ZEISS Vision Care

Five questions to ask about UV Protection

1. What does complete UV protection look like?

While the UV spectrum extends to 400 nm, optical industry standards allow manufacturers to claim 100 percent protection at 380 nm. The most common lens material sold globally typically only fully blocks UV below 360 nm.

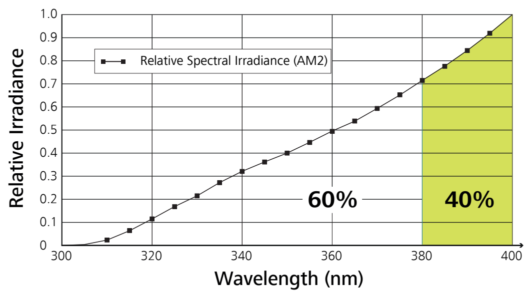

Figure 1. ISO 8980-3 solar UVR spectrum normalized to its maximum value at wavelength of 400 nm

These may seem like unimportant distinctions, but the gap between 380 and 400 nm accounts for 40 percent of total UV exposure at sea level[1]. That's why 400 nm is recognized as the limit of UV by the World Health Organization and is used by premium sunglass and sunscreen manufacturers.

2. How do harmful UV rays get in our eyes?

The most direct route between two points is a straight line. This is why the path by which more than 90 percent of UV light can reach our eyes is the path straight through the lens. While there is some reflective light that can come in from behind or the sides, the vast majority of UV and other rays are coming in to our eyes head-on.

3. Do UV Anti-Reflective (AR) coatings protect us?

One common misconception is that back UV AR coatings provide adequate eye protection. In fact, 90 percent of surveyed eye care providers felt UV AR coatings block all or most UV rays.[2] That is simply not true – they do not block UV.

Anti-Reflective UV coatings on the back of lenses are designed to reduce UV radiation that angle in from behind the head, reflect off the inside of the lens and ultimately hit the eye. But, as noted earlier, the vast majority of UV comes directly through the lens. It's like closing a window to stop a draught when all the house's doors are wide open.

Reflective back coatings leave the majority of UV rays unchallenged. In fact, a back coating alone can result in more UV exposure than having no coating at all (See question 5).

4. Does built-in UV protection in the lens protect the eyes?

Absolutely. Lens materials that directly block all UV up to 400nm are the most effective & effortless way to protect the eyes and the skin around them. In a typical spectacle frame, the greatest UV reduction (93-95 percent) comes from a UV-blocking material.[3]

5. What does the peer-reviewed research say?

New research[3] confirms what we've known for years: The only way to fully protect eyes from damaging UV radiation is to block it in the lens. UV AR coatings have no meaningful protective impact between 350 and 400nm, the bandwidth that accounts for 70 percent of total UV exposure at sea level.[1]

UV AR coatings can be a sensible way to augment UV protection – but only if the majority of rays are blocked by the lens. The fact is, anti-reflective (AR) coatings are designed to increase transmission of light through lenses. Without a UV blocking lens material, UV AR coatings will actually increase UV transmission coming directly through the lens. As demonstrated in a recently published scientific paper, the destructive interference pattern of a UV AR coating on the back surface actually allows more harmful UV through the lens.[3]

The research is clear: A lens material that fully blocks all UV - up to the scientifically-recognized 400nm limit - is the most effective way to protect eyes & surrounding skin.

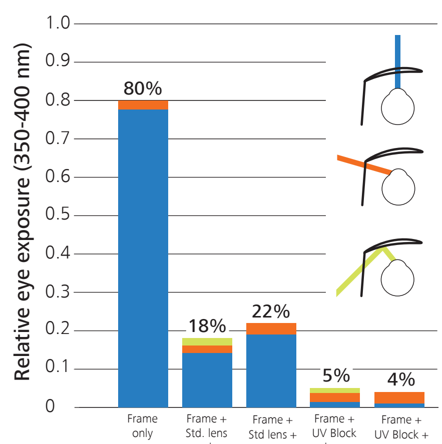

Figure 2. Measurement of Polycarbonate Index Lens Materials measurement under different situations.

UV Light's Optical Dangers

UV exposure is never good for the eyes, or the skin around them. Health risks associated with chronic UV exposure include:

➔ *Skin cancer, Iris melanoma, Cataracts, Corneal inflammation, Degenerative conjunctiva growths, Premature aging*

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ZEISS Vision Care

UV before Blue – Take care of UV before considering blue light protection

When it comes to eye health, consumers and eye care professionals have many concerns. One is Ultraviolet Radiation (UVR) - where decades of research have shown UV rays destroy ocular structures, and can cause cancer in the skin surrounding the eye. ZEISS has designed all their UVProtect spectacle lenses to fully block the harmful effects of UVR up to 400nm, while still providing maximum clarity in visible light.
More recently, there has been a growing worry over blue light, especially from smart phones and other digital devices. To some degree, the blue light conversation has eclipsed UVR concerns. Yet the evidence against blue light is at best unclear. While the media has latched on to blue light, there is today no firm clinical evidence to suggest that blue light from digital devices poses a health risk. Blue light coatings can provide a comfort benefit from bright digital displays, which also have been linked to melanopsin levels that impact the bodies sleep pattern. Blue light blocking materials by contrast do not block the peak of the potential blue light hazard, nor the peak intensity of smartphone displays, or melanopsin response - all while compromising lens clarity.

