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INFLUENCE ON HUMAN SLEEP OF DYNAMIC LIGHTING

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Abstract

The effects of light on circadian rhythms and sleep are influenced by phototransduction of rod cells, cone cells, and photosensitive retinal ganglion cells that contain melanopsin. In this study, we investigated the sleep quality of subjects in dynamic colour temperature lighting environments and dark environments. Eighteen men and twelve women (24 ± 2 years old) participated in the study. It was shown that in the dynamic colour temperature lighting environment the subjects had significantly improved β/α and θ/TP brainwaves and subjective-assessment questionnaire reveals that the use of the dynamic colour temperature lighting could have the subjects perceive better quality of sleep. Thus, quality of sleep was improved in a dynamic colour temperature environment than in a dark environment.

Keywords: dynamic lighting, EEG, colour temperature, sleep quality

1 Introduction

Light therapy is a non-pharmacological treatment that uses bright light for physiological adjustment of the human body. Actinotherapy has a wide range of effect, the most common is the use of actinotherapy to adjust the time of melatonin secretion in the human body, and then adjust the circadian clock. A typical actinotherapy experiment asks subject to sit in front of the bright light source in the morning for about an hour. Use bright light to suppress the secretion of melatonin and adjust the secretion time of melatonin to achieve the purpose of adjusting circadian clock. Daylight is a healthy light source, but people who stay indoors for a long time cannot receive enough sunlight. A healthy light source must be changed according to the needs of the human body , to form a dynamic lighting source for a full day. Use indoor lighting to regulate the non-visual biological response of the human body and regulate the melatonin secretion. [1]

Canazei et al.[2] proposed a dynamic lighting scheme for physiological experiments on female employees who need to work shifts. Because the sleep quality, mood, and stress of shift workers are worse than those of normal life. In order to adjust the staff's circadian rhythm, experiments were carried out using dynamic changes in the working environment light source. The results of the experiment showed that the staff who used the dynamic light source at work had a significant improvement in mood and sleep quality compared to the staff using general lighting. Currently, dynamic lighting sources are most commonly used in classrooms and offices but less frequently used for night sleep. Since dynamic light has an impact on physiology, this study explores whether it is equally effective in improving sleep. Dynamic colour temperature varies according to low and high colour temperature. We compare the effects of static light sources and dynamic lighting on stimulating the body.

2 Methods

Thirty healthy subjects (18 men (23.5 ± 2 years old) and 12 women (24 ± 2 years old) participated in this study. The subjects adapted to the lighting conditions for 5 minutes before sleeping for an hour. Their sleep was monitored by EEG monitoring for the entire duration.

This study was approved by the National Taiwan University Research Ethics Center (case number: 201807EM029). All subjects consented to participate in the experiment.

2.1 Experimental Environment and Condition

The experiment was carried out in a dark room at a room temperature of 26 ± 1°C. The experiment period was from 6 pm to 11 pm. The light source was positioned 1 meter from the subject's head. The subjects were required to have normal sleep schedules and were prohibited from consuming any substances that contained caffeine or alcohol 8 hours before the experiment. The subjects were required to have slept for 8 hours the night before the experiment and no visual dysfunction or cardiovascular diseases.

2.2 Lighting equipment

The experimental light source used in this study was a LED Cube illumination system dynamic colour temperature light source manufactured by the THOUSLITE Company (Changzhou, China). The fixed illumination was 5 lux (illumination on the eyelid), and the colour temperature was 1900 K and 3800 K. In the dynamic colour temperature lighting group, the colour temperatures were alternated every 30 seconds as shown in Figure 1. In the other group, subjects slept in a dark room. Each subject received the two treatments on separate days.

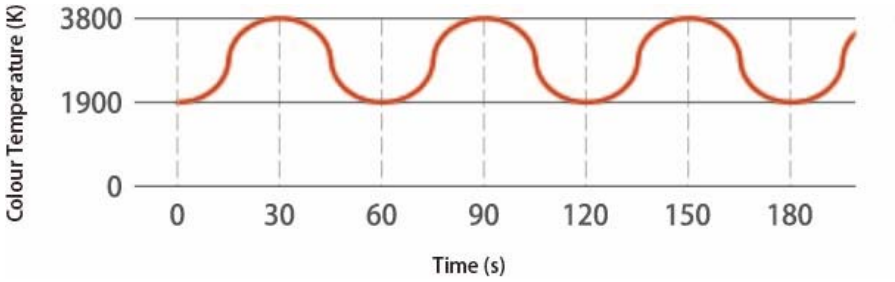

Figure 1 – Dynamic colour temperature lighting change with time

2.3 Analysis Method

Six points were selected to measure brain waves. Measurement electrodes were attached at O1, O2, C3, C4, T7, and T8. Sleep was divided into two major phases: non-rapid eye movement (NREM) and rapid eye movement (REM). NREM was divided into four stages of sleep. Stage one was somnolence, stage 2 was when light sleep occurs, and stages three and four are considered stages of deep sleep. The different stages of sleep can be distinguished through the different EEG readings [3]. During light sleep, the number of θ (4–8 HZ) waves increased [4-5]. During analysis, different fractions such as β/α and θ/TP were used instead of simply analyzing the changes in waves to account for individual differences [6]. The values present a clearer picture of the subjects' physiological state, and therefore it is possible to determine whether the subject enters sleep more quickly or feels more relaxed.

