

Physiology of Glare

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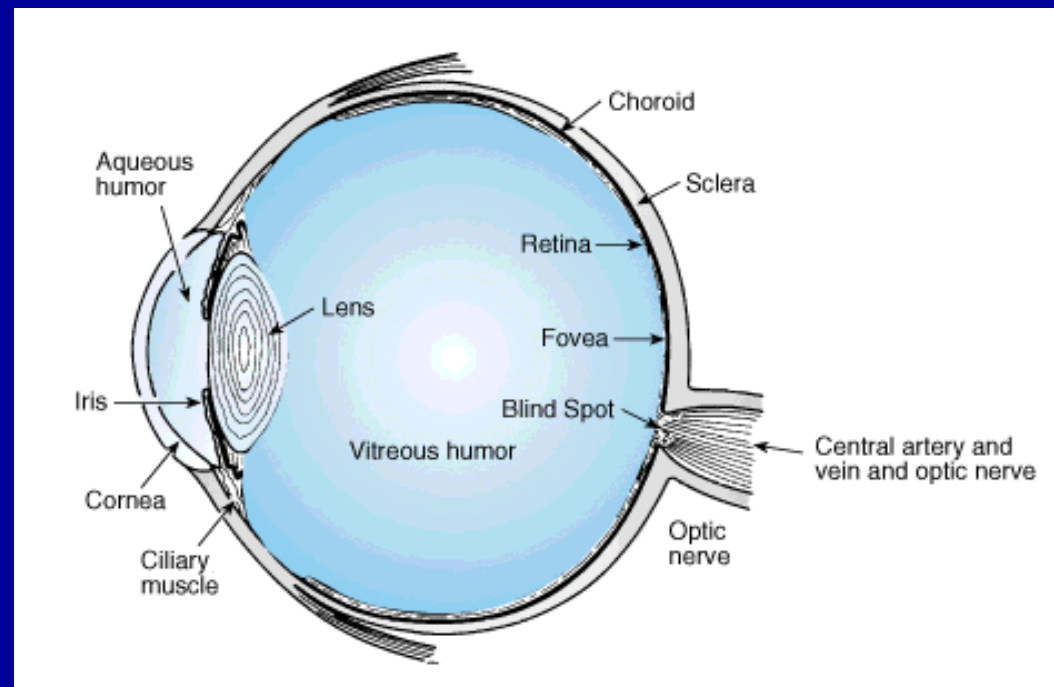


Outline

- Properties of the eye
- Scattering theory
- Induction
- Action spectra for glare - disability and discomfort

