

Study on Sleeping Improvement by the Daily Cycle Control of Illumination Lamp Irradiation

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Abstract

In recent years, inadequate sleep time has become a serious issue among Japanese people. Lack of adequate sleep causes various problems, including reduced productivity. Therefore, I focused on the process of waking up. The mechanisms of human awakening were studied with the goal of determining whether existing products provide the most efficient method for promoting awakening. Humans were easily awakened by suppressing hormonal secretion of melatonin, and manipulation of illumination was evaluated as a method for achieving this suppression. Specifically, wavelengths of blue light (420 to 480 nm) were more effective for suppression of melatonin secretion and promoting awakening. On the other hand, to promote sleep, it was sufficient to accelerate the secretion of melatonin and control brightness of illumination, thereby creating a sleep-friendly condition. In this study, we proposed a ceiling light, distinct from existing products, that is specialized for promoting sleep.

Key words: Lack of sleep time, Melatonin, Light

Introduction

Inadequate sleep time has become a serious issue, especially in many developed countries. Due to the development of the Internet, changes in labor styles, and the popularization of smartphones, people are able to work anywhere, at any time. Consequently, people sometimes have insufficient time to sleep, and therefore have difficulty waking up in the morning. Moreover, sleepiness persisted after awakening, leading to social issues such as a reduction in productivity.

Currently, the “sound” alarms were used as the most effective human waking method. According to previous reports, the feeling at the time of waking up deteriorated below the average value if only a sound alarm was used. However, when the awakening condition included illumination, the feeling was improved⁽¹⁾. Therefore, awakening by light is more effective than awakening in response sound. Thus, controlling the amount and wavelength of illumination from ceiling lights, which are relatively inexpensive, can promote favorable conditions for awakening. Moreover, the most effective wavelength for human awakening was from 420 to 480 nm⁽²⁻⁴⁾, corresponding to blue light⁽⁵⁾. In addition, suppression of melatonin secretion was also necessary to promote awakening and this is enhanced by irradiation of blue light⁽⁵⁾. Because melatonin secretion can be reduced by strong illumination, blue light with high light intensity should be used in the morning, whereas indirect light with low light intensity should be used at night. We proposed a ceiling light that is distinct from existing

products and specialized for sleeping, with the goal of promoting the maximum amount of sleep time.

Main discussion

1. Physical harm due to inadequate sleep time

Because many modern people go to bed late, in response to changes in working patterns, inadequate sleep time is a widespread problem in people of all age groups⁽⁶⁾. Moreover, due to the popularization of computers, the eyes are exposed to large amounts of light from the displays, leading to the collapse of circadian rhythms. Because the lack of sleep has a deleterious effect on metabolism and endocrine function, and causes phenomena similar to those that occur over the course of aging, inadequate sleep time can perturb bodily systems and promote aging⁽⁷⁾. Sleep affects systematic physical functions, and sleep shortage can result in impaired glucose tolerance and immune function and can also greatly influence mental health⁽⁸⁾. Therefore, inadequate sleep and sleep disorders can cause lifestyle diseases such as obesity, diabetes, and hypertension⁽⁹⁾.

2. Productivity reduction due to inadequate sleep

The impact of inadequate sleep is not limited to physical damage. Inadequate sleep has deleterious effects on concentration, memory, and the ability to accomplish daily work and to enjoy relationships with others; consequently, the quality of life (QOL) is reduced⁽⁸⁾, it was reported that “risk of industrial productivity decrease of a chronic insomnia person was seven times higher than of the general people”⁽⁸⁾. Thus, inadequate sleep decreases productivity. Additionally, in 1993 the United States government released a report by the sleep disorder research advisory stating that the total economic losses due to accidents related to the sleep was about 5 trillion yen per year⁽⁹⁾. The resultant economic loss on society as a whole is enormous⁽⁹⁾. Thus, inadequate sleep has a negative impact not only on the individuals, but also on society. Addressing this issue would improve the economic situation in society overall.

3. Bad feelings upon awakening due to inadequate sleep

As mentioned above, inadequate sleep is major source of social problems associated with our daily life. One of the problems that arises due to inadequate sleep is that we do not wake up feeling good in the morning. If many people have difficulty getting to work because they feel bad in the morning, it can result in huge losses to a company. Therefore, I focused on feelings upon awakening. In any case, it is necessary to design an appropriate alarm to promote awakening.

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4. Vibration is ineffective at promoting awakening

In considering awakening, I focused on Yasuragi 100, used by the JR staff. In this method, vibrations are applied to the body by repeating expansion and contraction of air bag. Because the body is vibrated directly, this method seems to be very effective for promoting awakening. Accordingly, I investigated firstly the use of vibration to promote awakening, based on Yasuragi 100. However, “the human unconsciously remove the goods while sleeping”⁽¹⁰⁾. Although Yasuragi 100 gives the vibration to the body, the human may unconsciously remove this vibration air bag while sleeping. Thus, vibration is not an effective means to promote awakening.