A self-evaluation questionnaire was used to evaluate the psychological feelings of the subjects after participating in the experiment. The questions mainly evaluated the subject's opinion on comfort, light brightness, sleep quality, and energy levels after waking up. The possible score for each question was between 1 and 6 points. The higher the given score, the higher the subject rated each parameter.

2.4 Statistical method

In this study, statistical analysis of brain wave data was performed using Sigma Stat 3.5 (Systat Software, Inc., San Jose, CA). Statistical significance was evaluated using a paired-t test ($p < 0.05$). Data from the two groups were compared to determine if there were statistical differences after the subjects slept in the two lighting conditions for 1 hour.

3 Results

As shown in Tables 1 and 2, in the dynamic colour temperature light source environment, there were significant differences in β/α brain waves in O1 and O2 of the occipital lobe and C3 of the central sulcus. There were also significant differences in the normalized θ wave in O1 and O2

and C3 and C4. It is evident from the increase in value that the brain could relax to a greater degree in the dynamic colour temperature lighting environment than in the dark environment.

Figure 2 depicts the results of the questionnaire that was completed by the subjects. The subjects generally experienced more comfortable, higher quality sleep and increased energy levels after sleeping in a dynamic colour temperature environment compared to sleeping in a dark environment.

Table 1 – Comparison of β/α brain waves in a dynamic color temperature lighting environment and in a dark environment

	Dynamic colour temperature	Dark room	p
	Mean ± SD	Mean ± SD	
O1	0.72 ± 0.22	1.45 ± 0.92	0.01*
O2	0.98 ± 0.62	1.66 ± 1.49	0.01*
C3	1.14 ± 0.47	1.62 ± 0.98	0.01*
C4	1.32 ± 0.65	1.71 ± 0.88	0.07
T7	1.33 ± 0.37	1.53 ± 0.65	0.17
T8	1.44 ± 0.48	1.58 ± 0.43	0.23

Table 2 – Comparison of θ/tp brain waves in a dynamic color temperature lighting environment and in a dark environment

	Dynamic colour temperature	Dark room	p
	Mean ± SD	Mean ± SD	
O1(%)	21.28 ± 3.57	18.85 ± 3.38	0.01*
O2(%)	21.07 ± 5.64	18.48 ± 3.83	0.05*
C3(%)	19.84 ± 3.40	18.57 ± 3.65	0.02*
C4(%)	19.90 ± 2.96	16.20 ± 5.82	0.01*
T7(%)	18.85 ± 3.14	18.53 ± 3.24	0.71
T8(%)	18.46 ± 3.47	18.47 ± 4.96	0.85

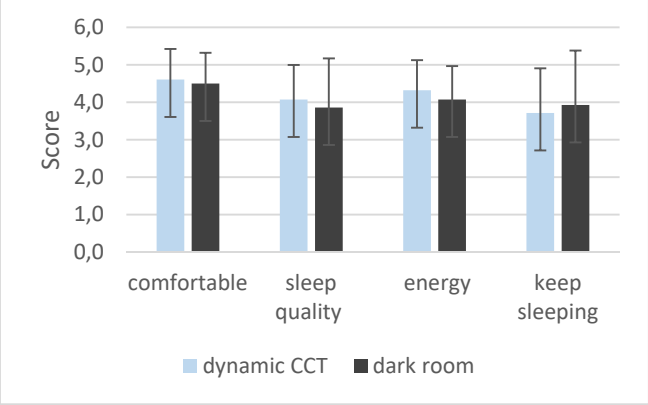

Figure 2 – Results from self-evaluation questionnaire

4 Discussion

Traditionally, it is believed that sleeping in a light-emitting environment is inferior to sleeping in a dark environment. Related studies on the effect of static light on sleep have shown that a

bedside lamp can affect the quality of sleep at night [7]. The presence of light at night may affect melatonin production, since melanopsin is most sensitive to 480 nm light [8 -9], which is optimal for use in the daytime for focus and thinking but it is not suitable for night- time use. This study confirmed that not all night-time light may reduce the quality of sleep. In this study, dynamic colour temperature light with varying warm and cool colour temperature changes were effective in improving sleep and relaxation.

Typically, humans open their eyes more during the daytime and close their eyes more at night. In the daytime, light can enter the pupil directly through the photoreceptor cells on the retina, which send signals to the brain to regulate physiological reactions. Therefore, it is very likely that intrinsically photosensitive retinal ganglion cells (ipRGCs) cells are involved in activity in weak light. Therefore, ipRGCs are mainly stimulated by low colour temperature lights. We can stimulate photoreceptor cells by regulating the amount of light that enters the eye and thus increase the power of θ and α brain waves.

This rhythmic change in light resembles a message for the brain that can be associated with changes in the circadian rhythm. There is still a lot of room for improvement in the design of the dynamic light spectrum. We hope that the combined use of music and lighting can become more effective in improving sleep quality in the future.

5 Conclusion

Dynamic lighting is a main focus of future lighting development. Compared with static light sources, dynamic lighting has more significant effects in stimulating the body. Silent environments are not necessarily optimal for sleep. Compared to a dark environment, dynamic colour lighting could induce and stimulate the secretion of melatonin and thus regulate the circadian rhythm and improve sleep quality.

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