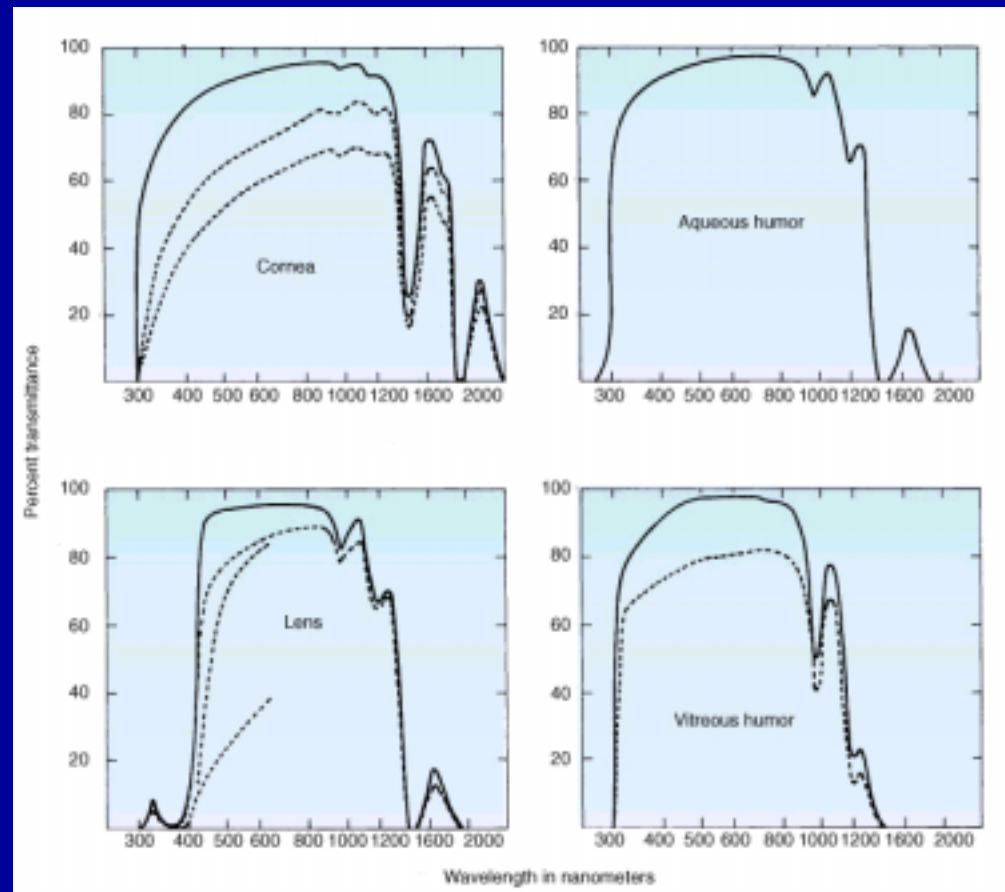
The human eye

- Light travels through the cornea, aqueous, lens and vitreous before reaching the retina



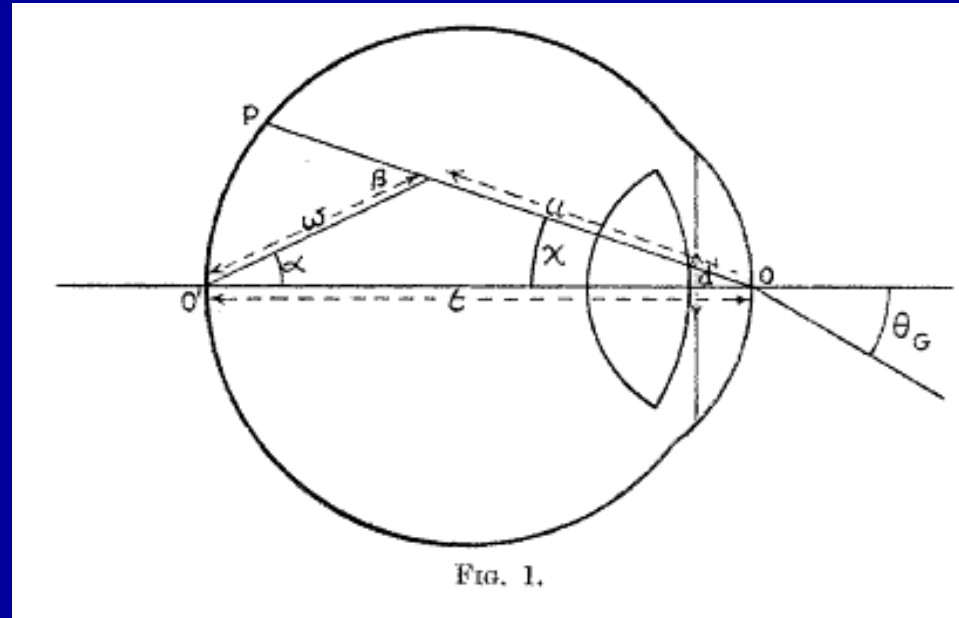
Transmission of ocular media

- Media are not transparent
- Transmission reduces with age: half by age 50, one-third by age 60



Scattering

- Holladay (1926) noted that a glare source in the field of view had the same effect on foveal (central) vision as a uniform luminous veil
- Upon adjusting the light to the blind spot the effect remained, and he postulated that scattered light in the eye actually created this veil
- Stiles (1929) and colleagues (Stiles and Crawford, 1937) refined the theory including peripheral vision



Stiles (1929)

