

Luminance and Chromatic Contrast Sensitivity at High Light Levels

Presenter: Maliha Ashraf – University of Liverpool

Sophie Wuerger – University of Liverpool

Rafal Mantiuk – University of Cambridge

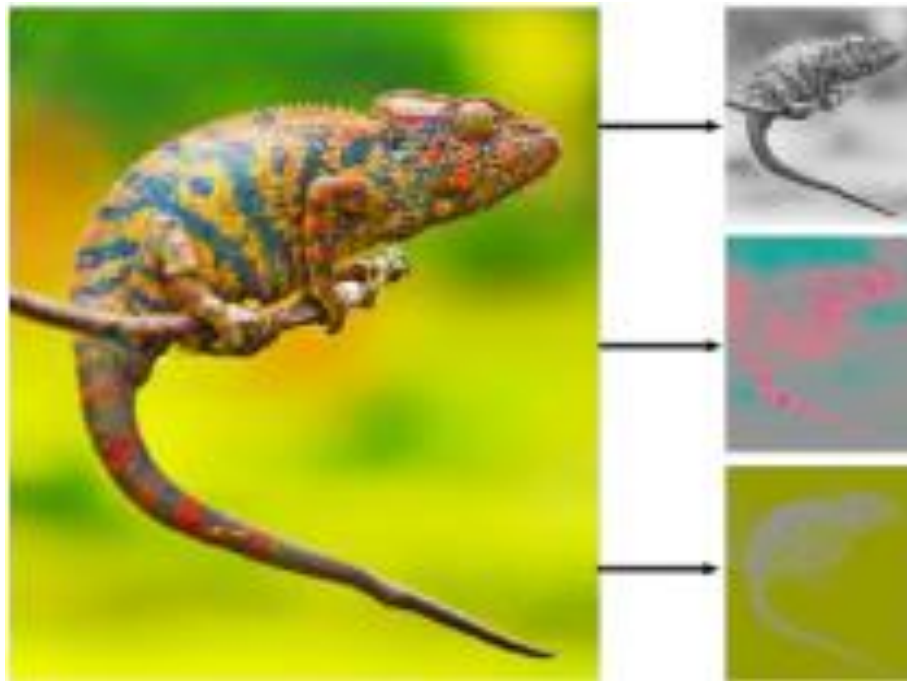
Jasna Martinovic – University of Aberdeen



Motivation

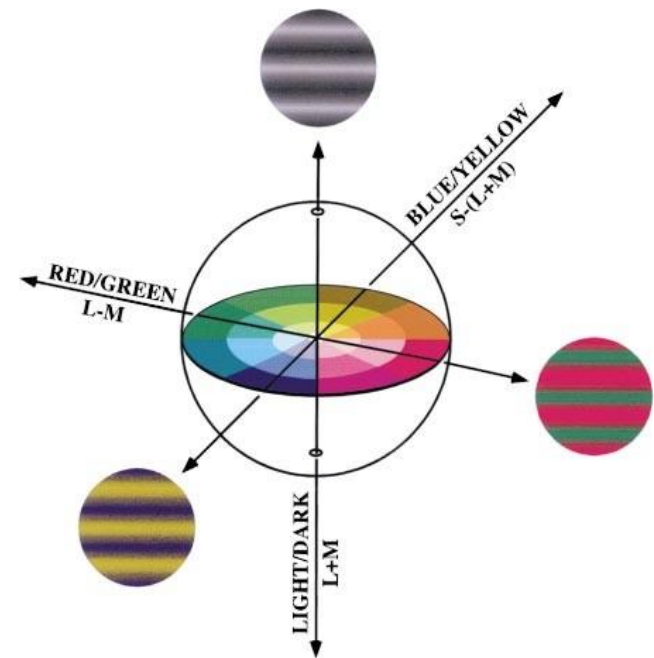
Motivation

- Long-term goal: To understand and model the appearance of spatio-chromatic images over a wide range of luminance levels (e.g. for retargeting)



Measurement

First step: Measure spatial contrast sensitivity for three cardinal directions for background luminances ranging from 0.02 to 7000 cd/m².

