35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

Effects of LED-backlit Computer Screen and Emotional Self-regulation on Human Melatonin Production

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Abstract— **Melatonin is a circadian hormone transmitted via suprachiasmatic nucleus (SCN) in the hypothalamus and sympathetic nervous system to the pineal gland. It is a hormone necessary to many human functions such as immune, cardiovascular, neuron and sleep/awake functions. Since melatonin enhancement or suppression is reported to be closely related to the photic information from retina, in this paper, we aim further to study both the lighting condition and the emotional self-regulation in different lighting conditions together with their effects on the production of human melatonin. In this experiment, five participants are in three light exposure conditions by LED backlit computer screen (No light, Red light (~650nm) and Blue light (~470nm)) for 30 minute (8-8:30pm), then they are collected saliva both before and after the experiments. After the experiment, the participants are also asked to answer the emotional self-regulation questionnaire of PANAS and BRUMS regarding each light exposure condition. These results show that positive mood mean difference of PANAS between no light and red light is significant with p=0.001. Tension, depression, fatigue, confusion and vigor from BRUMS are not significantly changed while we can observe the significant change in anger mood. Finally, we can also report that the blue light of LED-backlit computer screen significantly suppress melatonin production (91%) more than red light (78%) and no light (44%).**

I. Introduction

Melatonin or N-Acetyl-5-methoxytryptamine is a circadian hormone. It is rhythmically produced by the pineal grand in the brain with a low level during daytime and a high level during nighttime. The level of melatonin rises during the evening (8-11pm). It will reach the peak level between 2-4am and decrease to the baseline level during late morning (8-10am). This mechanism is controlled by the suprachiasmatic nucleus (SCN) which is inhibited by light and is stimulated by darkness. Melatonin is also known as a hormone necessary to many human functions such as immune, cardiovascular, neuron and sleep/awake functions.

In recent, technology development has led to energy-saving and effective electronic devices. The Light-Emitting Diode (LED) is one of those. It is widely used in display of electronic device such as smart mobile phone, television, desktop computer, notebook computer and tablet. However, the light form this device can suppress human melatonin production. Recently Studies, Wood et al (2013) showed that melatonin production can be suppressed after 1-2 hours by tablet with blue LEDs [1]. Cajochen et al (2011) showed that LED-backlit computer screen can significantly suppressed human melatonin production more than a non-LED backlit computer screen [2]. Furthermore, Figueiro et al (2011) showed that light from cathode ray tube computer screen can slightly suppressed human melatonin production and has suggested that the light from electrical devices at nighttime can suppress human melatonin production [3]. Lewy et al also showed that melatonin secretion in human can be suppressed by artificial light [4].

Besides the lighting condition, in parallel studies, stress, alertness and mood generated by both human themselves and environment are reported to have the effects on melatonin production. Plitnick et al (2010) showed that red light and blue light at nighttime can increase the beta-wave of electroencephalogram (12-30 Hz) and stimulate alertness and momentary mood and reduce sleepiness [5]. Cajochen et al (2005) showed that light at 460 nm stimulate alertness, effect on thermoregulation and heart rate, suppress melatonin production more than light at 550 nm [6]. Even though the research on lighting condition and emotion have been widely done, however, the correlation and connection between light and emotional self-regulation that have effect on melatonin production still missing. Therefore, in this paper, we emphasize on the effect of light from LED and emotional self-regulation in different light conditions on human melatonin production through the use of saliva-based hormone detection, enzyme-linked immunosorbent assay (ELISA) technique.

II. Materials and Methods

A. Participants

Five healthy participants with normal color vision (three male and two female) were recruited. The mean age of the participants was 25.4 years (SD = 2.24) with a range of 23-29 years old. All Participants did not take a prescription medication, alcohol and smoking before and during the study.

B. Study protocol

All participants arrived at the laboratory at 7:45pm and washed their mount for 5 minutes before collecting the saliva in the collecting tube. At 8pm, all participants started testing each light exposure conditions in the testing room with controlled room temperature at 25^0C. All participants sited on the chair which was 1-meter far from the LED-backlit

This project is supported in part by the government funding of Mahidol University.

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computer screen. This screen was used to generate different light exposure conditions. All participants were in each light exposure conditions for 30 minute and collected saliva in the collecting tube at 8:30pm (One light exposure condition per day). After that all participants were asked to answer the emotional self-regulation questionnaire of Positive and Negative Affect Scale (PANAS: Watson et al., 1998) [7] and Brunel Mood Scale (BRUMS: Terry et al., 1999, 2003) [8-9] for each light exposure condition. The study protocol is summarized in Figure 1.

