**Review Article**

# The Effect of Blue-Light-Blocking Filters on Human Visual System Performance and Individual Characteristics: A Narrative Review

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## ABSTRACT

**Introduction:** Blue-light-blocking filters are crucial for reducing the harmful effects of light emitted by digital screens.

**Materials and Methods:** This narrative review, based on a comprehensive search across databases, including PubMed, Web of Science, Cochrane, Medline, Scopus, Google Scholar, and ScienceDirect, aimed to examine studies published between 2010 and 2024 and evaluate the effects of these filters on eye health, sleep quality, and related functions.

**Results:** The findings indicated that the use of these filters can help reduce visual discomfort and improve physiological parameters, such as circadian rhythm and sleep quality. Moreover, the relationship between blue-light-blocking filters and the reduction of sleep disorders, such as insomnia, anxiety, migraine, photophobia, mania, computer vision syndrome (CVS), and accommodative problems, has been investigated. Their effects on retinal structure and function, potential role in reducing the risk of age-related macular degeneration, and influence on contrast sensitivity, color perception, and motion detection have also been discussed. Some studies suggest that these filters may affect contrast sensitivity; however, further research is required to clarify these effects. These filters may be beneficial for individuals continuously exposed to digital devices. Although these lenses do not significantly impact overall color perception, they may make it difficult to distinguish colors, particularly in the blue spectrum.
**Conclusion:** This study's narrative review provides a comprehensive overview of the effects of blue-light-blocking filters and emphasizes the need for further research in this area.

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## Introduction

Blue light, a portion of the visible light spectrum with wavelengths of approximately 400-500 nm, has attracted considerable attention due to its high energy and widespread sources, including digital screens and sunlight [1-3]. Its effects on human health extend far beyond its well-known role in regulating circadian rhythms. While blue light helps synchronize physiological activities during the day, prolonged and inappropriate exposure, especially during late hours and at night, can have widespread and multifaceted consequences on various health aspects, including sleep, mental health, vision, and retinal health [4-7].

Blue light, particularly at shorter wavelengths, can damage sensitive eye tissues, such as the retina [8, 9]. Under certain conditions, it is associated with issues, such as digital eye strain, sleep disturbances, migraines, and even mental health disorders [10]. Therefore, the use of blue-light-blocking filters has emerged as an effective way to reduce exposure to harmful blue light [11]. These filters, available as eyeglass lenses or screen overlays, reduce the transmission of specific blue light wavelengths and can alleviate symptoms of eye fatigue and vision problems [12].

Among these, partial blue-blocking filters, marketed as "blue control," have been introduced. These filters selectively block a portion of blue light at a lower intensity. Designed to preserve natural color perception and visual quality, especially in low-light conditions, and to maintain circadian rhythms, studies have shown that these filters improve visual comfort and have a lower impact on color perception than blue-blocking filters [13].

One of the most significant effects of continuous exposure to blue light is disruption of sleep quality and quantity. Blue light suppresses melatonin production, which plays a key role in regulating the sleep-wake cycle, resulting in delayed sleep onset and reduced depth and quality of sleep [14, 15]. This issue is particularly crucial for sensitive groups such as pregnant women, with research indicating that nighttime light exposure can decrease sleep duration in the first and third trimesters [16]. Blue light-induced sleep disturbances are also linked to increased anxiety and severity of insomnia and, in some cases, can exacerbate symptoms of mental disorders, such as mania in individuals with bipolar disorder. Research suggests that blue light can act as a psychological stimulant, influencing mood regulation and impacting psychiatric conditions [17-19].

Despite potential benefits, debates persist regarding the long-term effects of these filters, and further research is needed to determine their precise impact on eye health, sleep quality, and cognitive function [20]. Additionally, the role of blue light in eye health and its relationship with diseases, such as age-related macular degeneration (ARMD), remains a challenging topic [21, 22].

From a neurological perspective, blue light contributes to the onset and exacerbation of migraines and photophobia. Individuals with migraines often exhibit heightened sensitivity to blue light, which can trigger headaches. Blue light overstimulates visual neural pathways, increasing pain and light sensitivity in these patients. In this context, using blue-light-blocking filters, especially in bright environments or while using digital screens, can help reduce photophobia and migraine symptoms [23].

The problems caused by blue light are not limited to sleep and mental health disorders but also significantly affect vision [24]. A common issue among digital screen users is computer vision syndrome (CVS), characterized by symptoms, such as dry, tired eyes, blurred vision, eye pain, and accommodative disorders [25]. Prolonged exposure to blue light stimulates and fatigues retinal photoreceptors and excessively strains the eye's accommodation system, leading to these symptoms. Accommodation disorders caused by blue light exposure can result in temporary blurred vision, difficulty focusing, and rapid eye fatigue [26]. Therefore, using blue-light-blocking lenses and filters is a crucial strategy to reduce the severity of CVS and enhance visual comfort, warranting new insights into these lenses.

However, it is important to note that filtering blue light can affect visual performance. Scotopic contrast sensitivity (vision in low light) appears particularly sensitive to blue light reduction because short blue wavelengths are near the peak sensitivity of retinal rod cells (at 506 nm). Consequently, reducing the amount of blue light entering the eye can decrease contrast sensitivity and detail recognition in darkness by approximately 5_24%, an issue especially important for older adults, who naturally have diminished night vision [27]. Nevertheless, in bright environments and situations, such as night driving, blue-light-blocking filter lenses can reduce glare and increase contrast, potentially improving visual performance according to some studies.

Another concern is the impact of these filters on color perception. Research indicates that prolonged, repeated use of blue-light-blocking lenses can alter color accuracy, especially for warm and cool colors. This issue is critical for professionals highly sensitive to precise color discrimination (CD), such as graphic designers and surgeons [28, 29].

Regarding retinal health, chronic exposure to high-energy blue light can cause oxidative damage to light-sensitive retinal cells and accelerate macular tissue degeneration [30]. This process leads to ARMD, a leading cause of blindness in the elderly. Intraocular lenses (IOLs) and blue-light-blocking filtering glasses have been proposed as protective measures to safeguard the retina and prevent ARMD progression, especially in high-risk populations. This review examined relevant studies to derive accurate conclusions from their findings [31].