UVR - An undisputed threat to eye health

Scientific and international regulatory bodies agree: UVR is harmful to the human eye and its surrounding tissues

Ultraviolet Radiation (UVR), otherwise known as ultraviolet light, is light that ranges from 100 to 400nm. While UVR is mostly invisible, it can nonetheless severely damage the eyes and their surrounding structures.

UVR interacts strongly with molecules in human cells. Research has shown that the effects of UVR damage accumulate over a lifetime; retinal exposure very early in life may contribute to age-related macular degeneration later on. Other effects of UVR exposure include:

- Photoaging and xerosis of the eyelids and skin surrounding the orbital region
- Skin cancers of the same regions, accounting for 5 to 10 percent of all skin cancers
- Degenerative and unsightly growths on the conjunctiva
- Acute and painful inflammation of the cornea
- Melanoma of the iris, a potentially deadly type of cancer
- Nuclear sclerosis of the lens leading to reduced vision and ultimately to cataracts that require surgery

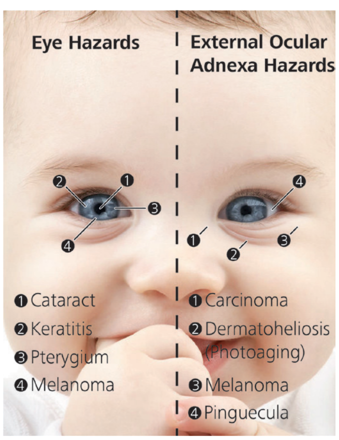

Figure 1. In her lifetime, this child will face many UVR hazards

Eyeglasses – The gap in our UV armour

Most eyeglass lenses do not fully block UVR

Given the potential harm that ultraviolet radiation may cause, it might seem obvious that doctors and consumers would seek the best UVR protection when recommending eyewear. However, this is not the case. Many eye care professionals and eyeglass wearers incorrectly believe that they already offer or have full UV protection.

The truth is that four out of five clear lenses sold today do not fully block UV light up to 400nm[1]. The World Health Organization, as well as multiple medical, scientific, and international regulatory institutions define 400nm as the threshold for UV light, yet today's most common clear lens materials only block wavelengths shorter than 380nm or even 360nm. In addition, arbitrary industry standards have somewhat conveniently defined the upper limit of UV to 380nm, allowing lens manufacturers to claim 100 percent UV protection for lens materials such as polycarbonate when they only block UV below 380nm. But 400nm is in fact the scientifically and clinically accepted UV threshold, and is applied in sunglasses, cosmetics and sunscreen products.
While the spectral gap between 380 and 400nm may not sound like much, it accounts for 40 percent of solar UVR experienced at sea level.

ZEISS has closed this significant spectral gap by including UVProtect technology in all ZEISS plastic lenses. This technology provides complete UVR blocking in the lens, all the way to 400nm, and maintains lens clarity without any noticeable tint.

The myth of UV Anti-Reflective Coatings

UV Anti-reflective (AR) coatings are often touted for their ability to reduce UV exposure. This is widely accepted in the industry – 90 percent of eyecare providers believe

AR coatings block UV[2]. These coatings merely reduce UV reflected off the lens back surface, and unfortunately provide a false sense of security.

A recent study, published in the journal Biomedical Optics Express, found that UV AR coatings provide no additional protection if the lens does not have UV absorption[3]. Testing lenses with UV absorption, backside coatings or both, the simulated real-life study found that lenses with sound UV absorption reduced exposure to 7 percent.

Those with just a coating still allowed 42 percent of UV radiation to reach the eyes.

The study also showed that, without a UV absorber, UV AR coated lenses provided worse protection than similar lenses without UV AR coating. This can be explained by ZEISS research which has shown UV AR coatings, applied to non-UV blocking lenses, increase UV transmission through the lens compared to the same lenses with normal AR coatings.

Only UVR absorption in the body of the lens can provide maximum protection, this is in all ZEISS UVProtect lenses.

The tenuous case against blue light

Unproven eye health risk from everyday blue light

Visible light can also damage eyes. Too much light can generate thermal damage and burn the retina, which is why children are repeatedly warned not to look directly into the sun, and no one should test a laser pointer by pointing it at their face. Another example is photochemical damage, in which visible light generates free radicals that impair the retina. Either type of damage is easy to recognize almost immediately after exposure.

Thermal and photochemical damage are a greater risk in industrial settings, where workers may be exposed to lasers and other energetic light sources. Agencies around the world have developed safety standards to mitigate these risks. However, most people are not exposed to enough high-intensity light to damage their eyes.

Recently, there has been much concern about visible blue wavelengths between 400 and 500 nm – the spectral region associated with blue light hazard (BLH). Some studies have linked long-term exposure to blue light in sunlight to macular degeneration.[4,5] Other research has contradicted these claims.[6,7]

Many studies have notable shortcomings. For example, researchers often ask participants to self-report how much time they spend outdoors to approximate light exposure. Also, many people who spend extended time outdoors have higher levels of other risk factors such as smoking. At best, the subject is controversial, so there is no clear dose-response relationship to help guide safety standards.

For these and other reasons, national institutes of health like the U.S. National Eye Institute (NEI) have no formal opinion on the blue light threat. Listing only age, race, family history, genetics and smoking as maculopathy risk factors. The NEI however does publish strong opinions on the eye health risk from UV exposure *(NIH National Eye Institute - https://nei.nih.gov/news/briefs/uv_cataract).*

Blue Light Hype in the Media?

