefulness and sleep
Stage 5 (REM Sleep)
REM sleep is distinguishable from NREM sleep by changes in physiological state, including its characteristic rapid eye movement. In this stage, heart rate and respiration speed up and become unstable, the brain-wave figure shows that the brain wave is rapid and irregular (figure 1), furthermore the face, fingers and legs my twitch. Dreaming is frequent and sometimes vivid.

But paralysis occurs simultaneously in the major voluntary muscle (muscle of the chin and neck). Because REM is a mixture of encephalic (brain) states of excitement and muscular immobility, it is generally thought that REM associated muscle paralysis is meant to keep the body from acting out the dreams that occur during this intensely cerebral stage. The first period of REM typically lasts 10 minutes, with each recurring REM stage lengthening, and the last one will last for an hour. The dreams that you can remember after being awake happened right after REM sleep, and those who wake up at this stage will be more vigilant and full of energy than other stages.

“Stage 1 does not turn into drowsy wakefulness, as one might expect. Instead, the sleeper brain begins to emit long bursts of very rapid, somewhat irregular waves. The heart rate increases, your blood pressure rises, and your breathing speeds up and becomes more irregular. Small twitches in your face and fingers may occur.

Because the brain is extremely active while the body is entirely inactive, REM sleep has also been called “paradoxical sleep.” It is during these periods that vivid dreams are most likely to occur. People report dreams when they are awakened from non-REM sleep, too, but non-REM dreams tend to be shorter, less vivid, and more realistic than REM dreams, except in the hour or so before a person wakes up in the morning.

REM and non-REM sleep continue to alternate throughout the night. As the hours pass, stages 3 and 4 tend to shorten or even disappear and REM periods tend to lengthen and occur closer together. This pattern explains why you are likely to be dreaming when the alarm clock goes off in the morning. But the cycles are far from regular. An individual may bounce directly from stage 4 back to stage 2 or go from REM to stage 2 and then back to REM. Also, the time between REM and non-REM is highly variable, differing from person to person and also within any given individual. The reasons for REM sleep are still controversial. If you wake people up every time they lapse into REM sleep, nothing dramatic will happen. When finally allowed to sleep normally, however, they will spend a longer time than usual in the REM phase, and it will be hard to rouse them. Electrical brain activity associated with REM may burst through into non-REM sleep and even into wakefulness, as if the person is making up for something he or she had been deprived of.” [1]

[1] Chapter 5 Body rhythms and mental states
2.1.2 Sleep cycle analysis

There are 5 stages in a sleep cycle, they repeat and occur cyclically, each lasts around 90 minutes. Each subsequent cycle lasts longer, as its respective REM stage extends. Usually people may complete four to five cycle in a typical night sleep. NREM sleep and REM sleep continue to alternate through the night in a cycle. Some scientists speculate that specific sequences of NREM and REM sleep optimize both physical and mental recuperation as well as some aspects of memory consolidation that occur during sleep, but this has not been confirmed.

As we can see in the figure 2, the time in deep stage 3 sleep decreases and in REM sleep increases, so there is a greater proportion of stage 3 sleep in the earlier night and REM sleep has a greater proportion later in the night, particularly during the final two sleep cycle.
2.2 Relation between light & circadian rhythm

Human beings, like many creatures, have biological clocks that can stabilize human behavior through a series of mechanisms of neuro-humoral regulation, includingsleep and appetite. Daily rhythm cycle of the biological clock in the living body is about 24 hours. Our biological clock will be adjusted according to external conditions and light is our most important external conditions. Light can stimulate the human retina, through the signal to the hypothalamus to regulate a series of physiological behavior and the most important one is sleep. People distinguish between day and night through the perception of light, so when the light is strong, people will wake up.

“There so-called circadian rhythms are autonomous oscillations of the living systems with a periodicity of about 24 hours which can work without any external stimuli or cues which are used to resetting the clock. The National Institute of Health define “circadian rhythms” as “physical, mental and behavioural changes that follow a roughly 24-hour cycle, responding primarily to light and darkness in an organism’s environment.” The term commonly is used to refer to the body’s natural sleep-wake cycle.” [1]

There is a biological clock in almost every cell in human body and the cycle is around 24 hours. The biological clock work in mammals mainly involves two linked transcriptional / translational negative feedbacks involving four interacting biological clock proteins: CLOCK, BMAL1, PER, CRY. The biological clocks located in the suprachiasmatic nucleus (SCN) and the biological clocks of other parts of the body also act to maintain the biological rhythm, but the biological clock of this part is the "supervisor" of the other biological clock, called master clock. SCN is the only biological clock to receive light stimulation: the external light signal can be transmitted through the retina to the SCN where the biological clock is stimulated by the light and “adjust the rest of the body's biological clock.

[1] Casciani Daria. Artificial Sunshine The shape of light to come [C]
“Circadian rhythms are variation in physiology and behavior that persist with a cycle length close to 24 hours even in the absence of periodic environmental stimuli. It is hypothesized that this system evolved in order to predict and therefore optimally time the behavior and physiology of the organism to the environmental periodicity associated with the earth’s rotation. Because the cycle length, or period, of this endogenous timing system is near, but, in most organisms, not exactly 24 hours, circadian rhythms must be synchronized or entrained to the 24-hour day on a regular basis. In most organisms, this process of entrainment occurs through regular exposure to light and darkness.

Early reports from studies of human circadian rhythm had suggested that humans were unlike other organisms, being relatively insensitive to light and more sensitive to social cues to entrain their circadian systems. However, subsequent studies, and re-analysis of results from those early studies, have found that the human circadian system is like that of other organisms in its organization and its response to light, and is as sensitive to light as other diurnal organisms.” [1]

Light exposure to the eyes is the strongest. Melatonin plays a large role in effects of light on circadian rhythm. When an organism is exposed to a light stimulus, the hormone melatonin is suppressed, or prevented from being secreted by the pineal gland.

2.3 Connection between light & sleep and wake up

In 2002, a group of scientists found a photoreceptor responsible for the stimulation of entrainment in the human beings: it is a new group of cells behind the eyes which will help control the sleep patterns. When the light gets into our eyes to reach the retina behind the eyeball, the photoreceptor contained in the retina will respond to light. These cells will signal to the brain and the brain will adjust the secretion of melatonin. The level of melatonin in the blood determines whether you are sleepy or remain completely awake. At night, the body secretion of melatonin gradually increase and it will help to fall asleep. When the sunshine gets through the curtains into the room, although the eyes have not yet opened, the cells in the retina have responded to the blue light. They signal to the brain’s biological clock to remind the pineal gland of reducing the secretion of melatonin. Therefore, the body will awaken and be increasingly more alert.

"Human beings have their principal biological clock in the lower part of brain, located above the optic chiasm, the point where the optic nerves cross, in the suprachiasmatic nuclei SCN (next to the hypothalamus) which is genetically pre-programmed to execute cycle of about 24.2-24.5 hours, even if different human beings can present differences in terms of regulation and length of their cycle. The fundamental properties of the circadian rhythms are that they exist without external stimuli with a periodism which is called “free-running”. This can be re-set by cues which are mainly light and medicine.

This duration which is not exactly the day length is the reason why we talk about circadian cycles from circa (about) die (day). To be always on time with the day/night cycles on the earth, the biological human clock is synchronized every morning when a person get up with the legal timing available. How? When the light hits the retina, it sends a signal to the SCN to synchronize the human clock with the solar 24 hours of the day/night routine. The photoreceptors on the retina (Intrinsically photosensitive retinal ganglion cells ipRCG + Cones + Rods) which are responsible for the circadian system are shaped in a network so that, each point located on the retina, when hit by light, can activate the circadian response."

[1] Casciani Daria. Artificial Sunshine The shape of light to come [C]
Nowadays some modern digital products such as computer screens, cellphones produce high level of blue light in their lighting spectrum, and this bluish light, seen for a prolonged period of time in specific moment of the day like evening, usually suppress the body’s production of melatonin. The connection is widely accepted in the scientific community. The majority of people could benefit from a more regular daily natural light or, if not possible, from an artificial lighting which imitate natural light and recent developments support this summary:

“1. Studies going back several decades have established the link between melatonin and circadian/sleep rhythms. Recent scientific and medical studies are providing empirical and epidemiological evidence of the potential positive and negative effects of lighting on sleep.
2. Better scientific understanding of human circadian physiology has increasingly revealed the quantity, quality, and timing of light that is best for maintaining natural sleep-awake cycles.
3. Advancements in lighting technology now allow for precise spectral tailoring with LED technology.” [1]
2.4 Sleep analysis for a certain group of people

2.4.1 Personal sleep record of several group of people

To analyze the human’s habit on lighting use related to sleep activities and phase in their daily life, a preliminary ethnographic study was performed in order to understand the attitudes, gestures, activities of people when they are approaching the sleep, when they sleep during the night and when they wake up. The aim of this applied research phase was to select a sample of users different in terms of age, gender, cultural background, living conditions, family conditions and geographical location in order to have a wider spectrum of information.

People were asked to complete a diary in order to track their sleep activity from before bedtime to awake phase by reflecting specifically on the following elements: time, location, activity, lighting condition (natural or artificial light, warm light or cold light), mental state. They were afterwards interviewed deeply in order to know more information about their feelings, interpretation, desires and latent needs. In the following paragraph the users information and the responses will be briefly reported and summarized.
She always sets up 5 alarm clocks from 8:00 to 9:00 to wake her up on working days!

If she sleep alone she definitely sleep with a bedside lamp turning on because of the sense of fear.


20:00-24:00 play the majiang, have the tea (write light)
00:00-00:30 drive to barbecue
00:30-1:30 have the barbecue and chat with friends (bright warm light)
1:30-2:00 drive home
2:00-3:00 have wash (bright write light in bathroom)
3:00-4:00 play the cellphone (bright write light) in the bedroom, and after 40min shut the light
4:00-4:30 brew sleepiness (turn on the light for one time and go to toilet)
9:00 alarm clock wake up several times (weak natural light in bedroom because of the Anti-UV curtains)
Then get up and have a wash, ready for the trip.


19:30 have dinner (warm light)
20:00-23:00 chat after dinner (warm light)
23:00-23:30 take a bath and ready to bed (bright write light)
23:30-00.30 play the cellphone on the bed (turn off the light, turn on the night shift mode on the iphone)
08.30 wake up by the phone call and go on to sleep, the curtain is not anti-UV so the bedroom was bright but doesn’t effect sleep (already daybreak)
9:30 wake up by the phone call and get up, have a wash and breakfast
Name: Zoe
Age: 26
Profession: Luxury buyer
Location: Milan, Italy
Highest education level: Bachelor
Marital status: Unmarried

She has a special habit!
When she sleeps alone she usually wakes up in the middle of the night and feels scared, so she turns on the light and go on to sleep, but if she sleeps with her boyfriend she will not have the problem!

