

*RETINAL PHOTOTOXICITY...
BLUE LIGHT HAZARDS?—
WHAT ARE WE LOOKING AT?*

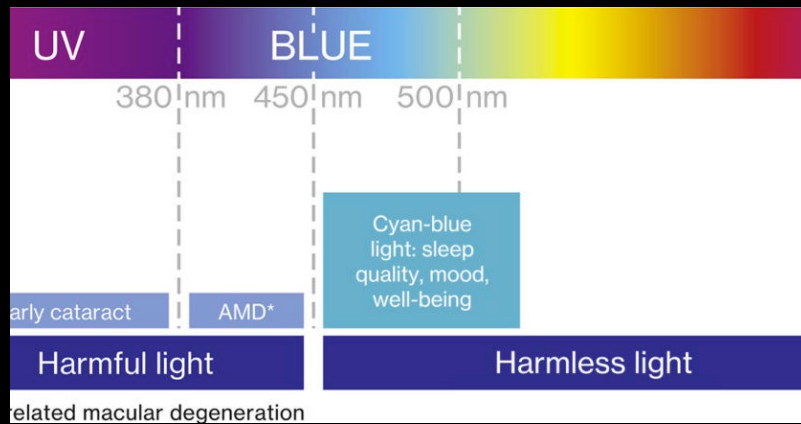


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“Blue-Light Hazard” – Surfing the Net ...



- **“risks associated...LEDs”**

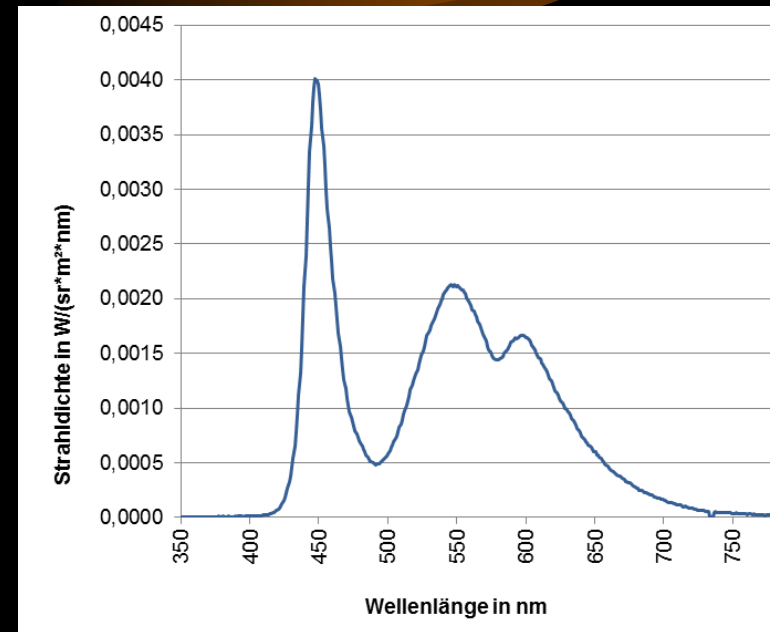
- Eye fatigue
- Sleep rhythm disorders
- Age-related macular degeneration (AMD)

- Buy our blue-blocker glasses!
- Cell phone displays!
- Computer displays!
- Drive with comfort at night!
- What can you do!!!??

The conclusion one could arrive at from a “blue-light” web search:

“Blue light is everywhere, especially in sunlight. Excessive exposure to harmful blue light, however, is due to the increased use of LED lamps and screens. Whether at work or at home, we spend a large part of our days in front of a screen.”

D Sliney 2018



Message & Fig. from German optometry website on blue light hazard (ergoptometrie.de)

...so what does the science really say?

The Puzzle of Light and AMD...

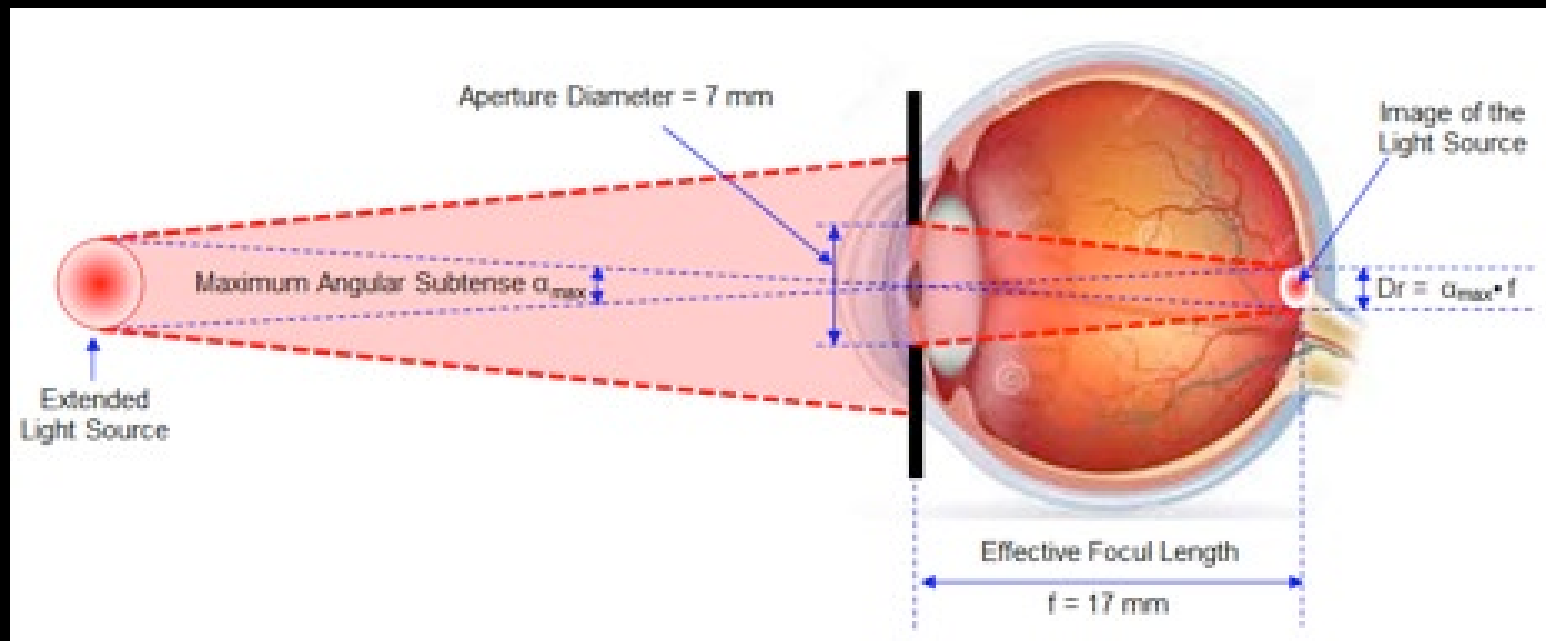
- Despite many *in vitro* and animal laboratory research studies over the last several decades pointing to the potential role of light — ***particularly short-wavelength light*** — as a cause of (etiology) or promotion of age-related macular degeneration (AMD), but only limited epidemiological evidence supporting this link.
- Why the lack of agreement in scientific studies?

For Retinal-Mediated Effects...for vision, for circadian, for blue-light

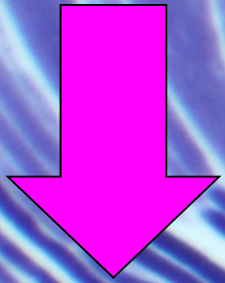
...we need to examine actual retinal exposure:

- $E_r = 0.27 L \cdot \tau \cdot d_e^2$

Retinal illumination is directly proportional to luminance and radiance – not to illuminance in lux!

