Blue Light: Separating Fact and Fiction

Phillip T. Yuhas, OD, MS, FAAO

Please silence all mobile devices and remove items from chairs so others can sit. Unauthorized recording of this session is prohibited.
Disclosure Statement:
Nothing to disclose
The most effective clear lens at selective light filtering
- Blocks the harmful light: UV + Harmful Blue-Violet light (transmitted by modern digital devices)
- Lets through the good light (including the essential Blue-Turquoise light)

2
Helps prevent premature eye aging
(Cataracts and AMD)

Has launched the world’s first lens that may help reduce the risk of aged-related macular degeneration (AMD) and cataract.

Is blue light hurting your child’s eyes?
What’s the deal?

• Review of blue light
• Harmful effects of blue light
• Beneficial effects of blue light
• “Blue-blocking” ophthalmic devices
Blue light basics

Electromagnetic radiation spectrum
Blue light basics

Sensitivity limitations of the human visual system

The cornea absorbs UV-C radiation (< 280 nm)

Blue light basics

Sensitivity limitations of the human visual system

The crystalline lens absorbs UV-B (280-320 nm) and UV-A (230-400 nm) radiation

Blue light basics

Sensitivity limitations of the human visual system

Blue light basics

Where’s the danger?

Blue light basics

Where’s the danger?

\[ \lambda = \text{Blue light} \]

Blue light basics

Outdoor spectral profile

Mobile devices spectral profile


Blue light basics

But how bright is it?

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Sensitivity</th>
<th>( \alpha )-opic lux</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Angry Birds ipad</td>
</tr>
<tr>
<td>Cysanopic</td>
<td>S cone</td>
<td>244.44</td>
</tr>
<tr>
<td>Melanopic</td>
<td>Melanopsin</td>
<td>176.25</td>
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<tr>
<td>Rhodopic</td>
<td>Rod</td>
<td>180.07</td>
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<tr>
<td>Chloropic</td>
<td>M cone</td>
<td>174.03</td>
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<tr>
<td>Erythropic</td>
<td>L cone</td>
<td>162.66</td>
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<table>
<thead>
<tr>
<th>Prefix</th>
<th>Sensitivity</th>
<th>( \alpha )-opic lux</th>
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<td>170.42</td>
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<td>318.52</td>
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<td>201.89</td>
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<td>38.87</td>
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<td>51.40</td>
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</table>

The ability of the light devices to stimulate the human retinal photopigments in the eye was assessed and is presented in this table. The potential ability of each light source to stimulate the S-cone (cyanopic), M-cone (chloropic), L-cone (erythropic), rods (rhodopic), and melanopsin (melanopic) photopigments, corrected for pre-receptoral filtering, was evaluated (16). The S-, M-, and L-cones make up the trichromatic visual system and melanopsin is the blue light sensitive iridessence detecting photopigment that is the primary contributor to the non-visual responses to light.

Light intensity irradiance is measured in micro-watts per square centimeter. Photon flux is the number of photons that get delivered by the device per square centimeter per second. Peak spectral irradiance is the wavelength (nanometers) of the peak where the irradiance is highest.

Blue light basics

But how bright is it?

Cloudy day:
1000 lux
Blue light basics

But how bright is it?

Blue light basics

But how bright is it?

“Comparing natural exposures with the reasonably foreseeable exposure to optical radiation from lamps, computer screens and mobile devices, such as smartphones shows that the actual spectrally weighted irradiance is lower than the natural exposures.”

“Under even extreme long-term viewing conditions, none of the assessed sources suggested cause for concern for public health.”

Blue light basics

But how bright is it?

“Continuous viewing of the blue sky…does not present a risk of eye injuries”

Harmful effects of blue light
Harmful effects of blue light

Photothermal damage
Harmful effects of blue light

Photochemical damage


Harmful effects of blue light

AMD: Effect on photoreceptors

*Photoreceptor apoptosis*

*Gross loss of photoreceptors*

Harmful effects of blue light

AMD: Effect on retinal pigment epithelium


Harmful effects of blue light

AMD: Evidence for an association between blue light and AMD

The Long-term Effects of Visible Light on the Eye

Hugh R. Taylor, MD; Sheila West, PhD; Beatriz Muñoz, MS; Frank S. Rosenthal, PhD; Susan B. Bressler, MD; Neil M. Bressler, MD

N = 838
Ages 30-95
Harmful effects of blue light

AMD: Chesapeake Watermen Study

Table 4.—Association Between Ocular Exposure to Blue Light Over Last 20 Years and AMD for Those Older Than 65 Years*

