



# Eyesafe® Display Requirement

## Blue Light Management and Color Performance for Display Manufacturers

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# Eyesafe® Standard for Display Devices

## Blue Light Management and Color Performance for Device Display Manufacturers

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*This guidance represents the current assessment of Eyesafe and the Vision Health Advisory Board on this topic. It does not establish any rights for any person and is not binding on Eyesafe or the public. You can use an alternative approach if it satisfies the requirements of the applicable statutes and regulations. From time to time, this Standard will be updated based upon guiding research and the latest information.*

### **1. Purpose**

This document summarizes measurement methods and defines criteria to certify a display product including smartphones, tablets, notebook and desktop computers, commercial displays, and televisions, as Eyesafe.

The device in question would be a display module (e.g. smartphone, tablet) or a display module having a certain level of blue light emission and color performance requirements, herein referred to as “Eyesafe Requirements”. Passing the proposed criteria would lead to a certification according to quality characteristics to be identified as “Eyesafe”.

With the emergence of light-emitting diodes (LEDs) and organic light-emitting diodes (OLEDs) technology, and its increasing use in electronic display products, public interest and concern about blue light has increased. Additionally, with daily screen time continuing to increase and close-up use of devices occurring at all times during the day<sup>1-3</sup>, users are being exposed to increasing amounts of high-energy blue light from their devices.

Current digital devices deliver higher levels of blue light to the retina than do conventional domestic light sources, causing the public to be exposed to greater levels of high-energy visible (HEV) blue light than ever before. Long-term health implications are now being studied, but eye strain and other immediate effects of display use affect people daily.

Recent studies have shown growing concerns over potential long-term eye health impacts from digital screen usage and cumulative blue light exposure<sup>4-6</sup>, in addition to recognized impacts of device use on circadian rhythms and sleep patterns<sup>7-11</sup>. Blue light exposure research and studies on animals' cells have shown that blue light in a range of 415 to 455 nm generated the greatest phototoxic risk to retinal pigment epithelium cells<sup>6,12,13</sup>, with photoreceptor cell apoptosis seen early after the retina is damaged by blue light<sup>5,6,13</sup>.

Several international standards have been published to quantify blue light radiation levels to humans. ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines on limits of exposure to broadband incoherent optical radiation (380 to 700 nm)<sup>14</sup> provide a spectral weighting function  $B(\lambda)$  for retinal blue light hazard. This standard will cover 300 to 780 nm to realistically oversee all optical hazards in this spectral area.

The Eyesafe standard identifies the amount of blue light emitted from displays within the range from 415 to 455 nm and evaluates the color accuracy of the display.

The Eyesafe standard measures the level of blue light based on the spectral weighting factors for blue-light hazard as published by the ICNIRP in 2013 and adopted by the American National Standard Institute (ANSI)<sup>15</sup> in 2015.

The purpose of this certification is to show to the end user that the product design provides partial reduction (not complete elimination) of blue light exposure in certain wavelength ranges and meanwhile ensures front of screen performance, including color range and correlated color temperature (CCT).

The enclosed Eyesafe standard includes non-binding industry recommendations. From time to time, Eyesafe may adjust the Eyesafe standard to reflect new guiding research and the latest available information.

## 2. Scope

The Eyesafe standard is intended primarily for electronic products with displays that typically emit visible radiation in the range of 380 to 780 nm. Examples of these products include (but are not limited to): computer monitors, and flat-panel displays, notebook computers, tablet PCs, e-book readers, smartphones, televisions, and commercial point-of-sale (POS) displays.

## 3. Background

### 3.1 Human vision, light and display technology

#### 3.1.1 Human vision system development

##### *i - The sunlight spectrum*

The human visual system is primarily structured to receive and process natural light (sunlight). Each part of the eye receives and absorbs various amounts of sunlight energy. The human eye over time has become well equipped to process a wide spectrum of sunlight wavelengths under various bright and dim levels of illumination.

