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ABSTRACT

Increased computer use has changed the visual demands of today's society based on aspects such as the angle of viewing, the working distance, and the types of eye movements required. However, the effects of screen light are not fully understood. Blue-light blocking lenses are promoted not only to reduce digital eye strain, but also to prevent the decline of ocular health – specifically photochemical retinal damage. Blue light is suggested to impact scotopic vision and circadian rhythm. Hard evidence is lacking in determining whether these lenses are effectively designed and are performing as advertised. Many of the studies are not long-term, lack a control for the placebo effect, or are poorly controlled.

The effects of blue light remain unclear. There have not been any reported negative consequences to blue-blocking lenses, but the objective data for them is still lacking and inconclusive. It is known that light impacts our visual comfort, circadian rhythm, and ocular health (if at high levels). Note that even the more popular lenses on the market may not be blocking as much light as advertised, and the patient may be better off changing their work environment and screen to "night mode" if they are interested in completely removing all blue light exposure. All this being said, this is the first time period in which screens have become such an integral part of our lives at such a young age, so it is an important body of work to pay attention to so we can best direct our patients. This literature review examines 5 studies in the area of blue-light blocking lens technology.

Effects of Blue Light-Filtering Intraocular Lenses on the Macula, Contrast Sensitivity, and Color Vision After a Long-Term Follow-up

Kara-Junior N, Espindola, RF, Gomes BAF, Ventura B, Smadja D, Santhiago, MR. J Cataract Refract Surg 2011;37:2115-9.

Short-wavelength rays, particularly 200-450 nm, have been shown to be the most harmful to the retina, and exposure to light has been linked to age-related macular degeneration (AMD). Technology has transformed our light environment and shifted the types and degrees of spectrums to which our eyes are exposed. As a result, many scientists and clinicians are examining the impact that light has on the health of our eyes.

As the lens ages, it accumulates yellow chromophores, which results in a steady reduction in the transmission of short wavelengths; in other words, a natural absorbing of short wavelengths. Cataract surgery offers an opportunity to manipulate this transmission pattern. Researchers sought to see whether using a blue-blocking/yellow-tinted IOL or an ultraviolet (UV)-blocking only IOL had different implications for visual function and health. Cataract surgeons are concerned since blue light is responsible for around 35% of aphakic scotopic vision, and theoretically the blue-blocking lenses reduce scotopic sensitivity by 14-21%. Suggested benefits of blue light-filtering IOLs include protection against retinal damage from blue light, which may play a role in the exacerbation of AMD and the variance of glare/color vision.

Patients with bilateral visually significant cataracts randomly receiveded a UV/blue light–filtering IOL (Acrysof Natural SN60AT) in 1 eye and an acrylic UV light–filtering only IOL (Acrysof SA60AT) in the fellow eye. Note that these are from the same manufacturer to reduce bias. The primary outcome measurements used were contrast sensitivity, color vision, and macular findings five years after surgery.

Patients recruited for this study had good ocular health and no reduced color vision. One surgeon completed all of the surgeries using standard small-incision phacoemulsification and IOL implantation in the capsular bag. All cases were targeted at emmetropia with one week between each eye's procedure.

Patients were examined before surgery, after 1 day, after 7 days, after 30 days, after 6 months, and after 5 years. At all visits, both the corrected and uncorrected distance visual acuities were measured. Additionally, after 5 years, color vision and contrast sensitivity were measured under both photopic and scotopic conditions.

Fifty eyes of the twenty-five patients (15 men and 10 women) were examined in this study, with an average age of about 60 years. There were no statistical differences with the IOL power, axial length, corrected distance/near acuities, refractive error, corneal curvature, or pupil size after the surgery. Only three patients required a YAG laser for posterior capsule opacification. None of the patients showed signs of AMD either on observation or with a Stratus optical coherence tomographer. The intraindividual design is a powerful control in this study since it accounts for confounding variables related to lifestyle and health.

Overall, both IOLs performed similarly. The blue light-filtering/yellow-tinted IOL did not clinically affect color perception or scotopic/photopic contrast sensitivity when compared to the IOL without the blue light filter. These results agree with some previous studies showing that when taken in context with the entire visual spectrum, the decrease in scotopic sensitivity is not clinically significant.

The researchers were careful to point out that in relation to AMD, the sample size is low; effects may be more related to cumulative light exposure or high-intensity exposure. They point out that the majority of findings are either theoretical or in animal experiments and that this study did not look at patients already in the early stages of AMD. Regardless, more research is needed before blue-blocking and/or yellow-tinted lenses are used as a preventative ocular health measure.

