

## Understanding Blue Light

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### ABSTRACT

With technological progress, humans have increasingly used and presumably will increasingly use electronic systems that emit blue light from their screens. The light pollution emitted by blue light is the cause of numerous problems in the human visual system, including dry eyes, cataracts, macular degeneration, and inhibition of melatonin production which affects sleep quality. For these reasons, the effects of Blue Light on human eyes are today an extremely important issue.

## THE NATURE OF LIGHT

Light is a transverse electromagnetic wave, the nature of which is demonstrated by polarization. The wave nature of light was first illustrated through the diffraction and interference experiments. As an electromagnetic wave, light can travel through a vacuum.

Doctors and physiologists have long been very interested in the influence that light has on health. Specifically, ophthalmologists and vision experts have conducted in-depth studies on the interactions between electromagnetic radiation and ocular structures.

Currently, since experimental results seem contradictory, physicists admit the dual nature of light. According to Sears (2015), the theory of electromagnetic waves explains the phenomenon of propagation, while the corpuscular theory explains the phenomenon of interaction of light.

The relationship between the frequency and wavelength of light is relevant to the effects of light on humans. The amplitude of a light wave is related to its intensity, which in turn is the absolute measure of the power density of a light wave. The relative intensity parameter perceived by the human eye is called brightness, while colour is related to the frequency of the light wave.

Light is sometimes also known as visible light to differentiate it from ultraviolet light and infrared light. Other forms of electromagnetic radiation that are not visible to humans are simply called light, which is determined by different frequencies. Reasoning on the basis of electromagnetic radiation, a high wavelength is associated with a low frequency. Therefore, since red

light has a lower frequency than blue light, it is expected to have a longer wavelength (Branley, 1980).

Variations in light can be measured by their wavelength, which is between 400 nm and 700 nm for the visible spectrum from purple to red. An explanatory graph of relative intensity versus frequency is shown in Figure 1.

(See Figure 1.)

According to Lindon et al. (2016), spectroscopy is the study of the interaction between matter and electromagnetic radiation.

Only a very limited part of the electromagnetic spectrum contains radiation that is visible to the eye; Bruno et al. (2005) state that the spectrum of the various wavelengths is divided into small bands.

(See Figure 2.)

(See Figure 3.)

Indigo is an intense colour close to blue on the colour wheel, a primary colour in the RGB colour space (RGB indicates red, blue and green).

Traditionally, it is considered a colour in the visible spectrum, as well as one of the seven colours of the rainbow: the colour between purple and blue. However, sources differ on its actual position in the electromagnetic spectrum.

Maerz and Paul (1930) observed that the first known use of indigo as a colour name in English was in 1289; the colour takes its name from the indigo dye obtained from the *Indigofera tinctoria* plant and related species. The modern English word refers to the dye, not the colour (hue) itself, and indigo is not traditionally part of the basic colour naming

system. Modern sources place indigo in the electromagnetic spectrum between 420 and 450 nanometres, which is located on the shortwave side of blue on the colour wheel, between blue and purple.

## INTERACTION BETWEEN LIGHT AND THE EYE

The processes leading to visual perception begin in the retina. The light entering through the cornea is projected first into the lower part of the eye, where a specialized sensory organ, the retina, transforms it into electrical signals.

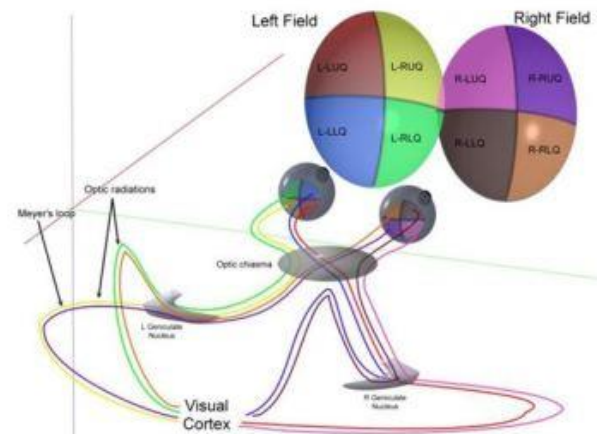
According to Catalano (2002), once the light rays are focused on the retina, the formed image is processed by millions of photoreceptor cells called cones and rods. These photoreceptors transmit the signal to the brain through the optic nerve.