BTW... she works with her cellphone every single day.


22:45 play the cellphone in living room (warm light with the floor lamp)
23:50 take a shower and go to bed, lying in bed and play the cellphone (warm light)
00:20 turn off the light and fall asleep in about 10mins
3:30 wake up naturally and turn on the light, then go on to sleep (warm light with the bedside lamp)

10:45 wake up naturally, turn off the light and play the cellphone for about 30mins, then fall asleep again

11:30 get up
Name: Alex  
Age: 28  
Profession: Bar operator  
Location: Lago maggiore, Italy  
Highest education level: Junior high school  
Marital status: Unmarried

When he has something to do on the schedule, he usually set up 4 alarm clocks.

Sometimes he prefers to keep a dark warm bedside light on during the sleep


22:20-00.10 made a phonecall for almost 2 hours (warm light)
00:10-00:25 take a shower
00:25-00:45 lying in bed and play the cellphone (no light in bedroom, 35% screen light)
00:45 listen to the fiction by cellphone and fall asleep in about 10 mins

8:30 wake up naturally (a little natural light in the bedroom)
8:30-9:00 half asleep, very sleep and listen to the fiction by cellphone.
9:00-13:00 keep resting in bed, play the cellphone
13:00 get up
Name: Yuan
Age: 26
Profession: Interaction Designer
Location: Shenzhen, China
Highest education level: Master
Marital status: Unmarried

She only sets up 1 alarm clocks forever and she can get up immediately. She got a stable circadian rhythm so even if on the weekend she wakes up at 7:00 and get up!


19:40 back home after working, turn on the lights in dining hall (warm light) and living room (white light)
19:45-19:55 feed the cat, shovel cat feces, change the water for cat
20:00-22:00 watch the television, chat with friends on cellphone in living room (white light)
22:10-22:25 take a shower (white light in the bathroom)
22:30-23:30 lying in bed play the cellphone (warm light with the bedside lamp, and the cellphone screen light is pretty dark) then fall asleep
6:50-7:10 wake up by the alarm clock at 6:50 and get up immediately, catch the company bus at 7:10
He always has the problem to fall asleep and wake up too early.


21:40-22:30 back home after dinner outside, chat with friends on cellphone in the living room (white light with an energy saving lamp)
22:31-23:10 have a wash in the bathroom (dark white light with an 8W energy saving lamp)
23:11-23:19 make a bed and ready to sleep (white light)
23:20-23:30 fall asleep gradually (with the opened curtain, any dark light outside)
03:20-03:26 wake up and pee, very sleepy and a little bit unconscious (no light turned on, only with a little light outside in the dark)
03:27-03:32 back to the bedroom, fall asleep again
06:00 the alarm rings, turn off the alarm, a little bit unconscious and keep lying on bed (daybreak)
06:30 lying on bed for around 30 mins, the mind to be clear then wake up (natural light)
06:34-06:35 go to the bathroom, pee, have a wash (natural light)
07:11-07:40 have breakfast and play the cellphone (natural light, not very bright but sight clear)
2.4.2 Sleep record timeline

Table 2.1  User sleep record timeline
2.4.3 Personal sleep analysis and target user determined

Sleep habits of young people

This personal sleep analysis is based on the individual age, profession location, highest education level and marital status. According to the records and individual interviews a very interesting phenomenon is that the office workers usually set up several alarm clock in the morning on working days, most of them have the difficulty to get up and they are used to turn off the alarm over and over again till they really have to get up. A very few people can get up at once.

Actually, before this investigation I thought that newbie mommies will have the problem to get up because they really tried to handle with the baby. In fact, from the research, they don’t have much difficulty to wake up to feed their baby at anytime, maybe because of the power of love.

Different sleep habits between elderly people and young people

As people age they tend to have a harder time falling asleep and more trouble staying asleep than when they were younger. The sleep cycle is repeated several times during the night and although total sleep time tends to remain constant, older people spend more time in the lighter stages of sleep than in deep sleep. Many older adults, though certainly not all, also report being less satisfied with sleep and more tired during the day and they probably wake up to go to the toilet in the middle of the night and wake up very early in the morning. From the interview, it was expressed a preference for natural light compared to artificial light in the daily life.

“The human eyes’ lens become thicker and more yellow with age (60 years and above), this resulting in the reduction of the amount and the transformation of the spectral quality of lighting reaching the retina. The lens of older adults filters out prominently UV and short wavelengths of the spectrum.

Along with the decreased visual acuity, changed colour perception and limited contrast sensitivity, older adults experience also cognitive changes derived from the reduction of the number of neurons in the retina and in the suprachiasmatic nucleus (SCN). In addition to this, the reduction of mobility abilities determines more sedentary lifestyle, with the consequence of receiving less qualitative natural light. All these transformations influence the capacity of the light for entraining the endogenous circadian rhythm of elderly people which can cause insomnia (e.g. frequent nocturnal awakenings followed by frequent diurnal naps) and can be associated with the reduction of physical health (e.g. cardiovascular problems, irregularities of the endocrine system operation, decline in immune functions).”[1]

Sleep habits of people with free working time
From the interview of the bar operator participant and the luxury buyer participant, since their working time is flexible, they don’t care too much about falling asleep and wake up time. This users just have no habitudinary timing for sleep and awake rythms. Usually they play the cellphone much time everyday especially before sleeping, which means they are often exposed to the blue light and it will let them fall asleep very slowly after going to bed. Sometimes they get up at noon and go to work. So this group of people, which have free-running timing and periods of its circadian rhythm might be not so interested in a product to wake them up and to reset their biological clack. On the other hand, their freerunning circardian rhythm could be negative, at long term, for their health and wellbeing, so a similar product could make them more aware of the necessity to have a more controlled sleep-wake up habits.

Night-time fear and safety perception
Two participants (young females) claimed the necessity of having dim warm light beside the bed when sleeping alone because of the sense of fear. Another participant (young male) sometimes also prefer sleeping with the light turned on. Scientists say that the fear of the dark is an evolutionary mechanism, passed down to us from our ancestors who were regularly attacked by nocturnal predators. As we grow up, it takes time for our brains to realize that our fears are unfounded. Psychologists believe that 50% of children between the ages of 2 and 7 are afraid of the dark. And left untreated, that fear can continue on into adulthood: Among grown-ups, 8% of women and 3% of men are scared of the dark, which often leads to insomnia. So, that’s why some people need a dim light with them when they sleep.

Despite of this necessity of having lighting as a companion during the night, circadian studies has also demonstrated that darkness at night is crucial to not have disruption in the circadian rhythm. For this reason, complete darkness should be preserved during night-time. If lighting is considered necessary for reassurance, this has to have a specific spectrum lacking blue wavelength and should be also of low intensity (also because the visual system at night works in a scotopic mode) and not directly directed into the eyes.
Summarized conclusions

In conclusion, from this individual sleep record and interview, we can get that, generally, almost all kinds of people (regardless of age, job, etc.) have a sleep problem, some are difficult to sleep, some are dark fear before going to bed, and some are really hard to get up in the morning. The office workers indeed need a product that could make them feel more comfortable and clear-headed to wake up efficiently on time on the work days. The dark fear group wants a product with dim light to accompany them to fall asleep to feel safe and relieved. Middle-aged adults would need a product can let them take less time to fall asleep and spend more time in deep sleep as much as possible. Consequently, the new product and its system need to meet these above conditions, and these three groups of people will become the target customers.
2.5 Competitive analysis

2.5.1 Summarized analysis of wake up alarm, blue light blocking products, sleep tracker

Nowadays, as people pay more and more attention to sleep problems, there are already some sleep products on the market to help people improve their sleep quality. To understand deeply the competitors on the market, I have performed a detailed research on the most popular wake up alarms, blue light blocking products and sleep trackers available, by analyzing and comparing their strengths and weaknesses. In addition to this, I have also analyzed what type of sleep products are better suitable for every group of customers.
The BioBrite has both a gradual sunset and gradual sunrise feature helping you fall asleep at night and get up in the dark morning. You can program the radio background sounds fade out after a set time.

The Lumie Bodyclock was the first dawn simulator alarm made by a company that specializes in light therapy products. It resets your sleep/wake cycle and is claimed to help with SAD syndrome (Seasonal Affective Disorder), winter blues and other physical difficulties with waking and sleeping.

The Philips HF3520 lets you wake up with light and slowly in volume increasing nature sounds which add to the gentle awakening experience. Philips have done extensive research on waking up with artificial dawn simulators.

### Table 2.2: THE SUMMARY

<table>
<thead>
<tr>
<th>NAME</th>
<th>INTRODUCTION</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioBrite SunRise Clock Radio</td>
<td>The BioBrite has both a gradual sunset and gradual sunrise feature helping you fall asleep at night and get up in the dark morning. You can program the radio background sounds fade out after a set time.</td>
<td>$126.99</td>
</tr>
<tr>
<td>Lumie Body Clock Active 250</td>
<td>The Lumie Bodyclock was the first dawn simulator alarm made by a company that specializes in light therapy products. It resets your sleep/wake cycle and is claimed to help with SAD syndrome (Seasonal Affective Disorder), winter blues and other physical difficulties with waking and sleeping.</td>
<td>$139.00</td>
</tr>
<tr>
<td>Philips Wake-Up Light HF3520</td>
<td>The Philips HF3520 lets you wake up with light and slowly in volume increasing nature sounds which add to the gentle awakening experience. Philips have done extensive research on waking up with artificial dawn simulators.</td>
<td>$169.99</td>
</tr>
</tbody>
</table>
## OF WAKE-UP LIGHTS

