Effects of VDT tasks with a bright display at night on melatonin, core temperature, heart rate and sleepiness

Shigekazu Higuchi, Yutaka Motohashi, Yang Liu, Mio Ahara and Yoshihiro Kaneko
Department of Public Health, Akita University School of Medicine, Akita, Japan

Correspondence to: Shigekazu Higuchi, Ph.D.
Department of Public Health,
Akita University School of Medicine,
1-1-1 Hondo, Akita City 010-8543, Japan
Tel: +81-18-884-6087
Fax: +81-18-836-2609
E-mail: higuchi@med.akita-u.ac.jp

Key words
Light, biological rhythm, video game, Internet, EEG

Running head
Effects of VDT task with a bright display on melatonin
Abstract: The effects of performing video display terminal (VDT) tasks with a bright display at night on nocturnal salivary melatonin concentration, rectal temperature, heart rate and sleepiness were examined. Seven healthy male adults performed exciting VDT tasks with a bright display (BD) and a dark display (DD) and boring VDT tasks with a BD and a DD from 23:00 to 2:00. The light intensities of the BD and DD were 45 lx and 15 lx at each subject’s eye level, respectively. The exciting VDT task with both BD and DD significantly suppressed the nocturnal decrease in rectal temperature and heart rate and the nocturnal increase in sleepiness. The BD significantly suppressed the nocturnal decrease in rectal temperature during both exciting and boring VDT tasks. The nocturnal salivary melatonin concentration was significantly suppressed by the combination of the exciting task and BD. The results suggest that performing an exciting VDT task with a bright display suppress the nocturnal changes in melatonin concentration and other physiological indicators of human biological clocks.
1. Introduction

The number of people in Japan using personal computers at night is increasing due to the rapid spread of information technology. According to a Japanese white paper on information technology (19), 53.7% of Internet users in Japan had delayed bedtimes and 45.4% of them had shortened sleeping hours. These statistics suggest that performing a VDT task influences the sleep-wake cycle and human biological rhythms. It is not clear, however, what factors of a VDT task are physiologically related to this phenomenon.

It is thought that gazing at a bright display of a light source while performing a VDT task is one of the factors that affect the human biological clock. Many studies have shown that exposure to a bright light during the night suppresses melatonin secretion (2, 5, 21, 23, 27, 32) and delays the acrophase of circadian rhythm in melatonin in humans (15, 31, 32). Melatonin secreted from the pineal gland is sensitive to light, and plasma or salivary melatonin concentration is often used as a physiological marker of the biological clock. In 1980, Lewy et al. (21) first demonstrated that the nocturnal melatonin was suppressed during exposure to bright light at 2500 lx in humans. More recent studies have shown that nocturnal melatonin secretion can be suppressed by exposure to a light of several hundred luxes (2, 5, 23, 32). Furthermore, Brainard et al. (6) found using subjects with pharmacologically dilated pupils that the melatonin secretion could be suppressed by exposure to light of even less than one hundred lux. Although the light intensity of a VDT is not so strong, it is worth examining its effects on melatonin levels, especially when a bright display is used.

Another factor affecting the human biological clock and sleep-wake cycle is thought to be increased mental activity caused by using a computer. It has been reported that melatonin level was influenced by exercise (29) and affective state (22). It has also been reported that social activities entrained the circadian rhythm in humans (17, 20). There is a need, therefore, to examine the effects of changes in mental activity level on nocturnal melatonin level.
In the present study, the effects of a bright display and increased mental activity level on nocturnal melatonin level while subjects performed VDT tasks at night were examined. Salivary melatonin concentration in each subject was measured, and rectal temperature was also measured because it has been used as a physiological marker of circadian rhythm and there are many studies showing that rectal temperature is influenced by exposure to bright light (11, 12). Heart rate and an electroencephalogram (EEG) were monitored to evaluate the activity levels of autonomic and central nervous systems.

2. Methods

The study was conducted in our laboratory during the period from January to March. Seven healthy male students volunteered to participate in the present study. Informed consent was obtained from all participants. The mean ± standard deviation in ages of the subjects was 24.7 ± 5.6 years. The mean score of morningness-eveningness preferences (18) was 48.3 ± 5.8. None of the subjects were either extreme morning-type or extreme evening-type. Beginning one week prior to the start of the experiment, the subjects were instructed to wake up between 8:00 to 9:00 and go to bed between 0:00 to 01:00 in order to maintain regular sleep-wake cycles. The average times when the subjects went to bed and wake up were 0:45 ± 19 mins and 08:16 ± 26 mins, respectively. Furthermore, beginning 3 days prior to the experiment, the subjects recorded their oral temperature approximately every 3 hours, except during sleep. The acrophase of the circadian rhythm of oral temperature was estimated using the cosinor method. The mean acrophase of oral temperature was 19:05 ± 80 mins.

