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Analysis of the Long-term Effect of Office Lighting Environment on Human Reponses

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***Abstract*—**This study aims to discuss the effect of illumination and the color temperature of the lighting source under the office lighting environment on human psychological and physiological responses. In this study, 21 healthy participants were selected, and the Ryodoraku measurement system was utilized to measure their skin resistance change.The findings indicated that the effect of the color temperature of the lighting source on human physiological responses is significant within 90 min after turning the lights on; while after 90 min the effect of illumination on human physiological responses is higher than that of the color temperature. Moreover, the cardiovascular, digestive and endocrine systems are prone to be affected by the indoor lighting environment. During the long-term exposure to high intensity of illumination and high color temperature (2000Lux -6500K), the effect on the psychological responses turned moderate after the human visual system adopted to the lighting environment. However, the effect of the Ryodoraku value on human physiological responses was more significant with the increase of perceptive time. The effect of long time exposure to a lighting environment on the physiological responses is greater than its effect on the psychological responses. This conclusion is different from the traditional public viewpoint that the effect on the psychological responses is greater.

***Keywords*—**Autonomic nervous system, Human responses, Office Lighting Environment, Ryodoraku, Meridian

I. Introduction

UNDER rapid economic development and improved living standard, the public's demand on healthy, comfortable living conditions has increased. According to the research results on the effects of indoor lighting environments on human responses, poor illumination or color temperature of lighting sources can affect users' vision and divide their attention, and hence cause users to feel tired or fretful [1-5]. Currently, the Taiwanese lighting specification (Chinese National Standards 12112, CNS 12112) specifies a reference value on the illumination based on work types, and has no mandatory provision on the color temperature of the lighting sources. Thus, users may experience uncomfortable psychological responses if the coordination between the illumination and color temperature is not considered when designing the indoor lighting environment [6].

Past studies regarding indoor lighting environments mostly evaluate and analyze the physical values of lighting environment factors [7-9], and focus on the effect of general lighting environments (below 1000 lux) on the human responses, including the effect of illumination on the arousal level or visual fatigue [4,10-12].

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Some studies discuss the physiological responses of participants under short term exposures (10 sec to 1 hr) by measuring their brainwaves, pulse rates, blood pressures and electrocardiogram [13-18,29]. However, the effect of long term exposure under high intensity of illumination and color temperature on human response has not been explored. Presently, the life style change and diversity of lighting sources have widened the influence of the indoor lighting environment quality; thus, it is necessary to explore the topic.

In the viewpoint of Western medicine, the activity mechanisms of human muscular contraction and internal organs are influenced by neruoelectricity conduction, including spinal cord of central nervous system (CNS), brain and somatic nervous system (SNS) of peripheral nervous system (PNS) and autonomic nervous system (ANS). The mechanism in human nervous systems responding to environment stimulation is the autonomic nervous system, and is divided into sympathetic nerve and parasympathetic nerve. According to related medical studies [14,19,20], when the human body is stimulated by external environment factors, the sympathetic nerve will release adrenalin, which causes physiological responses, such as vasoconstriction, blood pressure increase, heart beat increase, tachypnea and perspiration increase. Hence, the function of sympathetic nerve is mainly related to emergencies and energy release, whereas the function of parasympathetic nerve is mainly related to rest, recovery, energy storage and pleasantness [21]. Therefore, when the human body is stimulated by external environment factors, the sympathetic nerve and parasympathetic nerve will act alternately, so as to promote or inhibit the operation of human organs or tissues, and maintain normal physiological function [22].

When the human body is stimulated by external environment factors, if the stimulation of external environment factors is strong enough, as the activity of the sympathetic nerve of the nervous system increases or decreases, the neurons will have polarization or depolarization accordingly and result in action potential [23]. Human nerve fiber is used to transfer relevant information, and the concentration of intra-cellular Na+ and K+ may be influenced [24]. The physiological changes can be measured by using relevant instruments, such as ECG, EMG, skin electric reflection physiologic indexes. When a lot of neurons discharge at the same time, the aggregate capacitance will increase sharply; at this moment, by placing the electrode on the skin covering nerve, instead of on nerve fiber directly, the action potential can be recorded. Therefore, the Ryodoraku measurement system measures the changes in dermal resistance according to this physiological response principle, and evaluates the impact on human physiology based on physiologic indexes [25] (See Fig. 1).

