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Blue Light Blocking Ophthalmic Lenses and Their Benefits–A Review

E. Pateras[1*]

[1]*Biomedical Sciences Department, Course Optics and Optometry, University of West Attica, Greece.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

Light plays an important role in many functions of the human body. It improves visual acuity, contrast sensitivity and colour perception while improving mood, memory and maintaining hormonal balance through the regulation of the sleep-wake cycle. The low wavelength violet-blue light in the spectrum of 390-470 nm is high energy light and has been blamed for causing damage to the retina. Many studies have looked at how blue radiation affects eye health, visual acuity and circadian rhythm, especially in relation to the placement of filters that reduce the passage of blue light into the intraocular or ocular lens. In general, blue light improves contrast sensitivity and vision in intermediate lighting conditions, affects the sleep-wake cycle through melatonin secretion, and can cause several oxidative reactions in the retina resulting in the accumulation of photo deposits. Today it is well known that the spectrum in blue light radiation creates a wide range of health problems in every category of population, from premature infants to the elderly. This blue light spectrum is contained in the white light of Light Emitting Diode (LED) lamps, "economical" and any light source, such as that which comes from smartphones, computers, and many other devices whose light is a composition of colour spectra having the most powerful spectrum in blue. Blue blocker ophthalmic lenses provide a solution to all the above.

Keywords: Blue radiation; circadian rhythm; photoreceptors; contrast sensitivity; blue blocker ophthalmic lenses.

**Corresponding author: Email: pateras@uniwa.gr;*

1. INTRODUCTION

The sun and artificial light sources (led technology lamps) are the main sources of blue radiation, while at the same time the devices made with LED backlight technology such as mobile phones, computers and tablets are increasing, as a result of which our eyes are exposed to more blue light compared to the past [1]. This creates the need to consider whether this overexposure to blue light affects our vision, eye health, or other neuro-physiological functions of the body that are not related to vision. According to three studies, blue light plays an important role in color discrimination [2] mesopic and scotopic vision [1] and helps in emmetropization of the eye [3,4].

Other studies have concluded that placing intraocular lenses that filter blue light to some extent reduces the feeling of blurred vision [5] and that the use of glasses with a filter for blue light improves visual acuity in patients with dry eye [6].

The relationship between blue light and circadian rhythm has been analyzed in studies examining changes in melatonin secretion about the use of electronic devices with led lighting before bedtime [7,8]. Also, there are studies dealing with the change in vigilance and mood depending on the type of lighting in the workplace (fluorine enrichment enriched in blue or plain white), [5] and finally studies that assessed the quality of vision and any effects on circadian rhythm in patients with intraocular with blue radiation filter [1].

Experimental studies in animals have shown that blue radiation causes damage to the pigmented epithelium and destroys the photoreceptors [9,10]. A similar study concluded that blue light, through complex biochemical reactions, produces reactive oxygen molecules that disrupt the structures and functions of retinal nerve cell membranes [11]. The above is also explained by the research of Ham and Mueller [12] who distinguished the lesions that are created in the retina after radiation in infrared (IR) which are caused by long wavelengths (700 nm-1400 nm) and photochemical in the case of short wavelength radiation (400 nm- 800 nm).

2. BLUE LIGHT RADIATION AND VISUAL ACUITY

For the ability to see in the dark (scotopic vision) the rods are responsible, while for the vision in bright light (photopic vision) three types of cones are responsible: S (short), M (middle) and L (long). The rods are more sensitive than cones, they are activated with minimal light and are responsible for night vision with a maximum sensitivity of 507 nm. The S cones are sensitive to blue light around 455 nm and together with the rods are responsible for scotopic and mesopic vision.

