

Effect of ageing of human optics on spatio-chromatic contrast sensitivity

Maliha Ashraf, Sophie Wuerger, Jasna Martinović, Rafał Mantiuk



**How is spatio-chromatic
contrast quantified?**

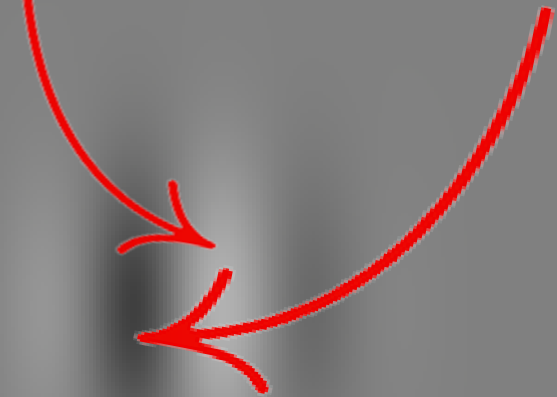
Weber Contrast

$$C = \frac{I - I_b}{I_b}$$



Michelson Contrast

$$C = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$



$$C = \frac{1}{3} \sqrt{\left(\frac{\Delta L}{L_0}\right)^2 + \left(\frac{\Delta M}{M_0}\right)^2 + \left(\frac{\Delta S}{S_0}\right)^2}$$

Chaparro, A., Stromeyer, C. F., Huang, E. P., Kronauer, R. E., & Eskew, R. T. (1993). Colour is what the eye sees best. *Nature*, 361(6410), 348-350.
Brainard, B. D. H. (1982). Appendix - Part IV: Cone contrast and opponent modulation color spaces. In *Human Color Vision* (pp. 563–579).

