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# Blue-light-filtering spectacle lenses in managing vision-related symptoms: an updated review

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***Abstract*:** Blue light, emitted by natural and artificial sources such as digital screens, has raised concerns regarding its impact on ocular health, visual comfort, and circadian rhythms. Prolonged exposure has been linked to digital eye strain (DES), visual fatigue, potential retinal damage, and sleep disturbances. Blue-light-filtering spectacle lenses have been developed to mitigate these effects by reducing short-wavelength blue light transmission, but their efficacy remains debated. Studies indicate that these lenses have minimal or no significant impact on contrast sensitivity, color discrimination, and task performance, with visual outcomes comparable to standard lenses. While some research suggests minor benefits in reducing DES and visual fatigue in specific populations, most studies report no significant differences. This highlights the multifactorial nature of DES. Experimental evidence supports the potential for blue-light-filtering spectacle lenses to reduce oxidative stress and phototoxicity in retinal cells, which may offer protection against retinal damage and age-related macular degeneration (ARMD). Additionally, these lenses show promise in neurological and psychological domains, including reduced migraine frequency, alleviation of mania symptoms, and improved sleep quality through circadian rhythm regulation. However, subjective sleep improvements are often not supported by objective measures. In summary, blue-light-filtering spectacle lenses may provide benefits in retinal protection, sleep regulation, and neurological health. However, their effectiveness in reducing visual fatigue, enhancing task performance, and preventing ARMD remains inconclusive. Further research with standardized methodologies and larger sample sizes is needed to clarify their clinical and everyday utility.

***Keywords:*** blue-light-filtering lenses, circadian rhythm regulation, digital eye strain, retinal protection, vision-related symptoms

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## Introduction

In recent years, the impact of blue light exposure on ocular health and visual comfort has garnered significant attention.[1–9] Blue light, characterized by wavelengths between 400 and 500 nm, is emitted not only by natural sunlight but also by artificial sources such as LED screens, smartphones, and fluorescent lighting.[5] The increasing reliance on digital devices has led to heightened concerns regarding prolonged exposure to blue light, which has been linked to digital eye strain (DES), sleep disturbances, and potential retinal damage.[6,8,10] The human eye is particularly susceptible to blue light due to its high energy and ability to penetrate deep into the retina, raising concerns about its role in the development of conditions such as age-related macular degeneration (ARMD).[1,11,12]

To mitigate these potential risks, blue-blocking (BB) and blue-control lenses spectacle lenses have been introduced into the market. These lenses are designed to selectively filter short-wavelength blue light while maintaining overall visual clarity.[13] The primary aims of these lenses are to reduce DES, improve contrast sensitivity, and protect the retina from potential phototoxic damage.[2,8,14–16] However, the efficacy of blue-light-filtering ophthalmic lenses remains a topic of debate within the scientific community, with studies yielding mixed results regarding their benefits for visual performance, eye health, and overall well-being.[13,17,18]

Given the growing body of literature on this subject, a narrative review is warranted to consolidate current evidence and evaluate the effectiveness of blue-light-filtering lenses. The objective of this review is to assess their impact on visual function and performance, protection against retinal damage, management of DES, neurological and psychological benefits, and implications for sleep and well-being. This review aims to provide a comprehensive understanding of the role of blue-light-filtering lenses and guide future research and clinical practice.

## Methods

### *Search strategy and database selection*

A narrative literature search was conducted across multiple databases, including PubMed, Scopus, Web of Science, and Google Scholar. Keywords such as "blue light filtering lenses," "blue-blocking glasses," "visual discomfort," "digital eye strain," "Computer Vision Syndrome," "color perception," "sleep quality," and "contrast sensitivity" were used. The search strategy included studies published from 1975 to March 2025, focusing on randomized controlled trials (RCTs), observational studies, and narrative reviews.

### *Inclusion and exclusion criteria*

Studies were included if they:

- Investigated the impact of commercially available blue-light-filtering spectacle lenses on visual performance, DES, retinal protection, neurological benefits, or sleep quality.
- Used human participants in clinical or experimental settings.
- Reported objective or subjective measures of visual function and discomfort.
- Utilized lenses designed and marketed specifically for blue light filtration in daily wear (i.e., not for specialized clinical or industrial use).

Studies were excluded if they:

- Focused solely on computational modeling without human trials.
- Were published in non-peer-reviewed sources.
- Used intervention lenses that were not true blue light filters, such as orange or amber lenses, soft red safety glasses, or lenses with relatively flat absorption across the spectrum. For example, studies using filters that block 99% of blue light but function as broad-spectrum orange filters were excluded, as these do not reflect the typical use or appearance of commercially available blue-light-filtering spectacle lenses for daily practice.
- Investigated blue-light-filtering contact lenses, intraocular lenses (IOLs), or interventions targeted at narrowly defined populations rather than general spectacle lens wearers.

In this review, particular emphasis was placed on studies that utilized validated and objective outcome measures [such as contrast sensitivity, color discrimination, and critical flicker fusion frequency (CFF)]. Where applicable, we also highlight the methodological strengths and weaknesses of the included studies, including potential confounding factors such as the influence of pupil size on CFF measurements. Furthermore, we critically discuss studies that primarily report subjective symptoms or non-visual outcomes (such as sleep quality) and address the limitations inherent in such approaches.

It should be noted that the scope of this review is limited to commercially available blue-light-filtering spectacle lenses. Studies involving blue-light-filtering contact lenses or IOLs were excluded to maintain consistency and ensure that the findings are directly applicable to spectacle lens users in everyday settings.

## Results

### *Visual function and performance*

*Impact on visual and task efficiency.* The impact of blue-light-filtering ophthalmic lenses on visual and task efficiency has been extensively explored in recent years due to the increasing prevalence of digital device usage, which often leads to visual discomfort and reduced task performance.[19] This subsection reviews the evidence from various studies to assess the effects of these lenses on visual performance and task efficiency, including visual fatigue, contrast sensitivity, reading speed, and data entry accuracy.

