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STUDY ON THE EFFECTS OF AROUSLA LIGHTING OF DORMITORY ON COLLEGE STUDENTS' SLEEP QUALITY, ALERTNESS AND MOOD IN SUMMER

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STUDY ON THE EFFECTS OF AROUSLA LIGHTING OF DORMITORY ON COLLEGE STUDENTS' SLEEP QUALITY, ALERTNESS AND MOOD IN SUMMER

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Abstract

Light exposure elicits numerous effects on human physiology and behaviour, such as better alertness and mood. Here we investigated the effects of natural eye light exposure before awakening on sleep quality and morning alertness and mood. 16 subjects from 4 dormitories in the same class of Tsinghua University were selected to conduct a 30-day field experiment in summer. Because of the different distance from the window and the wall shelter, the distribution of natural light in the 4 beds of dormitory in the morning is also different. The natural eye light exposure before waking up was obtained by a wireless probe, which could record illumination in real-time. The physiological and psychological indicators such as sleep quality at night, alertness and mood after waking up were obtained by questionnaires and sleep monitoring band. The results showed that the more the LEA before waking up, the better alertness and mood after waking up. But no significant correlation was found between sleep quality and LEA.

Keywords: Natural dawn lighting, Light exposure, Sleep quality, Alertness, Mood

1 Introduction

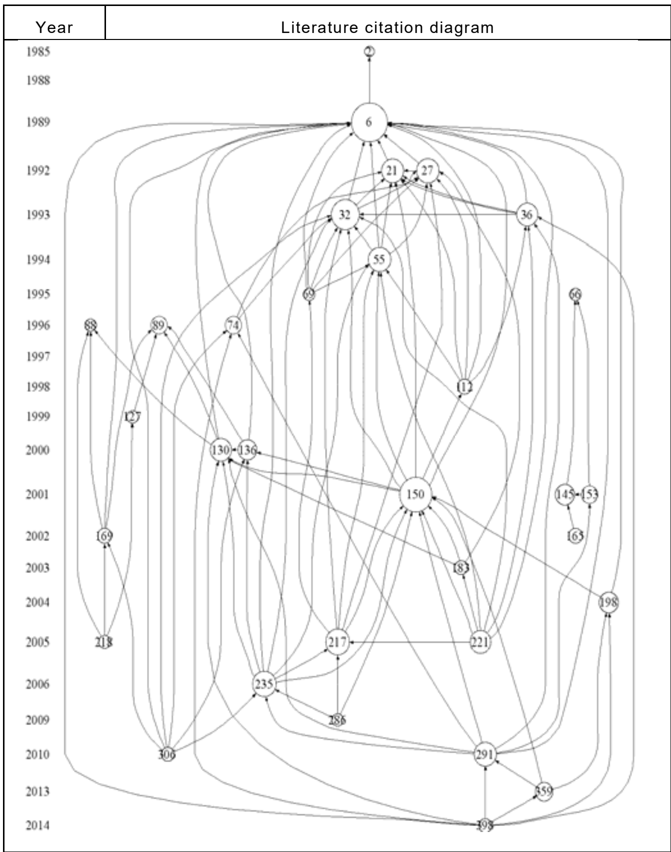
Light is the determining factor controlling the human biological clock cycle for nearly 24 hours(Lockley et al, 2002). Since David Berson et al. discovered the third type of photoreceptor cells in the human retina in 2002, i.e. ganglion cells (ipRGCs) (Berson et al, 2002), which revealed the non-visual biological effects of light on human body from a neurological view point. Many studies have been carried out on the effects of light on sleep quality (CIE, 2003), mood (Stone, 1999), wakefulness (Cajochen, 2007), melatonin (Lew et al, 1980) and cortisol (Scheer et al, 1999). In addition, a large number of experiments have confirmed that artificial bright light stimulation has a significant effect on the treatment of SAD (seasonal affective disorder) (Meesters et al, 2011; Pail et al, 2011).

