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Man and blue light: The influence of screen light on our health

Człowiek a światło niebieskie, czyli wpływ światła ekranu na nasze zdrowie

Abstract. The article considers the impact of blue light emitted by electronic screens on human health. Due to the progressing digitisation and the increasing use of electronic devices such as TVs, smartphones, tablets or computers, this topic has become particularly relevant. The article discusses the results of the latest scientific research on the impact of blue light on our health. Short-term as well as long-term effects of blue light exposure were analysed. The results of these studies indicate potential detrimental consequences for our sleep, eye health and general well-being. After an in-depth study of the topic, it was found that blue light emitted by electronic screens can disrupt our natural sleep rhythm by inhibiting the secretion of melatonin, the hormone responsible for the proper functioning of our "biological clock", supporting the regulation of the circadian sleep-wake cycle, thanks to which the body knows when it needs to go to sleep and when to get up. Nighttime exposure to blue light can lead to difficulty falling asleep, sleep disturbances and general daytime fatigue. In addition, prolonged exposure to blue light can have a negative impact on eye health, contributing to visual fatigue, irritation and an increased risk of developing eye diseases.

Keywords: blue light, health, circadian rhythm, digitisation

Streszczenie. Artykuł poświęcony analizie wpływu światła niebieskiego emitowanego przez ekrany elektroniczne na zdrowie człowieka. W świetle postępującej cyfryzacji i coraz większego użytkowania urządzeń elektronicznych, takich jak telewizory, smartfony, tablety czy komputery temat ten stał się szczególnie istotny. W artykule zostały omówione wyniki najnowszych badań naukowych dotyczących wpływu światła niebieskiego na nasze zdrowie. Przeanalizowano zarówno skutki krótkoterminowe, jak i długoterminowe ekspozycji na światło niebieskie. Wyniki tych badań wskazują na potencjalne negatywne konsekwencje dla naszego snu, zdrowia oczu i ogólnego samopoczucia. Po dogłębnej analizie tematu stwierdzono, że światło niebieskie emitowane przez ekrany elektroniczne może zakłócać nasz naturalny rytm snu poprzez

hamowanie wydzielania melatoniny, hormonu odpowiedzialnego za prawidłowe funkcjonowanie "zegara biologicznego", wspomagającego regulowanie dobowego cyklu snu i czuwania, dzięki czemu organizm wie kiedy musi iść spać a kiedy wstać. Nocna ekspozycja na światło niebieskie może prowadzić do trudności w zasypianiu, zaburzeń snu i ogólnego zmęczenia w ciągu dnia. Dodatkowo, długotrwałe narażenie na światło niebieskie może mieć negatywny wpływ na zdrowie oczu, przyczyniając się do zmęczenia wzroku, podrażnień oraz zwiększonego ryzyka rozwoju chorób oczu.

Słowa kluczowe: światło niebieskie, zdrowie, rytm dobowy, cyfryzacja

Introduction

Artificial light is becoming increasingly common and beginning to accompany us at every turn. Studies show that 90% of our day is spent in rooms illuminated by artificial light[1]. Compared with natural outdoor light, artificial light is much weaker and has a different spectral distribution than sunlight. The intensity of outdoor lighting can reach values of up to 130,000 lux depending on location, weather, and altitude. In contrast, the intensity of artificial light does not exceed 1,000 lux.

Being indoors with artificial light also exposes us to light at times of day when we would not normally receive sunlight[2]. During the course of human evolution, light has had a significant impact on physiological processes, and has been essential for our overall health and well-being[3]. The spread of electric lighting has significantly changed the brightness, spectral distribution and duration of light exposure when compared to that of our ancestors. This has had a measurable impact on our circadian system[4], and concerns about the effects of artificial light on human health are not new.

[1] Schweizer C., Edwards R.D., Bayer-Oglesby L., Gauderman W.J., Ilacqua V., Juhani Jantunen M., Lai H.K. Nieuwenhuijsen M., Künzli N. Indoor time-microenvironment-activity patterns in seven regions of Europe.

