
GUIDING HEALTH RESEARCH
Blue Light Health Impacts
Include Short and Long Term Concerns
and Populations at Risk
BLUE LIGHT
SUMMIT 2020

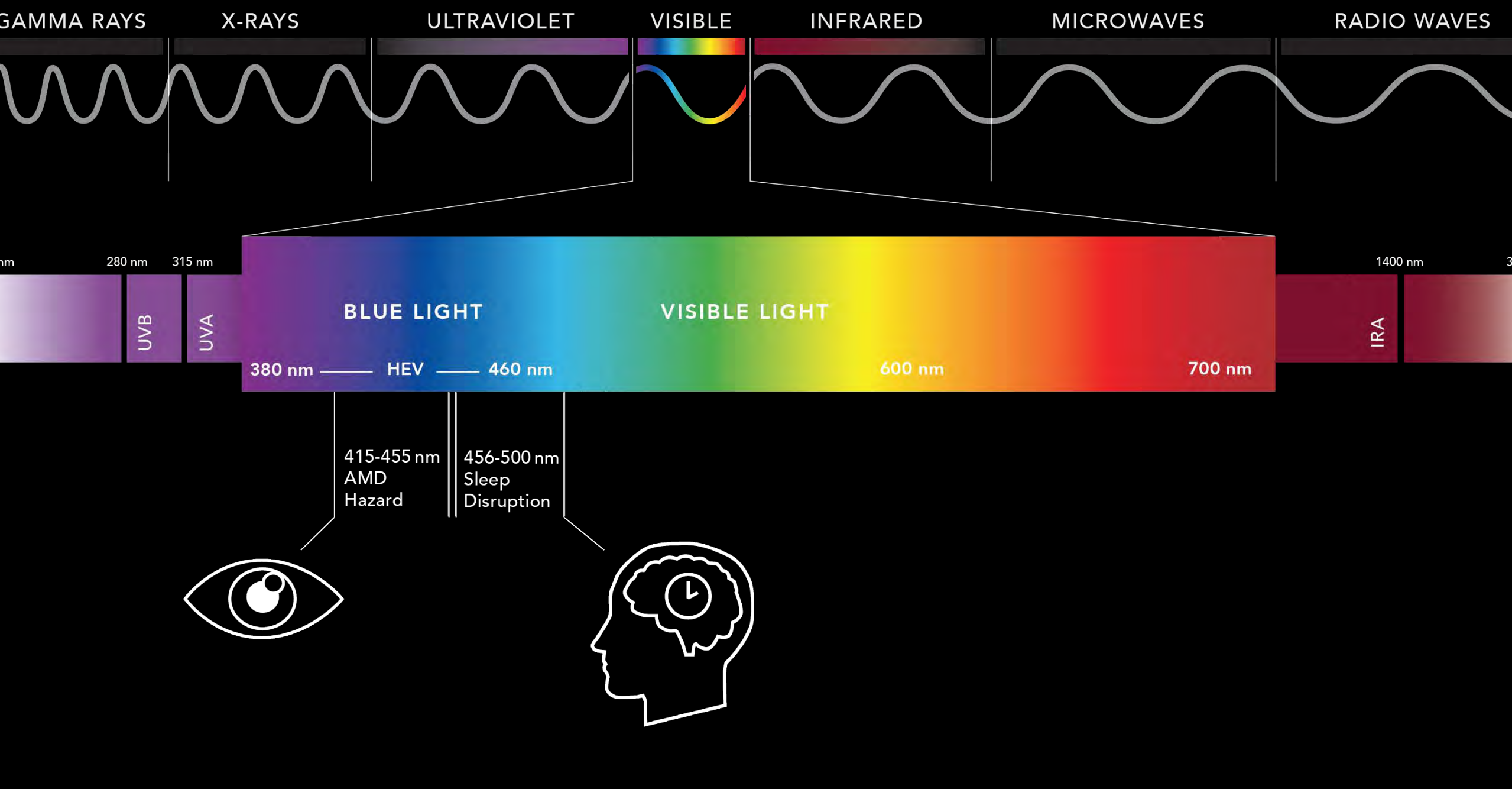
DAVID FRIESS, OD, FAAO

Vision Health Advisory Board

BLUE LIGHT SUMMIT 2020

Main Takeaways

- Growth in blue light-related health research
- Many knowns and unknowns involving vision and human health
- Long term health impacts