However, human convention of phototherapy and the study of the effects of light on circadian rhythm are usually come from laboratory studies and therapeutic manipulations of light timing and duration that have relied upon sudden off/on switching of lights (Terman et al, 1989), rather than gradually adjusting the intensity of light, without considering the biological sensitivity of the weak changes of light before and after dawn or dusk. Furthermore, bright light after waking up in the morning has been shown to increase cortisol levels in healthy humans while light at other times of the day does not Few studies test the effects of a dawn light signal in the early (Leproult et al, 2001; Ruger et al, 2006; Scheer et al, 1999).This indicates that there are significant differences in the effect of light on alertness in different periods of time(Mariana et al, 2014). Interestingly, it has been shown that a simulated dawn was more effective than a square-wave, bright-light stimulus (light-on/lights-off) in treating SAD patients (Avery et al, 2001; Terman et al, 2006). This suggests that light exposure before consciously waking up exerts some effect that cannot be achieved even with exposure to bright light after awakening.

In recent years, with the development of research on dynamic lighting exposure, the influence of early morning arousal light on physiological and psychological indicators such as sleep quality at night, mood and alertness after awakening has become the main research content. Studies have shown that artificial dawn lighting can reduce the complaints of sleep inertia (Gimenez et al, 2010) and improve the alertness, cognition and performance (Thompson et al, 2014), the dynamics of light exposure have been shown to directly affect the impact of morning light exposure on sleep inertia, well-being, and cortisol levels (Gimenez et al, 2010; Van de Werken et al, 2010; Thorn et al, 2004).

A 30-minute artificial dawn before waking up is more effective in reducing sleep inertia and improving alertness than 300lx bright light stimulation after waking up (Van de Werken et al, 2010). Pupils were given simulated dawn which gradually increased to 100lx within 30 minutes before waking up, and their mood after waking up was better than no simulated dawn (CIE, 2011).

Table 1 – Literature Citation Diagram



NO.	Author	LCS	Contents
2	LEWY AJ et al.	3	melatonin
6	TERMAN M et al.	37	melatonin SAD
21	AVERY D et al.	14	winter depression
27	AVERY DH et al.	15	winter depression
32	AVERY DH et al.	23	winter depression
36	NORDEN MJ et al.	13	winter depression
55	AVERY DH et al.	15	winter depression
66	WEHR TA et al.	4	melatonin
74	Ando K et al.	8	eyelid translucency
112	Lingjaerde O et al.	6	winter depression
130	Danilenko KV et al.	13	melatonin
136	Danilenko KV et al.	10	melatonin
150	AVERY DH et al.	29	SAD
153	Wehr TA et al.	8	melatonin
183	Benedetti F et al.	5	depression
198	Thorn L et al.	11	cortisol
221	TERMAN M et al.	12	SAD/ depression
235	TERMAN M et al.	16	SAD
291	Gimenez MC et al.	14	sleep inertia
306	TERMAN M et al.	5	winter depression
359	Gabel V et al.	9	Cognition/mood/cortisol/melatonin
398	Thompson A et al.	5	sleep inertia

NOTE LCS means local citation score

Table 2 – Important Papers Information of Arousal Lighting Research

Year	Number of participants	Position of luminare	Experimental time	Illumination duration and characteristics (Exp:experiment;E:illuminance)	Light type	Experimental period	Way of waking up	NO.
2000	Exp1:8 Exp2:9	ceiling mounted		Exp1: 0.001lx-1000lx-1000lx-30lx Exp2: 0.001lx-2000lx-30lx-30lx	Artificial Dawn	4 days	light	130
2001	Exp1:33 Exp2:31 Exp3:31	Exp1: 30cm from the eye Exp2\3: 4 feet from the pillow	Nov.-Mar.	Exp1:6:00-6:30; 10000lx Exp2: 4:30-6:00; E:0-250lx Exp3:4:30-6:00; E:0-0.5lx	Artificial Dawn	7weeks	clock	150
2003	12	Bedside	Jan./Feb.	30min before wake up, 0-250lx	Artificial Dawn	4weeks	clock	198
2006	99	Bedside: 91cm and toward the head of the bed at a 31cm distance	Nov.-Mar.	Group1: Dawn Simulation,0.0003lx-250lx; Group2: a 13-minutes dawn light pulse,250lx; Group3: 30 minutes bright light,10000lx	Dawn Simulation\ Dawn light pulse \Bright Light	unmentioned	light	235
2010	Exp1:23 Exp2:23	40cm from participant;	Nov.-Dec.	30minutes before wake up, Exp1: 2weeks,0lx; 2weeks,0-50lx, 2weeks,0-250lx; Exp2: 20lx-400lx	Artificial Dawn	Exp1: 6weeks Exp2: 4weeks	clock	291
2013	17	Blue LED: 50cm from participant; Dawn simulation Light: eye height	Jan.-Mar.	Blue LED: 100 lx, 20minutes, after wake up; Dawn simulation Light: 0-250lx, 30minutes before wake up and 20minutes after wake up; Dim Light:<8lx	Artificial Dawn	3periods of 48hours,	clock	359
2014	8	30cm from the bed	Dec.-Mar.	30 minutes before wake up, 0.001lx-300lx	Artificial Dawn	6days	clock	398