*Visual fatigue and critical flicker fusion frequency.* Several studies have investigated whether blue-light-filtering lenses alleviate visual fatigue during prolonged visual tasks. Singh et al., in a double-masked RCT, examined the effect of blue-light-filtering lenses on eye strain and task performance during a two-hour computer task. The study used CFF as an objective measure of eye strain. No significant differences were found between blue-light-filtering lenses and clear lenses in reducing visual fatigue. Furthermore, the study revealed no impact of clinician advocacy on the participants' perceived benefits of the lenses, indicating that the lenses themselves did not enhance task performance or reduce eye strain.[19] Similarly, Lawrenson et al., in a systematic review evaluated the effect of blue-light-blocking lenses on CFF and symptoms of visual fatigue. Their study found no significant differences in visual fatigue between individuals wearing low- or high-blue-light-blocking lenses and those wearing clear lenses. Although minor improvements in CFF were observed in the high-blue-light-blocking lens group during computer tasks, these changes were not clinically significant.[17] These findings suggest that the theoretical benefits of blue-light-filtering lenses in reducing visual fatigue may not translate into measurable effects during real-world tasks.

*Contrast sensitivity and color discrimination.* Contrast sensitivity and color discrimination are essential aspects of visual performance, particularly in environments with varying lighting conditions or when performing visually demanding tasks. A range of studies has evaluated the effects of blue-light-filtering lenses on these parameters, and the findings consistently suggest minimal or no adverse impact on visual performance.

Leung et al., conducted a pseudo-randomized controlled trial to evaluate the effects of blue-light-filtering lenses on contrast sensitivity under both glare and non-glare conditions, as well as on color discrimination.[20] Their study demonstrated no significant differences in contrast sensitivity or color discrimination between participants wearing blue-light-filtering lenses and those wearing clear lenses. This finding was consistent across young and middle-aged adults, indicating that blue-light-filtering lenses do not impair visual performance, even under challenging lighting conditions.[20] Also, a recent double-blinded, RCT with 64 participants found that blue-light-blocking glasses significantly reduced DES (computer vision syndrome (CVS) questionnaire scores decreased by 5.6 and 8.3 points at 2 and 4 weeks) and visual fatigue (visual fatigue questionnaire scores decreased by 6.1 and 5.8 points at 2 and 4 weeks). Although contrast sensitivity showed slight improvements (0.15 and 0.12 log units at 2 and 4 weeks), these were not clinically superior to standard lenses.[21]

Similarly, Baldasso et al. assessed the impact of BB lenses on color discrimination using three different color vision tests: the Cambridge Color Test, the Color Assessment and Diagnosis test, and the Farnsworth–Munsell 100 Hue Test. Their findings confirmed that the modest reduction in blue light transmission by BB lenses, ranging from 12% to 40%, did not lead to statistically or practically significant effects on color discrimination.[22] This result aligns with earlier studies on IOLs, which also found no significant impact on color vision when BB filters were used.[22] Thus, BB lenses appear to preserve normal color discrimination, making them suitable for users who require precise color perception in their daily tasks.

Expanding on the effects of blue-light-filtering lenses on contrast sensitivity, Lian et al. conducted a long-term RCT to evaluate the impact of blue-light-blocking lenses with different degrees of filtration (15% and 30% blue light blocking) on contrast sensitivity under scotopic and photopic conditions, with and without glare. Over 6 months of consistent use, the study revealed no significant differences in contrast sensitivity among the three groups (15% BB, 30% BB, and clear lenses) under any lighting condition. This finding underscores the conclusion that blue-light-blocking lenses do not compromise contrast sensitivity in either short-term or long-term use.[23] These results are particularly relevant for individuals who rely on optimal visual performance in low-light or high-glare environments, such as drivers or night workers.

Alzahrani et al. also explored the transmittance properties of commercially available blue-light-blocking lenses and their impact on visual sensitivity. These lenses reduced blue light transmission by 6%–43%, with corresponding reductions in scotopic sensitivity (5%–24%) and blue color perception (5%–36%). Despite these reductions, the study concluded that the effects were negligible and did not significantly impair task efficiency, visual performance, or practical usability.[3] Additionally, the study highlighted that the degree of blue light filtration is directly related to the wavelength-specific transmittance properties of the lenses, with higher filtration leading to slightly greater reductions in scotopic sensitivity and color perception. However, these effects were not clinically significant.

Further research by Alzahrani et al. specifically investigated the effects of BB lenses on color contrast sensitivity. Their findings indicated that BB lenses selectively affected blue color contrast sensitivity, particularly under scotopic conditions, with lenses that transmitted less blue light showing a greater reduction in sensitivity. For instance, lenses such as Blu-OLP, which blocked a higher percentage of blue light, led to poorer performance in detecting blue-colored targets. However, this effect was limited to scotopic condition and specific wavelengths, emphasizing that the practical impact on overall visual performance is minimal for most users.[3]

Despite these findings, studies have consistently shown that the performance of BB lenses is lens-specific. For example, Baldasso et al. noted that lenses with higher transmittance of blue light, such as Crizal Prevencia and Blue Guardian, did not significantly affect color contrast thresholds, even for blue-colored stimuli. This variation underscores the importance of selecting appropriate lenses based on individual needs and tasks that require precise color discrimination.[22]

In conclusion, the research consensus indicates that blue-light-filtering lenses do not adversely affect contrast sensitivity or color discrimination in meaningful ways. While slight reductions in scotopic sensitivity and blue color perception have been observed, these effects are lens-specific and clinically insignificant. Therefore, blue-light-filtering lenses represent a viable and safe option for users seeking to reduce blue light exposure without compromising visual performance or task efficiency.

*Glare disability and photostress recovery.* Glare disability refers to the reduction in visual performance caused by intense light sources, while photostress recovery describes the time required for vision to return to normal after exposure to bright light. Recent studies have explored whether blue-light-filtering or high-energy visible (HEV)-blocking lenses influence these parameters. Hammond et al. reported that blue-light-filtering IOLs significantly reduced glare disability and shortened photostress recovery time compared with non-filtering designs, suggesting improved resilience to light-induced visual stress.[24] Similarly, Renzi-Hammond et al. demonstrated that HEV-filtering contact lenses reduced glare-induced squinting by 44.9% and decreased photostress recovery time by 24.3% relative to clear lenses, indicating enhanced photic comfort and faster retinal recovery.[25]

However, findings are not entirely consistent across optical modalities. Alzahrani et al. found that under photopic (bright) conditions, commercially available BB spectacle lenses did not significantly alter photostress recovery times, whereas under mesopic (dim) illumination, some lenses actually prolonged recovery, particularly for blue-colored targets.[3] These results suggest that the effects of blue light filtration on glare and recovery are context-dependent and vary with lighting level, spectral selectivity, and target color. Moreover, some authors have argued that because both image and glare luminance are equally attenuated by spectral filters, blue-light-blocking lenses may not substantially improve disability glare.[26] However, this interpretation assumes homogeneous attenuation across wavelengths, a premise that has been criticized as optically inaccurate, since biological and optical filters exhibit spectrally selective rather than uniform absorption.[27]

Overall, current evidence indicates that while blue-light-filtering lenses may offer modest improvements in photostress recovery and visual comfort in high-glare environments, their effectiveness depends strongly on experimental conditions and lens design. Further randomized clinical studies using standardized glare and photostress testing protocols are warranted to clarify their real-world visual benefits.

