The Effects of Blue Light in Modern Society

Pascu Loredana-Sabina
Dunărea de Jos University of Galați
Strada Domnească 47, Galați, Romania
Phone: 0336 130 108

Domenico Perri
S. Giuseppe Moscati Hospital
Viale Antonio Gramsci, 81031 Aversa CE, Italy
Phone: +39 081 500 1111

Bradeanu Andrei Vlad
Dunărea de Jos University of Galați
Strada Domnească 47, Galați, Romania
Phone: 0336 130 108

Anamaria Ciubara
Dunărea de Jos University of Galați
Strada Domnească 47, Galați, Romania
Phone: 0336 130 108
anamburlea@yahoo.com

Marin Marilena
Dunărea de Jos University of Galați
Strada Domnească 47, Galați, Romania
Phone: 0336 130 108

Marina Virginia
Dunărea de Jos University of Galați
Strada Domnească 47, Galați, Romania
Phone: 0336 130 108

Abstract

In the past, more than 150 years ago, incandescent bulb light appeared with red light emitters but technology has evolved to the present and scientist people discovered and promoted ecological lighting by compact fluorescent lamps and light emitting diodes.

In modern society, most of the classic lamps have been replaced with LED technology, much more efficient in terms of the amount of light emitted, as well as energy consumption. Besides these advantages, it also presents some drawbacks that affect our daily life through the structures they come into contact with (skin, eyes) and are intensively studied.

One of the most important and frequent effects of blue light is shown by the link between melanopsin, a photo-pigment present in the retina, responsible for regulating circadian rhythm and sleep-wake cycle, and blue light that go through the eye and reach the retina. So, it explains the increasing incidence of sleep disorders, decreased sleep quality associated with a high degree of fatigue and disturbance of family and social life. But knowing these effects, blue light can be beneficial if used in the first half of the day; in patients with neurocognitive disorders such as patients with Alzheimer's disease, have been observed an improvement in symptomatology. On short term, blue light stimulates dopamine production, but long-term light exposure has the opposite effect and leads to symptoms such as anxiety, mood swings, inability to focus, lack of insight or self-awareness, low libido.

To be able to prevent the negative effects of blue light, first of all we need to know the devices that affect us and the main "enemies" are right next to us, present in our everyday life: smartphones, tablets, televisions.

1. Introduction

In the past, the most popular lighting sources were incandescent bulbs (red light emitters).

Lately, ecological lighting methods have been discovered and promoted.

The LED (blue light emitting) consumes 85% less than the classic lamps, surrounds us (smartphones, televisions, iPads, E-books) and its effects are in continuous research.

A study by researchers at Cambridge University Hospitals showed that 72% of adults in the UK are checking social networks immediately before going to bed. This seems to indicate that people are increasingly exposed to blue light and the constant fatigue that people are affected by is not caused by any new illness, but by their "always stay connected" style.

Over the last decades, evidence has accumulated that, besides the visual role, light affects the structures with which it has direct contact (eyes and skin), but it also has implications in human physiology, influencing the circadian rhythm, hormonal secretion, melatonin secretion, thermoregulation, vigilance (Phipps-Nelson et. al., 2003).

I. BLUE LIGHT and THE VISUAL ORGAN

The retina is the only component of the central nervous system that comes in direct contact with light with wavelengths between 380 and 780 nm.