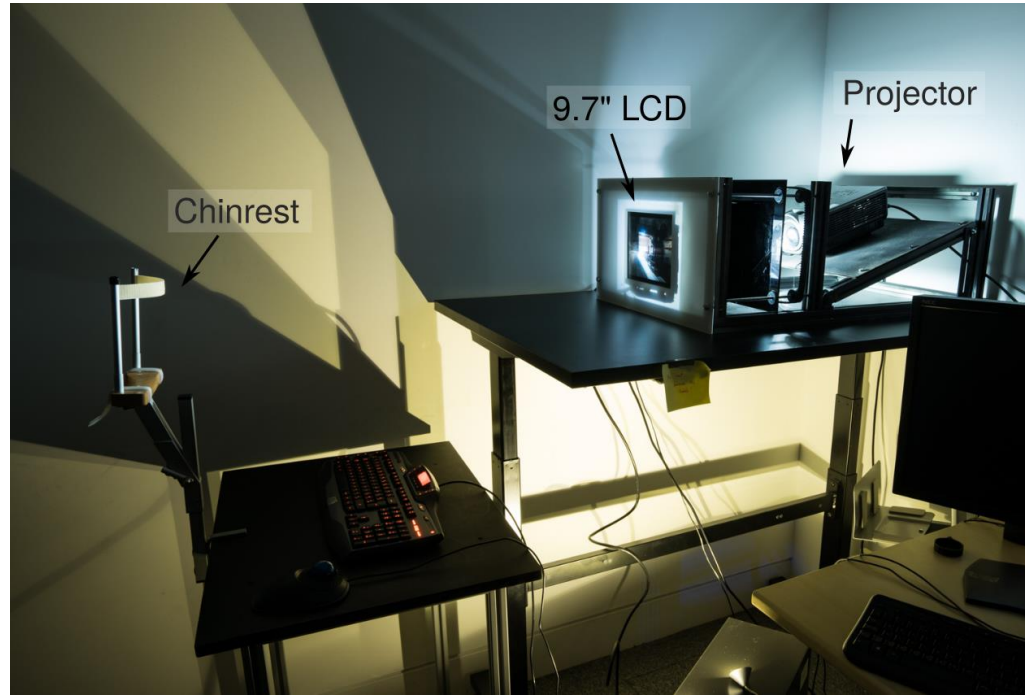


HDR Display

15,000 cd/m² high dynamic range display

Projector-based HDR display consisting of:

- 6000 lumen DLP projector with colour wheel removed (effective 18000 lumen)
- 9.7" iPad 3 2048x1536 LCD panel with removed backlight



Specification

- 15,000 cd/m² peak luminance
- 0.01 cd/m² black level
- LCD resolution: 2048x1536
- Backlight (DLP) resolution: 1024x768
- Geometric-calibration with a DSLR camera
- Display uniformity compensation
- 3D LUT color-calibration with a spectrometer (Specbos 1211)
- Bit-depth of DLP and LCD extended to 10 bits using spatio-temporal dithering