##### *ii – What we should know about blue light*

Light is made up of electromagnetic particles called photons that travel in waves. The wavelengths of visible and non-visible light are measured in nanometers (nm). In general, the shorter the wavelength, the higher the energy. Visible light is just a small portion of what's called the electromagnetic spectrum, which includes ultraviolet (UV) rays, x-rays, infrared radiation, microwaves, and other types of radiation.

Blue light, also known as high-energy visible (HEV) light, is the portion of the visible light spectrum that has the shortest wavelengths and therefore the highest amount of energy. The entire visible light spectrum comprises electromagnetic radiation with wavelengths ranging from 380 to 780 nm. Blue light is visible light with wavelengths ranging from 400 to 500 nm.

Because of its higher energy, blue light has greater potential than other wavelengths of visible light to cause harm to tissues of the eye. <sup>16-18</sup>

##### *iii – Visible and non-visible light*

Only the visible light spectrum — electromagnetic radiation with wavelengths ranging from 380 to 780 nm — is perceived by the human eye.

Ultraviolet (UV) radiation is adjacent to high-energy visible blue light on the electromagnetic spectrum. UV rays have shorter wavelengths (100 to 380 nm) and greater energy than visible blue light. Ultraviolet radiation sometimes is called “UV light,” but UV rays are invisible to the human eye.

Most UV radiation is absorbed by the atmosphere and does not reach the Earth's surface. However, longer-wavelength UV rays — especially the UVA range (315 to 380 nm) — does reach our eyes. Most UVA is absorbed by the cornea, lens and other structures of the eye, but some longer UVA rays can penetrate the eye and reach the light-sensitive retina at the back of the eye.

<sup>12, 19</sup>

The Eyesafe standard specifically addresses high-energy visible blue light (400 to 500 nm). Invisible UV radiation is beyond the scope of the standard.

### **3.1.2 Artificial lighting vs. natural lighting**

Natural light comprises a wide array of colors whose intensities and hues vary throughout the day.

LED and OLED-based artificial lighting and LCD backlight systems contain high energy blue light (400 to 500 nm), in a light spectrum that is mostly static. Our physiology is naturally better adapted to the dynamic spectrum of natural sunlight than to artificial lighting that constantly is emitting high levels of blue light.

Research has demonstrated that acute exposure to intense blue light causes photochemical damage (“phototoxic effects”) to retinal cell physiology, and potential harmful effects of cumulative exposure to HEV blue light may cause premature aging of the retina, according to some sources <sup>5, 7, 20</sup>.

Also, exposure to blue light in the evening and near bedtime from even low-level sources has been linked to sleep disruption and circadian rhythm changes that have been associated with multiple health problems <sup>7, 20</sup>.

Therefore, a major concern is how best to protect eye health and systemic health by optimizing the spectral distribution of display lighting and simulating the periodical changes of natural light.

### **3.1.3 Display technology development**

Display technology has accelerated dramatically in recent years. From CRT to CCFL, LCD, LED, and OLED, displays are becoming brighter and the concentration of HEV light has increased. Potential health issues from increased blue light exposure is especially concerning for children and adolescents, who typically spend many hours each day staring at display screens and whose eyes and bodies are still developing <sup>3, 4</sup>.

## **3.2. Health and Safety Concerns**

### **3.2.1 Potential dangers of blue light**

While the dangers of overexposure to ultraviolet (UV) radiation have been known for decades, potentially harmful effects of cumulative blue light exposure, have only recently begun to be understood <sup>9, 10, 12, 16, 22, 23</sup>.

To capture the body of medical data that has and continues to be published, Eyesafe has assembled an advisory team of noted optometrists and ophthalmologists that maintain a current awareness of published research and methods for treatment of critical exposures to damaging portions of the color spectrum.

Also, Eyesafe's research and technical teams are continually reviewing and cataloging the latest published research about blue light to offer a clear understanding of which portions of the blue light spectrum have the greatest impact on retinal health, macular degeneration risks, and disruption of human melatonin modulated sleep cycles <sup>24</sup>. For more information please visit [www.eyesafe.com/research](http://www.eyesafe.com/research)

### **3.2.2 Potential damage to vision and health**

A growing number of studies suggest that cumulative exposure to blue light over time could lead to premature eye health issues, among them damage to photoreceptor cells in the retina that may increase risks of vision problems such as age-related macular degeneration <sup>16, 19, 22</sup>.

