Without light, there is no sight –

Light and ocular health

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Bern, 19.03.2018

Introduction

- Light is essential for our visual system and visible light is defined as light between 400 and 780 nanometres in wavelength. [1]

- The International Commission on Non-Ionizing Radiation Protection (ICNIRP) defined the subgroups of ultraviolet and infrared radiation as follows: UVA: 315 - 400 nm; UVB: 280 - 315 nm; UVC: 100 - 280 nm and IRA: 700 - 1.400 nm; IRB: 1.400 - 3.000 nm; IRC 3.000 - 10.000 nm.[2]

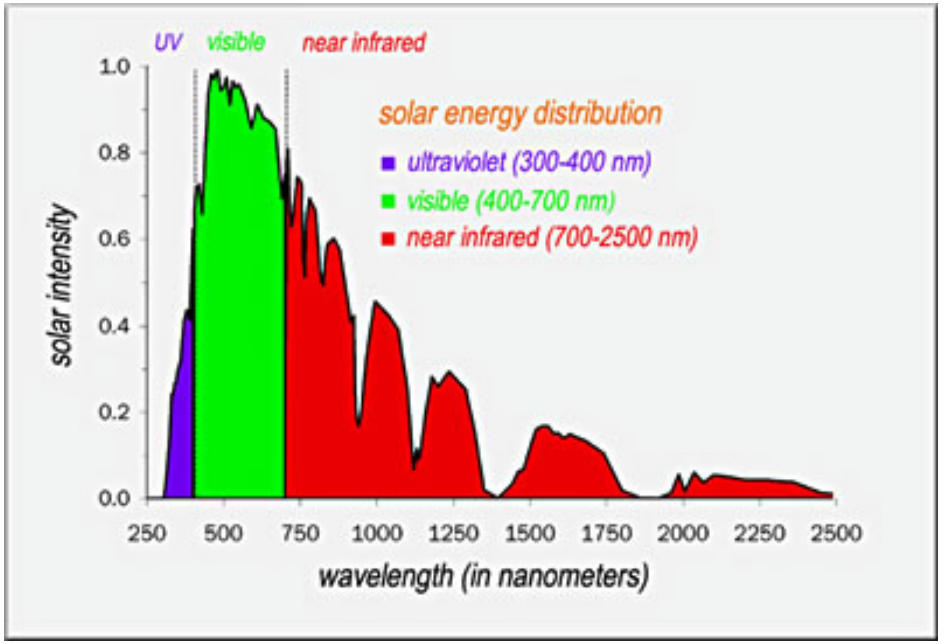

Figure 1. UV light, visible spectrum of light and infrared light (source: http://www.theoildrum.com/node/4964)

Introduction

- Light is transmitted through the eye and then after absorption, scattering and transduction, the signals are compressed and send via the optic nerve to the brain, directing both: the visual perception and the circadian rhythm.

- Because of its function and structure, the eye is most prone to light damage: It is designed to focus incoming light rays to form images on the neural retina. This has the effect of concentrating the light, or increasing the power density of light on the retina.

Introduction

- The absorption spectrum of each ocular tissue must be taken into account to understand its differential sensitivity with respect to wavelength. [3-4]

- The primary factors that determine whether ambient radiation will injure the human eye outside of defined laboratory conditions are (1) the intensity of the light, (2) the wavelength received by ocular tissues, and (3) the age of the recipient. [4]