**Chromatic
Direction**

**Spatial
Scale**

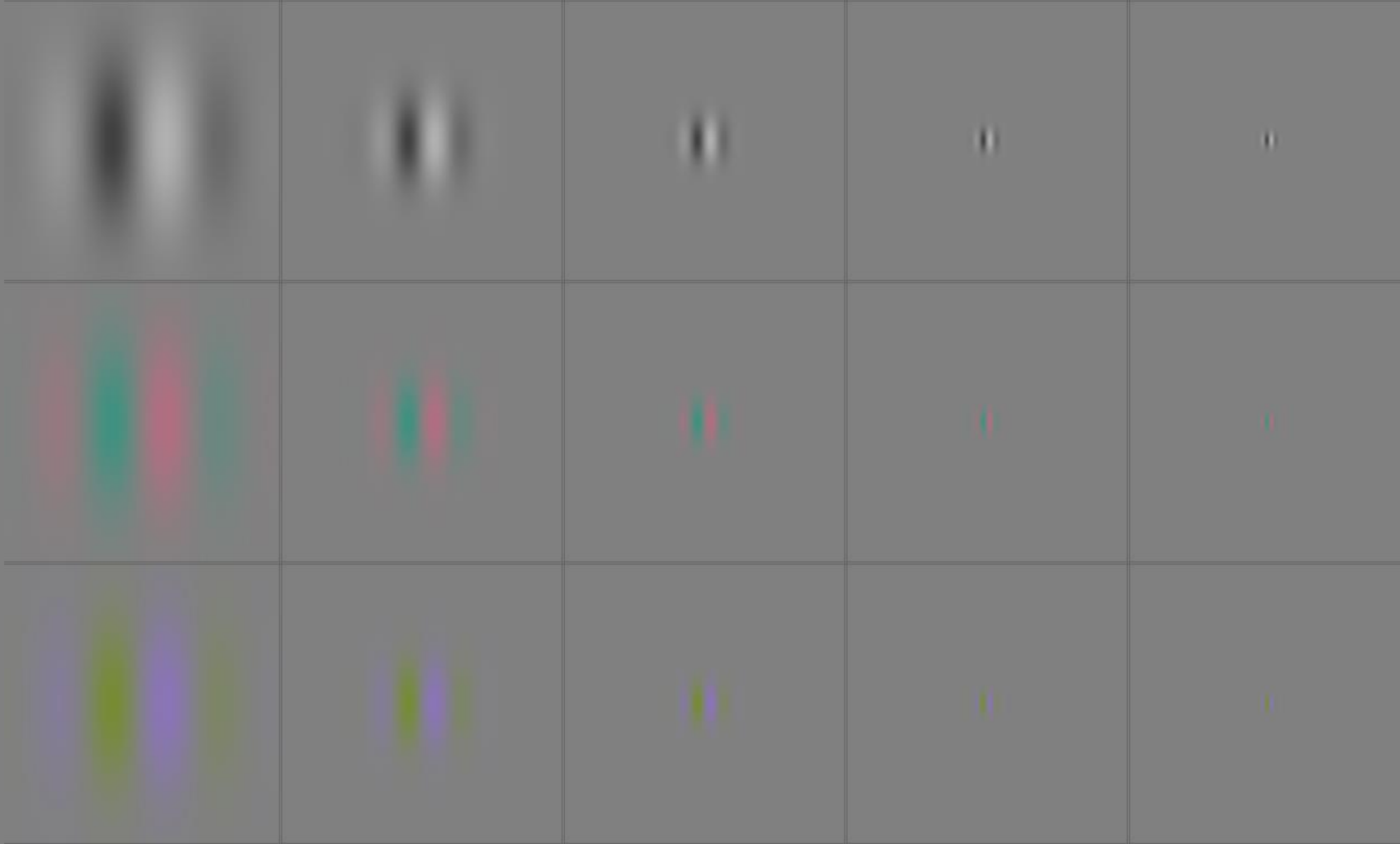
CSFs
depend on

**Mean
Luminance**

**Temporal
Frequency**

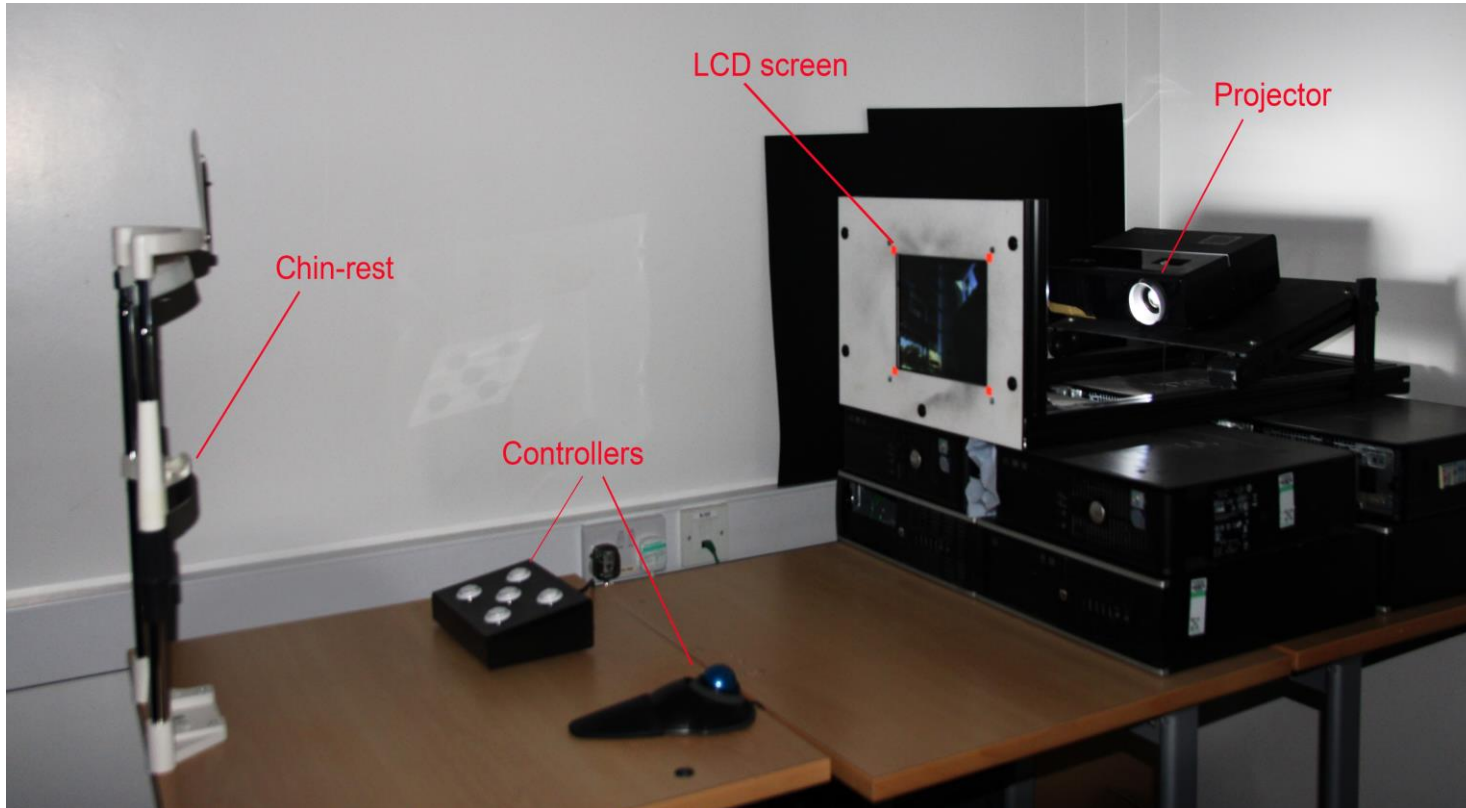


Stimuli & Experiment



APPARATUS

HDR display with peak luminance 35,000 cd/m²
and maximum contrast: 1,000,000 : 1



METHODOLOGY

4AFC detection task

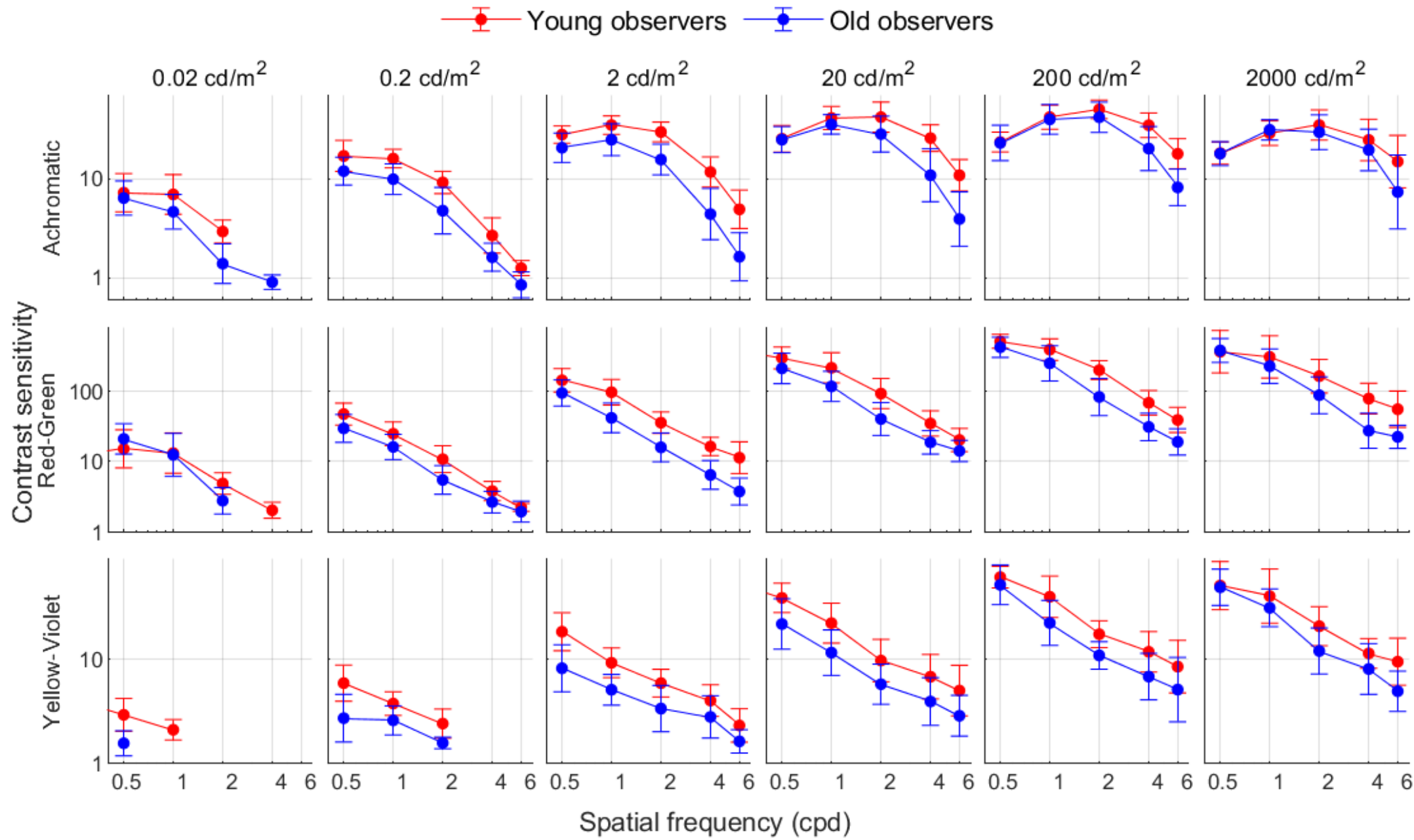
5 spatial frequencies and 3
colour directions interleaved
within each session

Viewing distance: 91 cm;
Display size: 12.5° x 9.4°

20 young colour-normal
observers (mean age: 33)

20 old colour-normal observers
(mean age: 65)

Results



Contrast sensitivity decreases with age

~ 0.3 LOG UNITS OR 3 DB

Ageing of Human Visual System

Optical

Transmission changes in lens, cornea, ocular fluids, pupil constriction, etc.

Sensory

Reduction in density of retinal photoreceptors, degradation in cone pathways

Cortical

Neural decline in visual cortex

How does ageing of optical elements affect vision?