GAMMA RAYS
X-RAYS
ULTRAVIOLET
VISIBLE
INFRARED
MICROWAVES
RADIO WAVES
nm
280 nm
315 nm
1400 nm
UVB
UVA
IRA
BLUE LIGHT
VISIBLE LIGHT
380 nm
HEV
460 nm
600 nm
700 nm
415-455 nm
AMD
Hazard
456-500 nm
Sleep
Disruption

Blue light research topic by the numbers

Molecular Vision 2016; 22:61-72 <http://www.molvis.org/molvis/v22/61>
Received 26 August 2015 | Accepted 21 January 2016 | Published 24 January 2016

Effects of blue light on the circadian system and eye physiology

Gianluca Tosini,[1] Ian Ferguson,[2] Kazuo Tsubota[3]

[1]Department of Pharmacology and Toxicology and Neuroscience Institute, Morehouse School of Medicine, Atlanta, GA; [2]College of Engineering and Computing, Missouri University of Science and Technology, Rolla, MS; [3]Department of Ophthalmology, Keio University School of Medicine, Tokyo, Japan

Light-emitting diodes (LEDs) have been used to provide illumination in industrial and commercial environments. LEDs are also used in TVs, computers, smart phones, and tablets. Although the light emitted by most LEDs appears white, LEDs have peak emission in the blue light range (400–490 nm). The accumulating experimental evidence has indicated that exposure to blue light can affect many physiologic functions, and it can be used to treat circadian and sleep dysfunctions. However, blue light can also induce photoreceptor damage. Thus, it is important to consider the spectral output of LED-based light sources to minimize the danger that may be associated with blue light exposure. In this review, we summarize the current knowledge of the effects of blue light on the regulation of physiologic functions and the possible effects of blue light exposure on ocular health.

Lighting sources and technology have experienced a revolution in the last 15–20 years. Lighting sources and technology, especially in non-commercial or industrial illumination applications, have traditionally been slow to change [1]. In most homes, the incandescent bulb and Edison socket have been omnipresent. In the past 10 years, we have seen significant use of other technologies, such as compact fluorescent lamps (CFLs), replacing incandescent sources. However, this transition has often been driven by legislation, which has focused on energy-efficient sources instead of consumer desire for different light sources. The general user quickly noted the difference in the quality of CFL source but not necessarily in the specifics of its power spectrum. Simultaneously, the development and performance of high brightness light-emitting diodes (LEDs) have experienced tremendous advances [2]. The coupling of a blue-light LED with a phosphor has also been used to produce a white light source, the white-light LED. This solid-state fluorescent analog has become known as solid-state lighting (SSL). This approach is now considered the next generation of illumination due to the many inherent and potential advantages over current technologies.

In addition to use for general illumination, LEDs quickly became the choice for mobile devices, such as smart phones [3]. The small size of LEDs and the limited screen size make them ideal for these applications. The potential for the use of LEDs for backlighted liquid crystal displays (LCDs) in laptop computers was also quickly realized. This transition was driven by the fragility of the microfluorescent lamps used for illumination and consumer desire for thinner screens. LEDs have now become the dominant technology for backlighted tablet displays, such as iPads and e-readers, and large LCD television sets. This now means that blue light prevails in red, green, and blue (RGB) and SSL illumination systems that did not exist a decade ago. The ways in which people read have also changed. Light is now being used directly for illumination in smart phones, tablets, and readers instead of for reflection, which is typical for reading from paper.

The white-light LED (i.e., the most common type of LED) is essentially a bichromatic source that couples the emission from a blue LED (peak of emission around 450–470 nm with a full width at half max of 30–40 nm) [4] with a yellow phosphor (peak of emission around 580 nm with a full width at half max of 160 nm) that appears white to the eye when viewed directly [5]. The specific pump wavelength of the phosphor in the range 450–470 nm depends critically on the absorption properties of the phosphor. Although the white-light LED can be considered the SSL analog of the fluorescent source, the power spectrum of the white-light LED is considerably different from traditional, fluorescent, or incandescent white light sources [6] (Figure 1).