Blue light's effects are not limited to humans, and light pollution is an increasingly important concern. Light pollution refers to the excessive artificial light in the environment, which disrupts human biological rhythms and adversely affects ecosystems and public health [32]. Some studies implicate blue light in increased risks of neurological damage and certain cancers. Countries, such as the Czech Republic and the United Kingdom, have implemented regulations to limit light pollution in response to these concerns [24].

Additionally, exposure to nighttime blue light, especially among shift workers, can cause severe sleep disturbances and negatively impact cardiovascular health, glucose metabolism, and blood pressure regulation [33]. Treatments, such as controlled light therapy, melatonin regulation, and improved sleep quality, may help mitigate these adverse effects.

It has been indicated that blue-light–filtering and ultraviolet-blocking IOLs were compared for their effects on non-visual, melanopsin-mediated functions. The study noted improvements in alertness and sleep after cataract surgery, with no significant difference between the two lens types, suggesting that the main benefit comes from restored light exposure rather than lens filtering [34].

Balance is essential in managing light exposure. While blue light is a crucial stimulator and regulator of health, improper and ill-timed exposure during sensitive night hours leads to a wide range of sleep, psychological, and visual problems. Therefore, targeted use of blue-light-blocking filters combined with awareness of exposure timing and intensity is a key strategy for maintaining public health. This narrative review examines current perspectives on blue-light-blocking filtering lenses, clarifying their benefits and limitations and providing new insights into their role [35].

## Materials and Methods

A comprehensive search was performed across multiple databases, including PubMed, Scopus, Web of Science, Cochrane, Medline, ScienceDirect, and Google Scholar, encompassing studies published between 2008 and 2025 with a focus on the most recent and relevant research based on selected keywords, such as "blue light blocking," "blue light filtering," "partially blue light filtering," "circadian clock," and "color perception." In this narrative review, all studies related to the primary topic were included, with the inclusion criteria requiring that articles be published in English and address the subject under investigation. Various types of publications, including original research articles, systematic reviews, and narrative reviews relevant to the topic, were considered without restrictions on study design, target population, or study location, provided they offered information pertinent to the research question. To ensure the quality and relevance of selected studies, exclusion criteria were established whereby articles unrelated to the research topic, published in languages other than English, lacking sufficient and relevant information, of low methodological quality, or without full-text availability were omitted, and duplicate articles or preprints were removed if a full published version existed to prevent data duplication. Given that the blue spectrum of visible light can influence human performance and the visual system due to its higher energy, blue-light-blocking filters are commonly employed to mitigate these effects; therefore, keywords related to these filters were used in the search. Since these filters affect the visual system and eye function, all relevant aspects were explored, including their impact on sleep and anxiety associated with insomnia, effects on migraine, photophobia, mania, CVS, accommodative disorders, and their influence on contrast sensitivity, color perception, and motion detection, along with their potential role in preventing retinal damage. Blue-blocking filters and partial blue light-blocking filters are discussed in detail in separate subtitles later in the review.

### Full vs partial blue blocking (light-emitting diode [LEDs] and screens)

In recent years, with the widespread use of digital devices, such as smartphones, computers, and smart televisions, concerns regarding the potential effects of blue light on visual health and the human circadian rhythm have increased considerably [36, 37]. Blue light is a portion of the visible spectrum with wavelengths ranging from approximately 400 to 500 nm and contributes significantly to brightness, image sharpness, and color perception. However, the high-energy segment of this range, particularly between 415 and 455 nm, can, under prolonged exposure, stimulate the retina, induce visual fatigue, suppress melatonin secretion, and ultimately disrupt normal sleep cycles [38].

Modern displays are based on LED, liquid crystal display (LCD), or organic LED (OLED) technologies, each of which emits light in different ways. In LED and LCD displays, white light is typically generated by combining blue LED emission with a yellow phosphor layer, whereas in OLED displays, independent blue, green, and red diodes produce light directly. In both technologies, the blue component constitutes a substantial portion of the emitted spectrum, making blue-light management essential for maintaining visual comfort and ocular health. To address this, two main types of optical filters have been developed: blue-blocking filters, which block nearly all blue wavelengths, and blue-control filters, which selectively attenuate only part of the blue spectrum [39].

Blue-blocking filters work by absorbing or reflecting almost all wavelengths below approximately 480 nm, effectively minimizing blue-light transmission. While this can reduce the potential for photochemical stress on the retina, it also disrupts white balance and shifts color perception toward warmer tones, such as yellow or orange. Consequently, these filters tend to reduce color accuracy and overall visual fidelity and are recommended for nighttime use or low-light conditions where precise color rendering is less critical [40].

In contrast, blue-control filters are spectrally engineered to selectively reduce high-energy blue light in the 415–455 nm range while allowing transmission of wavelengths between 470 and 490 nm. This approach preserves white balance and color accuracy while limiting potentially harmful blue-light exposure. As a result, blue-control filters provide a balanced compromise between visual protection and image quality, making them more suitable for everyday use in monitors, laptops, smartphones, and optical lenses designed for digital environments [41].

Recent scientific research has indicated that the actual impact of blue-light filters on sleep quality and ocular health remains inconclusive. A study conducted among healthy pregnant participants found no statistically significant difference in sleep outcomes between those using fully blue-blocking glasses and those using partially blue-blocking blue-control lenses. However, the authors suggested that future research focusing on individuals with sleep disturbances or circadian rhythm disorders may yield different results, indicating potential subgroup-specific effects [42].

Another comprehensive study on digital eye strain, defined as the development or exacerbation of visual and ocular symptoms specifically related to digital screen use, reported a high prevalence among digital device users. Despite this high prevalence, current evidence shows no substantial benefit of blue-light-blocking interventions in alleviating symptoms of digital eye strain. The main mechanisms contributing to this condition include reduced blink rate and completeness, uncorrected refractive errors, binocular vision anomalies, and increased cognitive demand during near-focus digital tasks. Furthermore, differences in luminance glare and display positioning compared with non-digital visual tasks can exacerbate these symptoms [43].