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Backup battery for settings</td>
<td>1. Only one alarm setting option</td>
</tr>
<tr>
<td>(light does not work on battery but audible alarm does)</td>
<td>2. Clock readability may become problematic when light is in full intensity.</td>
</tr>
<tr>
<td>2. LCD display fades to low level when you want to sleep</td>
<td>3. Rather bulky</td>
</tr>
<tr>
<td>1. Class 1 certified medical device</td>
<td>1. Rather bulky</td>
</tr>
<tr>
<td>2. Wake up with 6 different sounds including radio, traditional alarm</td>
<td>2. Not as pretty as some other light alarms</td>
</tr>
<tr>
<td>sound, or nature sounds.</td>
<td></td>
</tr>
<tr>
<td>3. Doubles as a security light.</td>
<td></td>
</tr>
<tr>
<td>1. LED bulb (no need for replacement for 20 years)</td>
<td>High price</td>
</tr>
<tr>
<td>2. Light intensity: up to 300 Lux</td>
<td></td>
</tr>
<tr>
<td>3. Scientifically proven to work</td>
<td></td>
</tr>
<tr>
<td>4. Colored sunrise simulation</td>
<td></td>
</tr>
<tr>
<td>5. LCD display level can be set and fades when it becomes dark.</td>
<td></td>
</tr>
<tr>
<td>NAME</td>
<td>INTRODUCTION</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Philips Hue wake up light feature</td>
<td>It makes use of the knowledge that your brain chemistry is affected in different ways by different wavelengths of light. Appropriate light settings can influence your mental and physical wellbeing.</td>
</tr>
<tr>
<td>Iwaku smart wake up light and SAD light box</td>
<td>Next to a wake up light, it’s a sleep cycle alarm clock, and SAD light box. Clinical trials show that blue light is best to energize and cheer people up who suffer from the winter blues (in SAD therapy).</td>
</tr>
<tr>
<td>Withings Aura Sleep Tracker Wake-up Light</td>
<td>It comes with the Sleep Sensor that’s needs to be tucked under your mattress, an active light &amp; sound Bedside Device, and a smartphone app. The device is designed to both monitor and improve sleep quality by tracking heart rates, breathing cycles and body movements.</td>
</tr>
<tr>
<td>JBL Horizon alarm clock</td>
<td>Just like all these devices its ambient LED light gradually increases in intensity to wake you up gently. JBL is known for its excellent speaker quality so waking up with FM radio on your alarm clock will become a whole new experience.</td>
</tr>
<tr>
<td>Verilux Rise and Shine Natural Wake-up Light</td>
<td>Verilux has a fall asleep mode, four nature sounds (spa soundscapes), and FM radio. Also as many others it can be used as a bedside lamp that simulates the sunset.</td>
</tr>
</tbody>
</table>

All the information is from Amazon (USA).
ADVANTAGES

1. Can be used as normal lights that fade on before your alarm
2. Controlled by smartphone app

1. LED bulb
2. Blue light
3. Multifunctional
4. Not the smallest but has a stand allowing more space efficient placement

1. Bulb: multi-color LED
2. Sunset lighting feature to let you doze off at night
3. Lots of sleep sensing functions (and environmental sensory features later on)
4. Compatible with a wide range of apps

1. Bulb: LED
2. Lets you set two separate alarms
3. Superb JBL sound
4. Gadget charger

DISADVANTAGES

Not the most affordable option

1. Not compatible with all smartphones
2. High price.

1. Not very well reviewed.
2. High price.

1. Programming the alarm clock can be difficult without the manual
2. Some users dislike the light not increasing smoothly but in 20 steps.
3. Some people hear a buzz produced by the bulb
4. Display has two brightness settings and a blackout setting

Dosen’t have obvious advantages
### Table 2.3: THE SUMMARY OF BLUE LIGHT BLOCKING PRODUCTS

<table>
<thead>
<tr>
<th>NAME</th>
<th>INTRODUCTION</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue light blocking eyewear</td>
<td>Wearing these FDA-registered glasses at least an hour before bed allows you to use phones, tablets, computers and e-readers freely without disrupting your sleep.</td>
<td>€66.00</td>
</tr>
<tr>
<td>Blue light blocking screen protectors</td>
<td>In addition to prevent you’re wrecking your sleep these help prevent eye damage from electronic screens too.</td>
<td>€10.00</td>
</tr>
<tr>
<td>SWANWICK SLEEP</td>
<td>This eye mask and blindfold creates the ideal sleep environment no matter where you are by blocking out the maximum amount of light that keeps you awake and causes insomnia.</td>
<td>€37.00</td>
</tr>
<tr>
<td>F. LUX Blue light blocking software</td>
<td>It makes the color of your computer’s display adapt to the time of day, warm at night and like sunlight during the day.</td>
<td>Free</td>
</tr>
<tr>
<td>Amber-tinted blue light blocking bulbs</td>
<td>Blue-blocking orange light bulbs are an excellent way to put on some mood lighting that also helps you sleep. They are modern-day night lights for evening use.</td>
<td>€15.00</td>
</tr>
</tbody>
</table>

All the information is from Amazon (USA).
<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>You can block the blue light whenever and wherever you want as long as you put on it.</td>
<td>Not so beautiful</td>
</tr>
<tr>
<td>Often, consumers are a little unwilling to wear special blue-blocking glasses and find blocking light from the source is much easier.</td>
<td>Doesn't have obvious disadvantages</td>
</tr>
<tr>
<td>Lustrous wonder fabric allows your eyes to relax naturally and is ideal for travellers, shift workers, afternoon naps, meditation and more.</td>
<td>It is possible that there are environmental nasties such as dust mites, mold, and fungus so it needs clean often.</td>
</tr>
<tr>
<td>1. Make your eyes more comfortable when you use the digital devices.</td>
<td>Doesn't have obvious disadvantages</td>
</tr>
<tr>
<td>2. It's free.</td>
<td></td>
</tr>
<tr>
<td>This type of bulb has 8000 hours of life and uses less than ¼ the energy that normal fluorescent bulbs do, saving both your eyes and your electric bill.</td>
<td>Doesn't have obvious disadvantages</td>
</tr>
</tbody>
</table>
The bird-nest-esque tracker is equipped with a whole bunch of sensors — including a microphone, light sensor, particulate sensor, and temperature and humidity sensor — that work to log a summary of your sleep environment. The environmental tracking data is combined with Sense’s tiny “sleep pill” that attaches to your pillow to log sleep patterns. The result is a sleep log that is displayed on Sense’s mobile app.

The bevy of biosensors on the Jawbone Up3 mean that sleep tracking is one area it should excel. By monitoring a user’s heart rate, respiration rate, body temperature and galvanic skin response, it would be able to tell the difference between REM, light and deep sleep in better detail than rival devices.

Among the fitness trackers, Misfit Ray beats out a lot of the competition with its accurate sleep monitoring abilities. Features are slim - there’s no REM tracking and it doesn’t differentiate for moments in the night you randomly wake up, but it’s able to tell when you’ve nodded off pretty much immediately.

It providing a detailed insight into your sleep quality through the combination of movement sensors and constant heart rate monitor. It keeps things simple where sleep tracking is concerned, checking how much sleep you got and how restless you were, and providing a couple of goals to improve your sleep.
## TRACKERS AND MONITORS

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Beautiful design which is small and unobtrusive.</td>
<td>1. The sleep tracking isn’t the most accurate. Can mistake being still for</td>
</tr>
<tr>
<td>2. Measures time asleep, time to fall asleep, wakeings, times restless,</td>
<td>being asleep. Sometimes needs the wake up time manually adjusting.</td>
</tr>
<tr>
<td>and time spent in deep, medium and light sleep.</td>
<td>2. The microphone doesn’t record noise – it just tells you that there was</td>
</tr>
<tr>
<td>3. Good App with overall sleep score, sleep timings and interruptions</td>
<td>3. No snooze function on the alarm.</td>
</tr>
<tr>
<td>due to factors like noise.</td>
<td></td>
</tr>
<tr>
<td>1. Very accurate and automatic sleep monitoring.</td>
<td>1. No screen display to provide you with information during the day.</td>
</tr>
<tr>
<td>2. Advanced sensors giving a detailed assessment of your sleep, including</td>
<td>2. Less detailed activity monitoring than many other devices.</td>
</tr>
<tr>
<td>time spent awake, in light, deep and REM sleep.</td>
<td></td>
</tr>
<tr>
<td>3. Great price.</td>
<td></td>
</tr>
<tr>
<td>1. Accurate sleep monitoring abilities.</td>
<td>1. No screen display to provide you with information during the day.</td>
</tr>
<tr>
<td>2. Fashion appearance.</td>
<td>2. Less detailed activity monitoring than many other devices.</td>
</tr>
<tr>
<td>1. Automatic sleep tracking.</td>
<td>3. No REM tracking.</td>
</tr>
<tr>
<td>2. Records the total time asleep, number of times restless or awake and</td>
<td>1. No built-in GPS. You can sync it with a mobile phone to track your route</td>
</tr>
<tr>
<td>total time restless.</td>
<td>if required.</td>
</tr>
<tr>
<td>3. Accurate activity tracking, measuring steps, distance, calories,</td>
<td>2. It’s not waterproof.</td>
</tr>
<tr>
<td>floors and heart rate.</td>
<td>3. As with most wearable devices, it might mistake resting in bed for</td>
</tr>
<tr>
<td>4. Accurate and continuous heart rate monitor.</td>
<td>sleeping. You can manually change the time you fell asleep though.</td>
</tr>
<tr>
<td>5. Dedicated activity tracking modes, such as running, cycling, weights</td>
<td></td>
</tr>
<tr>
<td>and cross-training.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>NAME</td>
<td>INTRODUCTION</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Beddit 2.0 Smart Sleep Monitor</strong></td>
<td>The Beddit Smart Sleep Monitor is a dedicated sleep tracker which consists of a simple strip which lies under your bed sheet to track your sleep, with an accompanying App to use on your smart phone.</td>
</tr>
<tr>
<td><strong>S+ By ResMed Personal Sleep Solution</strong></td>
<td>S+ by ResMed is the first personal sleep tracker to work without requiring any physical contact. It just sits on your bedside table and monitors your sleep and bedroom environment from a distance.</td>
</tr>
<tr>
<td><strong>Withings Aura Smart Sleep System</strong></td>
<td>The Withings Aura Smart Sleep System isn’t exactly a subtle addition to the bedroom, but it makes up for that with its wide range of features. As well as monitoring your sleep, it includes a light and sound unit to help you relax and fall asleep, and then wake you up gently in the morning.</td>
</tr>
</tbody>
</table>

All the information is from Amazon (USA).
**ADVANTAGES**

1. Lots of different data tracking: your heart rate, breathing and snoring, time asleep or restless and times out of bed, time spent in light or deep sleep.
2. Smart alarm system wakes you up in the best part of your sleep cycle.

**DISADVANTAGES**

The measuring strip has to be plugged into the mains during the night to work. The sleep coaching is sometimes a little too generic. If you sleep with a partner they can disturb your results.

1. Accurate tracking of light, deep, REM and wake stages.
3. Detailed results and sleep graphs on a very clear phone App, with even more on the website. Printable sleep report you can take to your doctor.