Early commercial devices lacked sophistication, adopting the currently available LED technology that was small, 350×350 mm^2, and operated at low drive currents, typically 20 mA, producing 1–16 mW of power. The last decade has seen the scaling of LEDs to larger areas, 1×1 μm^2, and higher drive currents of >350 mA with significantly increased power output >1,000 mW [2]. During this period, LED devices were also optimized for use in illumination applications, and reflected from a surface instead of emitted directly.

Correspondence to: Gianluca Tosini, 720 Westview Dr. SW, Atlanta

PLOS ONE

RESEARCH ARTICLE

The influences of smartphone use c
status of the tear film and ocular su

Jung Han Choi[1], Ying Li[1], Seon Ho Kim[2], Rujun Jin[1,3], Yung Hui Kim
Cheon You[4], Kyung Chul Yoon[1,3]*

1 Department of Ophthalmology, Chonnam National University Medical School and
Korea, 2 MSC Research Institute and Kim Seon Ho Eye Clinic, Gwangju, Korea, 3
Sciences and Centers for Creative Biomedical Scientists at Chonnam National Univ
University Medical School and

Hindawi

ential Targets and Initiators of the Blue Light
a

uan Zhou,[1,2] and Xin-Gen Zhu[1]

e Second Affiliated Hospital of Nanchang University, Nanchang 330006, China
, The Second Clinical Medical College, Nanchang University, Nanchang 330006, China

ssed to Xin-Gen Zhu; efyzxg@163.com

l 18 June 2019; Accepted 25 July 2019; Published 21 August 2019

ht-emitting diodes (LEDs) have an intense emission in the range of blue light, which has raised a heir potential risks as retinal hazards. Distinct from other visible light components, blue light is th, high energy, and strong penetration that can reach the retina with relatively little loss in a are abundant in retinal tissues, giving them relatively high access to blue light, and ed in the retina, have many mitochondria able to absorb blue light and induce photochemical sure of the retina to blue light tends to cause ROS accumulation and oxidative stress, which of the retinal mitochondria and trigger mitochondria-involved death signaling pathways. In ential roles of mitochondria in blue light-induced photochemical damage and programmed cell ctions for future research and preventive targets in terms of the blue light hazard to the retina, s in a rational way to prevent the blue light hazard.