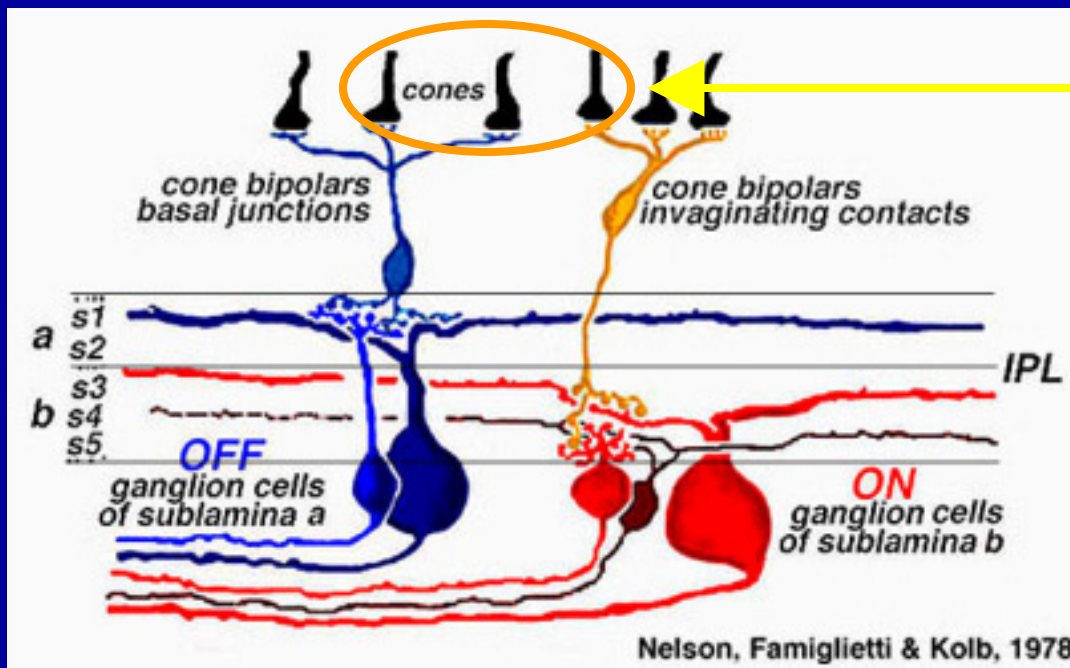
Scatter (cont'd.)

- Fry (1954) further refined the work of Holladay (1926), Stiles (1929) and others to derive the familiar equation promulgated by the *IESNA Lighting Handbook* (2000):

$$L_v = 9.2 \sum_{i=1}^n \frac{E_i}{\theta_i (\theta_i + 1.5)}$$

It's not just optics...

- Edges and contrasts are detected through receptive fields at the retinal level

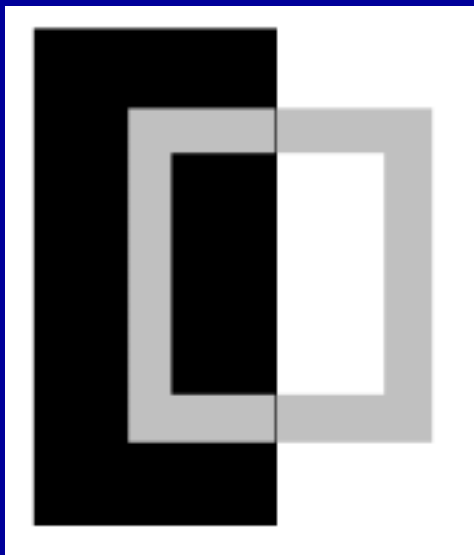


another field
uses these
receptors

Induction

- Fry's (1954) formula breaks down when the glare is near the line of sight
- **Induction** is a neural interaction:

- »very large differences in field of view affect their visibility
- »the way the visual system "enhances" edges through receptive fields, contrast might be a hindrance in a "hypercontrast" situation exacerbating effects of scatter



