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—in the etiology or promotion of age-related macular degeneration (AMD), there is little epidemiological evidence supporting this link.
• Why the lack of agreement in scientific studies?
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 outdoor is of the order of 0.02-0.1 mW/cm² (< 1 cd/cm²) and these levels are just comfortable to view
• Retinal illuminance outdoors is ~ 5x10⁵ td
• The sun’s image is more than 10,000 times greater (> 1 W/cm²) than sunlight from snow

The Macula Lutea - Pigment Lutein

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

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
- Is there a third?
Changing atmospheric pathlengths - and changing spectral appearance of solar disc
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

D Sliney 2006

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)
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

Individual Variability

- Generally ignored factor
- 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

Moderate Daylight, mostly cloudy (Area > 2x variation)
Results and Data Analysis of USUHS Pupil Measurement Study

Overcast, cloudy day so this was a conservative study of outdoor daylight pupil sizes when lid openings were somewhat greater

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<th>Std Dev</th>
<th>Min (mm)</th>
<th>Max (mm)</th>
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<th>95% CI for Mean UB</th>
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- Across all luminance measurements
- One point at 7957 cd/m², 1.82mm — a sunny day!
- Key QUESTION What causes the pupil 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)
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

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 youth pupil?
The setting sun is safe to view!

UVR and blue light are scattered out of the direct image making the yellow-to-red sun safe to view directly at sunset

Sliney’s 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!