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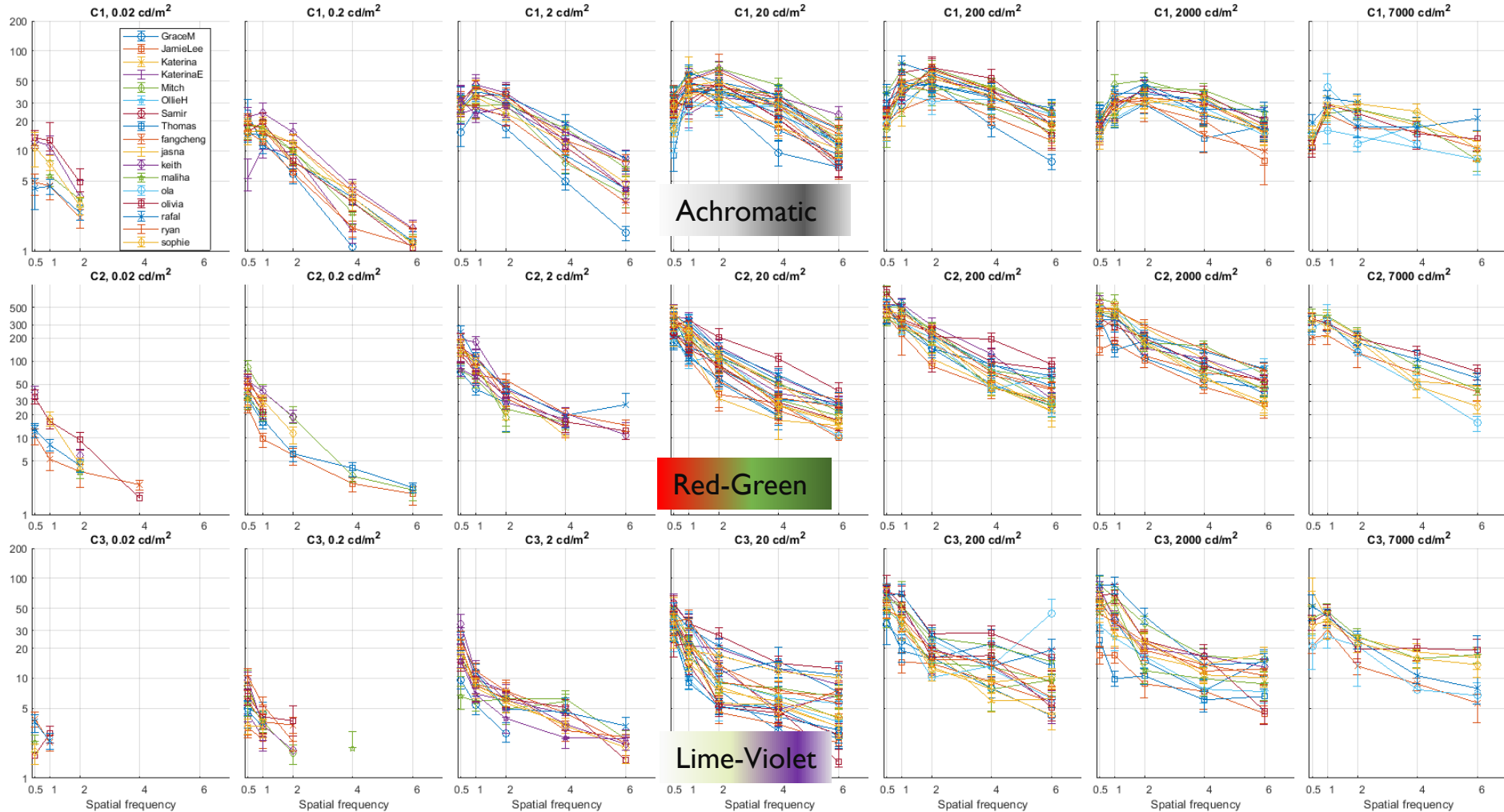
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$$S = \left(\left(\left| \frac{\Delta L}{L_0} \right|^2 + \left| \frac{\Delta M}{M_0} \right|^2 + \left| \frac{\Delta S}{S_0} \right|^2 \right)^{0.5} \cdot \frac{1}{\sqrt{(3)}} \right)^{-1}$$