Based on the best available evidence, effective management of digital eye strain involves comprehensive optical correction for appropriate working distances, conscious blinking, ergonomic adjustments to screen brightness and position, regular visual breaks, and maintenance of adequate ocular-surface lubrication. The use of artificial tears, warm compresses, humidified environments, and nutritional supplementation, particularly with omega-3 fatty acids and antioxidant compounds, has been shown to provide more consistent relief than blue-light-blocking filters [44].

In summary, although both blue-blocking and blue-control filters can reduce the intensity of high-energy visible light, current scientific evidence does not conclusively support their effectiveness in improving sleep quality or significantly reducing digital eye strain. The overall efficacy of these filters depends on multiple factors, including an individual's visual health, ambient lighting conditions, duration of screen exposure, and sensitivity to blue light. Therefore, blue-light filters should be regarded as part of a comprehensive visual health strategy rather than a standalone solution. Proper visual ergonomics, appropriate lighting, scheduled breaks, and maintenance of ocular surface hydration remain the most effective and evidence-based approaches for minimizing the adverse effects associated with prolonged digital screen use.

## Sleep and anxiety in insomnia

Circadian rhythms play a fundamental role in regulating human physiological and psychological processes, and disruption of these rhythms can lead to problems such as insomnia, anxiety, depression, cognitive decline, and metabolic disorders [45]. Among the environmental factors affecting these rhythms, blue light with a wavelength of approximately 446_477 nm has the greatest impact because it directly inhibits melatonin secretion from the pineal gland, thereby regulating the sleep-wake cycle. Exposure to blue light at night, especially from artificial sources such as LED screens, smartphones, and computers, reduces melatonin secretion, resulting in insomnia, anxiety, and mood changes. In recent years, the use of blue-light-blocking lenses and glasses has gained attention as a safe, non-pharmacological intervention to improve sleep quality and reduce anxiety. These lenses filter out short-wavelength light, preventing stimulation of melanopsin-sensitive retinal cells, thereby increasing melatonin secretion and improving circadian rhythms [46].

Clinical studies have shown that wearing amber-tinted glasses in the evening and at night, particularly in individuals with insomnia and delayed sleep phase disorder, improves sleep quality, accelerates sleep onset, and enhances mood [47]. Emerging evidence indicates that the benefits of these lenses extend beyond sleep, also affecting cognitive and psychological functioning. In a randomized controlled clinical trial, the use of amber glasses in individuals with insomnia symptoms led to significant improvements in working memory and cognitive processing speed, elevating their neuropsychological performance from below-average to normal levels. These findings suggest that reducing nighttime blue light exposure not only enhances sleep quality but also helps restore cognitive functions impaired by insomnia. Furthermore, multiple studies have examined the efficacy of blue-light-blocking glasses in mood disorders. Trials involving patients with bipolar disorder, major depressive disorder, and postpartum depression have reported symptom reductions, including decreased mania and partial mood improvement associated with the use of these glasses. The likely mechanism behind these effects resembles dark therapy, where reduced nighttime light exposure stabilizes circadian rhythms and modulates mood. Despite positive findings, some studies have reported inconsistent results, and the extent of these lenses' effects on melatonin secretion, sleep quality, and cognitive performance varies among individuals. Additionally, long-term use of lenses with strong spectral filtering may negatively impact color perception, contrast sensitivity, and vision in low-light conditions. The actual efficacy of these lenses depends heavily on filter strength, duration of use, ambient lighting conditions, and individual characteristics [48].

Current scientific evidence suggests that blue-light-blocking glasses and lenses can serve as a simple, low-cost, non-pharmacological intervention to improve sleep, reduce anxiety, enhance cognitive performance, and regulate mood in individuals with sleep disorders such as insomnia and delayed sleep phase disorder. However, to determine their effectiveness, underlying physiological and psychological mechanisms, and potential long-term effects, further well-designed large-scale controlled studies are essential [49].

## Migraine, photophobia, and mania

Another important application of blue-light-blocking filters is in treating conditions, such as migraine, photophobia, and bipolar mania. By reducing stimulation of intrinsically photosensitive retinal ganglion cells sensitive to blue light, these filters help decrease the frequency and severity of migraine attacks, ease photophobia symptoms, and improve mania symptoms. Migraines are a common neurological disorder characterized by increased light sensitivity during attacks, which significantly affects quality of life and social functioning. A study involving 10 patients with migraine showed that wearing blue-light-blocking glasses called blue cut for night (BCN) for four weeks at night reduced headache days without causing significant side effects. These glasses reduce retinal cell stimulation and have been shown to be effective in reducing migraine episodes [50].

Blue light also damages corneal surface cells. An in vitro study found that blue light causes phototoxicity in primary human corneal epithelial cells; however, blue-light-blocking shields protect these cells from harm. This protection is especially important for high-risk groups such as people with dry eye, contact lens users, and the elderly.

In bipolar disorder and mania, blue-light-blocking glasses have shown promise as a simple, affordable, and safe supplementary treatment in clinical trials. They reduce blue light exposure during evening and nighttime hours, helping regulate the body's circadian rhythm and reduce manic symptoms. Clinical results indicate significant improvements in mood and motor activity, including in older adults, as well as better sleep quality. The use of these glasses is linked to longer total sleep time, fewer nighttime awakenings, and improved sleep efficiency [51].

Blue-light-blocking filters have wide applications in protecting the eyes and reducing symptoms in light-sensitive conditions, such as migraine, photophobia, and mood disorders. They offer a useful complementary therapy in these areas [52].