Unfortunately, blue light's potential risks have been greatly exaggerated in the media. A 2018 study by researchers at the University of Toledo showed that blue light can damage the retina.[8] However, the study used a blue laser, at 445nm, to damage human cells in vitro.

Many press outlets interpreted the study to mean blue light from electronic devices can severely injure retinas. For example, a headline from Fortune Magazine stated: Blue Light Emitted From Electronics Can Cause Accelerated Blindness, Study Finds.[9]

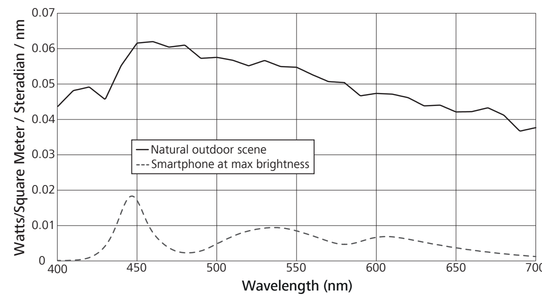

Figure 2. Spectral radiance of smartphone and typical outdoor scene

There was a profound disconnect between the findings in the study and these media stories. As noted, the researchers used blue lasers, which are far more powerful than blue light from actual devices. And while the 445nm wavelength can be hazardous, it is only one small piece of the spectrum, and no device or natural light source produces light solely at that (or any single) wavelength.

To compare apples to apples, a smartphone would have to exceed 100,000 nits to be considered unsafe by any regulatory agency. According to Samsung, their Galaxy 9 produces peak luminance of 1,130 nits.[10] In fact, 100,000 nits would be brighter than a snow covered mountain under a cloudless sky.

The study showed no cellular damage when exposure levels corresponded with outdoor light on an overcast day – which is still four to five times brighter than a digital display. Smartphones are also designed to dim indoors, which mitigates exposure.

If blue light were any hazard at all, the sun would be a far larger risk than any digital source, making a hike outdoors more dangerous than scrolling through Twitter. Given the current evidence, the eye health risk of blue light from digital devices (or natural sources) is almost certainly overblown.

Blue light can affect sleep patterns

Another concern is whether watching digital displays at night can adversely affect sleep. In recent years, scientists have discovered a new receptor type that responds to blue-green light. These receptors contain a light-sensitive pigment called melanopsin. When stimulated, melanopsin receptors control sensitivity to brightness, as well as how pupils respond to light, and influence our sleep cycles. Ideally, these receptors get turned on during the day and are left alone at night. Digital displays may increase blue-green light stimulation, and that may exacerbate sleep issues.

Researchers have also shown that, when using desktop screens for many hours, blue light can alter melanopsin levels.[11] However for smartphones and other small screens, the evidence is less clear. Still, these concerns have motivated handheld device manufacturers to include night-time modes to reduce blue light.

Blue light protection in eyeglass lenses

There is a lot of confusion in the marketplace over how to respond to blue light's perceived dangers. Lenses with blue light filters or coatings are becoming common.

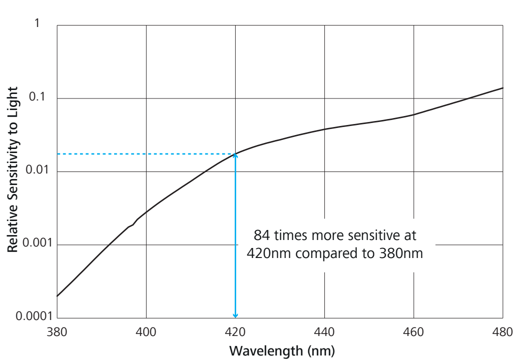

Figure 2. Human blue light sensitivity: CIE Luminosity Function

Blue light protection in eyeglass lenses

There is a lot of confusion in the marketplace over how to respond to blue light's perceived dangers. Lenses with blue light filters or coatings are becoming common.

Blocking above 400nm must have a visual compromise

Blocking blue light can be a zero-sum game. Adult visual sensitivity ramps up quickly between 380 and 420nm – increasing 84-fold. As a result, lenses that block UV below 400 nm appear clear to the human eye. However, those that block visible light above 400 nm may appear tinted and reduce visual acuity.

Neither lens type does much to protect against the potential blue light hazard, which peaks at 450nm, well above the wavelengths blocked by these materials. ZEISS research showed UV420 lenses pass 70 percent of BLH-weighted daylight, only a 22 percent reduction compared to an uncoated clear lens.12 SBF passes 83 percent with an even smaller reduction.

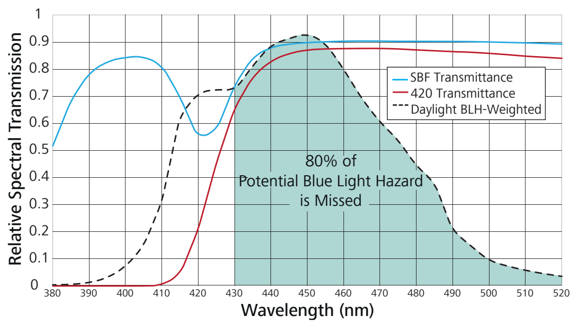

Figure 3. The minimal effect of filters on daylight Blue Light Hazard

These lenses were also ineffective at blocking wavelengths that produce the melanopsin response which also peaks above 450nm. UV420 materials pass 84 percent of the relevant wavelength intensity and SBF passes 88 percent.[13] No studies have shown any improved sleep quality from such small changes. In other words, these materials compromise vision but provide few actual benefits.

