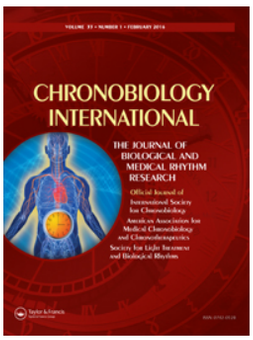

Taylor & Francis
Taylor & Francis Group

Chronobiology International

The Journal of Biological and Medical Rhythm Research

ISSN: 0742-0528 (Print) 1525-6073 (Online) Journal homepage: http://www.tandfonline.com/loi/icbi20

Protective effect of blue-light shield eyewear for adults against light pollution from self-luminous devices used at night

Masahiko Ayaki, Atsuhiko Hattori, Yusuke Maruyama, Masaki Nakano, Michitaka Yoshimura, Momoko Kitazawa, Kazuno Negishi & Kazuo Tsubota

To cite this article: Masahiko Ayaki, Atsuhiko Hattori, Yusuke Maruyama, Masaki Nakano, Michitaka Yoshimura, Momoko Kitazawa, Kazuno Negishi & Kazuo Tsubota (2016) Protective effect of blue-light shield eyewear for adults against light pollution from self-luminous devices used at night, Chronobiology International, 33:1, 134-139, DOI: 10.3109/07420528.2015.1119158

To link to this article: https://doi.org/10.3109/07420528.2015.1119158

Published online: 05 Jan 2016.

CHRONOBIOLOGY INTERNATIONAL
2016, VOL. 33, NO. 1, 134–139
http://dx.doi.org/10.3109/07420528.2015.1119158

Taylor & Francis
Taylor & Francis Group

SHORT COMMUNICATION

Protective effect of blue-light shield eyewear for adults against light pollution from self-luminous devices used at night

Masahiko Ayaki[a], Atsuhiko Hattori[b], Yusuke Maruyama[b], Masaki Nakano[b], Michitaka Yoshimura[a], Momoko Kitazawa[a], Kazuno Negishi[a], and Kazuo Tsubota[a]

[a]Department of Ophthalmology, Keio University School of Medicine, Shinjuku, Tokyo, Japan; [b]Department of Biology, Tokyo Medical and Dental University, Ichikawa, Chiba, Japan

ABSTRACT

We investigated sleep quality and melatonin in 12 adults who wore blue-light shield or control eyewear 2 hours before sleep while using a self-luminous portable device, and assessed visual quality for the two eyewear types. Overnight melatonin secretion was significantly higher after using the blue-light shield ($P < 0.05$) than with the control eyewear. Sleep efficacy and sleep latency were significantly superior for wearers of the blue-light shield ($P < 0.05$ for both), and this group reported greater sleepiness during portable device use compared to those using the control eyewear. Participants rated the blue-light shield as providing acceptable visual quality.

ARTICLE HISTORY
Received 5 September 2015
Revised 8 November 2015
Accepted 9 November 2015

KEYWORDS
Blue-light; light pollution; eyewear; melatonin; sleep; eye fatigue; retinal ganglion cells

Introduction

Visible blue light is generally recognized as ranging from 400 to 500 nm in wavelength and has pivotal roles in stimulating intrinsically photosensitive retinal ganglion cells (ipRGCs) in systemic homeostasis, maintaining and resetting circadian rhythms, and enhancing alertness (Berson et al., 2002; Viola et al., 2008). However, blue light worsens migraine symptoms in some sufferers (Noseda et al., 2010) and excessive levels of blue light can be hazardous to ocular cells (Narimatsu et al., 2014; Niwano et al., 2014), while evening exposure has been linked to circadian rhythm disorders including sleep disorders, and other conditions including cancer, obesity, hypertension, diabetes and depression (Europian Commission, 2012).

