



Self-luminous devices and melatonin suppression in adolescents

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Self-luminous devices, such as computers, tablets and cell phones can emit short-wavelength (blue) light, which maximally suppresses melatonin. Melatonin is a hormone that starts rising approximately 2 hours prior to natural bedtimes and signals darkness and sleep to the body. The present study extends from previously published studies showing that light from self-luminous devices suppresses melatonin and delays sleep. This is the first study conducted in the home environment that investigated the effects of self-luminous devices on melatonin levels in adolescents (age 15–17 years). Results show that 1-hour and 2-hour exposure to light from self-luminous devices significantly suppressed melatonin by approximately 23% and 38% respectively. Compared to our previous studies, these results suggest that adolescents may be more sensitive to light than other populations.

1. Background

Retinal light exposures during the night suppress melatonin production in a dose-dependent manner.¹ The degree of suppression is positively correlated with the irradiance and duration of light exposure.¹ Under strict laboratory conditions and in a dose-response dependent manner, exposure to ~100 lux of a cool white fluorescent light will cause 50% of the melatonin suppressive effect induced by exposure to 10,000 lux,¹ demonstrating the high sensitivity of the circadian pacemaker to light. The circadian system, as measured by acute melatonin suppression and phase shifting of dim light melatonin onset (DLMO), is maximally sensitive to short-wavelengths (peak $\lambda \approx 460$ nm). Light information is perceived by the retinal photoreceptors that project to the suprachiasmatic

nuclei via the retinohypothalamic tract, and then via the superior cervical ganglion to the pineal gland, to control melatonin production.^{2–6} It has been shown that some degree of melatonin suppression was observed after 90-minute exposure to 2 lux of 470-nm light, which emits most of its energy close to the peak sensitivity of the circadian system.⁷

In addition to the direct effects of light on suppressing melatonin production, light also affects the timing of melatonin production via the circadian pacemaker.⁸ For example, light stimuli applied within a few hours before the midpoint of the melatonin secretion episode will delay the phase of the circadian pacemaker, while light stimuli applied within a few hours after this midpoint will advance the phase. Thus, inappropriate light exposure can change the timing of melatonin production to an abnormal phase.

Morning light (i.e. light after the minimum core body temperature) promotes entrainment to the solar day and, therefore, supports

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daytime alertness and performance, while light in the evening and in the early part of the night may lead to acute suppression and delay the timing of melatonin production, both of which are hypothesised to be detrimental to sleep quantity and quality. Sleep deprivation has been associated with diabetes and obesity.⁹ Melatonin suppression by exposure to light at night and circadian disruption resulting from irregular light/dark patterns have been associated with more serious health risks, such as cancer.¹⁰ In adolescents, chronic sleep deprivation resulting from late bedtimes and early wake times has been associated with reduced school performance, increased risk of diabetes and obesity, mood disorders and drug addiction.^{11–13}

Self-luminous devices, such as computers and tablets that use light-emitting diodes (LEDs), emit short-wavelength (blue) light, close to the peak sensitivity of the circadian system. Advances in technology have led to larger and brighter screens, and these devices are being used for longer periods of time in the evening, when melatonin, a hormone signaling darkness to the body, starts rising. According to the U.S. Census Bureau, more than 75% of households have a computer¹⁴ and presumably use these devices in the evening hours.

Cajochen *et al.*¹⁵ examined the effects of LED-backlit computer screens on circadian rhythms and cognitive performance in a study of 13 participants. Two 5-hour experimental sessions were held with one of two computer screen types: (1) white LED backlit computer screen; (2) non-LED backlit screen (cathode fluorescent lamp). The screens had similar illuminance/visual comfort ratings, but different spectral compositions. Results showed that a 5-hour exposure to a LED backlit computer screen significantly suppressed melatonin, reduced sleepiness levels and enhanced cognitive performance (e.g. attention, memory) compared to a non-LED

backlit screen. Although melatonin levels still rose over the course of the night, they did not rise as steeply as when participants experienced the non-LED backlit computer screen condition. More recently, Chang *et al.*¹⁶ showed that compared to reading a paper book in near darkness, electronic readers acutely suppressed melatonin, delayed the onset of evening melatonin and negatively affected sleep quality.