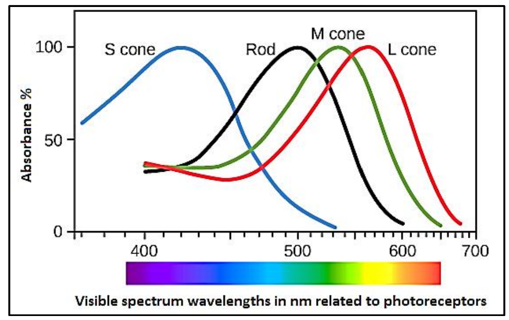

Fig. 1. Sensitivity of cones and rods at different wavelengths of the visible spectrum [13]

It is understood that low-wavelength light plays an essential role in the ability to see in low light conditions. Growing up, for various reasons such as the smaller diameter of the pupil and the gradual blurring of the crystalline lens, the scotopic vision decreases and in fact almost twice as fast as the photopic [14] while the sensitivity to the glaze increases. Hammond's [5] study evaluated visual performance in bright lighting conditions in patients with transparent intraocular lenses and with a UV filter (≤ 400 nm), which was intended to absorbed low wavelengths in the visible spectrum. He used an artificial LED light source which was intensified and caused glare in the study participants and examined the time the vision was restored wearing glasses with a blue radiation cut filter or just clear glasses and the tolerance limit in the glaze and visual acuity.

Recovery time was significantly lower and blur tolerance was higher in the group wearing the blue filter. Dry eye patients also had an improvement in visual acuity using a blue filter. Twenty-two people with low Break-up time (BUT) and eighteen healthy subjects were assessed for functional visual acuity (mean visual acuity during the examination). Those with dry eyes had significantly improved visual acuity wearing the glasses with the blue light filter [6].

In contrast, in the experimental research run by Wirtitsch and Schmidinger [4] where different types of intraocular lenses were placed on the same patient (one with a blue filter and one with a UV filter), significantly reduced contrast sensitivity was found mainly in mesopic lighting conditions and slight lag in color distinction at the eye with the blue filter intraocular lens. Decrease in color perception wearing glasses with a blue filter had patients with age-related macular degeneration (AMD) who had particular difficulty distinguishing between blue and black [2].

Finally, of particular interest is the conclusion of the experimental research of Rucker and Britton that showed that blue light plays a role in the metamorphosis of the eye by studying changes in axial length and corneal astigmatism in chickens that grew up in a space with blue or yellow lighting with fluctuations in intensity. The high time frequencies in combination with the yellow light resulted in a decrease in the axial length and hyperopia, while the opposite increase in the axial length and myopia had the low time frequencies with yellow light. These changes in axial length were not observed when the lighting also contained blue light, and a significant reduction in corneal astigmatism during development with the presence of blue light [3]. This statement may explain the lower rates of myopia in children who spend a lot of time outdoors in the sunlight that is rich in blue radiation.

3. BLUE LIGHT RADIATION AND SLEEP-WAKE CYCLE

The human circadian cycle allows a single phase of sleep that coincides with the hours of darkness during which there is an increase in the secretion of the hormone melatonin and is directly related to the amount of light reaching the eye. The light is perceived by the photoreceptors: The cones with a maximum sensitivity of 555 nm and the rods with a maximum of 507 nm, but the circadian rhythm is determined by photosensitive ganglion cells of the retina with a pigmented sensitivity of 48 melanocyte, which is maximal, for the blue light spectrum [15]. These photoreceptor cells are located in the inner layers of the retina, calculate the intensity of light and transmit this information to the superconducting nucleus of the hypothalamus which is the area that regulates the circadian rhythm in order to harmonize the internal biological clock with the environment.

The hypothalamus, depending on the information it receives through melanopsin, regulates the secretion of hormones that either promote alertness (cortisol) or suppress it (melatonin). Melatonin is secreted in the dark, reaches its maximum level in the middle of the night and gradually decreases until dawn. Then the levels of cortisol rise, which affects the action of the nervous system, metabolism and alertness of the body [14]. Given the sensitivity of melanopsin to blue light, Schechter and Kim's [8] study looked at people with insomnia symptoms who wore special treated glasses for a week, every night, for two hours before going to bed. The blue-filter glasses absorbed blue light by 65%, or transparent clear glasses that absorbed blue light by 10%. The duration and quality of sleep were significantly increased in the group wearing the glasses with the blue radiation filter.