[2] Blume C., Garbazza C., Spitschan M. Effects of light on human circadian rhythms, sleep and mood. *Somnologie.*

[3] Gehring W., Rosbash M. The coevolution of blue-light photoreception and circadian rhythms. *J. Mol. Evol.*

[4] Phillips A.J.K., Vidafar P., Burns A.C., McGlashan E.M., Anderson C., Rajaratnam S.M.W., Lockley S.W., Cain S.W. High sensitivity and interindividual variability in the response of the human circadian system to evening light.

The rapid development of digital devices over the past decade has provided a new source of artificial light. We now spend a significant portion of the day in front of digital screens which are illuminated by various types of light-emitting diodes (LEDs). In order for a digital display to generate a visible image, it must be backlit or self-luminous (e.g. organic LEDs). As a result, the displays of digital devices necessarily emit light. LEDs are often used to illuminate these displays, due to their energy efficiency, durability and small size[5]. These, in turn, produce light that appears white, but whose spectral distribution peaks in the blue part of the electromagnetic spectrum[6]. (Figure no. 1)

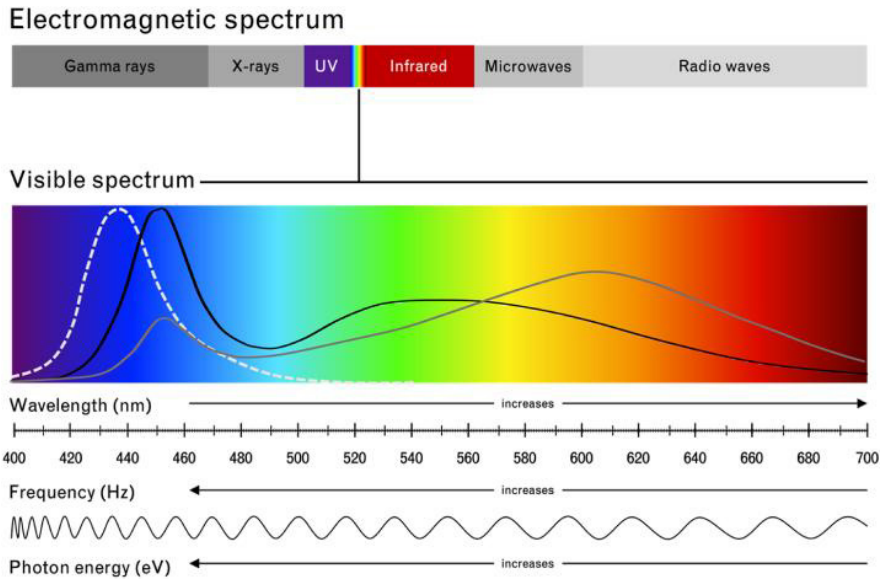

Figure no. 1

[5] Jeykishan Kumar K., Bharath Kumar G., Sudhir Kumar R. Photometric assessment of warm and cool white LED bulbs.

[6] Behar-Cohen F., Martinsons C., Viénot F., Zissis G., Barlier-Salsi A., Cesarini J.P., Enouf O., Garcia M., Picaud S., Attia D. Light-emitting diodes (LED) for domestic lighting: any risks for the eye? *Prog. Retin. Eye Res.*

Given the long time we spend in front of screens, questions have been raised about the impact of the artificial blue light emitted by these devices on our health, and particularly eye health.[7].

Blue light and its detection

The eye responds to incoming blue light through its rods and intrinsically photosensitive retinal ganglion cells (ipRGCs). At the high photon energy end of the visible spectrum, blue light poses a greater risk of damage than other wavelengths of visible light[8]. This risk is commonly referred to as *"blue light hazard"*. It is well known that under certain conditions (e.g. with prolonged exposure or at high intensities) exposure to visible blue light can cause photochemical damage to the retina and retinal pigment epithelium. Photochemical damage is thought to occur when excess absorption of light energy by chromophores in the retina and retinal pigment epithelium results in overproduction of reactive oxygen species[9]. However, the exact mechanism of photochemical damage remains a subject of ongoing research.