litochondrial

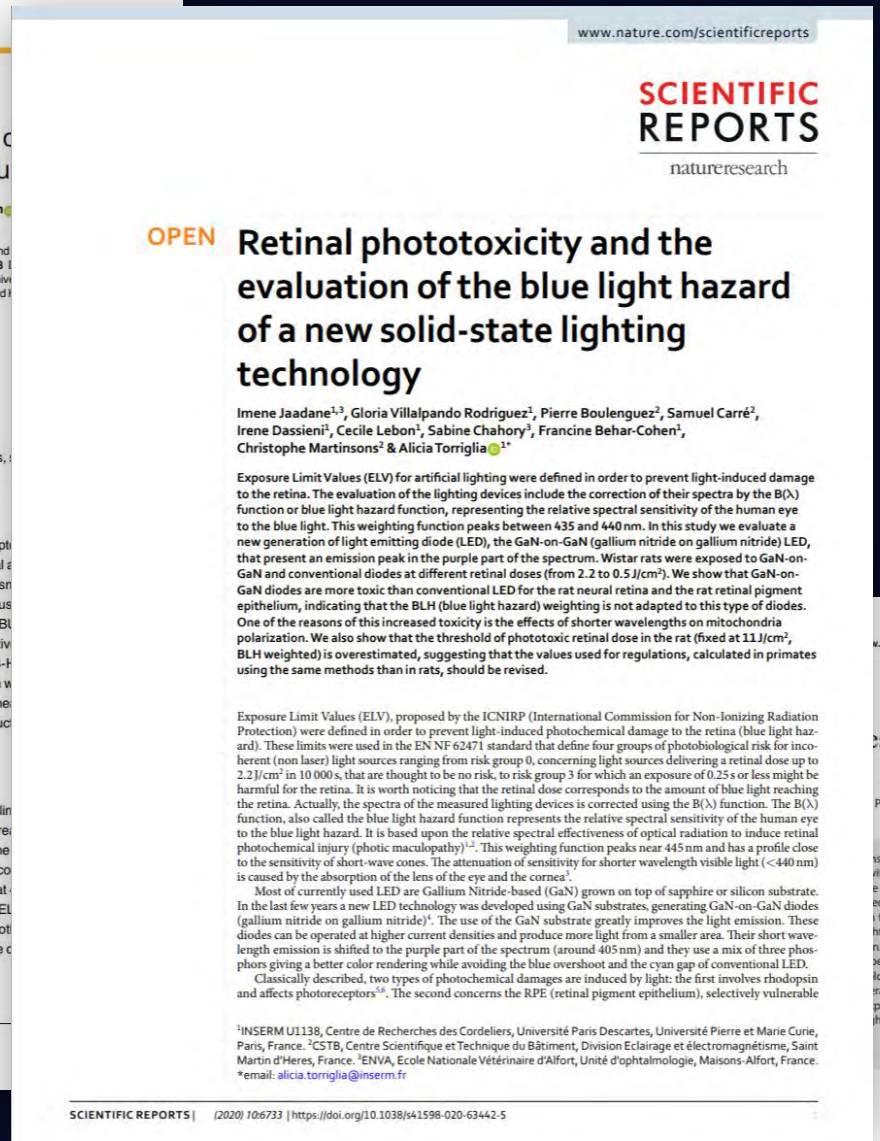
ve layer of the eye and that originates as an

plexus is at the nerve fiber layer (NFL), the intermediate plexus is near the proximal border of the inner nuclear layer (INL), and the deep plexus is proximal to the dendrites of the horizontal and bipolar cells in the OPL (outer plexiform layer) and distal to their somas. (2) The choroidal circulation

he use on ocular symptoms, nd at the ocular surface.

the study. Subjective sympt isease index (OSDI), visual a VS) score before and after sn he tear film was evaluated us ograph break up time (NIKBU iscus height (TMH). Oxidativ L), 4-hydroxy-2-nonenal (4-H e (8-OHdG) in the tear film w t the ocular surface were me measurements were conduc

p-wise differences at baselin ess showed significant increa t baseline (all $P < 0.05$). The d dryness scores than the co reased FBUT and NIBUT at up, the concentration of HEL seline and 1 h ($P < 0.01$). Bot hartphone group versus the c



www.nature.com/scientificreports

SCIENTIFIC REPORTS
nature research

OPEN

Retinal phototoxicity and the evaluation of the blue light hazard of a new solid-state lighting technology

Imene Jaadane[1,3], Gloria Villalpando Rodriguez[1], Pierre Boulenguez[2], Samuel Carré[2], Irene Dassieni[1], Cecile Lebon[1], Sabine Chahory[3], Francine Behar-Cohen[1], Christophe Martinsons[2] & Alicia Torriglia[1*]

Exposure Limit Values (ELV) for artificial lighting were defined in order to prevent light-induced damage to the retina. The evaluation of the lighting devices include the correction of their spectra by the B(λ) function or blue light hazard function, representing the relative spectral sensitivity of the human eye to the blue light. This weighting function peaks between 435 and 440 nm. In this study we evaluate a new generation of light emitting diode (LED), the GaN-on-GaN (gallium nitride on gallium nitride) LED, that present an emission peak in the purple part of the spectrum. Wistar rats were exposed to GaN-on-GaN and conventional diodes at different retinal doses (from 2.2 to 0.5 J/cm^2). We show that GaN-on-GaN diodes are more toxic than conventional LED for the rat neural retina and the rat retinal pigment epithelium, indicating that the BLH (blue light hazard) weighting is not adapted to this type of diodes. One of the reasons of this increased toxicity is the effects of shorter wavelengths on mitochondria polarization. We also show that the threshold of phototoxic retinal dose in the rat (fixed at 11 J/cm^2, BLH weighted) is overestimated, suggesting that the values used for regulations, calculated in primates using the same methods than in rats, should be revised.