The subjects performed exciting tasks on a VDT with bright display (exciting-BD) and dark display (exciting-DD) and boring tasks on a VDT with bright display (boring-BD) and dark display (boring-DD) between 23:00 to 2:00 the next day. The experimental order was
randomized and the interval of each experiment was more than one week. The exciting task was a shooting game and the boring task was a simple addition task. In the simple addition task, a pair of single digit numbers was presented on the display at intervals ranging from 3 seconds to 30 seconds and the subjects inputted the correct answer on the keyboard at their own pace. The subjects were instructed to gaze at the display during the task. If a subject did not respond because he closed his eyes, an alarm rang and the number was counted. The 17-inch color-display (Epson, CRV-1790FX, Japan) was placed at eye level 45 cm in front of the subject. The screen of the display was 240 mm long and 325 mm wide. The screen of the BD was white with 120 cd/m², and the screen of the DD was black with 0.5 cd/m². The vertical light intensities of the BD and DD were 45 lx and 15 lx at each subject’s eye level, respectively. The light in the experimental room was dim (<10 lx) and the room temperature was kept at 24 ± 1 °C. The subjects visited our laboratory at 22:00. The subjects sat on a chair and the preparations for the experiment such as attachment of EEG electrodes were carried out under dim light (<10 lx). The preparations were completed within 45 minutes. Then the first physiological measurements prior to the VDT task were started at 22:45 under dim light and were completed in about 15 minutes. A VDT task (45 min) and measurements (15 min) were repeated from 23:00 to 2:00.

Saliva samples were collected using cotton wool and a plastic tube (Salivette, Sarstedt, Germany) at 23:00 (before commencing the task) and at 02:00 (after completion of the task). After centrifugation (for 5 min at 3000 rpm), the saliva was kept frozen at −30 °C until used for analysis. Melatonin concentrations in the saliva samples were determined by a radioimmunoassay using a BUHLMANN (RIA) test kit (Buhlmann Laboratories, AG, Switzerland) in the SRL laboratory (Tokyo). Rectal temperature was recorded at 2-min intervals during each task (Gram Corporation, LT-8, Japan). Heart rate, electroencephalogram (EEG), and subjectively rated sleepiness were recorded before the start
of each task and every hour while the subjects rested between tasks. The EEG was recorded at the central location (Cz) for three minutes while the subjects closed their eyes using a bioelectric amplifier (Nihon-Kohden, MME-3116, Japan). Fast Fourier transformation (FFT) was performed using artifact-free EEG data. The mean power values were integrated for the theta (4.0-8.0 Hz), alpha (8.25-13.0 Hz) and beta (13.25-20.0 Hz) frequency bands, and the relative theta power was calculated as an index of physiological sleepiness. Subjective assessment of each subject’s sleepiness was made using the visual analogue scale method. A three-way (task, brightness of display, time of day) or two-way (task, brightness of display) analysis of variance with repeated measurements was performed to determine statistical significance.

3. Results

Figure 1 shows the changes in salivary melatonin concentration. The salivary melatonin concentration increased at 2:00 in all conditions. The salivary melatonin concentration was significantly influenced by the brightness of the display ($F = 7.27; df = 1.6; p < 0.05$). The salivary melatonin concentration was significantly lower during the exciting-BD than during the exciting-DD ($t = 2.51; df = 6; p < 0.05$), but there was no significant difference between salivary melatonin concentrations during the boring-BD and boring-DD.

The rectal temperature data averaged per 30-min intervals are shown in Figure 2. Significant effects of the task ($F = 33.27; df = 1.6; p < 0.01$) and time course ($F = 33.02; df = 5.30; p < 0.01$) were found, and significant interactions between the task and time course ($F = 8.09; df = 5.30; p < 0.01$) and between the task and brightness of display ($F = 3.03; df = 5.30; p < 0.05$) were also found. The rectal temperature decreased during the night in all conditions. The rectal temperature was higher during the exciting task than during the boring one. The rectal temperature was also significantly higher during the tasks with a bright display than
during the tasks with a dark display in the latter half of each task.

The changes in subjectively rated sleepiness, relative theta power of EEG and heart rate are shown in Figure 3. Significant effects of the task (p<0.01) and time course (p<0.01) on subjectively rated sleepiness, relative theta power and heart rate were found. The subjectively rated sleepiness and relative theta power increased during the task in all conditions. The subjectively rated sleepiness and relative theta power were higher during the boring VDT task than during the exciting one. No significant effect of bright display on subjectively rated sleepiness and relative theta power were found. The heart rate decreased during the task in all conditions. The heart rate was significantly lower during the boring VDT task than during the exciting one. Although no significant effect of bright display on heart rate was found, heart rate tended to be higher with the BD than with the DD (p<0.10).