Results

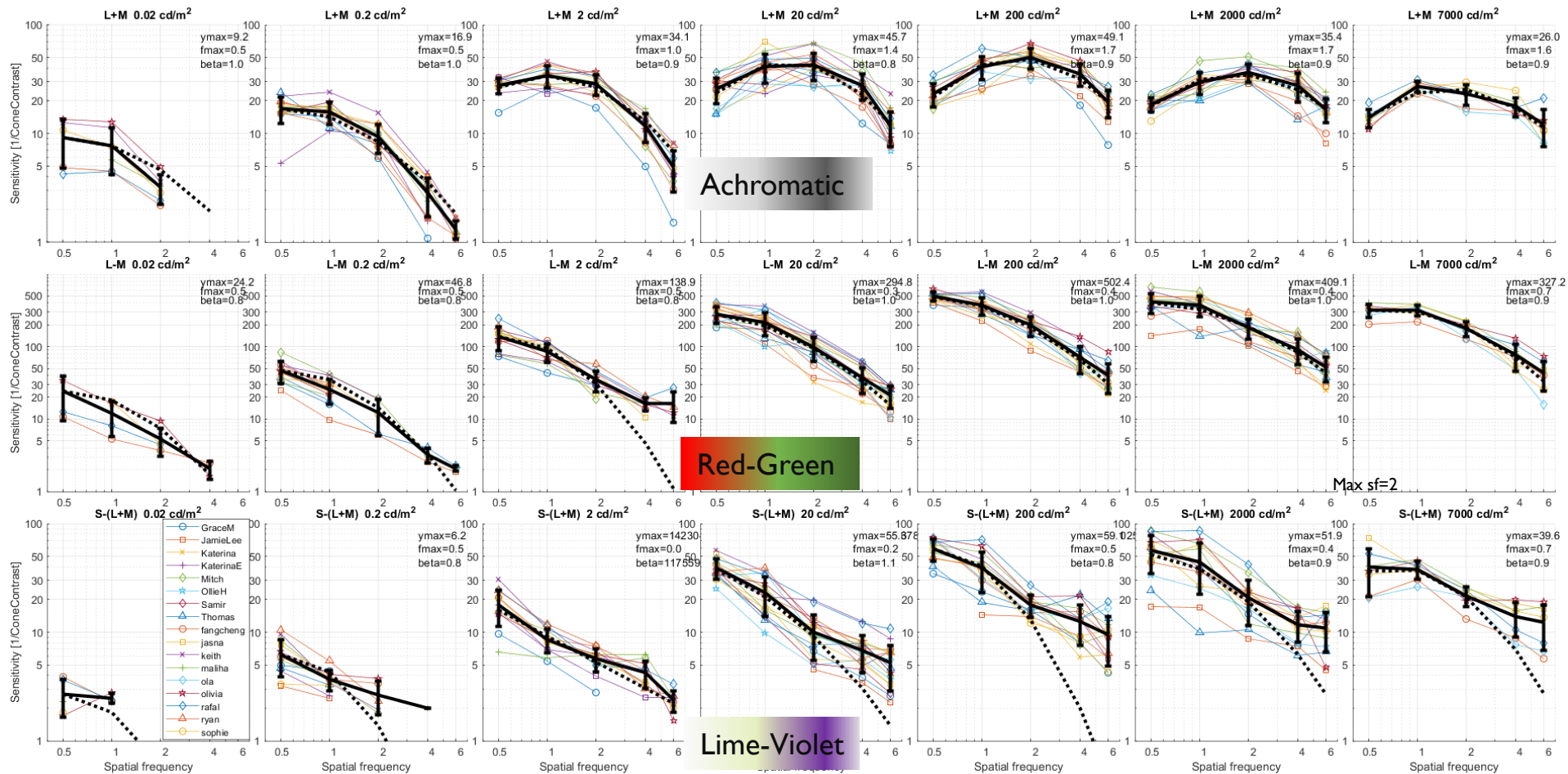
BG LUM: LOW ----- MEDIUM ----- > HIGH



Achromatic CSF: Lowpass → bandpass; Chromatic CSFs: Lowpass

Results (Mean data with parabola fit; Watson & Ahumada, 2005)