1. Uses a lot of mobile phone battery, but does have a USB port to charge during the night.
2. Needs to be paired with your phone throughout the night.
3. You have to use your phone to control it.

1. The unit emits a fading glowing light on a timer. The specific red wavelengths are designed to help trigger melatonin production.
2. It tracks your time awake, time restless, time it took to fall asleep, time spent in light, deep and REM sleep.
3. Environmental sensors monitor room temperature, light and noise. The App then tells you if these factors disturbed your sleep.

1. Complex App with no sleep coaching telling you what to do with all the potentially useful data.
2. The instructions, touch interface and data interpretation are confusing.
3. It’s very expensive compared to other sleep trackers.
2.5.2 Comparison about sleep trackers

The following maps based on the previous tables are about wake-up light products, sleep monitor located in the space and wearable sleep monitor. The comparison is based on their price and product effectiveness, the aesthetic degree and how practical they are.

In the following lines, it is presented a summary aimed to map the solutions and to gather an idea of the market trend, so to help my product and system positioning.

Table 2.5: COMPARISON ABOUT THE WAKE-UP LIGHTS
Philips Wake Up Light HF3520
Iwaku smart wake up light and SAD light box
Withings Aura Sleep Tracker Wake-up Light
Philips Hue wake up light feature
Lumie Body Clock Active 250 (SAD therapy, Class 1 certified medical device)
Verilux Rise and Shine Natural Wake-up Light
BioBrite SunRise Clock Radio
JBL Horizon alarm clock
In these two diagrams I divide the wake-up products by not so effective to effective, cheap to expensive and not so attractive to attractive, not so practical to practical.

The effectivity – not effectivity polar scale means how professional and how useful this product is, in relation to specific functions which are presented in the product descriptions and which are reported by the feedback of the users. The cheap to expensive polar scale take into account the price differences between products. The attractivity – not attractivity polar scale indicate the aesthetic of the product, The practicality and not practicality polar scale means how much the product is easy to users in order to figure out all the functions and how often the users reported to desire to operate the products.

According to the customer reviews from Amazon, Philips wake up light HF3520 has 2969 customer reviews, which is much more than other competitors, and 61% users give it a 5 stars for the total score (which means that this product is highly appreciated) It may not be the most affordable but it has the best design and the highest review rating.

Another 4 and half score product is Philips hue, 82% users give it 5 stars but there are only 34 reviews. Despite of the small amount of reviews, the product still is perceived as highly attractive. Although Hue is cheap, it is not the best choice for being a wake-up light because some comments indicate that these bulbs are the white spectrum dimmer bulbs in the Hue set. They don’t do colors but a full range of white lighting colour temperatures. By contrast, a Philips sunrise wake up alarm displays more vivid and natural colours. I have to mention that JBL horizon is a good competitor since it got a 4 stars for the total score, although there are only 75 reviews from customers, 45% of them gave a 5 stars and 26% for 4 stars, and many of the reviews indicate that the sound is terrific.

Withings Aura Sleep Tracker wake-up light got 253 customer reviews, which has the review rating just behind the Philips HF3520, but the 5 stars probability is only 33%, some users complain about the APP is not effective.

In contrast, Philips HF 3520 and Withings Aura Sleep Tracker wake-up light are located in the second quadrant, meaning that they have more advantages at the level of effectiveness, aesthetics and practical application than others. Consequently, a popular light therapy product should effectively improve users’ sleep, energy and well-being. It should let people relax and drift off to sleep with dimming sunset and sounds. Colored sunrise simulation alarm clock wakes users gradually with natural light and several calming wake-up sounds to choose would be really great, and a tap-to-snooze function will be welcomed by the people who usually need set several alarm in their cellphone to wake themselves up.
I have performed again several interviews with the users which were previously part of the preliminary ethnographic study. I asked them to choose one product from the competitors and give the reason.

WHAT DO THEY CHOOSE...?

Lizzie:
“From the aesthetics aspect, I like PHILIPS HF3520 best. It looks attractive, simple and chic.”

Monkey:
“JBL horizon seems pretty cool!”

Alex:
“I prefer PHILIPS HUE bulb because it’s small, flexible and convenient.”
Table 2.6: COMPARISON ABOUT SLEEP MONITORS IN THE SPACE

<table>
<thead>
<tr>
<th>EFFECTIVE</th>
<th>NOT SO EFFECTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXPENSIVE</td>
<td>CHEAP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effective</th>
<th>Not So Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expensive</td>
<td>Cheap</td>
</tr>
</tbody>
</table>

- Beddit 2.0 Smart Sleep Monitor
- Withings Aura Smart Sleep System
- S+ By ResMed Personal Sleep Solution
- Hello Sense and Sleep Pill
- Withings Aura Smart Sleep System
- S+ By ResMed Personal Sleep Solution
- Hello Sense and Sleep Pill
The maps above are based on the 5 stars rate and the feedback from Amazon.

From the customer reviews of Amazon, we found that all these 4 sleep monitoring system’s total score are 4 stars. Withing Aura Smart Sleep System got the most reviews (253 reviews), but the rate of 5 stars is only 33%. Many reviews about Hello sense and sleep pill mention that the appearance is attractive, but the total number of it’s feedback is only 57. Beddit 2.0 smart sleep monitor got 140 feedbacks and the 5 stars rate reaches up to 60%, which is pretty good. From the two maps we can see that Beddit 2.0 smart sleep tracker does well in the aspect of effectiveness and practical application. It seems like that users are more interested in a product which can track sleep time, heart rate, snoring, breathing and night-time event automatically and wake you up at an optimal hour of your sleep cycle, and a coaching tips on how to improve sleep and wellness would be attractive.
Table 2.7: COMPARISON ABOUT WEARABLE SLEEP MONITORS

<table>
<thead>
<tr>
<th>Device</th>
<th>Effective</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jawbone UP3</td>
<td>Effective</td>
<td>Expensive</td>
</tr>
<tr>
<td>Fitbit Blaze</td>
<td>Effective</td>
<td>Expensive</td>
</tr>
<tr>
<td>Misfit Ray</td>
<td>Not so effective</td>
<td>Cheap</td>
</tr>
</tbody>
</table>
From the purchase record of Amazon, Fitbit Blaze is the “Best seller” in smart watch, it got 5552 customer reviews, 4 stars in total score and 64% of the customer gave 5 stars. The famous Jawbone got 3396 customer reviews but only 3 stars for total score, 30% users gave it 1 star and they indicate that Jawbone doesn’t live up to their advertising.

Obviously Fitbit Blaze is the most popular one. Many users are satisfied with its accurate heart rate monitor and automatic track of steps, sleep, workout, heart rate without the need to manually start an activity. These elements are crucial for a activity and sleep monitor product.
WHAT DO THEY CHOOSE...?

Lizzie:

“I’m not interested in a wearable device because I don’t want to wear a watch 24 hours, it’s not convenient and clean, and I think there is radiation. So... I prefer a product in the space.”

Monkey:

“Jawbone UP3 looks good but I don’t want to wear a device the whole day.”

Alex:

“I will not choose none of them. First of all, I don’t wanna wear a smart watch for a whole day even if when sleeping I cannot take it off. Secondly, if I put a sleep monitor beside my bed I’m afraid there is a radiation. Thirdly, I have the same worry about the wearable devices.”

Customers can make their decision based on what they want from their choice. If he or she like the idea of having activity tracking as well as sleep tracking, a wearable device could be more appropriate. If someone wants to wear a device on his wrist at night, or isn’t interested in activity tracking, he or she might prefer a standalone device. I took a short interview again with these 3 users below to understand what kind of device they will choose and why.

All of them choose a standalone device, it seems like that users care a lot about the electronic product radiation and how convenient is to use it.
2.5.3 Study about Philips wake up light HF3520, Beddit 2.0 smart sleep monitor and Fitbit blaze

According to the comparison about several most popular wake up light and sleep monitoring system and depending on a great deal of customer feedbacks from Amazon in USA, Philips wake up light HF3520, Beddit 2.0 smart sleep monitor and Fitbit blaze watch win the highest rate of praise in their field because these three products have a higher review ratings and 5 stars ratings of the total score. They are the most appreciated for several reasons.

Philips Wake Up Light HF3520

Figure 2.1 Philips wake up light HF3520
OVERVIEW

Coloured Sunrise Simulation wakes you naturally
Inspired by nature’s sunrise, light gradually increases within 30 minutes from soft morning red through orange until your room is filled with bright yellow light. This process of changing an increasing light stimulates your body to wake up naturally. By the time light has filled the room your chosen natural sound completes the wake up experience, leaving you ready for the day ahead.

Choice of 5 different natural wake up sounds
At your set wake up time natural sound will play to complete the wake up experience and ensure you are awake. The selected sound gradually increases in volume to your selected level within one and a half minute. There are five natural sounds you can choose from: Bird Song, Birds in the forest, Zen Garden, Gentle piano and Seaside Sounds.

FM radio lets you wake up with your favorite radio show
Listen to your favorite radio show while you are waking up.

Display automatically dims itself when the bedroom gets dark
The brightness of the display adjusts itself. If the bedroom is filled with light, the brightness increases to keep the display readable. When the bedroom is dark the brightness dims so it doesn’t light up your bedroom when you are trying to sleep.

Just tap the product to snooze
A slight tap anywhere on the Wake-up light, sets the snooze mode. After 9 minutes the sound will gently start playing again.

The only Wake-up Light clinically proven to work
At this moment in time the Philips wake-up light is the only one scientifically proven to work. In order to make the Wake-up Light the best possible product it can be in genuinely waking you up naturally and energized we have done a lot of clinical research. This research was conducted by independent science facilities to study and prove the effects of the wake-up light on the overall wake up experience. This way we have proven, among other things, that the Philips Wake-up Light not only wakes you more naturally, but also more energized and that it improves your mood in the morning.

Developed by Philips, experts in light for over 100 years
Philips was founded over a 100 years ago as a company that produced and sold lightbulbs. Over 100 years Philips grew into a global company that brings innovation in lots of different areas. To this day lighting still is the soul of Philips. The Wake-up Light is proud to continue its heritage by building on years of knowledge and expertise of the world’s most well known lighting expert.
Dimming light and sound gently send you off to sleep
Sunset simulation is a light therapy used before you go to sleep. Sunset simulation prepares your body to fall asleep by gradually decreasing light and sound to your set duration.

92% of users agree that it is easier to get out of bed
Independent research shows that 92% of Philips Wake-up light users find it is easier to get out of bed (Metrixlab 2011, N=209)

20 brightness settings to fit your personal preference
The sensitivity to light differs per person. In general, when using a higher light intensity a person needs less time to become fully awake. The 20 light intensities of the Wake-up light can be personalized and even be set up to 300 lux.