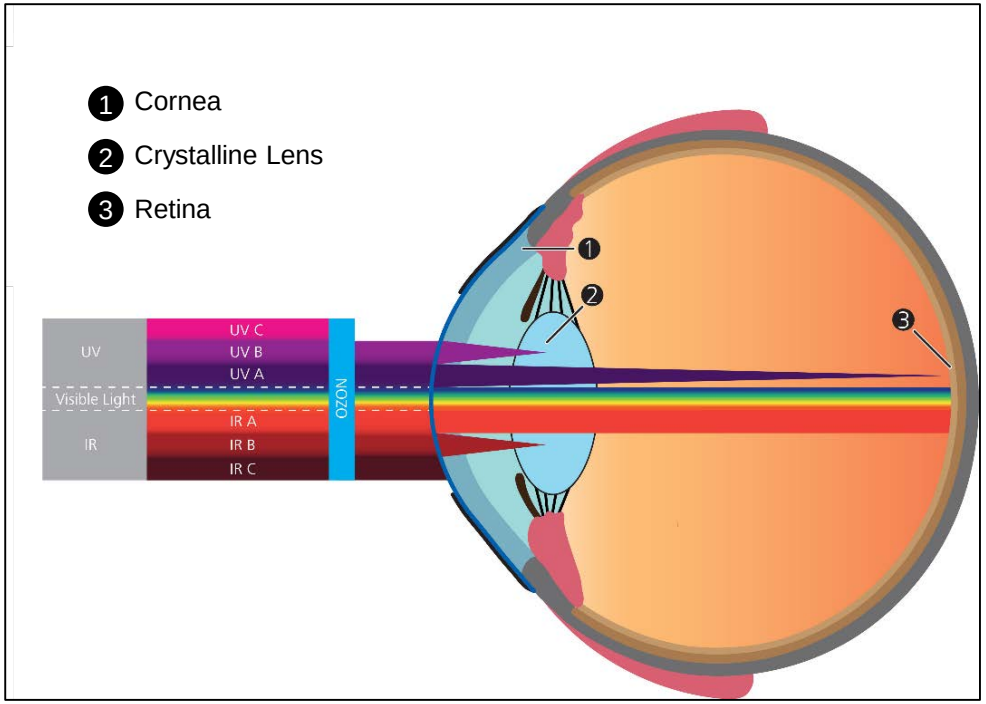

Figure 2. A schematic view of the eye showing the relative propagation of the different optical radiation bands through the ocular tissue. (Source: Carl Zeiss Vision Gmbh, Aalen)

Introduction

- It has long been speculated that visible light, even of ordinary everyday intensity, may cause retinal damage or contribute to the development of age-related maculopathy (AMD).[5]

- Extensive work in animal models and other experimental settings has unequivocally shown that visible light can cause retinal cellular damage to the photoreceptors and retinal pigment epithelium (RPE). [6]

- The purpose of the talk is to summarize recent research that was conducted to investigate the effects of low-wavelength light on the ocular health.

Impact of low-wavelength light:

The Cornea.

- The cornea absorbs most of the UV-B radiation and therefore, the cornea is especially sensitive to the damage induced by UV-B exposure.[7]

- A exposure to UV light
  - is the primary cause of photokeratitis, also known as UV keratitis and is associated with pain and reduced visual acuity. [8]
  - can also lead to a damage of the DNA of the corneal cells (epithelial, stromal and endothelial), resulting in apoptosis. [9]

- If the exposure to UV light is short-term, the cornea can heal itself, but a chronic exposure can cause permanent damage. [10]

Impact of low-wavelength light:

The Crystalline lens.

- Any modification in the clarity of the lens will degrade the quality of the image presented to the retina, and greatly affects visual perception.

- The most common cause for the clouding of the lens is a cataract that is mostly due to biological aging, but various epidemiologic studies have found a correlation between cataract formation and the exposure to UV-B light.[11-12]
  - More specifically, UV-B light has been connected to the development of cortical cataract. [11]

- In addition, there are many dyes, drugs and herbal medication that in the presence of both visible light and UV light can induce a cataract and this phototoxic reaction causes a very early cataract. [13]

Impact of low-wavelength light:

The Retina.

- In mammals, photoreception occurs in the retina by three types of photoreceptor: cones, rods, and the intrinsically photosensitive retinal ganglion cells (ipRGCs).[14]

- The classical photoreceptors (e.g., rods and cones) are mostly responsible for the image-forming vision. [15]

- The ipRGCs play a major role in non-image-forming photoreception, that is, the photoreceptive system that regulates circadian photic entrainment and the pupillary light response. [15]

Impact of low-wavelength light:

The Retina.