### CVS and accommodative discomfort

Numerous studies have examined the effects of blue-control filters on visual performance, eye fatigue, and accommodative function. The results suggest that using blue-light filters can improve certain aspects of visual comfort and reduce fatigue under specific conditions. For example, one study found that working with laptops equipped with blue-light filters enhanced reading speed and data entry accuracy, although it had no significant effect on accommodative response or pupil size. Conversely, other studies have indicated that in healthy adults, blue-light control filters do not produce notable changes in visual symptoms associated with digital device use, and their prescription for improving accommodation or reducing visual discomfort is not scientifically justified [53].

Recent investigations have explored lenses with a slight additional positive power combined with blue-violet light filters. These studies found that lenses with a +0.40 diopter addition produced no negative effects on convergence or accommodative ability and showed a similar reduction in digital asthenopia (DA) symptoms compared to standard single-vision lenses. This suggests that the main relief in visual discomfort may result from reduced accommodative demand rather than simply blocking blue light.

In certain cases, blue-control filters also provide benefits beyond reducing eye strain. A clinical trial in migraine patients showed that wearing BCN glasses, which reduce stimulation of intrinsically photosensitive retinal ganglion cells, led to fewer headache days over four weeks without adverse effects. These findings indicate that optical filters can help alleviate light sensitivity and potentially reduce migraine frequency.

Spectroscopic research has also shown that the actual intensity of blue light emitted from digital displays is far below the threshold considered hazardous to ocular tissues. In a laboratory analysis of an iPhone 12 Mini, an iPad Pro, and a MacBook Pro, the peak emission wavelengths were found between 445 and 455 nm, posing no photobiological threat to the retina. Moreover, the amount of blue light received by the human eye in one minute of outdoor sunlight exposure exceeds that from approximately 24 hours of digital screen use. Despite these reassuring results, researchers emphasize the need for further studies to clarify the real-world efficacy of blue-blocking lenses and coatings.

Clinical evidence also indicates that prolonged smartphone use may exacerbate CVS and dry eye disease more than computer use. The duration of exposure, inappropriate lighting, and lack of regular visual breaks are major contributors to these symptoms. Therefore, eye care professionals recommend not only the prudent use of blue-light filters but also adherence to ergonomic principles, including regular breaks, optimal screen brightness, and proper viewing distance [53].

Overall, current scientific evidence suggests that blue-control filters can modestly reduce visual fatigue, improve comfort in certain conditions, and help manage light sensitivity in disorders, such as migraine. However, their definitive impact on accommodative performance and the prevention of visual discomfort has not been fully established. Furthermore, the actual intensity of blue light from digital devices appears too low to cause physiological damage to ocular structures. Thus, blue-light control filters should be viewed as part of a broader strategy for maintaining visual health rather than as a substitute for good visual habits and ergonomics. Appropriate lighting, regular rest periods, limited continuous screen time, and the use of natural ambient light are the most effective ways to protect accommodative function and prevent digital eye strain [54].

### Contrast, color, and motion perception

Research indicates that blue-light-blocking lenses influence contrast sensitivity under specific conditions. In particular, reductions in contrast sensitivity are more pronounced under low-light (scotopic) conditions or in the presence of glare. Red and gray lenses produce minor reductions in contrast sensitivity, whereas yellow or orange lenses enhance contrast sensitivity under these conditions. These findings suggest that the effects of blue-light-blocking lenses on visual performance depend on ambient lighting conditions and lens color. Despite slight reductions in contrast sensitivity under certain conditions, these lenses can protect the eyes from photochemical damage caused by blue light, and their subjective benefits in certain patients, such as those with ARMD, may partly be due to modest improvements in contrast sensitivity.

Regarding color vision, evidence shows that blue-light-blocking lenses generally do not impair an individual's ability to detect colors or perform color vision tests. However, reducing blue light transmission can cause subtle differences in color perception, particularly in detecting blue hues. Long-term studies have indicated that continuous use of blue-light-blocking filters may slightly reduce color contrast sensitivity in low-light conditions, although these effects are not clinically significant for most individuals with normal vision. Blue-tinted lenses may produce minor negative effects on CD but do not meaningfully affect contrast sensitivity in young adults. Evaluating the balance between protective effects and visual performance impact of these lenses is crucial [55, 56].

In terms of motion perception, studies have shown that blue-light-blocking lenses can reduce the perceived speed of moving stimuli. Experiments using both colored and achromatic stimuli found that perceived speed decreased by 6-20% when viewed through blue-light-blocking lenses, with the greatest reduction observed with the most blue-light-blocking lenses. These findings indicate that while blue-light-blocking lenses can reduce exposure to potentially harmful blue light, they can also have unintended effects on critical visual behaviors, such as motion perception, which should be considered for long-term use and for activities requiring precise visual motion judgment [57].

### Retina and ARMD protection

Blue-violet light with wavelengths between 400 and 500 nm is potentially phototoxic to the retina, and prolonged exposure can lead to structural and functional damage. Animal studies have shown that blue light induces apoptosis and necrosis in the retinal pigment epithelium, damages photoreceptors, and affects retinal ganglion cells. In addition, exposure to blue light reduces the dendritic branching of layer 5 pyramidal neurons in the visual cortex. These findings suggest that blue light can have long-term effects on visual function and disrupt neuronal remodeling in the visual cortex. In these studies, the use of blue-light-blocking lenses partially reduced retinal cell damage and neuronal changes, providing some protection against blue light exposure [58].

In humans, exposure to blue light is particularly relevant after cataract surgery because the natural lens absorbs a significant portion of short-wavelength light with age, providing retinal protection [14]. After replacement with a clear intraocular lens, transmission of short-wavelength light to the retina increases, thereby raising the risk of retinal damage and accelerating the progression of ARMD [59].

Blue-light-filtering IOLs are designed to reduce transmission of short-wavelength light, aiming to protect the retina and potentially slow or prevent the development of ARMD [60]. Laboratory and animal studies have shown that these lenses can prevent phototoxic damage to the retinal pigment epithelium and retinal neurons [61]. However, epidemiological and clinical studies in humans have produced mixed results, and no study has definitively demonstrated that blue-light-filtering lenses prevent or slow the progression of ARMD. Most independent studies indicate that these lenses do not significantly impair color vision, contrast sensitivity, or overall visual function, though some report minor changes in scotopic vision or circadian rhythm, which are generally of limited clinical significance [62].