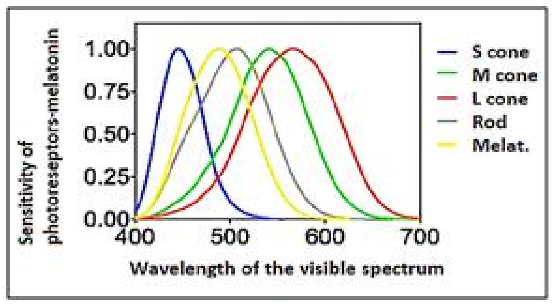

Fig. 2. Sensitivity to light depending on the wavelength. The sensitivity curves of the three types of cone S-cone, M-cone, L-cone. Rods are shown in gray. The sensitivity curve of melanopsin is shown in black [16]

However, during the day when we want increased levels of alertness and good performance at work, blue light has a beneficial effect. Workplaces with cool white fluorescent lighting that contain blue light, promote melatonin suppression, increase alertness, improve mood and concentration, and reduce fatigue [17]. Sleep disorders affecting 40-70% of the elderly are also attributed to the reduced amount of blue light that reaches the retina due to the yellowing of the crystalline lens that acts as a filter for blue light [18]. Between blue and red lighting conditions, blue light caused increased suppression of melatonin production [19].

Finally, the exhibition in the evening hours to devices with led lighting such as computer screens, smartphones and tablets caused a delay and reduction in the amount of secretion melatonin, reduced the feeling of sleep and the duration of REM sleep [7,8].

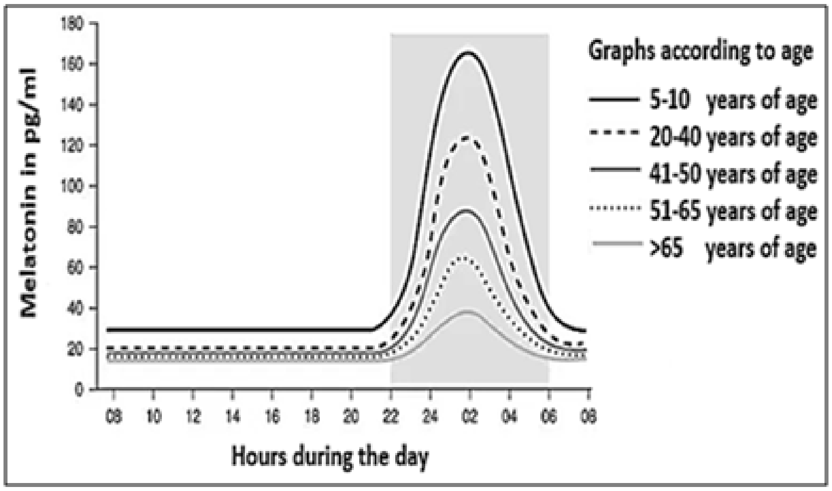

Fig. 3. Concentration of melatonin levels during the day and night. Circadian circle of melatonin across relatively to age. Gray area indicates darkness [20]

It is proven that blue blocker glasses restore the normal function of the epiphysis and the corresponding normal secretion of melatonin, which is a powerful repair agent. It is well known in the scientific community that "economy" lamps and any type of fluorescent lamp significantly inhibits melatonin secretion. In a recent study, melatonin levels were measured in people who wore blue blocker glasses that prevent blue radiation from penetrating the eyes and in another group wearing normal clear glasses. It was observed that the secretion of melatonin was not normal in those wearing ordinary normal glasses, in contrast to those people who wore blue blocker glasses that prevented the blue radiation from penetrating into their eyes [20]. Blue blocker glasses in another study showed that they can be useful to teens from preventing the negative effects of modern lighting (from exposure to LED lighting, smartphones, tablets and computer screens) to circadian physiology at night [21].