Blue light is considered to be a new element of environmental pollution in terms of irradiation; unlike exposure to sunlight, which has a diurnal rhythm, exposure to blue light can occur anywhere and at anytime (Falchi et al., 2011). Recent advances in information and communication technology and in light-emitting diode (LED) lighting have created environments that are rich in blue light, particularly for office workers, school children and portable device users. Nighttime use of self-luminous devices such as smartphones and tablet computers is increasing, including directly before bedtime. Excessive viewing of portable device displays before sleep might adversely impact psychiatric disorders and sleep problems, including dependency and insomnia, especially in school children (Cain & Gradisar, 2010; Owens et al., 2000). Many investigators have shown that blue light emitted from computer displays suppresses melatonin secretion during the evening (Chang et al., 2015; Figueiro et al., 2011; Heath et al., 2014; Santhi et al., 2012; West et al., 2011) and that blue-light shield eyewear impedes this effect (Burkhart & Phelps, 2009; Figueiro & Overington, 2015; Sasseville & Hébert, 2010; van der Lely et al., 2014). During the daytime, some children who are sensitive to blue light suffer from migraine, and colored glasses have been shown to provide effective relief from migraine symptoms (Good & Taylor, 1991; Wilkins et al., 2002). Blue-light shield eyewear might also be beneficial in terms of maintaining critical flicker frequency while subjects perform computer tasks during the

CONTACT Masahiko Ayaki, MD, mayaki@olive.ocn.ne.jp Department of Ophthalmology, Keio University, 35 Shinanomachi, Shinjuku, 1608582 Tokyo, Japan. Tel: +81-3-3353-1211. Fax: +81-3-3705-4801.

daytime (Ide et al., 2015). We previously reported that electrical responses from human ipRGCs, measured on an electroretinogram, were diminished by a blue-light shield (Kuze et al., 2015).

Since exposure to environmental blue light is rapidly increasing, the effects of blue light on vision, neuropsychiatric status and sleep need to be investigated. To our knowledge, the effect of blue-light shield eyewear on sleep after use of portable self-luminous devices has only previously been evaluated in adolescents (Figueiro & Overington, 2015). Sensitivity to light may depend on age, race and genetic factors (Chellappa et al., 2011; Higuchi et al., 2013), and further studies should be carried out with a wide variety of subjects, including older people and Asian populations. Adults are less sensitive to light than children due to lens opacity, decreased melatonin secretion and decreased circadian entrainment (Kessel et al., 2011; Turner & Mainster, 2008). Here, we describe a sleep study conducted in adults to explore whether blue-light shield eyewear can protect against the effects of blue-light pollution from self-luminous portable devices used at night.

Methods

Participants and ethics approval

This study was approved by the institutional review board of Shinseikai Toyama Hospital and was carried out in accordance with the approved guidelines. All participants provided written informed consent.

Participants were recruited via an advertisement in a research center and a database of 170 000 people operated by a research participant recruitment company. The selection criteria were habitual use of a portable device at night, normal vision and good general health according to a workplace health check. Normal vision was confirmed by an ophthalmologist for all participants before they completed the study. Exclusion criteria were history of shift work, systemic illness, use of medication and any history of psychiatric illness. Participants maintained their usual weekday lifestyle before the study period and were asked to refrain from drinking alcohol, smoking and consuming caffeine during the study period. The study was done during June and October 2014 in Tokyo, Japan, where the latitude is 35.68 degrees North and day length varies by 4–6 hours over the year according to averages for 1981–2010 reported by the Japan Meteorological Agency.

Study design and use of self-luminous portable devices

On two consecutive nights, participants were asked to stay in a dark room (<3 lux) from 21:00 to 22:00 while wearing control eyewear, and then spend 2 hours in the same dark room doing tasks on a portable self-luminous device while wearing either the blue-light shield or control eyewear. They were asked to go to bed at about midnight and sleep for 7 hours in the same dark room. A cross-over study design was used, so the type of eyewear was changed in the second phase (after 2 weeks).

The self-luminous devices used were iPad^{R} and iPhone^{R} (Apple Inc, Tokyo, Japan) and Arrows^{R} (Fujitsu Co Ltd, Tokyo, Japan) emitting approximately 410 cd/m^2 of visible light; they were held less than 25 cm from the participants' eyes. The tasks performed using these devices were reading (literature of each participant's choice) and/or writing about health and habits. Participants were observed hourly by certified psychologists to ensure that they stayed awake during the 2-hour task periods.