Figueiro *et al.*^{17–19} have performed three studies investigating the impact of three types of self-luminous devices (computer, iPad and television) on evening melatonin levels. In the first study, they investigated the effect of a 2-hour exposure to cathode ray tube (CRT) computer screens on acute melatonin suppression in college students.¹⁷ Twenty-one participants experienced three test conditions: (1) computer monitor only (experimental condition), (2) computer monitor viewed through goggles providing 40 lux of short-wavelength (blue; peak $\lambda \approx 470$ nm) light at the cornea from LEDs ('true-positive' experimental condition), and (3) computer monitor viewed through orange-tinted safety glasses that filtered optical radiation below 525 nm ('dark' control condition). Saliva samples were collected from participants at 23:00, before starting computer tasks, and again at midnight and 01:00 while performing computer tasks under all three experimental conditions. Melatonin concentrations after 2-hour exposure to the blue-light goggles were reduced compared to the dark control and to the computer monitor only conditions. Although not statistically significant due to high variance in suppression among participants, the mean melatonin concentration after exposure to the computer monitor was reduced by about 16% relative to the dark control condition.¹⁷ Using the same experimental design, they showed that iPad use did not significantly suppress melatonin after 1 hour (mean suppression = 7%), but after 2-hour exposure, suppression was statistically

significant (mean suppression = 23%).¹⁸ In their third study, Figueiro *et al.* showed that, compared to the dark control, melatonin levels continued to rise after 90-minute exposure to 70-inch televisions, suggesting that light coming from televisions is not strong enough to suppress melatonin in the evening.¹⁹

This field study extends those previously published and is the first study conducted in the home environment that investigated the effects of self-luminous devices on melatonin levels in adolescents (ages 15–17 years). Two test conditions were employed: (1) self-luminous devices viewed through orange-tinted glasses (optical radiation < 525 nm \approx 0) and (2) self-luminous devices viewed without orange-tinted glasses. The orange-tinted glasses served as a ‘dark’ control condition since they removed short-wavelength radiation that maximally suppresses melatonin production while participants performed tasks using self-luminous devices. Since, however, self-luminous devices deliver different corneal irradiances depending on the type, size and brightness of the display and on the postures of the viewers, and since each participant had a different type of self-luminous device, each participant was asked to wear a pendant Daysimeter,²⁰ a calibrated light meter that monitored circadian light exposures over the course of the data collection period.

2. Method

2.1 Participants

Twenty adolescents were recruited into this within-subjects study. The age range of the participants (7 males and 13 females) was between 15 and 17 years. Eligibility for the study required participants to be free of any major health problems, such as cardiovascular disease, diabetes or high blood pressure. Potential participants were excluded from the experiment if they were taking over-the-counter melatonin or prescription medication

such as antidepressants and sleep medicine. They were not excluded from the experiment if they were taking oral contraceptives. Participants were asked to self-report any eye diseases or colour blindness. Potential participants who stated they had an eye disease were excluded from the study.

2.2 Experimental and control conditions

Two lighting conditions were employed on two consecutive days in November 2013 in Albany, NY, USA. In both experimental conditions, participants were asked to use self-luminous devices starting 3 hours prior to their normal bedtimes. During the first night, participants were asked to use any kind of self-luminous devices while wearing orange-tinted glasses (SAF-T-CURE® Orange UV Filter Glasses) that filtered out all optical radiation below approximately 525 nm that could otherwise be effective for suppressing nocturnal melatonin. This served as the ‘dark’ control condition. On the following night, participants again performed tasks displayed on self-luminous devices for 3 hours prior to bedtimes, but they viewed the self-luminous devices through the orange-tinted glasses for the first hour only, after which they were asked to remove the orange-tinted glasses and continue to use the self-luminous devices for another 2 hours. The participants were allowed to use computers, tablets, e-readers, televisions and cell phones. They were asked to use the same type of self-luminous devices both nights, even though on one single night, they were allowed to use more than one type of self-luminous device. The ambient lighting in the room in which they were performing the tasks was the same during both nights.