2 Method

2.1 Participants

Participants are 16 (8 male, 8 female) freshmen in the School of Architecture of Tsinghua University. The male and female subjects live in 4 dormitories in two adjacent student apartments. Each apartment has one dormitory to the South and one dormitory to the north, as shown in Figure 1. They were recruited through the SRT (Student Research Training) program. All subjects were from the same major, aged 18-21. The whole day's class time and the lights out time at night is exactly the same, and also the three meals were served in the cafeteria is relatively uniform, so the exposure during the day is similar, which greatly reduced the experimental error caused by the differences in living habits of the study samples such as age, diet and work schedule. All subjects did not smoke, and did not have smoking history and mental disorders related diseases, nor taking drugs. During the experiment, the subjects were required to work and rest regularly. The diet was not allowed to contain nerve-stimulating drinks such as alcohol, caffeine or cocoa. Subjects got up at the usual schedule and filled out the corresponding questionnaires at fixed times every day. After getting up in the morning, subjects should report the wake-up time and the cause of your wake-up, and need to fill in the sleep diary, KSS(Karolinska Sleepiness Scale) alertness rating scale and mood assessment scale before class.

Table3 – Basic Information of Subjects

	Season	Mean±SEM	Min	Max
N		16		
Age		19.44±0.2	18	21
PSQI	Summer	5.8±0.43	4	10

2.2 Experimental space feature

The 4 dormitories are located on the 6th floor of the adjacent two dormitory buildings, which faces south orientation with inner corridor, as shown in Figure 1. The natural lighting of each dormitory comes from the glass area of the balcony door and the balcony window. The window is 1700mm high and the bed is 1750mm above the ground. Bed No. 2 is the closest to the window and receives the most natural light, however, due to the solid wall blocked the light, the bed No. 3 has less natural light during the day, and because of the distance is far from the window, less natural light reaches beds 1 and 4, as shown in Figures 2 and 3.

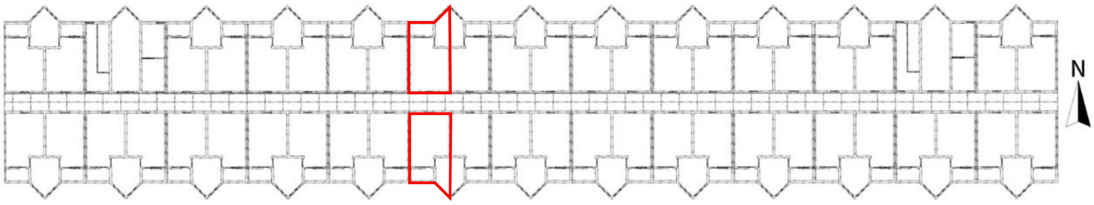


Figure1 – Layout Plan of Experimental Floor

2.3 Experiment design

2.3.1 Eye light exposure

A wireless illuminance sensor probe is mounted at the head position of each bed, and the probe is fixed to the wall outward, 15 cm above the bed. The probe is connected to the IoT Gateways through LoRa (Long Range) wireless transmission means. Two dormitories in each building share a gateway. The gateway is connected to the computer via USB cable, and the corresponding software is used to set the probe time interval of two illumination recording on the computer to obtain the LEA (Lighting Exposure Accumulation) before the subjects wake up. The illuminance data is stored in the gateway and exported to the computer once a week.