Blue Light AR Coatings are a better solution because blue light-absorbing materials have so many downsides, a better approach is AR coatings that actively reflect blue light. These coatings typically reflect blue light between 400 and 470nm, a broader range than blue blocking lenses. They reduce blue light in spectral regions of the potential BLH and activate melanopsin receptors. They are a good alternative for people who are concerned about blue light or may seek to reduce the glare associated with it.

The ZEISS Advantage: DuraVision BlueProtect

Blue light is a challenging subject. Current evidence suggests blue light only threatens eye health in extreme conditions, when people usually wear sunglasses or safety goggles. At present, there's little evidence digital displays endanger eye health.

Still, researchers make new findings every year, so it's possible blue light may pose a currently undiscovered hazard. In addition, major digital device use could disrupt sleep in some situations.

For those concerned about the potential risk, blue light AR coatings are the best bet. DuraVision BlueProtect was

Products *(in uncoated form)*	**UV Protection to 400nm (UVBlock*)**	**Luminous Transmit-tance (T%)**	**Yellowness (YI)**	**Assessment**
Ordinary 1.50 Index	**60%**	**92%**	**0.8**	World most common lens material
Branded competitors "smart" blue 1.50 Index	**62%**	**88%**	**2.7**	Does not take care about UVR
ZEISS UVProtect 1.50 Index	**99%**	**90%**	**2.4**	99% UVR Protection, clear lens
Typical UV420 1.50 Index	**100%**	**83%**	**4.8**	Big loss in clarity and colour

Table 1. Optical lens performance of selected lenses

designed to reflect relevant bands without distorting colors or distracting wearers with strong reflections. Blind testing[14] showed 79 percent of consumers found DuraVision BlueProtect lenses work better than the best-selling AR brand's[15] blue light AR coating.

The best way to protect our eyes is to fully block UVR

ZEISS UVProtect eyeglass lenses block UV to 400nm

The greatest eye health benefits come from preventing UV exposure. Clear lenses with ZEISS UVProtect block virtually all UV to 400 nm with no noticeable tint. Importantly, these lenses are effective because they absorb UV.

The risks of UV exposure over a lifetime are well documented, and there is no good reason today to accept eyeglass lenses that provide only partial UV protection – even if they claim 100% UV protection (up to 380nm) or include UV AR coatings.

Meanwhile, the debate over blue light will likely rage on, but the scientific and clinical data on UV are unequivocal. Eye health conversations may include blue light, but they absolutely need to start with UV protection first.

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12.Following the method of the ACGIH Blue Light Hazard evaluation, using the CIE D65 spectrum multiplied by the lens transmission curve, and weighted by the Blue Light Hazard Function.

[13]iPhone spectrum multiplied by the lens transmission curve, weighted by the melanopsin response curve of Brainard et al.

[14]Psyma. "Blue Light Lenses comparison" n=300. April 2018

[15]Essilor Website 09.11.2017: https://www.essilor.com/en/brands/crizal/, "Crizal®, the number one anti-glare lens brand worldwide*, is at the forefront of innovation." * Best-selling anti-glare lens brand worldwide, according to Essilor's market calculations

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USA 1-866-596-5467

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ZEISS UVProtect: Sunglass Level Protection From Harmful UV Radiation In All ZEISS Clear Lenses

Ultraviolet radiation (UVR) damages the eye and causes photoaging and cancer of the eyelids. Daylight exposes us to harmful levels of UVR at any time of year from mid-morning to late afternoon, even when people normally do not think to wear sunglasses, like on cloudy days. Many eye care professionals incorrectly believe that lens materials like polycarbonate completely block harmful UVR, when in fact they do not. The confusion stems from the fact that ANSI standards have ignored the hazard of UVR wavelengths longer than 380 nm, thereby creating a UVR protection gap. ZEISS has re-engineered its entire range of plastic lens materials, including polycarbonate, to provide full protection from harmful UVR.

Problem

Ophthalmic lens standards have not kept up with the latest research on the damaging effects of low-intensity UVR exposure. The ISO 8980-3 lens standard defines the UVR spectrum as stopping at 380 nm, even though the UVR hazard evaluation standard it relies upon defines a UVR hazard up to 400 nm. ANSI has adopted the same wavelength range as the ISO lens standard, even though virtually all other scientific and healthcare organizations define UVR as extending up to 400 nm. In fact, 40% of UVR in daylight lies between 380 and 400 nm, the span of wavelengths ophthalmic standards ignore.

Eyeglass wearers usually are aware that UVR is bad for the eyes, but many are told – or assume – that their eyeglasses already provide complete UVR protection. Often, this is because their eyecare professional trusts standards that are not up to date or they incorrectly assume that so-called Back UV coatings will fully protect their eyes. Back UV coatings merely reduce UV reflection off the lens back surface, they do not block UV light coming through the lens.

Photoaging of the skin can be prevented through regular application of sunscreen, but many people refuse, forget or are instructed not to apply cream to their eyelids. Long wavelength UVR up to 400 nm penetrates deep into the skin, damaging mitochondrial DNA in dermal fibroblasts. Such type of damage causes deep wrinkles and loose skin.