Recent growing concerns have been expressed in the eye care community over the potential long-term eye and health impacts from digital screen usage and cumulative blue light emitted from digital devices. A combination of factors including viewing distance, frequency and duration of use, physical responses to screen habits, and exposure to blue light, have been reported to cause visual discomfort in 65 percent of Americans <sup>1</sup>.

Exposure to blue light from digital devices has been cited as a contributor to digital eye strain <sup>1, 25-27</sup>, which is characterized by symptoms such as dry eyes, irritated eyes, blurred vision, sleep disruption, fatigue, reduced attention span, irritability, and neck and shoulder pain <sup>25, 26</sup>.

By stimulating retinal ganglion cells, blue light in the 460 to 480 nm wavelength range suppresses melatonin production and therefore plays an important role in alertness, memory, attention span and learning ability, and cognitive performances <sup>22, 25</sup>. Several studies have shown the impact of digital technology on disruption of circadian rhythms in adolescents and adults <sup>7-11, 20</sup>, resulting in reduced duration and quality of sleep, linked to various diseases such as obesity, depression, and possibly cancer <sup>3, 9, 11, 20, 28</sup>.

Recent research has shown that filtering blue light from digital displays before bedtime produced significant positive health benefits among teenagers by curbing the LED-induced melatonin suppression and decreased alertness <sup>29</sup>.

Other studies have shown that blue light filters reduce visual acuity loss among digital device users who have dry eyes and reduce glare and photo-stress associated with prolonged exposure to intense light <sup>28-30</sup>.

### 3.3. Recent Lighting Source Development

Methods used today to create artificial white light or enhancing the color of the lighting to make it pleasing to the eye are very sophisticated. LED and OLED display technology and color-altering phosphors can precisely blend red, green, and blue to very accurate levels.

Two key development trends should be noted:

1. LED light bulbs today are steadily increasing in luminance per watt, and therefore creating intense bright light from very small sources
2. In general, displays are increasing in luminance, with many operating at color temperatures of 7500 K and higher. By comparison, the color temperature of natural sunlight is approximately 5600 K, and indoor light bulbs range from 2700 K (warm hue) to 7500 K (bright cool hue).

These trends are concerning, since there is growing evidence that overexposure to blue light (characterized by higher color temperatures) may have significant vision and health consequences.

## 4. Eyesafe Requirements

Eyesafe<sup>®</sup> requirements focus on HEV blue light that is emitted by digital devices and relies on two photobiological safety standards from the American National Standards Institute <sup>15</sup> to guide its products development: Z80.3-2018 and Z87.1-2015, and the IEC/EN 62471 from the International Electrotechnical Commission, in addition to guiding industry research.

Displays identified and certified Eyesafe<sup>®</sup> should adhere to these guidelines, while maintaining color transmission. As such, solutions must not only manage blue light, but also maintain color transmission and D65 <sup>31</sup> illumination ratings.

Specifically, the following criteria must be met:

- Reduced light emissions in the blue-violet segment of the blue light spectrum (wavelengths of 415 to 455 nm)
- Meet photobiological safety guidelines
- Maintain Color Gamut and CCT requirements values

Reduced light emissions in the 415 to 455 nm range is achieved by integrating the weighting factors from the ANSI Z87.1-2020 Occupational and Educational Personal Eye and Face Protection Devices standard, which identifies a peak blue light hazard factor at 435 to 440 nm. (cf. Table C4. Spectral Weighting Factors for Blue-Light Hazard, p. 38 of the ANSI Z87.1-2020 standard).



Maintaining spectral transmittance of visible light is achieved by following indications from the ANSI Z80.3-2018 Nonprescription Sunglasses and Fashion Eyewear Requirements standard, which includes data for computing blue light transmittance.