<table>
<thead>
<tr>
<th></th>
<th>Blue</th>
<th>UV-A</th>
<th>UV-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD-1, grade 1 only</td>
<td>1.00 (0.90-1.13)</td>
<td>1.04 (0.81-1.34)</td>
<td>1.10 (0.88-1.38)</td>
</tr>
<tr>
<td>AMD-2, grade 2 only</td>
<td>1.04 (0.92-1.16)</td>
<td>1.02 (0.76-1.37)</td>
<td>1.02 (0.76-1.37)</td>
</tr>
<tr>
<td>AMD-3, grade 3 only</td>
<td>1.05 (0.95-1.16)</td>
<td>0.93 (0.78-1.11)</td>
<td>0.93 (0.76-1.11)</td>
</tr>
<tr>
<td>AMD-4, grade 4 only</td>
<td>1.36 (1.00-1.85)</td>
<td>0.92 (0.62-1.37)</td>
<td>0.92 (0.62-1.37)</td>
</tr>
</tbody>
</table>

*AMD indicates age-related macular degeneration.
†Odds ratio estimate for the increase in exposure of 0.1 Maryland sun-year. CI indicates confidence interval.

Harmful effects of blue light

AMD: Chesapeake Watermen Study

“Initial logistic regression analysis did not show a significant association between the presence of AMD of any grade and lifetime cumulative ocular exposure [to sunlight].”

“However, when the analysis considered the ocular exposure for the previous 20 years, a significant association was seen between AMD-4 and blue light exposure.”

“The lack of a significant association between ocular exposure and the presence of small drusen suggests these changes may have a different cause or a different significance in the evolution of sight-destroying AMD than that which is usually assumed.”

Harmful effects of blue light

AMD: Evidence for an association between blue light and AMD

Sunlight and the 5-Year Incidence of Early Age-Related Maculopathy

The Beaver Dam Eye Study

Karen J. Cruickshanks, PhD; Ronald Klein, MD; Barbara E. K. Klein, MD; David M. Nondahl, MS

Sunlight and the 10-Year Incidence of Age-Related Maculopathy

The Beaver Dam Eye Study

Sandra C. Tomany, MS; Karen J. Cruickshanks, PhD; Ronald Klein, MD, MPH; Barbara E. K. Klein, MD, MPH; Michael D. Knudtson, MS

N = 4926
Ages 43-84
Harmful effects of blue light

AMD: The Beaver Dam Eye Study, 5 Years

“People who reported spending 5 or more (leisure) hours per day outside in the summertime during their teenage years and 30s appeared to have a greater risk of developing early ARM as older adults than people who spent little time outside.”

Harmful effects of blue light

**AMD: The Beaver Dam Eye Study, 10 Years**

<table>
<thead>
<tr>
<th>Leisure time outdoors</th>
<th>Early ARM</th>
<th>Size &gt;250 μm in Diameter</th>
<th>Soft Indistinct Drusen</th>
<th>Increased Retinal Pigment</th>
<th>RPE Depigmentation</th>
<th>Late ARM</th>
<th>Pure Geographic Atrophy</th>
<th>Exudative ARM</th>
<th>Progression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference: low exposure</td>
<td>1.94 (1.00-3.74)</td>
<td>1.01 (0.53-1.90)</td>
<td>1.35 (0.74-2.47)</td>
<td>2.42 (1.05-5.68)</td>
<td>1.12 (0.56-2.24)</td>
<td>0.91 (0.32-2.56)</td>
<td>1.22 (0.16-9.33)</td>
<td>0.81 (0.24-2.69)</td>
<td>1.00 (0.60-1.68)</td>
</tr>
<tr>
<td>Moderate exposure</td>
<td>2.10 (1.02-4.73)</td>
<td>1.24 (0.55-2.77)</td>
<td>1.38 (0.64-2.78)</td>
<td>2.09 (1.01-4.27)</td>
<td>1.34 (0.57-3.11)</td>
<td>0.90 (0.24-3.59)</td>
<td>1.76 (0.16-18.53)</td>
<td>0.99 (0.16-4.69)</td>
<td>0.95 (0.54-2.02)</td>
</tr>
<tr>
<td>High exposure</td>
<td>0.04</td>
<td>0.61</td>
<td>0.44</td>
<td>0.02</td>
<td>0.50</td>
<td>0.98</td>
<td>0.64</td>
<td>0.86</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Harmful effects of blue light

AMD: The Beaver Dam Eye Study

“Participants with the highest levels of sun exposure...as well as those with moderate levels of sun exposure...were significantly more likely to develop early ARM and increased retinal pigment by the 10-year follow up period than those reporting the lowest levels of sun exposure.