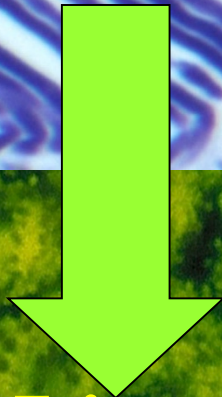


LIGHT LIGHT



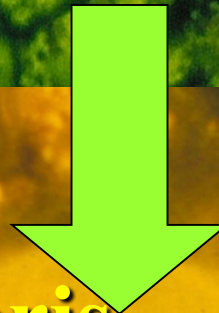
ROS

Disks



Lipofuscin

ROS



Debris

Drusen

Intra retinal



Cell Death

Compromised Transport

Choroidal

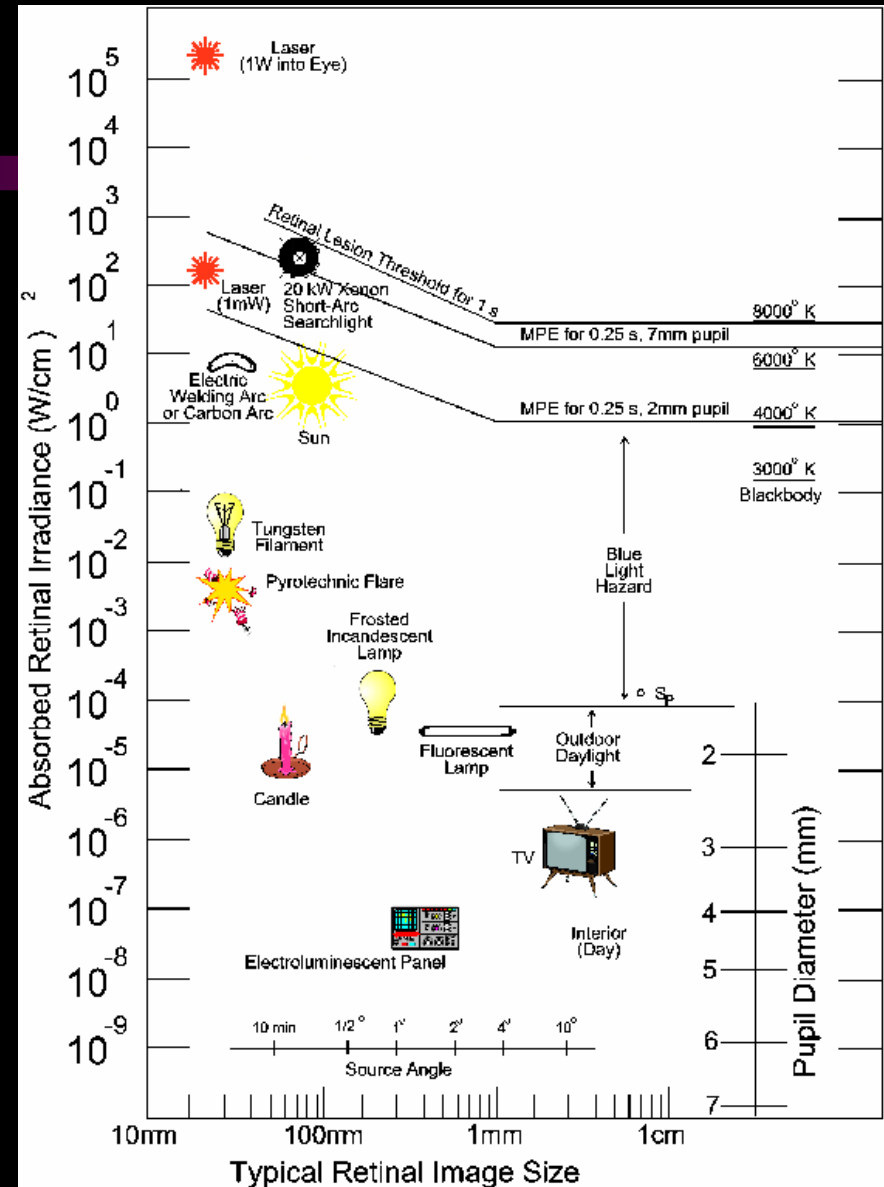


So...Some Key Questions

- ★ What is the typical retinal exposure from outdoor daylight, from lamps and artificial sources?
- ★ How do these levels compare to the retinal illumination levels used in research studies?
- ★ How do outdoor daylight exposures vary with different action spectra?
- ★ What about ultraviolet exposures of retinal tissues? Are they really insignificant?

Physiological Levels of Retinal Illumination

- The retinal illumination in the ambient outdoors is of the order of $0.02\text{--}0.1\text{ mW/cm}^2$ ($< 1\text{ cd/cm}^2$) and these levels are just comfortable to view
- Retinal illuminance outdoors is $\sim 5 \times 10^5\text{ td}$
- The sun's image is more than 10,000 times greater ($> 1\text{ W/cm}^2$) than sunlight from snow

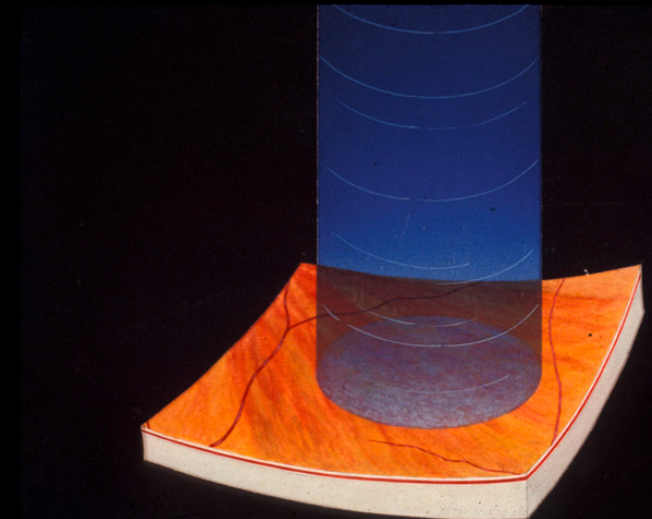
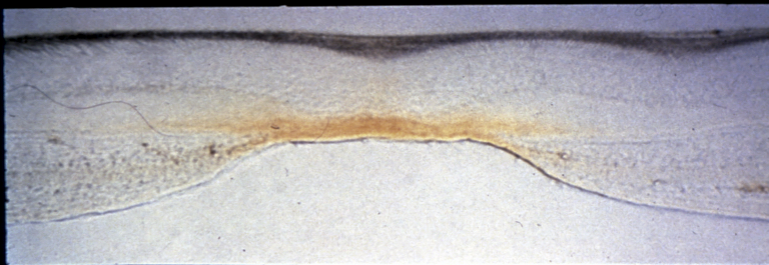


The Macula Lutea - Pigment Lutein

4



In the inner and outer
plexiform layers
Thought to minimize BLH



Photochemically Induced Retinal Injury — Exposure Duration

- At least 2 types of light damage are seen with time:
- Type 1
 - Noell, 1966—12 h/day
 - rhodopsin, cone opsins
- Type 2
 - Ham, Mueller, Sliney, 1976
 - blue-light chromophore 446 nm
 - photomaculopathy