Jin-Xin Tao et al. (2019) state, “the retina is the innermost light-sensitive layer of the eye and is part of the central nervous system that originates as an outgrowth of the developing brain”. The neural retina is comprised of several layers of neurons connected by synapses and is supported by an external layer of pigmented epithelial cells. The light-sensitive primary cells in the retina are photoreceptor cells, which are of two types: rods and cones.

Pescosolido (2013) indicates that in embryonic development of vertebrates, the retina and optic nerve originate as developing brain growths, so the retina is considered part of the central nervous system (CNS) and is actually brain tissue. It is the only part of the central nervous system that can be viewed non-invasively.

Figure 4.

### Optic Cabling



Note: From [th.wikipedia.org](http://th.wikipedia.org).

The cornea lies at the front of the eyeball and is the first structure that light encounters when passing through the eye. Some studies have shown that the survival rate of corneal epithelial cells decreases after blue-light irradiation.

Exposure to sunlight is commonly considered to be a risk factor for cataracts. A study by Osborne et al. (2014) found that blue light can induce the production of ROS in the mitochondria of lens epithelial cells, which may lead to the development of cataracts. We find similar deductions from Babizhayev (2011) and Xie et al. (2014), who both state that “oxidative stress was considered an important medium in the pathogenesis of age-related cataracts”.

The retina is the initial site of vision formation, and it is also the lesion site of various eye diseases that can lead to blindness. Pescosolido (2013) claims that blue light can penetrate through the lens to

the retina and cause photochemical damage to the retina. However, there are currently not many studies on the effects of blue light on the retina, and some are still under discussion.

## BLUE LIGHT

Blue light is emitted mainly from cell phone screens, computer monitors, and televisions. For a long time, scientists have been analysing the effects that this type of radiation has on human eyes.

When interacting with environments and within them with the most diverse materials, light greatly changes our perceptive approaches towards the space that surrounds us. Many authors have considered the scientific-notional aspect of light. In the case of blue light, knowledge has evolved over time.

To understand its importance, we must remember that Blue light wavelengths are everywhere. They collide with air molecules, which causes blue light to scatter and makes humans perceive the sky as blue. They also help to regulate the body's sleep and wake cycles, also known as circadian rhythm.

Since blue light is one of the shortest but most powerful energy wavelengths in the light spectrum, it blinks longer than other types of weaker wavelengths. This phenomenon (flickering) produces a glow that reduces visual contrast, affecting clarity and sharpness of images. This can cause eye strain and physical and mental fatigue. Human eyes are not structured to filter this type of artificial light. It is therefore important that doctors check the blue light exposure level of adults and children. Statistics from Zizi et al. (2002) supports the above, since currently 43% of adults have

job that requires a prolonged use of a tablet or computer; 74% of teens between the ages of 12 and 17 use electronic devices at least occasionally; 70% of adults who regularly use electronic devices report symptoms of digital eye strain; 93% of teens have access to or have a computer.

## RETINAL DEGENERATION AND MORPHOLOGICAL CHANGES

Kim et al. (2016) studied the effects of irradiation induced by blue LEDs on retinal function and morphology. The results showed that the amplitude of an electroretinogram decreased after irradiation with blue light and that blue light can accelerate the onset and development of age-related macular degeneration (AMD) after a cataract surgery. Furthermore, an experimental study on oxidative stress injury induced by blue light was conducted on rabbit retinas. It showed that after 24 hours of blue light irradiation, the retinas were disordered in the inner and outer segments of the photoreceptor cells compared to normal. This is a problem, given that the more disordered the cellular arrangement, the thinner the external nuclear layer, therefore a higher potential for tearing of the retina.

Figure 5.

*Wet Age-Related Macular Degeneration*



Note: From [www.cehjournal.org](http://www.cehjournal.org).

According to AUVA (2011), retinal photodamage caused by a conventional cold light source (light [emitted](#) at low temperatures from a source that is not [incandescent](#)) can become chronic if the exposure is high and long enough. By contrast, the use of filters to block blue light can significantly alleviate the functional loss of retinal photosensitive cells. Therefore, these filters could be an effective mechanism to protect people from eye diseases.