SPECIFICATIONS

Easy to use
Anti-slip rubber feet: Yes
Snooze type: Smart snooze
Display brightness control: Self adjusting
Instore demo fuction: Yes
Number of alarm times: 2
Tap snooze for sound: 9 minutes
Charges iPhone/ iPod Touch: No
Controlled by iPhone/ iPod App: No

Safety
UV-free

Sound
FM radio: Yes
Number of Wake-up Sounds: 5
Music from smartphone / iPod: No

Natural light
Brightness settings: 20
Colored sunrise simulation: Yes. Red, to orange to yellow
Light intensity: 300 Lux
Sunrise simulating process: adjustable 20-40 minutes
Sunset simulation: Yes

Technical specifications
Cord length: 150 cm
Frequency: 50/60 Hz
Insulation: Class III
Insulation Powerplug: Class II (double isolation)
Power: 16.5 W
Power Output Adapter: 12W
Type of lamps: Lumiled Luxeon Rebel
Voltage: 100/240 V

Figure 2.2 Philips wake up light HF3520
SOME NEGATIVE REVIEWS FROM AMAZON IN USA

No Full Dim Feature
“Having even a low light in your face all night is not acceptable.”

Too complicated to use
“It’s nice, but it is too complicated to use, and too easy to hit a button inadvertently, causing it to do things you hadn’t intended.”

“I tried my best to understand the instructions and set it up properly, but the light kept coming on and off at the wrong times in the night, and I hit the wrong button one night trying to turn it off and overslept the next morning.”

“There is no ‘easy’ way to turn off the alarm. ALL the buttons are very small on this product and it just make it awkward to reach/touch/switch the correct buttons without screwing up something (yes, I sound like an old lady, but it’s true!”)"
OVERVIEW

Beddit, as the name suggests, is a company focussed on sleep. In contrast to the increasing sophistication of wearable trackers, Beddit’s tech won’t monitor your fitness, count your calories or tell you when you missed a phone call. Fortunately, this one-trick pony happens to be an extremely solid performer in the sleep stakes.

Beddit Smart makes any bed a smart bed. With compatible iOS devices from Apple, the App automatically starts tracking your sleep when you go to bed. With compatible Android devices, you only need to open the Beddit App and select the start sleeping button. After you place the Beddit sensor strip on your mattress and under your bed sheet, download the App from Apple’s App Store or Google Play, and then pair the sensor with your device.

Enter some information about yourself. Go to sleep. In the morning, all you have to do is check the app to see your sleep data. Beddit will help you understand how well you slept, and offer suggestions on how to improve your sleep. Beddit Smart tracks your time in bed, your time asleep and awake, your sleep cycles and sleep patterns, resting heart rate, breathing frequency and your snoring.

SPECIFICATIONS

Beddit Smart monitors your sleep - without any disturbing wearable sensors.

Beddit Smart enables totally automatic sleep measurement with iOS devices, No user action is required to start the measurement.

Beddit tracks sleep time, heart rate, snoring, breathing and night-time events, e.g. bed exits.
Beddit’s Smart Alarm clock wakes you up at an optimal hour of your sleep cycle.

Beddit gives you coaching tips on how to improve your sleep and wellness. Kindly refer to the user manual for the instructions.

CSV export – Users who want to have access to their sleep stats in a text format can download a CSV file for easy import into Excel. This works well and gives you a clear, column by column layout of all the metrics you can see in the app.

API – Beddit’s application programming interface (API) allows developers to take Beddit’s sleep data and use it in third party apps and services. Future plans include access to ‘raw’ sensor data for complete control.

Apple Health – Beddit also offers full support for the Apple Health platform, allowing you to share your Beddit data with Apple devices that support iOS 8 or above. This includes the Apple Watch, which includes a SmartNap application.

Figure 2.4 Beddit 2.0 smart sleep tracker APP, watch and sleep sensor belt
SOME NEGATIVE REVIEWS FROM AMAZON IN USA

Sleep score is meaningless
“During which I slept as poorly as I normally do, I earned not one, but TWO perfect 100 sleep scores as well as a 99 last night, where I tossed and turned and woke twice from nightmares, taking almost an hour to fall back asleep.”

“I'm sleeping like a baby and the beddit keeps saying that I'm sleeping 2 hours per night... LOL.”

“I stopped using after about two weeks because I was too frustrated with how unreliable it was. Sometimes it wouldn't think that I went to bed until hours after I had been in bed. Other nights it wouldn't detect me at all. The nights that it did work, it gave really cool information.”
FITBIT BLAZE SMART FITNESS WATCH

OVERVIEW

Get fit in style with Fitbit Blaze—a smart fitness watch that helps you maximize every workout and every day. With advanced technology in a versatile design, this revolutionary device is built to track your workouts, monitor your performance stats, and gauge your progress. PurePulse continuous heart rate and multi-sport modes enhance every exercise, while next-generation features like Connected GPS and FitStar workouts on your wrist help you take your fitness to the next level. All-day activity and sleep tracking and call, text & calendar notifications help you track your day with ease. And interchangeable band and frames and customizable clock faces on the hi-res color touchscreen let you personalize your style for every occasion. With all this and more, Fitbit Blaze has everything you need to reach your goals, packed into one sleek time piece.

SPECIFICATIONS

Fitbit Blaze syncs automatically and wirelessly to 200+ leading iOS, Android and Windows devices using Bluetooth 4.0 wireless technology. Syncing to computers requires Internet connection and USB port. Syncing to mobile devices requires Bluetooth and Internet connection.

Syncing range: 20 feet

Water Resistance: Fitbit Blaze is sweat, rain and splash proof, but is not swim proof.

Battery life: lasts up to 5 days. Radio transceiver: Bluetooth 4.0

Charge time: One to two hours

Syncs with Windows Vista and later, Mac OS X 10.6 and up, iPhone 4S and later, iPad 3 gen. and later, and leading Android and Windows devices.
SOME NEGATIVE REVIEWS FROM AMAZON IN USA

Syncing Issues
“We tried not one, but two of these, and both had the exact same syncing issues – in that the watch refused to sync to the phone. We received a repeated error “Sync Error - Try Again”. The first one was returned for a replacement, and the replacement was returned for a refund. After hours of troubleshooting steps and almost an hour on the phone with Fitbit customer support, the issues could not be resolved. They had no idea why the phone (a Nexus 6P) would not sync to the watch, and after much research (after the fact) I have found that this is a very common problem with this particular style of Fitbit. Even the Amazon representative I spoke with said as much – Amazon in fact has information in their system that this is a common (and apparently) unexplained product defect.”

“I purchased this watch in August of this year. I loved it!! Now it will not sync with my phone (iphone) the time is wrong and I've tried everything that is suggested to fix and it won't fix. I am very frustrated that i've had this watch for only 4 months and it's not working properly and there is no return policy for such issues.”
CONCLUSION

People spend around a third of lifetime asleep, with the amount and quality of sleep having a huge impact on the other two thirds of lifetime. So it’s very important to know how long we really sleep and whether we are getting enough good quality sleep because we need to start a new day full of energy. More and more people realize that a good quality sleep and a comfortable waking up mean a lot for the whole day. According to the reviews of these three most popular products from amazon and the individual interviews, we get that the accuracy of sleep track device is very significant, although the technology is improving at a fast pace, there are still limitations to personal sleep tracking and this is the vital thing we need to figure out. Then, some people need absolute dark when sleeping, however, some prefer a dim warm light beside the bed and actually many people have this habit. For this reason, a new lighting system needs to integrate a function to guarantee a sense of safety and reassurance to this group of users. Moreover, the function of the product should be easy to understand and operate, I consider to use sensors inside the product and make it gesture-controllable. According to the customer feedbacks from amazon, many users complained about the buttons which are generally too small or too complicated to use. In contrast, a sensor device would be more convenient and modern. Furthermore, the light should set different colors and nuance of white lighting for every mode depending on user’s activities. Finally, since many users want to gather insights about their sleep, an APP is necessary for recording all the awake-sleeping data and it will analyze and give users sleep suggestions.
2.6 Analysis of LED

2.6.1 What is LED?

Light-emitting diode (LED) is a light emitting semiconductor electronic components, it is a composite light source through the trivalent and pentane elements. This kind of electronic components appeared in 1962, the earliest LEDs can only emitted low-intensity infrared light. Then it developed some other monochromatic light and nowadays modern LEDs are available across the visible, ultraviolet and infrared wavelengths, with pretty high brightness.

2.6.2 Working principle

When the diode is forward biased, then the electrons and holes are moving fast across the junction and they are combining constantly, removing one another out. Very soon after the electrons are moving from the n-type to the p-type silicon, it combines with the holes, then it disappears. Hence it complete the atom and make it more stable and it gives the little burst of energy in the form of a tiny packet or photon of light.

![Figure 2.7 The inner workings of an LED, showing circuit (top) and band diagram (bottom)](image-url)
"A P-N junction can convert absorbed light energy into a proportional electric current. The same process is reversed here (i.e. the P-N junction emits light when electrical energy is applied to it). This phenomenon is generally called electroluminescence, which can be defined as the emission of light from a semiconductor under the influence of an electric field. The charge carriers recombine in a forward-biased P-N junction as the electrons cross from the N-region and recombine with the holes existing in the P-region. Free electrons are in the conduction band of energy levels, while holes are in the valence energy band. Thus the energy level of the holes is less than the energy levels of the electrons. Some portion of the energy must be dissipated to recombine the electrons and the holes. This energy is emitted in the form of heat and light."[1]

2.6.3 Advantages & disadvantages

Advantages of LED

Energy Efficiency
It is estimated that an LED lamp offers between 80-90% energy efficiency when compared to a traditional incandescent light bulb. That means when the LED lamp is turned on, about 80% of the energy is used to illuminate actually goes into making the light, while the other 20% is given off as heat. While that may seem like a lot, it's not when you compare it to an incandescent light bulb where's the direct opposite -- 20% of the energy goes into the light and 80% is given off as heat. Obviously there's quite a bit of savings there, both in terms of the energy used and money being spent on that electricity. Plus being the lamp emits much less heat makes it safe as it's cool to the touch.

Lamp Life
LED has a incredibly long lifespan. Some LED lamps can last for as long as 100,000 hours, however a standard incandescent light bulb will last around 750 to 2,000 hours, and on average a fluorescent lamp will get you about 20,000 hours. Not only does its long life mean that you won't need to buy a lot of them, but it also means you can cut down on labor costs as you won't need to pay anyone to keep an eye on them or change them out for a very long time.