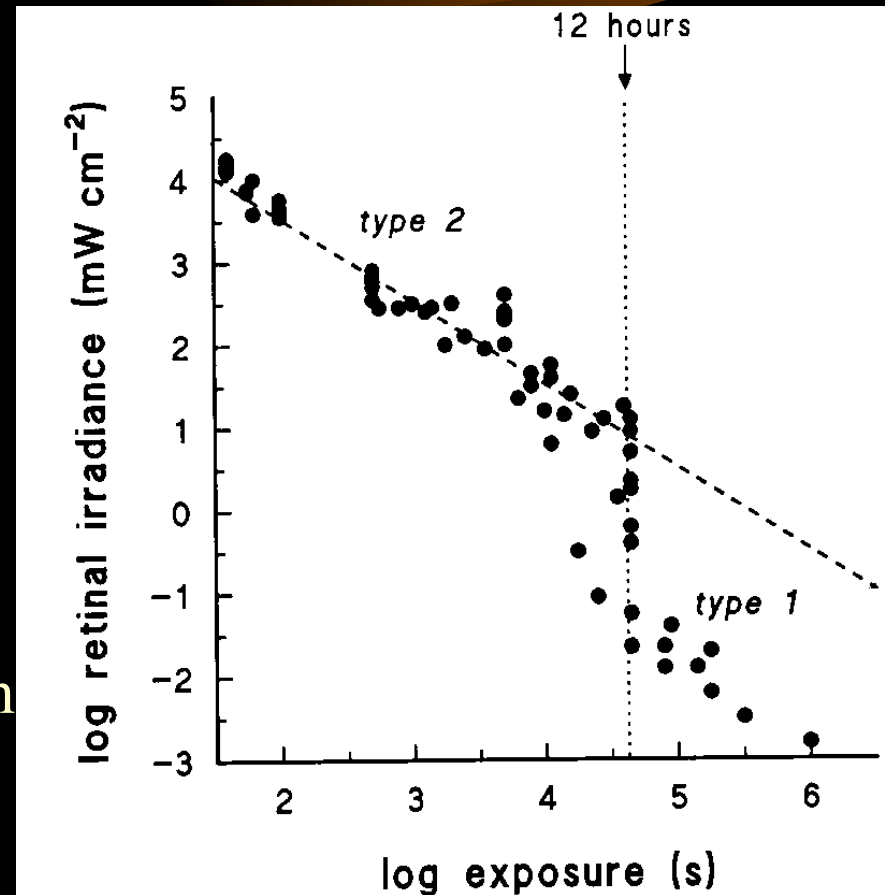
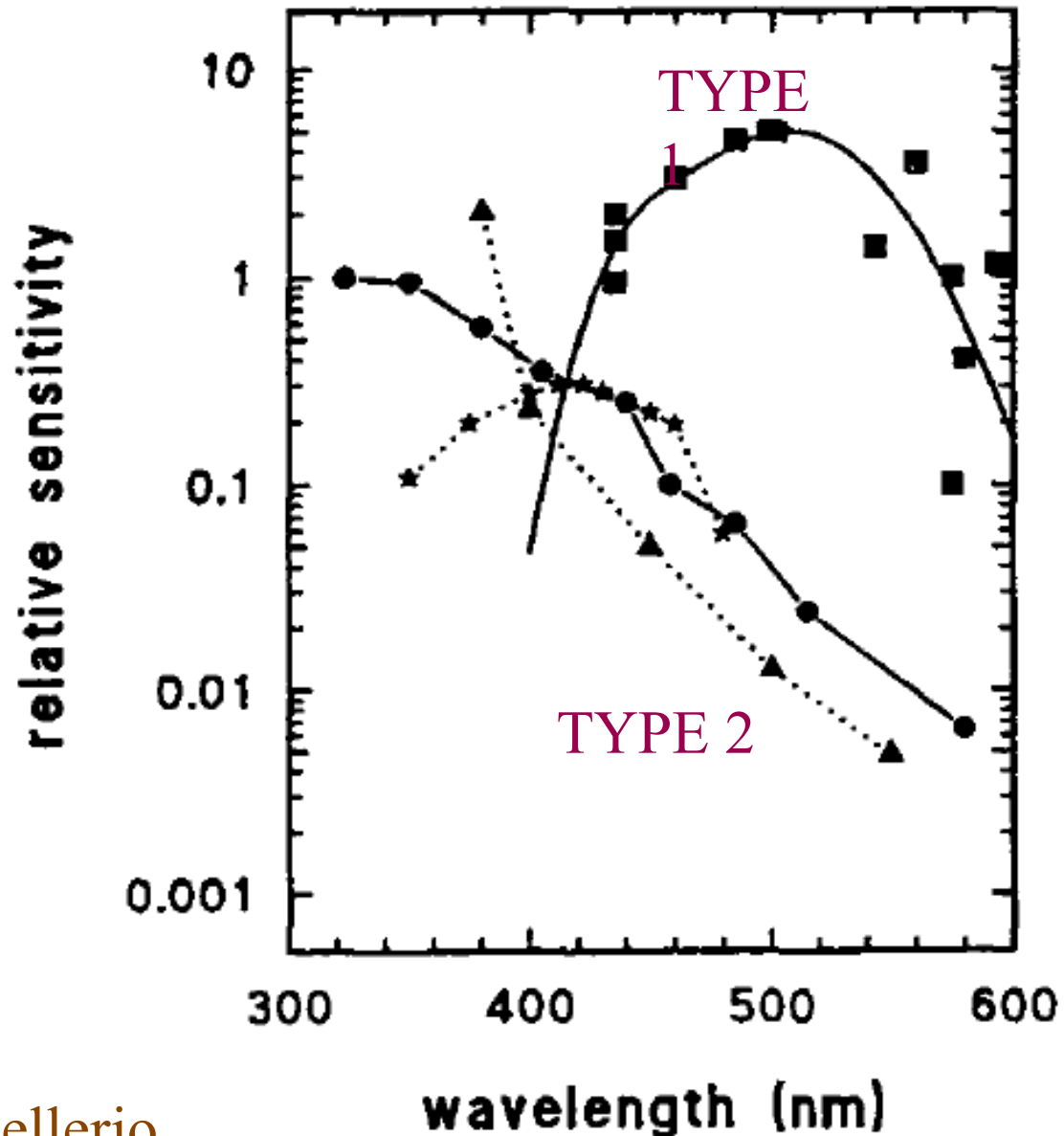


Fig from Mellerio

Two Types of Light Damage for the Mammalian Retina:

- Type 1 (Noell) resulting from a full-bleach of retinal pigments resulting in toxic build-up of retinoids in the Retinal Pigment Epithelium (RPE)
- Type 2 (Ham) resulting from phototoxic reaction in RPE—the blue-light hazard — IESNA RP-27
- Is there a third?