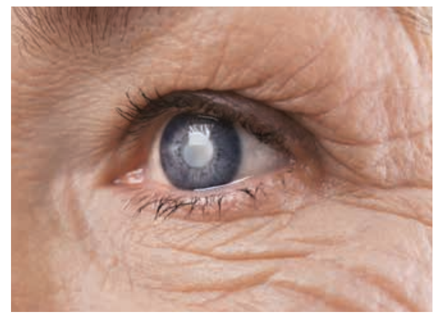
Skin cancers of the eyelid account for up to 10% of all skin cancers and because of the local anatomy, they may easily spread to the rest of the body. UVR is strongly implicated in the formation of skin cancers.

UVR also causes cataracts. It is becoming apparent that long-wavelength UVR accelerates pre-cataract changes. These changes increase light scatter, reduce contrast and mute colors long before surgery is necessary.

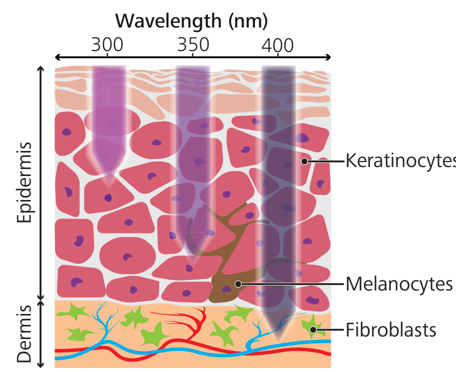
In light of these facts there is no reason for clear spectacle lenses to let any UVR through. Yet standard polycarbonate still passes a significant amount of UVR. In fact, because so much of the solar daylight UVR spectrum is concentrated in wavelengths between 380 and 400 nm, standard polycarbonate still passes 10% of the total UVR energy that we encounter outdoors every single day.

Solution

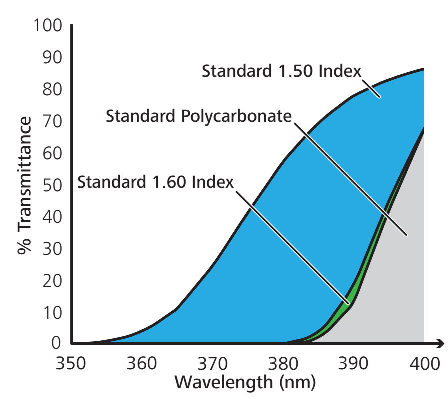
ZEISS scientists have found a way to engineer clear lens materials like polycarbonate to absorb the entire spectrum of harmful UVR right up to 400 nm, blocking 99% to 100% of sea-level solar daylight UVR. Even with such a sharp UVR cutoff, ZEISS polycarbonate lenses with UVProtect present no troublesome changes to visible light so that color and clarity are excellent. In a ZEISS consumer study, eyeglass wearers were asked to compare standard lenses to ZEISS UVProtect lenses in a randomized and masked presentation. Looking through each lens in both outdoor and indoor settings, a majority of respondents actually preferred vision through ZEISS UVProtect lenses.



UVR accelerates aging of the eye and eyelids



The longest UVR wavlengths at 400 nm penetrate deep into the skin



Although standard polycarbonate blocks more UVR than 1.50 or 1.60 materials, it still transmits a significant amount of harmful UVR up to 400 nm

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Take care of UV to 400nm, before considering blue light protection

Within the last year, ZEISS made a commitment to ensure that every one of its spectacle lenses fully blocks the harmful effects of ultraviolet light (UVR), while providing maximum clarity in visible light. Other companies have decided to ignore UVR or to deprecate its importance, as if it is old news. Instead, they have seized upon blue light as the main hazard to eyesight, implying that smartphones and digital devices are a credible ocular threat. The reality is the blue light in daylight far exceeds the intensity and dose of blue light from digital screens. There is no evidence that consumer electronic devices, or modern indoor lighting produce light intensity that even exceeds one percent of the level needed to damage eyesight. What are the facts about UVR and blue light, and what is just hype?

UVR - An undisputed threat to eye health

Scientific & International Regulatory bodies agree - UVR is harmful to the human eye and its surrounding tissues

UVR is the mostly invisible light ranging from 100 to 400nm. People can benefit from a few minutes every day of UVR exposure on their skin, including vitamin D production. But no amount of UVR exposure benefits the eyes or their surrounding structures. UVR interacts strongly with molecules in human cells and research has shown that the effects of UVR damage can be cumulative over a lifetime. The sites and type of damage include Figure 1:

- Photoaging and xerosis of the eyelids and skin surrounding the orbital region.
- Skin cancers of the same regions accounting for 5 to 10 % of all skin cancers
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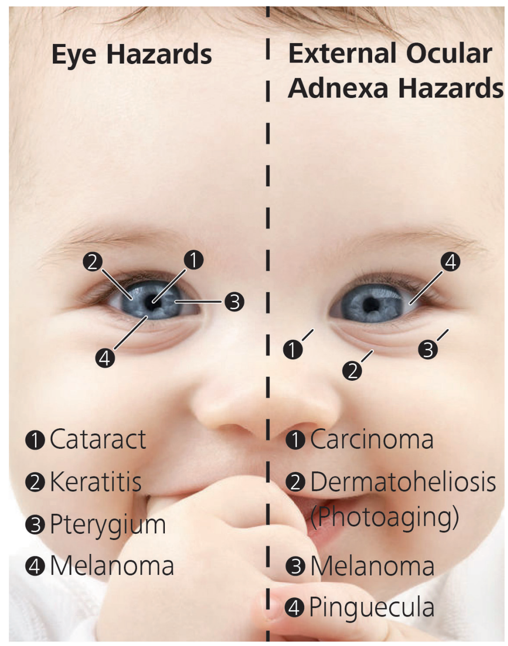