The following requirements were developed to assist device manufacturers in effective blue light filtration, color accuracy and adherence to leading industry standards.

Category	Items	Requirements
<b>High energy Blue Light requirement</b>	Blue light emission in the 415 to 455nm toxic region	The ratio of light in the range from 415-455nm compared to 400-500nm must be less than 50%
	Weighted blue light toxicity emissions based on ICNIRP Guidelines	The Blue light toxicity of weighted blue light vs total lux must be less than 0.085 *
<b>Maximum Energy</b>	Photobiological Safety requirement based on IEC/EN 62471	The blue light emission of the product must meet exempt group limits (Must be lower than $100 \text{ W.m}^{-2}.\text{str}^{-1}$ )
<b>Color Performance</b>	Color Gamut Coverage %	The color gamut coverage ratio of each client specified color mode shall meet at least one of the requirements: For product with sRGB color mode: $\geq 95\%$ of standard sRGB color space in CIE 1931. For product with Adobe RGB color mode: $\geq 90\%$ of standard Adobe RGB color space in CIE 1931. For product with DCI-P3 color mode: $\geq 90\%$ of standard DCI-P3 color space in CIE 1931. For product with NTSC color mode: $\geq 72\%$ of standard NTSC color space in CIE 1931 **
	Color Temperature	The Correlated Color Temperature (CCT) shall be within the range of 5500K and 7000K ***

\* Note: Maximum  $\pm 2\%$  deviation to the specified limit is allowed for the mass production

\*\* Note: Maximum  $\pm 5\%$  deviation to the specified limit is allowed for the mass production.

\*\*\* Note: this requirement is only applicable for laptop, monitor and AIO computer.

Eyesafe® Display Certificate will provide a report with collected results data:

- Pass/Fail of low blue light 415-455nm criteria
- Pass/Fail of blue light toxicity scaling criteria based on ICNIRP
- Pass/Fail of photobiological safety classification based on IEC/EN 62471
- Pass/Fail of color gamut percentage
- Pass/Fail based on color temperature (CCT)

Each unique display hardware combination must be tested for certification. Documentation must be supplied to demonstrate this hardware configuration. Eyesafe should be notified of any product specification change. Any such changes will require recertification.

## 5. Testing and Protocols

### 5.1 Setup

The display must be set at 100% brightness level. The standard test image is a white display image and should be loaded to display output for measurement of full visible light emission.

### 5.2 Laboratory condition

Tests are to be performed at an ambient temperature of  $73 \pm 5$  degrees F and humidity range between 30-60 % RH. To decrease error in the measurement, it must be taken under darkroom conditions where ambient light is  $< 1$  Lux.

### 5.3 Measurement equipment

A qualified spectroradiometer (Photo Research PR-655 or similar) will be used to measure light emission from the display by wavelength from 380 to 780 nm for color and visible light intensity measurement from 380 to 780 nm for all display types with at least accuracy of  $\pm 0.002$  or higher in CIE 1931 x, y and luminance accuracy of  $\pm 5\%$  or higher from 100 to 5000  $\text{cd}/\text{m}^2$ .

### 5.4 Recording

The following items should be recorded:

- Emission spectrum values between 380 to 780 nm of the display when set at the maximum level of red, green and blue as well as the measurement of the white point at full brightness.
- The calculated x, y coordinates for the spectrum measurement of red, green, blue and white point
- The CCT of the white point of the display for the above spectrum measurement

## 5.5 Calculation of Blue light ratio requirements

The ratio of display emission light in the range from 415-455 nm to the display emission of 400-500 nm shall be less than 50%.

$$\text{Blue light ratio} = \frac{\int_{415}^{455} L(\lambda) \cdot d\lambda}{\int_{400}^{500} L(\lambda) \cdot d\lambda}$$

In which:

$L(\lambda)$ : spectral radiance in  $\mu\text{W}\cdot\text{cm}^{-2}\cdot\text{nm}^{-1}$