2.3 Daysimeter measurements

To estimate the light exposures that participants were actually experiencing while using the self-luminous devices without the orange-tinted glasses, they were asked to wear a pendant Daysimeter²⁰ during the study.

Based on Figueiro *et al.*,²⁰ measurements obtained with pendant Daysimeters are more closely related to measurements obtained with the Daysimeter located near the eye than when the device is placed on the wrist. Moreover, compliance rates are better when wearing the pendant Daysimeters than when wearing a head-mounted device. Briefly, light sensing by the Daysimeter is performed with an integrated circuit (IC) sensor array (Hamamatsu model S11059-78HT) that includes optical filters for four measurement channels: red (R), green (G), blue (B) and infrared (IR). The R, G, B and IR photoelements have peak spectral responses at 615 nm, 530 nm, 460 nm and 855 nm, respectively. The Daysimeter is calibrated in terms of orthodox photopic illuminance (lux) and of circadian illuminance (CL_A). CL_A calibration is based upon the spectral sensitivity of the human circadian system proposed by Rea and colleagues.²¹ From the recorded CL_A values it is then possible to determine the circadian stimulus (CS) magnitude, which represents the input-output operating characteristics of the human circadian system from threshold to saturation. Values of CS are numerically equal to the amount of expected melatonin suppression from the CL_A exposures according to the model by Rea *et al.*²¹

2.4 Protocol

Every subject participated in the experiment on two consecutive nights. All participants were asked to maintain their regular sleep schedules for the week prior to the experimental sessions. Participants were also asked to refrain from napping and using products containing caffeine (coffee, tea, chocolate or soda) starting at 10:00 a.m. on the days of the experiment.

Prior to starting the study, each participant was given the Daysimeter and saliva tubes. On the days of the study, participants were asked to wear the Daysimeter from the time they woke up until the end of data collection,

which was just prior to their usual bedtime. Participants were asked to put on the orange-tinted glasses and start using their self-luminous devices (computers, tablets, e-readers, televisions and/or cell phones) 3 hours prior to their usual bedtimes. At the end of the first hour, participants were asked to collect one saliva sample (T1). On the first day of the study, participants were instructed to continue wearing the orange-tinted glasses and to collect two additional saliva samples: 2 hours (T2) after they started wearing the orange-tinted glasses, and 3 hours (T3) after they started wearing the orange-tinted glasses, just prior to bedtime. On the second day of the study, participants were asked to follow the same protocol, but they were instructed to remove the orange-tinted glasses right after the first saliva sample collection; therefore the last two saliva samples were collected while they were being exposed to the light from their self-luminous devices. Participants were asked to use the same self-luminous devices and to keep the same data collection times on both experimental nights.

Saliva samples were collected using the Salivette system (ALPCO Diagnostics, Salem, NH, USA). To provide a saliva sample for assessment of melatonin concentration, each participant removed a self-contained plain cotton cylinder from the plastic test-tube, moved the cotton around in the mouth until saturated with saliva, and returned the saturated cotton cylinder to the plastic test-tube. Each participant refrigerated the saliva sample and the experimenter collected the test-tubes at the end of the second day and delivered them to the Lighting Research Center, where the samples were then spun in a centrifuge for 5 minutes at 1000 g to remove the saliva from the cotton cylinder. The cotton cylinder was discarded and the saliva sample was immediately frozen (-20°C). The frozen samples were assayed in a single batch using melatonin radioimmunoassay kits. The sensitivity of the saliva sample assay was

reported to be 0.7 pg/mL and the intra- and inter-assay coefficients of variability (CVs) were 12.1% and 13.2%, respectively.

2.5 Data analyses

Two participants did not provide enough saliva at the last data collection period so statistical analyses include data from 18 participants who had complete data sets. After downloading the Daysimeter data, we performed visual inspection of the data to verify for compliance or any device malfunction. Device failure was determined when readings were extremely high for nighttime hours (e.g. light levels above 2000 lux) and non-compliance was determined when activity readings were zero. Of the 18 participants, data from 11 participants were included in the Daysimeter analyses. In order to determine the amount of light exposure received during the data collection period, we are reporting the mean and median photopic light levels (lux) and CS values for the last 2 hours in which participants were using self-luminous devices without the orange-tinted glasses.