In addition to glare disability and photostress recovery, blue-light-filtering spectacle lenses may also influence chromatic contrast, particularly for short-wavelength stimuli. Experimental and clinical work has demonstrated that selective attenuation of blue light can slightly reduce blue–yellow chromatic sensitivity, especially under scotopic or mesopic conditions, although these effects remain small and strongly lens-dependent.[3,22] For example, Alzahrani et al. reported measurable reductions in blue chromatic contrast sensitivity in lenses with higher short-wavelength attenuation,[3] while Baldasso et al. similarly found modest but statistically insignificant shifts in color discrimination with varying spectral transmittance profiles.[22] Furthermore, although positive dysphotopsias such as halos, light streaks, and glare phenomena are most commonly discussed in the context of IOLs, spectral filtering can also modify retinal illuminance patterns, and therefore, spectacle lenses may subtly alter the perception of photic artifacts in certain lighting environments.[26] Collectively, these findings suggest that the visual impact of blue-light-filtering lenses extends beyond luminance-based measures and includes wavelength-specific and perceptual components.

*Reading speed and data entry accuracy.* Research on blue-light-filtering lenses demonstrates their potential to enhance task performance, particularly in reading speed and data entry accuracy during prolonged screen use. Usgaonkar et al.[28] found a significant improvement in both metrics when participants wore blue-light-filtering lenses, indicating their effectiveness in improving task efficiency. However, participants also reported increased visual fatigue, suggesting a trade-off between enhanced performance and user comfort. Similar findings were noted by Alzahrani et al.[3] and Leung et al.,[20] who highlighted the lenses' role in reducing visual strain and preserving contrast sensitivity, which are crucial for maintaining accuracy in visually demanding tasks. Despite some reductions in contrast for blue and achromatic stimuli, these effects were not significant enough to impair overall performance, even under challenging lighting conditions.

Other studies such as Baldasso et al.[22] provide additional context by examining related aspects of visual performance, such as motion perception, contrast sensitivity, and color discrimination. They suggest that blue-light-filtering lenses do not introduce cognitive strain or impairments in visual processing, supporting their utility for tasks requiring focus and precision. However, the subjective discomfort reported by users highlights the need for ergonomic adjustments and breaks during extended use. While the lenses show promise in boosting objective measures of efficiency, further research is needed to address user comfort and optimize their long-term usability.

*Visual performance in low-light conditions.* The effects of blue-light-filtering lenses on visual performance in low-light conditions, which often pose additional challenges to task efficiency, have also been studied. Alzahrani et al. modeled the effect of these lenses on scotopic vision and circadian rhythm, demonstrating that blue-light-blocking lenses slightly reduced scotopic sensitivity by 5%–24%.[3] However, this reduction did not translate into significant impairment in visual performance during low-light tasks, indicating that the lenses may still be suitable for use in such conditions.

*Sleep and task efficiency.* The potential influence of blue-light-filtering lenses on task efficiency through their effects on sleep and circadian rhythm is also worth noting. Downie et al. highlighted that blue light exposure in the evening could disrupt circadian rhythms, thereby affecting alertness and task performance the following day.[13] While blue-light-filtering lenses have been proposed as a solution to mitigate these effects, the evidence supporting this claim remains inconclusive.[13] For instance, Leung et al. found no significant improvements in sleep quality or daytime alertness with blue-light-filtering lenses, suggesting that their impact on task efficiency through sleep regulation is minimal.[20]

*User preferences and subjective feedback.* User preferences and subjective feedback on lens performance provide additional insights into their impact on task efficiency. In a study by Leung et al., participants were asked to rate the performance of blue-light-filtering lenses after 1 month of use. While some participants reported improved anti-glare performance and comfort during computer use, others did not perceive any significant changes compared to clear lenses.[20] This variability in user feedback highlights the subjective nature of lens performance and the need for further research to establish their efficacy in improving task efficiency.

*Limitations of current evidence.* Although some studies have reported minor improvements in task efficiency with blue-light-filtering lenses, the majority of evidence indicates no significant benefits. The variability in study designs, outcomes measured, and participant characteristics makes it challenging to draw definitive conclusions. Moreover, the role of other factors, such as ergonomics, screen brightness, and individual visual needs, in determining task efficiency remains underexplored.

In summary, while blue-light-filtering lenses have been hypothesized to improve visual and task efficiency, the current body of evidence suggests limited benefits. Most studies have found negligible effects on visual fatigue, contrast sensitivity, color discrimination, and task performance, indicating that these lenses may not significantly enhance productivity during prolonged visual tasks. Further research with standardized methodologies and larger sample sizes is needed to clarify their role in improving visual and task efficiency.

### *Protection against light-induced damage: retinal protection and protection against age-related macular degeneration*

Blue-light-filtering ophthalmic lenses have been proposed as a potential protective measure against light-induced retinal damage and ARMD. The harmful effects of blue light on retinal cells and the role of oxidative stress in ARMD pathology have been extensively studied.[1,13,17,29–31] This subsection evaluates the evidence from experimental, epidemiological, and clinical studies regarding the protective effects of blue-light-filtering lenses on the retina and their potential to mitigate ARMD progression.