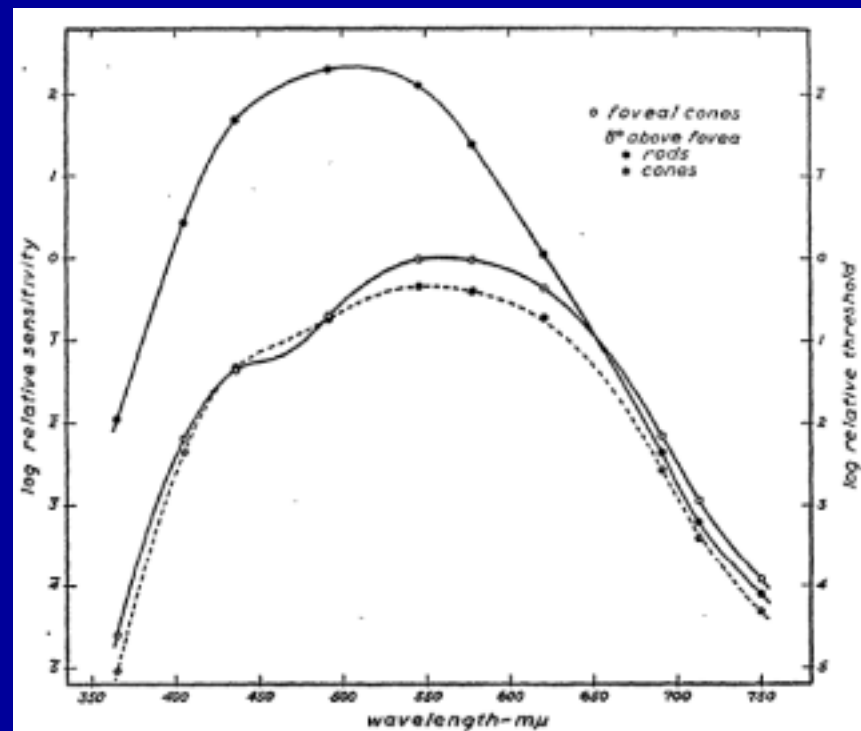
Boyce (1981)

Action spectrum?

- Holladay (1926) tested glare sources of differing colors (white, blue, red) and found a small (but not significant) difference between red and blue/white
- Holladay (1926) and Stiles (1929) assumed scatter in the eye to follow Rayleigh scattering $\propto 1/\lambda^4$ ("blue" scatters more than "red")
- Moon *et al.* (1943) demonstrated that is not the case - no wavelength dependence

Spectral response: Disability glare

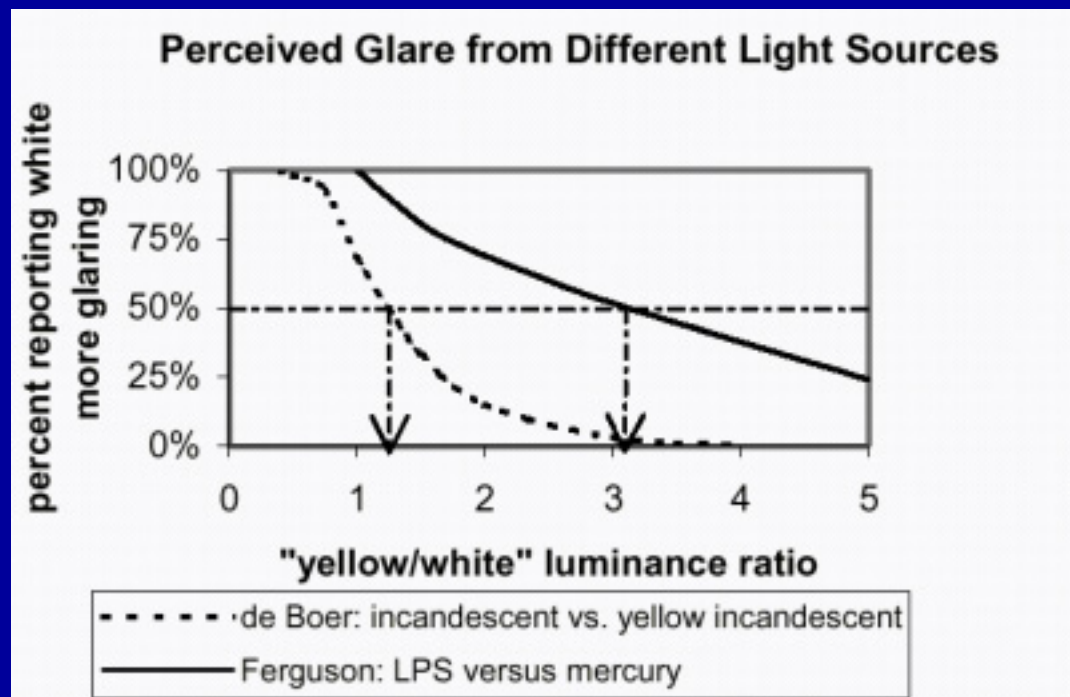
- No wavelength sensitivity, so the response mirrors the spectral sensitivity of the part of the retina in question, almost always the fovea (photopic)



