BLOCKING BLUE LIGHT

by

Nikolas Atleski
Luis Balderas

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Nikolas Atleski
Luis Balderas

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APPROVED:

[redacted]

Faculty Advisor:

ACCEPTED:

[redacted]

Faculty Course Supervisor

Ferris State University
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Blocking Blue Light

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ABSTRACT

Background: Blue light and its negative effects have become increasingly more known to the public, and in response many manufactures have developed various products. Research has found that short wavelengths impact many physiological functions in the body, but can also cause toxicity to retinal tissues. Finding the right product that fits the patient's needs and is effective proves difficult for providers. The aim of this project is to compare the effectiveness of various products to filter short wavelength blue, violet, and ultraviolet light, so that patients and providers can pick the most appropriate treatment.

Methods: Using a spectrophotometer, light transmission through various eyeglass lens materials and blue light filtering products was measured. A 2014 MacBook Air 13" laptop with an LED display screen at a 40 cm testing distance was used as the measured light source. The percent reduction of light transmission was compared among the various filters. The light transmission of specifically blue light relative to overall wavelength filtration was also compared.

Results: All of the lenses give some sort of reduction on the peak blue light radiance transmission, ranging from 14.40% to 54.09% reduction. The computer display software program filtered the most blue light with a 83.66% reduction. Relative to the overall color filtration, the blue-blocking specific products filtered blue light more than the standard lens materials.

Conclusion: The importance of the data collected from this project is that it provides examiners and patients the ability to easily compare what products can reduce blue

light with measured values. This allows providers to confidently prescribe their patients a product that filters varying amounts of blue light based on their everyday needs.

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CHAPTER 1

INTRODUCTION OF BLOCKING BLUE LIGHT

There has been well supported evidence showing the potentially adverse effects of "blue light" wavelength light exposure to eyes, including melatonin suppression and effects on circadian rhythm and photochemical injury at the level of the retinal pigmented epithelium (1,2). Furthermore, the American Academy of Pediatrics has recently (October, 2016) released new guidelines and recommendations for screen time use in adolescence, claiming a reduction in quality of sleep from overexposure (3). In an age of rapidly growing personal technology use with mobile phones, tablets, and computers there has been a complimentary increase in blue-blocking technology development and advertisement. Vendors and manufactures make claims about the beneficial value of their products, but how much value do those claims have and what should eye providers know so that recommendations can be made? And what should patients know about blue light and its effect on the eye and body? This study explored blue-blocking abilities of various ophthalmic lenses, blue-blocking lens coatings, and a software based screen filter combined with a blue light emitting device and correlated the data to research in the area to assist eye care providers and patients to better understand blue light.

CHAPTER 2

METHODS OF BLOCKING BLUE LIGHT

The light source used was a 2014 MacBook Air 13" laptop with an LED display screen set to maximum brightness. A blank Microsoft PowerPoint slide was displayed full screen to give a white light source. The laptop was set on a black surfaced table, perpendicular to the spectrophotometer located 40cm from the screen for all measurements. Ambient room light was minimized as much as possible with all window shades closed and overhead lighting turned off.

Standard eyeglass lens blanks of various materials and specific blue-blocking products were tested to analyze wavelength filtration effectiveness. Lenses were placed within 10mm in front of the aperture of the spectrophotometer. The eleven lenses tested include the following: crown glass, CR-39, CR-39 with RLX coating, polycarbonate, polycarbonate with photochromic and XTC, trivex, 1.74 high-index, Crizal UV AR, Crizal Prevencia, BluTech, and Gunnar (See appendix for additional information on materials tested).

Additionally, a computer software display filter called "F.Lux" was tested. F.lux (pronounced "flux" according to justgetflux.com) is a computer program that adjusts a display screen's color temperature profile based on the time of the day. It reduces blue light exposure by creating a warm color filter at the end of the day with the goal being to reduce eye strain and prevent sleep pattern disruptions. It is available to download across several different computer platforms.

Wavelength and radiance were measured with a spectrophotometer (Sekonic C-700 SpectroMaster) using a CMOS linear image sensor with a wavelength range of 380-780 nm. The spectrophotometer was calibrated to default for the ambient lighting of the darkened room. Each lens was tested by being placed over the spectrophotometer's sensory unit 40 cm from the MacBook display light source. The spectrophotometer's sensory unit was held 16.51 cm above the table's surface so that the unit faced the center of the display screen. The F.Lux display filtering software on the MacBook was also tested at the 40 cm test distance, and was set to the 2300K preset in the filter setting. The MacBook display light source was also measured without any lens filters to serve as a comparative baseline.

