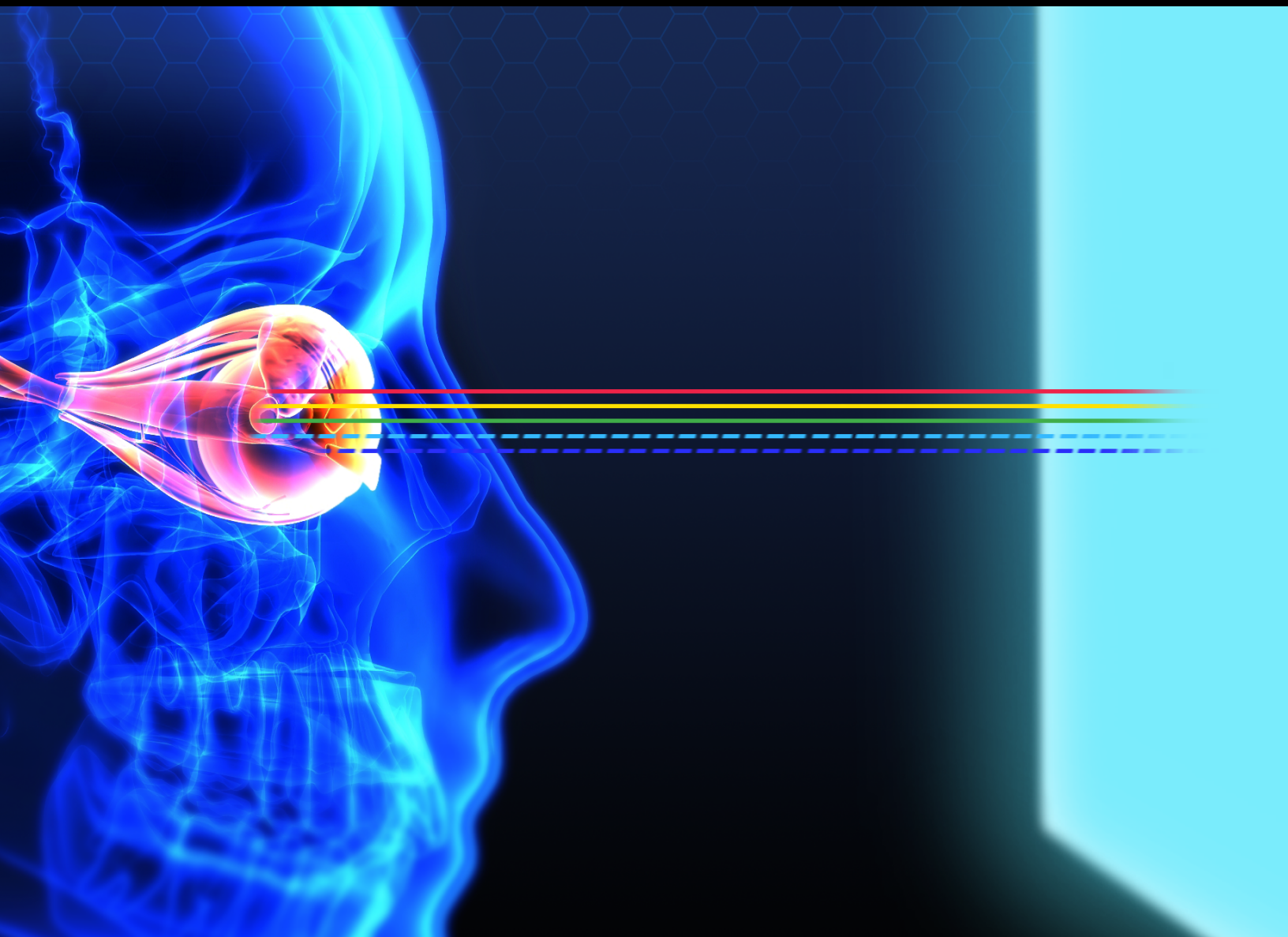
WHITE PAPER

# Defining Blue Light Requirements for Digital Displays

eyesafe | TÜVRheinland® Precisely Right.