The LEA is continuously changing and is affected by the size and duration of the eye. This study sets the natural illuminance data every 15 minutes, starting from the illuminance data record of the probe. The last time the illuminance data was recorded as the ocular illuminance value before waking up, and the illuminance change law was approximately linearly changed by data fitting. Therefore, the integral formula was used to calculate the ocular exposure cumulative amount.

$$LEA = \sum_{i=1}^{n} \frac{(t_{i+1} - t_i)(x_{i+1} + x_i)}{2} \tag{1}$$

LEA is the lighting exposure accumulation;

i is the accumulated frequency;

n is the number of illuminations recorded before waking up;

$t_{i+1}-t_i$ is the duration of the interval between adjacent illuminations;

$(x_{i+1}+x_i)/2$ is the mean illumination of adjacent two recorded illumination.

2.3.2 Questionnaire and test methods

The sleep quality of the first three months was obtained through the PSQI (Pittsburgh Sleep Quality Index). During the experiment, the KSS scale was used to get the subjects' subjective evaluation of alertness after getting up, and subjective evaluation of mood and morning fatigue was obtained by 5-Level Likert PANAS (positive and negative effect schedule). Subjective assessment of sleep quality was evaluated by filling in the sleep diary after waking up.

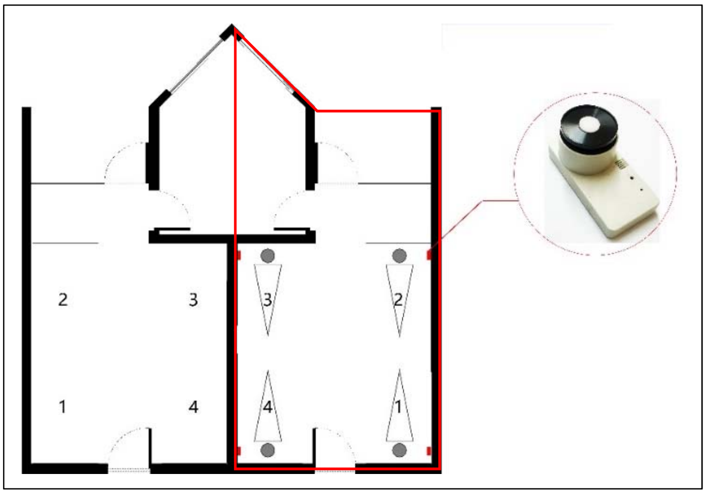


Figure 2 – Layout of the Dormitory and the Installation Position of Illumination Probe

2.3.3 Sleep quality

Some of the wearable trackers, such as Jawbone UP3, resulted in closer approximations to self-reported sleep outcomes (Lee et al, 2018), In this study, sleep timing, i.e., bedtime, sleep onset, alarm time, sleep offset, and get-up time, was recorded daily by self-monitoring systems—Jawbone UP3 and the sleep diary including both prospective and retrospective easurements, assist to correct singular data and lost data. This allowed us to check for a regular sleep-wake schedule and to record the timing of the artificial dawn.