Data collection was performed on August 15th, 2016 and the data was plotted using the spectrophotometer's built in software. We selected the peak wavelength for blue light by determining the highest spectral irradiance measured between 415-460nm. We then used the value for each material and divided it by the baseline spectral irradiance measured with no lenses to determine the percent reduction each lens had in the respective wavelengths.

CHAPTER 3

RESULTS OF BLOCKING BLUE LIGHT

Without any filters at 40 cm, the MacBook light source baseline gave an irradiance of 2.57[mW·m-2·nm-1] at the blue peak (450nm). Irradiance was 1.36[mW·m-2·nm-1] at the green peak (530nm) and 1.32[mW·m-2·nm-1] at the red peak (593nm).

All of the lenses give some sort of reduction on the peak blue light radiance transmission, ranging from 14.40% to 54.09% reduction. The Gunnar lenses gave the greatest reduction at 54.09%. The software product F.lux reduced the blue light emission more than any of the lenses with 83.66% reduction. The greatest reduction from a non-blue light specific product came from the standard CR-39 lens with 39.30%. The BluTech lenses designed specifically to filter blue light reduced blue light radiance transmission by 19.23%, second lowest only to standard Crown glass, with the other non-blue specific lens materials each providing greater reduction.

When comparing the amount of blue light reduction compared to overall light reduction averaged across all three wavelengths, most of the standard lenses did not limit blue light explicitly more than the green or red light. The blue blocking specific products did show greater blue filtering relative to the entire spectrum. Compared to the overall light filtering average across all three colors, Crizal Prevencia filtered blue light 1.13x, BluTech filtered 1.74x, Gunnar filtered 1.39x, and F.lux filtered 1.40x.

Table 1 of Materials with Respective Blue Wavelength Spectral Irradiance Readings

Material	Wavelength with peak spectral irradiance [nm]	Spectral irradiance[mW·m-2·nm-1]
Macbook @ 40cm	450	2.57
Crown Glass	450	2.2
CR-39	450	1.56
CR-39 w/ RLX coating	450	1.9
Polycarboante	450	1.95
Poly w/ Photochromic and XTC AR	450	1.8
Trivex	452	1.7
High index 1.74	450	1.75
Crizal UV AR	450	1.9
Crizal Prevencia	450	1.6
BluTech Lenses	450	2.1
Gunnar Lenses	452	1.18
Macbook w/ F.lux	450	0.42

Table 1: Table categorizing blue wavelength spectral intensity readings measured at the wavelength with the highest irradiance readings.

Table 2 of Materials with Respective Green Wavelength Spectral Irradiance Readings

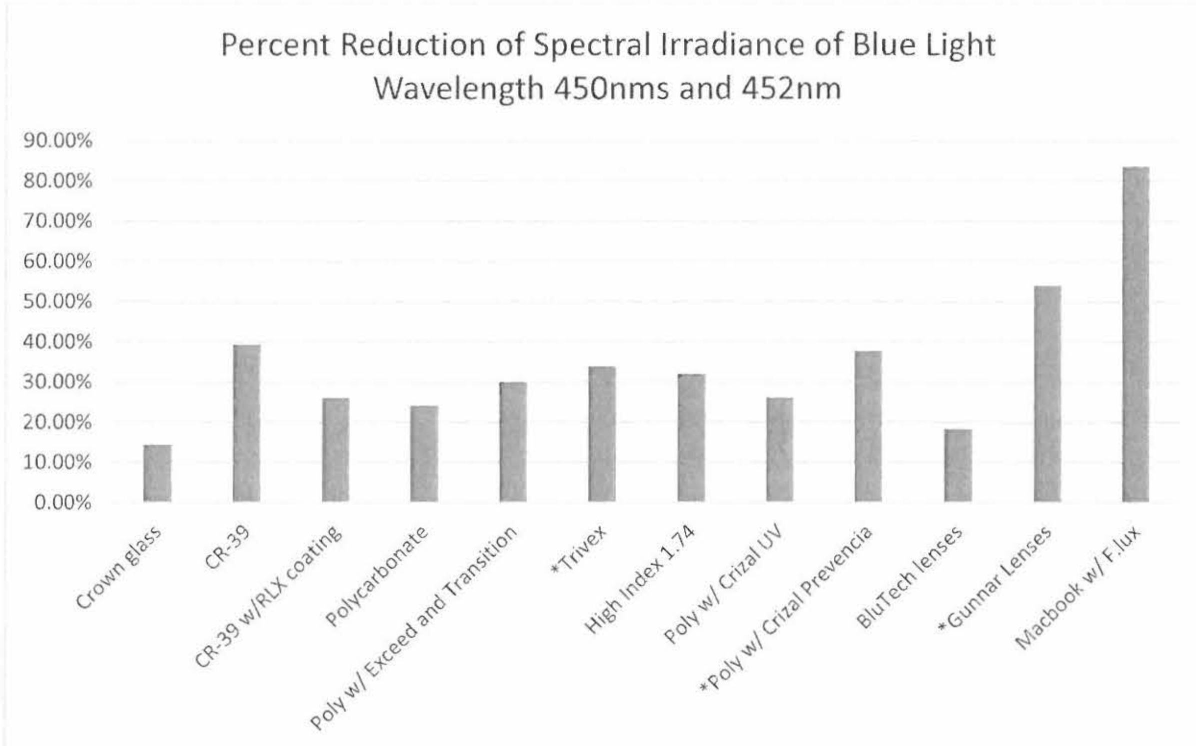
Material	Wavelength with peak spectral irradiance [nm]	Spectral irradiance[mW·m-2·nm-1]
Macbook @ 40cm	530	1.36
Crown Glass	530	1.07
CR-39	530	0.84
CR-39 w/ RLX coating	530	0.94
Polycarboante	532	0.99
Poly w/ Photochromic and XTC AR	530	0.87
Trivex	530	0.89
High index 1.74	528	0.82
Crizal UV AR	530	0.97
Crizal Prevencia	530	0.94
BluTech Lenses	530	1.21
Gunnar Lenses	530	0.91
Macbook w/ F.lux	530	0.36