“After adjusting for age and sex, the use of hats and sunglasses by participants at baseline or in their teens and 30s was not found to protect against the 10-year incidence of ARM.”

Harmful effects of blue light

AMD: Evidence against an association between blue light and AMD

Risk Factors for Age-Related Maculopathy

The Visual Impairment Project

Catherine A. McCarty, PhD, MPH; Bickol N. Makhes, PhD; Cara L. Fu, GradDip (IT); Paul Mitchell, FRACO; Jie Jin Wang, Mmed, MBBS; Hugh R. Taylor, MD, FRACO

Sun Exposure and Age-related Macular Degeneration

An Australian Case–Control Study

Peteris Darseins, BM, BS, FRACP, FRCPC; Paul Mitchell, MD, FRACO, FRCOphth; Richard F. Heller, MD, FRCP, FRACP, FAFPHM

Risk Factors for Neovascular Age-Related Macular Degeneration

The Eye Disease Case-Control Study Group

Light Exposure and the Risk of Age-Related Macular Degeneration

The Pathologies Oculaires Liées à l’Age (POLA) Study

Cécile Delcourt, PhD; Isabelle Carrière, MSc; Alice Ponton-Sanchez, MSc; Sylvie Fourrey, BSc; Annie Lacroux, MSc; Laure Papoz, PhD; for the POLA Study Group

Risk Factors for the Incidence of Advanced Age-Related Macular Degeneration in the Age-Related Eye Disease Study (AREDS)

AREDS Report No. 19

Age-Related Eye Disease Study Research Group

Risk Factors of Age-related Maculopathy in a Population 70 Years of Age or Older

Heli Hirvelä, MD; Heikki Lasukinen, MD; Esa Läädrä, Lic Sc; Leila Lasukainen, MD
Harmful effects of blue light

AMD: RPE melanin

Harmful effects of blue light

**AMD: Macular pigment**


Harmful effects of blue light

**AMD: Conclusions**

- *In vitro* studies implicate blue light as dangerous to photoreceptors and RPE cells.

- The results of epidemiology studies are mixed.

- There is no evidence of ocular damage from light emitted from personal electronic devices.

Harmful effects of blue light

Uveal Melanoma: In Vitro

“We present evidence that blue light exposure can influence uveal melanoma cells and further substantiate the results of previous in vitro studies. Our data demonstrated a significant increase in uveal melanoma cellular proliferation after exposure to blue light.”
Harmful effects of blue light

Uveal Melanoma: *In Vivo*

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Cases, No. (%)</th>
<th>Controls, No. (%)</th>
<th>Adjusted RR Estimate (95% CI)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative intense sun exposure, y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>116 (59)</td>
<td>239 (62)</td>
<td>1.0</td>
</tr>
<tr>
<td>1-40</td>
<td>38 (19)</td>
<td>77 (20)</td>
<td>0.8 (0.5-1.5)</td>
</tr>
<tr>
<td>&gt;40</td>
<td>43 (22)</td>
<td>69 (18)</td>
<td>1.7 (0.9-3.0)</td>
</tr>
<tr>
<td>Cumulative sunlight score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>61 (31)</td>
<td>128 (33)</td>
<td>1.0</td>
</tr>
<tr>
<td>Medium</td>
<td>69 (35)</td>
<td>118 (31)</td>
<td>1.3 (0.8-2.2)</td>
</tr>
<tr>
<td>High</td>
<td>67 (34)</td>
<td>139 (36)</td>
<td>1.0 (0.5-1.9)</td>
</tr>
</tbody>
</table>

Harmful effects of blue light

Sleep disruption

Trouble sleeping? Maybe it's your iPad

By John O. Stutie, CNN
May 13, 2019 9:08 a.m. EDT

There's growing concern that the glowing screens of laptops and the iPad may affect sleep if used right before bedtime.
Harmful effects of blue light

Sleep disruption: Melatonin

Melatonin levels peak in the middle of the night
Melatonin production increases in the evening
Melatonin levels fall to normal daytime low by early morning

Sandhills Neurologists; Fuquay, NC
Harmful effects of blue light

Sleep disruption: Effect of personal devices

Harmful effects of blue light

Sleep disruption: Effect of personal devices

Harmful effects of blue light

Sleep disruption: Effect of personal devices

Harmful effects of blue light

Sleep disruption: Effect of personal devices

“These results indicate that reading an LE-eBook in the hours before bedtime likely has unintended biological consequences that may adversely impact performance, health, and safety.”