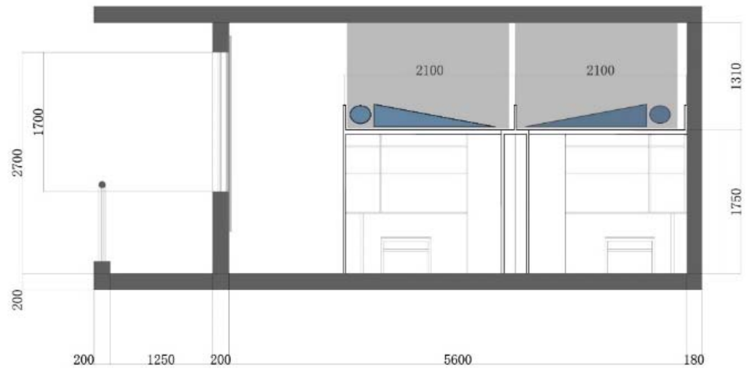


Figure 3 – Section Drawing of the Experimental Dormitory Units

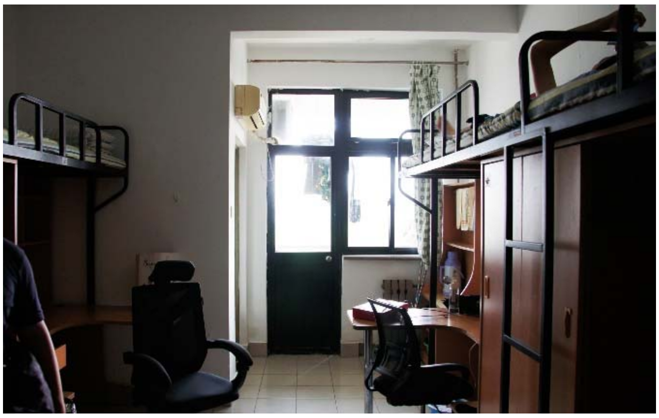


Figure 4 – Photos of the Inner Space of the Experimental Dormitory

3 Data analysis

The more LEA before wake up was expected to reduce morning fatigue and have a higher alertness and mood after wake up in the morning, as well as to improve sleep quality. Descriptive statistics on LEA and total sleep duration, deep sleep duration, and REM shows no significant correlation trend between the three sleep evaluation indicators and LEA, as is shown in Figure5. Descriptive statistics of LEA and alertness, mood and morning fatigue showed a significant correlation trend between alertness and LEA, but no significant correlation between mood, morning fatigue and LEA, as is shown in Figure6.

Among the different beds, the subjects’ LEA of other three beds had no significant regularity, except that the subjects’ LEA of bed 2 was significantly higher than that in other beds. Therefore, the beds were not used as the grouping basis in the difference analysis of physiological and psychological evaluation indexes, but were divided into 4 groups according to the quartile of 16 subjects' LEA. The one-way ANOVA was carried out for each evaluation index among 4 groups, and pearson correlation analysis was carried out for LEA and each evaluation index. 4 groups of alertness, mood and morning fatigue were analysed by ANOVA single-factor variance analysis, the results of single-factor homogeneity test were alertness, $p=0.220$, Mood, $p=0.118$, Morning fatigue, $p=0.808$, each p value is greater than 0.05, which indicated that single-factor variance analysis could be used.