Eco-Friendly
LED lighting is environmentally friendly. Because a LED lamp is not made with any hazardous chemicals, compared to fluorescent lamps that include mercury and need to be disposed of in a special way. About 95% of LED lamps are able to be recycled -- that would mean it would not have any type of hazardous material inside.

Disadvantages of LED

Price
Although over the past years the price point for LED lamps has continued to drop, it is still a bit higher than incandescent and fluorescent lamps, which could potentially make them cost-prohibitive for some people.

Qualitative lighting Limitations
Another potential con to using LED lighting is its ability to create white light. Additionally, as the LED lamp is used, sometimes the LEDs themselves can begin to degrade in terms of the color quality of the light produced. And in lamps that are poorly designed, this can also lead to flickering, loss of brightness, and unbalanced light.

Temperature
LED lighting has also been found to be sensitive in terms of temperature. If an LED lamp is used in a location that has a raised surrounding temperature, it may cause it to overdrive and fail. To avoid this problem, LEDs generally require a heat sink to help keep it cool and working properly.

"Lighting-class LEDs are now available that deliver the brightness, efficacy, lifetime, color temperatures, and white-point stability required for general illumination. As a result, these LEDs are being designed into most general lighting applications, including roadway, parking area, and indoor directional lighting. LED-based luminaires reduce total-cost-of-ownership (TCO) in these applications through maintenance avoidance (since LEDs last much longer than traditional lamps) and reduced energy costs.

There are over 20 billion light fixtures using incandescent, halogen, or fluorescent lamps worldwide. Many of these fixtures are being used for directional light applications but are based on lamps that put out light in all directions. The United States Department of energy (DOe) states that recessed downlights are the most common installed luminaire type in new residential construction. In addition, the DOE reports that downlights using non-reflector lamps are typically only 50% efficient, meaning half the light produced by the lamp is wasted inside the fixture.

In contrast, lighting-class LEDs offer efficient, directional light that lasts at least 50,000 hours. Indoor luminaires designed to take advantage of all the benefits of lighting-class LEDs can:
- Exceed the efficacy of any incandescent and halogen luminaire.
- Match the performance of even the best CFL (compact fluorescent) recessed downlights.
- Provide a lifetime five to fifty times longer than these lamps before requiring maintenance.
- Reduce the environmental impact of light: no mercury, less power-plant pollution, and less landfill waste." [1]

2.6.4 Applications

Today, LEDs are the lighting medium for general lighting applications. Thanks to improved luminous efficacy and brightness, along with efficiency and long life, they have revolutionized the market. It meets the need for energy-efficient lighting solutions unlike any other light source. This is where the LED is groundbreaking. You can find LEDs in all areas of life. Whether indoors or outdoors, for decorative or functional use - LEDs offer fascinating possibilities now and in future.

2.6.5 Introduction of RGBWW LED

SK6812 RGBWW Warm White LED strip is the newest upgraded version of WS2812B LED. SK6847 has a richer color change and color combination possibilities, which means every led lighting effect can be controlled. Work under DC5V, each LED is individually addressable, with 8 bits of red, green, and blue data shifted in for 24 bit color. Strips take data in green, red, blue order. Match use controller can appear colorful curtain-up/ flow water/raindrop/jump flash and so on hundreds of lighting effect, you can also edit animation effect by Coreldraw/Flash/LedEdit software. Low power consumption, Super-bright but running with low temperature. All the light spread and completely smooth and luminous. Every LED can be arbitrary cut off with good flexibility and can be arbitrary bending according to your requirement.

So for the SA light it is perfect to choose RGBWW Warm White LED strip to make the different lighting effects.

Figure 2.8 SK6812 RGBWW LED strip
3 CONCEPT DEVELOPMENT
3.1 The needs and strategies for the SA sleep light design

Due to the case study of the most popular products for the wake-up light and sleep monitor, and the large amount of customer feedbacks from Amazon in USA, combining to individual sleep records and interviews, I have grown to understand the users and their needs, and I’ve analyzed and synthesized my observations. With this solid background, a preliminary prototype has been designed and made in order to test the lighting output and the overall performances of the system. In the following paragraph I make the list of requirements of the SA lighting system:

1. Automatic monitoring of the sleep phases
   The sleep is monitored through the use of a reliable belt (piezoelectric sensor) under the bed sheet and the light will adjust itself automatically to different modes according to the users’ sleep stages.

2. Light imitating nature
   The lighting will imitate the natural sunrise light in terms of colours and shape: from dim red, warm orange to bright natural white light to wake the users up. The same biomimetic approach would happen for the nighttime when the users sleep requires the complete darkness. In order to ensure no circadian disruption, the lighting system during the night turns on a subtle luminous sign which resembles an half moon illuminating indirectly the wall and the pavement so to ensure visibility.

3. Lighting sign and companion
   Some people need the sleep environment completely dark, however, there is a group of people require a dim amber light near the bed when sleeping otherwise they will feel scared. The darkness is needed to not activate the circadian system and for this reason, even though a nocturnal light is made for fear problems it would be of a particular spectrum (missing blue) which is not creating the problem of rephasing the biological clock and it is going to be away from the direct eyes vision. Moreover its intensity would be very low but enough to ensure scotopic vision at night, it would be also an orientation signal and reassuring company for the night.

4. Simple to interact
   The light can also be controlled manually. It has a functional reading mode when users read before sleeping, and there are half-moon mode and dim moon light mode when users are ready to go to sleep or when they get up in the middle of night. The interaction happens through the use of a touch sensor and a gesture sensors which are placed at the bottom of the light. Touch capacitive sensors are used to turn on or turn off or to change mode. The gestural sensor is used to adjust the intensity and color temperature.
5. Gentle music to wake up:
A Gentle alarm clock can be set up by an APP connected to the mobile phone and it will ring when the monitoring system sends the signal after the sunrise lighting (the lighting helps users to wake up naturally and more comfortable and the gentle alarm will ensure users would get up). Since many people have the problem to wake up immediately when alarm is ringing, they are used to set up several alarms to really get up, so the snooze mode is necessary. Users can touch the bottom of the light to turn off the alarm sound.

6. APP
Users can get the sleep score of the last night and sleep analysis and suggestions from the app. They can set the sleep sound for going to fall asleep (sound of water flow, chirp, sea water ...etc) and wake up.
3.2 The concept and storyboard

According to the case study and user research, I make the product these functions to meet the target customer’s requirements.

READING MODE

22:00
WARM WHITE LIGHT  2700K

HALF MOON MODE

23:00
For those people who are used to sleep with a cozy dark warm light because of lacking a sense of security.

It will turn off automatically half a hour after you fall asleep (sleep tracker sensor is under your sheet)
SUNRISE MODE

SLEEP-WAKE UP MODE
IMITATE THE SUNRISE

07:00
DIM WARM RED LIGHT

07:10
WARM ORANGE LIGHT

07:20
BRIGHT LIGHT

Drawing 3.3  Design concept sketch
07: 25 Alarm ringing, touch the bottom, ringing stops
07: 35 Alarm ringing again, touch the bottom, ringing stops
07: 45 Alarm ringing again, touch the bottom, ringing stops
07: 55 Alarm ringing again, touch the bottom, ringing stops, get up.

Graph 3.1 The sleep stages and the lighting modes

Drawing 3.4 Design concept sketch
It’s smart light wakes you gently, up to around 50 minutes before your set time, depending on the stage in your sleep circle.

The sensor can monitor which sleep stage you are, and the wake up system will turn on automatically. For example, you set the get up time is 8:00, then the light will turn on at around 7:00 in dim warm red light as the sunrise, then it becomes warm yellow, then bright. Now REM step is nearly finish and your retina feels the light gradually and your brain is ready to wake up, in this moment, the alarm rings. the sound is your favorite music because you set it by your cellphone last night, you raise your hand and touch the bottom of the light gently to have a nap, after 10 minutes the lovely alarm rings again...another 2 times alarms later, you really refresh and get up.

SLAP:
There are two capacitive touch switches at the bottom of the light, one is for turning on/off the light (capacitive touch switch 1), the other one is for stopping the ringing (capacitive touch switch 2).

1. Touch the right bottom of the light one time to turn on the light, and one time again to the half moon mode.

2. When light turns off, touch the right bottom of the light two times to activate full moon mode, this mode is useful for people go to the toilet at night.
3. The gentle alarm will ring after the sunrise bright light mode, when it rings, one touch on the left bottom of the light can stop it.

There is a gesture sensor at the middle of the bottom of the light, users can adjust the lighting brightness and color temperature by moving a hand.

Users can adjust the lighting brightness from bright to dark by moving up and down the hand under the light.
Users can adjust the lighting color temperature from cold to warm by moving the hand from left to right.
Lighting effects

READING MODE
If the user wants to read a book before sleeping, touch the right bottom of the light one time to turn it on.

HALF MOON MODE
If the user is ready to sleep, touch the right bottom of the light again to half moon mode.
1. If the user prefers sleep with a dim light, 30 minutes after being tested to fall asleep, light turns off automatically.
2. If the user wants to sleep without light, touch the right bottom of the light one time again to turn it off.

FULL MOON MODE
When the user gets up in the middle of the night, touch the right bottom of the light two times to activate it.

SUNRISE MODE
55 minutes before the setting time to get up (REM stage)

45 minutes before the setting time to get up (REM stage)

35 minutes before the setting time to get up (REM stage)
3.3 Characteristics of the lighting output and experiments

3.3.1 Lighting test

It's necessary to have several test to preliminary mimic the lighting effect and color temperature of every mode in order to figure out how much luminance they need.
Figure 3.1 Materials for lighting test

- Osram Parathom Classic A 25
- 6W=25W
- 290Lm
- 3000K warm white

White plastic sheet
Osram Circolux EL
24W/827 220-240V E27

Philips EcoClassic A60
35W=75W
850Lm
2800K

(General Electric) 60W R63 ES
E27 Reflector Spot Light Bulbs

Osram Halolux Ceram 75W matt
E27 230V 165mm 64474IM

Illuminance Meter T-1H

Cables
Figure 2  Materials for lighting test

colorful plastic sheets

Red

Yellow

Dark Red

knife
I made the sheets to be covers, and put the bulbs into it as a light box. The light boxes will be put on the bedside table with different bulbs inside to do several tests.