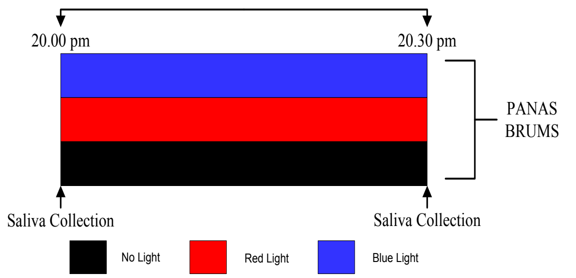

Figure 1. The study protocol: Participants were in no light, red light and blue light in test room for 30 minute (8-8:30pm) each day for each ligting condition. Saliva was collected before and after light exposure condition. The PANAS and BRUMS were tested after finished testing.

C. *Light exposure conditions*

In this paper, three light exposure conditions, i.e. no light, red light, and blue light, are employed. LED-backlit computer screen is used to generate different light exposure conditions. The screen is 20.0 inch with 0.2766 mm×0.2766 mm pixel pitch, resolution of 1600×900, and brightness of 250 cd/m^2.

For the first condition (no light condition), LED-backlit computer screen is turned off. For the second condition (red light condition), LED-backlit computer screen is set to the highest brightness with color temperature at the highest red color levels together with the lowest green and blue color level. This condition generates the long wavelength (~650nm) light. Finally, for the third condition (blue light condition), LED-backlit computer screen is set to the highest brightness, color temperature at the highest blue color level together with the lowest green and red color levels. This condition generates the short wavelength (~470nm) light.

D. *Emotional Self-regulation*

Positive and Negative Affect Scale (PANAS) and Brunel Mood Scale (BRUMS) are used to rate the scale of all participants after the experiments. PANAS is a 20-item mood scale and was developed to provide brief measurements of positive and negative effects. Each item is scored on 1-5 (1 means 'not at all', 2 means 'a little', 3 means 'moderately', 4 means 'quite a bit' and 5 means 'very much').

BRUMS is a 24-item mood scale that measures 6 identifiable affective states (tension, depression, anger, vigor, fatigue, and confusion). Each item is scored on 0-4 (0 means 'not at all', 1 means 'a little', 2 means 'moderately', 3 means 'quite a bit' and 4 means 'extremely').

E. *Measurement of human saliva melatonin*

Saliva was collected from five participants before testing (8pm) and after finishing the experiment (8:30pm) for each condition with clean collecting tubes and stored at ≤ -20^{0}C refrigerator immediately. After that, before the analysis, all collecting tubes were thawed at room temperature until being back to liquid. Then, enzyme-linked immune sorbent assay (ELISA) was used for direct human saliva melatonin concentration measurement (Buhlmann Laboratories, Schonenbuch, Switzerland) with sensitivity of 0.5 pg/ml and linearity of 92.2 %. It is a competitive immunoassay using a capture antibody technique. The Kennaway G280 anti-melatonin antibody was coated onto the microtiter plate.

In the first step, microtiter plate is incubated for 3 hours. The melatonin presented in the pretreated controls and standards, respectively, compete with biotinylated melatonin for the binding sites of this highly specific antibody. After washing, streptavidin conjugated to the horseradish peroxidase (enzyme label) is added. In the second step, microtiter plate is incubated for 60 minutes. The melatonin-biotin-antibody complexes are captured on the coated wells. Unbound enzyme label is removed by the second washing step and the TMB substrate is added to the wells. In the third step, microtiter plate is incubated for 30 minutes. Colored product is formed in the inverse proportion to the amount of melatonin presented in the sample. The color turns from blue to yellow after the addition of an acidic stop solution and can be measured at 450 nm. Anthos Lucy2 microplateluminometer is used to read the absorbance at 450 nm (Anthos Labtec Instruments Ges.m.b.H., Wals/Salzburg, Austria). Figure 2 presents human saliva melatonin ELISA kit.

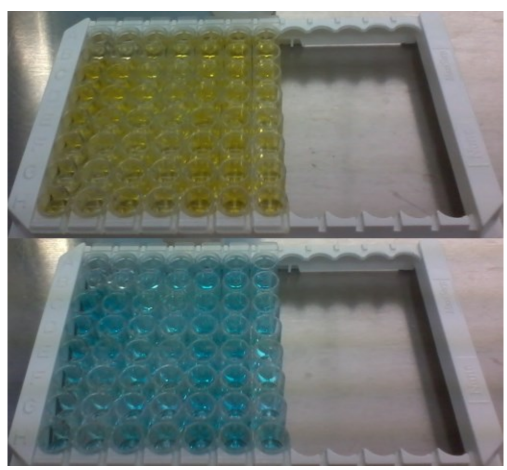

Figure 2. Human saliva melatonin ELISA kit (Buhlmann Laboratories, Schonenbuch, Switzerland).