International associations such as International *Commission on Non-Ionizing Radiation Protection* (ICNIRP) have published guidelines for measuring the blue light hazard of artificial sources, as well as safe viewing limits. Evaluations of blue light emitted from smartphones and tablets have shown that the blue light hazard of these and similar digital devices is well below safe viewing limits, even with prolonged exposure. While it is generally accepted that blue light from digital devices does not cause acute retinal damage, whether chronic exposure over a lifetime can have a cumulative effect (i.e. long-term degenerative impact) remains a subject of ongoing debate.

[7] Touitou Y., Point S. Effects and mechanisms of action of light-emitting diodes on the human retina and internal clock

[8] Algvere P.V., Marshall J., Seregard S. Age-related maculopathy and the impact of blue light hazard. *Acta Ophthalmol.*

[9] Ham W.T., Mueller H.A., Sliney D.H. Retinal sensitivity to damage from short wavelength light.

The risk that blue light poses to the eyes is one of the main concerns associated with the increased use of digital devices that emit artificial blue light. However, it can also affect circadian rhythms and other processes mediated by the melanopsin system.

Effects of artificial light on the eyes.

Directly exposed to electromagnetic radiation, the eye plays a special role in receiving and capturing incoming light[10], resulting in an increased risk of light-induced damage to ocular structures. As new artificial light sources are developed, it is important to understand how different characteristics of light affect the human eye. The blue component of the emission spectrum of LEDs is a matter of particular concern, given the high photon energy of blue light and the widespread application of LEDs in digital device displays[11].

Effects of blue light on neurosensory cells

The ability of visible light to photochemically damage the retina has been known since the 1970s[12]. This potential exposure to visible blue light, causing photochemical damage to the retina and retinal pigment epithelium, is a problem associated with the light emitted by LEDs. Measurements of blue light emitted by smartphones, tablets, and computers have consistently been shown to be well below the published blue light exposure limits set by ICNIRP. One study found that the spectral irradiance of blue light from tablets and smartphones set to maximum brightness ranged from 0.08 to 0.38% of the blue light exposure limit. In comparison, on a sunny June day, the blue light exposure when viewing the UK sky is approximately 10.4% of the

[10] Hunter J.J., Morgan J.I., Merigcan W.H., Sliney D.H., Sparrow J.R., Williams D.R. The susceptibility of the retina to photochemical damange from visible light.

[11] Zhao Z.C., Zhou Y., Tan G., Li J. Research progress about the effect and prevention of blue light on eyes.

[12] Ham W.T., Mueller H.A., Sliney D.H. Retinal sensitivity to damage from short wavelength light.

limit[13]. Another study found that the proportion of blue light emitted by LEDs did not differ from that of fluorescent lamps after accounting for colour correlated temperature. It was also found that LEDs did not pose any particular hazard to the eyes compared to other lamp types. It has become clear that the blue light emitted by digital devices, such as smartphones and tablets, poses no serious risk to the retina. It remains controversial whether there is a long-term effect of repeated exposure to low-illuminance artificial blue light.

Although there are studies[14] showing that chronic exposure to blue light emitted from digital displays should not have any long-term effects on the retina, some researchers remain concerned. This is because blue LEDs have been found to reduce cell viability and increase the production of reactive oxygen species in photoreceptors and retinal pigment epithelium cells[15]. However, most of the studies on the effects of blue light on photodamage to the eye have been conducted on animals, making it difficult to extrapolate these results. These studies encourage a more cautious approach to implementing LEDs to illuminate our homes and digital devices, given that existing standards for safe amounts do not take into account the cumulative impact of blue light exposure.

