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Original article

Blue Blocker Glasses as a Countermeasure for Alerting Effects of Evening Light-Emitting Diode Screen Exposure in Male Teenagers

Stéphanie van der Lely, M.Sc. [a], Silvia Frey, Ph.D. [a], Corrado Garbazza, M.D. [a], Anna Wirz-Justice, Ph.D. [a], Oskar G. Jenni, M.D. [b], Roland Steiner, B.Sc. [c], Stefan Wolf, Ph.D. [d], Christian Cajochen, Ph.D. [a], Vivien Bromundt, Ph.D. [a,*,1], and Christina Schmidt, Ph.D. [a,1]

[a] *Centre for Chronobiology, Psychiatric Hospital of the University of Basel, Basel, Switzerland*
[b] *Child Development Center, University Children's Hospital Zürich, Zürich, Switzerland*
[c] *Department of Physics, University of Basel, Basel, Switzerland*
[d] *Department of Mechanical Engineering, Lighting Engineering Group, Ilmenau University of Technology, Ilmenau, Germany*

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A B S T R A C T

Purpose: Adolescents prefer sleep and wake times that are considerably delayed compared with younger children or adults. Concomitantly, multimedia use in the evening is prevalent among teenagers and involves light exposure, particularly in the blue-wavelength range to which the biological clock and its associated arousal promotion system is the most sensitive. We investigated whether the use of blue light–blocking glasses (BB) during the evening, while sitting in front of a light-emitting diode (LED) computer screen, favors sleep initiating mechanisms at the subjective, cognitive, and physiological level.
Methods: The ambulatory part of the study comprised 2 weeks during which the sleep–wake cycle, evening light exposure, and multimedia screen use were monitored in thirteen 15- to 17-year-old healthy male volunteers. BB or clear lenses as control glasses were worn in a counterbalanced crossover design for 1 week each, during the evening hours while using LED screens. Afterward, participants entered the laboratory and underwent an evening blue light–enriched LED screen exposure during which they wore the same glasses as during the preceding week. Salivary melatonin, subjective sleepiness, and vigilant attention were regularly assayed, and subsequent sleep was recorded by polysomnography.
Results: Compared with clear lenses, BB significantly attenuated LED-induced melatonin suppression in the evening and decreased vigilant attention and subjective alertness before bedtime. Visually scored sleep stages and behavioral measures collected the morning after were not modified.
Conclusions: BB glasses may be useful in adolescents as a countermeasure for alerting effects induced by light exposure through LED screens and therefore potentially impede the negative effects modern lighting imposes on circadian physiology in the evening.

IMPLICATIONS AND CONTRIBUTION

Computer screen lighting can impact on sleep–wake regulation, a topic highly relevant for health and well-being in adolescents. Blue light–blocking glasses might be a useful countermeasure of the wake-promoting effects induced by light-emitting diode screen exposure before sleep onset.

Poor sleep quality, insufficient sleep duration, and daytime sleepiness are prevalent among adolescents [1]. These problems are associated with emotional instability, impaired daytime functioning, and poor school performance [2]. Adolescence is characterized by a prominent developmental shift of the internal

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* Address correspondence to: Vivien Bromundt, Ph.D., Centre for Chronobiology, Psychiatric Hospital of the University of Basel, Wilhelm Klein-Strasse 27, CH-4012 Basel, Switzerland.
E-mail address: vivien.bromundt@upkbs.ch (V. Bromundt).
[1] These authors contributed equally to the work.

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clock located in the suprachiasmatic nuclei of the hypothalamus toward eveningness. Late chronotypes (delayed sleep and wake time preferences) are predominant [3], with more mature adolescents having later circadian phases [4]. Accordingly, delayed sleep phase syndrome, characterized by a chronic or recurrent inability to fall asleep and wake up at socially conventional times, presents the highest prevalence (.5%–16%) in adolescents [5]. Beside the circadian system, sleep homeostasis also undergoes developmental changes, with a slower buildup rate for sleep need with increasing time spent awake in more mature teenagers [6]. Teenagers are thus ready to fall asleep only late at night, but they have to be early at school or work, which may consequently lead to accumulated sleep loss, daytime sleepiness, and impaired cognitive daytime functioning [7]. External influences, such as evening work, social opportunities, and reduced parental influences on bedtimes, may even potentiate such delayed and short sleep epochs in young people [8].