# Defining Blue Light Requirements for Digital Displays

## INTRODUCTION

**The last decade has seen a rapid expansion of digital devices in our daily life, far beyond instruments of work and entertainment. Digital devices are now used in every aspect of our lives, for gaming, sports, health, fitness, education, and more.**

All digital devices emit light in a spectral distribution dissimilar to natural daylight, whose composition varies during the day and to which our eyes are physiologically adapted. Digital displays emit high-energy visible (HEV) blue light, a range of visible light close in energy to that of ultra-violet radiation. As a result of its higher energy, blue light has greater potential than other wavelengths of visible light to cause harm to tissues of the eye.[1-4]

Researchers and eye care providers are increasingly concerned about potential long-term eye health impacts.

Long-term health implications resulting from cumulative blue light exposure are still being evaluated, but immediate effects of display use, such as the impacts on circadian rhythms and sleep patterns, affect people daily.[5-12]

As an area of concern, light emissions from digital displays and their potential impact on human health are becoming more prominent.

Research studies on the effect of light on the ocular system show two main types of potential retinal damage, photothermal, and photochemical. The potential damage from blue light is photochemical, involving injury to the eye in the range of 380-550 nanometers (nm). This could potentially arise from exposure to very bright blue-rich artificial light sources (metal halide, LEDs), hence the naming of these wavelengths as the blue light hazard.[1, 2, 13-16]

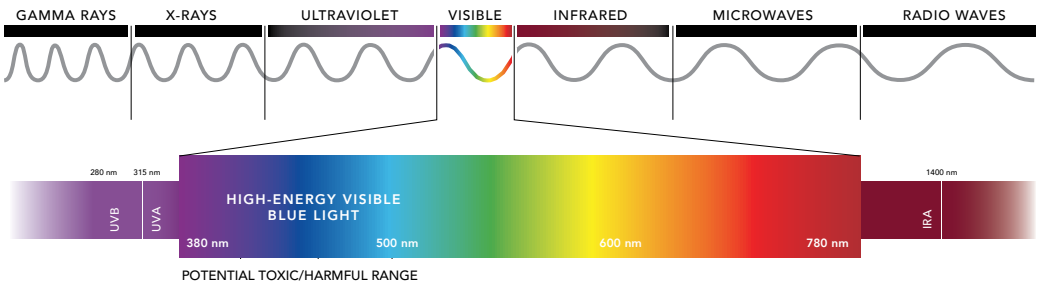
Photochemical damage to the retina, in particular, is thought to be irreversible and accumulates depending on exposure, duration, and intensity. Variables of exposure may include high intensity within a short time or low intensity over an extended period.

Epidemiologic studies have shown that age-related macular degeneration (AMD), the most common cause of blindness/vision impairment, may potentially be caused by the photooxidative retinal damage from cumulative exposure to natural solar blue light over a long time (years, even decades).[4, 17] With the increased presence of LCD and OLED displays in our environment, studies have only recently begun to evaluate the potential long-term effect of their low-intensity blue light emission, starting with animal studies and even suggesting a revision of available exposure limit values which have limited scope for addressing high-intensity lighting systems.[18-20]

*"With screen time up significantly since the onset of COVID-19, reducing blue light emissions is more important than ever for the global population,"*

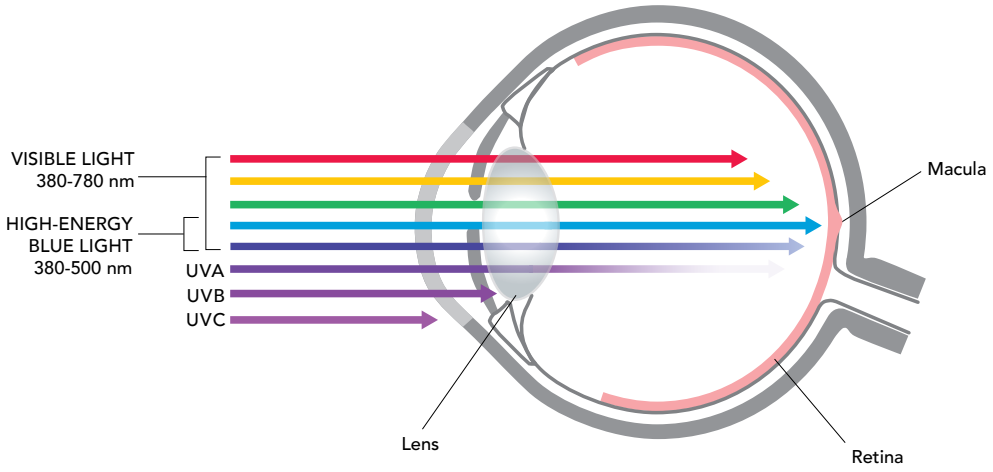
– Dr. David Friess, Eyesafe Vision Health Advisory Board

Certain bands of blue light within the visible light spectrum have been linked to health concerns.