Two Distinct Action Spectra



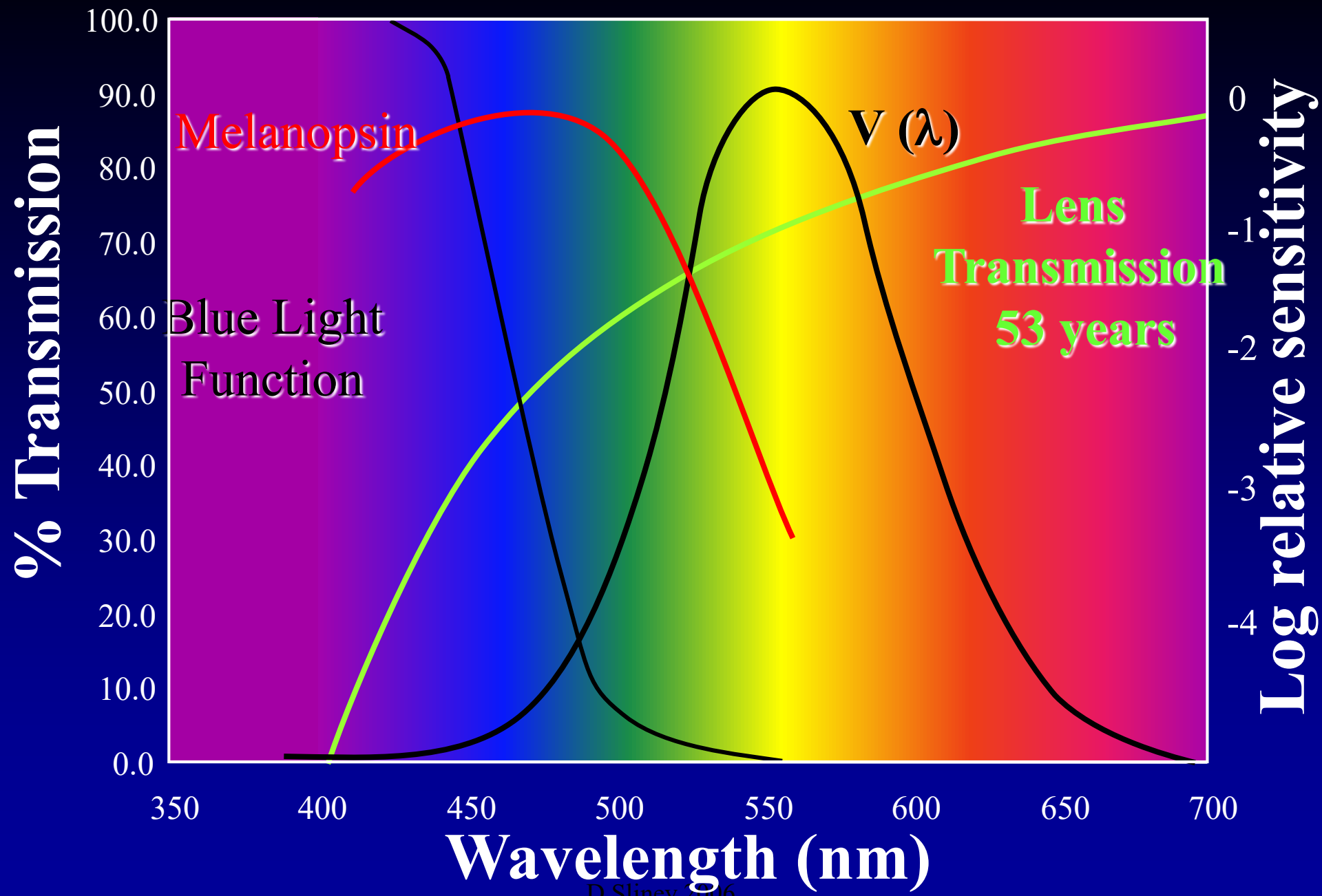


Fig. Courtesy, J. Marshall

D Sliney 2006

Melanopsin from Berson et al, Science, 295, 2002



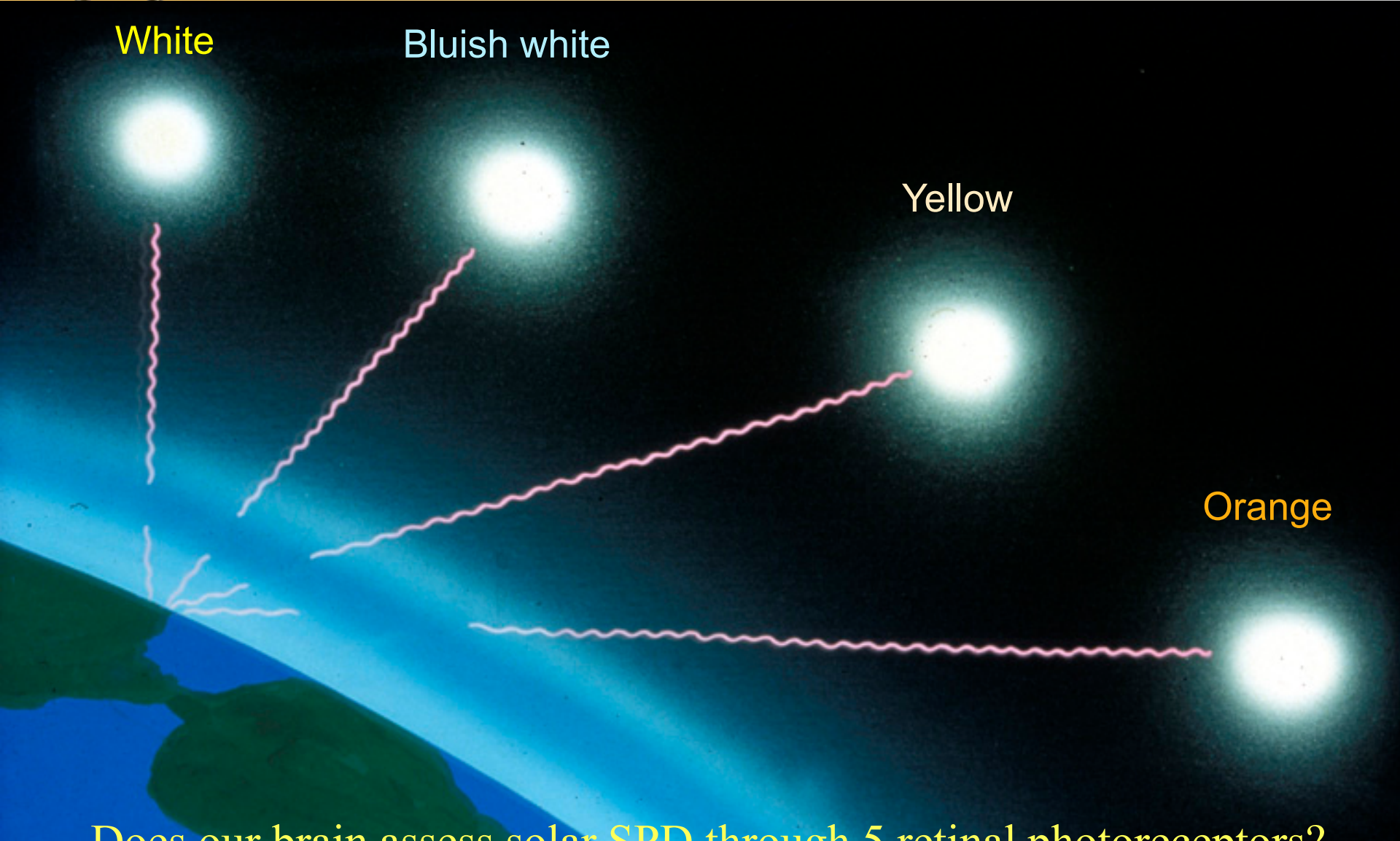
Changing atmospheric pathlengths - and changing spectral appearance of solar disc

White

Bluish white

Yellow

Orange



Does our brain assess solar SPD through 5 retinal photoreceptors?

Staring at the Sun...When is it safe?
- The risk of acute retinal exposure



UVR and blue light are scattered out of the direct image making the yellow-to-red sun safe to view directly at sunset, but staring at the sun at midday produces photomaculopathy



Environmental Agents and Ocular Disease

- ★ Epidemiological studies produced surprisingly inconsistent findings relating ocular disease to ambient light as well as estimated UV exposure.
- ★ Can a lack of consistent results be due largely to incomplete or erroneous estimates of optical dose?
- ★ ***Of greatest importance are the geometrical factors that influence retinal exposure, as well as UV exposures to different segments of lens, cornea and retina.*** (also need local temperature for lens)



