Photobiology And The Human Eye:

What Eye Care Providers Should Know About UV and Blue Light Protection

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INTRODUCTION

As scientific knowledge about the health effects of electromagnetic radiation on the human eye has grown over the past several decades, eye care providers are becoming more concerned about the risks that ultraviolet (UV) and high-energy visible (HEV) blue light pose to their patients' vision and eye health.

In response to this concern, eyeglass lens manufacturers have introduced lenses that attenuate specific wavelengths of UV and blue light and have marketed these lenses as being beneficial to eye health and visual comfort.

Though the body of research that supports the value of protecting the eye from UV and blue light is substantial and growing, confusion remains about the risks associated with blue light and which wavelengths are the most potentially damaging to the eye.

Some of this confusion may come from marketing materials for specific brands of eyeglass lenses that "cherry pick" research findings to support the absorptive (radiation blocking) characteristics of these lenses.

At this time, though studies suggest protecting the eye from high-energy visible light is a good idea, a consensus does not yet exist among eye care providers regarding what the absorptive characteristics of such protective eyewear should be.

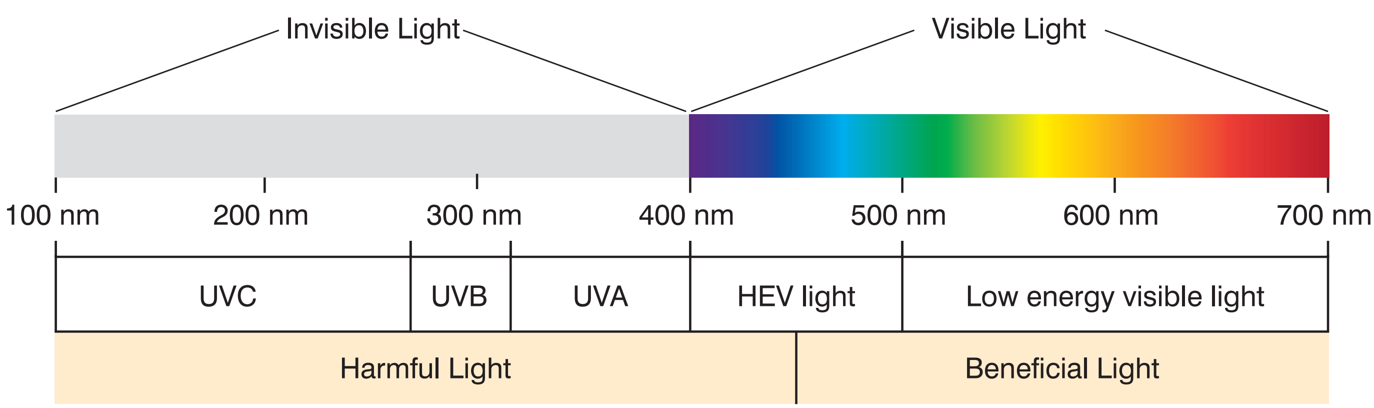
In this paper, I will attempt to provide a brief snapshot of what we currently know—and don't know—about the effects of UV and high-energy visible ("blue") light on the human eye and offer a prudent, evidence-based protocol for prescribing eyewear that protects the eye from UV and blue light damage.

PHOTOBIOLOGY OF THE HUMAN EYE: THE BASICS

Here are a few key points about the UV and high-energy visible bands of electromagnetic radiation and the interaction of these invisible (UV) and visible (blue light) rays with the human eye:

- Electromagnetic radiation (EMR) is radiant energy that travels in synchronized waves of electric and magnetic fields. Visible light is one type of electromagnetic radiation; others include UV rays, infrared light, radio waves and X rays.
- The energy of EMR is dependent on its wavelength. Rays with shorter wavelengths have higher energy; those with longer wavelengths have less energy.
- Wavelengths are measured in units called nanometers (nm). One nanometer equals one billionth of a meter.
- There is a lack of consistency among scientific and health organizations regarding where invisible UV radiation ends and visible light begins. For the purposes of this paper, I am using the definitions of UV and visible light adopted by the World Health Organization, the International Organization for Standardization (ISO) and the U.S. National Aeronautics and Space Administration (NASA), which say UV radiation has wavelengths ranging from 100 to 400 nm and visible light has wavelengths ranging from 400 nm to 700 nm.[1,2,3]
- Ultraviolet radiation has higher energy than visible light. There are two categories of UV radiation that penetrate the Earth's atmosphere and reach the eye: UVB (280-315 nm) and UVA (315-400 nm).[3]
- High-energy visible light ("blue light") comprises the end of the visible light spectrum adjacent to UV and has higher energy and shorter wavelengths (400-500 nm) than other visible light (500-700 nm). The color spectrum of blue light ranges from violet (400 nm) to turquoise (500 nm).
- The Earth's atmosphere blocks the sun's UVB rays with wavelengths shorter than 290 nm, but does not block UVA from sunlight. So some UVB rays (290-315 nm) and all UVA rays (315-400 nm) reach our eyes.[3]
- The cornea of the human eye absorbs (blocks) UVB rays with wavelengths shorter than 295 nm.[4]

