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Blue Light And Eye Health: A Study Of The Characteristics Of The Color Blue In The Light Spectrum And Its Significance In Eye Strain

(Chapter 2-3)

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Chapter 2: Review of Related Literature

Blue Light Properties

To better understand the properties of blue light and how it is related to eye strain, we must review the nature and the representation of visible colors in the light spectrum. According to Wong & Bahmani (2022), the visible spectrum has wavelengths between 400 and 700 nm (nm). The frequency (Hz; Hertz) and photon energy (eV; electronvolt) of light decrease with increasing wavelength. Among the colors in the visible spectrum that is considered to have the highest energy band, which spans from 380 to 500 nm, is blue light, with blue-violet (380 to 450 nm) being a high-energy violet (Cougnard-Gregoire et al, 2023). This is why different colors in the light spectrum can be determined by examining a particular wavelength and frequency of the electromagnetic wave.

Blue light can be produced either through natural or artificial means, and each source follows a different condition when it comes to intensity and nature. For solar blue light, its intensity greatly varies depending on certain factors; such as certain time of day (noon being the highest blue-light intensity); latitude, altitude, meteorological conditions, and season (Cougnard-Gregoire et al, 2023). Aside from sunlight as the source of blue light, nowadays blue light can also be produced by artificial light sources. According to Wong & Bahmani (2022), artificial light sources such as light emitting diodes (LEDS) generate a small wavelength spectrum, as opposed to phosphor emission spectrum. Moreover, Wong and Bahmani (2022) also stated in their article that blue-LED is commonly used alongside with yellow phosphor to produce polychromatic “white” LEDs, making digital screens appear white with a wavelength that is within the blue portion of the electromagnetic spectrum.

Understanding the electromagnetic spectrum of visible light can help us understand how certain wavelengths affect the eye, and in this case, how blue light and its properties when exposed to a certain amount of time. According to Cougnard-Gregoire et al. (2023), the retina in the eye receives all of the spectrum of sunlight, including blue light, as well as any artificial light source. Through visual and nonvisual processes, the retina transmits environmental information to the brain. Moreover, due to having shorter wavelength and higher frequency, blue light can easily pass through the eye, penetrating through the vitreous humor to the retina (Wong & Bahmani, 2022). Because of this, artificial light sources that emit blue light, such as LEDs, have been a main concern in recent years due to its potential to cause photochemical damage to both the retina and retinal pigment epithelium of the human eye (Hatori et al., 2017). Thus, long exposure to blue light is one of the factors that contributes to numerous eye diseases, particularly digital eye strain.

Digital Eye Strain

As the usage of digital screen devices has increased throughout the 21st century, numerous studies about eye health and prolonged exposure to screens have emerged, and its topic of interest are mainly about Digital Eye Strains and its effects on the human body.

The year 2019 was considered as the peak of the Covid-19 pandemic, and the majority of the countries declared nationwide lockdowns to combat the spread of the SARS-COV-2 virus. Because of the limited access to the outside environment during the pandemic, there has been a significant increase of screen device usage daily. A research study conducted by Ophthalmol (2021) shows that the usage of digital devices has significantly increased from pre-COVID 1.9 ± 1.1 hours ($P = <0.0001$) to 3.9 ± 1.9 hours in the COVID-19. However, some studies argued that the increase of digital screen devices spent by users was already prevalent even before the Covid-19 pandemic. In a research article written by Sheppard and Wolffsohn (2018), they found that by the age of three, 68% of children in Europe have begun regularly using a computer, and 54% engage in online activities. And in 2016 it was estimated that adults in the UK use digital media for four hours and forty-five minutes a day on average, based on a multinational study.

Due to the growth of digital device usage in education, work, or leisure, more people from all ages are now vulnerable to developing digital eye strain, dry eyes, and other screen related eye conditions. And individuals who used two or more devices concurrently were more likely to report DES than those who only used one device at a time, with prevalence of 75% and 53%, respectively (Sheppard and Wolffsohn, 2018). Similarly, results from a large-scale Japanese study with 102,582 participants ages from 40 to 74 years old shows males that spend more than or equal to 5 hours of screen exposure per day obtained a higher chance of acquiring Dry Eye disease (22.3%) while females having a similar chances of acquiring said eye disease (36.6%) compared to individuals who spent less than one hour of device usage daily (16.1% for males and 26.5% for females) (Mehra & Galor, 2020).