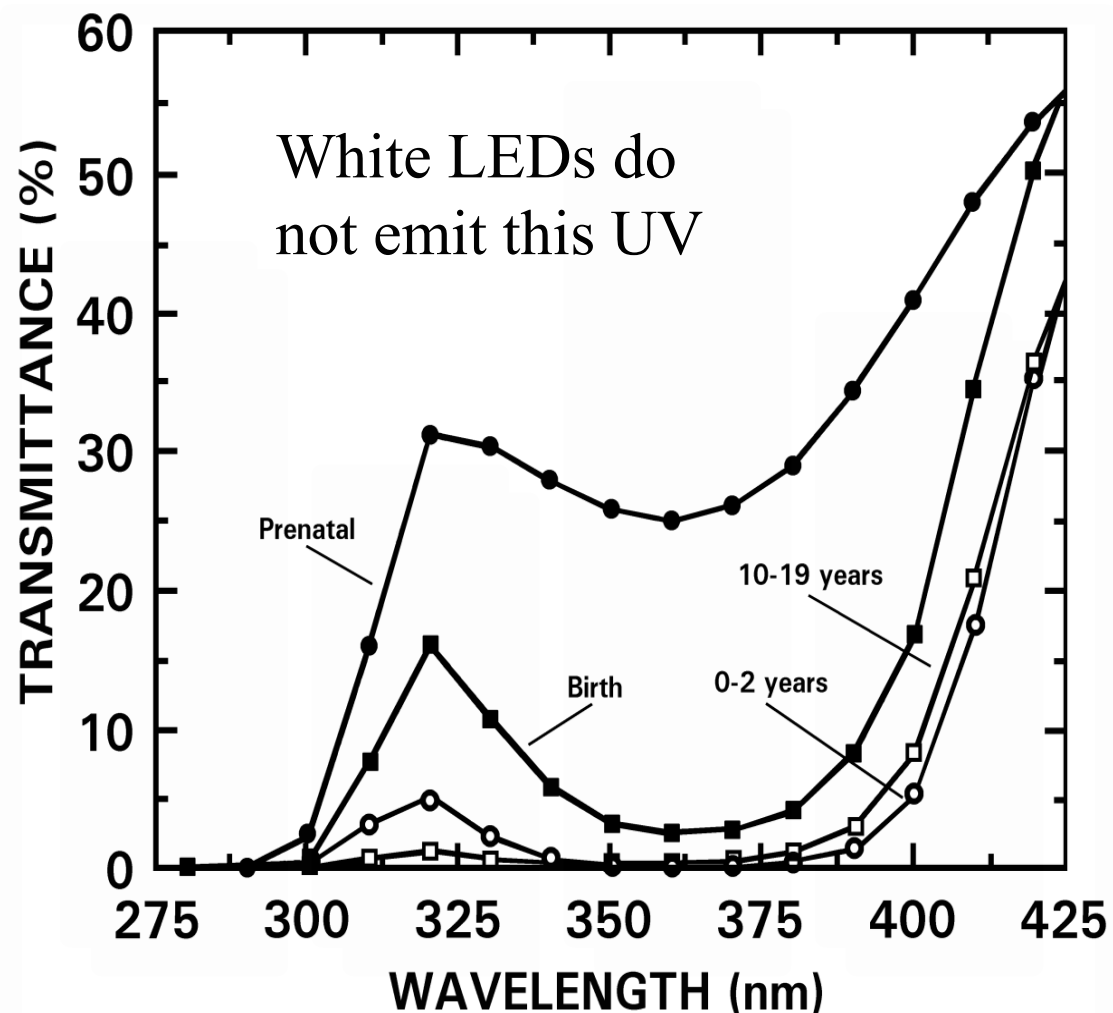
Individual Variability

- ★ Generally ignored factors
 - Individual's pupil size
 - Individual's sun-avoidance behavior
 - Individual lid opening – really!?
 - Individual's lens/corneal spectral transmission – varies with age, latitude
 - Potential photophobia
- ★ How big a factor can each of these be?



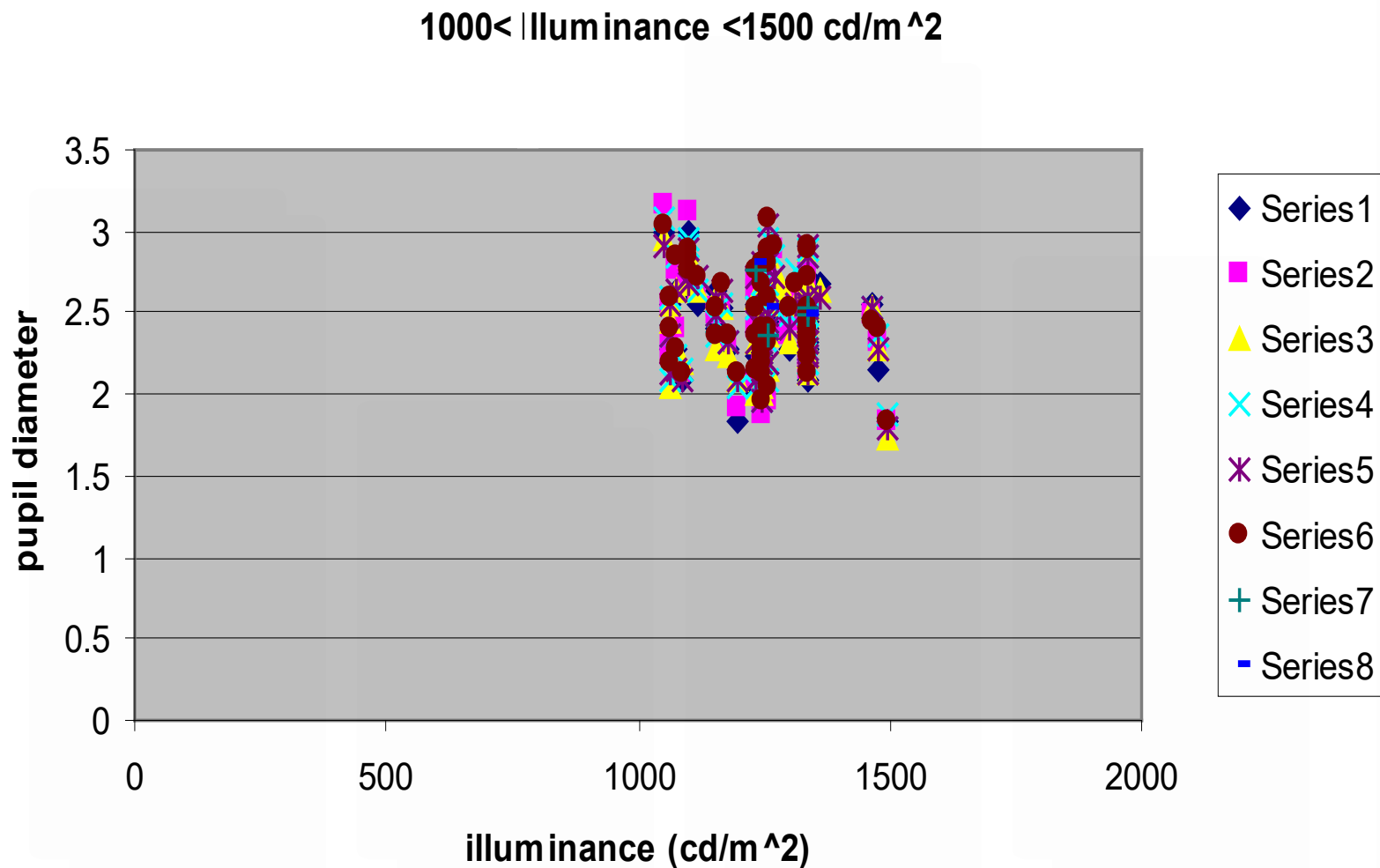
For very small children, small amounts of 295-325 nm UV reach the retina

- ★ **Childhood** sunlight exposure frequently overlooked
- ★ UV/violet Spectral Transmittance of the Human Lens (Data of Barker & Brainard)
- ★ UV-A absorbing chromophores have fascinated biochemists – some lenticular fluorophores





Pupil Size in Moderate Daylight, mostly cloudy (Area > 3x variation)





Our Natural Protection: Upper-Lid Moves Downward (“squinting”)

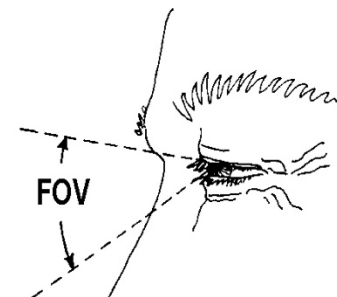
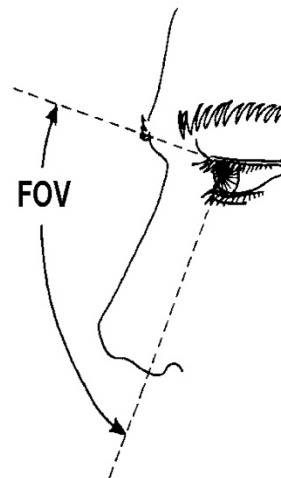
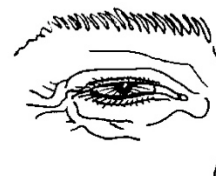
★ Geometrical factors are seldom appreciated!