These studies warn that repeated exposure to low-illuminance blue light may contribute to age-related macular degeneration, which is attributed to cumulative sun exposure. However, it remains unclear to what extent visible blue light contributes to macular degeneration[16]. A meta-analysis found no conclusive evidence that blue-light-blocking intraocular lenses prevent the development or progression of macular

[13] O'Hagan J.B., Khazova M., Price L.L.A. Low-energy light bulbs, computers, tablets and the blue light hazard.

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degeneration. These findings suggest that blue light filtering has no significant long-term retinal health benefit and can be interpreted as the absence of a significant impact of blue light on retinal viability. Overall, blue light emitted by digital devices does not appear to pose a risk to the retina with chronic exposure; however, there is insufficient evidence to exclude the impact of artificial blue light on the retina over a lifetime.

Effects of artificial blue light on visual performance

In addition to concerns about light-induced damage to the eye, one should also consider potential effects of blue light on visual performance. Commonly defined by the speed and accuracy with which visual stimuli can be perceived, key measures of visual performance include visual acuity and contrast sensitivity. As part of the visible spectrum, blue light is involved in image formation processes. By altering the light environment, artificial light can potentially affect visual performance. In older studies using incandescent light bulbs, elevated contrast sensitivity and acuity[17] were measured under blue light compared to green, red, yellow and white light. Analysis of the results indisputably showed that blue light significantly affects visual performance by stimulating melanopsin.

Among other things, melanopsin is responsible for contrast sensitivity[18]. By activating ipRGCs, blue light can also alter retinal dopamine[19] which is involved in various processes, in particular in the adaptation of the retina to light. Dopamine acts on all major cell types in the retina, adapting retinal signalling over a wide range of light levels. In the retina, dopamine is also responsible for circadian rhythm and retinal development. There is an increasing number of studies demonstrating the involvement of dopaminergic processes in

[17] Baker K.E. Some variables influencing vernier acuity.

[18] Allen A.E., Martial F.P., Lucas R.J. Form vision from melanopsin in humans.

[19] Zhang D.-Q., Wong K.Y., Sollars P.J., Berson D.M., Pickard G.E., McMahon D.G. Intraretinal signaling by ganglion cell photoreceptors to dopaminergic amacrine neurons.

the retina in myopia development[20]. In the future, it remains to be seen how artificial blue light from digital devices might affect the quality of vision in the long term.

Artificial light and circadian rhythm

The effect of blue light on the circadian rhythm (Figure no. 2) is another issue related to the growing trend of digital devices. The circadian rhythm is a biological cycle with a period of about 24 hours. Environmental stimuli have a great impact on our circadian rhythm, and the most important of these is light, particularly short-wavelength visible light.

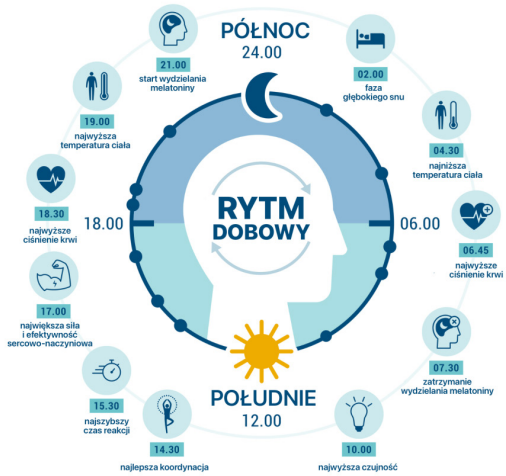

Figure no. 2[21]. Effects of blue light on the circadian rhythm

Explanation to Figure no. 2: 21.00 melatonin secretion start; MIDNIGHT 24.00; 02.00 deep sleep phase; 19.00 highest body temperature; 04.30 lowest body temperature; 18.30 highest blood pressure; Rytm dobowy – CIRCADIAN RHYTHM; 06.00 06.45 highest blood pressure; 17.00 highest cardiovascular strength and efficiency; 15.30 fastest reaction time; NOON 12.00; 07.30 melatonin secretion stop; 14.30 best coordination; 10.00 highest alertness;

[20] Feldkaemper M., Schaeffel F. An updated view on the role of dopamine in myopia.