Visible light is transmitted to the retina from natural and artificial light sources, between the range of 380-780 nm. The cornea and lens of the adult human eye are effective at limiting UV rays from reaching the light-sensitive retina. HEV blue light is different, passing through the cornea and lens to the retina and macula.




## Eyesafe® Display Requirements

Eyesafe® Requirements limit blue light emissions to address the growing body of research suggesting potential risks of blue light exposure. The display requirements also address the industry's need for accurate color quality. Eyesafe® Display Requirements and certification have been broadly adopted by leading OEMs and panel manufacturers, including Dell, Lenovo, HP, LG Display, and BOE, among others.

Eyesafe® Standards reflect the input of world-renowned optometrists and ophthalmologists. Devices are certified to meet Eyesafe® Requirements by TÜV Rheinland, a global leader in independent third-party testing for manufacturing. Together, Eyesafe and TÜV Rheinland have created a standard testing methodology and report for a better assessment of display emissions and performance with comparable outcomes, making it easier for the end-user to compare multiple displays and their blue light emission.

There are multiple approaches to measure blue light emissions and the impact and exposure.[21, 22]

The Eyesafe® Requirements for blue light emissions and color performance align with international standards and guidelines developed by the American National Standards Institute (ANSI) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The requirements quantify blue light radiation levels and their potential impact to human eyes[21, 22] using the aforementioned standards' spectral weighting function B(λ) for retinal blue light hazard and overseeing all-optical hazards in the visible spectral range.

| **EYESAFE® DISPLAY REQUIREMENTS 2.0** | | |
|---|---|---|
| High-Energy Blue Light | Weighted blue light toxicity emissions based on ICNIRP Guidelines | Radiance Protection Factor (RPF®) Pass/Fail of certification will be at RPF35. Measurement of blue light toxicity, based on research and optical testing. The RPF® scale is tested and verified by TÜV Rheinland. |
| Color Performance | Color Gamut Coverage % | For sRGB color mode: ≥95% of standard sRGB color space in CIE 1931; 1976<br>For Adobe RGB color mode: ≥90% of standard Adobe RGB color space in CIE 1931; 1976<br>For DCI-P3 color mode: ≥90% of standard DCI-P3 color space in CIE 1931; 1976<br>For NTSC color mode: ≥72% of standard NTSC color space in CIE 1931; 1976*<br>*For battery powered products NTSC color mode: ≥45% of standard NTSC color space in CIE 1931; 1976 |
| | Color Temperature | 5500-7000K**<br>**Only applicable to AIO, NB, Monitors |

## Blue Light Toxicity Factor (BLTF)

Standard testing procedures are necessary to accurately compare the performances of displays in terms of blue light reduction and color integrity. Eyesafe® Requirements utilize the Blue Light Toxicity Factor (BLTF) as a primary metric to quantify the blue light emission because it is a comprehensive, health-based measurement that includes the most harmful portion of high-energy blue light based on the blue light hazard function B(λ).

The blue light hazard function represents the relative spectral sensitivity of the human eye to the blue light hazard ranging from 380 nm to over 500 nm (with a peak at 435-440 nm).[21-23] Recent published research studying the effects of blue light through *in vitro* and *in vivo* studies have demonstrated the importance of the blue light-weighting function to evaluate the risks posed by light emissions reaching the retina, with some research authors arguing that current exposure limits originally set for intense lighting systems should be revised to address potential display-related blue light impacts and identified groups of populations at risk (children, people with pre-existing conditions, etc.)[17-19]

With these considerations in mind, BLTF takes into account not only the most harmful portion of the blue light range, but also extends beyond to cover all of the blue light regarding health concerns based on published research.[21-23] BLTF corresponds to the ratio of the display's blue light effective radiance over the calculated display's luminance and should be less than 0.085.

