cells contain a melanopsin associated by a third photoreceptor, discovered in irradiance detection tasks are triggered biological functions. These non-visual the eye can also affect many non-visual functions. (See Figure 3.)

Summary
The 4-year rigorous research work, jointly released by scientists from Essilor’s R&D department and Paris Vision Institute, shows that RPE cell apoptosis is specifically amplified in a 40 nm narrow range within the Blue-Violet light spectrum, from 415 nm to 455 nm, centered at 435 nm. The identification of this precise "tissue band" represents the heart of this scientific discovery.

Thus, we now have specific criteria for selective photo-protection. Essilor has developed a truly new category of ophthalmic lenses—Citea® Prevenica® No-Glare lenses. This new technology can simultaneously selectively filter harmful light—Blue-Violet and UV lights—while passing through all beneficial light and still maintaining lens transparency.

Furthermore, the unique illumination system is currently being used to measure the cell protection brought by various blue filtering lenses. Hence, for the first time, lens protective efficacy can be evaluated in vitro physiological sunlight conditions, based on objective measurements of cell viability.

This evidence, though preliminary, strongly suggests that new filters could aid in preventing patients from premature AMD onset, and possibly other diseases as well.

References


Figure 1. Electromagnetic spectrum and zoom on visible and blue light

BLUE LIGHT, VISION, AND THE EYE

By developing an experimental framework to distinguish beneficial blue light rays from harmful ones, Essilor has effectively created a new field in photobiology research.

The electromagnetic spectrum encompasses every possible wavelengths of radiation in our universe. At one end lie the high-energy gamma rays that are so powerful that exposure to these rays can cause cancer in living creatures; while far away on the opposite end lie the low-energy frequencies that cause nothing more harmful than AM radio. Near the center of this vast continuous spectrum between ultraviolet and infrared energy, runs a very thin sliver of bandwidth that we see as visible light and colors—also known as optical radiation, which ranges from about 380 nanometers (nm) to 780 nm. (See Figure 1.)

Within optical radiation, the colors that are blue and blueish, from violet to turquoise, take up a lot of space, about 380 to 500 nm. They have tighter wavelengths and pack greater energy than greens, reds and yellows. Thus blue light is sometimes referred to as high-energy visible (HEV) light.

Blue light tends to occur at higher frequencies outdoors via sunlight and at lower ones indoors, where, until recently, most illumination was provided by incandescent light sources, which burn at higher red and yellow frequencies than the sun.

It is known that prolonged exposure to outdoor radiation (both visible and non-visible light) can result in cumulative damage to eye tissues, both anterior and posterior. Ultraviolet radiation is harmful to the cornea and crystalline lens and are associated with cataract development. HEV light is a known risk factor for age-related macular degeneration (AMD). It can induce and accelerate photochemical reactions and cell photo-damage, largely mediated by the accumulation of reactive oxygen species in the retina, researchers believe.

And yet we also know that exposure to HEV light has a beneficial effect as well. It plays an important role in non-visual functions, such as circadian rhythms involving sleep-wake cycles, as well as cognitive, psychomotor, and hormonal balance.

Although they have a great deal in common, these two areas of scientific inquiry—the study of HEV light’s positive effects on the one hand and its negative impact on the other—have up until now operated largely independently of each other. But recently, Essilor’s R&D department, working in conjunction with the Paris Vision Institute, unveiled data that maps out a very precise retinal phototactic spectrum within HEV radiation: For the first time ever, researchers can measure the precise physiological conditions of illumination using an in vitro model. This paves the way for a whole new discovery of corrective lenses that filter out harmful HEV frequencies while allowing beneficial ones, to pass through to the eyes untouched.

Blue Light Sources
Every light source emits a spectrum that can be expressed as a function of a monochromatic wavelength and shown on a graph. For example, Figure 2 represents the spectra in the visible range of typical sunlight, an incandescent bulb, a fluorescent lamp, a halogen lamp, and a cool white light-emitting diode (LED).
Depending on atmospheric conditions, time of day, geography, etc., the blue light portion of sunlight is 25-30% percent. Existing artificial light sources are based on one of two processes: incandescence or luminescence. In incandescent light sources, that is, incandescent bulbs (of the Thomas Edison variety) and halogen lamps, a filament is heated and emits a light radiation.

In luminescent light sources, which include compact fluorescent lamps (CFL), fluorescent bulbs, and LEDs, the atoms of a gas or a semiconductor are excited via a discharge or a carrier recombination, leading to the emission of visible radiation.

Luminescent light sources tend to contain a greater portion of blue light. For example, compact fluorescent lamps contain 26% blue light, and cool white LEDs emit at least 35%. By contrast, traditional incandescent lamps emit only 3% blue light.