$d\lambda = 1 \text{ nm}$

## 5.6 Calculation of Blue light toxicity

Data from spectral power distribution (SPD), over the range 380-780 nm and with an increment of 1 nm is preferably used for the calculation of the blue light toxicity-

Blue Light Toxicity Factor (BLTF) is a weighted hazardous blue ratio compared to display luminance calculated according to the toxicity weighting function  $B(\lambda)$ . Blue light toxicity factor vs. total lux must be less than 0.085.

$$\text{BLTF} = \frac{100}{683} \times \frac{\int_{380}^{780} L(\lambda) \times B(\lambda) \times d\lambda}{\int_{380}^{780} L(\lambda) \times \bar{Y}(\lambda) \times d\lambda}$$

In which:

$d\lambda = 1 \text{ nm}$

$L(\lambda)$ : spectral radiance in  $\mu\text{W}\cdot\text{cm}^{-2}\cdot\text{nm}^{-1}$

$B(\lambda)$ : Blue Light Hazard Function

$\bar{Y}(\lambda)$ : CIE 1931 XYZ luminosity function

683 - maximum spectral luminous efficacy constant (683 lumens per Watt at 555 nm)

*Note - The scaling factor of 0.001 was used for 700 to 780nm*

*- The blue light hazard function is interpolated for every 1 nanometer*

## 5.7. Photobiological safety

The product must meet exempt group limits as outlined in IEC/EN 62471<sup>34</sup>

The blue light emission of the product must meet exempt group limits (Must be lower than 100  $\text{W}\cdot\text{m}^{-2}\cdot\text{str}^{-1}$ ). Display products emitting only within the 380-780 nm visible range and with a peak luminance level lower than 10,000  $\text{cd}/\text{m}^2$ , can be considered in the exempt group.

## 5.8. Color gamut

For this measurement, the color data for base red, green and blue image should be collected and the area between these three points falling within the color standard should be calculated according to CIE 1931. The resulting area calculated from the measured points must be above the required value.

The color gamut coverage ratio of each client specified color mode shall meet at least one of the requirements:

- For product with sRGB color mode:  $\geq 95\%$  of standard sRGB color space in CIE 1931.
- For product with Adobe RGB color mode:  $\geq 90\%$  of standard Adobe RGB color space in CIE 1931.
- For product with DCI-P3 color mode:  $\geq 90\%$  of standard DCI-P3 color space in CIE 1931.
- For product with NTSC color mode:  $\geq 72\%$  of standard NTSE color space in CIE 1931;

Note: Maximum  $\pm 5\%$  deviation to the specified limit is allowed for the mass production”

## 5.9. Correlated color temperature (CCT)

The CCT of display white displaying the white image at 100% brightness should be within the range of 5500K and 7000K.

\*\*\* Note: this requirement is only applicable for laptop, monitor and AIO computer.

## 6. Vision Health Advisory Board Commentary

*The Vision Health Advisory Board <sup>32</sup> comprises leading eye care professionals across ophthalmology and optometry. They help to define and shape the future of eye health and vision related to use of digital devices. The Vision Health Advisory Board collaborates with Eyesafe to provide the latest guiding research and implications to eye and human health for the display industry.*

In review of the current research, the known and unknown health impacts from cumulative use of digital devices, <sup>7, 9, 10, 23</sup> our guidance to manufacturers centers around the high-energy blue light spectrum.

The research indicates there is a certain band of blue light which may be categorized as “healthy” and another as “toxic” <sup>17, 19, 22</sup>, the topic of light emissions from displays and human impact is getting more and more prominent and should be managed effectively by the display industry.

Studies show the intense blue light emitted from digital devices can contribute to eye health issues and potential sleep disorders <sup>7, 9, 20</sup>. Given that eyes are still developing through the teenage years, this issue of prolonged screen use is concerning for children's eyes <sup>1, 25</sup>.

Additionally, studies undertaken in laboratories have shown that cumulative blue light exposure is linked to slow degeneration of the retina <sup>5, 12</sup>, which could accelerate long-term vision problems such as age-related macular degeneration (AMD) and cataracts <sup>13</sup>.