AGEING LENS

Lens yellows over time naturally even in the absence of any optical pathology

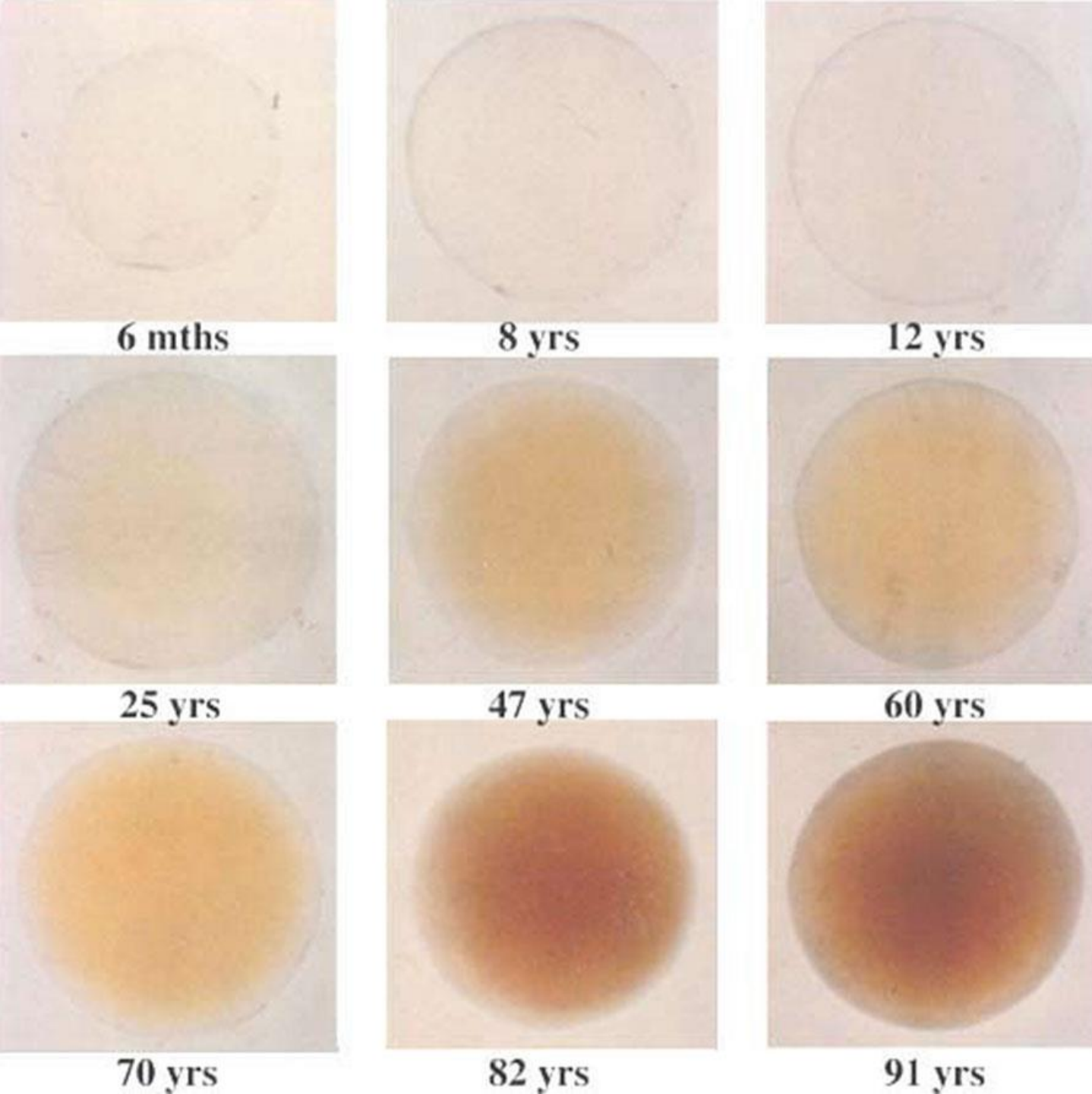


Image Source: Lerman, Sarah. (1980). *Radiant energy and the eye* (Vol. 1). Macmillan.

SENILE MIOSIS

- Pupil size decreases with age

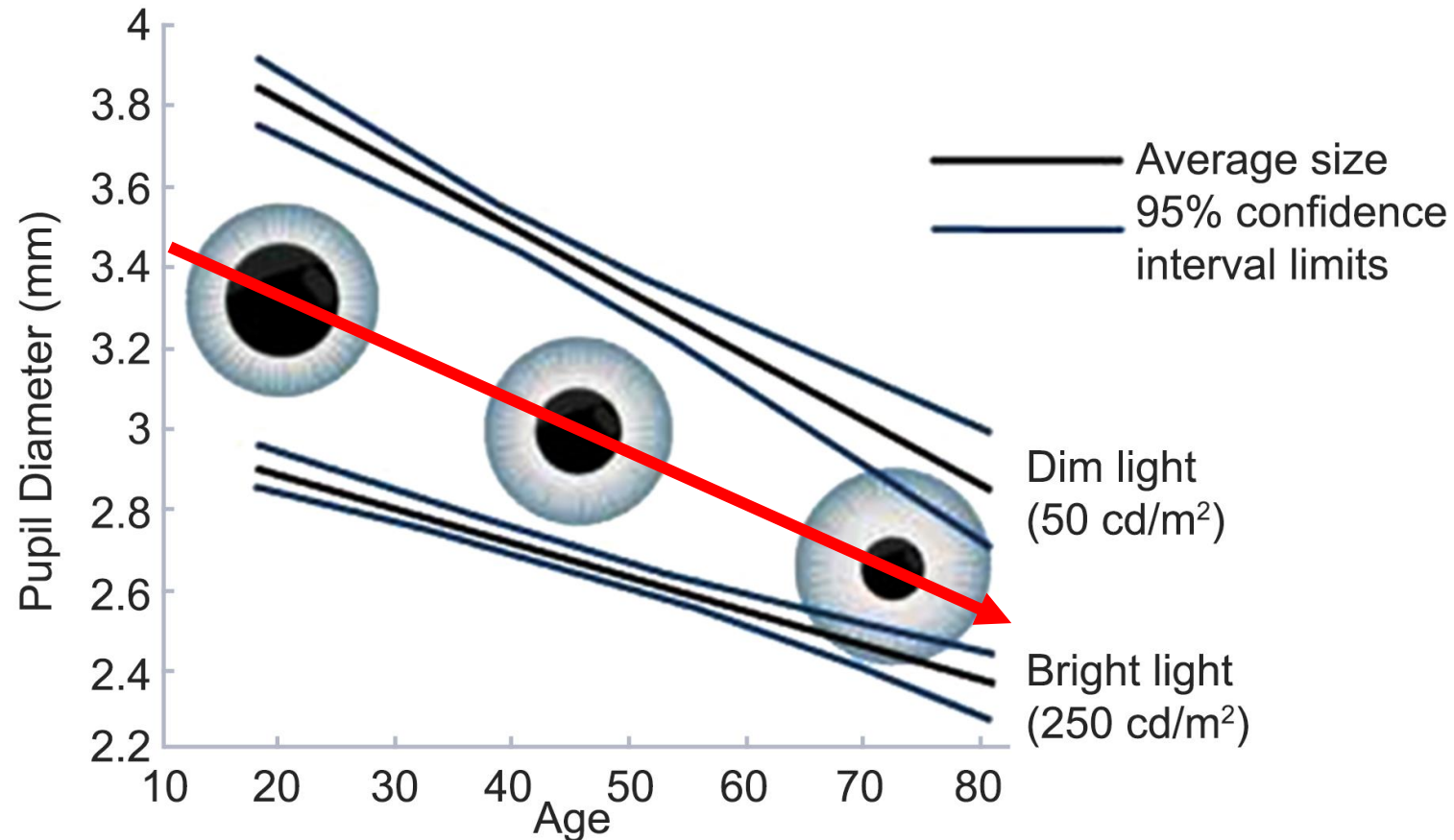


Image Source: Dumbleton K, Guillon M, Theodoratos P et al. The effects of age and refraction on pupil size and visual acuity: implications for multifocal contact lens design and fitting. Poster at BCLA Clinical Conference, May 2015.