Although participants were asked to maintain a regular schedule, the exact times that they started and ended data collection on each day varied. In fact, five participants started data collection between 30 and 120 minutes later on Night 2 than on Night 1. Therefore, melatonin concentrations at T2 and T3 were normalised to the concentrations at T1, which was always collected in circadian darkness, because participants wore the orange-tinted glasses during the first hour of the data collection period on both experimental nights.

Based upon data from 18 participants, a 2×3 factor (Night, one control and one experimental condition, and Time, three sample collection times) analysis of variance (ANOVA) was performed on the un-normalised melatonin concentrations. We also performed a 2×2 factor (Night, one control and one experimental condition, and Time, two

sample collection times) ANOVA using the normalised to T1 melatonin concentrations. In this analysis, the concentrations at T1 were considered to be 1 and were not included in the analyses. Where appropriate, *post-hoc* two-tailed paired Student's *t*-tests were also performed and a $p < 0.05$ criteria was used.

Melatonin suppression was calculated using the ratio of the melatonin concentrations at T2 and T3 on Night 2 relative to the melatonin concentrations at T2 and T3 obtained on Night 1 ('dark' control condition). On each night, melatonin concentrations at T2 and T3 were normalised to T1 and melatonin suppression at each time (i.e. T2 and T3) was calculated using the following formula:

$$1 - \left(\frac{M2}{M1} \right)$$

where $M2$ is the normalised melatonin concentration at each time on Night 2 and $M1$ is the normalised melatonin concentration at each time on Night 1.

A two-tailed, one-sample *T*-test was used to determine whether suppression was significantly different than zero.

3. Results

3.1 Daysimeter data

The mean \pm standard error of the mean (SEM) photopic light level from the Daysimeter data was 87 ± 32 lux and the median photopic light level was 37 lux. The mean \pm SEM CS value was 0.04 ± 0.01 and the median CS value was 0.02. This suggests that predicted suppression after 1 hour exposure, assuming a pupil diameter of 2.3 mm would be about 4%.

3.2 Melatonin concentrations

For melatonin concentrations, the ANOVA revealed a significant main effect

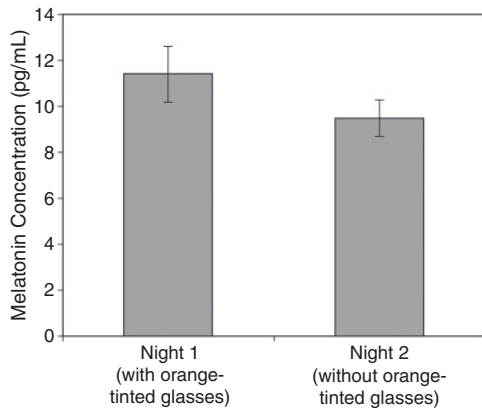


Figure 1 Mean \pm standard error of the mean (SEM) of the melatonin concentrations on Night 1, when participants were using the self-luminous devices while wearing orange-tinted glasses that filter out optical radiation below 525 nm and on Night 2, when participants were asked to use self-luminous devices without the orange-tinted glasses. There was a statistically significant ($p=0.045$) reduction in melatonin concentrations on Night 2 compared to Night 1