Blue-light blocking spectacle lenses reduced phototoxicity by 10.6% to 23.6% and melatonin suppression by 5.8% to 15.0%, with no significant decrease in contrast sensitivity but also decreased scotopic sensitivity by 2.4% to 9.6%. Blue-light blocking lenses filter high-energy short-wavelength light without substantially degrading visual performance and provide sleep quality [22,23,24,25]. High blue-blocking lenses have a more significant improvement to the sleep quality, based on a 10-point Likert scale, compared to the low blue-blocking lens [26].

4. BLUE LIGHT AND MACULAR DEGENERATION

Ultraviolet radiation (UV) is divided into three regions in the electromagnetic spectrum: UVA (from 315 to 400 nm), UVB (from 280 to 315 nm) and UVC (from 100 to 280 nm). UVC does not reach the earth's surface, because it is completely absorbed by the protective barrier of the atmospheric ozone in the upper atmosphere which also weakens the UVB that reaches the earth, but also UVA radiation. The amount of UVB that reaches our eyes varies, of course, depending on the location, the time of year and the time of day (the position and direction of the sun). The cornea absorbs ultraviolet radiation up to 300 nm and the crystalline lens absorbs most of the UV up to 400 nm, protecting the retina from the harmful effects of UV radiation. So, it is well known that from the ultraviolet spectrum UV-C is absorbed entirely by the ozone layer, only 5% of UV-B will make it through the atmosphere but alarmingly up to 95% of UV-A radiation will get to our eyes without any interruptions. Growing up, the transmission and absorption of light changes mainly due to the reduction in the diameter of the pupil and the yellowing of the lens, resulting in a smaller amount of blue light reaching the retina. In other words, the color absorbance of the crystalline lens acts like a natural one, although not a perfect filter in blue light [27]. This does not apply after cataract surgery where a much larger amount of violet-blue light reaches the retina. In a clinical trial on Intra-ocular lenses (IOLs) their result suggests the selection of blue light filtering IOLs for pediatric and presbyopic lens cataract surgery. The benefit of using such IOLs provides better quality of vision, reduced glare and better protection against retinal phototoxicity which is related to potential risk for advanced macular degeneration (AMD) [28,29,30].

When light reaches the retina, it stimulates the cones, rods, and photosensitive ganglion cells that contain, as it is mentioned, melanopsin. The light that is not absorbed by the photoreceptors as well as the light coming from diffusion is bound by melanin to the pigmented epithelium. The pigmented epithelium with this capacity improves the visual performance and protects the rest of the retina from the large amount of light radiation and the creation of oxidative stress.

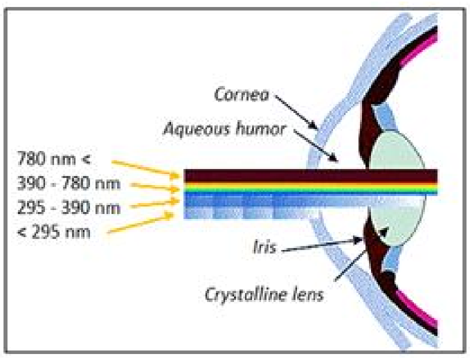

Fig. 4. Absorption and transmission of visible light to the eye. The cornea and crystalline lens absorb UVB and most of the UVA resulting that the wavelength reaching the retina being blue-violet radiation

The pigmented epithelium cells produce and drain various growth factors that are necessary for the proper functioning of photoreceptors, nutrients such as glucose, fatty acids, ions and water, and remove free radicals. In this way they play a vital role in the renewal of vision pigments and contribute to the smooth functioning of the rods and cones. As we grow older, these functions are weakened and lipids and other photoreceptor degradation products produce lipofuscin, which gradually accumulates under Bruch's membrane, creating drusen exudates that destroy photoreceptors and cause atrophy in the macula. Lipofuscin contains different fluorophores, where A2E is a major retinal fluorophore, derived from vitamin A-aldehyde and ethanolamine, A2E is originating from oxidative damage to the photoreceptor outer segments. Other components of lipofuscin produced from free radical induced oxidation of polyunsaturated lipids. Lipofuscin is associated with cellular dysfunction [28,31]. Going through research work it is obvious that blue light-emitting diode (LED) and blue light radiation in general produced retinal degeneration due to retinal toxicity. A2E affect RPE (damages occur to the cells) when A2E is exposed to blue light radiation. Blue light produces angiogenesis in RPE cells and increases VEGF levels in A2E-Laden RPE cells [32,33].