[21] Source: https://mobirank.pl/2023/04/11/naukowcy-zbadali-dzialanie-zegara-biologicznego/

Exposure to blue light during the day is essential for the functioning of the circadian rhythm and for general well-being[22]. Blue light during the day has a beneficial effect on alertness, mood, and productivity. As a result, daytime exposure to blue light from digital devices is unlikely to have a negative impact on the circadian rhythm. However, the effect of blue light on the sleep-wake cycle and circadian rhythm depends on when the exposure occurs. In general, exposure to light early in the morning shifts the circadian rhythm earlier (accelerates the phase) while exposure to light in the evening and at night shifts the circadian rhythm later (delays the phase), and exposure at midday has relatively the smallest impact on circadian synchronisation[23]. Blue light is very effective in changing the phase of the circadian rhythm, and studies agree that evening exposure to blue light can significantly affect sleep quality, especially if the light exposure is chronic. In contrast to the debate regarding the effects of blue light on the eye, researchers generally agree that repeated exposure to blue light at night has negative consequences for circadian health[24].

There is growing evidence that the blue light emitted by digital devices is sufficient to disrupt sleep when used at night[25]. Delayed sleep onset can occur after using digital devices in the evening with screen illuminance as low as 30 lux[26]. Using digital devices before bed can also alter sleep quality, sleep quantity and sleep efficiency. It remains to be established to what extent blue light from digital devices during nighttime use affects the sleep-wake cycle and other circadian processes.

[22] Wahl S., Engelhardt M., Schaupp P., Lappe C., Ivanov I.V. The inner clock – blue light sets the human rhythm.

[23] Rüger M., St Hilaire M.A., Brainard G.C., Khalsa S.B.S., Kronauer R.E., Czeisler C.A., Lockley S.W. Human phase response curve to a single 6.5 h pulse of short-wavelength light.

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[25] Höhn C., Schmid S.R., Plamberger C.P., Bothe K., Angerer M., Gruber G., Pletzer B., Hoedlmoser K. Preliminary results: the impact of smartphone use and short-wavelength light during the evening on circadian rhythm, sleep and alertness

[26] Chang A.M., Aeschbach D., Duffy J.F., Czeisler C.A. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness.

The negative impact of evening exposure to blue light has led to the development of various blue light filtering products. Although healthy adults generally do not appear to benefit from wearing blue-light-blocking glasses at night[27], there is evidence that wearing blue-light-blocking glasses in the evening reduces sleep onset latency in people who have sleep disorders, change time zones, or perform shift work[28]. In contrast to studies attributing the poor sleep experienced in older age to the natural filtering of blue light due to yellowing of the crystalline lens[29], prolonged blue light depletion from blue-light-blocking intraocular lenses does not appear to affect the sleep-wake cycle.

Effects of artificial light on other cognitive processes

Blue light may also affect other circadian rhythms, not only those related to the sleep-wake cycle. The eye undergoes rhythmic changes to optimise functioning in response to daily variations in light intensity[30]. Irregular light exposure times can alter the rhythm of the eye and affect the regulation of its growth[31]. In studies conducted on animal models, blue light was found to inhibit myopia development and slow ocular growth[32].

[27] Bigalke J.A., Greenlund I.M., Nicevski J.R., Carter J.R. Effect of evening blue light blocking glasses on subjective and objective sleep in healthy adults: a randomized control trial.

[28] Hester L., Dang D., Barker C.J., Heath M., Mesiya S., Tienabeso T., Watson K. Evening wear of blue-blocking glasses for sleep and mood disorders: a systematic review.

[29] Chellappa S.L., Bromundt V., Frey S., Cajochen C. Age-related neuroendocrine and alerting responses to light.

[30] Stone R.A., Quinn G.E., Francis E.L., Ying G.S., Flitcroft D.I., Parekh P., Brown J., Orlow J., Schmid G. Diurnal axial length fluctuations in human eyes.