This importance is also affirmed by Tejedor (2018), who concludes that “retinal photodamage caused by a conventional light source (cold) can become chronic if exposure is high and long enough and that photoreinitis is a pathology of a photochemical nature”.

The onset of photoreinitis is due to exposure to blue-violet light. In blue-light photoreinitis, photoreceptors are no longer able to perform signal translation activities because they are excessively stimulated creating progressive damage proportional to the time spent exposed to the radiation. Symptoms are blurred or impaired vision due to the progressive degeneration of photoreceptors. Retinal burns can also occur with loss of vision when the damage is extensive and concentrated.

Other studies that determine complications for the eyes from blue light exposure:

Jaadane et al. (2017) detected retinal oedema induced by blue light in two mouse models through fundus imaging and optical coherence tomography (OCT).

Ishii et al. (2017) proved localized cell damage in the retinal pigment epithelial cells. Li *et al.* (2014) found that blue light

may be involved in the lesion of the retinal pigment epithelial cells.

Finally, a study by Del Olmo-Aguado et al. (2016) states that “blue light impinging on the many mitochondria associated with retinal ganglion cells (RGCs) in situ has the potential of eliciting necroptosis”.

### **EFFECTS OF BLUE LIGHT ON REFRACTIVE DEVELOPMENT**

The results of a study by Czepita et al. (2010) show a higher incidence of myopia related to the increase in the length of screen exposure time of students.

Foulds et al. (2013) concluded that “manipulation of chromaticity may be applicable to the management of human childhood myopia”, while Zou et al. (2018) state that “altered retinal cones and opsins induced by monochromatic lights might be involved in the refractive development in guinea pigs”.

### **EFFECTS OF BLUE LIGHT ON CIRCADIAN RHYTHM**

“A circadian rhythm is a natural, internal process that regulates the sleep-wake cycle and repeats roughly every 24 hours”, as established by Aschoff (1965). It can refer to any biological process that displays an endogenous, entrained oscillation of about 24 hours. Rubio et al. (2016) state that “these 24-hour rhythms are driven by a circadian clock, and they have been widely observed in plants, animals, fungi, and cyanobacteria”.

As described by Albini (2019), the circadian rhythmicity is present in the patterns of sleep and feeding of animals and humans, and it is

now evident that it influences patterns of internal body temperature, brain wave activity, hormone production, cell regeneration, and other biological activities. Photoperiodism, the physiological reaction of organisms to the length of the day or night, is therefore vital for health and development of plants and animals. The circadian system also plays a role in measuring and interpreting the length of the day. Numerous studies, such as one by Münch et al. (2016), have shown that blue light regulates the body clock and promote alertness, memory and cognition.

However, if exposure to blue light is excessive, especially in the evening when melatonin production peaks, it can damage the retina. Moreover, it can stimulate the brain, inhibit melatonin secretion, and increase the production of corticosteroids, thus inhibiting hormonal secretion and negatively affecting sleep quality.

In any case, blue light is not entirely bad. We must remember that the main mechanism is that blue light stimulates the secretion of melatonin in the pineal gland, which can increase or decrease cortisol expression, depending on the time of day, and regulate human circadian rhythm.

Gabel et al. (2017) monitored the quality of sleep in the elderly and found that it improved somewhat after cataract surgery (the clouded lens is removed, and a clear artificial lens is implanted). The reason is that the transparent artificial crystals allow more blue light to penetrate, thus confirming that it can regulate the circadian rhythm.

Bellantuono (2003) asserts that the benefits of sunlight for the human body are numerous and vital. Ultraviolet B-rays (UVB) help people synthesize vitamin D. Moderate daily exposure to the sun directly impacts mood

because it stimulates the production of serotonin, a monoamine neurotransmitter. It also helps regulate a person's biological clock and sleep: their eyes receive sunlight and transmit it to the brain, which sends information to the pineal gland and ultimately secretes melatonin, which promotes sleep.

The importance of this physiological process is highlighted by Hunt et al. (2007), who conclude that the clock plays a key role in the host-pathogen relationship, the inflammatory response to infection, and the disturbances caused by tumour growth. Based on current knowledge, it is critical to decipher the role of specific epigenetic regulators in controlling the circadian epigenome.