How does environmental light modulate circadian rhythms?

Intrinsically photosensitive retinal ganglion cells

Fundamental properties

- Represent a rare subset of human RGCs (<1%)
- Receive input from rods and cones
- Express blue-light sensitive photopigment melanopsin


Intrinsically photosensitive retinal ganglion cells

**Fundamental properties**

IpRGC project to the suprachiasmatic nucleus — the body’s central clock — with the purpose of entraining physiological sleep-wake cycles to environmental light levels.
Intrinsically photosensitive retinal ganglion cells

**Fundamental properties**

- ipRGC project to the suprachiasmatic nucleus – the body’s central clock – with the purpose of entraining physiological sleep-wake cycles to environmental light levels.

- **Wild type:** can photoentrain

- **Ablated ipRGCs:** Cannot photoentrain

Intrinsically photosensitive retinal ganglion cells

Fundamental properties

I pRGC project to the suprachiasmatic nucleus – the body’s central clock – with the purpose of entraining physiological sleep-wake cycles to environmental light levels


Intrinsically photosensitive retinal ganglion cells

Mediators of additional beneficial effects of blue light
Beneficial effects of blue light

Increased alertness: healthy subjects

“These results demonstrate that the alerting response to light is wavelength dependent, such that short wavelength light (460 nm) is more effective than longer wavelength light (550 nm) in reducing sleepiness in the evening.”

Beneficial effects of blue light

Increased alertness: TBI and outer retinal disease subjects


Beneficial effects of blue light

Effects on mood: seasonal affective disorder

“Short-wavelength LEDs of 468 nm significantly outperformed the dim long-wavelength LED condition.”

Blue-blocking ophthalmic products

Intraocular lenses
Blue-blocking ophthalmic products

Intraocular lenses: how much blue light do they block?

“Blue blocking IOLs offer 20% less blue-green phototoxicity protection than a 53 year old crystalline lens.”

“There is no clinical or experimental proof that normal light exposure or repetitive acute phototoxicity causes AMD. The use of blue-blocking chromophores in IOLs to reduce AMD risks is not evidence-based medicine.”

Blue-blocking ophthalmic products

Intraocular lenses: negative effects on vision

“The present study shows statistically significant worse contrast acuity and blue/yellow foveal threshold in eyes with blue-light-filtering IOLs compared with UV-filtering IOLs. The largest differences between blue-light- and UV-filtering IOLs were detected under low-mesopic light conditions.”

Blue-blocking ophthalmic products

Blue blocking coatings and light tints


Blue-blocking ophthalmic products

Blue blocking coatings and light tints


Blue-blocking ophthalmic products

Blue blocking coatings and light tints

Blue-blocking ophthalmic products

Blue blocking heavy tints

Blue-blocking ophthalmic products

Blue blocking heavy tints

Å “PSQI scores decreased (i.e. improved) or remained the same for all subjects after the experimental period, with an average score of 5.6 ± 2.9 at baseline, and a score of 3.0 ± 2.2 after wearing blue blocking glasses (P < 0.0005).”

Å “Objectively measured sleep duration statistically significantly increased by 24 min (P = 0.001).”

Å Average baseline time of sleep was 12:24 am ± 1:04, and during the experimental period was 11:57 pm ± 1:03, which was statistically significantly earlier by 27 min (P = 0.004).”
Blue-blocking ophthalmic products

Take-home messages

There is no scientific evidence that blue blocking ophthalmic products provide an enhanced safety profile.

Reduction of light before bedtime improves sleep quality. The role of blue-blocking products has yet to be investigated in a rigorous manner.
Conclusions

• **Blue light is theorized to be harmful to eye health because it is high energy and is not filtered by the ocular media as much as UV light is.**

• **Although in vitro studies suggest blue light is deleterious to photoreceptors and RPE cells, the human epidemiological evidence is mixed, at best.**

• **ipRGCs mediate blue light’s influence over behavior, such as enhancements of alertness, awareness, and mood.**

• **There is no scientific evidence that blue blocking ophthalmic products provide an enhanced safety profile. Their effect on sleep demands more research.**
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