Recent research has found that filtering out blue light from LED screens before bedtime produced significant positive health benefits for teenagers by curbing LED-induced melatonin suppression and decreased alertness <sup>29</sup>. Other studies have shown that patients with unstable tear film achieved better results in visual acuity tests when using a blue light filter, and that filtering blue light can reduce the glare and photo-stress associated with prolonged exposure to intense light <sup>28-30</sup>.

The Eyesafe® Display Requirements <sup>33</sup> are based on the growing body of research that suggests potential health impacts of blue light exposure and the industry's requirements for accurate color quality. The Eyesafe Standard has been developed to provide transparency to consumers and is further built upon existing standards and guidelines developed by the American National Standards Institute (ANSI), the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and TÜV Rheinland.

While we anticipate evolution of Eyesafe standards around each of the variables indicated above, we support the efforts of display manufacturers and suppliers to meet Eyesafe standards to protect human health and promote greater industry transparency.

## 7. Partner Commitments & the Eyesafe Name and Marks

Following are the terms of the Eyesafe Partnership Agreement as it pertains to the manufacture and labeling of Eyesafe qualified products.

Eyesafe® and registered trademarks of Eyesafe and their use is subject to partner agreements. The Eyesafe Partner must adhere to the following partner commitments:

### Qualifying Products

- Comply with current Eyesafe Eligibility Criteria, which define performance requirements and test procedures.
- **Prior to associating the Eyesafe name or mark with any product**, obtain written certification of Eyesafe qualification from Eyesafe.

## Using the Eyesafe Name and Marks

- Comply with current Eyesafe Identity Guidelines, which define how the Eyesafe name and marks may be used. Partner is responsible for adhering to these guidelines and ensuring that its authorized representatives, such as advertising agencies, dealers, and distributors, are also in compliance. The Eyesafe Identity Guidelines are available at: [Eyesafe.com/standards](http://Eyesafe.com/standards).
- Use the Eyesafe name and marks only in association with qualified products. Partner may not refer to itself as an Eyesafe Partner unless at least one product is qualified and offered for sale in the U.S. and/or Eyesafe partner countries.
- Provide clear and consistent labeling of Eyesafe products. The Eyesafe mark should be clearly displayed on the front of the product, on the product packaging, in the product literature (i.e. user manuals, spec sheets, etc.) and on the manufacturers site where information about Eyesafe qualified models is displayed.

## Ongoing Product Qualification

- Certified products have achieved Eyesafe requirements with Eyesafe or an agreed third party for verification if agreed upon in advance.

## Training and Consumer Education

Partner shall comply with the following, product-specific requirements concerning training and education. Provide Eyesafe sales training to all sales staff. This training shall include:

- Identification of Eyesafe-qualified products;
- Tips for selling Eyesafe-qualified products; and
- Tips for answering questions about Eyesafe

## 8. Guiding Research & Sources

1. *Digital Eye Strain Report 2016*. TheVision Council [https://visionimpactinstitute.org/wp-content/uploads/2016/03/2016EyeStrain\\_Report\\_WEB.pdf](https://visionimpactinstitute.org/wp-content/uploads/2016/03/2016EyeStrain_Report_WEB.pdf)
2. *The Total Audience Report: Q1 2016*. Nielsen Audience Report. <https://www.nielsen.com/us/en/insights/reports/2016/the-total-audience-report-q1-2016.html>
3. *Children and electronic media: How much is too much?* J. da Silva, in *American Psychological Association* 2015. <https://www.apa.org/pi/about/newsletter/2015/06/electronic-media>
4. *The 21st Century Child: Increased Technology Use May Lead to Future Eye Health and Vision Issues*. American Optometric Association. <http://www.aoa.org/newsroom/the-21st-century-child-increased-technology-use-may-lead-to-future-eye-health-and-vision-issues>
5. *Effects of light-emitting diode radiations on human retinal pigment epithelial cells in vitro*. E. Chamorro, C. Bonnin-Arias, M.J. Perez-Carrasco, J. Munoz de Luna, *et al.*, *Photochem Photobiol*, 2013. **89**(2): p. 468-73. <https://www.ncbi.nlm.nih.gov/pubmed/22989198>