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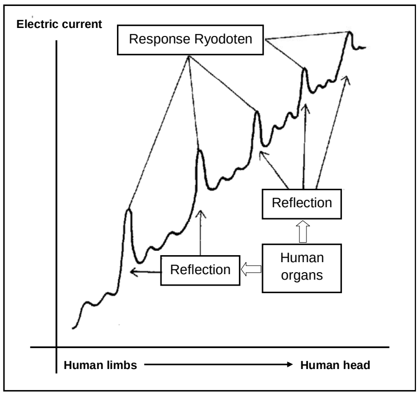

Fig. 1 The Ryodoraku measurement system measures

Mukae, H. et al. used the variance in heart rate variability (HRV) to analyze the influence of different types of lighting environment on human autonomic nerve in a short time in 1992 [20], the illumination stimulates factor as 3000K, 5000K, 6700K three kinds different colour temperature and 100lux, 300lux, 900 lux three kinds of different intensities of illumination. The experimental results showed that higher colour temperatiure leads to more obvious changes in the testees' heart sympathetic nerve activity responses. In order to understand the effect of long-term exposure under different types of lighting environment on human psychological and physiological responses, this study simulated the lighting environment of different intensities in the laboratory, and applied the Ryodoraku measurement system to measure the human skin resistance change in order to understand its range of influence on the human meridian and parts, and the physiological change of their organs represented by relevant measure points. Questionnaire survey was conducted on their psychological responses to explore human responses under long-term exposure to different illumination and color temperatures. Based on the experimental results, appropriate lighting environments, or work and rest style and time table were suggested to help construct a healthy and comfortable indoor lighting environment.

II. Experimental Design

In order to understand the effect of long term exposure under different lighting environments on human psychological and physiological responses, this study adopted the experimental method by selecting 21 healthy participants and applying the Ryodoraku measurement system. Questionnaire survey was conducted to measure the Ryodoraku value and psychological responses of participants in order to discuss the effect of continuous lighting stimulation on human responses.

A. Experimental factors

The experimental variables are the indoor illumination and the color temperature of the lighting source. According to the Taiwanese indoor working illumination standard (Chinese National Standards 12112, CNS 12112), the precision work such as designing and mapping requires a higher illumination (1500lux-2000lux), and the illumination reference value of the general office space is 500lux. Generally, the color temperature of the lighting source in an office space is 4000K and 6500K [26-29]. In this study, the experimental variables are 500lux-4000K, 500lux-6500K, 2000lux-4000K, and 2000lux-6500K to simulate the lighting environment of an actual office space. This study selected the Philips TBS 305LH/436IC+M5 2'×4' OA fluorescent lamps. Table 1 shows the basic information relevant lighting sources.

TABLE I
The Basic Information Relevant Lighting Sources.

Lamp Types		TLD Fluorescent lamps	
Color Temperature(K)		4000	6500
CRI(Ra)		85	85
Flux(lm)		3350	3250
Luminous efficiency(lm/W)		93.1	90.3
Model number		'TL' D 36W/840NG	'TL' D 36W/865NG
Lamp Size(mm)	Tube length	1213.6	1213.6
	Tube diameter	28	28

B. Participant selection and experimental environment control

21 healthy participants with normal vision were selected, including 11 male participants, and 10 female participants, between the age of 20-28, and were required to have a good night sleep before the experiment to avoid the measured value error caused by fatigue. The clothing insulation of participates was 0.7clo.

A laboratory (L:5.2m, W:3.2m, H:2.6m) meeting the experimental requirements was selected to conduct the lighting environment test [30]. The surrounding walls of the laboratory were covered with a black curtain, and the environmental variables were accurately controlled within the range, including the room temperature: 28.5±0.5℃, the relative humidity 70±2%, the wind speed <0.09m/s, and the background noise <45dB (A). This experiment complied with the Taiwanese indoor working illumination standard (Chinese National Standards 12112, CNS 12112) where the height of the indoor work level was set as 0.75m. Furthermore, the uniformity ratio of illumination at working level under different indoor lighting environments was kept between 0.83-0.84. The laboratory design is shown in Figure 2.

