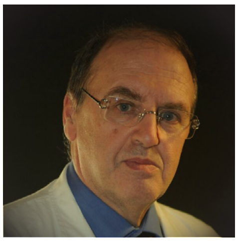
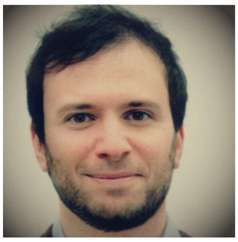
EXPLORING CLINICAL EVIDENCE AND THE BENEFITS OF FILTERING OUT HARMFUL LIGHT

The purpose of this paper is to explore evidence-based findings on the effects of harmful light. Based on literature and articles published in peer-reviewed journals, the authors offer a critical analysis of the current therapeutic implications of the selective manipulation of short-wavelength high energy light. With the appearance of new medical devices, in particular clear ophthalmic lenses capable of filtering both UV radiations and blue-violet light, this is an area of growing interest for clinical practice and potential preventive measures.



Prof. Francesco Loperfido
Head of general ophthalmology, occupational ophthalmology and diagnostic ophthalmology for driving licences services at University Vita Salute IRCCS Ospedale San Raffaele, Milan; consultant of the "Commissione Difesa Vista"; Assistant Professor of ophthalmology at University Vita Salute IRCCS Ospedale San Raffaele, Milan, Italy.



Dr. Alessandro Marchese
Resident in ophthalmology at University Vita Salute IRCCS Ospedale San Raffaele, Milan; works with Dr Loperfido in the general ophthalmology service.

KEYWORDS
UV, blue-violet light hazard, harmful light, tear film dysfunction, dry eye, visual fatigue, visual discomfort, glare, AMD, cataract, prevention with ophthalmic lenses filtering.

Visible light is composed of wavelengths ranging between approximately 380 and 780 nm. In humans, the components of this spectrum do not only interact with photoreceptors of the eye, but also have multiple local and systemic effects, which are yet to be fully documented. Blue light has recently been the subject of much interest. "Blue light" is generally considered as covering the part of the visible spectrum with wavelengths between approximately 400 and 500 nm. However given the significant differences, in terms of phototoxicity and biological effects, between the components at either end of this range, it is more appropriate to distinguish between blue-violet light (400-455 nm) and blue-turquoise light (465-500 nm).

Because of its high energy, short-wavelength light in the narrow range (415-455 nm) – blue-violet light – has been associated with possible harmful effects, particularly on the retina [1]. The macula is especially vulnerable to damage from high-energy radiation. Most UV radiation is absorbed by the cornea and crystalline lens and it is in these structures that excessive exposure to these frequencies primarily manifests, typically in the form of photokeratitis, conjunctival alterations (acute damage) and cataracts (chronic damage). However, almost all visible radiation passes through the anterior segment of the eye with little attenuation (85-90% transmittance) [2, 3] before being absorbed by the retina and the retinal pigment epithelium (RPE). Although less harmful to biological tissue than UV radiation, the short-wavelength end of the

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visible spectrum can also cause photochemical damage, especially from prolonged and cumulative exposure. [4] The damage caused to the RPE and the neuroretina by blue light has been documented in a number of scientific publications. [5, 6, 7]
Recent studies have drawn attention to the toxicity of blue-violet light to retinal ganglion cells, whose axons make up the optical nerve. [8] These cells are less protected by the macular carotenoids due to their location in the retina, they are also rich in mitochondria which produce the energy necessary for the continuous generation of action potentials. The chromophores contained in these organelles are most stimulated by blue-violet light, impairing their function and increasing the production of oxygen free radicals. These effects constitute an important area of research with the potential for new strategies of neuroprotection, a topic of central importance in retinal vasculopathies such as diabetic retinopathy. The use of selective filters in clear ophthalmic lenses is also an increasingly reliable source of retinal protection. Due to their high energy, short wavelengths are also capable of causing damage to cellular DNA, either directly or by increasing the formation of reactive oxygen species (ROS), and are among the suspected risk factors in uveal melanoma. [9, 10]

Blue-violet light and age-related macular degeneration

While age-related macular degeneration (AMD) is a multifactorial condition, various studies have suggested a connection with blue light. [11, 12, 13, 14, 15, 16] As the leading cause of vision impairment in over-50s, this pathology has significant social impact. [17] Prolonged and continuous exposure to short wavelengths is believed to contribute to the development and progression of AMD. The use of lenses that can selectively filter the light, especially at the blue-violet end of the spectrum, reaching the retina is thus likely beneficial. The blue-violet band in fact has greater phototoxic potential than the blue-turquoise band. [18]
It has recently been reported that the implantation of pigmented intraocular lenses (IOL) which block blue-spectrum light reduces, over time, the development of autofluorescence anomalies in the fundus of the eye compared to patients with transparent IOL implants with anti-UV blocking only. [19] Fundus autofluorescence is a standard test for early diagnosis of RPE alterations associated with AMD. The findings of this study have evoked strong interest, although they need to be confirmed by randomized trials. These alterations are triggered by various mechanisms, including the production of oxygen free radicals. The type of IOL in the anterior segment has been demonstrated to have a significant impact on the levels of oxidative stress measured in the vitreous gel. In nuclear cataracts there is a yellowing of the lens, increasing its ability to filter blue light up to 60% [20] and the oxidative stress to which the retina is exposed is considerably lower when nuclear cataracts are present than in patients with transparent IOL implants with UV blocking only. [21]

Blue-violet light and refraction

The potential benefits of filtering out blue-violet light are not limited to broad protection of the retina and RPE, but also extend to vision quality. The eye is a complex dioptric system, and the light rays which pass through it undergo scattering before arriving at the retina. The components of a beam of white light are deflected differently in accordance with their wavelengths, producing chromatic aberrations. This occurs because the refraction index of a light-carrying medium differs according to the wavelengths transmitting through it. The shorter the wavelength, the higher the refraction. This principle accounts for the formation of rainbows, in which water droplets in the air act as microscopic prisms.