Until recently, traditional artificial light was provided mostly by incandescent lamps. However, such older light sources can be replaced by products based on LEDs, which have a longer lifetime, lower energy consumption, and less negative environmental impact. In Europe, it is predicted that by 2016 traditional incandescent light sources will no longer be available for domestic lighting. Leaders in the lighting industry believe that by 2020, more than 90% of all light sources worldwide will be based on solid state lighting products and LEDs. We can see this all around us as luminescent light sources progressively conquer office environments. TV screens, computer monitors, mobile phones, tablets, etc.

This trend significantly increases exposure to these new LED-based artificial light sources, consequently elevating the proportion of total blue light that reaches the eye.

**Blue Light and Vision**

To function properly, rod and cone photoreceptors must constantly regenerate. Retinal pigment epithelium (RPE) cells play a critical role in this regeneration. Without RPE cells, rods and cones cannot survive. Several retinal pathologies can be linked to RPE and photoreceptor degeneration, including AMD, retinitis pigmentosa, and Stargardt’s disease.

Over the last 20 years, many studies have linked the role of sunlight exposure to the prevalence of AMD. For example, the EUREYE study found significant associations between blue light exposure and neovascular AMD in individuals having the lowest antioxidant levels. Another study performed on 838 fishermen in the Chesapeake Bay area showed that patients with advanced AMD had been exposed to high levels of blue light over the preceding two decades.

Furthermore, granules that accumulate in the RPE cells in the early stages of AMD are made up of a substance called lipofuscin. Lipofuscin is produced by an incomplete phagocytosis of the photoreceptor’s outer segments and can be activated by specific proteins, with a maximum absorption in the blue spectral range.

How does this occur? During very prolonged or extreme light exposure, an accumulation of all-trans-retinal (ATR) can occur in the photoreceptor outer segments (POS). The ATR is photosensitive to light ranging from violet to blue, with an absorption profile decreasing from 400 nm to 500 nm. When the ATR is excited by visible light, it can react with oxygen to form singlet oxygen, which can damage the POS.

One area in which preventative measures might be particularly effective is dry AMD, where anti-inflammatory, anti-oxidant, and anti-angiogenic treatments have been successful.

**Preventive Measures**

AMD is a serious worldwide problem, with more than 100 million people worldwide living with this disease. In 2010, AMD population was roughly estimated to 100 million people in 2012, and if demographic trends continue at current rates, this number will double in the next 30 years.

While great advances have occurred over the past 10 years in the treatment of AMD, especially in the field of anti-vascular endothelial growth factor (VEGF) injection therapy, the longevity of treatment benefits remains frustratingly short, and there seems to be no endpoint to the frequent intra-vitreal injections required to maintain it. Any measures that could be taken to prevent the onset of this blinding disease would no doubt be enthusiastically welcomed by the ophthalmic community.

One area in which preventative measures might be particularly effective is dry AMD, where anti-inflammatory, anti-oxidant, and anti-angiogenic treatments have been successful.

Another degenerative disease in which preventative options would be welcome is retinitis pigmentosa. Like AMD, retinitis pigmentosa is characterized by RPE and photoreceptor degeneration. Progressive retinal atrophy causes a slow peripheral vision loss in both eyes. Cones are also affected at later stages of the disease. No treatment solutions for this disease in an advanced stage have yet been commercialized.

Stargardt’s disease is an inherited juvenile form of macular degeneration that causes progressive central vision loss. The pathological features of Stargardt’s include the accumulation of fluorescence lipofuscin pigments in the RPE and the degeneration of photoreceptors. Some in vivo studies on Stargardt’s disease models suggest that light exposure increases the formation of lipofuscin granules. The exact nature of the relationship between light exposure and photoreceptor degeneration is not clear, but it is likely that prolonged or extreme light exposure can accelerate the degeneration process.

**Non-visual biological functions**

The eye doesn’t only serve an optical function, but also plays a role in non-visual processes, which take place in response to light. These non-visual effects range from short-term to lifelong and include physiological, psychological, and emotional effects.

**Daylight**

Daylight affects our natural rhythms. It helps us to regulate our sleep-wake cycle, our mood, and our activity. For example, exposure to bright light in the morning can help reset our internal clock, improving sleep and alertness. Light exposure can also improve mood and reduce symptoms of depression.

**Incandescent**

Incandescent light sources, such as traditional incandescent lamps, can affect our mood and sleep. For example, exposure to incandescent light in the evening can disrupt our sleep cycle, making it harder to fall asleep. On the other hand, exposure to incandescent light in the morning can improve our alertness.

**Fluorescent**

Fluorescent light sources, such as compact fluorescent lamps, can also affect our mood and sleep. For example, exposure to fluorescent light in the evening can improve our mood and alertness, while exposure in the morning can disrupt our sleep cycle.

**Halogen**

Halogen light sources, such as halogen lamps, can affect our mood and sleep. For example, exposure to halogen light in the evening can improve our mood and alertness, while exposure in the morning can disrupt our sleep cycle.

**Cool White LED**

LED light sources, such as cool white LEDs, can affect our mood and sleep. For example, exposure to cool white LED light in the evening can improve our mood and alertness, while exposure in the morning can disrupt our sleep cycle.

**References**