A Randomized, Double-Blind, Placebo-Controlled Trial of Blue Wavelength Light Exposure on Sleep and Recovery of Brain Structure, Function, and Cognition Following Mild Traumatic Brain Injury

Killgore WDS, Vanuk JR, Shane BR, Weber M, Bajaj S. Optom Vis Sci 2015;92(1):1076-84.

Sleep and circadian rhythms heavily influence the cognitive process and yet have some of the least understood mechanisms. Deficits in either result in decreased attention and cognitive capacities. Light exposure has been shown to influence these processes and therefore could be used as an intervention therapy and treatment for those with disruptions. About 50% of patients with a mild traumatic brain injury (mTBI) experience chronic sleep disruption associated with cognitive deficits. The researchers used the circadian resetting effects of blue light to study the influence that it has on the sleep patterns of mTBI patients.

Thirty-two adult patients (18-48 yrs) participated in a randomized, double-blind, placebo-controlled trial to examine the effects of blue light on brain structure, connectivity, and cognitive performance. These subjects had a documented history of an mTBI within 18-24 months of the study and reported sleep disturbances as a result. Exclusion criteria included attributes such as psychological conditions, pregnancy, contraindications to MRIs, abnormal/uncorrectable visual acuity, medications that influence sleep, shift work, changes in time zones, or drug/alcohol use.

Participants completed three laboratory visits, including two full-day neurocognitive assessments plus neuroimaging scans over the seven weeks of the study. During the intake exam, various baseline measurements were taken. Subjects underwent neuroimaging, diffusion tensor imaging to measure gray matter volume, resting state functional connectivity, and directed connectivity. Additionally, a battery of established neurocognitive assessments, traumatic brain injury surveys, sleep latency tests, balance/stability tests, and sleep questionnaires were given. Upon beginning the study, each participant was given an Actiwatch Spectrum watch to measure sleep and circadian phase shift. For 6 weeks, subjects were exposed to 30-minute pulses of blue light (469 nm) each morning verses amber placebo light (578 nm). The therapy occurred within two hours of wakening but not after 11 am. During the post-treatment session, a similar battery of psychological testing and imaging was completed. Results were analyzed, and odds ratios were calculated whenever possible. Participants all performed similarly on baseline psychological/neurocognitive and survey testing.

When looking at sleep duration and circadian phase shift, the researchers controlled for interparticipant variability, external variables that may impact sleep, and the degree of the mTBI. Patients undergoing blue-light therapy experienced a significant phase advance in sleep onset and offset times. Those being treated with blue light fell asleep 57.5 min earlier and awoke 55.9 min earlier in the final week of treatment when compared to the start. Patients subjected to amber light fell asleep 13.8 min later and awoke 16.1 min earlier than at baseline. However, there was no significant changes in mean total sleep time in either of the light conditions. Eighty percent of blue-light patients had evidence of earlier sleep onset when compared to only 58% of those in the amber group. Interestingly, 87.5% showed reduced daytime sleepiness while only 37.5% of those in amber showed the same. The blue light group reported needing fewer hours of sleep to feel "good" as well as a reduced sleep latency (i.e., more alert) during the "post-lunch dip" around 2 pm when compared to those in the amber group.

Contrary to prediction, there was no significant difference between the groups with psychomotor vigilance testing or neurocognitive performance (memory, visual spatial, attention, delayed memory, etc). Both groups improved on the Tower of London executive function planning tasks, but blue light participants improved significantly better.

Pulvinar regions of the left and right thalamus showed significant changes in the blue-light group. Interestingly, greater volume increases in the left thalamus were associated with faster bead pick-up time on the Tower of London test, as well as subjective daytime sleepiness. Blue light also showed increases in resting state functional connectivity, particularly in the thalamocortical regions associated with the sleep/wake cycle.

Overall, when compared to the placebo, morning blue light led to phase-advanced sleep timing, reduced daytime sleepiness, and improved executive function and was associated with increased volume of the posterior thalamus, greater thalamo-cortical function connectivity, and increased axonal integrity of these pathways.

A few limitations of this study should be kept in mind. The researchers could not completely monitor compliance, some of the patients had experienced more than one concussion, and outcome measurements were performed after only 6 months. However, the findings are compelling enough to warrant further study.

Blue-Blocking Filters and Digital Eye Strain

Palavets T, Rosenfield M. Optom Vis Sci 2019;96:48-54.

One of the promoted benefits of using blue-blocking lenses is the reduction of digital eye strain. These researchers sought to evaluate the use of blue-blocking lenses in the reduction of symptoms of digital eye strain during sustained near work. Previous studies either lacked control for the placebo effect or were poorly controlled for other variables.