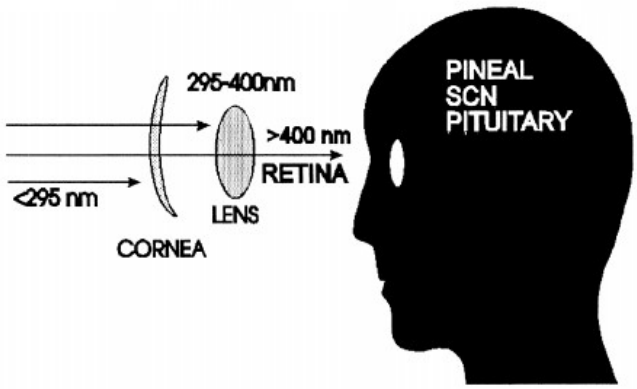

Figure 1

New studies claim that a new photo-pigment, MELANOPSIN (part of the retino-hypothalamic tract), would be responsible for regulating the circadian rhythm. Retinal melanopsin glandular cells contain neurotransmitters that play an essential role in the body's response to light and the effect on the sleep-wake cycle. Researchers have found that blue light - specifically, with a wavelength of 446-477 nanometers - is more effective than others in suppressing melatonin production which keeps people in a state of alertness (compared with green light, which is 3 times less harmful under the same study conditions).

Exposure to light with wavelengths between 380 and 500 nm can cause:

- photoreceptor lesions (Georgiev, 2019)
- astenopathy (Yamadera et. al., 2000; Gavrilescu et. al., 2015)
- glaucoma,
- drying the cornea,
- macular degeneration (Georgiev, 2019; Moderie et. al., 2017; Moon et. al., 2017)

Ophthalmologic pathologies (receptor lesions, astenopathy, corneal dryness) occur following exposure to short wavelength radiation as the radiation is taken up by the ***chromophores*** in the mitochondria present in the retinal ganglion and the disruption of mitochondrial activity leads to the death of glandular cells and, over time, to glaucoma and macular degeneration.

Melanopsin, present in the retina, has numerous functions: dilate the pupil, regulates dopamine secretion, reduce melatonin secretion, increases cortisol level (*a glococortic is released in*

response to stress and participates in the metabolism of fats, proteins and carbohydrates), lowers the secretion of the alpha-melanocytic stimulant hormone (*role in energy homeostasis, sexual activation, protection against ischemia*), reduces grenaline secretion (*hunger hormone*) and increases leptin secretion (*satiety hormone*).

II. BLUE LIGHT and CIRCADIAN RHYTHM

Each person has a slightly different circadian rhythm. To maintain a 24-hour cycle, the biological clock needs the temporal clues of the environment (sunrise, sunset, etc.) or daily routine (Nowak et. al., 2011).

An experimental study placed volunteers in special rooms without clocks or other clues of time, volunteers tended to sleep one hour later and wake up an hour later each day, so the human "internal clock" seems to work for about 25 hours (Chang et. al., 2015; Penn et. al., 1999; Meltzer et. al., 2017). Therefore, people need some clues about the time/moment of the day to integrate into the environment.

Extensive exposure to artificial light at unsuitable times of the day (evening or night) can affect the circadian rhythm and can lead to multiple conditions (Landers et. al., 2009; Zhang et. al., 2014).

Blue light inhibits photoreceptors that produce melatonin release (the hormone that helps induce sleep) – the pineal gland. The pineal gland is extremely sensitive to light, and recent research has shown that it only secretes the required amount of melatonin under full darkness (Roberts, 2006).

Recent studies have also shown that exposure to light after 9 p.m. leads to **insomnia**, decreased sleep duration, decreased sleep quality triggered by an increased number of nighttime awakenings, high body temperature and increased heart rate, all of which also affect the quality of sleep (Lupu et. al., 2017; Stevens et. al., 2015). Moreover, studies have shown that light exposure can result in elevated corticosterone, which is not compatible with sleep (Ciubară et. al., 2015; Pilorz et. al., 2016; Hill et. al., 2009).

Until now, there have been several theories that tried to explain the "Chronic Fatigue Syndrome" aetiology – from nanobacteria to retroviruses.

Currently, the study of blue light and melatonin secretion seems to explain symptoms such as fatigue, anxiety, myalgia, sleep disturbances (Ciobotea et. al., 2016).