SENILE MIOSIS

- Pupil size decreases with age
- **Pupil flexibility decreases with age**

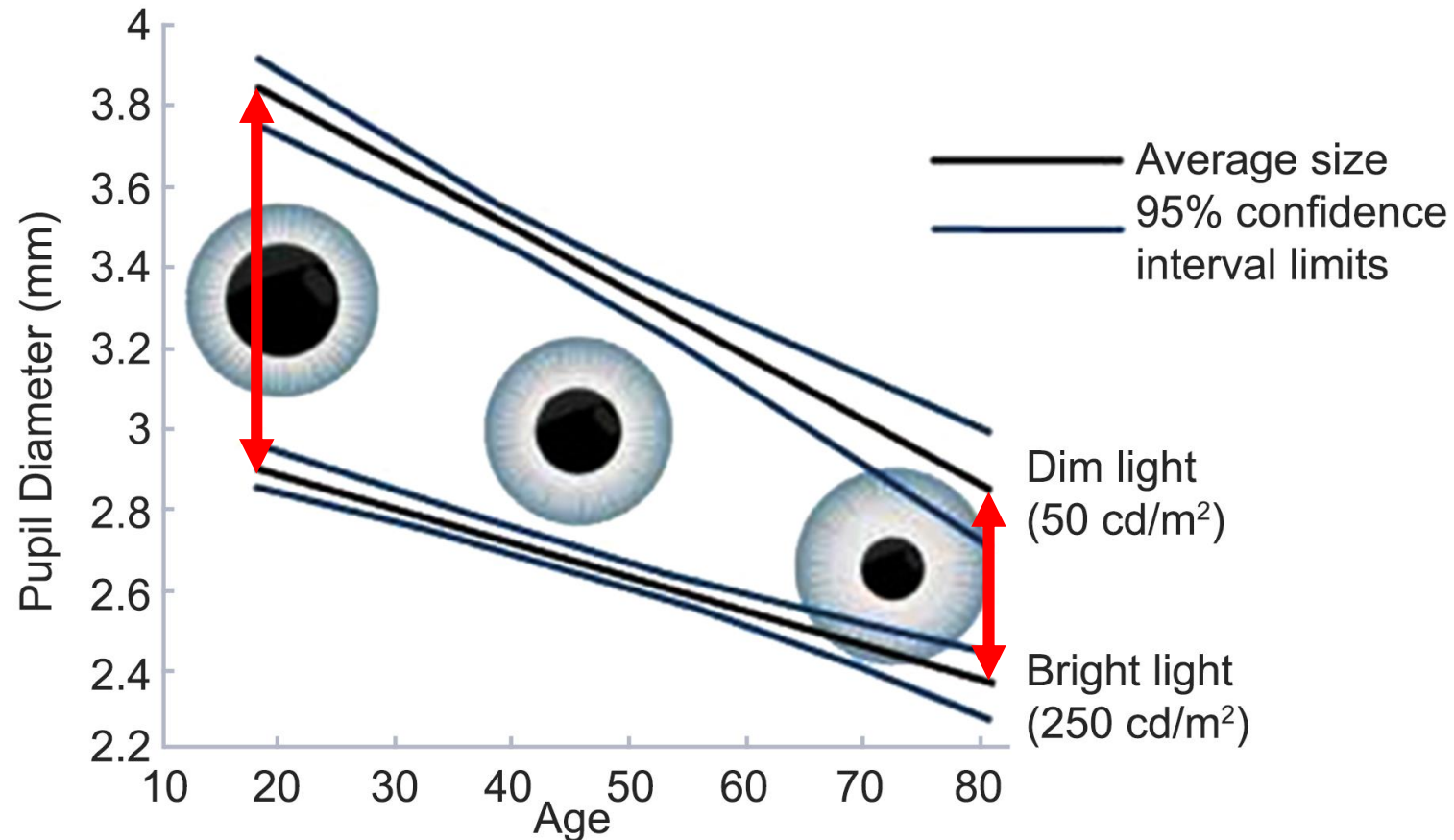
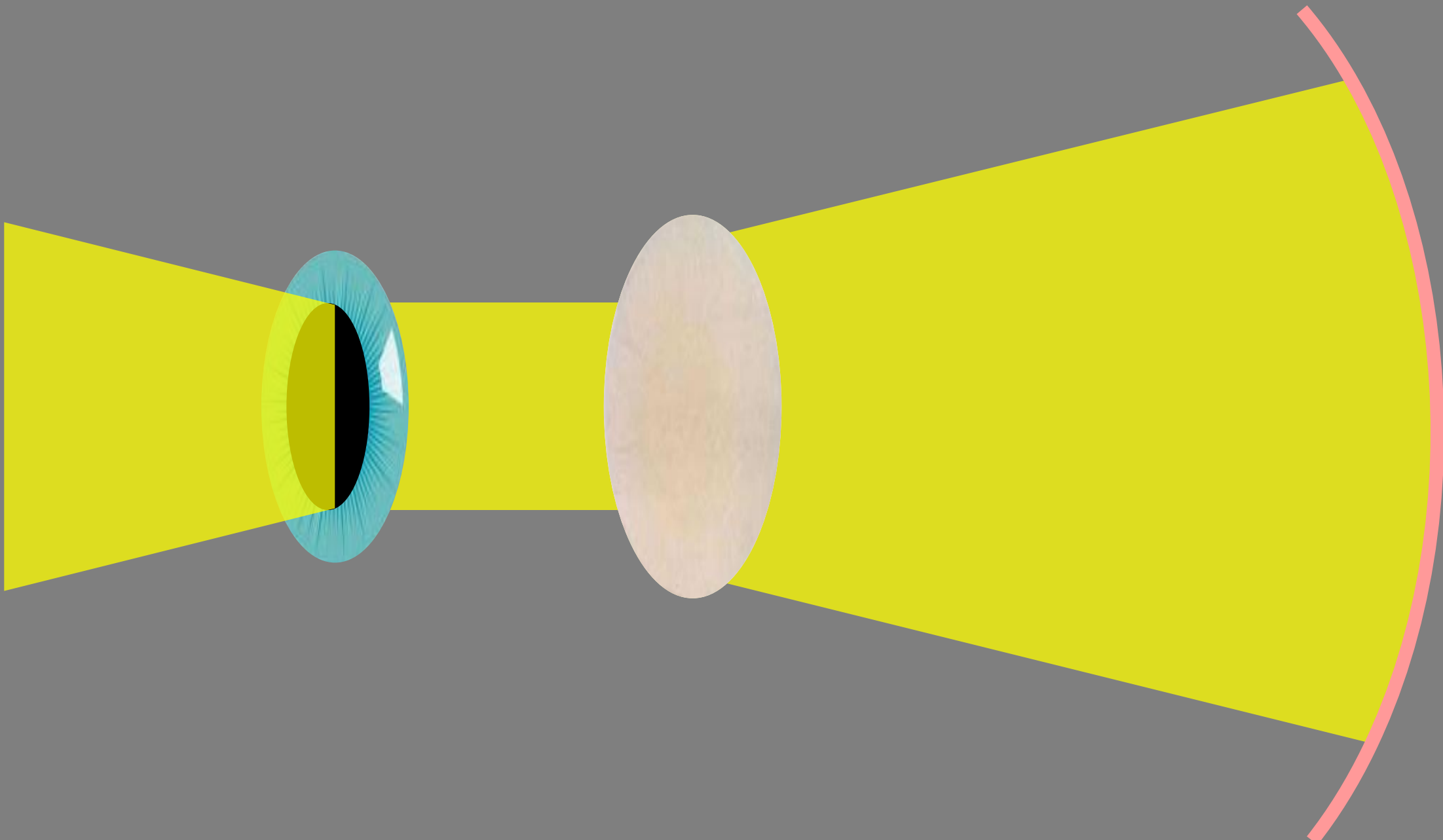
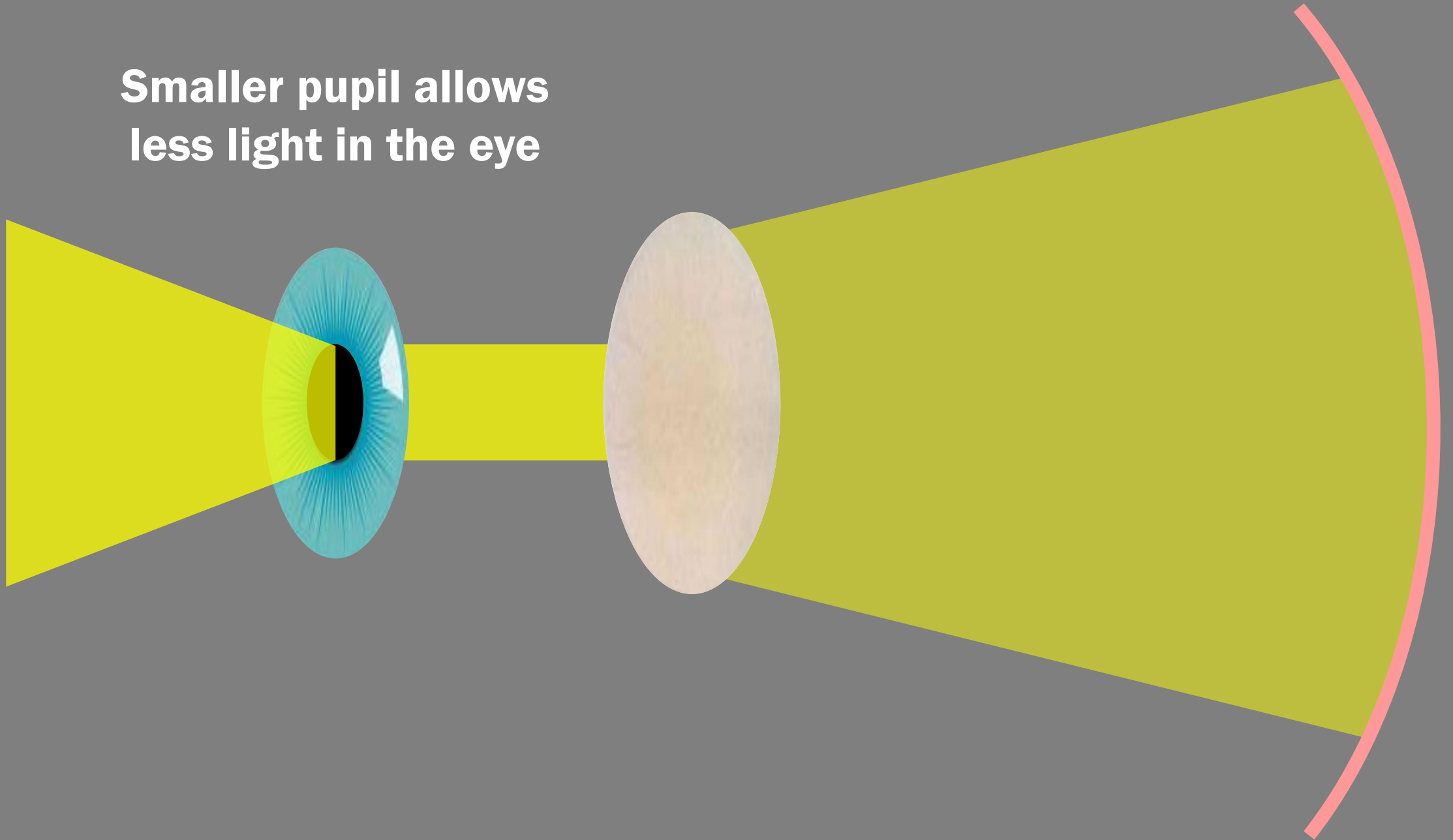