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

In which:

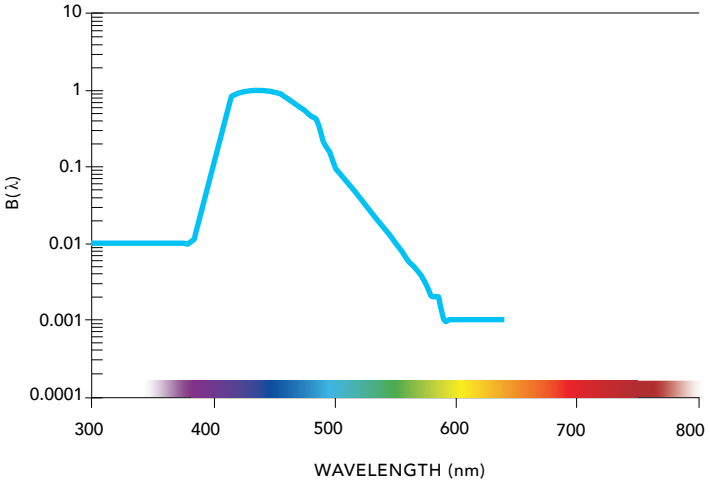
$d\lambda = 1$ nm

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

$B(\lambda)$: 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)




Action spectra for blue light hazard. The blue light hazard function B(λ) represents the relative spectral sensitivity of the human eye to the blue light hazard ranging from 380 nm to over 500 nm (with a peak at 435-440 nm).

| | EMISSIONS (nm) | BLUE LIGHT HAZARD FUNCTION* |
|---|---|---|
| UV | 200-380 | 0 |
| HIGH-ENERGY VISIBLE BLUE LIGHT | 380 | 0.01 |
| | 385 | 0.01 |
| | 390 | 0.03 |
| | 395 | 0.05 |
| | 400 | 0.10 |
| | 405 | 0.20 |
| | 410 | 0.40 |
| | 415 | 0.80 |
| | 420 | 0.90 |
| | 425 | 0.95 |
| | 430 | 0.98 |
| | 435 Peak | 1.00 |
| | 440 Peak | 1.00 |
| | 445 | 0.97 |
| | 450 | 0.94 |
| | 455 | 0.90 |
| | 460 | 0.80 |
| | 465 | 0.70 |
| | 470 | 0.62 |
| | 475 | 0.55 |
| | 480 | 0.45 |
| | 485 | 0.40 |
| | 490 | 0.22 |
| | 495 | 0.16 |
| | 500 | 0.10 |

AREAS OF RESEARCH

- Ocular Surface Impacts
- Cataracts
- Retinal Cell Impact
- Potential for Age-related Macular Degeneration
- Circadian Rhythm Impact
- Melatonin Supression

*American National Standards Institute (ANSI) Z80.3 Table
International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, most toxic portions of the blue spectrum

Blue light toxicity and its potential impact on eye health and overall human health.

## Introducing Radiance Protection Factor (RPF®) for Display

BLTF is difficult to understand for the end-user because of its complexity. To translate the complex BLTF formula and resulting Eyesafe® Requirements to the end-user (consumer), Eyesafe is introducing RPF® for Display. This simple metric provides a rating system to help the end-user identify and compare devices and their respective blue light emissions at a specific brightness level (200 nits). RPF® for display is calculated based on the BLTF of a display in comparison to the D65 illuminant BLTF.

$$RPF = 260 \times \frac{(BLTF_{D65} - BLTF_{Tested})}{BLTF_{D65}}$$

In which:

$BLTFD_{65} = 0.098$

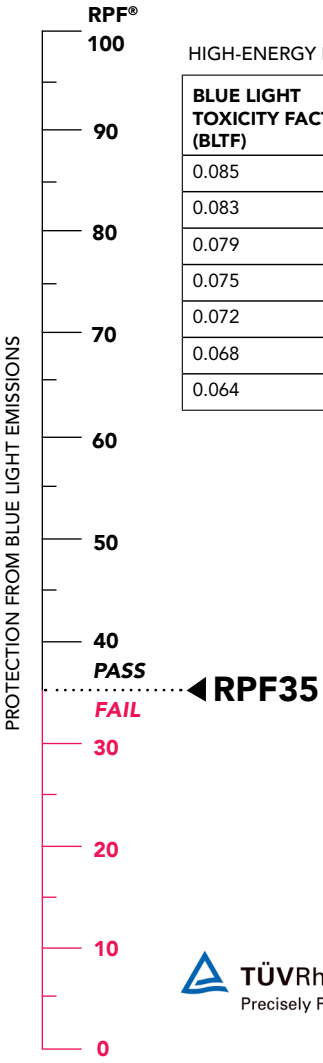
260 – Scaling factor

$BLTF_{Tested}$: The BLTF of the tested sample

D65 is widely used in the lighting industry as a baseline because it roughly corresponds to the average midday light in Western Europe and Northern Europe (comprising both direct sunlight and the light diffused by a clear sky). D65 is not a real light source, but a simulation used to represent daylight at a given day and time.

RPF® is calculated using a scaling factor that is based on the current technological limits of recent LCD and OLED technologies. The goal is to provide the end-user with a number (1-100) that reflects the blue light toxicity of the display, effectively simplifying the complex blue light toxicity formula used for measurement. Similar to how Sun Protection Factor (SPF) measures protection for the skin, the RPF® scale measures blue light emissions and potential risk for the eyes. The higher the number, the better — in essence, higher RPF® numbers indicate a greater reduction of high-energy blue light in a display.

To meet the Eyesafe® Display Requirements for blue light emissions, a display must achieve an RPF® of 35 or higher. This is equivalent to a BLTF rating of 0.085. This requirement reflects the latest research and optical testing. It is supported by the Eyesafe Vision Health Advisory Board, a panel of world-renowned optometrists and ophthalmologists from around the world.




HIGH-ENERGY BLUE LIGHT REDUCTION

| BLUE LIGHT TOXICITY FACTOR (BLTF) | RADIANCE PROTECTION FACTOR (RPF®) |
|---|---|
| 0.085 | 35 |
| 0.083 | 40 |
| 0.079 | 50 |
| 0.075 | 60 |
| 0.072 | 70 |
| 0.068 | 80 |
| 0.064 | 90 |

TÜVRheinland® Precisely Right.

EYESAFE VISION HEALTH ADVISORY BOARD

RPF®, which designates the level of high-energy blue light reduction in digital displays, is a metric that is based on research, third-party verified, and supported by leaders in the eye care community.

*"RPF® simplifies the requirements so end-users can easily understand and compare displays in regard to high-energy blue light reduction."* – Dr. David Friess, Eyesafe Vision Health Advisory Board

Displays are tested for RPF® by TÜV Rheinland, a global leader in independent third-party certification. TÜV Rheinland is widely respected and touted for it's independent evaluation, testing and assessment services. Third-party certification provides end-users with the confidence that a display has been independently verified to meet the Eyesafe® Requirements.

"TÜV Rheinland Group has always been on the forefront of new benchmark standards in the industry, and we are pleased to be offering certification services for Eyesafe. The launch of the Eyesafe® Display Requirements 2.0 comes at a critical juncture for the global display industry," remarked Stanley Liu, Director of the TÜV Rheinland Ergonomics Technical Competence Center. "As more and more brands have begun to offer an array of low blue light display options, it seems imperative that independent certification bodies like TÜV Rheinland begin to offer standards for brands that want to offer more precise information to consumers."

*"The Eyesafe® Display Requirements 2.0 with Radiance Protection Factor for display, or RPF® scale, lifts open the curtain to what's behind brands that are labeled 'low blue light' and empowers consumers to make comparisons among competing solutions."*
– Stanley Liu, TÜV Rheinland

TÜVRheinland®
Precisely Right.


Devices are tested and certified to meet Eyesafe® Requirements for blue light emissions and color performance by TÜV Rheinland.

*"RPF® removes the guesswork for consumers, who have seen massive proliferation of low blue light devices in the marketplace in the past two years."* – Dr. Dagny Zhu, Eyesafe Vision Health Advisory Board

**David Friess, OD, FAAO** is Chair of the Eyesafe Vision Health Advisory Board. Dr. Friess has over 20 years of experience as a globally recognized optometrist spanning clinical research, medical affairs, patient care, regulatory and strategic market development with ophthalmic medical device and pharmaceutical companies.