III. RESULTS

A. *Emotional Self-regulation*

The positive effect value of PASNAS in no light, red light and blue light conditions are 10.4, 14.8 and 13.0, respectively. The negative effect value of PANAS in no light, red light and blue light conditions are 13.2, 16.2 and 12.2, respectively. Analysis of variance (ANOVA) reveals that the mean difference of positive effect is significant at the 0.05

level (F=9.175, p =0.004) but the mean difference of negative effect is not significant at the 0.05 level (F=1.752, p =0.215). Multiple comparisons test of LSD (Least Significant Difference) reveals that the mean difference is significant at the 0.05 level of no light - red light (p=0.001) and no light - blue light (p=0.027). The results are presented in Table 1 and graphical results of PANAS in light exposure conditions are presented in Figure 3.

The tension, anger, depression, fatigue, confusion and vigor mood of BRUMS in no light of participants are 1.2, 0.4, 1.4, 3.2, 1.2 and 0.6, respectively. The tension, anger, depression, fatigue, confusion and vigor mood of BRUMS in red light of participants are 2.4, 3.4, 2.8, 2.2, 2.8 and 2.8, respectively. The tension, anger, depression, fatigue, confusion and vigor mood of BRUMS in blue light of participants are 0.8, 1.0, 1.2, 2.2, 1.6 and 2.2, respectively. Analysis of variance (ANOVA) reveals that the mean difference of anger at the 0.05 level (F=10.500, p =0.002) is significant, however, the mean differences of tension, depression, fatigue, confusion and vigor are not significant at the 0.05 level (F=1.195, p =0.336; F=1.239, p=0.324; F=0.758, p=0.490; F=1.268, p=0.316 and F=1.416, p=0.280, respectively). Moreover, the multiple comparisons test of LSD (Least Significant Difference) reveals that the mean difference of anger is significant at the 0.05 level of no light - red light (p=0.001) and red light - blue light (p=0.005). The results are presented in Table 1 and the graphical results of BRUMS in light exposure conditions are presented in Figure 4.

TABLE I. PANAS, BRUMS AND MELATININ SUPPRESION

Measure	Light exposure conditions			P-value
	No light	*Red light*	*Blue light*	
PANAS				
Positive affect	10.4±0.6	14.8±2.6^{+}	13.0±1.0^{+}	0.004*
Negative affect	13.2±5.0	16.2±3.2	12.2±1.5	0.215
BRUMS				
Tension	1.2±1.6	2.4±2.1	0.8±1.3	0.336
Anger	0.4±0.5	3.4±1.5^{+}	1.0±1.0^{++}	0.002*
Depression	1.4±2.1	2.8±1.9	1.2±1.1	0.324
Fatigue	3.2±1.6	2.2±1.1	2.2±1.6	0.490
Confusion	1.2±1.8	2.8±1.5	1.6±1.7	0.316
Vigor	0.6±1.3	2.8±2.6	2.2±2.3	0.280
Melatonin suppression (%)	44±21	78±14^{+}	91±12^{+}	0.001*

Note: Values represent mean±SD. + = The mean difference is significant at the 0.05 level between no light and red light, no light and blue light. ++ = The mean difference is significant at the 0.05 level between red light and blue light. * = The mean difference is significant at the 0.05 level.

B. Human saliva melatonin

The percent of human saliva melatonin suppression in no light, red light and blue light are 44%, 78% and 91%, respectively. Analysis of variance (ANOVA) reveals that the mean difference of melatonin suppression is at the 0.05 level (F=11.778, p =0.001). Multiple comparisons test of LSD (Least Significant Difference) reveals that the mean difference is significant at the 0.05 level of no light - red light (p=0.018) and no light - blue light (p=0.002). The results are presented in Table 1 and the graphical results of melatonin suppression (%) in light exposure conditions are presented in Figure 5.