## TECHNOLOGY AND HUMAN BIOLOGY

Computer vision syndrome (CVS) is also referred to as digital eye strain. The American Optometric Association (2018) describes a group of eye- and vision-related problems that result from prolonged use of computers, tablets, e-readers, and cell phones. Many individuals experience eye discomfort and vision problems when viewing digital screens for extended periods. The level of discomfort appears to increase with the amount of digital screen use. The most common symptoms associated with CVS are eye strain, headaches, blurred vision, dry eyes, and neck and shoulder pain. These symptoms may be caused by poor lighting, glare on a digital screen, improper viewing distance, poor seating posture, uncorrected vision problems, or a combination of these factors.

LED lights are increasingly present in daily life, more so since 2009 when the European

Commission published EC regulation no. 244/2009 introducing the gradual ban on traditional incandescent and other energy-inefficient lightbulbs.

There has been an increase in the use of new ophthalmic aids, including intraocular lenses and spectacle lenses, designed to protect the eyes from potential photochemical damage. These lenses claim to use filtering materials or surface coatings to reduce the spectral transmittance of short-wavelength blue light.

Technological development (we also think only what the Optical Coherence Tomography (OCT) can give us in clinical terms today compared to a few years ago to visualize the different layers of the retina ) will allow future researchers to go even deeper into the problems arising from blue light, which today are a novelty about which the population should have greater information to allow greater awareness of the risks and therefore adequate protection.

## CONCLUSION

A key challenge when using ophthalmic lenses with special treatments to find the balance between effectively reducing the risks of a long blue light exposure (especially at night), and benefiting from the positive properties of natural light and therefore essential visual functions in everyday life. In summary, to a certain extent, blue light can promote human eye refractive development and regulate circadian rhythms, but the harmful effects of blue light on human eyes should not be ignored. blue light can cause varying degrees of damage to the cornea, crystalline lens, and retina.

As time passes, it is likely that more evidence of the effects of blue light will be found. We are only at the beginning of a long battle.

This thesis is intended as a starting point for reflection on the evolution that human beings have experienced thanks to studies on light over the centuries; it is also a warning not to underestimate the hidden effects of a part of it, since the effect of blue light on ocular health has become an important concern for the future.

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## APPENDIX

Figure 1.

### Visible Spectrum

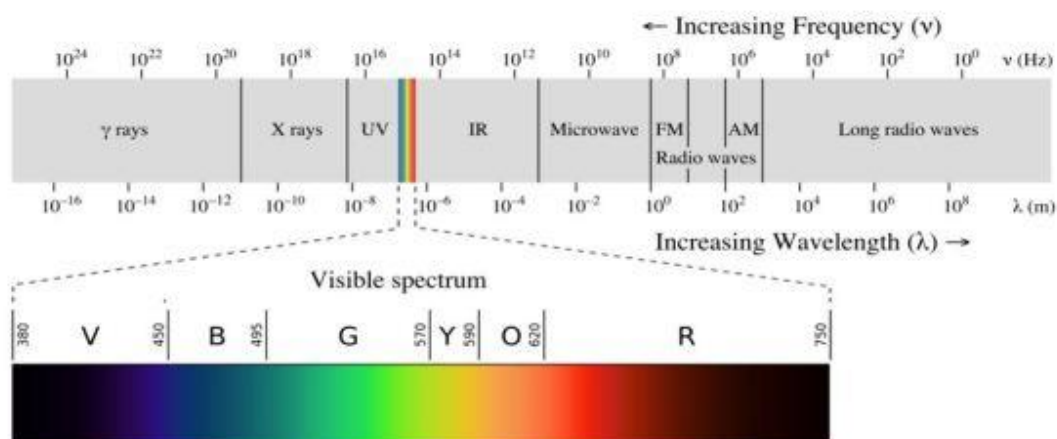
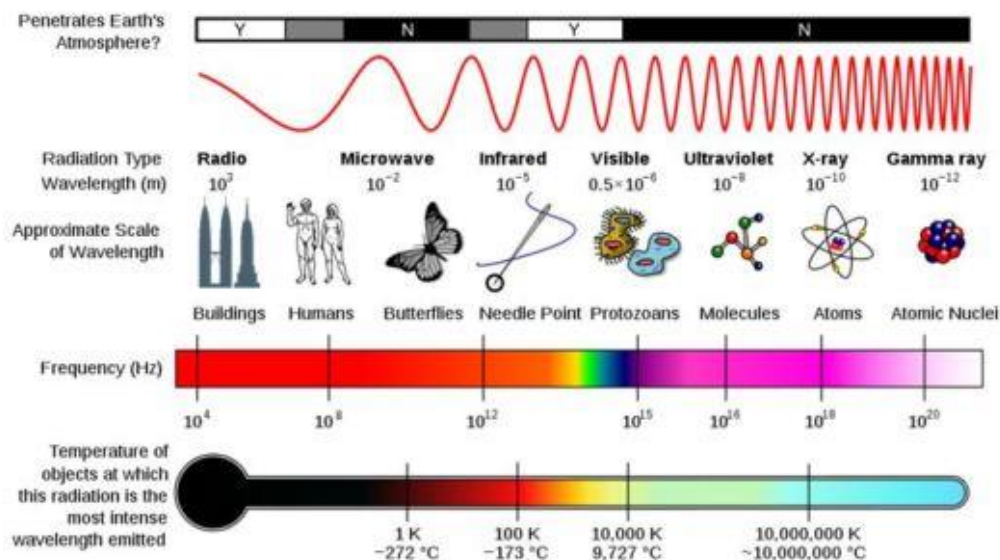