- Although the retina receives very little UV light, it is still exposed to blue light.

- Taylor et al. and Fletcher et al. found a direct relationship between exposure to blue light and the development of age-related macular degeneration (AMD), especially in older individuals.[10,11,16]

- An increased risk for AMD is also stated for lightly pigmented iris individuals.[17]

Impact of low-wavelength light:

The Retina.

- The retina itself has a self-protection mechanisms that reduces the amount of low-wavelength light reaching the retina – the so-called macular pigment.[18]

  - A low density of macular pigment may represent a risk factor for age-related macular degeneration (AMD) by permitting greater blue light damage. [19]

  - The macular pigments are most effective in filtering blue light at wavelengths between 400 and 550 nm with a peak around 446 nm. [20]

Findings from epidemiological studies

- As the leading cause of older people's blindness in most developed countries[21], AMD accounts for 14% of individuals' blindness over 55 years and for 37% of cases in people over 75 years of age. [22]

- It is being speculated that visible light, even of ordinary everyday intensity, may cause retinal damage or contribute to the development of age-related maculopathy (AMD). [23]

- Extensive work in animal models and other experimental settings has unequivocally shown that visible light can cause retinal cellular damage to the photoreceptors and retinal pigment epithelium (RPE). [23]

Findings from epidemiological studies

- The Blue Mountains Eye Study. [24]
  - investigated the longitudinal associations between iris/hair/skin colours, skin sun sensitivity and the 5-year incidence of AMD.
  - After adjusting for age, sex and smoking, no significant associations were found between iris or hair colour and incident AMD.
  - The authors concluded that their longitudinal data provided no support for previously reported cross-sectional associations between iris colour and AMD.

Findings from epidemiological studies

- Darzins et al. [25]
  - A large population-based case-control study on the relationship between AMD and sun exposure. The authors found that sun exposure was even greater in their control group than in subjects that developed AMD.

- Chesapeake Bay Watermen Study. [10]
  - the scientist did not found evidence for a increased risk of age-related macular degeneration associated with UV-B or UV-A exposure in phakic subjects, even with high levels of sunlight exposure

BUT

Light affects the refractive development!

- Monochromatic cues can modulate the development of refractive errors in different species, including chicks, guinea pigs, tree shrews and rhesus monkeys. [26]

Experimental findings	animals
Shift towards hyperopia after treatment with short wavelength light	chicken, guinea pig
Shift towards myopia after treatment with long wavelength light	chicken, guinea pig
Shift towards of hyperopia treatment with long wavelength light	tree shrews, rhesus monkey
Reverse shift after treatment	chicken, tree shrews
No refraction difference after treatment with monochromatic light	chicken, macaq monkey
No refraction difference after continuous light treatment	guinea pigs

BUT

Light affects the refractive development!

- Animal studies support the idea that high polychromatic light exposure, especially outdoors, interacts with myopia development in a protective manner. [27]

- Rose et al. 2008 found in children in the Sydney Myopia Study, that children had less myopic refraction when they spent more time outdoors. [28]

- A Meta-analysis concluded that "The overall findings indicate that increasing time spent outdoors may be a simple strategy by which to reduce the risk of developing myopia and its progression in children and adolescents." [29]

Summary

- The bottom line is: without light, there is no sight

- While experimental studies, such as cell culture, mostly consider the naked retina, real irradiation is strongly attenuated by cornea, lens, pupil constriction and the human effort to shade the eye from direct sun light to avoid glare.

- Epidemiologists have investigated if the exposure to sunlight is a risk factor for the development of age-related macular degeneration in phakic and non-phakic eyes. Especially in phakic eyes there remains an ongoing dispute over this association due to insufficient evidence and unreliable data.

  - Paracelsus: “It is the dose that makes a thing poisonous”

Thank you!

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