Figure 3.3 Lighting test 1 in bedroom

THE LIGHT TEST 1

I use the Illuminance Meter T-1H instrument to measure the illuminance on a book of these 6 bulbs (see figure 3.16) in the following photo when the user sits at the position 1 on the bed and learns on the bedside with his or her legs at an angle of 45°on the bed, reading a book at the position 1 (figure 3.15). I will know the lighting effect of each bulbs and its illuminance on the pages of the book.
<table>
<thead>
<tr>
<th>Lighting Bulbs</th>
<th>Illuminance</th>
<th>Lighting Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osram Circolux El 220-240V E27 24W/827</td>
<td>155 lux</td>
<td>2700K</td>
</tr>
<tr>
<td>Osram Dulux El Longlife 15W/827 15W=75W</td>
<td>53 lux</td>
<td>2700K</td>
</tr>
<tr>
<td>Philips EcoClassic A60 53W 850Lm</td>
<td>72.9 lux</td>
<td>2800K</td>
</tr>
<tr>
<td>Osram Parathom Classic A 25 6W 290Lm</td>
<td>28.5 lux</td>
<td>3000K</td>
</tr>
<tr>
<td>General Electric 60W R63 ES E27 Reflector</td>
<td>17.8 lux</td>
<td>2700K</td>
</tr>
</tbody>
</table>
THE LIGHT TEST 2

To find the appropriate lighting for reading before sleeping, I make an user sit on the bed and read a book, and I’ll measure the illuminance on the page (refer to Figure 3.15).

Step 1:
Sit on the bed at the position 1 and put the book on the legs at the angle of 45°, draw the mesh in 5 x 5 cm on the page of A4, use Illuminance Meter T-1H to test the illuminance of Osram Circolux El and (General Electric) 60W R63 ES E27 Reflector Spot Light Bulbs at every point of the mesh on the page then get an average data.

Step2:
Measure the illuminance on the retina of both left and right eyes when looking straight ahead.

Osram Circolux El
24W/827 220-240V E27
1600Lm
2700k

AVG = 126.94Lux
The illuminance on the retina when looking on the page
left eye: 13.5 Lux
right eye: 12.9 Lux

Figure 3.4 Lighting test 2 Osram Circolux El
24W/827 220-240V E27 lighting on the page of the book
(General Electric) 60W R63 ES E27 Reflector Spot Light Bulbs 2700k

AVG = 21.1 Lux
The illuminance on the retina when looking on the page
left eye: 12.4 Lux
right eye: 11.9 Lux

CONCLUSION:
The Osram bulb (126.94 lux) is more appropriate than GE (21.1 lux) for reading on the bed before sleeping, the illuminance is gentle but users can still read the words clearly. Based on this experimental study, I would assume that SA lighting system should have at least a total flux of 1600 lumen in order to ensure that the illuminance on the page is comfortable and useful for visual performances.

In addition to this, this flux and distribution would also provide, based on the measurements, lower levels of lux (120-200 lux) on the eyes, this not inducing circadian phase shift and so not having disruptive consequence on sleep/awake cycles.
THE LIGHT TEST 3
I'll use the bulb and several colorful plastic cover to make a lamp to mimic the sunrise light. I'll simulate the sunrise mode from dim red to warm orange then to bright yellow and these three modes' illuminance need to be measured. I will measure the illuminance at these 6 points on the bed (figure) and get an average value for each mode.
(General Electric) 60W R63 ES E27 Reflector Spot Light Bulbs 2700k

Figure 3.7 Lighting test 3 to mimic the sunrise dim red lighting effect

AVG = 0.27 lux

Figure 3.8 Average value illuminance in the bedroom of the dim red lighting
Philips EcoClassic A60
53W
850Lm
2800k

Figure 3.9 Lighting test 3 to mimic the sunrise warm red lighting effect

AVG = 0.55 lux

Figure 3.10 Average value illuminance in the bedroom of the warm red lighting
Philips EcoClassic A60
53W
850Lm
2800K

Figure 3.11 Lighting test 3 to mimic the sunrise warm yellow lighting effect

AVG = 2.29 lux

Figure 3.12 Average value illuminance in the bedroom of the warm yellow lighting
Philips EcoClassic A60
53W
850Lm
2800K

Figure 3.13  Lighting test 3 to mimic the sunrise bright lighting effect

AVG = 7.37 lux

Figure 3.14  Average value illuminance in the bedroom of the bright lighting
CONCLUSION:

For the sunrise mode the illuminance for the bedroom should start from extreme darkest light (<1 lux) to 5-10 lux for the bright sunrise, and at least 10-15 lux for the position on the bed that near the SA lighting to let users feel the light get their retina and be awake gradually without feeling disgusting.
4 TECHNOLOGICAL STUDIES
4.1 Sleep monitor and tracking

4.1.1 Introduction of the smart monitor and tracking

If someone’s doctor suspects that he or she has a sleep disorder, they might refer their patients to a sleep clinic. And there, depending on the patients’ circumstances, they might decide to do a sleep study, known as polysomnography (PSG). This typically takes place over a night or two, with different pieces of equipment measuring your sleep stages and cycles. Someone will usually observe you while you sleep as well, and so a lot of information is gathered about your sleep, including:
- Brain waves (EEG).
- Breathing, including how easily or not your breathe, how often you stop breathing and for how long.
- Heart rate and rhythm.
- The flow of air in and out of your lungs.
- Muscle activity.
- The positions you sleep in during the night.
- The movement of your eyes.
- Oxygen levels in your blood.
All of this information is then used by the sleep specialists to assess your sleep and diagnose any sleep disorders. It’s easy to see then why Polysomnography is sometimes referred to as the gold standard of sleep monitoring.

The key measuring tool of sleep monitors is called actigraphy. Actigraphy essentially involves recording movement through a measuring device called an accelerometer.

“The idea being then that a certain amount of movement corresponds with being awake, and periods of being still corresponds with being asleep.

It has in fact been used by sleep clinicians for 30 years to measure sleep. Even though Polysomnography is the gold standard for sleep measurement, actigraphy also plays an important role, especially as Polysomnography isn’t without its own issues.

When a patient is hooked up to multiple machines with around 20 electrodes placed on their head, and in a lab rather than their own bed, they understandably might not sleep normally.

So not only is actigraphy less expensive than Polysomnography, but people can wear a device in their own home for a week or two, giving a more natural insight into their sleep than just one or two nights in a clinic.” [1]

So sleep monitoring technology used to be expensive, bulky and complicated to set up but the last few years with a growing awareness of sleep as a health concern, the development of smart phones, the rise in “big data” analytics and a trend towards personalized healthcare, there has been an explosion of interest in gadgets and software designed to evaluate our sleeping and nowadays millions of people are using gadgets to monitor it. According to my research before, a sleep monitor in the space is more popular than a wearable sleep tracker, so it is reasonable to choose a sleep monitor belt to be set under the bed sheet to tracker our users sleep activities.
4.1.2 Smart mattress sleep sensor belt signal docking instructions

For the sleep sensor belt I chose the IM-90060A/B sleep sensor, 900mm x 60mm, is made my silver plating PVDF piezoelectric film with high level sensitivity aimed to monitor users’ breath, heartbeat, waking, leaving the bed and sleep quality information.

The smart mattress sleep sensor signal docking instructions is presented below:

1. Connecting to the sensor belt with USB serial device, the pin signal of the sensor is defined as follows:

<table>
<thead>
<tr>
<th>PIN</th>
<th>signal</th>
<th>signal description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VBUS</td>
<td>Power source, 3.3V-5V</td>
</tr>
<tr>
<td>2</td>
<td>TX</td>
<td>TTL UART TX 2.5V</td>
</tr>
<tr>
<td>3</td>
<td>RX</td>
<td>TTL UART TX 2.5V</td>
</tr>
<tr>
<td>4</td>
<td>NC</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td>Power source ground</td>
</tr>
</tbody>
</table>

Table 4.1 pin signal of the sensor

2. Open this USB serial device with the serial debugging software on the PC, as shown below:

![USB serial device with serial debugging software on the PC](image)
3. The data is analyzed as follows:

<table>
<thead>
<tr>
<th>Bytes description</th>
<th>Prefix</th>
<th>Value (High)</th>
<th>Value (low)</th>
<th>Random bytes</th>
<th>checksum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate</td>
<td>1</td>
<td>2</td>
<td>44</td>
<td>1</td>
<td>48</td>
</tr>
<tr>
<td>Respiration rate</td>
<td>3</td>
<td>0</td>
<td>ce</td>
<td>1</td>
<td>d2</td>
</tr>
<tr>
<td>Sleep indication</td>
<td>4a</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4b</td>
</tr>
<tr>
<td>Urging instructions</td>
<td>4b</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4c</td>
</tr>
<tr>
<td>Weak breathe indication</td>
<td>4C</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4d</td>
</tr>
<tr>
<td>Slowly removed indication</td>
<td>4d</td>
<td>0</td>
<td>0</td>
<td>32</td>
<td>7f</td>
</tr>
<tr>
<td>Indication from by someone to no one</td>
<td>4e</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4f</td>
</tr>
</tbody>
</table>

Table 4.2 Data pack format (hexadecimal)

A detailed description of the prefixes in the table above is as follows:

<table>
<thead>
<tr>
<th>prefixes (hexadecimal)</th>
<th>letter</th>
<th>description</th>
<th>Numerical description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4B</td>
<td>K</td>
<td>Urging instructions</td>
<td>The value is constant: 0</td>
</tr>
<tr>
<td>4D</td>
<td>M</td>
<td>Slowly removed indication</td>
<td>The value is constant: 0</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Heart rate</td>
<td>Numerical interpretation method: actual value = Received value ÷ 10, unit: times/min</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Respiration rate</td>
<td>Numerical interpretation method: actual value = Received value ÷ 10, unit: times/min</td>
</tr>
<tr>
<td>4C</td>
<td>L</td>
<td>Weak breathe indication</td>
<td>The value is constant: 0</td>
</tr>
<tr>
<td>4E</td>
<td>N</td>
<td>Indication from by someone to no one</td>
<td>The value is constant: 0</td>
</tr>
<tr>
<td>4A</td>
<td>J</td>
<td>Sleep indication</td>
<td>The value is constant: 0</td>
</tr>
</tbody>
</table>

Table 4.3 Detailed description of the prefixes
The sleep sensor will convey the sleep activities data to the SA light, and the three LED strips inside the light will be controlled by these data and turn to the corresponding mode automatically. There are 3 LED strips in the light, strip 1 and 3 are on the front inside the light, strip 2 is on the back of light outside.

**READING MODE** (awake stage)
If the user wants to read a book before sleeping, touch the right bottom of the light one time to turn it on.