Exposure Limit Values (ELV), proposed by the ICNIRP (International Commission for Non-Ionizing Radiation Protection) were defined in order to prevent light-induced photochemical damage to the retina (blue light hazard). These limits were used in the EN NF 62471 standard that define four groups of photobiological risk for incoherent (non laser) light sources ranging from risk group 0, concerning light sources delivering a retinal dose up to 2.2 J/cm^2 in 10 000 s, that are thought to be no risk, to risk group 3 for which an exposure of 0.25 s or less might be harmful for the retina. It is worth noticing that the retinal dose corresponds to the amount of blue light reaching the retina. Actually, the spectra of the measured lighting devices is corrected using the B(λ) function. The B(λ) function, also called the blue light hazard function represents the relative spectral sensitivity of the human eye to the blue light hazard. It is based upon the relative spectral effectiveness of optical radiation to induce retinal photochemical injury (photic maculopathy)[1,2]. This weighting function peaks near 445 nm and has a profile close to the sensitivity of short-wave cones. The attenuation of sensitivity for shorter wavelength visible light (<440 nm) is caused by the absorption of the lens of the eye and the cornea[3].

Most of currently used LED are Gallium Nitride-based (GaN) grown on top of sapphire or silicon substrate. In the last few years a new LED technology was developed using GaN substrates, generating GaN-on-GaN diodes (gallium nitride on gallium nitride)[4]. The use of the GaN substrate greatly improves the light emission. These diodes can be operated at higher current densities and produce more light from a smaller area. Their short wavelength emission is shifted to the purple part of the spectrum (around 405 nm) and they use a mix of three phosphors giving a better color rendering while avoiding the blue overshoot and the cyan gap of conventional LED.

Classically described, two types of photochemical damages are induced by light: the first involves rhodopsin and affects photoreceptors[5,6]. The second concerns the RPE (retinal pigment epithelium), selectively vulnerable

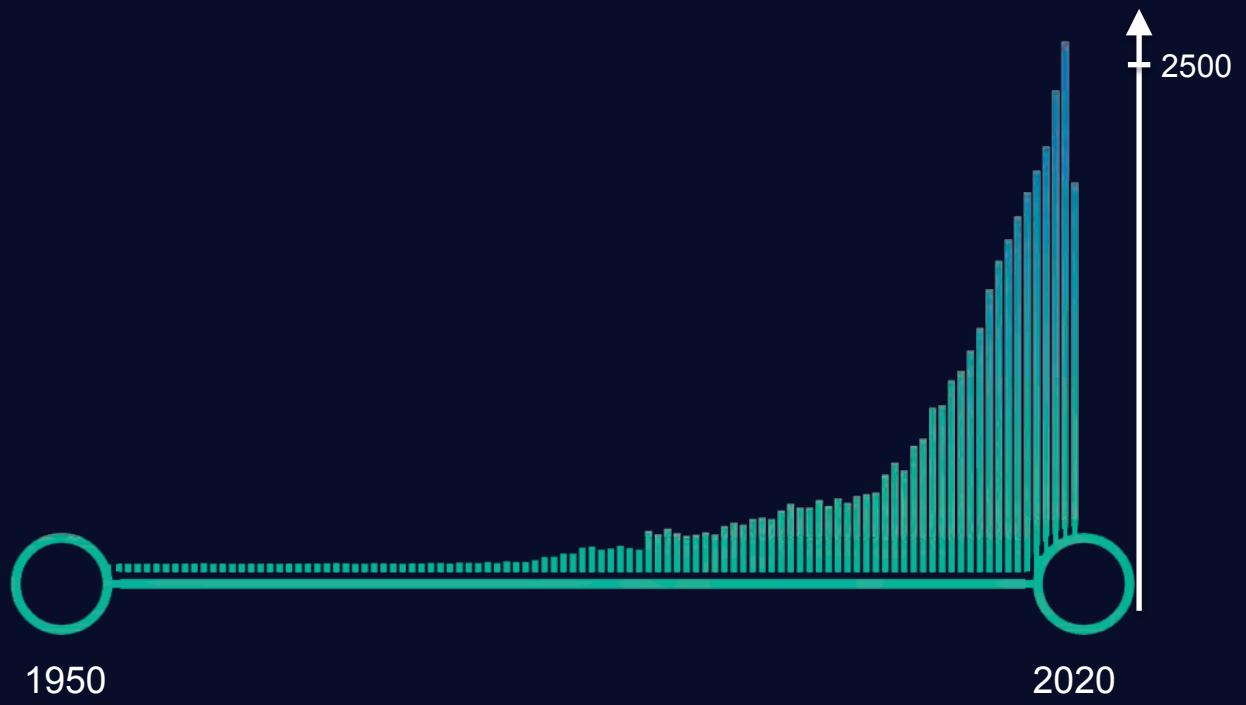
[1]INSERM U1138, Centre de Recherches des Cordeliers, Université Paris Descartes, Université Pierre et Marie Curie, Paris, France. [2]CSTB, Centre Scientifique et Technique du Bâtiment, Division Eclairage et électromagnétisme, Saint Martin d'Heres, France. [3]ENVA, Ecole Nationale Vétérinaire d'Alfort, Unité d'ophtalmologie, Maisons-Alfort, France. *email: alicia.torriglia@inserm.fr