Digital eye strain can manifest into multiple symptoms, as numerous research studies suggest. An article about Computer Vision Syndrome, another term for digital eye strain, states that an individual affected by CVS can manifest the common symptoms which include dryness, irritation, sensations of burning, asthenopia, epiphora, hyperemia, blurred vision, diplopia, glare sensitivity, and transient deceptions in color perception (Parihar et al., 2016). Similarly, results from a study conducted by Usgaonkar et al. (2021) reported that an increase of digital device use can lead to ocular symptoms such as watering eyes, dry eyes, itching eyes, and pain behind the eyes as well as muscular pains in the shoulders and back.

Blue Light In The Perspective Of Causing Eye Strain

Eye strain can be caused by many things (Mayo Clinic, 2018). One combination of causes is bright lights and prolonged focus, both of which are associated with increased screen usage, and by extension increased blue light exposure. However because of these combinations of causes, it is difficult to determine the effect of blue light itself on causing digital eye strain.

While blue light, especially in high intensity doses, has been proven to cause damage to the eye (HAM et al., 1976). However, these results do not map on to the common blue light experienced through nature or screens.

Some studies do recommend using blue light or blue filtering glasses as a method to manage digital eye strain (Alabdulkader, 2021). But this is along with other more impactful management tools such as controlling brightness, and avoiding and limiting blue light exposure entirely. It is also important to note that ophthalmologists may have a conflict of interest in recommending blue light glasses to clients as they stand to gain directly from both its sale and its rise in popularity.

The Effectiveness of Blue Light Glasses

The blue light glasses market is expected to grow significantly in 2022 and 2027 (TheExpressWire, 2022). However that growth is directly connected to growing concerns about eye health in the face of screens. That concern is, however, unfounded in most academic circles. Blue light, particularly from screens, do not generate enough low wavelength light at a bright enough (O'Hagan et al., 2016). O'Hagan, Khazova, and Price's results show that even in extreme cases, such as looking at a bright blue-light emitting HDMI monitor at around 100mm does not generally cause concern. Their methodology showed that in such extreme and unlikely cases, it would still take more than 60 minutes of continuous viewing to cause significant damage to the eye.

A study by Palavets & Rosenfield (2019) has also shown that extreme blue light glasses, those that prevent 99% of blue light, have shown a non-significant effect on eye strain. In contrast, regular blue-light glasses block on average, 10-20% percent of blue light (May, 2022). From this, the effectiveness of blue light glasses in relation to eye strain may not be as significant as marketing would lead you to believe.

Blue Lights Effect on Sleep

According to a study done by Guarana et al., (2020), blue light does affect the circadian rhythm of those exposed to it. Primarily, it delays a person's natural sleep time causing lower sleep quantity and quality. This effect has also been linked with the habits that produce blue light such as late night phone usage, which does correlate with a lower sleep quality (Jniene et al., 2019).

Blue light blocking glasses have also been shown to increase sleep quantity and quality, specifically when used to counteract night time exposure in working adults (Janků et al., 2019). This finding, as well as many others (Nagai et al., 2019) agrees with blue lights' negative effects on human sleep cycles.

However those negative effects are specifically for blue light exposure during the night, as during the day blue light is healthy and important to human processes such as alertness and cognitive performance (Wahl et al., 2019). This, combined with usage of screens in the night, could mean that the effect of blue light on sleep is not as significant due to the difficulty of isolating the variables in this type of experiment. Some studies however, have also shown inconclusive results when testing the effects of blue light glasses on sleep and eye strain (Singh et al., 2023).

Chapter 3: Review of Related Literature

The method for conducting this research study was done by utilizing research articles sites such as Google Scholar and the National Library of Medicine MEDLINE database using a PubMed search to articles related to the research objectives. The keywords used are the following: “blue light”, “blue light properties, ", "eye strain”, “blue light effects”. After selecting the appropriate articles for this study, the articles are then analyzed and synthesized based on the objectives of this research paper.

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