Light transmittance of eyewear

The experimental blue light shield eyewear that participants wore in this study was brown-tinted and designed to transmit 43.8% of visible blue light (395–490 nm) and 76.9% of whole luminous light. The control eyewear was gray-tinted and designed to transmit 93.2% of visible blue light and 76.4% of whole luminous light. These specifications were measured according to EN ISO 12312-1:2013. Participants wore the experimental and control eyewear without any other form of eyewear.

Questionnaires

Participants completed a validated questionnaire (which incorporated the Pittsburgh Sleep Quality Index and Karolinska Sleep Scale) before and during the experiment (at 22:00, 23:00 and 24:00). The

visual quality of the experimental and control eyewear (clarity, sharpness, eye fatigue and hue) was evaluated using a visual analogue scale ranging from 5 (best) to 1 (worst) compared with vision through naked eyes.

Actigraphy

Each participant's sleep/wake cycles were monitored by a micro-motion logger (AMI, New York, NY, USA) during the study period. Micro-motion data were analyzed using the Cole–Kripke algorithm (Cole et al., 1992).

Urine melatonin

First morning-void urine samples were collected from all participants at about 7:00 on the days following each intervention. The samples were frozen immediately and stored at −20 degrees Celsius until testing was undertaken. Urinary 6-sulfatoxymelatonin levels were measured by enzyme-linked immunosorbent assay (ELISA) using a Melatonin-Sulfate Urine ELISA kit (IBL International GmbH, Hamburg, Germany). The sensitivity of this assay was 0.41 ng/mL, and the intra-assay and inter-assay coefficients of variation were 1.2% and 5.7%, respectively. To adjust for variation in the dilution of urine, 6-sulfatoxymelatonin concentration was expressed as urine 6-sulfatoxymelatonin/urine creatinine using LabAssay Creatinine (Jaffe method) (Wako Pure Chemical Industries, Ltd, Tokyo, Japan) (Oba et al., 2008).

Statistical analyses

Data obtained on the second night of each phase of the study were analyzed and, where appropriate, are given as mean ± standard deviation. Sleep indices and melatonin levels obtained during the experimental and control eyewear phases were compared. All analyses were performed using StatFlex (Atech, Osaka, Japan) and SPSS version 21 (SPSS Inc, Chicago, IL, USA). *P* values less than 0.05 were considered significant.

Results

Twelve healthy Japanese adults (age range, 24–40 years; mean age, 29.0 ± 5.0 years; 6 women) participated the study.

The mean Pittsburgh Sleep Quality Index global score for participants was 4.9 ± 1.5. Sleep efficacy and sleep latency measured by actigram were significantly better after blue-light shield eyewear was worn compared with control eyewear (Wilcoxon test) (Table 1). Wake up time after sleep onset was also reduced in participants wearing the blue-light eyewear compared to control eyewear users, although the difference was not statistically significant.

Sleepiness while tasks were performed on the self-luminous devices was greater while participants wore blue-light shield eyewear compared with control eyewear, but this was not statistically significant (Table 1, Figure 1). Urine melatonin levels were significantly higher after wearing the blue-light shields (Figure 2), as was the mean urine 6-sulfatoxymelatonin/urine creatinine level (54.8 ± 6.3 ng/mg for the control phase and 62.4 ± 7.8 ng/mg for the blue-light shield phase ($P < 0.05$, Wilcoxon test). Visual quality of the eyewear differed in terms of sharpness, which was significantly better for the blue-light shield eyewear compared with the control eyewear (Table 2).

Discussion

Our results show that, according to some sleep indices, sleep quality is significantly better in healthy adults after using the blue-light shield eyewear while using self-luminous portable devices at night, compared with control eyewear users performing comparable tasks. Blue-light shield eyewear could, therefore, protect against unconsciously decreased sleep quality due to

Table 1. Sleep quality indices and sleepiness measures after use of control and experimental eyewear.

	Control eyewear	Blue-light shield eyewear	*P* value
Sleep efficacy (%)	91.8 ± 7.2	97.0 ± 2.8	<0.05[a]
Sleep latency (min)	13.2 ± 10.8	5.7 ± 2.7	<0.05 [a]
Wake up time after sleep onset (min)	23.3 ± 22.0	7.7 ± 9.5	n.s.
Sleepiness during task[b]	5.9 ± 2.3	6.6 ± 2.2	n.s.