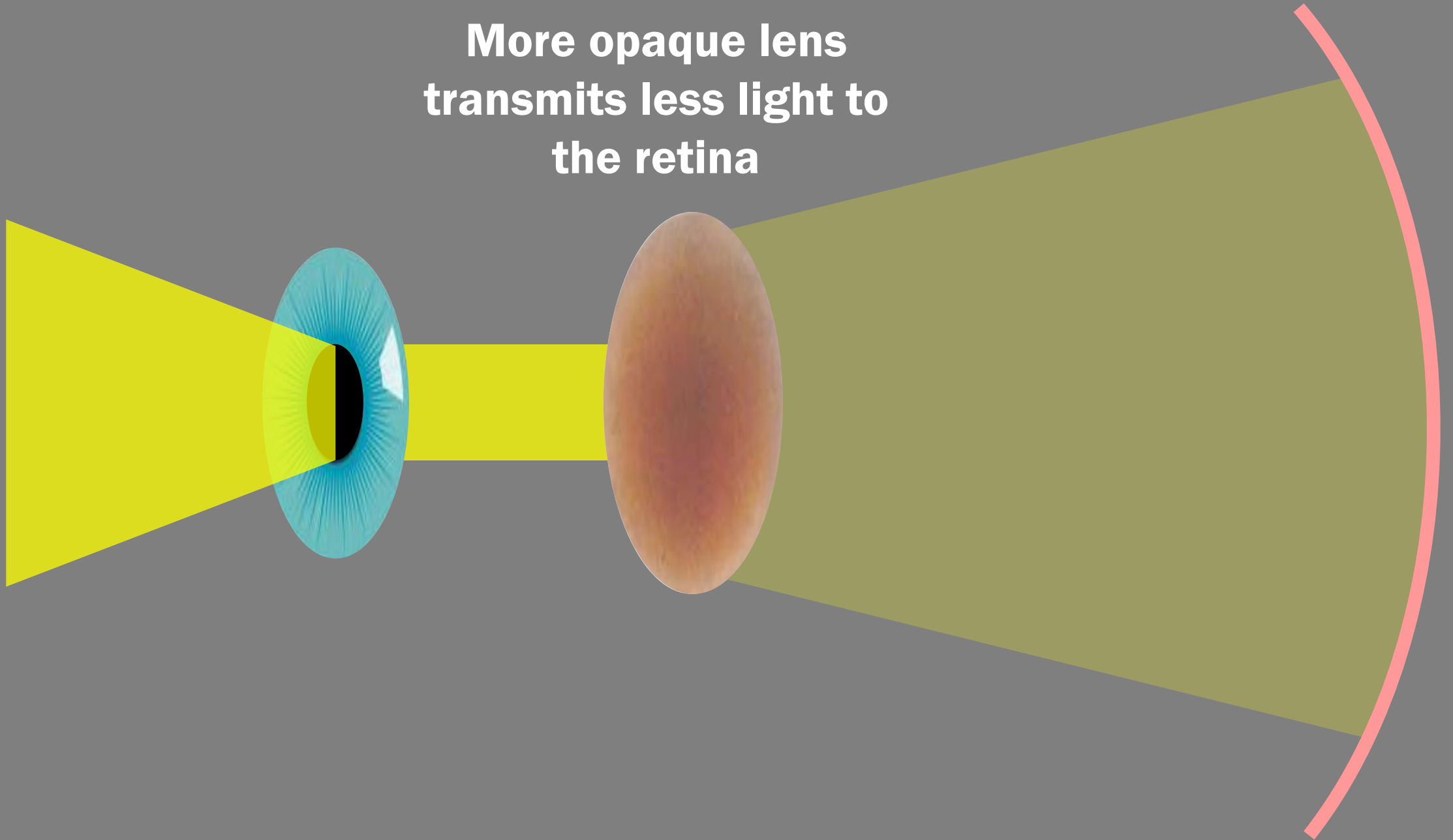
Image Source: Dumbleton K, Guillon M, Theodoratos P et al. The effects of age and refraction on pupil size and visual acuity: implications for multifocal contact lens design and fitting. Poster at BCLA Clinical Conference, May 2015.