Overexposure to blue light can cause brain aging and decreased cognitive function, and avoiding these rays at night can significantly reduce the risk of multiple sclerosis. The "Chronic Fatigue Syndrome" seems to be directly linked to exposure to blue light. Studies have shown that the effects of blue light on sleep have led to: alteration of mood, impairment of family life and domestic responsibilities, disturbance of social life (Valcea et. al., 2016).

III. BLUE LIGHT and the IMMUNE SYSTEM

All wavelengths have a rather high potential to modify the immune system and the light modulates it through eyes-brain and skin responses.

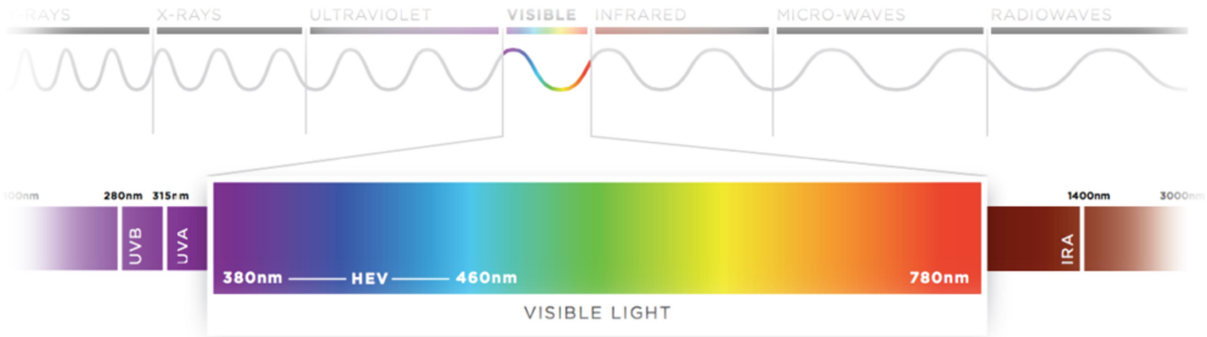

Figure 2

Wavelengths below 400nm interact with the skin and alter the immune function.

Ultraviolet radiation can be divided into UV-C (200-290 nm), UV-B (290-315 nm), UV-A (315-400 nm), which have a different mechanism of inducing an immunosuppressive response.

UV-A (315-400 nm) induces the secretion of α-Melanocyte-stimulating hormone (MSH) and Adrenocorticotropic hormone (ACTH), while visible light (400-750nm) leads to increased level of gastrin-releasing peptide (GRP), corticotropin-releasing hormone (CRH), neuropeptide Y and follicle-stimulating hormone (FSH) and a decreased level of the vasoactive intestinal peptide (VIP) (Meltzer et. al., 2017).

During one day, the proliferation and the level of circulating T, B and NK lymphocytes vary: in the morning, the best response to antigen is T lymphocytes, in the evening it is B lymphocytes, and in the afternoon it is the expression of IL-2 receptors and the proliferation of NK cells (Meltzer et. al., 2017).

Light influences the level of the following neurotransmitters:

- **Increases**: Serotonin, dopamine, GABA, cortisol, which deactivates the immune response through ACTH/CRH/cortisol modulation, blocking antibody production and inhibiting IL-4, Ig E;
- **Decreases**: Acetylcholine, melatonin, norepinephrine, which blocks IL-1, IL-2.

Therefore, it increases the susceptibility of disease occurrence like rheumatoid arthritis, allergies, and also the susceptibility to aggression of several pathogens, but over 10 serious infectious diseases were eradicated (Centers for Disease Control and Prevention) due to vaccinations.

By far, vaccination has proved to be the most powerful weapon that science made available to humanity with the purpose of preventing and even eradicating the main diseases of massive spread. The essential condition in accomplishing and maintaining this desideratum is the achievement of a reasonable immunity in population, which can only be obtained by vaccinating the entire receptive population, according to a well-established schedule (Landers et. al., 2009).