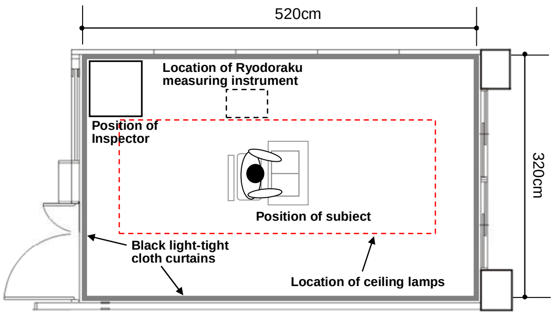

Fig. 2 The setting of the experimental environment

III. Methods

A. Psychological response evaluation method

In order to realize the changes of psychology experiencing under different types of lighting environment for long time. The seven-dimensional semantic differential method (SD Method) was employed to measure and analyze the psychological responses of participants in different lighting environments; and a questionnaire survey was used for evaluation. The relevant evaluation items include comfort, arousal level, sense of relaxation and tiredness [31-33].

B. Physiological response evaluation method

This study utilized a comprehensive analysis on the measured values of electrical conductions on the skin at acupuncture points using the Ryodoraku measurement system (Health Monitor, Model No.SD-802P, Skylark Device & Systems CO., LTD., Taiwan) to measure and evaluate the influence ranges of human physiological response changes, parts and physiological changes of organs at the measured points in different lighting environments. The Ryodoraku measurement system is designed based on the principle of Electro-Dermal Screening Test (EDST) [34] (See Fig. 3). When the human body is stimulated by the external environment or internal organs have changes, the body surface skin has electric potential change because the cells have polarization or depolarization. At this moment, if the skin is conducted with feeble current (below 12V, 200μA), it is found that the meridian point positions in Chinese acupuncturology have less skin electric resistance, and are likely to have electric current passed. These points that are likely to have electric current passed are the so-called Ryodoten [35]. The Ryodorakus of human body are distributed on the front and back sides of trunk, and 12 Ryodorakus are distributed on the left and right sides of human body respectively. According to the acupuncturology and the meridian theory of traditional Chinese medicine, these 12 meridians correspond to the changes in viscera and relevant organs, therefore, when the stimulation of external environment factors causes the response of internal organs, or the viscera have pathological changes, they will be reflected or transferred by the autonomic nervous system of human body and shown at the skin points connecting meridians and body surface [25]. The meridian response can be known by measuring the changes in the magnitude of current of the Ryodoten on the human body Ryodoraku, and then the influence on human physiology. The Ryodoraku measurement method measures the magnitude of current of 24 representative points of 12 meridians (Ryodoraku value) to evaluate the fatigue, excitement, relaxation or disturbance of internal organs. If the magnitude of current measured by Ryodotens is too high or too low, it indicates that the human body energy is distributed nonuniformly, namely the human physiology has abnormal conditions. This study used Ryodoraku to measure the variance in the current values of 12 meridians, and evaluated the influence on human physiology, so as to discuss the influence of different types of lighting environment stimulations on human physiology.

In practical measurement, the testee holds the conductive guide, and the tester presses the measuring guide on the skin point of the testee. Since the human body with resistance is between the conductive guide and the measuring guide, the magnitude of current must decrease to below 200μA, and then the measured magnitude of current is called Ryodoraku value.

Theoretically, each Ryodoraku has many Ryodotens; however, according to relevant researches, the mean Ryodoraku value of the Ryodoraku values of several Ryodotens (i.e. representative measuring points) in each meridian of human body and all Ryodotens in this meridian has a trend of parallel change. Therefore, each meridian only needs to measure the Ryodoraku value of a representative measuring point and then make a comprehensive evaluation, so as to find out the human physiological changes [36,37]. The positions of 12 representative measuring points on both hands and feet of human body Ryodoraku and the related meridians corresponding viscera and organs are shown in Fig. 4 and Table 2.