*Retinal damage from blue light exposure.* Exposure to blue light, particularly wavelengths in the 400–500 nm range, has been shown to induce photochemical and oxidative damage to retinal cells. Animal studies have consistently demonstrated that blue light exposure can cause structural and functional damage to the retina. For example, blue light exposure in rats has been shown to result in photoreceptor apoptosis, retinal pigment epithelium (RPE) dysfunction, and increased reactive oxygen species (ROS) production, all of which are implicated in retinal damage.[32] Similar findings were observed in porcine RPE cells exposed to blue LED light, where significant cytotoxicity was observed, leading to decreased cell viability and increased oxidative stress. The use of selective blue-filtering (S-BF) lenses in these experiments demonstrated a protective effect by reducing ROS production and enhancing the expression of antioxidant enzymes such as catalase and peroxiredoxin-3.[29] In another study, Leung et al. suggested that blue-light-filtering spectacle lenses could act as a supplementary option to protect the retina from potential blue light hazards.[20]

Histological analysis of retinal tissues in animal models has further elucidated the extent of blue-light-induced damage. Chronic exposure to blue light has been shown to disrupt the outer retina, including photoreceptor outer segments and the RPE, and trigger apoptosis in the ganglion cell layer. Studies using commercially available blue-light-blocking lenses, such as Crizal Prevencia and Duravision Blue, demonstrated reduced caspase-3 immunostaining in the retinal ganglion cell layer compared to unfiltered blue light exposure, suggesting a reduction in apoptotic activity.[32]

*Role of blue light in ARMD pathogenesis.* ARMD is a leading cause of vision loss worldwide, with oxidative stress being a major contributing factor to its pathogenesis. Blue light exposure exacerbates oxidative stress by inducing ROS generation in the retina, which damages photoreceptors and RPE cells. Lipofuscin, an age-related pigment that accumulates in RPE cells, is particularly sensitive to blue light. The interaction of blue light with lipofuscin leads to the generation of singlet oxygen and other ROS, contributing to cellular damage and ARMD progression.[17]

Epidemiological evidence suggests a potential link between cumulative blue light exposure and ARMD risk. Studies such as the Beaver Dam Eye Study have reported associations between sunlight exposure and advanced ARMD, with individuals exposed to higher levels of blue light being at greater risk.[1] However, conflicting data from other population-based studies highlight the need for further investigation to establish a definitive causal relationship.

*Protective effects of blue-light-filtering lenses against ARMD.* Theoretical and experimental evidence supports the use of blue-light-filtering lenses as a protective measure against ARMD. These lenses reduce the transmission of short-wavelength light to the retina, thereby mitigating photochemical and oxidative damage. In vitro studies have demonstrated that blue-light-filtering lenses can significantly reduce retinal phototoxicity. For instance, Sparrow et al. reported that blue-light-filtering IOLs effectively protected lipofuscin-laden RPE cells from apoptosis induced by blue light exposure.[30]

In animal models, the use of blue-light-filtering lenses has shown promising results in reducing retinal damage. For example, S-BF lenses reduced blue-light-induced ROS production and improved cell survival in porcine RPE cell cultures.[29] Similarly, in rodent models, blue-light-blocking lenses attenuated retinal damage and preserved the structural integrity of the retina, as evidenced by reduced histological disruption and lower levels of apoptotic markers.[32]

While experimental evidence supports the protective effects of blue-light-filtering lenses, clinical evidence remains limited. A systematic review by Lawrenson et al. highlighted the paucity of high-quality RCTs investigating the effects of blue-light-filtering lenses on ARMD progression.[17] The available studies have primarily focused on short-term outcomes such as visual performance and sleep quality, with limited data on long-term retinal health and ARMD prevention.

*Considerations and future directions.* Despite the potential benefits, there are concerns regarding the use of blue-light-filtering lenses. Blocking blue light may impair scotopic vision, which relies on short-wavelength light, and could disrupt circadian rhythms. Additionally, the extent to which blue light contributes to ARMD progression remains debated, with some studies suggesting that other factors, such as genetic predisposition and oxidative damage from other sources, may play a more significant role.[31]

Because AMD develops over many decades and remains relatively rare, prospective long-term trials following thousands of individuals are unlikely to be feasible. Therefore, inference from experimental models, epidemiological associations, and cumulative exposure data provides the most realistic basis for evaluating the potential role of blue-light-filtering lenses. Clinical trials are still needed to clarify short- to medium-term outcomes, but their role is primarily in assessing surrogate markers rather than long-term incidence of AMD.

In summary, blue-light-filtering lenses show promise in protecting the retina from light-induced damage and mitigating ARMD risk. However, further research is necessary to establish their clinical efficacy and optimize their use for retinal protection.

### *Digital eye strain and lighting: applications in digital eye strain and computer vision syndrome*

DES and CVS are increasingly recognized as significant health issues associated with prolonged digital screen exposure.[33–36] Blue-light-filtering ophthalmic lenses have been proposed as a potential intervention to alleviate these symptoms.[4] This subsection examines the evidence on the application of blue-light-filtering lenses in managing DES and CVS.

Similarly, Singh et al. conducted a double-masked RCT to investigate the impact of BB lenses on CVS. The study found no significant differences in critical CFF or subjective symptom scores between participants using BB lenses and those using clear lenses after a 2-h computer task. This finding aligns with the hypothesis that blue light emitted from digital devices may not be the primary factor in CVS symptoms, and other factors such as ergonomics and screen glare may play a more significant role.[19]

In contrast, Dabrowiecki et al. explored the effects of blue-light-filtering glasses on CVS symptoms in radiology residents. Although the differences were not statistically significant, the study reported a trend toward reduced symptom severity when participants wore blue-light-filtering glasses. Symptoms such as eye redness, blurred vision, and dry eyes were consistently rated as less severe during the blue-light-filtering lens phase, indicating potential benefits in highly screen-intensive work environments.[4]

While the evidence remains inconclusive, these studies highlight the variability in outcomes associated with blue-light-filtering lenses. The mixed findings underscore the multifactorial nature of DES and CVS, suggesting that interventions should address additional factors such as ergonomics, screen brightness, and proper lighting conditions. Further research is warranted to clarify the role of blue-light-filtering lenses in managing DES.

### *Neurological and psychological impacts: Migraine relief, mania symptoms, and anxiety in insomnia*

Blue-light-filtering ophthalmic lenses have shown promise in addressing various neurological and psychological conditions, including migraine relief,[37] reduction of mania symptoms,[38] and alleviation of anxiety in insomnia patients.[39] This subsection evaluates the evidence on these impacts.