6. *Phototoxic Action Spectrum on a Retinal Pigment Epithelium Model of Age-Related Macular Degeneration Exposed to Sunlight Normalized Conditions.* E. Arnault, C. Barrau, C. Nanteau, P. Gondouin, et al., *PLoS ONE*, 2013. **8**(8): p. e71398. <https://doi.org/10.1371/journal.pone.0071398>
7. *Effects of blue light on the circadian system and eye physiology.* I.F. Gianluca Tosini, Kazuo Tsubota, *Molecular Vision* 2016. **22**(2157-2518): p. 61-72. <http://www.molvis.org/molvis/v22/61>
8. *Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness.* A.-M. Chang, D. Aeschbach, J.F. Duffy and C.A. Czeisler, *Proceedings of the National Academy of Sciences*, 2015. **112**(4): p. 1232. <http://www.pnas.org/content/112/4/1232.abstract>
9. *Disruption of adolescents' circadian clock: The vicious circle of media use, exposure to light at night, sleep loss and risk behaviors.* Y. Touitou, D. Touitou and A. Reinberg, *Journal of Physiology-Paris*, 2016. **110**(4, Part B): p. 467-479. <http://www.sciencedirect.com/science/article/pii/S0928425717300347>
10. *Evening exposure to a light-emitting diodes (LED)-backlit computer screen affects circadian physiology and cognitive performance.* C. Cajochen, S. Frey, D. Anders, J. Späti, et al., *Journal of Applied Physiology*, 2011. **110**: p. 1432-1438. <https://www.ncbi.nlm.nih.gov/pubmed/21415172>
11. *Unrestricted evening use of light-emitting tablet computers delays self-selected bedtime and disrupts circadian timing and alertness.* E.D. Chinoy, J.F. Duffy and C.A. Czeisler, *Physiological Reports*, 2018. **6**(10): p. e13692. <https://doi.org/10.14814/phy2.13692>
12. *Light-emitting diodes (LED) for domestic lighting: Any risks for the eye?* F. Behar-Cohen, C. Martinsons, F. Viénot, G. Zisis, et al., *Progress in Retinal and Eye Research*, 2011. **30**(4): p. 239-257. <http://www.sciencedirect.com/science/article/pii/S1350946211000267>
13. *Blue light excited retinal intercepts cellular signaling.* K. Ratnayake, J.L. Payton, O.H. Lakmal and A. Karunaratne, *Scientific Reports*, 2018. **8**(1): p. 10207. <https://doi.org/10.1038/s41598-018-28254-8>
14. *ICNIRP Guidelines on Limits of Exposure to Incoherent Visible and Infrared Radiation* International Commission on Non-Ionizing Radiation Protection, in *Health Physics*. 2013. p. 74-96. [https://www.icnirp.org/cms/upload/publications/ICNIRPVisible\\_Infrared2013.pdf](https://www.icnirp.org/cms/upload/publications/ICNIRPVisible_Infrared2013.pdf)
15. American National Standards Institute (ANSI). <https://webstore.ansi.org/>
16. *Bad Blue, Good Blue, Eye and Vision* T. Villette, *Points de Vue – International Review of Ophthalmic Optics online publication*, 2013. **68**: p. 7-8. <https://www.pointsdevue.com/article/bad-blue-good-blue-eyes-and-vision>
17. *Blue Light: It's Both Bad and Good For You* G. Heiting. 2017; Available from: <https://www.allaboutvision.com/cvs/blue-light.htm>
18. *Warding Off the Blues.* B. Hefner, *Review of Optometry*, 2018. **155**(6): p. 71-78.
19. *The Blue Light Paradox: Problem or Panacea* J. Marshall, *Points de Vue – International Review of Ophthalmic Optics online publication* 2017: p. 2-8. <https://www.pointsdevue.com/article/blue-light-paradox-problem-or-panacea>
20. *Global rise of potential health hazards caused by blue light-induced circadian disruption in modern aging societies.* M. Hatori, C. Gronfier, R.N. Van Gelder, P.S. Bernstein, et al., *npj Aging and Mechanisms of Disease*, 2017. **3**(1): p. 9. <https://doi.org/10.1038/s41514-017-0010-2>
21. *Effect of Visual Display Unit Use on Blink Rate and Tear Stability.* S. Patel, R. Henderson, L. Bradley, B. Galloway, et al., *Optometry and Vision Science*, 1991. **68**(11). [https://journals.lww.com/optvissci/Fulltext/1991/11000/Effect\\_of\\_Visual\\_Display\\_Unit\\_Use\\_on\\_Blink\\_Rate.10.aspx](https://journals.lww.com/optvissci/Fulltext/1991/11000/Effect_of_Visual_Display_Unit_Use_on_Blink_Rate.10.aspx)
22. *Blue Light: A Blessing or a Curse?* C.C. Gomes and S. Preto, *Procedia Manufacturing*, 2015. **3**: p. 4472-4479. <http://www.sciencedirect.com/science/article/pii/S2351978915004606>