**Dagny Zhu, MD** is a Cornea, Cataract, and Refractive Surgeon, and Medical Director and Partner at NVISION Eye Centers in California. Dr. Zhu is a nationally acclaimed, board-certified ophthalmologist and member of the Eyesafe Vision Health Advisory Board.

**Stanley Liu**, Director of TÜV Rheinland Ergonomics and Laser competence center, Local Field Manager. He has more than 15 years visual ergonomics testing and certification experience in display, he also leads AR/VR and laser radar performance standard development for TÜV Rheinland.

**Amir Soleimanpour, PhD** is Director of Research and Advocacy at Eyesafe. He has more than ten years of experience with new product development and a deep background in materials science, physics and chemistry.

**Alya Pender, PhD** is a Research Scientist at Eyesafe. She graduated from the University Pierre & Marie Curie, Paris, France and has an international research experience working in the areas of materials science and polymer surface modification.

## SOURCES


1. *Retinal photodamage.* M. Boulton, M. Rózanowska and B. Rózanowski, Journal of Photochemistry and Photobiology B: Biology, 2001. 64(2): p. 144-161. 10.1016/S1011-1344(01)00227-5
2. *Photochemical Damage of the Retina.* J. Wu, S. Seregard and P.V. Algvere, Survey of Ophthalmology, 2006. 51(5): p. 461-481. 10.1016/j.survophthal.2006.06.009
3. *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. 10.1111/j.1751-1097.2012.01237.x
4. *Oxidative stress in the light-exposed retina and its implication in age-related macular degeneration.* Y. Ozawa, Redox Biology, 2020. 37: p. 101779. 10.1016/j.redox.2020.101779
5. Computer Vision Syndrome (Digital Eye Strain). EyeWiki - The Eye Encyclopedia written by Eye Physicians & Surgeons. American Academy of Ophthalmology. (2021) https://eyewiki.org/Computer_Vision_Syndrome_(Digital_Eye_Strain).
6. The Nielsen Total Audience Report Hub. 2020. https://www.nielsen.com/us/en/insights/article/2020/the-nielsen-total-audience-report-hub/
7. *Effects of blue light on the circadian system and eye physiology.* G. Tosini, I. Ferguson and K. Tsubota, Molecular Vision 2016. 22(2157-2518): p. 61-72. http://www.molvis.org/molvis/v22/61
8. *Analysis of circadian properties and healthy levels of blue light from smartphones at night.* J.H. Oh, H. Yoo, H.K. Park and Y.R. Do, Nature Scientific Reports, 2015. 5:11325. 10.1038/srep11325
9. *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. 10.1038/s41514-017-0010-2
10. *Blue light at night acutely impairs glucose tolerance and increases sugar intake in the diurnal rodent Arvicanthis ansorgei in a sex-dependent manner.* A. Masís-Vargas, D. Hicks, A. Kalsbeek and J. Mendoza, Physiological reports, 2019. 7(20): p. e14257-e14257. 10.14814/phy2.14257
11. *Systematic review of light exposure impact on human circadian rhythm.* L. Tahkamo, T. Partonen and A.K. Pesonen, Chronobiology International, 2019. 36(1510170). 10.1080/07420528.2018.1527773
12. *Are Displays Giving Us the Blues?* J.D. Bullough, S. Peana and S.J. Camardello, in SID Symposium Digest of Technical Papers. 2020.
13. *Sensitivity of the retina to radiation damage as a function of wavelength.* W.T. Ham, H.A. Mueller, J.J. Ruffolo and A.M. Clarke, Photochemistry and Photobiology, 1979. 29: p. 735-743. 10.1111/j.1751-1097.1979.tb07759.x
14. *Retinal light damage: Mechanisms and protection.* D.T. Organisciak and D.K. Vaughan, Progress in Retinal and Eye Research, 2010. 29(2): p. 113-134. 10.1016/j.preteyeres.2009.11.004
15. *Light-emitting diodes (LED) for domestic lighting: Any risks for the eye?* F. Behar-Cohen, C. Martinsons, F. Viénot, G. Zissis, et al., Progress in Retinal and Eye Research, 2011. 30(4): p. 239-257. 10.1016/j.preteyeres.2011.04.002
16. *Personal risks posed by LEDs used in everyday devices.* E. Chamorro, C. Bonnin, L.L. Lobato-Rincón, J.J. Navarro-Valls, et al., Seguridad y Medio Ambiente - N128, 2012. 32(N128): p. 1-7. http://www.mapfre.com/fundacion/html/revistas/seguridad/n128/en/article3.html
17. *Age-related maculopathy and the impact of blue light hazard.* P.V. Algvere, J. Marshall and S. Seregard, Acta Ophthalmologica Scandinavica, 2006. 84(1): p. 4-15. 10.1111/j.1600-0420.2005.00627.x
18. *Blue Light Hazard: are exposure limit values protective enough for newborn infants?* S. Point, Radioprotection, 2018. 53(3): p. 219-224. 10.1051/radiopro/2018025
19. *Retinal phototoxicity and the evaluation of the blue light hazard of a new solid-state lighting technology.* I. Jaadane, G. Villalpando Rodriguez, P. Boulenguez, S. Carré, et al., Scientific reports, 2020. 10(1): p. 6733-6733. 10.1038/s41598-020-63442-5
20. *Blue Light from Cell Phones Can Cause Chronic Retinal Light Injury: The Evidence from a Clinical Observational Study and a SD Rat Model.* H. Li, M. Zhang, D. Wang, G. Dong, et al., Biomed Res Int, 2021. 2021: p. 3236892. 10.1155/2021/3236892
21. American National Standards Institute (ANSI). https://webstore.ansi.org/
22. *ICNIRP Guidelines on Limits of Exposure to Incoherent Visible and Infrared Radiation in Health Physics.* 2013. p. 74-96. https://www.icnirp.org/cms/upload/publications/ICNIRPVisible_Infrared2013.pdf
23. IEC 62471:2006 *Photobiological safety of lamps and lamp systems.* International Electrotechnical Commission. I.E. Commission. https://webstore.iec.ch/publication/7076