of Night ($F_{1,17}=4.7$; $p=0.045$; partial $\eta^2=0.22$), a main effect of Time ($F_{2,34}=14.2$; $p<0.001$; partial $\eta^2=0.45$) and a significant interaction between the variables ($F_{2,34}=16.4$; $p<0.001$; partial $\eta^2=0.49$). As shown in Figure 1, melatonin concentrations were significantly higher on Night 1, when participants wore the orange-tinted glasses, than on Night 2, when they used the self-luminous devices without the orange-tinted glasses. The mean \pm SEM melatonin concentrations were 11.4 ± 1.2 pg/mL on Night 1 and 9.5 ± 0.8 pg/mL on Night 2. In general, melatonin concentrations increased from T1 to T3. Melatonin concentrations were significantly higher at T3 than at T1 ($p=0.001$) and at T2 ($p=0.009$). Melatonin concentrations were also significantly higher at T2 than at T1 ($p=0.001$). The mean \pm SEM melatonin concentrations were 8.2 ± 0.8 pg/mL at T1, 10.8 ± 1.1 pg/mL at T2 and 12.3 ± 1.2 pg/mL at T3. Figure 2 shows the mean \pm SEM melatonin concentrations at T1, T2 and T3 on each experimental night. The mean \pm SEM

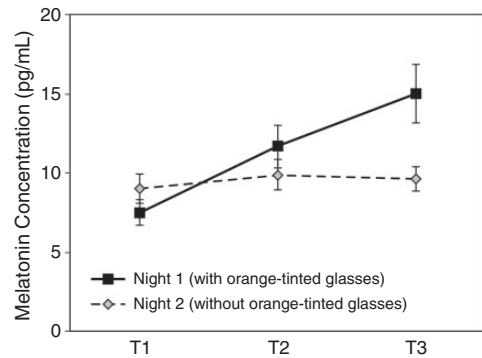


Figure 2 Mean \pm standard error of the mean (SEM) of the melatonin concentrations at T1, T2 and T3 on Nights 1 and 2. On both nights at T1, saliva samples were collected 1 hour after participants started using the self-luminous devices while wearing orange-tinted glasses. Melatonin concentration was significantly higher ($t_{17}=2.4$; $p=0.03$) on Night 2 than on Night 1 at T1 but significantly lower ($t_{17}=3.6$; $p=0.002$) on Night 2 than on Night 1 at T3. The higher melatonin levels obtained at T1 on Night 1 may be due to the fact that five participants started data collection on Night 2 between 30 and 120 minutes later than on Night 1. At T2 and T3, saliva samples were collected 2 hours and 3 hours after participants started using the self-luminous devices. Participants wore orange-tinted glasses for the duration of the data collection period on Night 1. On Night 2, participants were instructed to remove the orange-tinted glasses right after the first saliva sample collection

melatonin concentrations on Night 1 were 7.5 ± 0.8 pg/mL at T1, 11.7 ± 1.4 pg/mL at T2 and 15.0 ± 1.9 pg/mL at T3. On Night 2, the mean \pm SEM melatonin concentrations were 9.0 ± 0.9 pg/mL at T1, 9.9 ± 1.0 pg/mL at T2 and 9.6 ± 0.8 pg/mL at T3. *Post-hoc* two-tailed Student's *t*-tests revealed that melatonin concentration was significantly higher ($t_{17}=2.4$; $p=0.03$) on Night 2 than on Night 1 at T1 but significantly lower ($t_{17}=3.6$; $p=0.002$) on Night 2 than on Night 1 at T3. On Night 2, the higher melatonin concentrations at T1 (i.e. after participants wore the orange-tinted glasses for 1 hour) was likely due to the fact that five participants started the data collection 30 to 120 minutes later on the second evening than on the first evening, and therefore, their melatonin concentrations at T1 were higher because it was a later time in the evening.