s brain

Piotr Bebas

s are exposed to
vith normal sleep
e lifespan are not
ed that flies
flies maintained
ht per day
n. We report that
ses were evident
id flies but not in
eral known blue-
pected effects of
ght at the cellular

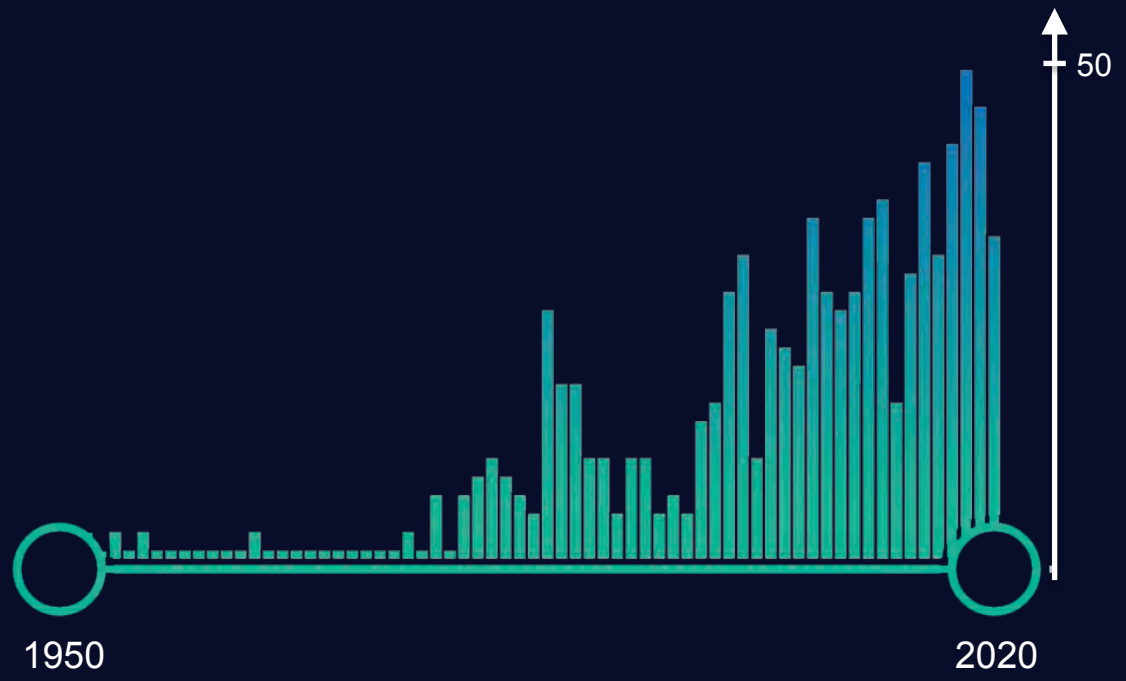
Surge in Published Research



Published research on “blue light”