*Migraine relief.* Blue light is a known trigger for migraines, particularly due to its stimulation of intrinsically photosensitive retinal ganglion cells (ipRGCs), which influence non-visual pathways in the brain. Tatsumoto et al. evaluated the effect of blue cut for night (BCN) glasses, which filter blue light in the 480–500 nm range, on migraine patients. Participants who wore the glasses for 4 weeks showed a significant reduction in the number of headache days (7.0 ± 4.37 days) compared to a pre-intervention period (8.7 ± 5.03 days). Additionally, the intensity of photophobia was significantly reduced during the daytime, nighttime, and indoors. These findings highlight the potential of blue-light-filtering lenses in mitigating migraine symptoms and associated photophobia.[37]

*Mania symptoms.* Blue light exposure has been linked to exacerbating mania symptoms in bipolar disorder due to its effects on circadian rhythms and arousal pathways. Henriksen et al. conducted an RCT to evaluate BB glasses as an additive treatment for mania. Patients wearing BB glasses from 6 PM to 8 AM for 7 days exhibited a significant reduction in Young Mania Rating Scale (YMRS) scores compared to a placebo group. The mean YMRS score reduction in the BB group was 14.1 points, with an effect size of 1.86, indicating a substantial antimanic effect. The glasses were well-tolerated, and motor activity measured by actigraphy confirmed reduced activation, suggesting that BB glasses may be an effective intervention for mania.[38]

*Anxiety in insomnia.* Insomnia is often accompanied by heightened anxiety, which may be exacerbated by evening blue light exposure. Smotek et al. investigated the effect of combining blue-light-blocking glasses with cognitive behavioral therapy for insomnia (CBT-I). Patients wearing BB glasses for 90 min before bedtime showed a significant reduction in anxiety, as measured by the Beck Anxiety Inventory (BAI), compared to a placebo glasses group. The active group also demonstrated improvements in subjective total sleep time and a decrease in hyperarousal, suggesting that blue-light-blocking glasses can enhance the efficacy of CBT-I by consolidating circadian rhythms and reducing anxiety.[39]

These studies collectively demonstrate that blue-light-filtering lenses can have significant neurological and psychological benefits, particularly in managing migraine, mania, and insomnia-related anxiety.

### *Sleep and well-being, sleep quality*

The impact of blue-light-filtering ophthalmic lenses on sleep and overall well-being has been an area of considerable research due to the role of blue light in suppressing melatonin and disrupting circadian rhythms.[13,40] This section explores the influence of BB lenses on sleep quality, subjective well-being, and associated parameters.

*The impact of circadian timing of blue light exposure on circadian light hygiene.* Enhancing public health and regulating the circadian rhythm are influenced by the timing of light exposure throughout the day and night, especially exposure to blue light. Exposure to natural sunlight during the day helps improve the circadian rhythm, increases alertness, and enhances cognitive performance by activating brain regions such as the prefrontal cortex and thalamus.[41,42] However, exposure to blue light at night suppresses melatonin secretion and disrupts both sleep and circadian rhythm.[43] The concept of circadian light hygiene emphasizes the importance of appropriate timing and duration of light exposure over the 24-h cycle. Objective measures such as nocturnal light excess and daytime light deficit, obtained through actigraphy devices, are used to assess actual light exposure.[41,43] Practical suggestions include spending at least 90 min outdoors in natural daylight during the day, increasing outdoor activities, and reducing blue light exposure to the eyes at night through the use of dimmers and warmer lighting.

*Effectiveness in improving subjective sleep quality.* BB glasses have been shown to improve subjective sleep quality in certain populations. A study by Janků et al. investigated the combination of CBT-I with blue-light-blocking glasses in individuals diagnosed with insomnia. The study reported a significant improvement in subjective total sleep time (36.87-min increase) and reduced subjective sleep latency in the group wearing BB glasses compared to a placebo glasses group. However, no significant changes in objective sleep parameters, such as actigraphy-measured sleep duration, were observed. This highlights that BB glasses may enhance subjective sleep quality, even if objective sleep metrics remain unchanged. The researchers attributed these benefits to the acceleration of melatonin secretion and strengthened circadian rhythm consolidation.[44] In another study, an open-label trial examined the effects of blue-light-blocking amber glasses on patients with delayed sleep phase disorder (DSPD). Over 2 weeks, patients wore the glasses from 9:00 p.m. to bedtime. Results showed an average advance of 78 min in dim light melatonin onset (DLMO) and a significant 132-min advancement in sleep onset time, as measured by actigraphy. These findings suggest that amber lenses may be a safe and effective intervention for DSPD, though further research with larger sample sizes is needed.[45]

*The role of melanopsin stimulation and light characteristics in circadian effects of blue light.* Recent studies have contributed to a better understanding of the effects of blue light on the circadian rhythm.[46,47] For instance, Spitschan et al.[47] reported that the circadian system and associated brain responses are not exclusively reactive to short wavelengths such as blue light. Instead, they also respond to the level of melanopsin stimulation. Notably, melanopsin activation varies based on different spectral compositions and temporal light patterns. In their study, even non-blue light, when presented in specific temporal patterns, such as flickering light, was able to induce similar effects on the circadian rhythm. Therefore, blue light is not the sole factor responsible for circadian disruption. It is important to note that all these findings were obtained under controlled laboratory conditions, and their application in real-world settings is still under investigation. As a result, while blue light filtering does not entirely block melanopsin stimulation, it can significantly reduce excessive exposure, especially during the evening and nighttime hours, making it a useful strategy for supporting sleep hygiene.