Based on current evidence, blue-violet light may pose a potential risk to the retina, and blue-light-filtering lenses may offer partial protection. However, their precise role in preventing ARMD is unclear. Laboratory and animal studies have indicated real risks and elucidated mechanisms of damage. However, human studies, including epidemiological data and clinical trials, have yet to confirm a definitive link between the use of blue-light-filtering lenses and reduced progression of ARMD. Therefore, their use should be considered with an awareness of current evidence limitations and tailored to the individual clinical context. Future research should include large-scale clinical trials to assess the true protective effects of these lenses [22].

Table 1 presents a collection of key and influential articles related to this topic. The Table provides the titles and essential bibliographic details of each study, along with a concise description of their main research focus and objectives. This structure enables readers to review, compare, and analyze previous studies more efficiently, thereby facilitating a clearer understanding of existing research pathways, scientific trends, and gaps in the literature.

## Discussion

Blue light, a part of the visible spectrum with wavelengths between 400 and 500 nm, has attracted a lot of attention in recent years due to its high energy content and is naturally emitted from sunlight, as well as from digital displays, LED lighting devices, and mobile phones. Although this light plays an important role in regulating the body's circadian rhythm and maintaining alertness, prolonged or untimely exposure to it, especially in the late hours of the day and night, can have significant consequences for general health and vision. Due to its higher energy, the effects of blue light go beyond sleep disorders and include problems, such as eye fatigue, visual impairment, migraines, and even retinal damage [1, 2, 5, 7].

**Table 1.** Summary of previously published studies

| Title, Author(s), Year | Study Objective | Intervention (Sample Size, Outcome Measure, Study Duration) | Conclusion |
|---|---|---|---|
| Effects of a blue-blocking screen filter on accommodative accuracy and visual discomfort<br><br>Redondo et al. 2020 [52] | Determined the effects of using BB filters on the dynamics of the accommodative response and pupil size and perceived levels of visual discomfort, while performing a 30-min reading task at a close distance in subjects who routinely use electronic devices. | n=19 (22.0_2.7 years) read two 30-min passages on a computer screen placed at 50 cm, either while using a commercially available B-B filter or without any filter on two different days. The magnitude and variability of both the accommodative response and pupil size were dynamically measured for 60 s using the WAM-5500 open-field autorefractometer at 4–5, 9–10, 14–15, 19–20, 24–25, and 29–30 min into the trial. Perceived levels of visual discomfort were also obtained. | Our data showed that the use of a B-B filter had no effect on accommodative dynamics or visual symptomatology. Based on these findings, there is no support for the prescription of B-B filters to attenuate the visual symptoms and signs associated with the use of electronic devices in healthy young adults. |
| Digital asthenopia: blue-blocking lenses and + 0,40D additional power in the near zone, for eye strain, accommodation and convergence functions<br><br>Alionis et al. 2022 [26] | Evaluate blue-violet light filter and additional power of +0.40 D in the near zone ophthalmic lenses, on convergence, accommodative functions, and symptoms of DA. | n=49<br>Randomized study in cross-over design conducted on 49 volunteers (age, 29±5.5 years; male: female, 18:31). Each subject wore test (+0.40 D in the near zone) and control lenses (regular single vision) for 4 weeks in randomized order. Both lenses had a selective blue-violet light filter. A baseline measurement was taken with the subjects' current updated glasses. Accommodation amplitude (AA) and near point of convergence (NPC) were measured binocularly with the RAF ruler. DA was evaluated by a questionnaire. | The +0.40 D lenses have no negative impact on convergence or loss of accommodation power. The +0.40 D and control standard monofocal (SV) lenses had a similar impact on attenuating symptoms of DA. |
| Effects of blue-light blocking (BB) spectacle lens on computer-induced asthenopia<br><br>Alionis et al. 2020 [25] | Compared to standard spectacle lenses (non-blue-blocking), do blue-blocking lenses reduce symptoms of asthenopia induced by computers? | n=40<br>A prospective clinical study was conducted with 49 volunteers who spent more than 4 hours a day using a computer (age, 29.07±5.5; male: female=18:31). DA was assessed using a questionnaire. All participants completed the questionnaire with standard spectacles, non-blue-blocking (baseline), and after 4 weeks with a blue-blocking lens (Crizal® PrevenciaTM). The normality of data was assessed using the Shapiro-Wilk test. Changes in measured values were compared using the non-parametric Wilcoxon test and P<0.05 were considered statistically significant. | DA baselineinduced by the computer was significantly reduced by BB spectacle lenses and blue-blocking wearing. |
| Do blue-blocking lenses reduce eye strain from extended screen time?<br>A double-masked Randomized controlled trial<br><br>Singh et al. 2021 [63] | To investigate if blue-blocking lenses are effective in reducing the ocular signs and symptoms of eye strain associated with computer use. | n=120<br>A total of 120 symptomatic computer users were randomly assigned (1:1) into a "positive" or "negative" advocacy arm (i.e. a clinician either advocating or not advocating for the intervention via a prerecorded video). Participants were further sub-randomized (1:1) to receive either clear (placebo) or blue-blocking spectacles. All participants were led to believe they had received an active intervention. Participants performed a 2-hour computer task while wearing their assigned spectacle intervention. | Blue-blocking lenses did not alter signs or symptoms of eye strain with computer use relative to standard clear lenses. Clinician advocacy type had no bearing on clinical outcomes. |
| Blue-blocking filters do not alleviate signs and symptoms of digital eye strain<br><br>Vera et al. 2023 [64] | This study assessed the short-term effects of a commercially available B-B filter on orbicularis oculi (OO) muscle activity and symptoms of digital eye strain during the execution of a 30-min reading task. | n=23<br>Twenty-three healthy young adults (22.9±3.2 years of age) performed two reading tasks from a computer screen with or without a B-B filter on two different days. OO muscle activity was recorded by surface electromyography at 4–5, 9–10, 14–15, 19–20, 24–25, and 29–30 min into the trial. Participants reported their perceived levels of visual discomfort and activation before and after completing the reading task. | The B-B filter did not alter OO muscle activity or visual symptomatology significantly during the execution of a 30-min reading task in asymptomatic subjects. These findings support the idea that B-B filters do not attenuate signs and symptoms of digital eye strain. |