Figure 1. In her lifetime, this child will face many UVR hazards

Eyeglasses can protect from UV radiation – Most do not

Most eyeglass lenses do not fully block UVR

With so much potential harm from UVR, it would seem obvious that doctors and consumers would seek maximum UVR protection for their eyes. But people often refuse to apply sunscreen to the area around their eyes because of irritation. And many eyeglass wearers believe they already have full UV protection.

The truth is 4 out of 5 clear lenses sold today do not fully block up all UV light. The world's most common lens material typically only blocks wavelengths shorter than 360nm. Industry standards that arbitrarily define a UV range ending at 380nm have allowed lens manufacturers to claim 100% UV protection for materials such as polycarbonate and high index even though they only block UVR below 380nm. But 400nm is the threshold for UV light used by the World Health Organization and multiple medical, scientific, and international regulatory institutions. It also is the cutoff accepted for premium sunglasses and sunscreen products. While the spectral "gap" between 380 and 400nm may not sound like much, it accounts for 40% percent of solar UVR experienced at sea level.

ZEISS has closed the gap by including UVProtect technology in all ZEISS plastic lenses to provide complete UVR blocking in the lens - all the way to 400nm - while the lenses remain clear without any noticeable tint.

True UV protection comes by blocking UV to 400nm, UV AR coatings do not block UVR

Many companies have recently promoted a type of antireflective coating that is claimed to protect against UVR by reducing UVR reflection on the back surface. Unfortunately its function is largely misunderstood. In a recent survey[1], 90% of eye care providers thought that this kind of coating actually blocks UVR. It does not. In fact, by reducing UVR reflection, it actually can increase UVR transmittance without a UV blocking lens material.

A recent study has shown that backside UV AR coatings provide little additional protection if applied to a lens material that does not also include a UVR absorber[2]. The study evaluated UVR, quantifying the amount blocked by the spectacle frame or passing through and around lenses to reach the eyes. 79% of the UVR that could possibly reach the eye had to pass through spectacle lenses. Frames only blocked 18% of exposure, and only 3% of UVR bypassed both frame and lenses, either directly or by reflection. Thus the greatest potential protection can only be provided by UVR absorption in the body of the lens. The study actually also showed that a back-side UV AR coating on a lens without a UVR absorber provided worse protection than a similar lens without the UV AR coating. The likely cause for this result may be explained by internal studies in ZEISS, that found a back-side UV AR coating applied on a non-UV blocking substrate increased UV transmittance compared to the same substrate with just a normal AR coating. Meaning a back-side UV AR without UV blocking substrate can increase direct UVR exposure.

Blue light – No credible eye health threat in everyday life conditions

Visible and blue light hazards – only proven in extreme situations

Under special circumstances visible light can damage the eye. Two processes of damage have been identified. Thermal damage is caused by any wavelength and is literally a burn of the retina when it is exposed to too much light. Photochemical damage is a chemical reaction triggered by any wavelength of light, but blue wavelengths between 400 and 500nm are especially effective in starting the reaction. Either type of damage can be recognized almost immediately after exposure. Safety standards have been established around the world to protect workers from excessive exposure to potentially harmful light, especially because lasers, or artificial light sources generated from industrial processes may be far more energetic than anyone would encounter in everyday life. Under ordinary circumstances people are not exposed to enough light to damage their eyes.

Some researchers have reported that long-term exposure to blue light in sunlight is implicated in macular degeneration[3,4,] but other studies contradict them[5,6]. The lack of conclusion about hazards from long-term blue light exposure is evident by the position taken at institutions tasked with understanding eye disease. For example, the National Eye Institute in the United States currently lists only age, race, family history, genetics and smoking as risk factors for maculopathy, and has not established an opinion on blue light. One of the problems with this kind of research is that it relies on self-reported histories of time spent outdoors to approximate light exposure, but many people who have outdoor jobs also have higher levels of other risk factors such as smoking. At best, the subject is controversial and there is no clear dose-response relationship to guide safety standards.

Hype about blue light & digital devices – Fake news

In recent months the internet was buzzing about a press release from the University of Toledo in the United States. Online titles like „Blue Light Emitted From Electronics Can Cause Accelerated Blindness, Study Finds"[7] spread rapidly. Unfortunately, this is pure hype, lacking substantiation. The study cited does not mention digital devices and did not study macular degeneration. It used a blue laser to damage human cells, but the irradiance was hundreds of times greater than a smartphone display could produce at the retina.

The 445nm laser wavelength used by the authors lies very close to the peak of the blue light hazard function defined by international safety standards, but no natural light source or digital device concentrates all its energy in a single wavelength.

In fact, a smartphone's luminance would have to be more than 100,000 nits to be deemed unsafe by standards organizations. This is brighter than any natural scene you can find, exceeding noontime on a mountain with full sunshine blazing on freshly fallen snow. The authors' study found no cell damage at exposure levels corresponding to outdoor light levels under an overcast sky, yet even that level of luminance is four or five times brighter than a digital display at its brightest. Once indoors, smartphone displays automatically dim and the typical exposure level is far below anything that can cause damage.