*Impact on melatonin suppression and circadian rhythm.* The capacity of BB lenses to prevent melatonin suppression has been extensively studied. Sasseville et al. demonstrated that orange-tinted glasses, which block wavelengths below 540 nm, effectively prevented melatonin suppression during a 60-min bright light exposure. While the control group wearing neutral gray lenses experienced a 46% reduction in melatonin levels, the group wearing blue blockers showed no significant melatonin suppression. This suggests that BB glasses can mitigate the adverse effects of nighttime light exposure on melatonin, thereby preserving circadian alignment.[48] In another study, Figueiro et al. conducted a study involving 12 participants who were periodically exposed to 1 h in either the blue or red spectrum while remaining awake for 27 consecutive hours. The findings revealed that only blue light effectively suppressed nocturnal melatonin levels, indicating that the synthesis of this hormone by the pineal gland is specifically influenced by short-wavelength light.[49]

*Subjective and objective discrepancies in sleep outcomes.* Bigalke et al. conducted an RCT to assess both subjective and objective sleep parameters in healthy adults wearing BB glasses. They found that while subjective measures, such as sleep onset latency and awakenings, improved with BB glasses, objective measures, including actigraphy-measured total sleep time, did not show significant benefits. Interestingly, there was even a paradoxical trend toward reduced total sleep time in the BB condition compared to the control group. These findings suggest that while BB lenses may positively influence perception of sleep quality, their effects on objective parameters require further investigation.[50]

*Enhancing sleep in shift workers.* Shift workers, who are particularly vulnerable to circadian misalignment due to exposure to morning light, may benefit significantly from blue-light-filtering lenses. Sasseville et al. highlighted the potential of BB glasses to prevent the undesired phase-advancing effects of morning light exposure. This is particularly relevant for shift workers who need to maintain a delayed circadian phase. By blocking short-wavelength light, BB glasses could facilitate adaptation to night work and improve overall sleep quality in this population.[48]

*Long-term sleep benefits and cognitive function.* Other studies emphasize the broader implications of improved sleep quality on well-being and cognitive function. Janků et al. reported that the combination of BB glasses and CBT-I not only improved subjective sleep quality but also did not shorten objective sleep duration, unlike placebo glasses.[44] This suggests a potential protective role of blue blockers against sleep deprivation-related cognitive impairments. Furthermore, the findings align with Bigalke et al., who noted that BB glasses reduced subjective awakenings and sleep onset latency, highlighting their potential role in mitigating sleep fragmentation and associated cognitive deficits.[50]

*Challenges in objective sleep measurement.* Despite promising subjective results, the lack of consistent objective findings remains a challenge in evaluating the efficacy of BB lenses. For instance, Bigalke et al. suggested that the absence of significant changes in objective total sleep time might be attributable to the participants' unchanged evening behaviors, such as screen time. This underscores the need for more comprehensive studies incorporating polysomnography and melatonin assays to better understand the physiological mechanisms underlying the subjective benefits of BB glasses.[50]

*Application in healthy populations.* Studies on healthy populations, such as the one conducted by Bigalke et al., indicate that BB glasses may have limited utility in individuals without significant sleep disturbances. While these glasses improved subjective perceptions of sleep, the lack of objective benefits raises questions about their effectiveness in populations with normal circadian rhythms.[50] However, their potential to enhance sleep quality in individuals with poor subjective sleep metrics or circadian misalignment remains a promising avenue for further research.

*Broader implications for sleep hygiene.* The findings from these studies collectively suggest that blue-light-blocking lenses may serve as a valuable tool for improving subjective sleep quality and mitigating the disruptive effects of artificial light exposure on circadian rhythms. Sasseville et al.[48] emphasized the importance of spectral control in reducing melatonin suppression, while Janků et al.[44] highlighted the potential of combining BB lenses with behavioral interventions like CBT-I for maximizing therapeutic outcomes.

In summary, while blue-light-filtering lenses show promise in enhancing subjective sleep quality and protecting circadian rhythms, their impact on objective sleep parameters remains inconsistent. Future research should aim to elucidate these discrepancies and explore the long-term benefits of BB interventions across diverse populations. Table 1 shows key clinical studies examining the effectiveness of blue-light-filtering lenses in alleviating eye-related signs and symptoms.

## Discussion

This review study evaluated the efficacy of blue-light-filtering lenses in managing vision-related symptoms, retinal protection, and their potential neurological and psychological benefits. The findings revealed mixed evidence across various domains, highlighting the importance of understanding both the benefits and limitations of these lenses in clinical and everyday settings.

While blue-light-filtering lenses have been marketed as a solution to DES and visual fatigue, the evidence remains inconclusive. Studies by Singh et al. and Lawrenson et al. showed no significant differences in reducing visual fatigue or improving task performance compared to clear lenses, suggesting that the theoretical benefits of blocking blue light may not translate into measurable improvements, particularly during real-world tasks.[17,19]

Similarly, contrast sensitivity and color discrimination studies consistently reported minimal or no adverse impact, with findings from Leung et al. and Baldasso et al. concluding that blue-light-filtering lenses do not impair essential visual functions under challenging lighting conditions.[20,22] These results suggest that while blue-light-filtering lenses preserve normal visual performance, their role in reducing visual fatigue during prolonged screen use remains limited for most users.

Evidence supporting the protective effects of blue-light-filtering lenses against retinal damage and ARMD is stronger in laboratory and animal studies than in clinical settings. Experimental studies, such as those by Yu et al. and Sparrow et al., demonstrated that blue-light-filtering lenses significantly reduced oxidative stress and phototoxicity in RPE cells, indicating a potential protective mechanism at the cellular level.[29,30] Additionally, animal models showed reduced apoptotic markers and preserved retinal integrity with blue-light-filtering lenses, further supporting their potential role in mitigating retinal damage.[32]

However, clinical evidence remains limited. Most human studies focus on short-term outcomes, such as visual performance and subjective comfort, rather than long-term retinal health or ARMD prevention. For instance, Lawrenson et al. highlighted the lack of high-quality RCTs examining the impact of these lenses on ARMD progression.[17] While the experimental data are promising, the absence of long-term clinical studies raises questions about the practical applicability of these findings. Furthermore, blue light is only one of several factors contributing to ARMD, with genetic predisposition, oxidative stress, and environmental factors also playing critical roles.[31] Therefore, while blue-light-filtering lenses may offer some degree of retinal protection, their effectiveness as a standalone intervention for ARMD prevention remains uncertain.