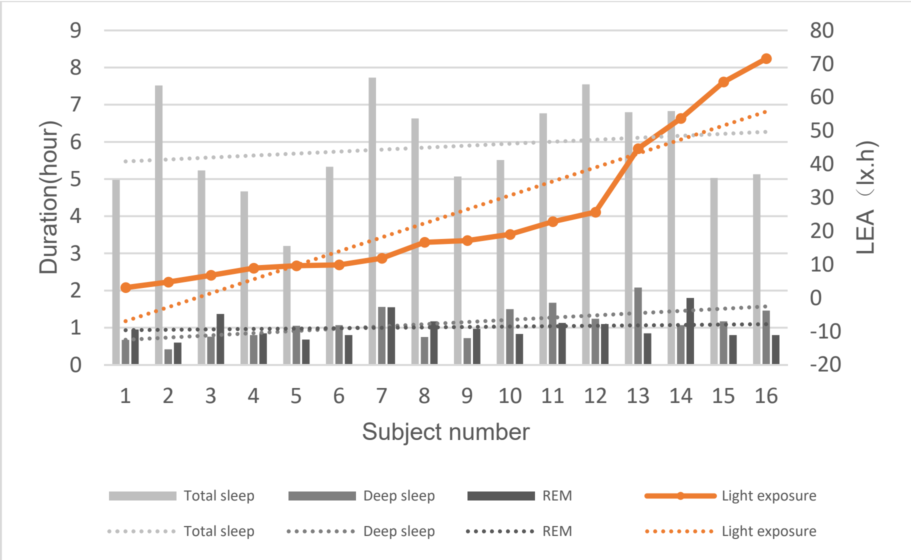


Figure 5 – Relationship between *LEA* and Sleep Quality

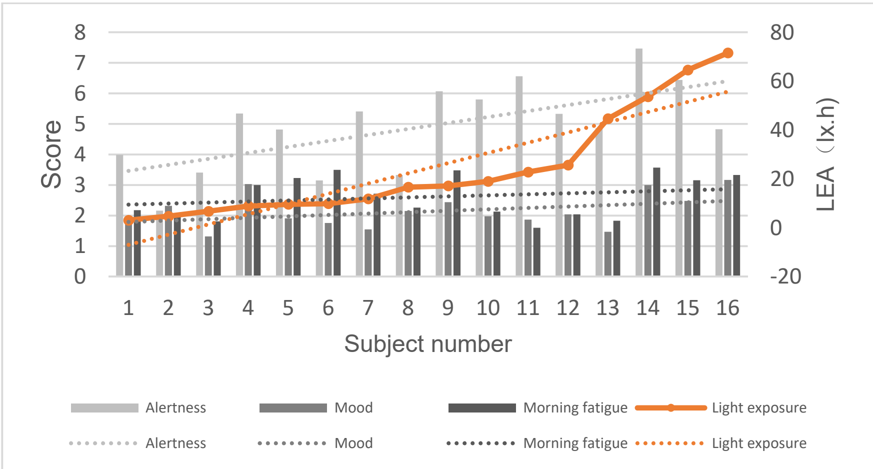


Figure 6 – Relationship between *LEA* and Alertness, Mood, Morning Fatigue

4 Result

4.1 Alertness

In this study, a KSS scale with 9 levels was used. The subjects underwent self-evaluation of alertness after waking up to obtain the alertness data. The higher the score, the higher the alertness. The 16 LEA were divided into 4 groups according to quartiles (Group1:<9.4575, Group2:9.4575-16.905, Group3:16.905-30.4175, Group4: >30.4175;), and significant difference were found between G1, G2 and G3, G4 respectively. Result of analysis of variance, $p = 0.028 < 0.05$, $F = 4.328$. The G3 alertness evaluation score was 2.215 and 1.7625 points higher than G1 and G2 on average, and G4 was 2.175 and 1.7225 points higher than G1 and G2, respectively. In addition, there was a significant correlation between LEA and alertness ($p=0.041<0.05$, Pearson=0.516), and the more LEA, the higher alertness after waking up.

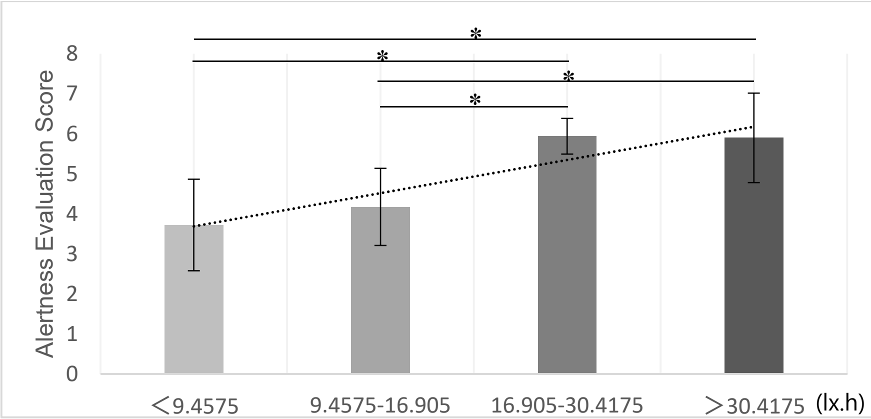


Figure 7 – Alertness Evaluation. Mean±SEM values of alertness evaluation after waking up. It was found that there were significant differences between G1, G2 and G3, G4.

4.2 Mood and morning fatigue

Mood and morning fatigue were evaluated by a five-level Likert scale with a full score of 5 points, and the higher the score, the better the mood and the lower the morning fatigue. Accord to the results variance analysis, the differences between mood($p=0.412>0.05$, $F=1.036$) and morning fatigue($p=0.317>0.05$, $F=1.307$) in the 4 groups divided by LEA quartiles were not significant. However, it can be seen from Figure 8 that G2 had significant difference with G3 and G4 of mood evaluation, and only G1 is abnormal. Further analysis found that of the correlation between LEA and mood ($p=0.043$, pearson=0.511) is significant, and not significant between LEA and morning fatigue ($p=0.225$, pearson=0.321). Subjects' mood evaluation is significantly correlated with total sleep duration of G1, but other three groups are not.