Source: PubMed.gov

Surge in Published Research



Published research on “blue light *and* retinal damage”

Source: PubMed.gov

Google keyword searches for “Screen Time”

Source: Google Trends

GUIDING RESEARCH

Health Impacts: Short Term

Circadian Rhythm

"Blue light sends non-image forming (NIF) signals to biological clock through retinal ganglion cells ipRGCs"

Tosini G, Ferguson I., Tsubota K., Molecular Vision 2016; 22:61-72

"Light in the 460 nm range is more effective in phase-shifting the circadian system than exposure to light of longer duration and higher irradiance."

Tosini G, Ferguson I., Tsubota K., Molecular Vision 2016; 22:61-72

Digital Eye Strain and Dry Eye

"The long-term ocular effects of smartphone and handheld digital device use are unknown." "However, a range of short-term ocular surface discomfort, visual discomfort and aesthenopic symptoms are reported with smartphones and tablets use."

S. Jaiswal, et al., Clinical and Experimental Optometry, 2019.102 (5) 463-477

"Smartphone use can deteriorate the tear film via the reduced rate of eye blink, incomplete closure of the eye, and exposure of the ocular surface. It can also induce the oxidative stress response at the ocular surface, thus aggravating ocular symptoms."

J.H. Choi, et al, PLOS ONE, 2018. 13(10): p. e0206541

GUIDING RESEARCH

Health Impacts: Long Term

Long Term Impact - In Vitro Studies

"Cell viability decreased and apoptosis increased significantly after exposure to LCDs with higher emitted energy...Cell viability decreased significantly on day 3 after exposure to 300 nits LCD. No significant cell death was observed upon exposure to LCDs with lower luminance."

C.-W. Lin, C.-M. Yang and C.-H. Yang, International journal of molecular sciences, 2019. 20(9): p. 2318.

"Blue light induces expression of stress-responsive genes in old flies but not in young, suggesting that cumulative light exposure acts as a stressor during aging." "A surprising outcome of our study is that blue light not only damaged the retina, but also caused neurodegeneration in the brain."

T.R. Nash, et al., npj Aging and Mechanisms of Disease, 2019. 5(1): 8.

Long Term Impact - Reactive Oxidative Species

“Excessive exposure of the retina to blue light tends to cause ROS accumulation and oxidative stress, which affect the structure and function of the retinal mitochondria and trigger mitochondria-involved death signaling pathways.”

JX Tao et al., Oxidative Medicine and Cellular Longevity 2019, Article ID 6435364

Long Term Impact - Cumulative Impact

"Long-term exposure to blue light from portable devices emitting blue light from a short distance may cause potential damage to ocular health, especially in high-risk populations, such as people with DED, contact lens users, the malnourished and the elderly, due to accumulated oxidative stress that is a result of an imbalance between reactive oxidative species (ROS) generation and scavenging."

Y. Niwano, A. Iwasawa et al. BMJ Open Ophthalmology 2019 ;4:e000217

"Blue light has cumulative damaging effects, but the damage can be halted upon removal of this type of stress, provided that it does not accumulate beyond a certain irreversible threshold that causes death."

T.R. Nash, et al., npj Aging and Mechanisms of Disease, 2019. 5(1): 8

Higher Risk Populations

- Children
- Populations with preexisting conditions such as dry eyes, retinal disorders

Higher Risk Populations

"The absorption spectrum of the lens changes with age. In young children, more than 65% of blue light is transmitted to the retina. At around 25 years, only 20% of the light between 400 and 460 nm and 50% of wavelengths between 400 and 500 nm are transmitted"

F. Behar-Cohen, C. Martinsons, et al., Progress in Retinal and Eye Research, 2011. 30(4): p. 239-257

"Blue light induced cell death and significant ROS production, and altered the expression of inflammatory genes and operation of the cellular defensive system. We established for the first time that hyperosmolar stress impacted phototoxicity, further suggesting that DED patients might be more sensitive to blue light ocular toxicity"

Marek V., et al. Free Radic. Biol. Med. 2018, 126 : 27-40.