DES and CVS are increasingly prevalent due to prolonged screen use, yet studies on the role of blue-light-filtering lenses in alleviating these

**Table 1.** Key clinical studies examining the effectiveness of blue-light-filtering lenses in alleviating eye-related signs and symptoms.

| References | Year | Study design | Samples | Parameters | Follow-up | Main findings |
|---|---|---|---|---|---|---|
| Sasseville et al.[48] | 2006 | Randomized clinical trial | 14 normal participants | Amount of salivary melatonin | Two consecutive nights | • Blue-blocking glasses effectively prevent melatonin suppression caused by light exposure. |
| Kiser et al.[51] | 2008 | Non-randomized clinical trial | 22 bilateral pseudophakic patients with early AMD | • VA<br>• Sock color sorting<br>• Dark-adapted full-field flash test | • 2 phases (first phase included 9 subjects and second phase had 13 new participants)<br>• All measurements were performed in single visit which lasting about 4 hours. | • The impact of blue-blocking filters on scotopic vision is unlikely to have a clinically significant effect. |
| Van der Lely et al.[52] | 2015 | Non-randomized, crossover clinical trial | 11 healthy teenagers | • Salivary melatonin<br>• Subjective sleepiness<br>• Vigilant attention | 2 weeks | BB glasses may help counteract the alertness effects from LED screen exposure in adolescents. |
| Henriksen et al.[38] | 2016 | Single-blinded, randomized, placebo-controlled trial | 23 subjects with bipolar mania | • YMRS for assessing symptoms<br>• Actigraphy for motor activity | 1 week | • BB glasses can be a viable add-on treatment for bipolar mania. |
| Esaki et al.[45] | 2016 | Open-label trial | 9 individuals with delayed sleep phase disorder | • DLMO<br>• Actigraphic sleep data | 2 weeks | • Amber lenses may offer a safe and effective solution for individuals with DSPD. |
| Leung et al.[20] | 2017 | Single-masked pseudo-randomized controlled clinical trial | 80 computer users | • Visual performance<br>Sleep quality | 4 weeks | • Blue-light-filtering lenses reduce high-energy short-wavelength light without significantly affecting vision or sleep quality. |
| Dabrowiecki et al.[4] | 2019 | Prospective crossover non-randomized clinical trial | 10 radiology residents | • CVS-Q<br>• SOFI | 2 weeks | • Findings suggest a potential reduction in CVS symptoms with BLFL use. |

*(Continued)*

**Table 1.** (Continued)

| References | Year | Study design | Samples | Parameters | Follow-up | Main findings |
|---|---|---|---|---|---|---|
| Šmotek et al.[39] | 2019 | Non-randomized clinical trial | 30 people diagnosed with insomnia | • Subjective and objective sleep parameters<br>Daily symptoms (anxiety, depression, hyperarousal). | 6 weeks | • Blocking short-wavelength light in the evening may help insomnia patients by lowering anxiety levels.<br>• Blue light blocking may also help reduce hyperarousal and depressive symptoms. |
| Janků et al.[44] | 2020 | Randomized clinical trial | 30 patients | • Subjective sleep parameters<br>• Objective sleep parameters<br>• Daily symptoms (anxiety, depression, hyperarousal) | 6 weeks | • Evening blue light blocking benefits insomnia sufferers. |
| Redondo et al.[53] | 2020 | Non-randomized clinical trial | 19 healthy and young adults | • Accommodative response<br>• Pupil size | 2 days | • B-B filters did not impact accommodative dynamics or visual symptoms. |
| Bigalke et al.[50] | 2021 | Two-week, randomized, controlled, crossover design | 20 healthy adult people | • Objective sleep parameters (using wrist actigraphy)<br>• Subjective sleep measures (using sleep diaries)<br>• Perceived sleep quality (using Karolinska Sleep Diaries) | 4 weeks | • Blue-light-blocking glasses did not significantly improve sleep quality or duration in healthy adults. |
| Baldasso et al.[22] | 2021 | Randomized controlled trial | 10 individuals | • Computer-based color vision tests | 1 week | • The slight reduction in blue light transmittance from "blue-blocking" lenses did not meaningfully impact color vision. |
| Singh et al.[19] | 2021 | Double-masked, randomized controlled trial | 120 symptomatic computer users | • CFF<br>• Eye strain symptom score | 1 day | • Blue-blocking lenses did not reduce eye strain symptoms from computer use compared to standard clear lenses. |

*(Continued)*

**Table 1.** (Continued)

| References | Year | Study design | Samples | Parameters | Follow-up | Main findings |
|---|---|---|---|---|---|---|
| Helmhout et al.[54] | 2022 | Randomized controlled cross-over | 86 security guards | • 11-item NFRS<br>• CIS<br>• Stress Level<br>• Additional questionnaire items | 5 weeks | • Blue light exposure from light-emitting glasses had no measurable effect on fatigue, stress, or recovery needs in night-shift security guards. |
| Liset et al.[55] | 2022 | Randomized controlled trial | 60 women in third trimester of the pregnancy | • Salivary melatonin<br>• Subjective sleep quality | 2 weeks | • Blocking blue light in the evening positively influenced the circadian system, leading to earlier melatonin production in pregnant women. |
| Lian et al.[23] | 2022 | Randomized controlled trial | 144 healthy adult people | Contrast sensitivity under four light conditions | 6 months | • Blue-light-blocking lenses had no significant long-term effect on contrast perception under different lighting conditions. |
| Tatsumoto et al.[37] | 2023 | Non-randomized clinical trial | 10 subjects with migraine | Questionnaire parameters for migraine | 4 weeks | • BCN glasses, designed to reduce ipRGC stimulation, may help decrease migraine occurrences. |
| Usgaonkar et al.[28] | 2023 | Randomized clinical trial | 40 individuals | • NPA<br>• AF<br>• Visual discomfort questionnaire | 2 days | • While a BL filter improved task performance, users reported increased visual fatigue. |
| Saleem et al.[21] | 2025 | Double-blinded, randomized controlled trial | 64 participants | • Contrast sensitivity<br>• Digital eye strain (using the Computer Vision Syndrome Questionnaire)<br>• Visual fatigue (using the Visual Fatigue Questionnaire) | 4 weeks | • Blue-light-blocking glasses effectively reduce digital eye strain and visual fatigue but do not improve contrast sensitivity beyond standard lenses. |

AF, accommodative facility; AMD, age related macular degeneration; BB, blue blocking; BCN, blue cut for night; BL, blue light; BLFL, blue-light-filtering lenses; CFF, critical flicker-fusion frequency; CIS, checklist individual strength; CVS, computer vision syndrome; CVS-Q, Computer vision syndrome questionnaire; DES, digital eye strain; DLMO, dim light melatonin onset; DSPD, delayed sleep phase disorder; ipRGC, intrincically photo Responsive Retinal Ganglion Cells; LED, light-emitting diode; ND, neutral density; NFRS, need for recovery scale; NPA, near point of accommodation; SOFI, Swedish Occupational Fatigue Inventory; VA, visual acuity; YMRS, Young Mania Rating Scale.

conditions have produced inconsistent results. For instance, Singh et al. reported no significant improvements in CFF or subjective symptom scores in participants using blue-light-filtering lenses during a two-hour computer task.[19]

In contrast, Dabrowiecki et al. observed a trend toward reduced DES symptoms among radiology residents wearing blue-light-filtering glasses, particularly in highly screen-intensive environments.[4] This suggests that while blue-light-filtering lenses may not universally alleviate DES, they could benefit specific populations with high visual demands. The variability in outcomes underscores the multifactorial nature of DES and CVS, with factors such as ergonomics, screen brightness, and lighting conditions likely playing more significant roles than blue light exposure alone.