It has been known since 1916 that bright light such as the sun or lasers causes damage to the retina [34] believing that these were solely the result of the thermal energy of light. However, a study by Ham and Mueller in 1976 [35] showed that prolonged exposure (more than 1000sec) to blue light (441 nm) results in alterations in retinal photochemicals with no increase in temperature. While wavelengths of 580 nm and above cause mainly thermal damage to the retina, low lengths in the visible spectrum cause photochemical damage that differs histologically from thermal damage. The type of damage depends on the intensity of the radiation and the time of exposure and it has been found that mild photochemical lesions can be repaired over time [12].

The above findings are supported by Ham's research in 1968 [10] which monitored alterations in monkeys under the same conditions three months after irradiation. On the first day after exposure, the neural retina, the choroid, and the pigment epithelium did not change. Alterations in pigment epithelium pigments were visible on the second day after exposure, while lesions in the outer part of the photoreceptors, degradation and paleness of pigment epithelial, while pigments became visible on the fifth day after exposure. These changes appear to be reversible as they were not visible ninety days after exposure but are very similar to the retinal alterations of the elderly.

A study on mice [9] examined lesions in the pigment epithelium and photoreceptors between exposure to 1100 lux led illumination at 456 nm from one to three days and exposure to fluorine lighting of 8000 lux for three days. The mice exposed to blue light showed reduced white spots on the sixth day after exposure in contrast to those exposed to fluorescent lighting which had a smaller reduction in the thickness of the outer nuclear layer and the absence of white spots.

The composition of the exudates formed in the mice exposed to blue light was from lipid peroxides and the process of their formation was proportional to that of the age-related macular degeneration. Age-related macular degeneration causes irreversible visual impairment and often results in blindness in the elderly. It is distinguished in dry and wet form of macular degeneration with the wet form possessing 10-15% of cases and the main feature is the neovascularization of the choroid and the retina. Dry degeneration is characterized by a gradual loss of vision due to progressive damage to the pigment epithelium and then to the photoreceptors resulting in retinal atrophy and gradual loss of vision.

5. CONCLUSION

Nowadays, people of all ages spend many hours using computers, mobile phones or tablets with LED backlight technology. Also, lighting with LED lamps dominates the work and home space due to the high efficiency of lighting and economy. So, we are exposed daily to a large amount of blue radiation either from the sun or from the environment in which we live and perform our daily activities. Although there is generally a tendency to blame blue light for eye health, blue light is essential in various human functions: it helps us see better in the dark, distinguishes colors better and regulates various physiological functions of the body that are not related to vision. It synchronizes our biological clock, improves memory, mood and maintains hormonal balance. However, long-term exposure to blue light has been found to cause damage to the structure of the retina and is a risk factor for developing age-related macular degeneration, transmitted it from the clear at these ages crystalline lens. Also, blue blocker glasses can be useful to people who are exposed to LED lighting, smartphones, tablets and computer screens) during night hours so the circadian physiology is not disturbed. Finally, we must find a way to take advantage of the benefits and avoid future risks from exposure to blue radiation. Blue blocker ophthalmic lenses have incorporated filters that block or absorb blue light, in addition to the harmful ultra-violet (UV) light. These lenses do not allow UV and blue radiation up to certain nanometers to enter the eye and in the long-term produce damage to the functional tissues of the eye. Blue blocker ophthalmic lenses are proven to be helpful when looking at a screen of smartphones, tablets, computer monitors, especially after dark. These lenses reduce the exposure of the eye from blue light waves that can affect negatively the circadian rhythm and produce sleep disorders.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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