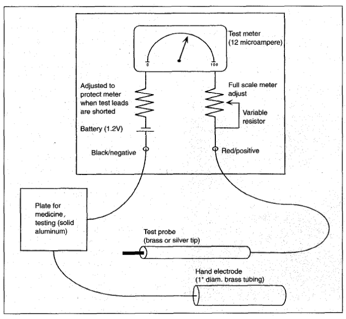

Fig. 3 A simple schematic diagram of an EDSD

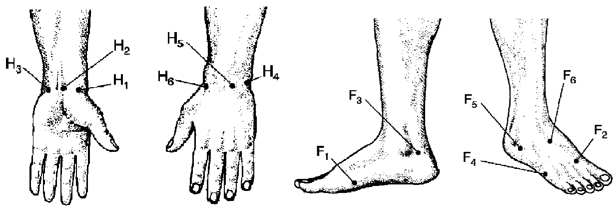

Fig. 4 Representative measuring points

TABLE II
HUMAN 12 MERIDIANS AND COLLATERALS OF SPOT AND CORRESPONDING INTERNAL ORGANS

Representative measuring points	Human 12 meridians	Corresponding human organs
H1	Lung meridians	Lung , Nose , Skin
H2	Heart Constrictor meridians	Pericardium, Blood vessel
H3	Heart meridians	Heart , Tongue , Eyes
H4	Small Intestine meridians	Small intestine , Eyes , Tongue
H5	Triple Heater meridians	Lymphatic vessel , Ear , Eyes
H6	Large Intestine meridians	Large intestine , Mouth , Tooth , Nose , Tongue , Skin
F1	Spleen Pancreas meridians	Spleen , Pancreas , Stomach , Brain
F2	Liver meridians	Liver , Eyes , Genitals , Muscle
F3	Kidney meridians	Kidney , Brain , Eyes , Bone , Nasal cavity

F4	Bladder meridians	Bladder , Ear , Nose , Eyes , Brain
F5	Gall Bladder meridians	Gallbladder , Head , Eyes , Muscle
F6	Stomach meridians	Stomach , Mouth , Tooth , Nose

C. Experimental flow and analysis of measured values

Normally, people stay under the indoor lighting for more than three hours continuously in the office, except for during lunch breaks. Consequently, this study set the lighting hours as 210 min (3.5 hr) to study the effect of long-term exposure under the office lighting environment on human responses. The experimental lighting sequence is 500lux-4000K, 500lux-6500K, 2000lux-4000K, 2000lux-6500K. The preparation stage (light-out state) before each test is 30 min, and followed by the light-on state that lasts 210 min. Then, the participants rested for 1.5 hours. This cycle was considered one test unit, and was repeated for subsequent tests.

The sample number is 21, and this is a paired comparison test of small samples. After testing, Microsoft Excel was acquired for the paired t-test of the mean differences of measured data. The analysis method was to verify whether the values collected at various times after the lights are on and the data collected during the 15 min before the lights are on show any statistical difference ($P<0.05$). If $P<0.05$, this indicates that the lighting environment changes have effect on the Ryodoraku values.

IV. Results and Discussion

A. Psychological response changes during long term exposure to different lighting environments

1. Change of comfort through time

During the 15 min after lights are on, the comfort of four different types of lighting environments increased sharply. In the lighting environment of general illumination level (500Lux), regardless of the color temperature, the comfort of participants was significantly higher than the lighting environment of high illumination level (2000Lux). This phenomenon remained until the test was completed, which indicates that the illumination has great effect on human conform (Fig. 5).

2. Change of relaxation through time

The lighting environment of general illumination (500Lux) produced higher relaxation within two hours after the lights were on; after the two hours, the color temperature of 4000K produced a greater relaxation than that of 6500K as time increased. During the 3.5 test hours, the lighting environment of 500Lux-4000K generated a greater relaxation (Fig. 6).

3. Change of arousal level through time

Among the four types of lighting environments, the lighting environment of high illumination (2000Lux) increased the arousal level more significantly than the general illumination (500Lux). This illustrated that high illumination was prone to raise the human arousal level. In the lighting environment of high illumination, 6500K had more positive effect on increasing the arousal level than 4000K after 45 min. In the lighting environment of general illumination, 4000K and 6500K had no significant difference after 90 min (Fig. 7).

4. Change of tiredness through time

In four types of lighting environments, the participants experienced tiredness after 45 min, indicating a short rest is necessary after 45 min of working under the office lighting environment. The participants were more tired after 60 min. However, the 2000Lux-4000K condition was less likely to cause tiredness than the other types of lighting environments (Fig. 8).