In this study, blue-blocking lenses (BBLs) were used on 23 visually normal subjects doing near work on a tablet for 30 min. The lenses blocked 99% of the wavelengths between 400 and 500 nm. The 7 males and 17 females were between the ages of 22 and 27 years old. The subjects had best-corrected acuity of at least 20/20 in each eye, with no known binocular or ocular health issues. Subjects were not asked about habitual computer use or prior knowledge of blue-blocking filters.

As a control, the researchers had subjects gaze at a distance 20/20 line for 5 minutes to reduce any stress from prior near work. The reading material selected was cognitively demanding, and subjects read aloud to ensure compliance. An Apple iPad was held at 43.5 cm and was controlled for font and contrast.

Each subject's accommodative response, pupil diameter, and vertical palpebral aperture dimension was measured at 0, 9, 19, and 29 minutes. Upon completion of the task, they were given a previously used questionnaire to quantify symptoms of digital eye strain using a 10-point Likert scale. They completed the task twice for a cross-over design.

The results demonstrated that the filter was no more effective at reducing symptoms of digital eye strain than an equivalent neutral density filter. This 30-minute near-point task was effective at eliciting symptoms of digital eye strain in both conditions. In fact, the scores of around 42 were higher than in other studies conducted using the same questionnaire. However, this task may not be representative of natural situations where people have less cognitively demanding near work but for much longer periods of time. The study lacked a control group with no filter in place. However, other studies using similar methods suggest that a neutral filter would not have an impact on symptoms of digital eye strain. Another concern that the researchers addressed was how the survey was administered after the reading task rather than as a pre- and post-test assessment. They argue that distance viewing has been shown previously to eliminate any residual near-point or digital stress. The researchers acknowledged that this study did not look other proposed impacts of BBLs, mainly contrast sensitivity and color distinction. The validity of using changes in critical fusion frequency as a measure of visual fatigue remains open to question, and current research yields mixed and inconclusive findings.

Evidence in other studies supports the idea that the type of lighting can influence the comfort of people in work environments, but there is yet to be a clear mechanism or solid evidence that blue-blocking filters reduce symptoms of digital eye strain; therefore, they should not be marketed as such.

Modeling the Effect of Commercially Available Blue-Blocking Lenses on Visual and Non-Visual Function

Alzahrani HS, Khuu SK, Roy M. Clin Exp Optom 2019;DOI:10.1111/cxo.12959

Blue-blocking lenses are marketed for numerous conditions, including circadian rhythm control, concussion rehabilitation, and retinal protection. Researchers and clinicians alike are collecting evidence to determine in what context these lenses could be used to benefit patients. The selective reduction in visible wavelengths transmitted through BBLs is known to influence the photosensitivity of retinal photoreceptors, which affects both visual and non-visual functions. This study measured the spectral transmittance of BBLs in order to model their effect on blue perception, scotopic vision, circadian rhythm, and protection from photochemical retinal damage.

High-energy blue light (400-500 nm) is essential for visual perception, circadian regulation, mood, and mental performance, yet it has also been linked to retinal damage. Ocular exposure rates and the amount of blue light exposure has changed with the introduction of new light sources, particularly screen technology. Certain wavelengths in the range of blue light result in the maximal activation of retinal cells. For example, 507 nm activates the scotopic rod receptors, 430 nm activates the blue S-cones, and 480 nm activates intrinsically photosensitive retinal ganglion cells (related to melanopsin). Researchers generally accept that 440 nm is the maximum for retinal damage.

The researchers in this study looked at seven different types of blue-blocking lenses (BBLs) by six manufacturers in three different powers (+2.00 D, plano, -2.00 D). The lenses examined—the Crizal Prevencia and Smart Blue Filter (Essilor), Blu-OLP (GenOp), Blue Control (Hoya), UV++Blue Control (JuzVision), SeeCoat Blue UV (Nikon), and Blue Guardian (Opticare)—blocked blue wavelengths either through absorption or reflection of blue light.

The whiteness index was calculated for each of the lenses, as well as the spectral transmittance. The researchers used a Welch ANOVA and Brown-Forsythe test to evaluate statistical significance between lens powers and lens brands. For the clear control lenses, transmission was about 88%, while blue-blocking lenses ranged from 6-43% reduction. Within the same brand, there was no variation between powers for Crizal Prevencia, SeeCoat, Blue Control, and Blue Guardian. There was a difference between Blu-OLP, Smart Blue Filter, and UV++ Blue Control.

There was no statistical significance within a certain power between brands for: UV++Blue Control and Blue Guardian lens (−2.00 D), UV++Blue Control and Blue Guardian lens (+2.00 D), Blue Control and SeeCoat Blue UV lens (+2.00 D), Blue Guardian and Crizal Prevencia lens (+2.00 D), UV++Blue Control and Crizal Prevencia lens (+2.00 D), SeeCoat Blue UV and Blue Control (Plano), and Blue Guardian and Crizal Prevencia lens (Plano). There was a difference measured with the other BBLs.