- UV protection provided by the crystalline lens of the eye depends upon age. The lens of a young child allows UVA rays with wavelengths as short as 320 nm to reach the retina. As the lens ages it blocks more UV. In adults, the crystalline lens blocks all UVA up to 400 nm.[4] But the exact time frame required for the lens of a young eye to attain full UV-blocking potential is unknown and may vary from person to person.
- With equal intensity and duration, electromagnetic radiation with shorter wavelengths (higher energy) is more damaging to human tissue (including the eye) than rays with longer wavelengths (lower energy).
- Visible blue light has less energy than UV rays, but much more blue light reaches the retina over the course of a person's lifetime. The adult retina is protected from UVB and UVA rays by the cornea and lens; but in young eyes, the retina is exposed to significant amounts of UVA rays until the lens develops its full UV-blocking potential sometime in early adulthood.
- The intensity of electromagnetic rays plays a significant role in their potential to cause damage. The unit used to quantify of the intensity of light experienced by the human eye is called the *lux*. The sun emits 32,000 to 130,000 lux of visible light. By comparison, a computer screen emits around 300 lux of visible light. In other words, blue light from sunlight is more than 100 times more intense than blue light emitted by computer screens and portable electronic devices. It takes approximately 13 hours of looking at a computer screen to get the same dose of blue light received from being in direct sunlight for 15 minutes.[5]
- Circadian rhythm refers to the changes in human behavior and physiology that occur within roughly a 24-hour period. Longer wavelength / lower energy blue light (460 to 500 nm) plays a role in regulating circadian rhythm in humans.[6] Though animal studies have shown that even this low-energy blue light is capable of causing retinal damage,[7] the duration and intensity of the light used in these studies makes it difficult to draw conclusions regarding whether this band of blue light poses a risk of significant eye damage in humans in real-life conditions.



NOTES

1 Global solar UV index: a practical guide. World Health Organization. 2002.
2 Cosmetics—sun protection test methods—review and evaluation of methods to assess the photoprotection of sun protection products (ISO/TR 26369:2009). International Organization for Standardization. 2009.
3 Ultraviolet radiation: how it affects life on earth. The Earth Observatory; EOS Project Science Office; NASA. September 6, 2001.
4 Roberts JE. Ocular phototoxicity. *Journal of Photochemistry and Photobiology B: Biology*. November 2001.
5 Data on file. Vision Ease. March 2016.
6 Roberts JE. Circadian rhythm and human health. American Society for Photobiology. July 27, 2010.
7 Hunter JJ, et al. The susceptibility of the retina to photochemical damage from visible light. *Progress in Retinal and Eye Research*. January 2012.

WHAT WE KNOW (AND DON'T KNOW)

Based on a review of research that's been published over the past several decades, here's a brief summary of what we currently know and don't know about the effects of UV and blue light on the human eye:

1. **Lifetime exposure to solar UV radiation has a significant association with the development of cataracts and other eye problems.**

   Multiple studies have shown an association between exposure to UV radiation and cataract formation.[1] In addition to cataracts, the sun's UV rays have been associated with or have been shown to be the cause of: photokeratitis ("snow blindness"); pinguecula; pterygium ("surfer's eye"); premature aging of the skin around the eye; certain types of cancer.

2. **Protection from UV and blue light is helpful at any age, but there's good reason to believe that starting in early childhood is the most effective approach.**

   As mentioned above, research has shown that a young crystalline lens allows more UV to reach the retina than the lens of an adult eye. And though the retina is exposed to significantly more visible light than UV radiation over the course of a person's lifetime, a meta-analysis of animal studies has shown that retinal damage occurs at far lower doses of UV, compared with doses of blue light required to cause damage—in some cases, the dose threshold was up to an order of magnitude different.[2]

   It's possible that long-term damage to the human retina from UV and blue light follows a course similar to that of certain skin cancers caused by solar UV radiation, which are characterized by a long latency between the time of exposure to a carcinogen (i.e., the sun's UV rays) and the actual development of the disease.

   If this is the case, protecting the eyes of children and young adults from UV and high-energy visible light takes on an even greater importance for maintenance of the health of the retina, since it is during childhood (and possibly early adulthood, to a lesser degree) that the retina receives most of its exposure to UVA up to 400 nm.