- Overhead protection by the brow ridge, upper lid
- Ground reflections--unimportant for skin exposure, but critical for the eye
- Temporal side exposure (Coroneo)
- Clinical FOV $\sim \pm 30^\circ$

WALKING,
LOOKING DOWNWARD -15°

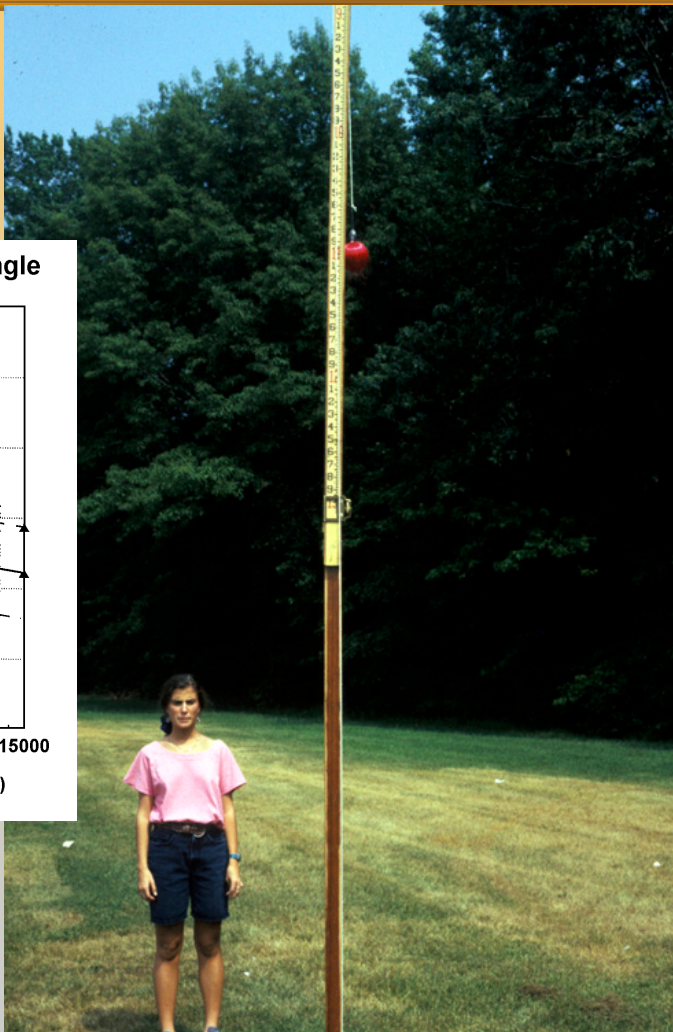
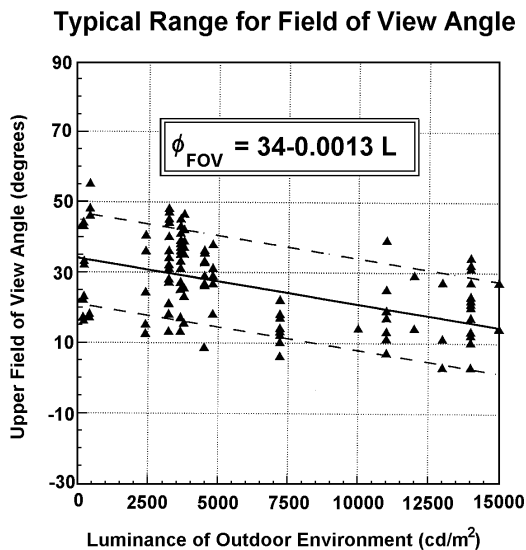


SQUINTING





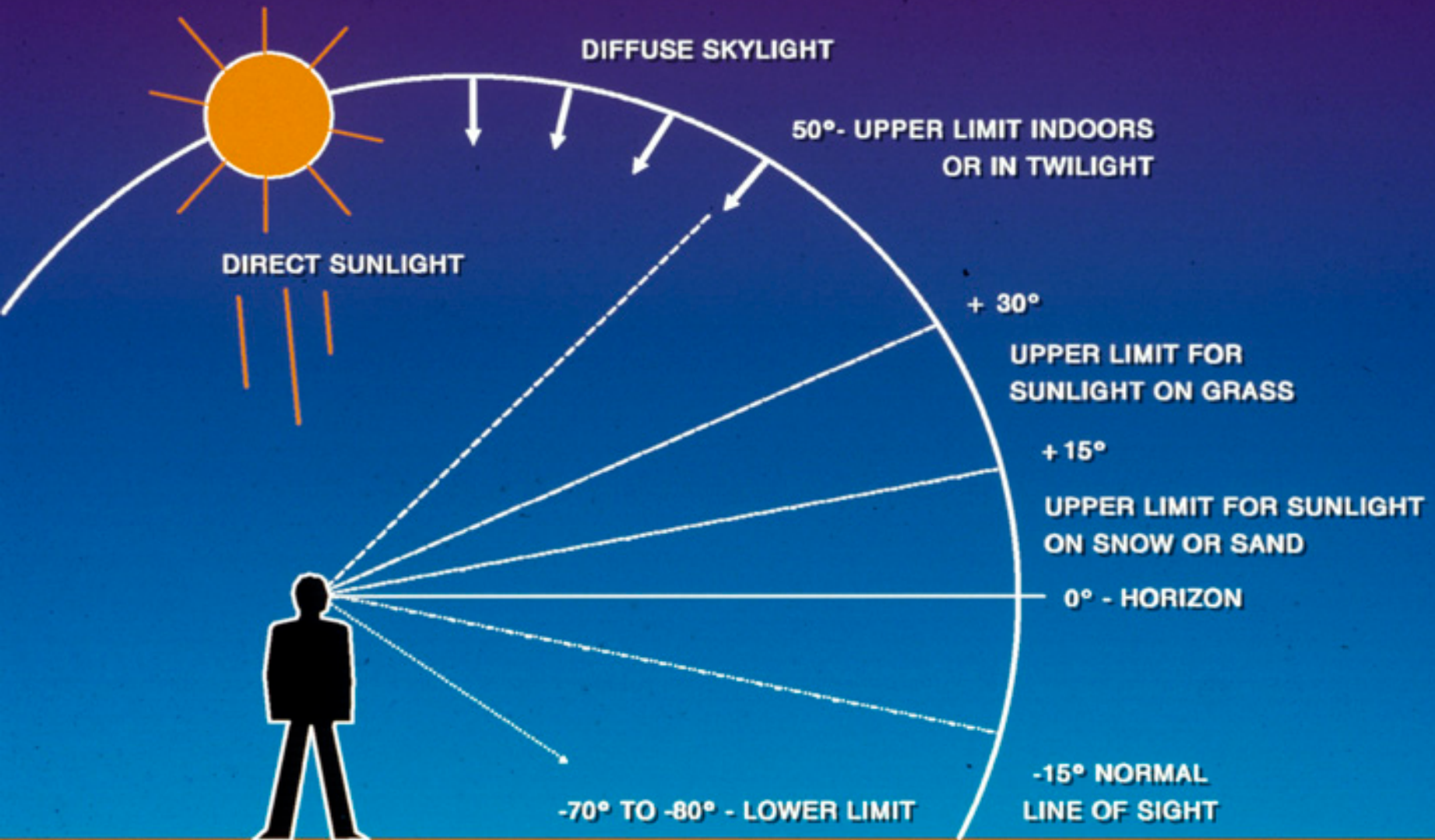
Lid-Opening Studies



- ★ Studies performed by Deaver, Sliney et al. of lid opening by measuring vertical field of view in outdoor environments
- ★ Upper lid lowers with increased scene luminance (brightness)



Corneal exposure and blue light entering the pupil is limited to 15° in a bright-light sunlit environment