When the researchers focused on 440 nm as a means of evaluating retinal damage, they found that Blu-OLP and Crizal Prevencia reduced transmittance by 62-80 percent. Crizal Prevencia had a higher whiteness index (i.e., appeared clearer) than Blue-OLP. At all powers, the Crizal Prevencia transmitted wavelengths just below 400 nm, whereas Blue-OLP's transmittance began right after 400 nm. One could hypothesize that the Crizal lens allowed for more melatonin activation than the other lenses.

The authors were careful to recognize that multiple factors go into blue-light exposure, including the physical set-up of the frames, back reflection, how often they are worn, and an individual's reaction. This study was done to propose theoretical connections as well as empirical measurements for current lenses on the market, but the benefits have yet to be proven clinically.

Blue-Light Filtering Spectacle Lenses: Optical and Clinical Performances

Leung TW, Li RW, Kee C. PLoS ONE 12(1):e0169114. doi:10.1371/journal.pone.0169114

Societal changes in type and duration of light exposure have prompted researchers and clinicians to examine the impact that light has on our visual system. Of particular interest, blue light (400-500 nm) has received attention due to its connection with circadian rhythm, mood regulation, retinal damage, and cognition. Retinal damage from cumulative short-wavelength exposure has been linked in vitro to the progression of macular degeneration. While theoretically harmful, blue light is also appearing necessary for daily function.

The researchers conducted two studies. The first evaluated the spectral transmittance of 5 commercial blue-blocking lenses (BlueControl—Hoya, Japan; BlueProtect—Zeiss, Germany; Crizal Prevencia—Essilor, France; StressFree and Noflex—Swiss Lens, Hong Kong) and calculated the relative changes in phototoxicity, scotopic sensitivity, and melatonin suppression using theoretical models. The second study tested the function of two of these lenses (StressFree and Noflex) in a pseudo-randomized controlled study of 80 computer users. Researchers tested color vision, contrast sensitivity, night vision, and sleep quality of the participants after wearing blue-light filtering lenses for one month.

For the first study, the researchers measured transmittance using a spectrometer and evaluated changes in phototoxicity/hazard, scotopic sensitivity, and melatonin suppression using ophthalmic optics standard equations. They evaluated the AR coating for reflectance and the material's ability to absorb blue light. All of the lenses almost completely blocked UVA, UVB, and near UV (380-400 nm). BlueControl, BlueProtect, Crizal Prevencia, and StressFree reduced blue-light transmission mainly by surface coatings. Noflex had a regular anti-reflection coating on the front surface and reduced blue light transmission through absorption. In summary, blue-light filtering spectacle lenses theoretically reduced the calculated phototoxicity by 10.6%-23.6%. Light sensitivity under a dark environment reduced by 2.4%-7.5% and caused a small decrease in melatonin suppression efficiency of 5.8%-15%.

The second study used 80 subjects and divided them into young adults (18-35 years) and middle-aged adults (38-40 years) since it is accepted that visual function naturally declines in middle age. Wearing one of the three lenses, subjects were given the Mars contrast sensitivity test and Farnsworth Munsell 100-hue test. For the next month, the subjects wore lenses for at least two hours during the day. Upon returning, night vision quality and sleep quality were assessed subjectively using a Likert-scaled questionnaire, after which subjetcs were asked for their preferred lens.

All of the tested blue-light filtering spectacle lenses theoretically reduced calculated phototoxicity by 10.6% to 23.6%. Although the use of blue-light filters also decreased scotopic sensitivity by 2.4% to 9.6% and melatonin suppression by 5.8% to 15.0%, over 70% of the participants could not detect these optical changes.

As for the second study, the eighty participants saw no significant impact on contrast sensitivity with glare/no glare or color vision. Older adults predictably had lower contrast sensitivity scores when compared to younger participants. No significant difference was found in sleep quality; however, young participants reported problems with color contrast, color discrimination, and lens appearance.

Overall, the protective effect of blue-blocking lenses remains theoretical. However, the lenses in this study successfully blocked blue wavelengths but did not subjectively decrease visual performance and sleep quality. The authors note that the lenses were only worn for limited hours during the day, and retinal disease, particularly age-related macular degeneration, is multifactorial and not a focus of this study. Additionally, subjective reports are not the most reliable way to evaluate sleep quality. The value in this paper lies in the technical analysis and comparisons of the various BBLs on the market, as well as some of the subjective feedback of the participants. The use of BBLs as a protective measure still needs to be clinically evaluated before being marketed.

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Lyons K. Review of the literature: The impact of blue light. Optom Vis Perf 2021;9(2):115-9.