[a]Wilcoxon test; [b]Karolinska Sleep Scale score at 24:00 bedtime; n.s. = non-significant.

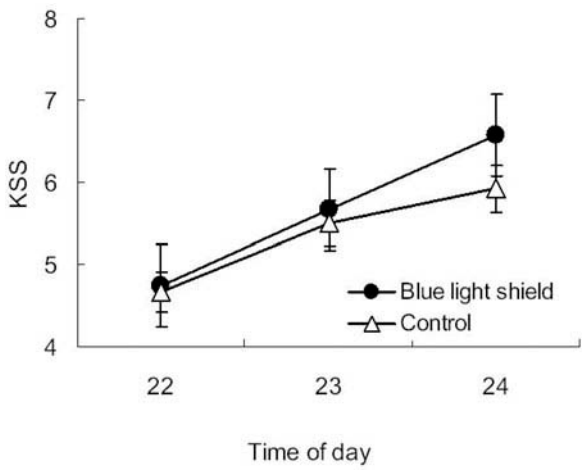

Figure 1. Sleepiness of participants while they performed tasks on the self-luminous devices and wore control eyewear (open triangles) or experimental eyewear (closed circles), from 22:00 to 24:00, measured on the Karolinska Sleep Scale (KSS). Sleepiness was greater with the blue-light shield eyewear but the difference was not statistically significant.

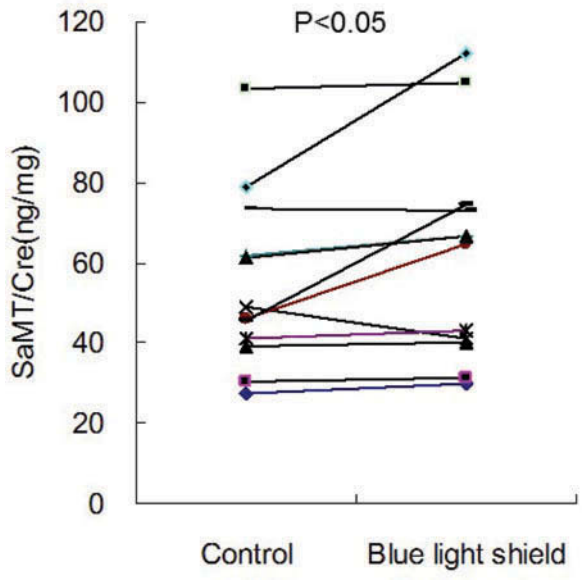

Figure 2. Overnight urine melatonin levels after use of control and experimental eyewear for each participant. There was a significant difference in melatonin secretion between the two types of eyewear ($P < 0.05$, Wilcoxon test). Note there was a wide variety in the measured values and changes among participants, suggesting many confounding factors for melatonin secretion in adults. SaMT/Cre = urine 6-sulfatoxymelatonin adjusted for urine creatinine.

blue-light pollution from self-luminous devices at night. In addition, the enhanced visual quality provided by the blue-light shield eyewear during use of self-luminous devices might contribute to sleep quality because of reduced eye strain. The experimental eyewear used in our study reduced blue-light energy input to ipRGCs, as measured on an electroretinogram (Kuze et al., 2015), and we speculate that decreased photoreception by ipRGCs with use of the blue-light shield could increase the secretion of melatonin. Although there was high variation in our data, statistically significant differences were detected for some indices (Figure 2), suggesting that many confounding factors could affect sleep quality in adults.

Table 2. Visual quality of control and experimental eyewear.[a]

	Control eyewear	Blue-light shield eyewear	*P*-value
Clarity	3.1 ± 1.1	3.6 ± 1.0	n.s.
Sharpness	3.0 ± 0.8	3.8 ± 0.9	<0.05[b]
Less fatigue	3.9 ± 1.3	3.7 ± 1.3	n.s.
Hue	3.2 ± 1.4	3.6 ± 1.2	n.s.

[a]Each element of visual quality was assessed on a visual analogue scale from 5 (best) to 1 (worst) compared with vision through naked eyes; [b]paired t test; n.s. = non-significant.