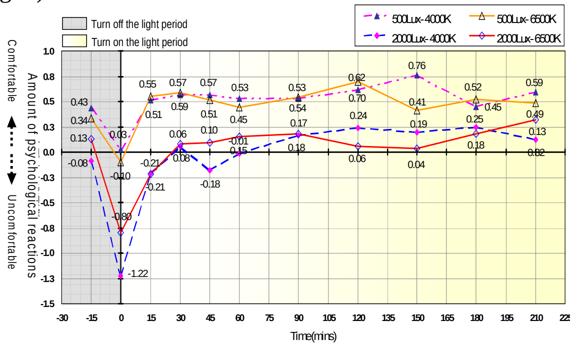

Fig. 5 The change of comfort under 4 types of lighting environment for long time

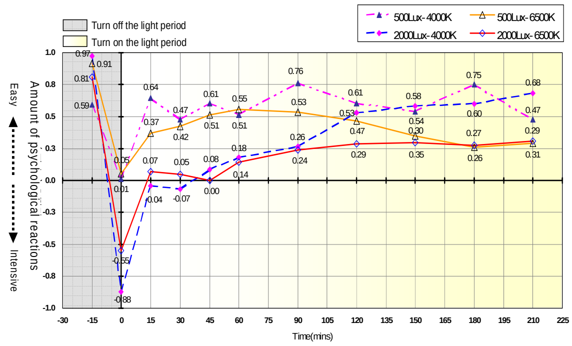

Fig. 6 The change of relaxation under 4 types of lighting environment for long time

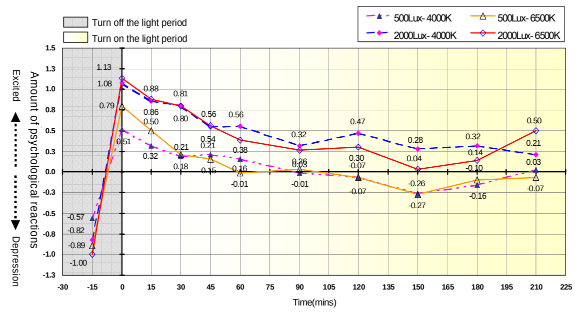

Fig. 7 The change of arousal level under 4 types of lighting environment for long time

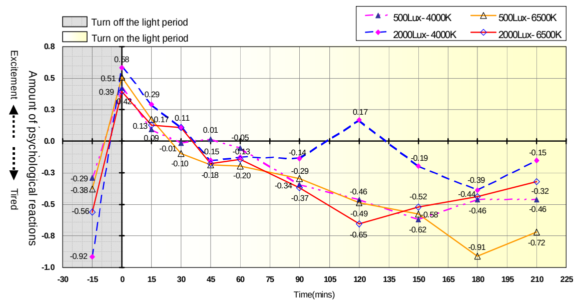

Fig. 8 The change of tiredness under 4 types of lighting environment for long time

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B. Physiological response change during long-term exposure to different lighting environments

1) Duration impact analysis

Figure 9 illustrates the change trend through time of the human Ryodoraku values under the four types of lighting environments. The experimental results indicated that the human Ryodoraku response in the lighting environment of high illumination (2000Lux) increased with time, and the average Ryodoraku value increased to 12.4μA~14.8μA after the lights were turned on. In the lighting environment of general illumination of 500Lux and the color temperature of 6500K, the Ryodoraku values of participants showed a significant change at 90 min, and the average Ryodoraku values increased by 6μA after the lights were on. After 90 min, the effect of the lighting environments on the human physiological responses was reduced gradually. In the lighting environment of the color temperature 4000K, the Ryodoraku values witnessed a rapid drop after 15 min. This phenomenon indicated that Ryodoraku values of participants are different due to the different illumination levels and the color temperature of different light environments, and have different effects on the physiological responses during different periods as perceived time increases.

To discuss the effect of different lighting environments on the Ryodoraku responses during long time exposure, this analysis method was to verify whether the Ryodoraku values during different time periods after turning the lights on and the values measured during the 15 min before the lights were on indicate any statistical difference ($P<0.05$). If $P<0.05$, this showed that the lighting environments may cause the change in the Ryodoraku values, as seen in Table 3 for the analysis results. The experimental results indicated that the effect of color temperatures on the Ryodoraku values is higher than the effect of illumination within 90 min after turning the lights on; the higher the color temperature is, the more significant its effect on the physiological reaction is. After 90 min, the effect of illumination on the Ryodoraku values was greater than the color temperature; the higher the illumination is, the more significant it is on the Ryodoraku values.

2) Affected meridian Duration impact analysis

The effect of the lighting environment of 500Lux-4000K on the physiological responses declined after 15 min; the effect of the lighting environment of 500Lux-6500K on the Heart Constrictor meridians and Heart meridians Ryodoraku values remained the same from turning the lights on to completing the test. However, after 90 min, the Bladder meridians was affected by the lighting stimulation, and the effect of the lighting environment on the Kidney meridians and the Gall Bladder meridians declined gradually. In the lighting environment of 2000Lux-4000K, an instantaneous effect of turning the lights on the Heart Constrictor meridians, Spleen Pancreas meridians and Bladder meridians were significant; after 90 min in the same lighting environment, the Lung meridians and Heart meridians were affected. In the lighting environment of 2000Lux-6500K, it had a continuous effect on the Heart Constrictor meridians, Liver meridians, Kidney meridians and Gall Bladder meridians upon turning the lights on; between 15 and 30 min, it had affects on the Bladder meridians and Spleen Pancreas meridians. The Ryodoraku values of the Lung meridians, Heart meridians, Small Intestine meridians, Triple Heater meridians, Large Intestine meridians and Stomach meridians were also affected after 45 min (see Table IV).