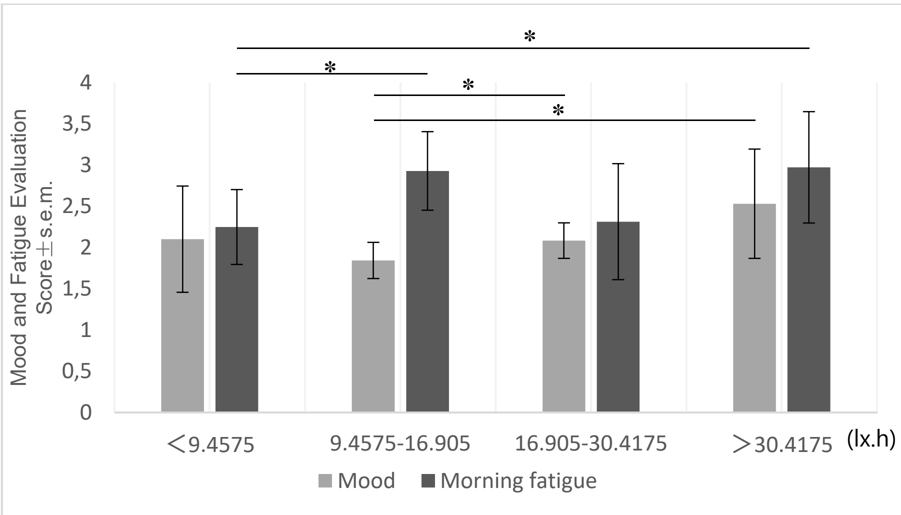


Figure 8 – Mood and Morning Fatigue. Mean±SEM of mood evaluation after waking up. There were significant differences between G2 and G3, G4. Mean±SEM of morning fatigue, there were significant differences between G1 and G2, G1 and G4, respectively.

4.3 Sleep quality

The quality of sleep was evaluated by three indicators: total sleep duration, deep sleep duration and REM (rapid eye movement sleep duration). Results of one-way ANOVA of the three factors' p value>0.05. So, further analysis of variance found that only deep sleep duration ($p=0.05$, $F=3.502$) is significantly different among 4 groups. The correlation between the three evaluation indicators and LEA were not significant, as is shown in Table 4.

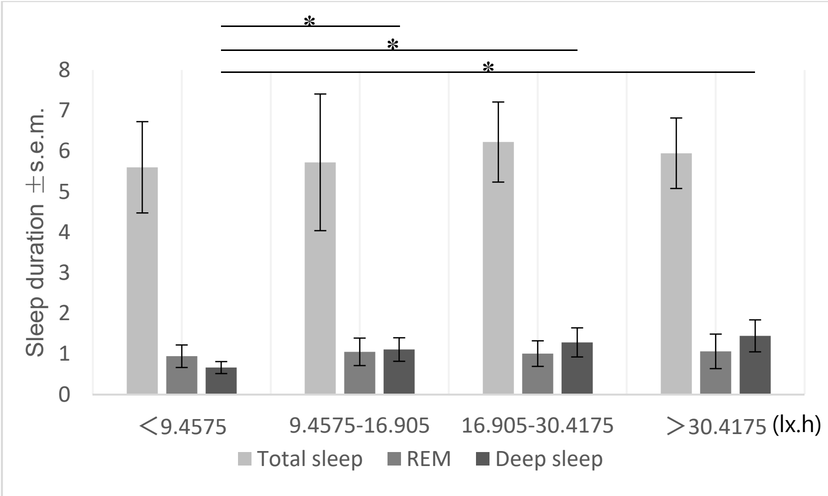


Figure 9 – Sleep Quality. Mean±SEM of total sleep duration, deep sleep duration and REM duration showed that only G2, G3, G4 and G1 of deep sleep duration were significantly different among the three indicators.

Table 4 – Correlation between LEA and sleep quality

	Value	
	Person	P
Deep sleep	0.481	0.059
REM	0.076	0.781
Total sleep	0.051	0.852

5 Discussion

In addition to LEA based groups, the subjects were classified by orientation and gender to discuss the experimental results. It was found that only the mood evaluation was significantly different by gender grouping, and the female subjects' mood evaluation was higher, and there were no significant differences of various evaluation indicators between southward and northward dormitories.