Extensive studies on blue light and blue-light shields have been conducted, but portable self-luminous devices and functional eyewear have only recently been included in such studies. The energy of irradiance from the display of such devices is inversely proportional to the square of the distance from it; in this sense, light from portable devices has considerable effects, particularly when used in dark conditions (when the pupils are more dilated) compared with bright conditions. In a study of 15–17-year-olds who used self-luminous devices while wearing commercial orange-tinted glasses that filter optical radiation below 525 nm (for 3 hours on one night and 1 hour on a second night before sleep in a room with a mean light level of 87 lux), the increase of saliva melatonin were significantly different when compared with control conditions (Figueiro & Overington, 2015). Similar results have been reported from a similar study design in which an LED screen was used as a light source (van der Lely et al., 2014). A questionnaire-based study of 20 participants aged 18–68 years that was used to evaluate sleep for 3 weeks with or without blue-light shield eyewear demonstrated that sleep was better when a blue-light shield was used (Burkhart & Phelps, 2009).

Visual quality is very important for eyewear, with hue, contrast and darkness especially important for tinted lenses, however, these qualities have not been discussed in sleep studies. In a study that used ophthalmological techniques to investigate the effect of blue-light shield lenses on eye strain and eye fatigue, these measures were not significantly different for two tinted lenses compared with clear lenses, although blue-light blockage was beneficial in terms of critical flicker frequency (Ide et al., 2015). In our study, participants rated visual quality as better with the blue-light shield eyewear than with the control eyewear, and we believe that the experimental blue-light shield eyewear, which was carefully prepared for comfortable optical performance, was acceptable for vision despite a brown tint.

Blue-light shield eyewear is inexpensive, safe and easy to use for controlling exposure to blue light. Our results thus suggest raising the general awareness about sleep disorder risk among people who use portable devices in bed just before going to sleep. Millions of people currently use blue-light shield eyewear in Japan, and our results suggest that it may be effective before bedtime in terms of preventing disruption to circadian rhythms by suppressing photic stimulation of ipRGCs. Importantly, some people are very sensitive to blue-light blockage and should therefore be careful about wearing blue-light blockers as they may induce excessive sleepiness at night or decreased alertness in the daytime, leading to discomfort and/or decreased performance. It should be noted that a blue light-rich environment at night is unnatural and protective blue-light shields may help simulate more natural conditions at night.

This study has some limitations. The sample size was small, and the sleep quality data we collected should be extended to a larger number of participants to cover variations in age, race, level of light sensitivity, ocular status, systemic status and genetic background. Sleep should be evaluated by polysomnography in an environment that is strictly controlled for light level. Also, the study period was short, so longer observation periods should be used in future research to determine the effect of blue-light shields on circadian rhythms.

Acknowledgements

We thank Dr Takayuki Abe for help with statistical analyses. We acknowledge Inter-Biotech (http://www.inter-biotech.com) for assistance with the English language editing of this manuscript.

Declaration of interest

Funded by JIN CO LTD. The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

References

Berson DM, Dunn FA, Takao M. (2002). Phototransduction by retinal ganglion cells that set the circadian clock. Science. 295:1070–3.

Burkhart K, Phelps JR. (2009). Amber lenses to block blue light and improve sleep: A randomized trial. Chronobiol Int. 26:1602–12.

Cain N, Gradisar M. (2010). Electronic media use and sleep in school-aged children and adolescents: A review. Sleep Med. 11:735–42.

Chang AM, Aeschbach D, Duffy JF, Czeisler CA. (2015). Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. Proc Natl Acad Sci USA. 112:1232–7.

Chellappa SL, Viola AU, Schmidt C, et al. (2012). Human melatonin and alerting response to blue-enriched light depend on a polymorphism in the clock gene PER3. J Clin Endocrinol Metab. 97:E433–7.

Cole RJ, Kripke DF, Gruen W, et al. (1992). Automatic sleep/wake identification from wrist activity. Sleep. 15:461–9.