Table 2: Table categorizing green wavelength spectral intensity readings measured at the wavelength with the highest irradiance readings.

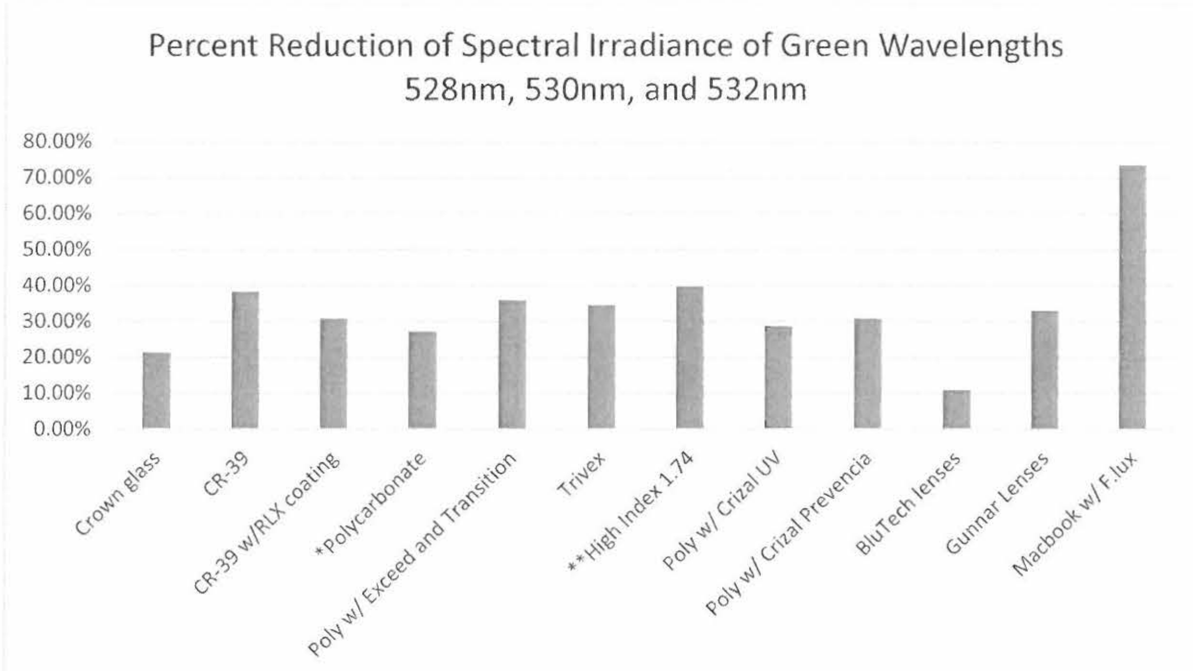
Table of Materials with Respective Red Wavelength Spectral Irradiance Readings