   It's also noteworthy that children typically spend more time outdoors than most adults. One researcher[3] suggests that nearly 50 percent of a person's lifetime exposure to UV radiation can occur prior to age 18—when the crystalline lens does not protect the retina from UVA up to 400 nm.

   Unfortunately, few American children routinely wear UV- and HEV-protective sunglasses. A recent survey of parents with children under age 13 found that 33.7 percent of these children "rarely" or "never" wore sunglasses, and another 41.5 percent wore them only "sometimes."[4]

3. **Higher energy (shorter wavelength) blue light is more damaging to specific components of the retina than lower energy (longer wavelength) blue light.**

   Research that evaluated the impact of blue light emitted from light-emitting diodes (LEDs) on retinal nerve cells of rats found that short-wavelength (411 nm) blue light caused changes in cell mitochondria at low irradiance levels and caused cell death at high irradiance levels. By comparison, long-wavelength (470 nm) blue light failed to produce these cellular effects or cell death, even at high irradiance levels.[5]

4. **Different components of the retina are susceptible to different wavelengths of blue light.**

   A series of animal studies has shown that UVA and blue light with wavelengths up to 440 nm cause damage to photoreceptors (light-sensitive cells) in the retina, and blue light with wavelengths higher than 440 nm cause damage to the retinal pigment epithelium (the layer of pigmented cells between the choroid and the retina that plays an important role in nourishing and maintaining the photoreceptor cells).[6]

5. **At least one human population study shows long-term exposure to high environmental levels of blue light is associated with AMD.**

   A population study designed to evaluate the relationship between long-term exposure to sunlight and eye problems among 838 men who worked many years on Chesapeake Bay found that, on average, study participants with advanced (grade 4) age-related macular degeneration (AMD) had a 48 percent higher exposure to blue light over the previous 20 years than their age-matched controls who did not have AMD.[7]

UNCERTAINTIES REMAIN

Because there is significant research that shows UV radiation increases the risk of cataracts and other eye problems, UV-blocking sunglasses should be worn by virtually everyone to reduce the risk of UV-related eye damage.

When it comes to blue light, though animal studies have shown the eye-damaging potential of HEV light, these findings are not predictive of the risk that blue light poses for the development of AMD or other retinal disease in human eyes. And though studies of human macular pigment density and the risk of AMD progression following cataract surgery support the hypothesis that blue light plays a role in the development of macular degeneration, population studies are inconclusive.[8]

More research is needed to understand more about a possible association between blue light exposure and macular degeneration (and other eye problems). In particular, future studies should include a large-scale clinical trial to evaluate the effect of blue light filters on the progression of AMD.[7] Also, studies should be designed to determine whether long-term exposure to low-intensity blue light emitted from computer screens and portable digital devices represents a meaningful increase in the risk of eye damage beyond that caused by high-intensity UV and blue light from sunlight.

NOTES

1 Roberts JE. Ultraviolet radiation as a risk factor for cataract and macular degeneration. *Eye & Contact Lens*. July 2011.

2 Van Norren D and Gorgels T. The action spectrum of photochemical damage to the retina: a review of monochromatic threshold data. *Photochemistry and Photobiology*. March 2011.

3 Stern RS. Proportion of lifetime UV dose received by age 18: what Stern et al actually said in 1986. *Journal of Investigative Dermatology*. May 2005.

4 Protection for the naked eye: sunglasses as a health necessity. The Vision Council. 2015.

5 Knels L, et al. Blue light stress in retinal neuronal (R28) cells is dependent on wavelength range and irradiance. *European Journal of Neuroscience*. August 2011.

6 Rozanowska M, Rozanowska B, Boulton B. Light-induced damage to the retina. *American Society for Photobiology*. March 9, 2009.

7 Taylor HR, et al. The long-term effects of visible light on the eye. *Archives of Ophthalmology*. January 1992.

8 Margrain TH, et al. Do blue light filters confer protection against age-related macular degeneration? *Progress in Retinal and Eye Research*. September 2004.

YOUR ACTION PLAN: EDUCATE AND PRESCRIBE

Protecting eyes from the ill effects of UV and HEV light is an important task for eye care providers. Greater success in this endeavor may reduce the number of patients becoming afflicted with sight-threatening conditions later in life.

The first (and most important) step you can take to protect patients' eyes from UV and blue light is to prescribe and emphasize the importance of UV- and HEV-protective sunglasses.