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Absorption of blue light by specific ophthalmic lenses reduces chromatic aberrations, thereby improving the sharpness of images. In patients with an unstable tear film, this effect on visual quality is even more pronounced. Patients with dry eye and an unstable tear film are known to have decreased visual acuity. [22] This is because light rays undergo greater dispersion when they pass through an irregular tear film, and this dispersion is greater with short-wavelength light. These aberrations create blurred images, increasing visual fatigue and photo-stress, ultimately causing headaches and epiphora.

Since blue-violet light is the most critical part of the visible spectrum causing such aberrations, blocking this light should reduce discomfort. Supporting this, a recent study showed that patients with an unstable tear film achieved better results in visual acuity tests when using a blue-violet filter. [23] Another study showed that the use of blue light-blocking ophthalmic lenses can reduce the glare and photo-stress associated with prolonged exposure to intense light. [24] Clear ophthalmic lenses with these blocking properties would avoid the need for tinted lenses in situations where photo-stress is particularly strong, such as after cataract surgery.

FIG.1| Prof. Loperfido with a patient

« Absorption of blue light by specific ophthalmic lenses reduces chromatic aberrations, thereby improving the sharpness of images »

These studies also demonstrated how the use of filters which block short-wavelength light can produce significant and measurable clinical effects, including when incorporated into glasses lenses. In optical terms, therefore, the ability to selectively filter out blue-violet light is likely to be of value, as it helps to improve the quality of vision without significantly affecting cone and rod function. [25] In this way, scotopic and photopic sensitivity remain almost unchanged. Preserving night vision is an essential requirement for permanent lenses. The number of rod cells in the retina diminishes with age, while the number of cones remains fairly constant throughout an individual's lifetime. [26] This phenomenon explains the reduced ability to adapt to darkness and the problems with night vision reported by so many adults.

The duality of blue light

Although using lenses with short-wavelength cut-off filters may provide the retina with better protection against the harmful effects of photoexposure and reduce chromatic aberrations, the non-selective attenuation of blue light spectrum will also eliminate any associated beneficial effects. Many studies have shown that blue-turquoise light is one of the principal regulators of the circadian rhythms, contributing to chronobiological functions, with melanopsin stimulation peaking at 482 nm. [27] This photopigment does not contribute to the generation of a visual signal, but sends impulses to the neurosecretory nuclei regulating circadian rhythms by releasing mediators such as melatonin. During the day, exposure to blue-turquoise light promotes alertness, improves reaction times and regulates mood. [28]

As blue light exhibits pathological as well as physiological characteristics, the ideal non-tinted ophthalmic lens would therefore block the harmful effects of blue-violet light while preserving chronobiological functions associated with blue-turquoise light. A study on tinted (yellow) IOLs analysed the biological effects of these lenses, locating the equilibrium point between photoprotection and photoexposure at 445 nm. [27] However, it is very important to bear in mind that not all blue-filtering IOL implants are equivalent, with very large variations in the amount and type of light filtered by these implants.

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Conclusion

In recent years, significant clinical evidence has emerged for the benefits of reduced exposure to blue-violet light. Those who particularly stand to benefits include sufferers of tear film dysfunctioning and dry eye (especially when associated with prolonged use of digital devices and intense exposure to natural light), patients suffering from, or with a family history of, macular impairment, and patients requiring additional neuroprotection.

In recent years, the risk of repeated and prolonged exposure to blue light sources has increased. Several reasons contribute to this, including the widespread adoption of low-consumption light sources such as LEDs, and intensive use of tablets and computers. In theory, filtering blue light could reduce the cumulative damage associated with chronic exposure, such as by incorporating filters in the light sources themselves, or individual photoprotection. The latter option could take the form of tinted IOLs for patients undergoing cataract surgery or glasses for all other patients.

There are numerous aesthetic and functional advantages to incorporating selective blue-violet filters in the transparent lenses of conventional eyewear. Currently, most available non-tinted lenses have surface coatings for filtering blue-violet light, but lenses with a built-in capacity for absorbing UV and blue-violet light are now coming to the market with high transparency and improved aesthetics. •

KEY TAKEAWAYS

- The harmful effects of short-wavelength high energy light, specifically UV and blue-violet light, have been clearly demonstrated by a large body of peer-reviewed literature.
- The potential benefits of filtering out UV and blue-violet light offer not only greater protection of the anterior segment of the eye and the retina, but also extend to the quality of vision.
- The use of blue-violet light-filtering ophthalmic lenses can reduce the glare and photo-stress associated with prolonged exposure to intense light.
- Those who particularly stand to benefit from clear blue-violet light filtering lenses are:
  - Patients who suffer from tear film dysfunctioning and dry eye, especially when associated with prolonged use of digital devices and intense light exposure,
  - Patients suffering from, or with a family history of, macular impairment,
  - Patients requiring additional neuroprotection.
- The new ophthalmic lenses coming to the market reflect a growing interest for clinical implementation of light filtering from the perspective of visual comfort and/or potential preventive measures.

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