Material	Wavelength with peak spectral irradiance [nm]	Spectral irradiance[mW·m-2·nm-1]
Macbook @ 40cm	593	1.32
Crown Glass	593	1.05
CR-39	593	0.79
CR-39 w/ RLX coating	593	0.91
Polycarboante	593	0.91
Poly w/ Photochromic and XTC AR	593	0.83
Trivex	593	0.85
High index 1.74	593	0.79
Crizal UV AR	593	0.91
Crizal Prevencia	593	0.91
BluTech Lenses	593	1.29
Gunnar Lenses	593	0.93
Macbook w/ F.lux	595	1.03

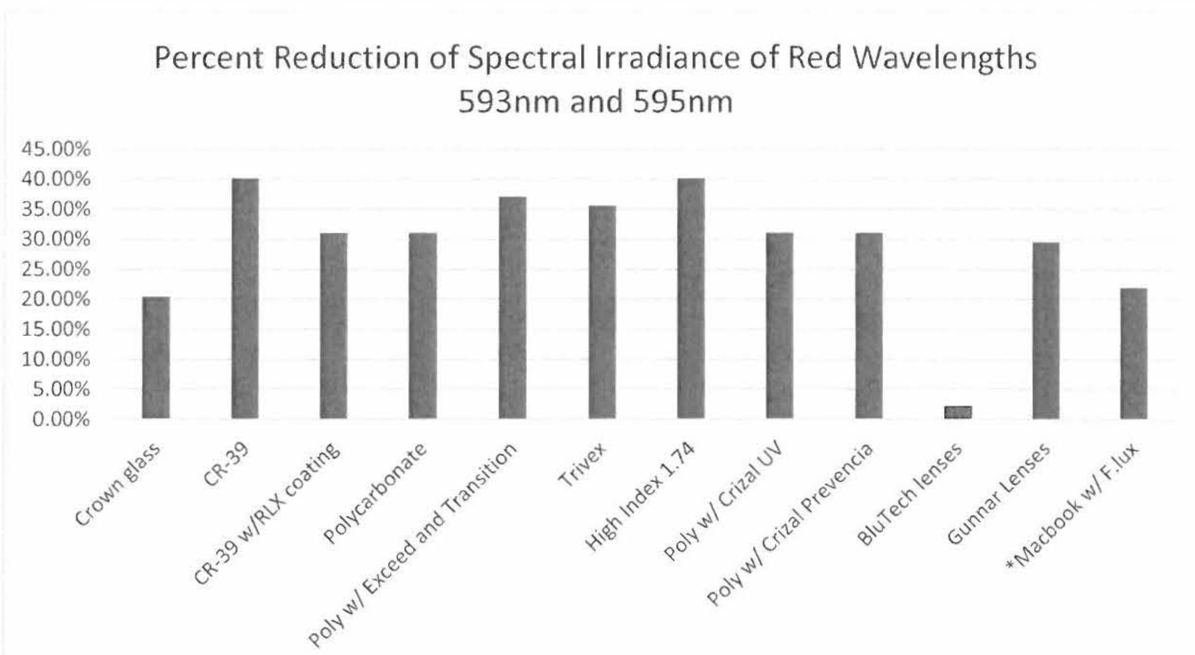
Table 3: Table categorizing red wavelength spectral intensity readings measured at the wavelength with the highest irradiance readings.



Graph 1: Graph showing the percent reduction of spectral irradiance for each material measured at the wavelength with peak irradiance. (* indicates a wavelength of 452 that gave peak irradiance)



Graph 2: Graph showing the percent reduction of spectral irradiance for each material measured at the wavelength with peak irradiance. (* indicates a wavelength of 532 that gave a peak irradiance, ** indicates a wavelength of 528 that gave a peak irradiance)



Graph 3: Graph showing the percent reduction of spectral irradiance for each material measured at the wavelength with peak irradiance. (* indicates a wavelength of 595 that gave a peak irradiance)

CHAPTER 4

DISCUSSION OF BLOCKING BLUE LIGHT

Our data shows that all manner of ophthalmic lenses along with blue blocking lenses have measurable and significant abilities to reduce the spectral irradiance emitted from a LED light source. Even the material with the least ability to reduced irradiance managed to reduce blue wavelengths by 14%, while the material with the best reducing ability cut down irradiance by 54%.

