The eye can also affect many non-visual biological functions. These non-visual insulins to detect waves are triggered by a third photoreceptor, discovered in 2002, called intrinsically photosensitive retinal ganglion cells, or ipRGCs. These cells contain a melanopsin associated pigment. Melanopsin pigment absorbs around 480 nm to 15 nm, (about what we see as turquoise which is now commonly known as the "chromo- logical spectral band").

Non-visual photoreceptor is essential for circadian rhythms in many non-visual functions, encompassing sleep/wake state (melatonin synthesis), pupil light reflex, cognitive performance, mood, locomotor activity, memory, and body temperature, among other bodily functions. (See Figure 3.)

Chronobiotic disruptions can cause sleep disorders, gastrointestinal disorders, depression, anxiety—and even increased risks of cancer for shift workers, according to studies (HAS-French Haute Autorité de Santé 2012 report).

Thus, it is now widely believed that exposure to blue light within the chromo-biologic spectral band should be maintained to ensure a good synchronization and regulation of non-visual biological functions.

**Experimental Model**

The achievement of Essilor and the Paris Vision Institute has been to establish an *in vitro* experimental model that produces accurate, reproducible photobiology results. This model consists of an illumination device that allows researchers to convey light on very restricted, narrow wavelengths, passing the visual light spectrum into 10-nanometer bands. Each band is guided by an optic fiber toward a cell incubator, which contains swine cells. This allows researchers to precisely control the degree of illumination for each wavelength.

Researchers have extracted from this *in vitro* model a formula to calculate blue light risk. It describes the biological risk linked to the photochemical degradation of RPE cells when the retina is exposed within certain blue light range. (See Figure 4.)

Moreover, the newly established selective photo-toxicity spectrum creates the starting points for two very practical areas of research: the invention of selective photo-protection ophthalmic filters and the calculation of how well these filters function.

**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 "toxic band" represents the heart of this scientific discovery.

Thus, we now have specific criteria for selective photographic protection. Essilor has developed a truly new category of ophthalmic lenses—Crizal® Prevencia® No-Glare lenses. This new technology can simultaneously selectively filter harmful light—Blue-Violet and UV light—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 under *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**


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 Thomson filament 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 55%. 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 are now being rapidly 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 occur in the photoreceptor outer segments and can be activated by specific protons, 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 photoreceptor digestion generates lipofuscin granules in the POS. When the POS are oxidized, they cannot be correctly phagocytized by RPE cells. This incomplete intracellular digestion generates lipofuscin granules in the RPE. The end result of all these processes is RPE degeneration and photoreceptor death.

Preventative Measures

AMD is a serious worldwide problem, one expected to worsen as life expectancies increase and mean population ages continue to rise. The worldwide AMD population was roughly estimated to 100 million people in 2012, and if demographic trends continue at current rates, this number will rise 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-oxidative dietary supplements, containing lutein or zeaxanthin, have yielded positive results.

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 rod 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 fluorescent 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. For instance, researchers have observed that mice kept in dark environments demonstrated almost no lipofuscin deposits.

Beyond the lack of therapeutic treatments for patients suffering from degenerative retinal diseases, a dearth of preventative solutions coupled with a generally late diagnosis explain the irreversible and numerous negative effects on vision.

Blue Light and Non-visual Functions

While it is obvious that light regulates the visual process, photons received by