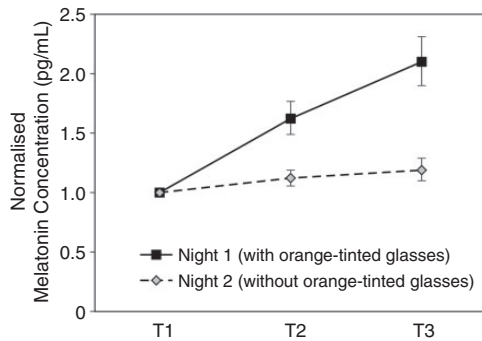


Figure 3 Mean \pm standard error of the mean (SEM) of the normalised melatonin concentrations at T1, T2 and T3 for Nights 1 and 2. Melatonin concentrations at T2 and T3 were normalised to the concentrations obtained at T1, which was always obtained in circadian darkness because participants were wearing the orange-tinted glasses for 1 hour prior to saliva data collection at T1. Normalised melatonin concentrations at T3 were significantly higher than at T2 on Night 1 ($t_{17} = 4.8$; $p < 0.001$) but not on Night 2 ($t_{17} = 0.12$; $p > 0.05$). Normalised melatonin concentrations were also significantly higher on Night 1 than on Night 2 after 1 hour of self-luminous device use (T2) and after 2 hours of self-luminous device use (T3) without orange-tinted glasses ($t_{17} = 3.3$; $p = 0.004$ and $t_{17} = 4.8$; $p < 0.001$, respectively)

For the normalised melatonin concentrations, the ANOVA revealed a significant main effect of Night ($F_{1,17} = 19.5$; $p < 0.001$; partial $\eta^2 = 0.53$), a significant main effect of Time ($F_{1,17} = 16.1$; $p = 0.001$; partial $\eta^2 = 0.49$) and a significant interaction between the variables ($F_{1,17} = 12.3$; $p = 0.003$; partial $\eta^2 = 0.42$). Normalised melatonin concentrations were significantly higher on Night 1 than on Night 2 and at T2 than at T3. The mean \pm SEM normalised melatonin concentrations were 1.84 ± 0.2 pg/mL on Night 1 and 1.15 ± 0.07 pg/mL on Night 2 and 1.36 ± 1.2 pg/mL at T2 and 1.63 ± 1.4 pg/mL at T3.

As shown in Figure 3, normalised melatonin concentrations rose over the course of Night 1 but did not rise as much on Night 2, when participants were performing the tasks on self-luminous devices without the orange-tinted glasses. *Post-hoc* Student's *t*-tests revealed that normalised melatonin

concentrations at T3 were significantly higher than at T2 on Night 1 ($t_{17} = 4.8$; $p < 0.001$) but not on Night 2 ($t_{17} = 0.12$; $p > 0.05$), suggesting that on Night 2, when participants were using the self-luminous devices without the orange-tinted glasses, melatonin levels did not rise as much as on Night 1. *Post-hoc* Student's *t*-tests also revealed that normalised melatonin concentrations were significantly higher on Night 1 than on Night 2 at T2 and at T3 ($t_{17} = 3.3$; $p = 0.004$ and $t_{17} = 4.8$; $p < 0.001$, respectively).

3.3 Melatonin suppression

The two-tailed, one sample *t*-test revealed that the normalised melatonin suppression was significantly different than zero at T2 ($t_{17} = 3.7$; $p = 0.002$) and at T3 ($t_{17} = 6.3$; $p < 0.0001$). The mean \pm SEM suppression was $22.8\% \pm 6\%$ at T2 and $38.3\% \pm 6\%$ at T3. These results show that exposure to 1 hour and 2 hours of light from self-luminous devices significantly suppressed melatonin in adolescents.

4. Discussion

The present field study results extend from laboratory data,^{15–19} and show that using self-luminous devices for 1 or 2 hours in the evening can reduce melatonin concentrations in adolescents. These findings are consistent with those from the previous studies discussed above,^{15–19} except that the present study was conducted in the field, did not select a specific self-luminous device, and all participants were adolescents. One of the most striking findings from the present study was that adolescents (ages 15 to 17 years) seem to have a heightened sensitivity to evening light for acute melatonin suppression. The amount of suppression compared to the predicted suppression from the Daysimeter measurements observed in the present study was much