The great accomplishments of vaccinology seem to be eclipsed by the actualities of the past few years, when in certain areas, even in the Romanian capital, there has been a decrease in the vaccination percentage by 20% (Bucharest), and the population immunization percentage has decreased under 75%, which means that the critical mass necessary for epidemic outbursts has been exceeded (Landers et. al., 2009).

Nowadays, 50 years after the beginning of antibiotics and vaccination programs in Romania, we are facing malaria and tuberculosis threatening to resurrect and also new species of drug-resistant microbes.

For example, in 2016, in Romania, a severe infection was reported with Neisseria meningitidis Serogroup C at a 1-year old child. Septic arthritis due to N. meningitidis is rare and bone infections have been reported exceptionally (Straticiuc et. al., 2016).

The correct understanding of the role of vaccination in the community life, of the fact that it is the only manner that ensures personal and collective security against epidemic diseases and equally corresponds to the ethical principles of cohabitation in society must prevail before any considerations (Landers et. al., 2009).

So, an immune-prepared organism and a functional vaccination program can greatly increase the quality of life and the survival rate.

IV. BLUE LIGHT and HORMONES

Light affects the production of hormones, melatonin. It can change body temperature, heart rate, hunger levels (reducing the Ghrelin hormone – responsible for hunger, and increasing the Leptin hormone – responsible for the feeling of satiety) and increasing the risk of developing heart disease and high blood pressure (Stevens et. al., 2015).

Incorrect exposure to blue light beams can cause body weight gain by producing new fat cells at night and may increase insulin resistance.

Moreover, light affects the function of the pituitary gland and reduces the secretion of melatonin.

It determines hypersecretion of estrogens and progesterone and hypersecretion of FSH-LH releasing hormone. This results in early and prolonged stimulation of breast tissue.

Melatonin suppresses ROR-alpha transcriptional activity and blocks BMAL-1 gene expression resulting a reduced expression of SIRT1, histone diacetylase and diacetylase protein which will inhibit the expression of DNA repair enzymes (p53, BRCA1 and 2 and Ku70) (Stevens et. al., 2015).

In 2007, the International Agency for Cancer Research, the World Health Organization, reported that work in shifts could be a cancerous factor, especially breast cancer (Cajochen et. al., 2005).

V. BLUE LIGHT and DAILY ACTIVITY

Exposure to blue light reduces brainwave and induces low frequency activity (correlated with sleepiness) at the cerebral level and may increase alpha waves that are characteristic of alertness (Moderie et. al., 2017; Moon et. al., 2017).

Alpha brainwaves move towards deep relaxation, imagination and intuitive thinking, as they accompany:

- a relaxed mind after complex thinking into a mode of relaxation,
- meditation and setting the mind's attention to itself, away from outside distractions,
- reco–very from stressful thoughts and emotional despair (Moon et. al., 2017).

Blue light has beneficial effects when used at times of day when we are physiologically exposed to light. It increases vigilance, improves mood and cognitive performances by increasing neurotrophic factors (brain-derived neurotrophic factor (BDNF) and nerve growth factors (NGF) (Penn et. al., 1999; Chang et. al., 2015).

Over-exposure to blue light can cause brain aging and decreased cognitive function and avoiding these rays at night can significantly reduce the risk of multiple sclerosis (Nowak et. al., 2011).

Exposure to blue light in the evening has the effect of delaying the sleep-wake cycle, suppressing melatonin, reducing the REM sleep phase and, implicitly, reduces the quality of sleepiness, increases fatigue, and diminishes vigilance the next morning (Ciubară et. al., 2018).

Studies have shown that the effects of blue light on sleep have led to ("Annual Sleep in America Poll Exploring Connections with Communications Technology Use and Sleep | National Sleep Foundation", 2019):

- alteration of mood,
- impairment of family life and domestic responsibilities,
- disturbance of social life.

Moreover, in patients with Alzheimer's disease exposed to blue light in the morning, an improvement in consciousness was observed (Yamadera et. al., 2000; Nowak et. al., 2011).