FOR MORE INFORMATION

**Researchers and eye care providers are increasingly concerned about the potential health impacts of high-energy blue light exposure. Eyesafe® Display Requirements have been developed to limit blue light emissions based on the growing body of research.**

## About TÜV Rheinland

TÜV Rheinland is a global leader in independent inspection services, founded 147 years ago with a worldwide presence. Its independent experts are committed to ensuring quality and safety for people, technology, and the environment in nearly all aspects of life. TÜV Rheinland inspects technical equipment, products, and services, oversees projects, and helps to shape processes and information security for companies. To this end, TÜV Rheinland employs a global network of approved labs and centers for testing and education. Since 2006, TÜV Rheinland has been a member of the United Nations Global Compact to promote sustainability and combat corruption. Learn more at TÜV.com

TÜVRheinland®
Precisely Right.

## Developed with Doctors

Developed with the Eyesafe Vision Health Advisory Board, a group of leading optometrists and ophthalmologists from across the globe. These distinguished eye doctors consult with Eyesafe to provide valuable insights that help drive research regarding the effects of blue light on the eyes and brain. They also help guide the development of Eyesafe® technology and industry standards to limit blue light emitted by the displays of electronic devices and other sources. Eyesafe industry-leading low blue light certification is based on optical testing and research.

EYESAFE
VISION HEALTH
ADVISORY
BOARD

## About Eyesafe

Eyesafe Inc. is the worldwide supplier of advanced blue light mitigating technology, solutions, and standards. With pioneering products and services, in collaboration with healthcare, Eyesafe is shaping the future of consumer electronics designed for human health. Eyesafe® Standards, Eyesafe® technology, and the associated intellectual property portfolio is developed by a world-class team of eye doctors, engineers, and scientists with decades of experience in electronics, display materials, light management, optometry, and ophthalmology. The Eyesafe® brand is trusted by consumers and integrated in millions of digital devices from Dell, HP, Lenovo, ZAGG and others. Eyesafe was recently ranked #5 in the computer hardware category in the Inc. 5000 Fastest-Growing Private Companies in America. Learn more at eyesafe.com

**eyesafe.com/standards**

eyesafe®

R111422