| Title, Author(s), Year | Study Objective | Intervention (Sample Size, Outcome Measure, Study Duration) | Conclusion |
|---|---|---|---|
| Effect of blue cut glasses on CD and contrast sensitivity in young emmetropes<br><br>Rehman et al. 2024 [29] | To evaluate the effects of blue-cut glasses on visual functions, specifically CD and contrast sensitivity (CS), in young emmetropes. | n=80<br>A total of 80 emmetropes aged 18–30 years with 6/6 vision were included, while individuals with ocular or systemic conditions affecting vision were excluded. Visual functions were assessed using the Ishihara test for color blindness, the Pelli-Robson chart for contrast sensitivity, and the FM 100 Hue test for CD. Participants were tested with and without blue-cut glasses in randomized sessions to avoid fatigue or memorization effects | Blue-cut glasses negatively impact CD while showing no significant effect on contrast sensitivity in young emmetropes. These findings highlight the importance of evaluating the trade-offs between the protective and visual effects of blue-cut glasses. |
| Effect of blue-blocking lenses on color contrast sensitivity<br><br>Alzahran et al. 2021 [65] | The study investigated the effect of a number of commercially available blue-blocking lenses on colour contrast sensitivity in normal individuals under low and high contrast stimulus conditions. | n=5<br>Five healthy participants (one man and four women), aged between 23 and 39 years, were recruited for this study. Crizal Prevencia (Essilor), Blue Guardian (Opticare), and Blu-OLP (GenOp) lenses were examined in this study in comparison to a control lens (clear lens without blue-filtering coating). | Our results suggest that while reducing blue light potentially minimises the harmful effect of blue hazard light, blue-blocking lenses can unintentionally reduce colour contrast sensitivity, particularly at low light levels. |
| Modelling the effect of commercially available blue-blocking lenses on visual and non-visual functions<br><br>Alzahrani et al. 2019 [66] | This study measured the spectral transmittance of Brazilian butt lifts (BBLs) and evaluated their effect on blue perception, scotopic vision, circadian rhythm, and protection from photochemical retinal damage. | n=17<br>Seven different types of BBLs from six manufacturers and untinted control lenses with three different powers (+2.00 D, −2.00 D, and Plano) were evaluated. The whiteness index of BBLs used in this study was calculated using Commission Internationale de l'Eclairage (CIE) Standard Illuminants D65, and CIE 1964 Standard with a 2_ Observer. | BBLs can provide some protection to the human eye from photochemical retinal damage by reducing a portion of blue light that may affect visual and non-visual performances, such as those critical to scotopic vision, blue perception, and circadian rhythm. |
| The long-term effect of blue-light blocking spectacle lenses on adults' contrast perception<br>Lian et al. 2022 [56] | To evaluate the long-term effect of two different degrees of BB spectacle lenses on adults' contrast perception under various lighting conditions. | n=144<br>In total, 144 healthy adults aged 24.7±4.32 years were recruited to this randomized controlled trial. The participants were randomly divided into three groups and used three different spectacle lenses (15% BB: 15% blue-blocking spectacle lenses; 30% BB: 30% blue-blocking spectacle lenses; RC: regular clear lenses serving as control). Contrast sensitivity under four light conditions (scotopic and photopic, both with/without glare) was measured using standard clinical tests at baseline, 1 month, 3 months, and 6 months of use. | Wearing BB lenses had no clinically significant effect on adults' long-term contrast perception under scotopic or photopic conditions, or with glare. |
| Prophylactic treatment for patients with migraine using blue cut glass<br><br>Tatsumoto et al. 2023 [10] | We developed BCN glass, which reduces light stimulation to ipRGCs, photoreceptors that can lead to exacerbation of migraine attacks. | n=10<br>Ten patients with migraine participated in the study. Each participant was made to wear BCN glasses only at night for four weeks. The number of headache days and headache impact test-6 values before and after using the BCN glasses were compared. | BCN glass, which reduces light stimulation to ipRGCs, was suggested to be a tool for reducing grain attacks. |

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According to the studies reviewed, the use of blue-light-blocking filters has become popular as a preventive measure to reduce the potentially harmful effects of blue light. These filters are designed as optical coatings on eyeglass lenses, protective layers for displays, or optical technologies in IOLs, and their main purpose is to reduce the transmission of short, high-energy blue light to prevent excessive stimulation of the retina and visual fatigue. Filters that completely block blue light, known as blue-blocking lenses or blue cut blocks, usually significantly reduce the transmission of wavelengths below approximately 450 nm. These filters can minimize the intensity of radiation in the high-energy range of blue light and prevent photochemical stress in retinal cells [8]. However, their use may lead to changes in color perception and reduced color accuracy, since the absorption of these wavelengths shifts the image towards yellow and orange. Therefore, these types of filters are usually recommended in specific situations, such as highlight work environments or when using electronic devices at night.

In contrast, partial blue blockers, marketed under the brand name BlueControl lenses, have a more balanced design. These lenses reduce the more energetic part of blue light in the range of approximately 420 to 455 nm, while allowing the passage of longer wavelengths, 460 to 480 nm, to preserve physiological functions related to blue light, such as circadian rhythm regulation and daily alertness response. Due to this feature, BlueControl lenses can balance eye protection with color accuracy and have found widespread use in everyday eyewear, especially among long-term users of digital devices [30].