**Smaller pupil allows
less light in the eye**



**More opaque lens
transmits less light to
the retina**

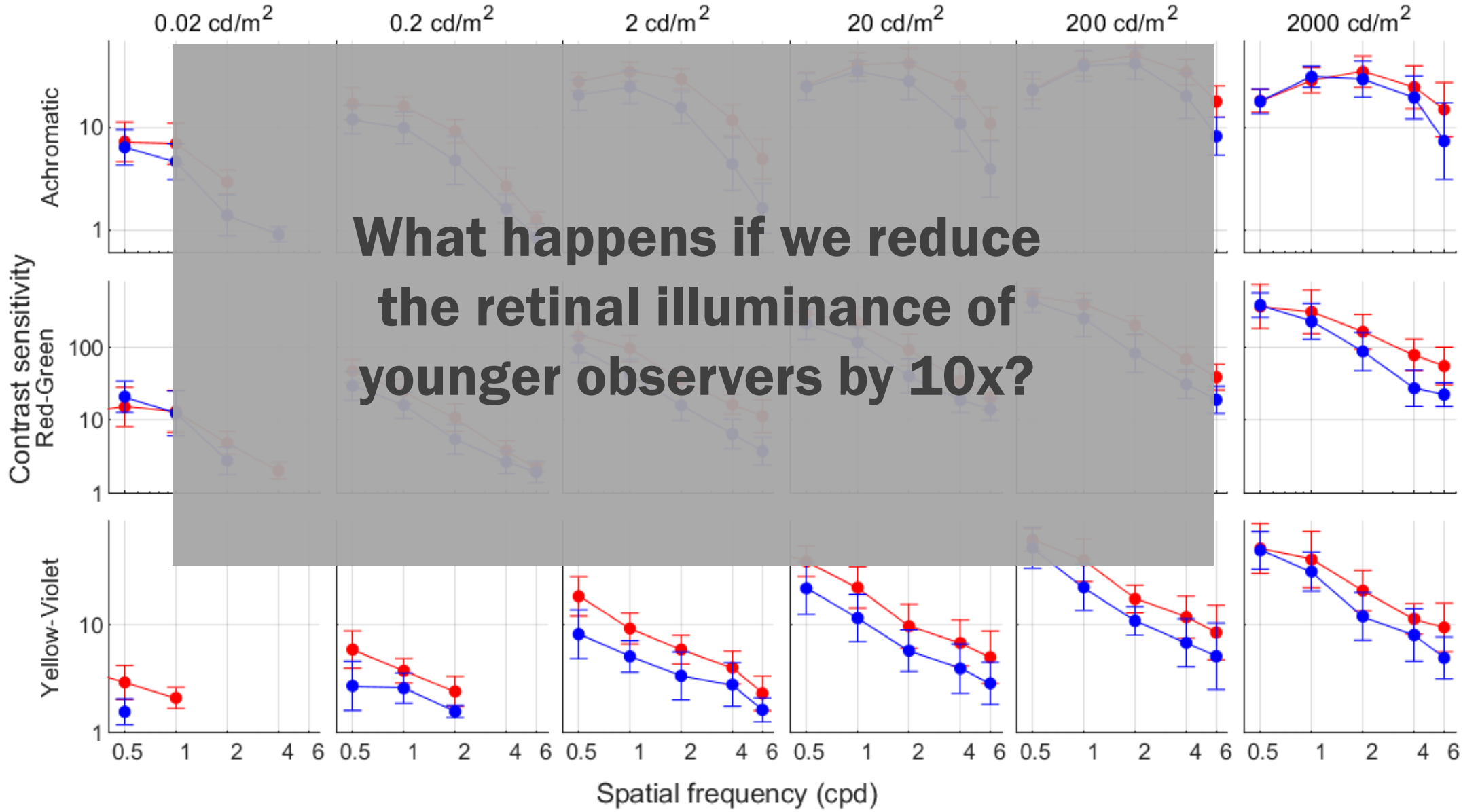


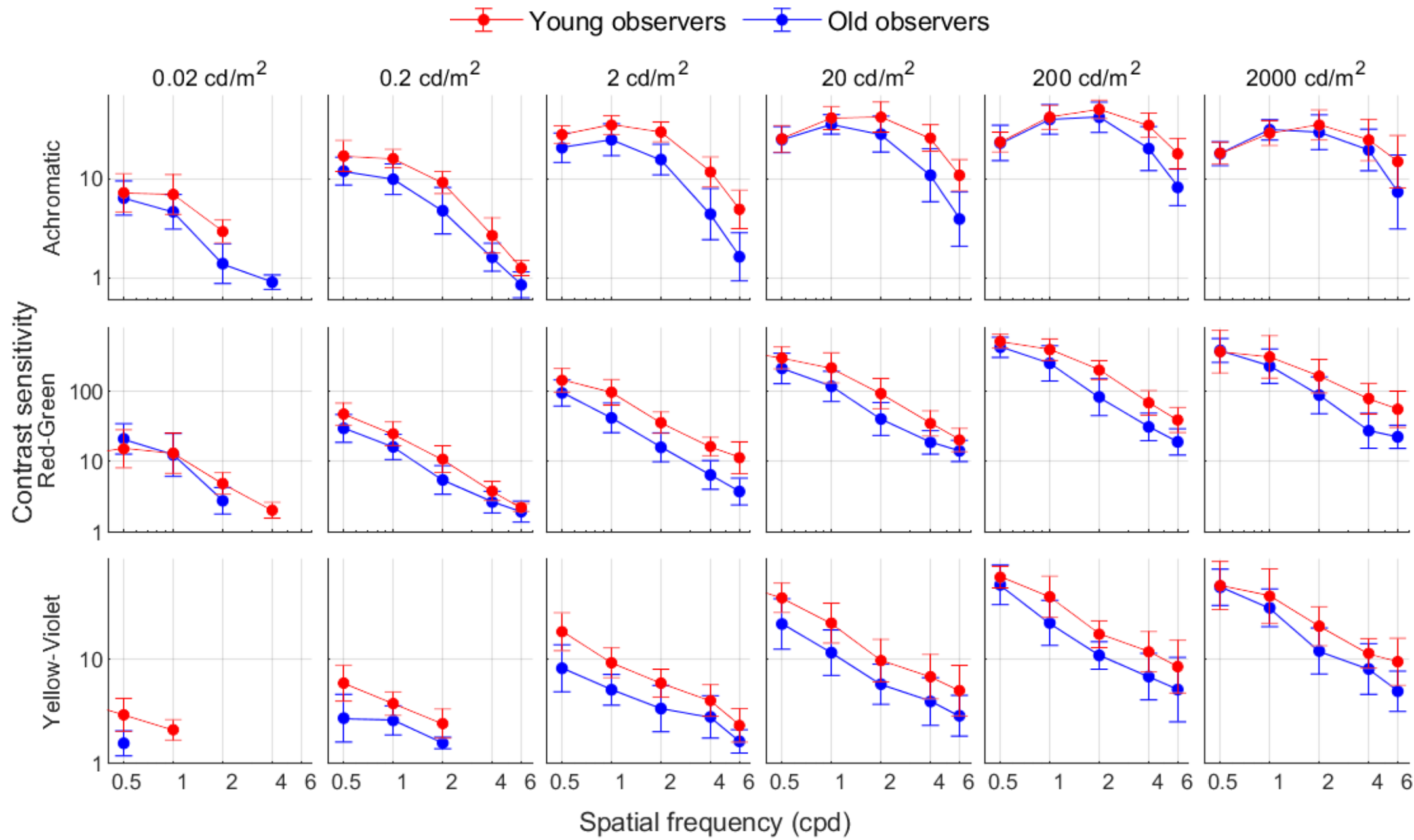
Retinal illumination decreases with age

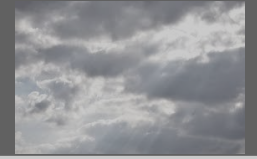
**60 y.o.a transmit ~1/3 the light compared to a
20 y.o.a**