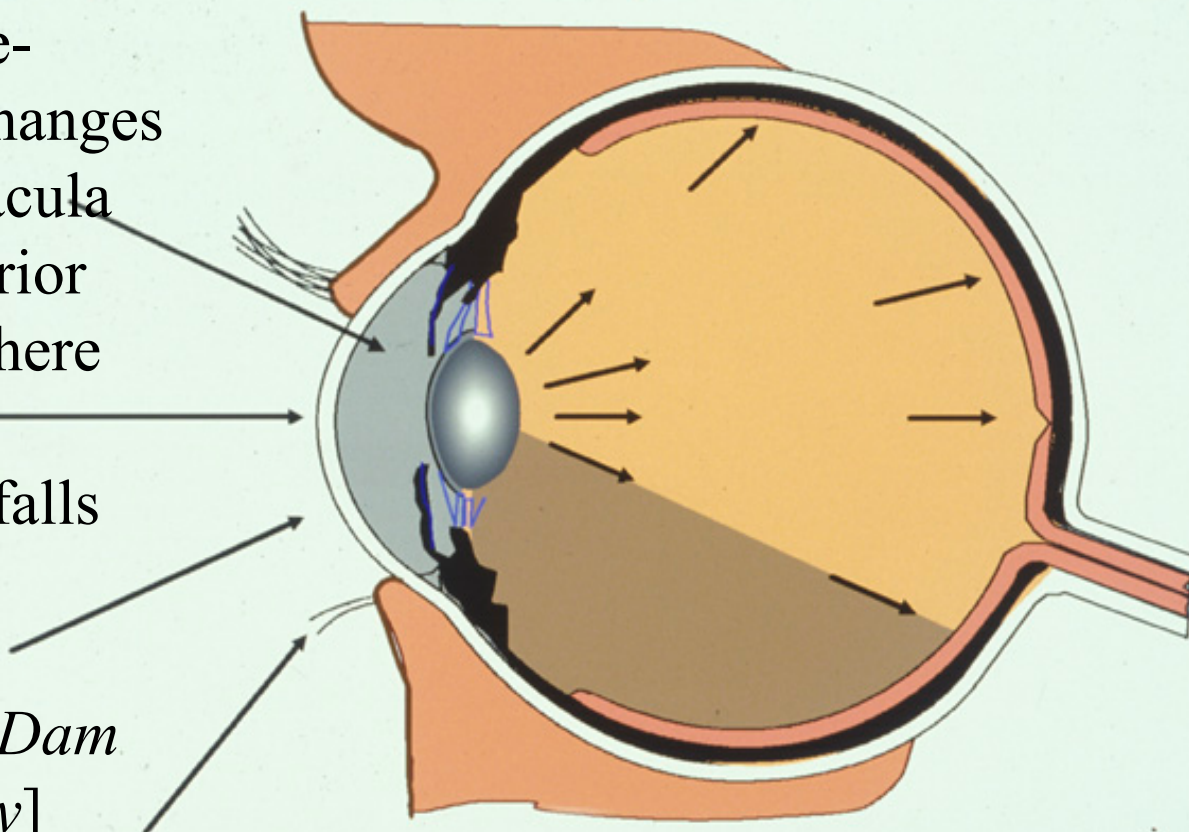




Retinal Exposure in Sunlight *(inferior retina is not exposed)*

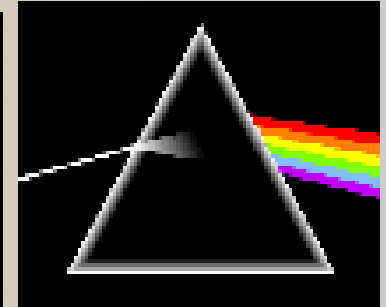
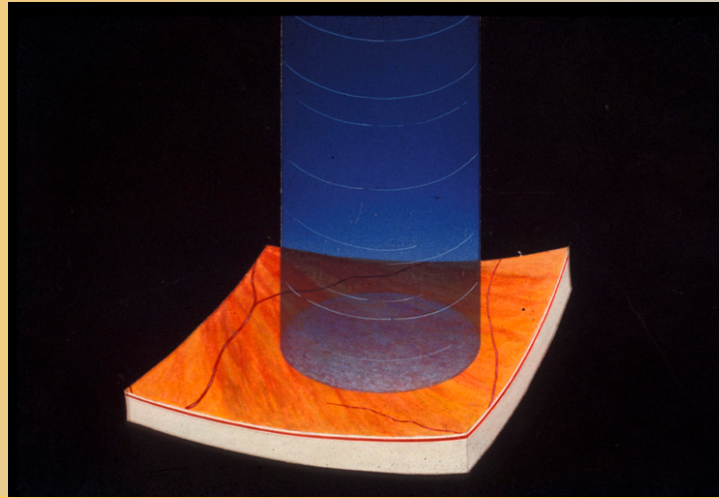
More age-related changes in the macula and superior retina, where reflected sunlight falls

{*Beaver Dam Eye Study*}



Note: Glickman: Inferior retina is more sensitive for melatonin suppression

Retinal Exposures to Light

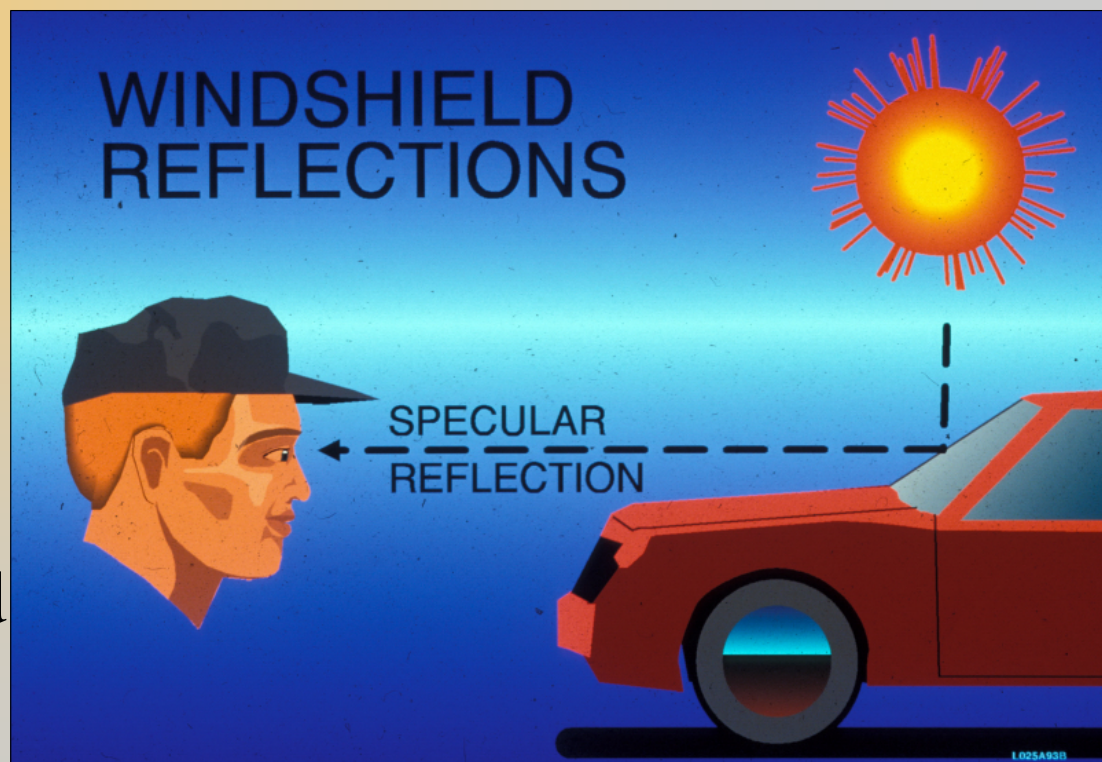


- Ocular Dosimetry for bright-light retinal exposure, whether unintentional or intentional is possible, but it must be individual-based
- but “simple” cases are not always straightforward
 - The macula is always exposed to light
 - Durations are hard to define well
 - Anisocoria? Compare retina of left and right eye
 - Does pupil size at 70 y tell us about pupil size in youth?