Strong light devices have shown that they can treat seasonal affective disorder (SAD), bipolar disorder and postpartum depression; this may be due to action on melanopsin that stimulates dopamine secretion.

Conversely, long exposure can produce adverse effects and leads to inhibition of dopamine secretion.

RED FLAGS

- Blue light has beneficial effects when used at times of day when we are physiologically exposed to light. It increases the ability to concentrate and memorize, vigilance and improves mood.
- Overexposure or inappropriate exposure disrupts whole body homeostasis and acts on brain, hormonal, cardiac functions and can cause obesity, diabetes, depression, and cancer.
- To prevent the negative effects on the eyes (eye strain symptoms, corneal dryness), on sleep, and the state of mind, we should use lenses with blue light filters, use special applications on the phone and laptops, as we blink more often when exposed to monitor light, and avoid exposure to bright lights before bedtime.

References

Cajochen, C., Münch, M., Kobialka, S., Kräuchi, K., Steiner, R., & Oelhafen, P. et. al. (2005). High Sensitivity of Human Melatonin, Alertness, Thermoregulation, and Heart Rate to Short Wavelength Light. The Journal of Clinical Endocrinology & Metabolism, 90(3), 1311-1316. doi: 10.1210/jc.2004-0957.

Chang, A., Aeschbach, D., Duffy, J., & Czeisler, C. (2014). Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. Proceedings Of The National Academy Of Sciences, 112(4), 1232-1237. doi: 10.1073/pnas.1418490112.

Ciobotea, D., Vlaicu, B., Ciubara, A., Duica, C. L., Cotocel, C., Antohi, V., Pirlog, M. C. Visual Impairment in the Elderly and its Influence on the Quality of Life. Revista de Cercetare si Interventie Sociala, 54, 66-74.

Ciubară A. B., Nechita A., Tudor R. C. et. al. (2018). Social and Medical Ethics: Implications for Romanian Protocols Regarding the Therapy of Alcohol Withdrawal Syndrome in Trauma Patients. Revista de Cercetare si Interventie Sociala, 60, 174-179.

Ciubară, A., Burlea, Ş., Săcuiu, I., Radu, D., Untu, I., & Chiriţă, R. (2015). Alcohol Addiction – A Psychosocial Perspective. Procedia - Social And Behavioral Sciences, 187, 536-540. doi: 10.1016/j.sbspro.2015.03.100.

Gavrilescu, O., Mihai, C., Anton-Paduraru, D. T., Moisa, S., Ciubara, A., Cijevschi-Prelipcean, C. (2015). Impact of Inflammatory Bowel Diseases on Quality of Life. Revista de Cercetare si Interventie Sociala, 50, 80-95.

Georgiev, D. (2019). Color Temperature - Iris - Software for Eye protection, Health and Productivity. Retrieved from https://iristech.co/color-temperature-and-blue-light/.

Hill, S., Frasch, T., Shulin Xiang, Lin Yuan, Duplessis, T., & Lulu Mao. (2009). Molecular Mechanisms of Melatonin Anticancer Effects. Integrative Cancer Therapies, 8(4), 337-346. doi: 10.1177/1534735409353332.

Landers, J., Tamblyn, D., & Perriam, D. (2009). Effect of a blue-light-blocking intraocular lens on the quality of sleep. Journal Of Cataract & Refractive Surgery, 35(1), 83-88. doi: 10.1016/j.jcrs.2008.10.015.

Lupu, V. V., Ignat, A., Stoleriu, G., Ciubara, A. B., Ciubara, A., Lupu, V., Burlea, M., Stratciuc, S. (2017). Vaccination of Children in Romania between Civic Obligation and Personal Choice. Revista de Cercetare si Interventie Sociala, 56, 123-132.