higher than the suppression observed in Figueiro *et al.*,¹⁷ in which all participants were college students (mean age = 28 years). In their studies, 1-hour exposure to computer screens delivering a CS value of 0.19 suppressed melatonin by about 16%. In the present study, 1-hour use of self-luminous devices delivering a CS value of 0.04 was sufficient to significantly suppress melatonin by about 23%. Wood *et al.*¹⁸ showed that participants in their study (mean age = 19 years) who were exposed to iPads delivering a CS value of 0.03 for 1 hour suppressed melatonin by about 7%. In their study, five of the 13 participants were between 13 and 15 years of age. Consistent with the hypothesis that some younger adolescents may be more sensitive to evening light for melatonin suppression, a *post-hoc* re-analysis of their data revealed that four of these younger participants were among the ones who exhibit the greatest melatonin suppression after using the iPads. Their measured melatonin suppression amounts ranged from 31% to 59% after a 2-hour exposure to light from the iPads. Except for one participant who suppressed melatonin by 39%, all other older participants (ages between 18 and 29 years) exhibited melatonin suppression amounts below 30% after using the iPads for 2 hours. These results are also consistent with Higuchi *et al.*,²² who showed a significant melatonin suppression by light (140 lux) in children (mean age = 9 years) but not in adults (mean age = 42 years).

It should be noted that in the present study, participants were wearing the Daysimeter as a pendant, unlike the studies by Figueiro *et al.*¹⁷ and Wood *et al.*,¹⁸ where participants were asked to wear the device at eye level. Given that predictions of acute melatonin suppression with Daysimeter data have been shown to be fairly close to actual suppressions in other studies,^{17,18} the lower CS values obtained in the present study may have been an artifact of device location. For example, if participants

were using a cell phone close to the eye, the pendant device will likely not capture that light exposure; therefore, the actual light exposures during the experiment may have been higher than those recorded by the pendant Daysimeter. Measurements of various types and models of self-luminous devices performed at our laboratory²³ revealed that certain desktop computer screens deliver a CS value of as much as 0.27 (equivalent to 27% suppression). Since in the present study, suppression after 1 hour was about 23%, it is possible that CS values from the self-luminous devices used by participants during the study were higher than those recorded by the pendant Daysimeter. This assumption would only be valid, however, if all participants were using certain models of desktop devices, which did not seem to be the case in the present study. Self-reports of device usage showed that not all of the participants were using desktop computers. Therefore, the present data may suggest that adolescents are more sensitive to evening light than other populations. Future studies, using Daysimeters that measure light at the eye, should be designed to specifically confirm the present findings.

As with every field study, the present study has limitations. Even though participants were asked to use their self-luminous devices at the same time on both nights of the study, there was, in some cases, a 30 to 120 minute difference in the data collection start and end times. However, because the first saliva sample was always collected after participants remained in circadian darkness for 1 hour, this clock time difference was taken into account in the normalised melatonin data analyses. It is still not possible, from the present data set, to determine whether it was the light from the self-luminous displays alone or in combination with the ambient light that suppressed their melatonin. Moreover, it is not possible to determine exactly what type of self-luminous device is more likely to result in acute melatonin suppression because participants

were allowed to use more than one type of self-luminous device in one night. In addition, even though participants were asked to use the same type of self-luminous device on both experimental nights, the type of device that each participant used (i.e. computers, tablets, e-readers, televisions and cell phones) differed. Nevertheless, the data strongly suggest that adolescents may be more sensitive to evening light for acute melatonin suppression. The present study has face validity, given that, in real life, one may use more than one type of self-luminous device before bedtime.

The practical implications of these results could be significant. If the present results are replicated in future studies that are designed to specifically test the hypothesis that adolescents are more sensitive to evening light than other populations, individuals can take immediate actions to reduce exposure to evening short-wavelength light from self-luminous devices. For example, adolescents may choose to turn off self-luminous devices about 2 hours prior to their desired bedtimes, or if this is not possible, they can filter out the short-wavelength light by adding theatrical gels to their devices or by wearing the orange-tinted glasses. These simple actions may result in earlier bedtimes that should help improve mood, wellbeing and perhaps even school performance in this population. Keep in mind, however, that simply using these devices may be stimulating to the brain, even if melatonin is not being suppressed.

Given that morning light (i.e. after minimum core body temperature) is important to promote circadian entrainment, the use of these self-luminous devices upon waking may be a useful way to deliver circadian active, entraining light to teenagers. Future work needs to be performed, however, to further investigate the effectiveness of light from self-luminous displays on entraining the circadian system and to determine whether teenagers also show a heightened sensitivity to light in the phase advance portion of the phase response curve.

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