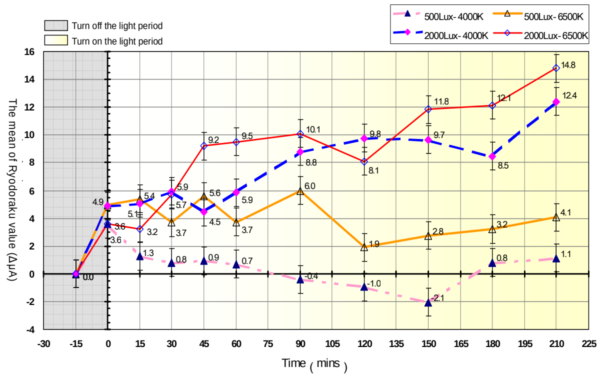

Fig. 9 The Ryodoraku experimental results indicated

TABLE III
THE RYODORAKU VALUE WHICH 24 PRESENT POINTS AVERAGE VALUE BEFORE AND AFTER TURN ON THE LIGHTS UNDER FOUR TYPES OF LIGHTINT ENVIRONMENT

Percipience Period	4 types of lighting environment							
	500Lux-4000 K		500Lux-6500 K		2000Lux-4000 K		2000Lux-6500 K	
	Mean±s.d	P value	Mean±s.d	P value	Mean±s.d.	P value	Mean±s.d	P value
Before turning on the light	50.44±14.59	**0.003•**	45.52±16.03	**0.0015•**	46.81±15.47	**0.001•**	49.11±14.35	**0.004•**
Turning on the light wink	54.02±14.05		50.47±16.85		51.69±14.89		52.69±14.76	
Before turning on the light	50.44±14.59	0.550	45.52±16.03	**0.012•**	46.81±15.47	0.074	49.11±14.35	0.194
Turning on the light in lasted 15 minutes	51.72±15.40		50.93±16.36		51.87±14.91		52.34±13.67	
Before turning on the light	50.44±14.59	0.696	45.52±16.03	0.096	46.81±15.47	0.073	49.11±14.35	**0.033•**
Turning on the light in lasted 30 minutes	51.26±14.10		47.80±16.63		52.73±16.20		54.84±13.63	
Before turning on the light	50.44±14.59	0.671	45.52±16.03	**0.036•**	46.81±15.47	0.157	49.11±14.35	**0.001•**
Turning on the light in lasted 45 minutes	51.38±12.69		51.10±15.73		51.26±16.08		58.31±14.47	
Before turning on the light	50.44±14.59	0.805	45.52±16.03	0.167	46.81±15.47	0.114	49.11±14.35	**0.001•**
Turning on the light in lasted 60 minutes	51.16±14.30		49.25±17.17		52.67±15.14		58.59±11.85	
Before turning on the light	50.44±14.59	0.907	45.52±16.03	**0.032•**	46.81±15.47	**0.010•**	49.11±14.35	**0.001•**
Turning on the light in lasted 90 minutes	50.04±13.97		51.52±17.80		55.61±14.02		59.19±14.27	
Before turning on the light	50.44±14.59	0.789	45.52±16.03	0.414	46.81±15.47	**0.010•**	49.11±14.35	**0.01•**
Turning on the light in lasted 120 minutes	49.49±14.00		47.44±15.99		56.58±16.42		57.21±15.04	
Before turning on the light	50.44±14.59	0.616	45.52±16.03	0.284	46.81±15.47	**0.004•**	49.11±14.35	**0.0002•**
Turning on the light in lasted 150 minutes	48.39±16.28		48.28±15.83		56.46±14.37		60.94±14.06	
Before turning on the light	50.44±14.59	0.812	45.52±16.03	0.258	46.81±15.47	**0.007•**	49.11±14.35	**0.001•**
Turning on the light in lasted 180 minutes	51.25±15.58		48.74±15.23		55.28±14.38		61.23±15.13	
Before turning on the light	50.44±14.59	0.773	45.52±16.03	0.116	46.81±15.47	**0.002•**	49.11±14.35	**0.00003•**
Turning on the light in lasted 210 minutes	51.59±14.21		49.60±16.11		59.21±12.19		63.91±13.28	