23. *Effects of Blue Light on Cognitive Performance*. N. Bansal, N.R. Prakash, J.S. Randhawa and P. Kalra, *International Research Journal of Engineering and Technology*, 2017. **4**(6): p. 2434-2442. <https://www.irjet.net/archives/V4/i6/IRJET-V4I6475.pdf>
24. *Eyesafe Research*. Available from: <http://www.eyesafe.com/research/>.
25. *Digital eye strain: prevalence, measurement and amelioration*. A.L. Sheppard and J.S. Wolffsohn, *BMJ Open Ophthalmology*, 2018. **3**(1). <http://bmjophth.bmj.com/content/3/1/e000146.abstract>
26. *Management of digital eye strain*. C. Coles-Brennan, A. Sulley and G. Young, *Clinical and Experimental Optometry*, 2018. **102**(1): p. 18-29. <https://doi.org/10.1111/cxo.12798>
27. *Smartphone use is a risk factor for pediatric dry eye disease according to region and age: a case control study*. J.H. Moon, K.W. Kim and N.J. Moon, *BMC Ophthalmology*, 2016. **16**(1): p. 188. <https://doi.org/10.1186/s12886-016-0364-4>
28. *Reducing Short-Wavelength Blue Light in Dry Eye Patients with Unstable Tear Film Improves Performance on Tests of Visual Acuity*. M. Kaido, I. Toda, T. Oobayashi, M. Kawashima, et al., *PLoS ONE*, 2016. **11**(4): p. e0152936. <https://doi.org/10.1371/journal.pone.0152936>
29. *Blue Blocker Glasses as a Countermeasure for Alerting Effects of Evening Light-Emitting Diode Screen Exposure in Male Teenagers*. S. van der Lely, S. Frey, C. Garbazza, A. Wirz-Justice, et al., *Journal of Adolescent Health*, 2015. **56**(1): p. 113-119. <https://doi.org/10.1016/j.jadohealth.2014.08.002>
30. *Attenuating Photostress and Glare Disability in Pseudophakic Patients through the Addition of a Short-Wave Absorbing Filter*. B.R. Hammond, *Journal of Ophthalmology*, 2015. **2015**: p. 8. <http://dx.doi.org/10.1155/2015/607635>
31. *What is D65 and what is it used for? Waveform Lighting*. <https://www.waveformlighting.com/color-matching/what-is-d65-and-what-is-it-used-for>
32. *Vision Health Advisory Board*. Available from: <http://www.eyesafe.com/visionhealthadvisory/>.
33. *Eyesafe and TUV Requirements*. 2019; Available from: <http://www.eyesafe.com/standards/>.
34. *IEC 62471:2006 Photobiological safety of lamps and lamp systems*. International Electrotechnical Commission. <https://webstore.iec.ch/publication/7076>