In particular, due to the significant potential for retinal damage posed by UVA up to 400 nm—especially among children and young adults whose crystalline lens does not yet provide full natural protection from this high-energy radiation—sunglasses and clear lenses that block 100 percent UVA up to 400 nm from sunlight and artificial sources of light should be strongly recommended to every patient for lifelong retinal health.

Because of the strong association of UV radiation with damage to the crystalline lens, sunglasses that block 100 percent UVA up to 400 nm should be recommended to patients of all ages to reduce the risk of cataracts.

For individuals who refuse to wear sunglasses outdoors or are unwilling to purchase prescription sunglasses, all-purpose eyewear with clear lenses that provide 100 percent UV protection up to 400 nm should be recommended.

Clear lenses that block UVA up to 400 nm (and provide additional protection from near-UV, high-energy visible light without compromising lens clarity) also are recommended for children and adults who spend a good deal of their day using a computer and/or portable digital devices for supplemental protection from potentially harmful rays emitted by low-intensity sources.

One of the first challenges is being able to efficiently educate your patients about the potential for eye damage from sunlight and artificial sources of UV and blue light.

An effective approach is to briefly explain this danger and your eyewear recommendations when you hand them their eyeglass prescriptions at the end of their exam.

(Yes, I recommend you write two prescriptions — one for sunglasses outdoors and a second prescription for clear lenses indoors.)

Here's a script that you can use and modify for this purpose:

> *"Research is showing that exposure to the sun's UV rays and a special type of light from sunlight and digital devices called "high-energy visible light" or "blue light" may significantly increase the risk of serious eye problems like cataracts and macular degeneration later in life.*
>
> *"For this reason, it's important to wear lenses that protect your eyes from these rays—particularly when you're outdoors in daylight and when you're using a computer, watching TV or looking at other digital displays for extended periods.*
>
> *"The best way to keep your eyes healthy is to wear sunglasses outdoors and clear lenses indoors that block these damaging light rays. Here is a prescription for both your sunglasses and for clear lenses indoors that provide the right amount of protection."*

Whether you choose to issue separate prescriptions or a single prescription that can be used for both indoor and outdoor lenses, make sure your prescription includes these specifications:

Outdoor Sun Lenses

- Polycarbonate material for lightweight comfort and safety
- 100 percent protection from UVB and UVA
- Absorption of highest energy blue light (400-440 nm range)
- Choice of lens tints (gray for true colors; green for clarity and comfort; brown for enhanced contrast)
- Scratch-resistant coating for durability
- Backside AR coating to eliminate reflective glare

Indoor Clear Lenses

- Polycarbonate material for lightweight comfort and safety
- 100 percent protection from UVB and UVA up to 400 nm
- Absorption of highest energy blue light (400-440 nm range)
- Clear lens for night driving and optimum vision in low light
- Scratch-resistant coating for durability
- AR coating to eliminate reflective glare

When prescribing eyeglasses that provide protection from UV and blue light, emphasize that this protection is essential for people of all ages—and especially for children.

In fact, because the crystalline lens in a child's eye does not protect the retina from UVA up to 400 nm and children tend to spend more time outdoors than adults, prescribing UV-protective eyewear for children is essential to reduce lifetime exposure to these potentially damaging rays.

Notice that this two-pair presentation begins with the outdoor lenses. Sunglasses have traditionally been relegated to being suggested as the "second pair" of eyewear (if mentioned at all). This should stop.

When discussing protecting eyes from the harmful effects of UV and high-energy visible light, sunglasses should be discussed FIRST. Due to the intensity of these rays emitted by the sun (compared with low-intensity artificial sources), sunlight is the 800-pound gorilla of UV and blue light exposure, not computer screens or portable digital devices. For this reason, quality sunglasses that block 100 percent UV up to 400 nm and provide additional protection from high-energy visible light (without disrupting color vision) is the first line of defense from radiation-induced eye damage.

Though more research is needed to better evaluate how much protection is needed from low-intensity blue light emitted by computer screens, smart phones and other portable digital devices, the prudent course of action at this time is to also prescribe clear lenses that shield eyes from a significant amount of the highest energy (shortest wavelength) blue light—without causing a noticeable loss of visible light transmittance in the lenses for driving and other low-light activities.

WHAT ABOUT TINTED COMPUTER LENSES?

Though tinted "computer glasses" may be comforting for people who spend long hours in front of a digital screen, these lenses can distort color vision and should therefore be considered "special use" eyewear.

Most consumers prefer clear lenses for general purpose eyewear. (Remember the resistance many people had to early-generation photochromic lenses because they had a noticeable tint indoors?)

Also, tinted lenses should not be worn when driving at night or in other low-light conditions where maximum light transmittance is needed for optimum visual acuity.