4. Discussion

We found that the nocturnal salivary melatonin was suppressed after performing the exciting VDT task with the bright display. The melatonin was suppressed by exposure to a light of lower intensity than previous reported (2, 5, 23, 32). The light intensity of the bright display used in the present study was only 45 lx, while the light intensities in previous study were more than several hundred luces. The suppression of the nocturnal melatonin at lower light intensity observed in the present study seemed to be related to the VDT task. Each subject in the present study had to continue gazing at a bright display of a light source to perform the VDT tasks, while subjects in the previous study did not gaze at light sources for such a long time (32). It has also been reported that pupil size influenced the nocturnal melatonin by exposure to light (13) and that the melatonin was suppressed by exposure to light with an intensity of only 40 lx in subjects with pharmacologically dilated pupils (6). In the present study, pupil size might have been related to the suppression of salivary melatonin. The
subjects’ pupils might have dilated while they performed the exciting task with a bright display, because an increase in pupil size is induced by acceleration of the sympathetic nervous system activity (9). We found that the heart rate, which reflects the state of the sympathetic nervous system, was significantly higher while the subjects performed the exciting task with the bright display than while the subjects performed the boring task with the bright display. It is thought that a combination of a bright display and an exciting task induces suppression of nocturnal melatonin secretion.

In addition, during the boring task with the bright display, three of the seven subjects closed their eyes 6 to 12 times, as estimated by counting the number of missing inputs for answers in the addition task. Although no statistically significant correlation was found between the melatonin level and number of times the subjects closed their eyes because of insufficient samples, this might be the reason why melatonin suppression did not occur during the boring task with the bright display. Furthermore, high brightness contrast of a bright display in the present study might also be related to the suppression of melatonin.

In the present study, physiological indicators other than salivary melatonin concentration were also influenced by the bright display and exciting task. The rectal temperature was significantly higher during the task with a bright display than during the task with a dark display. Although it has been reported that the bright right suppressed the nocturnal decrease in rectal temperature (11, 12), we found that the nocturnal decrease in rectal temperature was also suppressed by exposure to bright display. It has been reported that melatonin induced a decrease in body temperature (4, 26). The suppression of nocturnal decrease in rectal temperature during the exciting task with a bright display is thought to be caused by the suppression of melatonin. Heart rate, subjective sleepiness and relative theta power of EEG were not affected by the bright display, although some previous study showed that bright light accelerated autonomic nervous system activity (30) and EEG activity (3, 8, 16, 28). The
light intensity in the present study is thought to be insufficient. The significant effects of the exciting task both with the dark display and the bright display were observed all indicators except for the melatonin level. This result shows that nocturnal melatonin is not easily masked by changes in mental activity level, and that nocturnal variations in rectal temperature, sleepiness and heart rate are masked by changes in mental activity level. It has been reported that the circadian variations in body temperature are masked by exogenous factors such as rest-activity cycle and arousal state (21).

The suppressive effects of an exciting VDT task with a bright display on nocturnal variations in physiological indicators, including melatonin concentration, are termed masking or exogenous effects (25). However, it is known whether an exciting VDT task with a bright display induces a phase shift of circadian rhythm. This should be examined in a future study.

Some observational studies have demonstrated that exposure to an electric magnetic field (EMF) suppressed melatonin level in humans (7, 10), but this was not found in some laboratory studies carried out under carefully controlled experimental conditions (1, 14). As the intensity of the EMF from a bright display is much lower than that used in these laboratory studies, it is thought that the EMF from the bright display had little effect on melatonin level.

In conclusion, performing an exciting VDT task with a bright display influences the nocturnal melatonin concentration and other physiological indicators of the human biological clock.
References


11. Dijk DJ, Cajochen C, Borbély AA. Effects of a single 3-hour exposure to bright light on core


21. Lewy AJ, Wehr TA, Goodwin FK, Newsome DA, Markey SP. Light suppresses melatonin


Legends to figures

Fig.1  Salivary melatonin concentrations at 23:00 (before the start of the VDT task) and at 02:00 (after the completion of the VDT task). A significant difference was found between the salivary melatonin concentrations during the exciting-BD and the exciting-DD (p<0.05). All data are expressed as means + S.E.

Fig.2  Changes in rectal temperature from 23:00 (before the start of the VDT task) to the end of the VDT task. Significant effects of task (p<0.01) and time course (p<0.01) on rectal temperature were found, and significant interactions between task and time course (p<0.01) and between task and brightness of display (p<0.05) were also found. All data are expressed as means + S.E.

Fig.3  Changes in subjectively rated sleepiness, theta power of EEG and heart rate from 23:00 (before the start of the VDT task) to the end of the VDT task. Significant effects of tasks (p<0.01) and time course (p<0.01) on subjectively rated sleepiness, relative theta power and heart rate were found. All data are expressed as means + S.E.
Fig. 1

Salivary melatonin concentration (pg/ml) vs. Time of day (h), during tasks vs. before tasks. Exciting-DD, Exciting-BD, Boring-DD, Boring-BD. (*: p<0.05)
Fig. 2

Rectal temperature (Δ T) vs. Time of day (h)

- Exciting-DD
- Exciting-BD
- Boring-DD
- Boring-BD

-1.0 before during tasks
-0.5
0.0
1.0

23 0 1 2
Time of day (h)

before during tasks
Fig. 3

- Exciting-DD
- Exciting-BD
- Boring-DD
- Boring-BD