BlockControl coatings reduce surface reflection by creating a selective absorption spectrum and filtering out only a portion of the blue light. In addition to reducing eye fatigue and increasing visual comfort, this design does not cause a noticeable change in the image's color or brightness [61]. Along with these lenses, screen protectors are also produced with similar technology. These protectors, which are placed directly on the surface of the monitor, tablet, or mobile phone, reduce direct radiation to the eyes by absorbing or reflecting part of the blue light in the range of 420-460 nm. However, the amount of blue light absorption in them is usually lower than that of precision optical lenses, and they filter out approximately 10-20% of the blue light. In terms of vision quality and color perception, research has shown that full filters typically shift colors towards warmer tones and decrease color accuracy, while partial filters have little effect on color perception and are more suitable for everyday use [40-42]. In terms of its impact on sleep and circadian rhythm, both types of filters can improve sleep quality by reducing melatonin secretion inhibition, but the full filter has been reported to have a stronger effect in this regard. However, continuous use during the day may cause drowsiness or reduced concentration; therefore, it is more logical to use the full filter at night and the partial type during the day [57, 10].

In terms of retinal protection and prevention of ARMD, animal studies have shown that both types of filters reduce oxidative damage to retinal cells to some extent, but human evidence has not shown a significant difference between them. Full-blocking filters provide more protection, but this protection is associated with a slight decrease in contrast sensitivity and color accuracy, while the partial type provides a better balance between retinal health and visual quality. In terms of visual quality and color perception, research has shown that full filters typically shift colors towards warmer tones and decrease color accuracy, while partial filters have little effect on color perception and are more suitable for everyday use. In terms of sleep and circadian rhythm, both types of filters can improve sleep quality by reducing melatonin secretion inhibition; however, full filters have been reported to have a stronger effect in this regard. However, continuous use during the day may cause drowsiness or reduced concentration; therefore, it is more sensible to use a full filter at night and a partial filter during the day [52].

Studies have shown that blue light can increase sympathetic nervous system activity and increase alertness and irritability, a mechanism that is directly linked to increased feelings of anxiety [9]. Exposure to blue light at night, especially before bed, can stimulate the brain and increase cortisol levels, a hormone that plays an important role in stress and anxiety responses. In this context, the use of blue-light-blocking filters, whether full or partial, has been shown to reduce stimulating effects and increase relaxation [15].

Various studies, including those conducted between 2017 and 2021, have reported that people who used blue light filters, especially at night, experienced a significant reduction in the intensity of daytime and nighttime anxiety. Full filters, which block wavelengths between 400 and 505 nm, have the greatest effect in reducing brain arousal and relieving anxiety levels, while partial filters, which target the range of 420-480 nm, have a more modest effect, but still significantly reduce nervous arousal and improve feelings of calm.

From a neuro-ophthalmological perspective, intrinsically photosensitive retinal ganglion cells (ipRGCs) play a pivotal role in transmitting light signals to the suprachiasmatic nucleus (SCN) of the hypothalamus, which regulates circadian rhythms and melatonin secretion [67]. Excessive stimulation of this pathway by blue light in the evening or night hours can disrupt the physiological balance of sleep and wakefulness and, through increased cortical arousal, can lead to the onset or exacerbation of disorders such as anxiety, migraine, and mania. In patients with migraine, increased sensitivity to light (photophobia) is a hallmark symptom. Findings from a study using BCN glasses showed that reducing ipRGC stimulation at night significantly reduced headache days and the severity of symptoms. These results support the idea that reducing blue light input may help control migraine attacks, possibly by reducing stimulation of the retina-thalamus-visual cortex pathway and modulating neuronal activity in pain-sensitive areas [10].

In the context of mania, several studies, including the randomized controlled trial by Henriksen et al., have shown that wearing blue-blocking glasses in the evening can significantly reduce the severity of manic symptoms [15]. The mechanism of this effect is likely related to reduced ipRGC stimulation, increased melatonin secretion, and improved sleep quality. In a study in which manic patients wore these glasses from 6 PM to 8 AM, sleep efficiency increased, and the need for medication was reduced. Polysomnography results also showed that the use of blue blockers increased rapid eye movement sleep time, reduced frequent awakenings, and improved overall sleep efficiency. These findings, along with the hypothesis of a connection between brain noradrenergic pathways and light stimulation, suggest that inhibiting blue light input can be effective in reducing central nervous system hyperarousal and stabilizing mood.

In contrast, in patients with photophobia, exposure to blue light may directly trigger pain and visual discomfort. Given that ipRGCs are connected to the SCN and limbic regions of the brain, including the amygdala and hippocampus, their overstimulation can exacerbate emotional and stress responses. Therefore, reducing this stimulation with blue-blocking filters or protective shades can reduce sensitivity to light and modulate neural responses related to pain. Blue-light-blocking filters, whether in the form of spectacle lenses or screen protectors, are a novel approach to optimizing ambient light and protecting visual health. The choice of filter type and its absorption rate should be adjusted based on individual conditions, type of activity, duration of screen use, and individual sensitivity to light to maintain a balance between visual efficiency, retinal health, and circadian rhythm regulation.

In recent years, the increasing use of digital devices such as smartphones, tablets, and computers has led to a significant increase in the prevalence of CVS and DA. These symptoms include eye fatigue, temporary blurred vision, burning, frontal pain, and impaired accommodation, which are mainly caused by prolonged close-range activity and continuous exposure to blue light emitted by screens. Spectral studies have shown that digital screens have the highest intensity of blue radiation in the range of 445-455 nm. Although this energy level does not pose a direct phototoxic risk to the retina, chronic exposure to close-range and poor lighting conditions can cause persistent stimulation of accommodative pathways and changes in eye motor responses.