Figure 2.

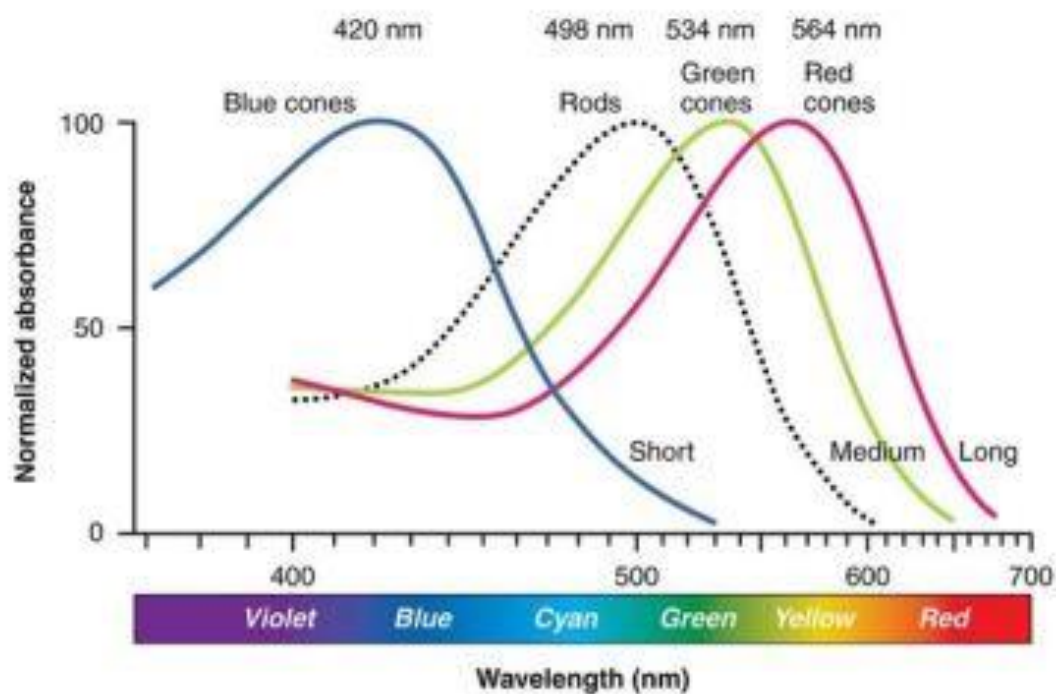
### The Electromagnetic Spectrum



Note: From commons.wikimedia.org.

Figure 3.

*Colour Sensitivity*



*Note: From commons.wikimedia.org.*