Meltzer, E., Sguigna, P., Subei, A., Beh, S., Kildebeck, E., & Conger, D. et. al. (2017). Retinal Architecture and Melanopsin-Mediated Pupillary Response Characteristics. JAMA Neurology, 74(5), 574. doi: 10.1001/jamaneurol.2016.5131.

Moderie, C., Van der Maren, S., & Dumont, M. (2017). Circadian phase, dynamics of subjective sleepiness and sensitivity to blue light in young adults complaining of a delayed sleep schedule. Sleep Medicine, 34, 148-155. doi: 10.1016/j.sleep.2017.03.021.

Moon, J., Yun, J., Yoon, Y., Park, S., Seo, Y., & Park, W. et. al. (2017). Blue light effect on retinal pigment epithelial cells by display devices. Integrative Biology, 9(5), 436-443. doi: 10.1039/c7ib00032d.

Nowak, L., & Davis, J. (2010). Qualitative Analysis of Therapeutic Light Effects on Global Function in Alzheimer's Disease. Western Journal Of Nursing Research, 33(7), 933-952. doi: 10.1177/0193945910386248.

Penn, A., & Shatz, C. (1999). Brain Waves and Brain Wiring: The Role of Endogenous and Sensory-Driven Neural Activity in Development. Pediatric Research, 45(4, Part 1 of 2), 447-458. doi: 10.1203/00006450-199904010-00001.

Phipps-Nelson, J., Redman, J., Dijk, D., & Rajaratnam, S. (2003). Daytime Exposure to Bright Light, as Compared to Dim Light, Decreases Sleepiness and Improves Psychomotor Vigilance Performance. Sleep, 26(6), 695-700. doi: 10.1093/sleep/26.6.695.

Pilorz, V., Tam, S., Hughes, S., Pothecary, C., Jagannath, A., & Hankins, M. et. al. (2016). Melanopsin Regulates Both Sleep-Promoting and Arousal-Promoting Responses to Light. PLOS Biology, 14(6), e1002482. doi: 10.1371/journal.pbio.1002482.

Roberts, J. (2006). Light and Immunomodulation. Annals Of The New York Academy Of Sciences, 917(1), 435-445. doi: 10.1111/j.1749-6632.2000.tb05408.x.

Annual Sleep in America Poll Exploring Connections with Communications Technology Use and Sleep | National Sleep Foundation. (2019). Retrieved from https://sleepfoundation.org/media-center/press-release/annual-sleep-america-poll-exploring-connections-communications-technology-use-.

Stevens, R., & Zhu, Y. (2015). Electric light, particularly at night, disrupts human circadian rhythmicity: is that a problem?. Philosophical Transactions Of The Royal Society B: Biological Sciences, 370(1667), 20140120-20140120. doi: 10.1098/rstb.2014.0120.

Straticiuc, S., Ignat, A., Hanganu, E., Lupu, V., Ciubara, A., & Cretu, R. (2016). Neisseria meningitidis Serogroup C Causing Primary Arthritis in a Child. Medicine, 95(5), e2745. doi: 10.1097/md.0000000000002745.

Valcea, L., Bulgaru-Iliescu, D., Burlea, S. L., Ciubara, A. (2016). Patient's rights and communication in the hospital accreditation process. Revista de Cercetare si Interventie Sociala, 55, 260-270.

Yamadera, H., Ito, T., Suzuki, H., Asayama, K., Ito, R., & Endo, S. (2000). Effects of bright light on cognitive and sleep–wake (circadian) rhythm disturbances in Alzheimer-type dementia. Psychiatry And Clinical Neurosciences, 54(3), 352-353. doi: 10.1046/j.1440-1819.2000.00711.x.

Zhang, K., Duan, L., Ong, Q., Lin, Z., Varman, P., Sung, K., & Cui, B. (2014). Light-Mediated Kinetic Control Reveals the Temporal Effect of the Raf/MEK/ERK Pathway in PC12 Cell Neurite Outgrowth. Plos ONE, 9(3), e92917. doi: 10.1371/journal.pone.0092917.