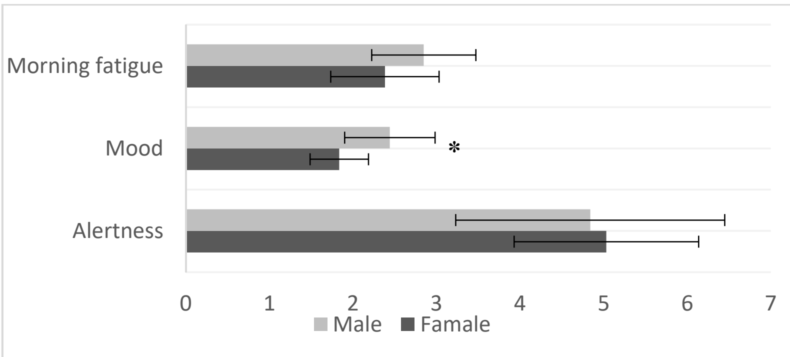


Figure10 – General Well being. Gender based mean ±SEM values for subjective ratings on different parameters to assess general well-being after waking up. It was significantly different of mood evaluation between male and female, and female subjects were better.

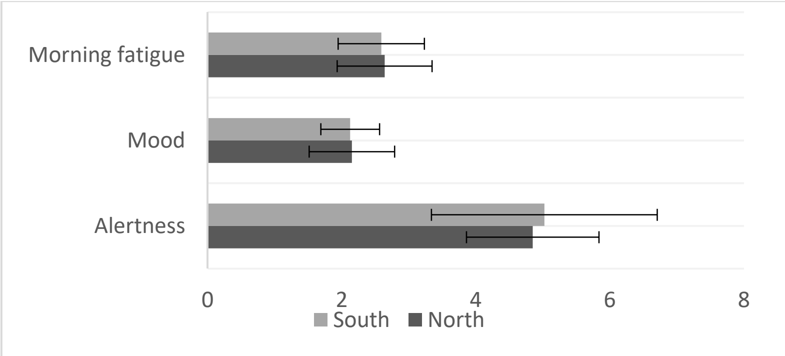


Figure 11 – General Well being. Orientation based mean ±SEM values for subjective ratings on different parameters to assess general well-being after waking up. There was no significant difference of each parameter.

Different from most of the researches completed in this research field, this study attempted to use the wireless illumination probe to record the LEA of the subjects before waking up in real time, and obtain the LEA before waking up by the integral formula. The natural light differences existed between the beds in the experimental space selected in this study, and the subjects in the same class were more regular and consistent, and they had lived and will live in this environment for a long time, which created favourable research conditions for this study. However, there are some limitations in this research. For example, the position of the wireless illumination probe is installed in the head area of each subject, and the illuminance value in only one direction can be recorded. It is impossible to record the illumination in different directions according to the face orientation of each subject, resulting in a certain error in the recording of the amount of natural eye light exposure.

Simulated dawn appears to be a safe, relatively well-tolerated, and possibly effective means of alleviating sleep disturbances related to the shorter photoperiod during winter. However, some study showed that the improvement on quality of sleep was modest (Leppämäki et al, 2003). There was also no significant correlation between natural light arousal illumination and sleep quality in this study. Most of the current studies are related to the effect of dawn lighting on melatonin secretion time (Konstantin et al, 2000; Danilenko et al, 2000). Therefore, the effect of dawn lighting on sleep time and bedtime alertness will be more significant.

The study was conducted in the northern hemisphere with a latitude of 35 degrees. According to the differences analysis in the LEA quartile based groups, 16.9lx.h may be a threshold value of LEA to exert positive impact on the alertness after waking up, and subjects below this value had a relatively low alertness. Therefore, the natural light exposure of some students who get up at 08:00 in the morning is not enough to be "waked up", indicating that even if there is natural light as a wake-up condition, but it may be blocked by walls and curtains, the bed height, the wake-up time, the season and the indoor surface reflectivity, etc., lead to insufficient LEA before waking up, which provides more research space and research value for artificial dawn simulation.

6 Conclusion

This study clearly showed that the more LEA before waking up the better mood and higher alertness in the morning. However, as tested in the present study, no significant correlation between LEA and sleep quality were observed. The dawn lighting signal, although not capable of having circadian effects, is hypothesized to assert an effect on physiological processes at waking up by activating/alerting the system.

Acknowledgements

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