The plain fact is that the intensity of blue light in daylight far exceeds digital screens. If there really is a cumulative blue light risk, and this is very uncertain, what matters is the amount of time spent outdoors, not viewing digital screens. A more realistic concern is whether prolonged, indoor viewing of digital displays at night can adversely affect sleep patterns.

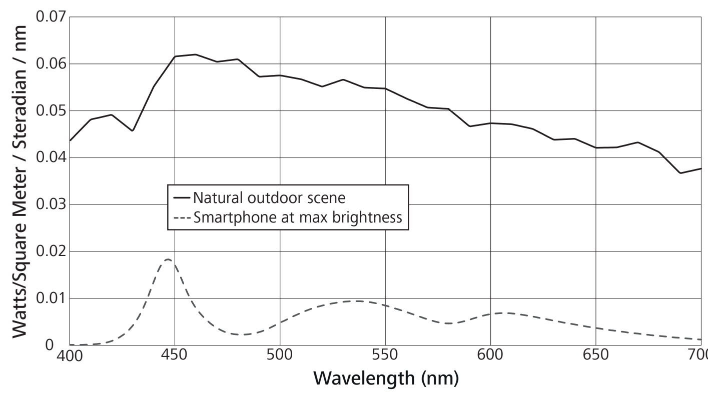

Figure 2. Spectral radiance of smartphone and typical outdoor scene

Blue light – possible effect on sleep patterns, large dose needed

Blue-green light & sleep patterns

Not long ago, scientists discovered a new kind of light receptor in the human eye. These receptors contain a light sensitive pigment called melanopsin that responds to blue-green light. When stimulated, these receptors control our sensitivity to brightness, like a volume control for a loudspeaker. They also control the pupil response to light, and they aid the body's clock to establish the normal and healthy diurnal sleep cycle. Proper regulation of the cycle happens when the melanopsin-bearing receptors are stimulated during daytime and not stimulated at night. Unfortunately, excessive use of digital displays at night may increase the stimulation of these receptors, and some researchers are concerned that this will cause sleep disorders. Researchers[8] have shown the blue light effect on melatonin levels when using large and bright desktop screens with many hours of use, but for smaller screens such as tablets and smartphones it is less clear. Because of such concerns, most smartphone and handheld device manufacturers include night-time modes that reduce blue light.

Products *(in uncoated form)*	**UV Protection to 400nm (UVBlock*)**	**Luminous Transmittance (T%)**	**Yellowness (YI)**	**Assessment**
Ordinary 1.50 Index	**60%**	**92%**	**0.8**	World most common lens material
Essilor Smart Blue Filter (SBF) 1.50 Index	**62%**	**88%**	**2.7**	Does not take care about UVR
ZEISS UVProtect 1.50 Index	**99%**	**90%**	**2.4**	99% UVR Protection, clear lens
Mitsui UV420 1.50 Index	**100%**	**83%**	**4.8**	Big loss in clarity and colour

Table 1. Optical lens performance of selected lenses

Some lens manufacturers have sought to capitalize on this current concern by offering lenses with blue light filters. Typically the marketing of such lenses conflates concerns about blindness and sleep disorders, as if somehow the two processes are the same. They are not, and the introduction of such products has created a lot of confusion.

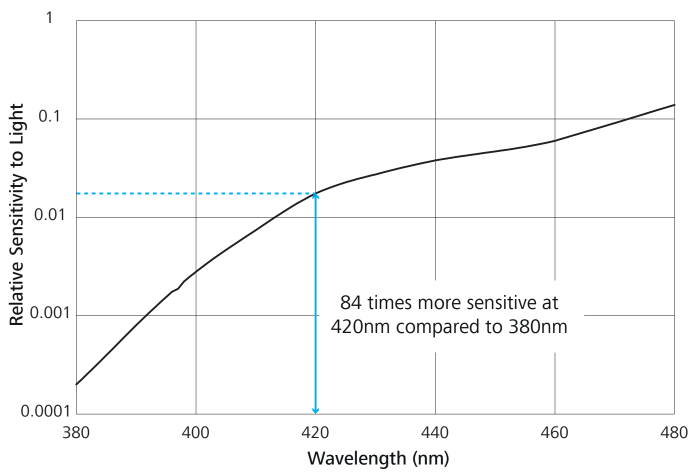

Figure 3. Human blue light sensitivity: CIE Luminosity Function

The human eye – Blocking above 400nm must have a visual compromise

In daylight human vision is most sensitive to green wavelengths around 550nm, but wavelengths between 400 and 700nm make a significant contribution to colour perception. Adults have little visual sensitivity to wavelengths shorter than 400nm, but sensitivity rises quickly from there to the peak.

The plain fact is that the intensity of blue light in daylight far exceeds digital screens. If there really is a cumulative blue light risk, and this is very uncertain, what matters is the amount of time spent outdoors, not viewing digital screens. A more realistic concern is whether prolonged, indoor viewing of digital displays at night can adversely affect sleep patterns. In fact, our sensitivity at 400nm is 14 times greater than at 380nm, and 84 times greater at 420nm (Figure 3)! This means that it is possible to have lenses that appear clear to the human eye that block all UVR, but if lenses block a significant fraction of light above 400nm, the lens will appear tinted.