Wald (1945)

Spectral response: Discomfort glare

- If **discomfort** glare also had a photopic response, glare sources of differing spectral content would be rated equally uncomfortable



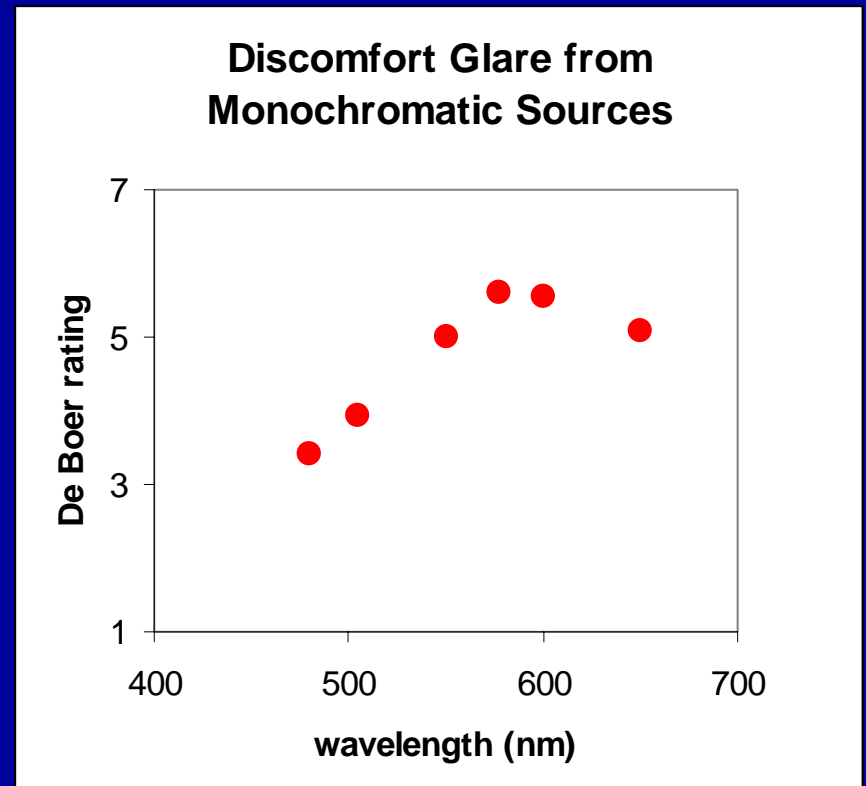
**vertical
arrows
would land
at 1.0 if
photopic!**

Ferguson et al. (1953); De Boer (1955); Bullough and Rea (2001)

Discomfort glare

- Scotopic? No - HID and halogen headlamps have similar scotopic (rod-stimulating) output but HIDs are consistently rated more uncomfortable (Flannagan, 1999)
- Short-wavelength-cone? Maybe (Fotios and Levermore, 1998) based on excess "brightness"
- Color channel? Maybe (Flannagan *et al.*, 1989)
- Maybe both?

Flannagan et al. (1989)



The nighttime driving environment

- Potential glare sources abound
 - oncoming headlights
 - street lights
 - traffic lights
 - one's own dashboard
- Knowing physiological responses will help in improved design of the roadway visibility system



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