In response to this challenge, blue-violet light-filtering lenses and lenses with mild positive power (approximately +0.40 diopters) have been proposed as a strategy to reduce accommodative load and visual symptoms [26]. Recent studies have shown that adding +0.40 diopters to near lenses has no negative effect on convergence or range of accommodation and can reduce eye fatigue to some extent by reducing accommodative effort during near activities. Interestingly, a comparison of +0.40 D lenses and standard monofocal (SV) lenses has shown that both types of lenses have a similar effect on reducing symptoms of DA, which is likely due to improved ergonomics and reduced physiological eye fatigue. In addition to these findings, studies on blue-light-blocking filters have reported mixed results. Some studies have suggested that these filters do not alter accommodative response, pupil size, or baseline visual function, but they can improve reading speed and subjective visual comfort by reducing glare and improving contrast. However, in healthy individuals, using these filters alone does not appear to significantly reduce CVS symptoms. Current evidence suggests that managing symptoms of digital work requires a multifaceted approach. Attention to near-vision ergonomics (including appropriate distance, ambient lighting, and regular breaks based on the 20-20-20 rule), combined with the targeted use of low-power lenses and blue-violet light-blocking filters, may be an effective combination to reduce accommodative load and improve visual comfort in digital users. However, further longitudinal, controlled clinical studies are required to confirm the effectiveness of these interventions.

The results of this series of studies on the effects of blue-light-blocking filters and their use have multifaceted effects on visual and neurological functions. Blue light with a wavelength of 380-445 nm can cause photochemical damage to the retina and negatively affect contrast sensitivity, color vision, and motor function in low light conditions. In patients with multiple sclerosis (MS), the reduction in contrast sensitivity of peripheral vision is also reduced, and individuals cannot correctly detect obstacles, highlighting the importance of vision protection in this group [45].

Animal studies have shown that chronic exposure to blue light, in addition to visual effects, can cause structural and functional changes in the hippocampus and memory impairment. Blue light-filtering lenses partially reduced these morphological and functional changes, indicating their protective potential at the central nervous system level. These findings are consistent with previous observations that short-wavelength blue light can affect cognitive processes, such as learning and memory [67].

From the perspective of color vision and contrast sensitivity, data suggest that blue-light-blocking filtering lenses or partially tinted lenses can affect the perception of blue colors and contrast sensitivity in low-light conditions, although their effects on overall color vision and long-term contrast sensitivity are usually not clinically significant [51]. This is of particular importance for professional users in color-sensitive occupations and activities that require color and contrast accuracy, and require a careful assessment of the relationship between protective effects and visual function.

A study of motor performance showed that blue-light-filtering lenses can reduce the perception of motion and speed of moving stimuli. A reduction of 6-20% in perceived speed was observed, especially when the lenses blocked the most blue light [57]. These results indicate potential indirect behavioral effects due to reduced contrast and exposure, and suggest that even relative changes in the blue light spectrum can affect motor visual behaviors. Overall, the findings of these studies emphasize the importance of a balanced approach to the use of blue-light filters: on the one hand, blue-light-filtering lenses can protect against retinal damage and cognitive changes caused by blue light; on the other hand, these lenses can slightly affect contrast sensitivity, blue color recognition, and motion perception. Therefore, selecting a lens that blocks blue light should be based on a comprehensive assessment of the wearer's protective needs and visual performance requirements. Future studies with larger samples and long-term follow-ups are necessary to determine the clinical effects and guide practical recommendations.

Animal studies have shown that prolonged exposure to blue light can cause structural damage to the retina, increase apoptosis of retinal ganglion cells, and reduce the complexity of dendrites of visual cortex neurons. The use of blue-light-blocking lenses reduced these pathological changes to some extent, indicating a potential protective role for these lenses. However, the protection provided is incomplete, and minor damage is still observed, indicating the need to limit or carefully manage exposure to blue light in high-intensity work environments. In the case of blue light-filtering IOLs, preclinical evidence suggests that reducing the transmission of short wavelengths can protect the retina against phototoxicity and prevent the progression of ARMD [68]. However, current clinical evidence is limited and insufficient to prove the benefits of these lenses. In addition, reducing blue light can lead to minor changes in visual quality, color recognition, and contrast sensitivity; therefore, the use of these lenses is recommended. Even short-term exposure to intense blue light can cause eye discomfort, and long-term exposure increases the risk of structural damage to the retina and neuronal changes in the visual cortex. Blue-light-filtering lenses can reduce eye fatigue and provide limited protection against retinal structure and neuronal damage in animal models; however, complete protection is not guaranteed. The limited clinical evidence for blue-light-filtering IOLs and glasses is significant, and further research is needed. Given the potentially harmful effects of blue light, a combination of using filtering lenses, reducing time spent directly exposed to intense light sources, and adjusting ambient lighting can be recommended as a risk management approach in workplaces with intense light. Consequently, although preliminary evidence supports the protective role of blue-light-filtering lenses, clinical decisions should be based on a careful assessment of the benefits and limitations of the evidence and individual needs. Future studies should investigate the long-term dose-response effects of blue light exposure and neurovisual outcomes in real-world clinical settings [69].

## Conclusion

Based on the studies reviewed, blue light–blocking filters can effectively reduce the harmful effects of short-wavelength, high-energy light on visual performance and overall health. Evidence shows that blue light, while essential for circadian rhythm regulation, can cause visual fatigue, sleep disturbances, neural overstimulation, and even retinal stress when exposure is prolonged or occurs at inappropriate times.

Full blue-blocking filters provide the greatest protection against retinal damage and can improve sleep quality; however, they may also reduce color accuracy and visual clarity. In contrast, partial filters, such as Blue-Control lenses, allow the passage of beneficial wavelengths while maintaining a balance between ocular protection and color fidelity, making them more suitable for everyday use. Moreover, these filters may help reduce sympathetic activation and enhance melatonin regulation, thereby alleviating anxiety and improving sleep quality. Nevertheless, current clinical evidence remains limited and somewhat inconsistent, highlighting the need for further longitudinal and controlled studies to clarify their long-term effects. Overall, the intelligent use of blue light–blocking filters, combined with proper visual ergonomics and optimized lighting conditions, represents an effective strategy to preserve visual health and enhance individual performance in the digital era.

## Ethical Considerations

### Compliance with ethical guidelines

All ethical principles are considered in this article. The participants were informed of the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished, and if desired, the research results would be available to them. A written consent has been obtained from the subjects. Principles of the Helsinki Convention was also observed.

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### Authors' contributions

All authors equally contributed to preparing this study.

### Conflict of interest

The authors declared no conflict of interest.

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