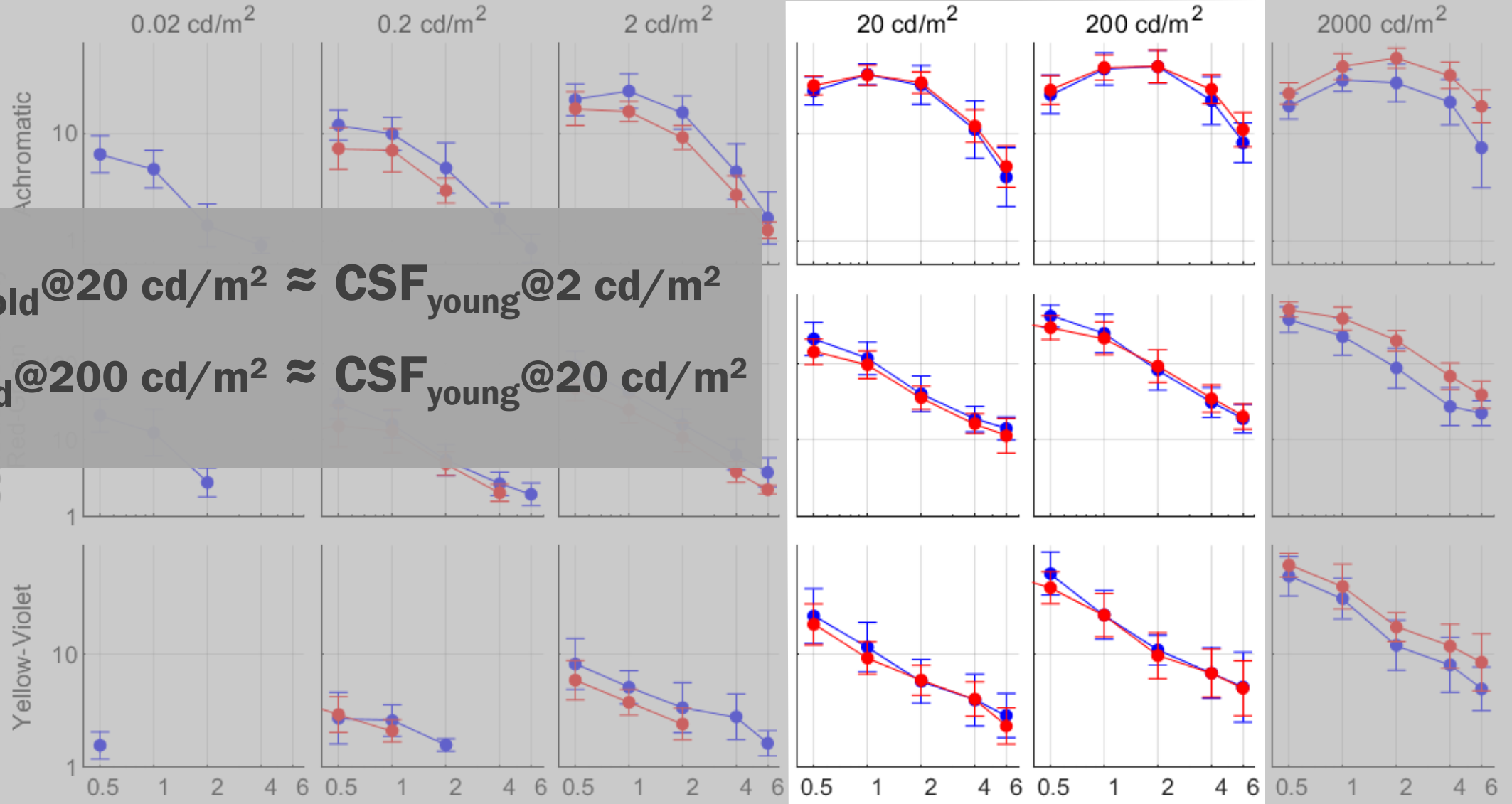
—●— Young observers —●— Old observers







—●— Young observers (reduced luminance)
 —●— Old observers



$CSF_{old}@20 \text{ cd/m}^2 \approx CSF_{young}@2 \text{ cd/m}^2$
 $CSF_{old}@200 \text{ cd/m}^2 \approx CSF_{young}@20 \text{ cd/m}^2$