Note：1.Unit：μA 2."• "is representing P value < 0.05

TABLE IV
THE RYODORAKU VALUE WHICH 24 PRESENT POINTS AVERAGE VALUE BEFORE AND AFTER TURN ON THE LIGHTS UNDER FOUR TYPES OF LIGHTING

Lighting Environments		500Lux-4000 K										500Lux-6500 K										2000Lux-4000 K										2000Lux-6500 K									
Percipience Period / Meridians		A	B	C	D	E	F	G	H	I	J	A	B	C	D	E	F	G	H	I	J	A	B	C	D	E	F	G	H	I	J	A	B	C	D	E	F	G	H	I	J
Lung meridians	L	●										●										●					●		●	●	●	●									●
	R																					●		●			●		●	●	●				●	●	●		●	●	●
Heart Constrictor meridians	L	●										●	●		●		●					●					●	●	●	●	●	●					●				●
	R									●		●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●
Heart meridians	L	●										●	●									●					●		●	●	●	●									●
	R	●										●	●	●	●		●	●	●	●	●	●					●		●	●	●	●			●	●	●		●	●	●
Small Intestine meridians	L							●	●			●																				●			●		●	●	●	●	●
	R	●																																	●		●	●	●	●	●
Triple Heater meridians	L											●	●									●										●			●	●	●	●	●	●	●
	R												●									●													●	●	●	●	●	●	●
Large Intestine meridians	L											●	●				●															●				●	●	●		●	●
	R	●																											●		●				●	●	●	●	●	●	●
Spleen Pancreas meridians	L							●									●					●	●	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●	●
	R														●						●	●	●	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●	●
Liver meridians	L												●									●									●			●	●	●	●	●	●	●	●
	R																																	●	●	●	●		●	●	●
Kidney meridians	L	●											●		●	●	●					●	●								●				●	●	●		●	●	●
	R	●	●										●	●	●	●	●				●	●					●	●	●	●				●	●	●	●		●	●	●
Bladder meridians	L										●	●					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	R											●					●		●		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Gall Bladder meridians	L											●	●			●	●					●	●						●		●	●	●		●	●	●		●	●	●
	R	●												●								●						●	●						●		●		●	●	●
Stomach meridians	L											●	●																			●			●	●	●		●	●	●
	R		●																																●	●	●		●	●	●

Note：1. `●` is representing P value < 0.05.
2. A：Turning on the light wink, B：Turning on the light in lasted 15 minutes, C：Turning on the light in lasted 30 minutes, D：Turning on the light in lasted 45 minutes, E：Turning on the light in lasted 60 minutes, F：Turning on the light in lasted 90 minutes, G：Turning on the light in lasted 120 minutes, H：Turning on the light in lasted 150 minutes, I：Turning on the light in lasted 180 minutes, J：Turning on the light in lasted 210 minutes

C. Relation between psychological and Ryodoraku responses

To discuss the correlation between the psychological responses and the physiological Ryodoraku values during long term exposure to different lighting environments, this study conducted a comprehensive comparison analysis of the changes of the psychological and physiological responses, the analysis results are shown in Figure 10(a)-(d). Under the long term exposure to the lighting environment of high illumination and color temperatures, and the effect on the psychological responses decreased after the human visual system had adapted to the lighting environment; Yet the effect on the Ryodoraku values was more and more significant as time increased. The experimental results indicated that the effect of color temperatures was more significant on physiological responses than that of illumination within 90 min. On the other hand, the effect of illumination on physiological responses was higher than that of color temperatures after 90 min. In the lighting environment of 2000Lux-6500K, the Ryodoraku value rose violently, and its increase range was greater than other lighting environments. From the above, it could be concluded that the lighting stimulation has greater effect on the physiological responses than the psychological responses during long term exposure to different lighting environments. This is different from the public viewpoint that lighting is prone to affect psychological responses. This phenomenon should be debated, and special attention should be given in application in the future.