European Commission; Scientific Committee on Emerging and Newly Identified Health Risks. (2012). Health effects of artificial light. Available from: http://ec.europa.eu/health/scientific_committees/opinions_layman/artificial-light/en/index.htm#1 [last accessed 23 Aug 2015].

Falchi F, Cinzano P, Elvidge CD, et al. (2011). Limiting the impact of light pollution on human health, environment and stellar visibility. J Environ Manage. 92:2714–22.

Figueiro MG, Wood B, Plitnick B, Rea MS. (2011). The impact of light from computer monitors on melatonin levels in college students. Neuro Endocrinol Lett. 32:158–63.

Figueiro M, Overington D. (2015). Self-luminous devices and melatonin suppression in adolescents. Lighting Res Technol. doi:10.1177/1477153515584979

Good PA, Taylor RH, Mortimer MJ. (1991). The use of tinted glasses in childhood migraine. Headache. 31:533–6.

Heath M, Sutherland C, Bartel K, et al. (2014). Does one hour of bright or short-wavelength filtered tablet screenlight have a meaningful effect on adolescents' pre-bedtime alertness, sleep, and daytime functioning? Chronobiol Int. 31:496–505.

Higuchi S, Hida A, Tsujimura S, et al. (2013). Melanopsin gene polymorphism I394T is associated with pupillary light responses in a dose-dependent manner. PLoS One. 8:e60310.

Ide T, Toda I, Miki E, Tsubota K. (2015). Effect of blue light-reducing eye glasses on critical flicker frequency. Asia Pac J Ophthalmol (Phila). 4:80–5.

Kessel L, Siganos G, Jørgensen T, Larsen M. (2011). Sleep disturbances are related to decreased transmission of blue light to the retina caused by lens yellowing. Sleep. 34:1215–9.

Kuze M, Matsubara H, Ayaki M, et al. (2015). Effect of blue light cut-off filter on the electroretinogram from intrinsically photosensitive retinal ganglion cells. Inv Ophthalmol Vis Sci. 2015: ARVO eAbstract No. 5570.

Narimatsu T, Ozawa Y, Miyake S, et al. (2014). Biological effects of blocking blue and other visible light on the mouse retina. Clin Exp Ophthalmol. 42:555–63.

Niwano Y, Kanno T, Iwasawa A, et al. (2014). Blue light injures corneal epithelial cells in the mitotic phase in vitro. Br J Ophthalmol. 98:990–2.

Noseda R, Kainz V, Jakubowski M, et al. (2010). A neural mechanism for exacerbation of headache by light. Nat Neurosci. 13:239–45.

Oba S, Nakamura K, Sahashi Y, et al. (2008). Consumption of vegetables alters morning urinary 6-sulfatoxymelatonin concentration. J Pineal Res. 45:17–23.

Owens JA, Spirito A, McGuinn M. (2000). The children's sleep habits questionnaire (CSHQ): Psychometric properties of a survey instrument for school-aged children. Sleep. 23:1043–51.

Santhi N, Thorne HC, van der Veen DR, et al. (2012). The spectral composition of evening light and individual differences in the suppression of melatonin and delay of sleep in humans. J Pineal Res. 53:47–59.

Sasseville A, Hébert M. (2010). Using blue-green light at night and blue-blockers during the day to improves adaptation to night work: A pilot study. Prog Neuropsychopharmacol Biol Psychiatry. 34:1236–42.

Turner PL, Mainster MA. (2008). Circadian photoreception: Ageing and the eye's important role in systemic health. Br J Ophthalmol. 92:1439–44.

van der Lely S, Frey S, Garbazza C, et al. (2015). Blue blocker glasses as a countermeasure for alerting effects of evening light-emitting diode screen exposure in male teenagers. J Adolesc Health. 56:113–9.

Viola AU, James LM, Schlangen LJ, Dijk DJ. (2008). Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality. Scand J Work Environ Health. 34:297–306.

West KE, Jablonski MR, Warfield B, et al. (2011). Blue light from light-emitting diodes elicits a dose-dependent suppression of melatonin in humans. J Appl Physiol (1985). 110:619–26.

Wilkins AJ, Patel R, Adjamian P, Evans BJ. (2002). Tinted spectacles and visually sensitive migraine. Cephalalgia. 22:711–9.