Determining the potential retinal hazards from viewing specular images of the sun

- ★ Performed measurements with spot photometer and spectroradiometer
- ★ Assessed potential blue-light hazard and safe viewing times
- ★ An unfinished study





Measuring Spatially Averaged Irradiance or Radiance – the hood

- ★ With a 1-sr hood over an irradiance detector head, one can better measure what actually enters the eye.
- ★ The eyes generally are directed $\sim 15^\circ$ downward; and overhead luminaires are generally not in the measured Field-of-View!



Hood With Optometer



So what can we say about LED exposure? Is there a metric?

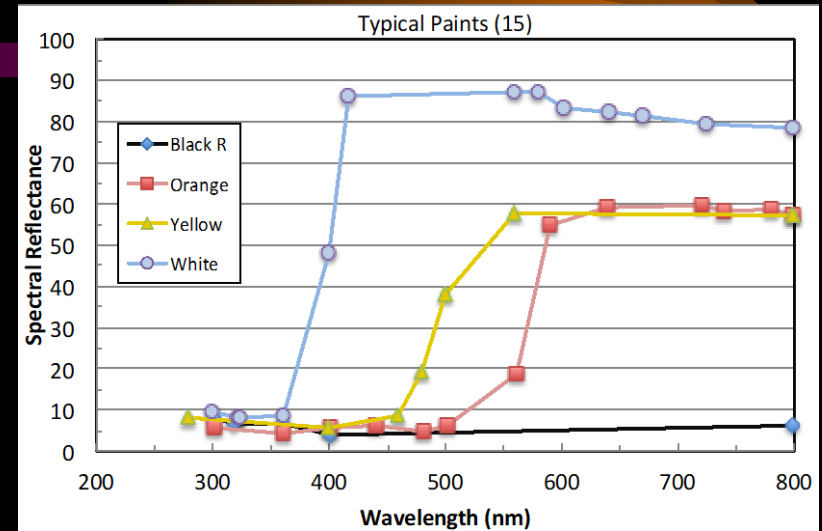
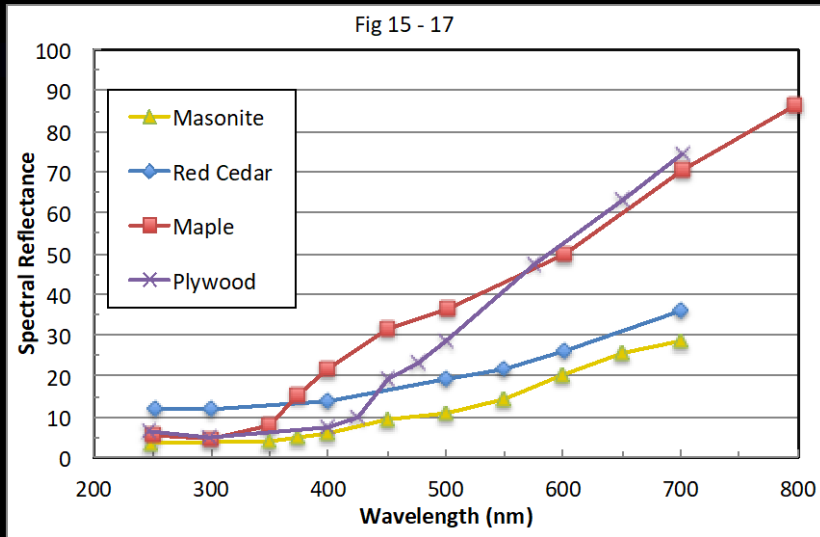
- ★ Sunlight exposure dwarfs retinal exposure compared to indoor lighting – particularly quality lighting (low discomfort glare).
- ★ Measuring retinal exposure to blue-light:
 - Neither horizontal or vertical illuminance is a good metric to account for realistic FOV
 - Different for indoor and outdoors
 - A hooded illuminance meter (e.g., 1 steradian) measures spatially averaged irradiance & radiance
 - Result – little blue found when downward facing!



Spectral reflectance in our FOV dominates retinal exposure

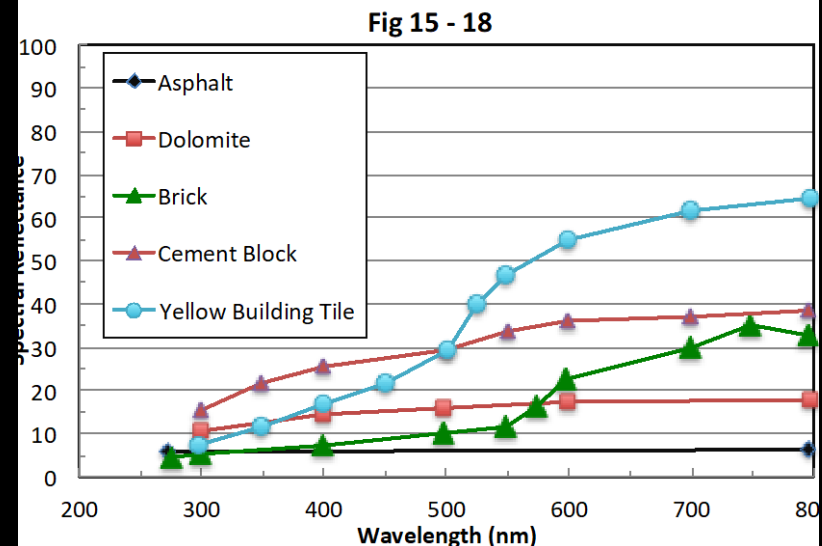
- Measurements with hooded blue-light $B(\lambda)$ radiometer showed a smaller reflected blue-light component in most outdoor and indoor environments.
- ***One Key Point:*** The luminaire SPD is NOT very indicative of retinal exposure and calculating a melanopic or BLH response fraction can be misleading!

Reflectance of natural surfaces & in built environments: low in blue-violet



- The spectral reflectance of most materials below 500 nm is lower than longer wavelengths
- Exceptions are snow or white paint! ...or blue paint!
- Hooded B(λ) radiometer meas.

From Sliney & Wolbarsht book, Chap 15, 1980





Just Published: CIE S026 2018

(publications available at discount to members of CIE-USA)

-
- ★ CIE Standard CIE S026 *SYSTEM FOR METROLOGY OF OPTICAL RADIATION FOR IPRGC-INFLUENCED RESPONSES TO LIGHT*
 - ★ Aim - “This International Standard defines spectral sensitivity functions, quantities and metrics to describe the ability of optical radiation to stimulate each of the five photoreceptor types that can contribute, via the melanopsin-containing intrinsically-photosensitive retinal ganglion cells (ipRGCs), to retina-mediated non-visual effects of light in humans.” [Note: It ignores melanopsin isomer]



Some Take-away Points

★ The weight of scientific evidence indicates:

- Intense sunlight accelerates retinal aging
- A subset of individuals endure a much higher exposure than most (pupil & lid response less)
- Area of retina exposed impacts ipRGC response
- Good lighting design blocks intense luminaires below $\sim 45^\circ$ and the inferior retina in dark outdoors
- Indoor LED lighting if richer in short wavelengths may hardly impact retinal exposure because of low blue-violet reflectance of viewed surfaces.

★ Don't throw away your LED lighting!

- Comfort may be a good guide; also meeting RP27-3-2017



Sliney's AMD Hypothesis to Test

- ★ There is a subset of the general population who have a reduced ipRGC/melanopsin-mediated response compared to the normal physiologic response to bright light (pupil and lid reduction of retinal illumination).
- ★ Finding that subset should show an increased incidence of AMD if there really is any link.
- ★ Linking two Research Areas – neurological ipRGC research and ophthalmic epidemiology!



Action Spectra of Interest – Visible Radiant Energy (the known)