Evidence supporting the neurological and psychological benefits of blue-light-filtering lenses is more robust, particularly in managing migraines, mania, and insomnia-related anxiety. Studies such as those by Tatsumoto et al.[37] and Henriksen et al.[38] demonstrated significant reductions in migraine frequency and mania symptoms, respectively, when participants used BB lenses during the evening. These findings suggest that by reducing stimulation of ipRGCs, blue-light-filtering lenses can mitigate the non-visual impacts of blue light exposure on brain pathways.

Similarly, BB glasses have shown promise in reducing anxiety associated with insomnia. Smotek et al. found that combining BB glasses with CBT-I significantly reduced anxiety and improved sleep outcomes, highlighting the potential of these lenses as adjunctive tools for psychological interventions.[39] While the evidence in this area is promising, further research is needed to evaluate the long-term effects of BB lenses on neurological and psychological health.

One of the most widely studied benefits of blue-light-filtering lenses is their impact on sleep and circadian rhythms. Studies consistently suggest that these lenses can mitigate the suppressive effects of blue light on melatonin production, thereby preserving circadian alignment. For instance, Sasseville et al. demonstrated that orange-tinted glasses effectively prevented melatonin suppression during nighttime light exposure, while Esaki et al. found that wearing BB glasses in the evening advanced circadian rhythms and improved sleep onset in patients with DSPD.[45,48] However, discrepancies between subjective and objective sleep outcomes remain a challenge. While studies such as those by Bigalke et al. reported improvements in subjective sleep quality with BB lenses, objective measures such as actigraphy often showed no significant differences.[50] These inconsistencies may be attributed to unchanged evening behaviors, such as screen time, or individual variations in circadian sensitivity to blue light. Future studies incorporating more comprehensive methodologies, such as polysomnography and melatonin assays, are needed to clarify these discrepancies and establish the physiological mechanisms underlying the benefits of BB lenses.

In addition to the well-established role of ipRGCs, recent studies highlight the importance of melanopsin—the photopigment found in these cells as a key driver of non-visual light perception, including melatonin suppression, circadian phase shifting, and alertness regulation. To more accurately assess the potency of light stimuli, a metric known as melanopic Equivalent Daylight Illuminance (melanopic EDI) has been introduced, offering a method for weighting light exposure according to melanopsin sensitivity. This framework allows for a more precise evaluation of various light spectra in terms of their circadian impact.[56] Furthermore, increasing attention in research has been devoted to significant inter-individual differences in circadian and neuroendocrine responses to light exposure. For instance, Phillips and colleagues reported that even under similar lighting conditions, individuals show substantial variability in melatonin suppression responses. These findings indicate that considering physiological, genetic, and chronotypic differences as part of personalized strategies could contribute to optimizing methods such as blue light filtering aligned with circadian rhythms.[57]

Despite the growing body of research on blue-light-filtering lenses, several limitations persist. Variability in study designs, populations, and outcomes measured makes it challenging to draw definitive conclusions. Additionally, most studies focus on short-term outcomes, with limited data on the long-term effects of blue-light-filtering lenses on retinal health, sleep, and well-being. The role of confounding factors, such as ergonomics, lighting conditions, and individual visual needs, also remains underexplored.

In addition to the effects of external blue-light-filtering lenses, it is important to acknowledge the role of natural blue light filtration mechanisms within the eye. The macular pigment, composed of dietary carotenoids such as lutein and zeaxanthin, and the natural yellowing of the crystalline lens, both act as intrinsic filters that selectively absorb short-wavelength (blue) light. There is substantial inter-individual variability in macular pigment optical density (MPOD) and lens density, which can significantly influence the degree of blue light reaching the retina. Individuals with higher MPOD or denser lenses may experience less blue light exposure at the retinal level, potentially diminishing the added benefit of external blue-light-filtering lenses. Conversely, those with low MPOD or clearer lenses may be more susceptible to blue-light-related visual or non-visual effects, and thus might derive greater benefit from external interventions. Future research should consider these individual differences when evaluating the efficacy of blue-light-filtering lenses and interpreting study outcomes.

## Conclusion

This review study highlights the mixed evidence regarding the efficacy of blue-light-filtering lenses in managing vision-related symptoms, protecting retinal health, and addressing neurological and psychological conditions. While experimental studies suggest potential benefits in reducing retinal phototoxicity and oxidative stress, clinical evidence on long-term protection against ARMD remains limited. Similarly, blue-light-filtering lenses show promise in alleviating insomnia-related anxiety, improving migraine symptoms, and supporting circadian rhythm regulation, yet their impact on objective sleep outcomes is inconsistent. For DES and visual fatigue, the lenses offer minor benefits in specific populations, though they appear no more effective than standard lenses for most users. Overall, blue-light-filtering lenses may provide targeted benefits in specific contexts, but their universal effectiveness is inconclusive. Further research with standardized methodologies and long-term follow-up is essential to refine their clinical applications and maximize potential benefits.

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### *Ethics approval and consent to participate*

None.

### *Consent for publication*

Yes

### *Author contributions*

**Masoud Khorrami-Nejad:** Conceptualization; Methodology; Project administration; Visualization; Writing – original draft; Writing – review & editing.

**Shehzad A. Naroo:** Conceptualization; Writing – review & editing.

**Ahmed Oklla:** Conceptualization; Methodology; Writing – original draft.

**Foroozan Narooie-Noori:** Conceptualization; Methodology; Writing – original draft.

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