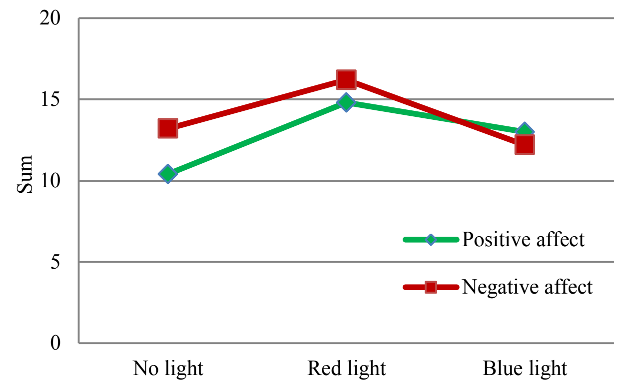

Figure 3. PANAS in light exposure conditions

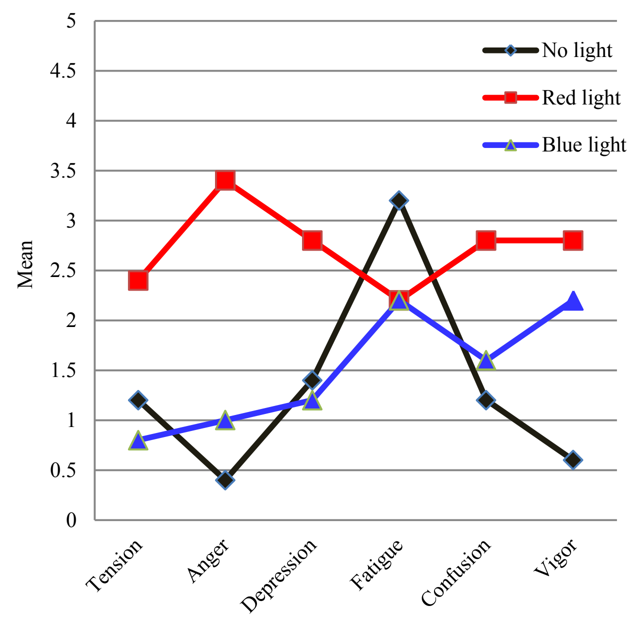

Figure 4. BRUMS in light exposure conditions

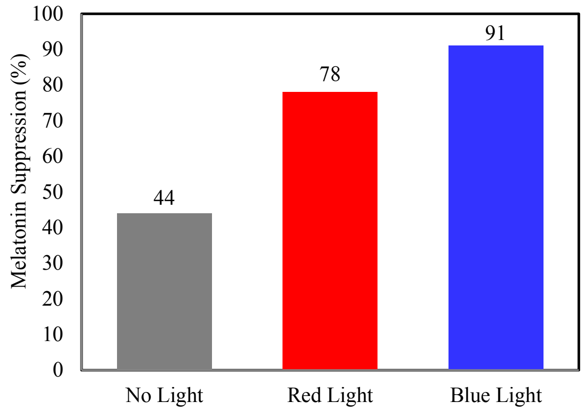

Figure 5. Melatonin suppression (%) in light exposure conditions

IV. CONCLUSION

The aim of this study was to investigate the effects of light from LED and emotional self-regulation in different light conditions on healthy human melatonin production. These results show that blue light of LED-backlit computer screen significantly suppress melatonin production more than red light of LED-backlit computer screen and no light. Many studies have shown that blue light significantly inhibit melatonin production at night since the blue light (460 nm) has short wavelength with peak of sensitivity of melanopsin [2-5]. However, it is also important to consider the long term exposure and different intensities of brightness since these factors also have the effects on human melatonin production.

In general, alertness, stress and mood can be reliably measured by simply asking the participants or rating scale. PANAS revealed that the positive effect of mood is stimulated by red and blue light of LED backlit computer screen more than no light, but the negative effect of mood is not difference in each light exposure conditions. BRUMS revealed that red light of LED- backlit computer screen can stimulate tension, anger, depression and confusion moods more than blue light and no light which are related to the negative effect of mood. Vigor mood in red light condition is also higher than blue and no light condition.

Red and blue light have effect on emotional self-regulation more than no light because it stimulates stress, alertness and momentary mood. This is related to the melatonin production. Many studies have shown that red light and blue light at nighttime increased beta-wave of electroencephalogram (15-30 Hz), stimulated alertness and momentary mood as well as reduce sleepiness [5-6]. Moreover, it also has direct and indirect effects via suprachiasmatic nucleus (SCN) to brain areas implicated in the regulation of arousal [10-11].

Intuitively speaking, the earth rotates around the sun every day. This phenomenon causes day and night, or light and darkness. The human have adapted to this phenomenon. Human sleeps at night. This period is no light. It does not suppress the melatonin production then human falling asleep. In the morning, human wakes up by the light. This period contains red light more than any light. It stimulates alertness and suppresses melatonin production. During a day, this period contains blue light more than any light. It suppresses melatonin production. In the dusk, this period contains red light more than any light again. It induces the melatonin production more than blue light then human falling asleep.

In conclusion, blue light has effect on melatonin production more than red light. Red light stimulates positive affect and anger more than blue light. It also has effect on melatonin production. Finally, this conclusion can be used to design and develop the electrical display devices used before sleep that cannot stimulate alerting or stress and suppress melatonin production. Melatonin suppression by light at night increases the risk for more serious diseases such as breast cancer [12]. In addition, artificial light technology is used in the design of more effective lighting at novel house or workplace with no effect on human physiology and health maintenance.

ACKNOWLEDGMENT

The project is supported in part by the government funding of Mahidol University. We would like to thank Prof. Ahnond Bunyaratavej and Dr. Monnipha Sila-Asna for discussion in results, members of Cell Engineering and Tissue Growth Research Group (CETG), members of Brain-Computer Interface Laboratory (BCI Lab) of Mahidol University and all participants.

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