5. The light is effective

Finally, I focused on the light. Because we may not worry about to remove the light from the ceiling unconsciously while sleeping, and it is possible to sense light through closed eyelids⁽¹¹⁾, light can be used to reliably wake people up. In addition, light before wake-up promotes natural and pleasant awakening⁽¹⁾ because the level of melatonin, a hormone involved in sleep, is decreased by light stimulation⁽¹⁾. Light with a wavelength from 420 to 480 nm, corresponding to blue light, is most effective for promoting awakening. Based on the findings that melatonin dosage, once increased at nighttime, decreases significantly upon illumination by light with an intensity of 3000 lux after 40 minutes⁽¹²⁾, I hypothesized that 3000 lux blue-light irradiation for one hour before waking up would be useful to promote awakening. In considering existing products, I evaluated the Awakening Akari and Relaxation Akari of Panasonic Co. The Awakening Akari is a lighting system that supports a comfortable awakening light and sound environment⁽¹³⁾; upon wake-up time, the device gradually increases light intensity, and triggers the sound alarm when the set time approaches⁽¹³⁾. Based on this idea, the newly developed product generates blue light at 3000 lux one hour before waking. Because light is effective on its own, sound is not used in this product. On the other hand, the Relaxation Akari is a lighting system in which light scene is switched to indirect lighting at the set time, creating an environment suitable for sleep⁽¹³⁾. Based on this idea, also in the developed product, the light is switched to indirect lighting one hour before sleeping.

To evaluate the effect of the Awakening Akari on children, experiments were performed on elementary school students from third to sixth grades under the supervision of Prof. Yasuo Kamikawa at Toyama University⁽¹³⁾. The results revealed that the number of children who had to be awakened by their parents decreased, and their feelings upon awakening were improved⁽¹³⁾.

In this study, we propose the use of a ceiling light that can change in brightness, based on the Awakening and Relaxation Akari concepts. The ceiling light is switched to indirect lighting one hour before sleeping and blue-light irradiation starts one hour before waking. Because this type of ceiling light is inexpensive and easy to install, it could be widely adopted. Moreover, such a light could be operated by a smart phone, allowing it to be controlled from a remote location and to adapt to the user's behavior. Although the study described here is an original work, the targets and methods were limited. Because the proposed light system is adaptive, it can be improved by collecting data about feelings upon waking up, and subjecting these data to analysis. Based on the results of such analyses, this lighting system could be applied to a wide range of users.

Conclusion

1. Summary of this study

In recent years, inadequate sleep time has become a serious issue. Inadequate sleep results in bad feelings upon awakening. In this study, I focused on waking up in the morning. Suppressing the secretion of melatonin, which promotes sleep, results in comfortable awakening. Because melatonin secretion is decreased by illumination, the proposed lighting system uses strong illumination in the morning to promote awakening, and weak illumination at night to promote sleep. Moreover, because light with a wavelength from 420 nm to 480 nm is effective for promoting awakening, a blue light is used at waking-up time, but not when the user is falling asleep. The light can be operated by a smart phone, making it possible to be controlled from a remote location and to adapt to the user's behavior. The proposed lighting system can assure long sleep times, and thereby help to address the social problems resulting from inadequate sleep.

In this study, a new ceiling light system specialized for sleep was developed to address issues related to inadequate sleep. I believe that the social problems due to inadequate sleep could be solved by commercialization and wide adoption of this product.

2. Challenge

Although the influence of the amount of visible light during the day remains unknown, the hypothesis that blue light affects the retina⁽¹⁴⁾ warrants a search for different lighting conditions with effects similar to those of blue light. The use of Sora LED (purple light) represents such an alternative light source. By using the Sora LED, we can decrease or eliminate health damage.

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照明照射の日次サイクル制御による睡眠改善サービスの研究

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要旨

近年, 日本人の睡眠不足が大きな問題となっている. また, 睡眠不足により生産性の低下などの様々な問題が生じている. ここでは「起きる」ということに注目した. 人間が目覚める仕組みを研究し, 既存の製品が最も効率的な起こし方であるのかを探った. メラトニンというホルモンの分泌を抑制することにより, 目が覚めやすくなることがわかった. メラトニンの分泌は光によって抑制されるので, 光を利用する方法が有効であると考えた. 特に 420 nm-480 nm の青色光がメラトニンの分泌抑制と覚醒に有効である. 一方, 眠るためにはメラトニンの分泌を促進すればよいので, 夜は光を調節し, 眠りやすい環境づくりを行う. 以上より, 既存の製品とは差別化された, 睡眠に特化したシーリングライトを考えた.

重要語句: 睡眠不足, メラトニン, 光

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