The data comparing blue light reduction to the red and green light reduction showed that the blue blocking specific products did in fact do a good job at specifically filtering out blue light relative to the other color wavelengths. The standard products do filter blue light, but not extensively more than the red and green light. BluTech actually filtered the blue light most relatively compared to green and red light (1.74x), even though it did not filter most blue light overall. By allowing greater transmission of red and green light it makes the amount of blue light filtered by comparison seem like more.

Although that the data was all measured at 40 centimeters, we found that the wide variety of personal devices on the market had varying working distances and that 40 centimeters was the distance that most closely mimicked the average working distance of device interfaces. Yet, using the equation: $E = \Phi/4\pi r^2$, where E = Radiant power upon a surface, Φ = radiant power of the source, and r = distance from the source, we can assume that as you decrease the working distance the amount of radiant power increases and likewise, as the working distance increases there is a reduction in the amount of radiant power(4). As technological advancements continue to transform the way we interact with data and the world around us, there is a respective increase in the amount of time we spend exposing ourselves to screens and artificial light.

Numerous studies and experiments have been performed to understand what affect short wavelength light has on our health. Most notably is the effect screen exposure has on our circadian rhythm or ability to maintain regular sleep cycles. Although there has been some debate about if the light levels produced by screens is enough to cause any effect on human physiology, a study by Cajochen et al. (5) showed that even low-level light exposure from screens had an effect on salivary melatonin levels and subjective sleepiness. Furthermore, a study by Van der Lely et al. (6) found that the use of lenses with blue blocking capabilities was able to reduce the amount of melatonin suppression in adolescent teenagers after exposure to LED screens. Sasserville et al. (7) demonstrated a similar result with his study using short 1 hour exposures to blue light using blue blocking lenses versus a grey tinted lens. Their study found that filtering out specific wavelengths in the blue spectrum had a significant effect in preventing melatonin suppression compared to the grey lens which reduced the spectral intensity evenly across all wavelengths. Given the findings of previous studies and the data we collected during our experiment, filtering short wavelengths appears to be beneficial in reducing melatonin suppression caused by LED screen use, and furthermore, lenses that filter more specifically in the shorter wavelength spectrum can be more effective in preventing that suppression.

Blue wavelength light has also been shown to cause changes at the cellular level within the retina, specifically the retinal pigment epithelium (RPE). The RPE is essential to normal visual function as it plays a key role in the metabolic function of the photoreceptor cells. When this layer is disrupted, accumulations of a material called lipofuscin can build up in abnormal quantities. Lipofuscin and its components have been hypothesized to cause various retinal degenerations such as age related macular degeneration (AMD). A study by van der Burght et al. (2) tested one specific photoreactive molecule (A2E) found in lipofuscin combined with blue light exposure at 430nm wavelength. Their study concluded that when RPE cells with A2E were exposed to short wavelength light (430nm) there was measurable cell death recorded, and that the longer the exposure the greater numbers of non-viable cells were found. Yet, the study mentions that findings were done *in vitro* and that there may be different interactions and expression of genes that should be explored with an *in vivo* study. Thus, it is difficult to say if our data can definitively say one product can prevent RPE changes over another lens based purely on spectral irradiance reduction.

In conclusion, we find that all manner of lenses can cause changes in the transmission of light. While it is hard to say if they offer any beneficial value in protecting our retinal health, studies have shown that reducing blue light transmission and intensity can be beneficial for normal sleep cycles. Our study is limited to one type of LED screen and testing distance, and simply measured only changes in spectral irradiance. Therefore, future studies with human subjects using different types of ophthalmic lenses and blue-blocking products could be beneficial in understanding the direct effect each medium has on our physiology. Furthermore, we need to have a better understanding of the effect that exposure, intensity, and duration have on our physiology before making recommendations of "safe" levels.

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PRODUCT INFROMATION

*Nonfinancial disclosure: There was no financial compensation awarded in this study. The products tested in this study are only for research purposes and any conclusions drawn from this study are strictly objective observations. The products tested were not evaluated for sake of promoting or undermining any particular goods or services.

1. MacBook Air: https://support.apple.com/kb/sp700?locale=en_US
2. Exceed: mid-level A/R coating by Harbor Opitcal, http://www.aabeer.com/?page_id=83
3. Crizal UV products: http://www.crizalusa.com/content/crizal/us/en/ecp-tools-information/lenses.html
4. Crizal Prevencia: http://www.crizalusa.com/content/crizal/us/en/Prevencia.html
5. Transitions: http://trade.transitions.com/resources/public/10004/2016-availability%20guide-Final.pdf
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7. Gunnar lenses: https://gunnar.com/lens-technology/#bluelightsection
8. f.lux: https://justgetflux.com/