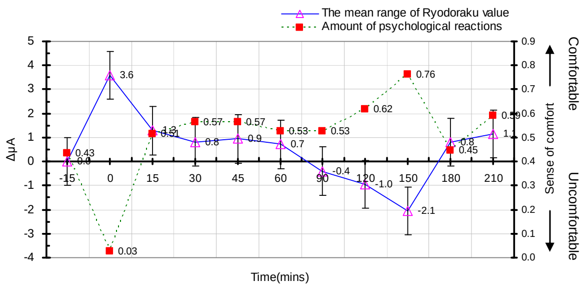

Fig. 11 The relevance of the change of comfort and the Ryodorku responses under long time with 500Lux-4000K illumination environment

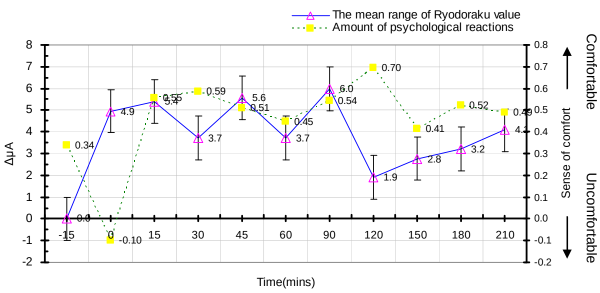

Fig 12 The relevance of the change of comfort and the Ryodorku responses under long time with 500Lux-6500K illumination environment

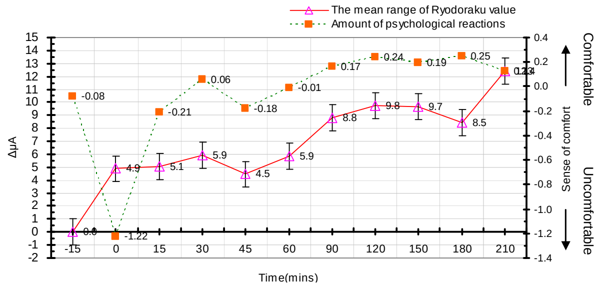

Fig. 13 The relevance of the change of comfort and the Ryodorku responses under long time with 2000Lux-4000K illumination environment

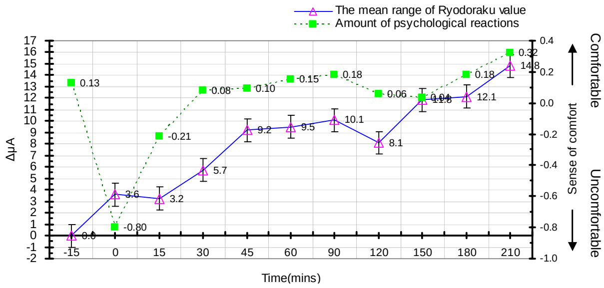

Fig. 14 The relevance of the change of comfort and the Ryodorku responses under long time with 2000Lux-6500K illumination environment

V. Conclusions

To discuss the effect of lighting environments on the psychological and physiological responses, this study employed the Ryodoraku measurement system and conducted a questionnaire survey to measure the psychological responses and the Ryodoraku values in four different types of lighting environment during pretest, test and post-test and their changes. The research results are as follows:

A. Effect of illumination on psychological responses is more significant

In the lighting environment of general illumination, regardless of color temperature, comfort evaluation is higher than high illumination. In the lighting environment of high illumination, the effect on increasing the arousal level was higher than general illumination, regardless of color temperatures. In the four types of lighting environments, illumination had a significant effect on the comfort and increase of the arousal level.

B. Effect of long lighting stimulation on changes of physiological responses is significant and continuous

Within the 90 min after turning the lights on, color temperatures had a higher effect on the Ryodoraku values as compared to illumination. The effect of color temperature 6500K on the sympathetic nerve change was higher than that of color temperature 4000K. After 90 min, the effect of illumination on the physiological responses was higher than the effect of color temperatures; the higher the illumination was, the more significant the physiological responses were. In the four types of lighting environments, the blood circulation, digestive and endocrine systems generated continuous and significant response changes due to the lighting stimulation. The effect of the lighting environment 2000Lux-6500K was more significant than the other lighting environments; and after 45 min, the Ryodoraku values of the 12 meridians were also affected.

C. Physiological effects under lighting environments tend to be easily neglected.

When the human vision adapts to the lighting environment, the psychological effects of the lighting environment will turn moderate, but the effect on the Ryodoraku values continues.

This is different from the public viewpoint that the lighting environment is prone to affect the psychological responses, hence, attention should be paid to extremely high illumination and color temperatures since they affect physiological responses.

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