**Reduced retinal illumination
with age should explain
some changes in CSFs**

$$CSF = f(x, l, c, \sigma)$$



**Spatial
frequency**

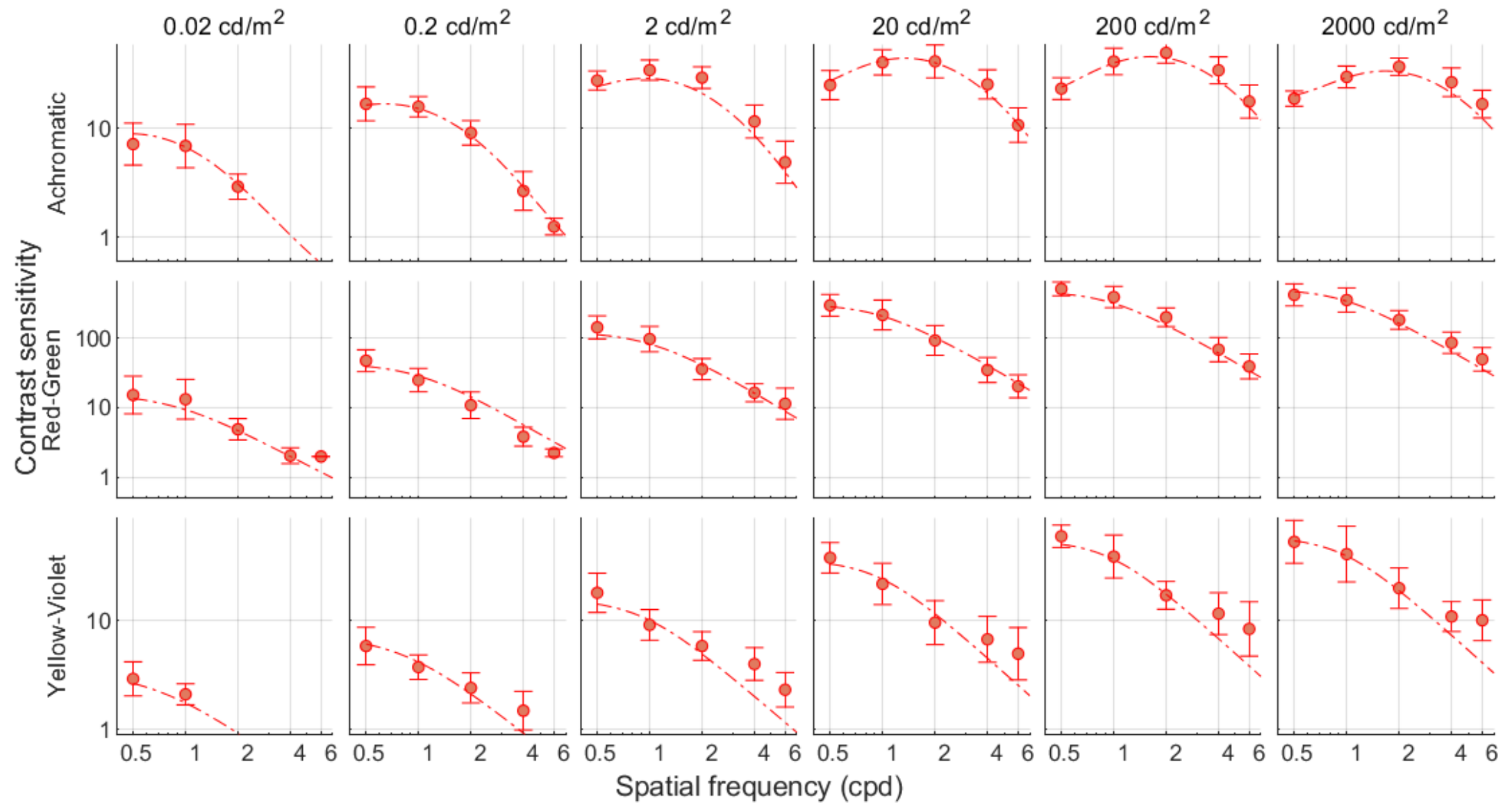
**Mean
luminance**

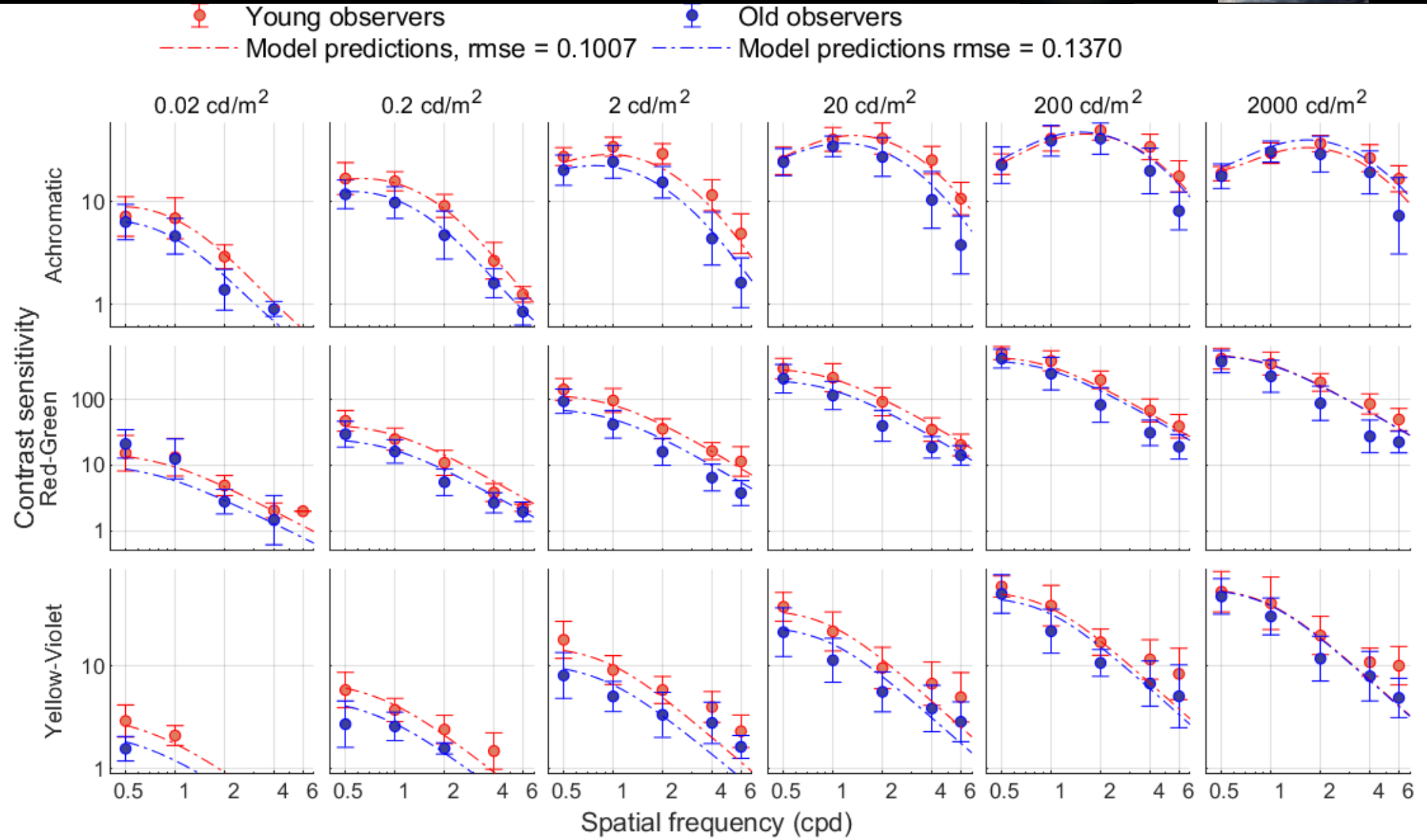
**Colour
direction**

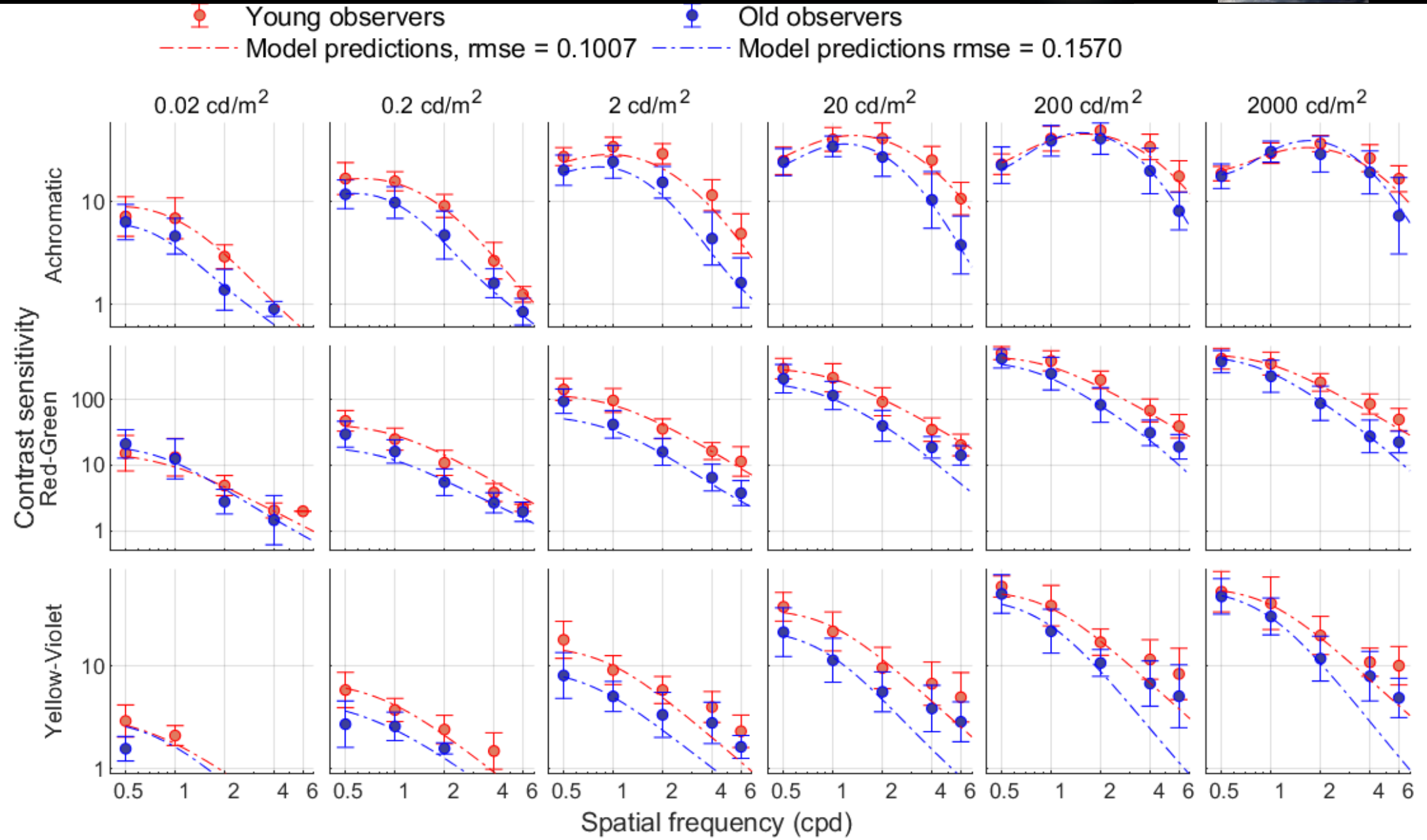
**Stimulus
size**



 Young observers  Model predictions, rmse = 0.1007







SUMMARY

- Both chromatic and achromatic contrast sensitivities are reduced as we age
- The affect of age varies at different luminance levels and spatial scales
- Optical changes with age play a large part in CSF changes

Thank you



Sophie Wuerger



Rafal Mantiuk



Jasna Martinovic