[31] Chakraborty R., Ostrin L.A., Nickla D.L., Iuvone P.M., Machelle T., Stone R.A. Circadian rhythms, refractive development, and myopia.

[32] Foulds W.S., Barathi V.A., Luu C.D. Progressive myopia or hyperopia can be induced in chicks and reversed by manipulation of the chromaticity of ambient light.

Effects of blue light on well-being and mental health

The last, but not least important, topic related to the impact of blue light on human health is its effect on mood and mental health. A growing body of research shows a link between blue light exposure and our emotional state, mood, and risk of mental disorders[33].

Research suggests that lack of sufficient natural light, especially blue light, can lead to seasonal disorders such as seasonal affective disorder. This phenomenon is particularly noticeable in winter when days are shorter and exposure to natural light is limited. Exposure to blue light can have a beneficial effect on improving mood and reducing symptoms of seasonal affective disorder[34].

In addition, exposure to blue light can affect our circadian cycle of hormones, including serotonin – the neurotransmitter responsible for regulating mood. Blue light deficiency can lead to a decrease in serotonin production, which in turn can affect our mood and overall emotional balance.

The effects of blue light on mental health are particularly evident in people who are subjected to prolonged exposure to artificial light, such as office workers, students who spend long hours in front of a computer or those who work night shifts. Inadequate lighting and blue-light exposure in these conditions can lead to decreased mood and an increased risk of anxiety or depression.

There are several strategies that can be effective in minimising the negative effects of blue light on mood and mental health. It is worth trying to spend more time outdoors and expose oneself to natural light, especially in the morning. Adequate lighting in workplaces and homes that eliminates excessive exposure to blue light can also help improve mood and mental health.

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[33] Thanaboonyawat I, Wataganara T, Boriboonhiransarn D, Viboonchart S, Tontisirin P. Effect of halogen light in fetal stimulation for fetal well-being assessment. J Med Assoc Thai. 2006 Sep;89(9):1376-80. PMID: 17100372.

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Ways to protect against the negative effects of blue light

Despite the lack of firm research results regarding some of the negative effects of prolonged exposure to artificial light, a few ways have emerged to protect against its potential harmful effects.

One of the most common ways to protect against excessive blue light is to reduce the luminous intensity of screens. By adjusting the brightness and spectral distribution of the light emitted by digital devices, the proportion of blue light in the total light emitted by the screen can be reduced. This method can be implemented by changing the screen settings in the operating system or by using dedicated applications that allow one to control the intensity and spectrum of light emitted by devices.

Another effective way to protect against the negative effects of blue light is through protective filters. Absorptive or absorptive-reflective filters, such as blue-blocker lenses, help to reduce the amount of blue light reaching the eyes. These filters absorb or reflect blue light, reducing its impact on our eyes and brain. Different types of filters are available, such as yellow or amber filters, and filters with anti-reflective coating which are more effective in reducing blue light.

Protection against the negative effects of blue light is becoming increasingly important in the digital age. Using protective filters and adjusting the background colour of the screen can help to reduce vulnerability to these effects. It is worth remembering the importance of a good balance between digital device usage and health protection. Research is still being conducted to better understand the effects of blue light on our bodies. This may contribute to the further development of effective methods to protect against this phenomenon.

Conclusions

In our artificially lit modern world, light-emitting smartphones and tablets are some of the only light sources at which we look directly. As we spend more and more time with these digital devices, it is important

to understand how the blue light they emit can affect our health and well-being. Although it is generally accepted that low-intensity artificial blue light from digital devices does not have an acute effect on the eyes, there is still a lack of high-quality research using appropriate light parameters and exposure conditions to truly understand how blue light from these devices may affect our eyes in the long term. A better understanding of the impact of artificial blue light on human health is crucial to inform the safe introduction of new technological solutions into our daily lives. As the impact of artificial blue light continues to be studied, it will be important to consider not only the potential consequences of ever-evolving technological advances on human health, but also how technology can be used to our benefit.

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