Blue Light protection in Eyeglass Lenses

Blue-blocking lens materials – Not so smart

If we compare two types of blue filters offered by competitors, some facts become apparent. One approach is Essilor's Smart Blue Filter (SBF) with an absorption notch around 420nm. The other approach is so called "UV420" materials which block light below about 410nm, and partially block light up to 450nm. UV420 lenses do fully block UVR to 400nm, but also block a significant amount of visible light above 400nm making lenses darker and yellower (Table 1).

Both lens types have problems. SBF passes a lot of hazardous UVR. Neither lens does much to protect against a potential blue light hazard (BLH). ZEISS also found that the UV420 lens passes 70% of BLH-weighted daylight[9] for a 22% reduction compared to an uncoated clear lens; the Smart Blue Filter passed 83% with an even smaller reduction (Figure 4). This is a minimal level of protection against a hazard that is unlikely to exist. Nor were the lenses effective at blocking wavelengths that produce the melanopsin response: the UV420 material passes 84% of the relevant wavelength intensity and the Smart Blue Filter passes 88%[10].

...these materials compromise vision with no real blue light benefit...

No investigator has shown improved sleep quality in response to such a small change in light level. In short – these materials compromise vision with no real blue light benefit and they missed the target when aiming to protect against a very uncertain hazard. A fact-based approach shows that there is more hype than light in the claims for these products.

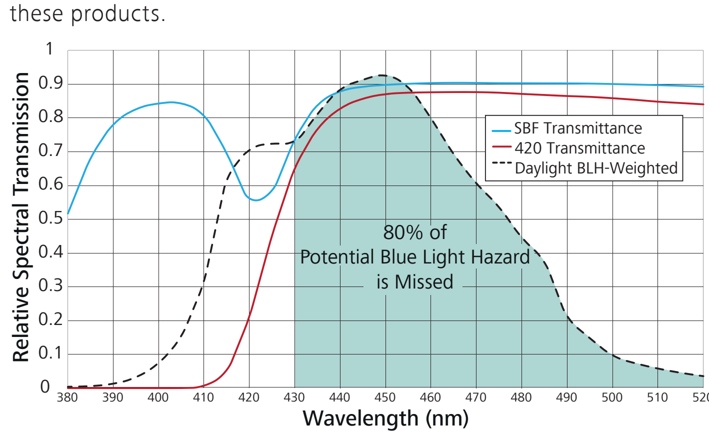

Figure 4. The minimal effect of filters on daylight Blue Light Hazard

Blue light coatings – broader spectral effect, limited impact – DuraVision BlueProtect is consumer preferred

An alternative to blue light absorption is an Anti-Reflective (AR) coating with enhanced reflection in the blue light range, reducing transmittance to the eye. These products typically reflect part of blue light between 400-460nm, a broader spectral range than affected by blue blocking lens materials. Such coatings may be a good alternative for those who are looking for decreased discomfort glare from blue light, or are concerned about blue light. Many manufacturers offer these products, and ZEISS responded to market trends by offering its own blue light coating. Unlike the weakness of blue absorbing materials, the blue reflective coatings reduce blue light in a spectrum overlapping the blue light hazard peak and reaching into the activation spectrum of melanopsin-bearing receptors.

...79% of consumers say ZEISS DuraVision BlueProtect looks better than the best-selling AR brand's blue light AR coating.

However because of the eye's strong sensitivity to light above 400nm, there is a limit to how much light can be reflected before lenses become unattractive, distort colours and distract wearers with disturbingly strong reflections. ZEISS designed its DuraVision BlueProtect to be the best-looking coating in this category. Blind testing[11] found 79% of consumers say ZEISS DuraVision BlueProtect looks better than the best-selling AR brand's[12] blue light AR coating.

protect eye health with ophthalmic lenses.

The best way to protect our eyes – block UVR

The greatest good for eyeglass wearers comes from blocking all UVR. ZEISS UVProtect lenses block virtually all UVR to 400nm in every lens material. That block is achieved by absorption in the lens material, because UV anti-reflective (AR) coatings are not effective at reducing UVR exposure by themselves.

The evidence suggests that bue light is only a threat to ocular health in extreme conditions when people are most likely to wear sunglasses or specialty safety glasses. Digital displays are not a threat to eye health. Although evidence is not conclusive, some researchers think the excessive use of digital devices may contribute to disrupted sleep patterns in some situations. For those concerned about this affect, blue light AR coatings can reduce discomfort glare from digital devices.

ZEISS UV Protect: A great opportunity

The risks of UVR exposure over a lifetime are well documented, and there is no good reason to allow lenses to pass any UVR. The implication is clear. All lenses should fully block UVR, yet 4 out of 5 eyeglass lenses sold today do not. ZEISS has recognized this real UV risk and the deficiencies in products available on the market. All ZEISS UVProtect lenses block UVR to 400nm, in all clear lens materials without any noticeable tint. ZEISS UVProtect is your greatest opportunity to protect eye health with ophthalmic lenses.

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* UVBlock is a calculation that represents the integrated sum over the whole UV range of the UVR blocked by an given lens. Formula detailed at www.zeiss.com/uvblock. October 2018

Carl Zeiss Vision Inc.

USA 1-866-596-5467

www.zeiss.com/lenses