A further potential contributing factor to poor sleep quality in adolescents is the use of multimedia screens in the evening hours for entertainment, identity formation, and socialization [9]. In-bed computer and phone usage before sleep has been positively associated with insomnia and negatively with morningness [10]. Because light is the most important zeitgeber (i.e., synchronizer) for the circadian timing system, its emission by computer or multimedia screens (smartphones, tablets, and so forth) impacts on the internal clock and thus on circadian physiology [11], probably also including sleep–wake regulation. Morning light phase advances circadian rhythms, whereas light in the evening induces circadian phase delays [12]. Individuals with delayed sleep phase seem to be even more sensitive to evening light than earlier chronotypes [13].

The impact of light on the circadian timing system is classically measured by suppression of the “darkness hormone” melatonin, a key circadian phase marker secreted only during the night [14]. Light also enhances alertness and cognitive performance [15]. These responses are mediated by a subset of retinal ganglion cells containing the photopigment melanopsin, most sensitive to wavelengths within the blue light spectrum around 480 nm [16,17], which transmit light signals via the retinohypothalamic tract directly to the suprachiasmatic nuclei [18]. Accordingly, blue light has been shown to act most strongly on circadian physiology, alertness, and cognitive performance [11].

Light-emitting diode (LED) screens present a high proportion of short-wavelength light. The screen light of tablets can suppress melatonin [19]. A 5-hour LED screen exposure in the evening not only suppressed melatonin secretion but also increased subjective and objective alertness in young adults [11]. Orange-tinted blue light–blocking glasses (BB)—so-called blue blockers—can be used to counter such light effects because they filter out the short wavelengths in the blue range portion of the spectrum. BB glasses prevented light-induced melatonin suppression and alerting effects in young adults [20,21]. Wearing BBs in the evening significantly improved subjective sleep quality after a continuous 2-week application [22]. In contrast, blocking short-wavelength light in the morning with BB glasses delayed circadian phase in young adults [23,24]. However, the impact of BB glasses as a potential countermeasure in adolescents' sleep and waking behavior has only begun to be investigated, particularly with objective measures, although this population appears to be at particular risk of further delaying sleep timing secondary to evening light exposure.

We therefore investigated in a group of male teenagers, used to sitting in front of LED screens for several hours daily and tending toward extreme evening types, whether wearing BB glasses could modify melatonin secretion, alertness, cognitive performance, and sleep (monitored by electroencephalography [EEG]) compared with wearing clear lenses (CL) as a control condition. All these variables have previously been shown to be affected by prior light exposure [15].

Methods

Study participants

Healthy, male, high-school students between 15 and 17 years old were recruited for the study in the Basel (Switzerland) area through oral presentations in schools, Web postings, and advertisements. Potential participants underwent a screening survey about their general health, sleep, and well-being (see Supplementary Data). Thirteen study volunteers (mean ± standard deviation, 16.46 ± .66 years old) were finally included in the study. Supplementary Table 1 summarizes their screening survey data.

All participants and their parents were informed about the study details and provided written informed consent before the study onset. The study was approved by the local ethics committee (Ethikkommission beider Basel, Basel, Switzerland) and conformed to the Declaration of Helsinki.

Study protocol

The study protocol lasted 16 days and was organized in two study parts in a balanced crossover design separated by an intervening period of at least 1 week to maximally 5 weeks (2.00 ± 1.29 weeks). Each study part comprised a 15.5-hour stay in the laboratory and a preceding ambulatory week. The participants were asked to maintain their usual sleep–wake rhythm but were not permitted to go out in the evenings or nap during the day for 3 days before the in-laboratory part. Caffeinated drinks were not allowed, and the participants were asked to refrain from drinking more than three glasses of alcohol per week.

Ambulatory part

Glasses/Luxblick. During the ambulatory week preceding the laboratory night, participants wore orange-tinted BB glasses, so-called blue blockers (Chron-optic Inc., Quebec City, Quebec, Canada), or glasses of equal design with CL as control condition (Chron-optic Inc.) from 18:00 hours until sleep onset (for as much time as possible) in a counterbalanced crossover design. The light transmittance spectra of the two glasses are depicted in Supplementary Figure 1. Besides blocking the blue light portion of the spectrum, reduced light transmittance resulted also in lower light intensity levels in BB (30% transmittance) compared with CL (92% transmittance).

Additionally, to control for light exposure, a small low-weight device called “Luxblick” [25] was fixed on the glasses frame between the eyes to measure vertical illuminance and irradiance at second intervals (see Supplementary Data for details). Participants also kept a diary indicating when and for how long they wore the glasses, and how much time they spent in front of a LED/non-LED screen. Compliance of wearing the glasses was