**HALF MOON MODE** (awake to asleep)
If the user is ready to sleep, touch the right bottom of the light again to half moon mode.

**OFF**
1. If the user prefers sleep with a dim light, 30 minutes after being tested to fall asleep, light turns off automatically.
   - sensor data: 4a 44 4d
2. If the user wants to sleep without light, touch the right bottom of the light one time again to turn it off.

**FULL MOON MODE**
When the user gets up in the middle of the night, touch the right bottom of the light two times to activate it.

**SUNRISE MODE**
55 minutes before the setting time to get up (REM stage)
- sensor data: ce

45 minutes before the setting time to get up (REM stage)
- sensor data: ce

35 minutes before the setting time to get up (REM stage)
- sensor data: ce

![LED Strip 1 warm white](image1)
![LED Strip 2 warm orange](image2)
![LED Strip 3 warm white](image3)

![LED Strip 1 off](image4)
![LED Strip 2 warm white](image5)
![LED Strip 3 off](image6)

![LED Strip 1 off](image7)
![LED Strip 2 off](image8)
![LED Strip 3 off](image9)

![LED Strip 1 off](image10)
![LED Strip 2 off](image11)
![LED Strip 3 off](image12)

![LED Strip 1 dim red](image13)
![LED Strip 2 off](image14)
![LED Strip 3 dim warm white](image15)

![LED Strip 1 dim orange](image16)
![LED Strip 2 off](image17)
![LED Strip 3 warm white](image18)

![LED Strip 1 cold white](image19)
![LED Strip 2 off](image20)
![LED Strip 3 warm white](image21)

Drawing 4.1 Lighting effects and LED strips
4.2 LED lighting automatical control

4.2.1 What is Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware and software that was born at the Ivrea Interaction Design Institute in 2005 as an easy tool for fast prototyping. Including hardware (various models of Arduino board) and software (Arduino IDE). It is built on an open source simple I/O interface and has the development environment similar with Java, C language Processing/Writing. It contains two main parts: the hardware part is the Arduino circuit board which can be used to do the circuit connection, the other one is Arduino IDE, it is the program development environment in your PC. What you need to do is writing the program code in the IDE and up load it to the Arduino circuit board, the program will give the instruction to the board and tell it what to do.

Arduino can perceive the environment by a variety of sensors, then it has a feedback and affects the environment by controlling the lights, motors and other devices. The microcontrollers on the board can be programmed in Arduino's programming language, compiled into binary files, and burned into microcontrollers. The programming of Arduino is done through the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing).
4.2.2 Programming for LED lighting automatical control

Use Arduino software to program coding to control the lighting and upload it to the physical Arduino board.
4.3 Lighting interaction study

4.3.1 Introduction of sensor

A sensor is a device that detects and responds to some type of input from the physical environment, usually consisting of a sensing element and a switching element. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing.

4.3.2 Classification of sensor

Here we classify the sensors by their application. We can classify them in pressure sensor, temperature sensor, temperature sensor, pH sensor, flow sensor, level sensor, ultrasonic sensor, immersion sensor, illuminance sensor, differential pressure transmitter, acceleration sensor, displacement sensor, weighing sensor and distance sensor.

As we introduced before, the SA light need two pressure sensor to control the switch on/off and the speaker, and a distance sensor to adjust the illuminance level and lighting color temperature.
4.3.3 Introduction of Sparkfun ZX distance and gesture sensor

The ZX Distance and Gesture Sensor is a touchless sensor that is capable of looking for simple gestures. Developed in conjunction with XYZ Interactive, the sensor uses their GestureSense® technology to recognize the distance of an object away from the sensor up to about 12 inches (30cm, referred to as the “Z” axis) and the location of the object from side to side across the sensor in about a 6-inch (15cm) span, referred to as the “X” axis. You will be able to use I2C or UART to communicate with the ZX Sensor via a microcontroller or computer.

The ZX Sensor works by bouncing infrared (IR) beams of light from the two LEDs on either side off of an object above the sensor. The bounced light returns to the receiver in the center of the sensor, and a microcontroller on the back of the sensor interprets the data. ZX Sensor is capable of detecting simple gestures.

Figure 4.5  Sparkfun ZX distance and gesture sensor
Users can adjust the lighting brightness from bright to dark by moving up and down the hand under the light and adjust the lighting color temperature from cold to warm by moving the hand from left to right.
4.3.4 Introduction of TinkerKit touch sensor

The Touch Sensor is sensitive to skin contact. Output: This module normally outputs 0v, but when touched, sends 5v. When connected to an input on the Arduino using the TinkerKit Shield, you will see 0 when there is no touch, and 1023 when touched. Module Description: on the back of the module you can find a signal amplifier, a capacitor, a QT 100A single touch controller, a green LED that signals that the module is correctly powered and a yellow LED whose brightness depends on the values output by the module.

Figure 4.7  TinkerKit touch sensor
The touch sensor 1 is for turning on/off the light, touch sensor 2 is for stopping the ringing.

1. Touch the right bottom of the light one time to turn on the light, and one time again to the half moon mode.
2. When light turns off, touch the right bottom of the light two times to activate full moon mode, this mode is useful for people go to the toilet at night.
3. The gentle alarm will ring after the sunrise bright light mode, when it rings, one touch on the left bottom of the light can stop it.
4.4 Bluetooth

4.4.1 Introduction of the Bluetooth technology

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz[4]) from fixed and mobile devices, and building personal area networks (PANs).

“The research on Bluetooth was initiated at Ericsson of Sweden in 1994. The idea of Bluetooth comes from the desire to connect cellular phones with other devices without a cable. It’s named after the 10th century Viking king of Denmark Herald Bluetooth. The advancement in microelectronics makes it possible to integrate complex functions into one small chip and thus achieve a low cost. With its low cost, low power consumption and low profile, you can virtually put one anywhere you want. This will make many concepts like smart appliances and embedded Internet possible. The development gained support from many companies.” [1]

“Bluetooth is a low cost, low power RF technology for short-range communications. It could be used to replace cables connecting portable devices. Compared to other similar wireless technologies, its biggest advantage is the low power and low cost, which makes it suitable for mobile applications.” [2]


4.4.2 Bluetooth module

Bluetooth module is an integrated Bluetooth PCBA board for short-range wireless communications, according to the function is divided into Bluetooth data module and Bluetooth voice module. The bluetooth module is the basic chip circuits integration of integrating bluetooth functions for wireless communication. General module has a semi-finished product attributes and is based on the chip on the processing, so that makes the follow-up application more simple.

4.4.3 Introduction of DSD TECH HC-05 Bluetooth classic pass-through module

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Bluecore 04 - External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature).
Users could connect the SA light APP in their cellphone with the light via bluetooth and control it by wireless connection, also the SA light system can uploading users' sleep record to the APP.
5 THE PRESENTATION OF
SA (SLEEP-AWAKE) LIGHT DESIGN
5.1 Product 3D model and rendering

5.1.1 solidworks 3D modeling

The 3D modeling is made by Solidworks, after modifying several times the appearance and the structure here is the ultimate modeling.
Figure 5.3 3D model by Solidworks

Figure 5.4 3D model by Solidworks
5.1.2 Rendering
Figure 5.5  Sunrise dim red lighting effect rendering by V-ray
Figure 5.6  Reading mode lighting effect rendering by V-ray
Figure 5.7  Half moon mode lighting effect rendering by V-ray

Figure 5.8  Full moon mode lighting effect rendering by V-ray
Figure 5.9  Sunrise lighting effect rendering by V-ray
5.2 Structure display and analysis

5.2.1 Technical drawing
5.2.2 Explode view

1. opaline Evonik PMMA cover
2. gesture sensor for adjusting the light
3. touch sensor for controlling the lighting
4. touch sensor for stopping the sounds
5. RGBWW LED strip
6. RGBWW LED strip
7. aluminium structure and Mcpet & Mcpolyca paper
8. aluminium base plate
9. silicone transparent band
10. RGBWW LED strip
11. aluminium
12. arduino uno
13. bluetooth module
14. speaker
15. rear cover
Drawing 5.2  2D Exploded drawing and material presentation
Back part for electronics and wall grasing lighting system

Lighting system circular lighting and controls holding part

Cover
5.3 Model making

Figure 5.10 Laser cutting on a 4mm thickness wood sheet

Figure 5.11 Laser cutting on a 4mm thickness wood sheet
Figure 5.12  Model components and parts

Figure 5.13  The designer is working on the model
Figure 5.14  LED strip assembly

Figure 5.15  Making model with the help of professors
5.4 Prototype photography

Figure 5.16  SA light photography

Figure 5.17  Reading mode lighting photo
Figure 5.18  Sleep dim light mode photo

Figure 5.19  Sunrise mode photo
Figure 5.20  Sunrise mode photo

Figure 5.21  Sunrise mode photo
Figure 5.22  Sunrise mode photo
5.5 APP design

The application design has been developed in order to let users interact with the system, program the lighting application and also set up the alarm clock. In addition to this the system is also enabling to download different sounds, to adjust the lighting output and also to check the sleeping activities in a statistical diagrams. The application interface has been developed as a concept.

SA (sleep-aware) sleep light APP start interface. Connect cellphone and SA light via bluetooth.
Set an alarm, the sunrise mode lighting will start at the lightest sleep stage before the alarm time.

Choose an alarm song, it will start after the sunrise mode lighting and wake you up gently.

sleep score

sleep results
MARKET ANALYSIS
6.1 Possible application and target user extension

It was designed in order to give the users a great sleep experience and in order to provide an overall better quality of life, it could make people sleep and wake up more comfortable, especially for the people who focus on sleep and their own health. The sleep analysis function of SA light APP allows people with sleep difficulties to know their own sleep status and get useful advice to improve sleep quality. In addition to using it in bedroom at home, this lamp is also suitable for the hotel's bedroom, it can help reduce jet lag for the long-distance travel tourists, so that the traveler can have a good rest at night and get up with more energy when leaving home.
6.2 Comparison of the product with the competitors

Automatically control lighting effects according to the sleep stage
It is smarter and more convenient, at the same time this function requires higher accuracy of the sleep tracker sensor.

Gestures control lighting
Abandon the traditional button, the use of sensors to adjust the lighting allows users to control their own lighting effects.

Bedtime reading mode
Compared to the competitors, it is not only a sleep lamp, but also a lamp for the sleep relative activities, it's a light that can always accompany you in your daily life.

Sleep dim lighting mode
Based on the reliable market researches and user studies, it has the consideration of a group of people who are afraid to sleep alone in the dark, this function would give them a sense of security.
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