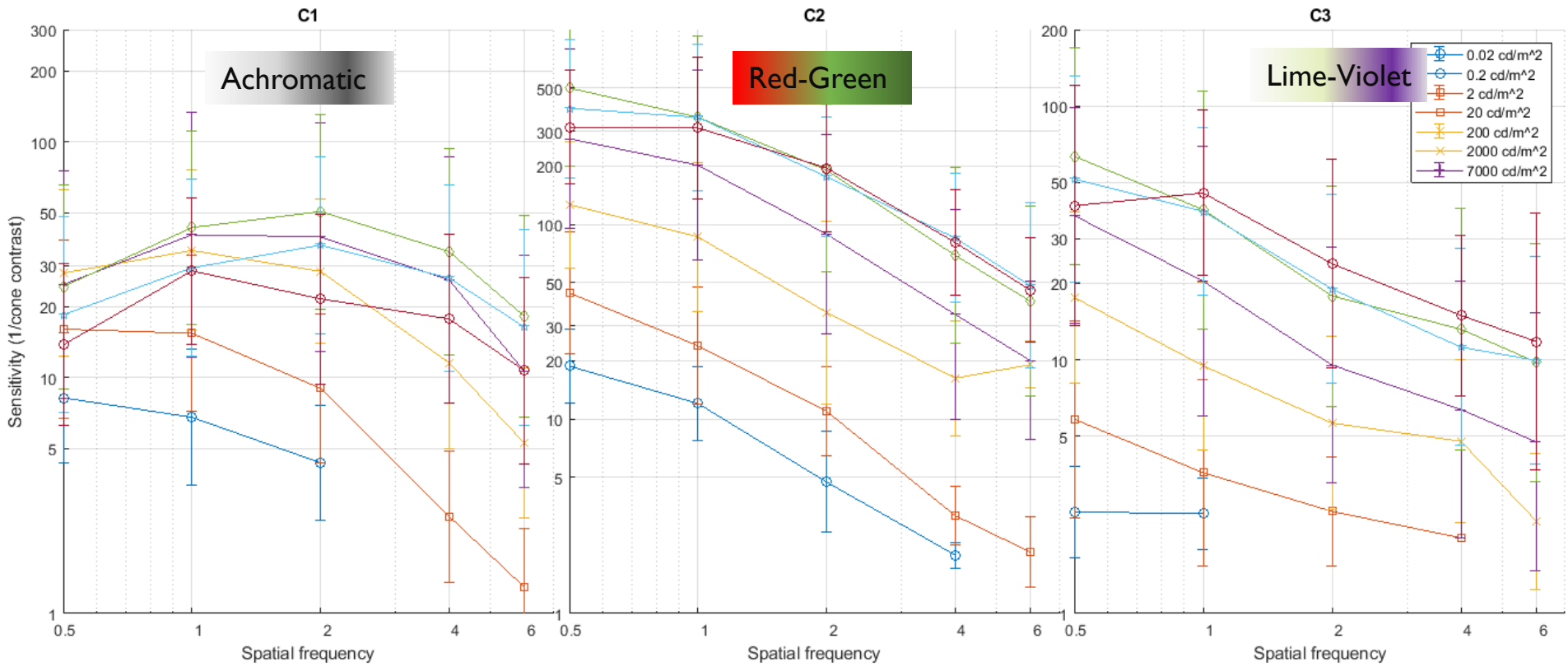
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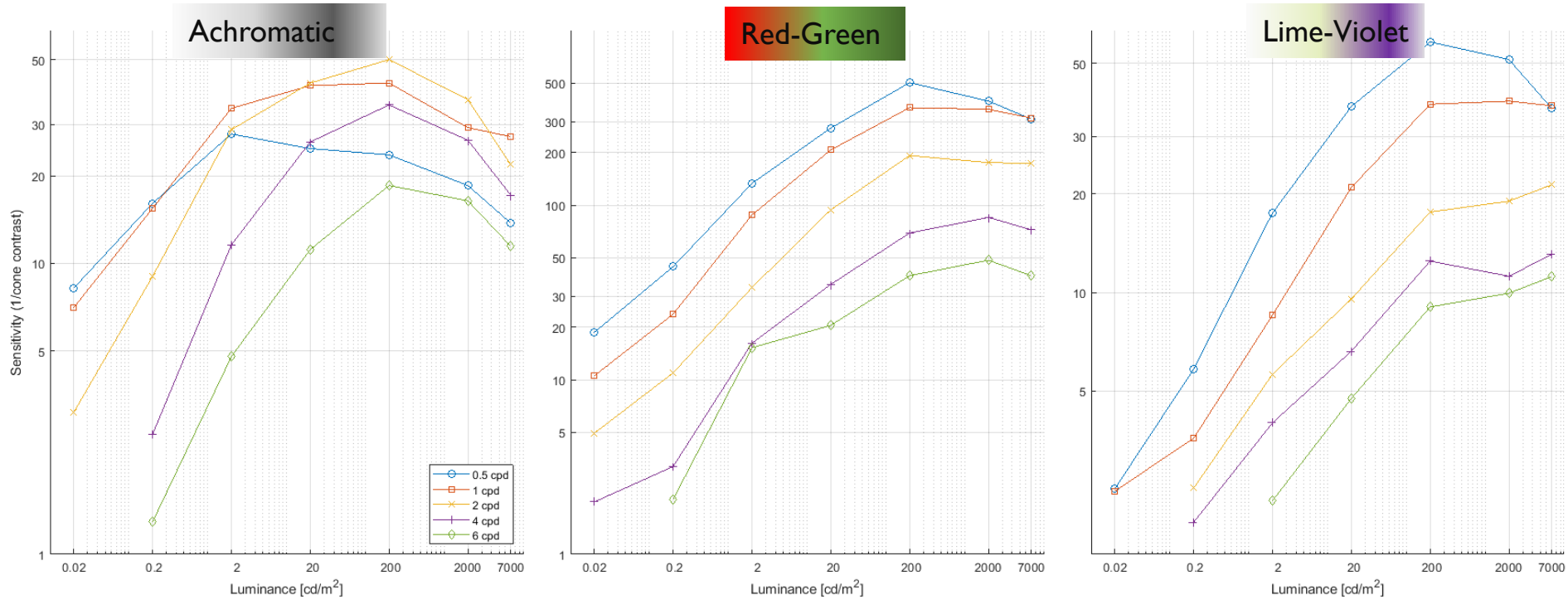
Achromatic CSF: peak sensitivity (ymax) at 20-200, then decreases; fmax increases with increasing bg lum.

Chromatic CSFs: peak sensitivity (ymax) at higher bg lum (~ 200-2000); decrease at 7000

Contrast sensitivity as a function of spatial frequency



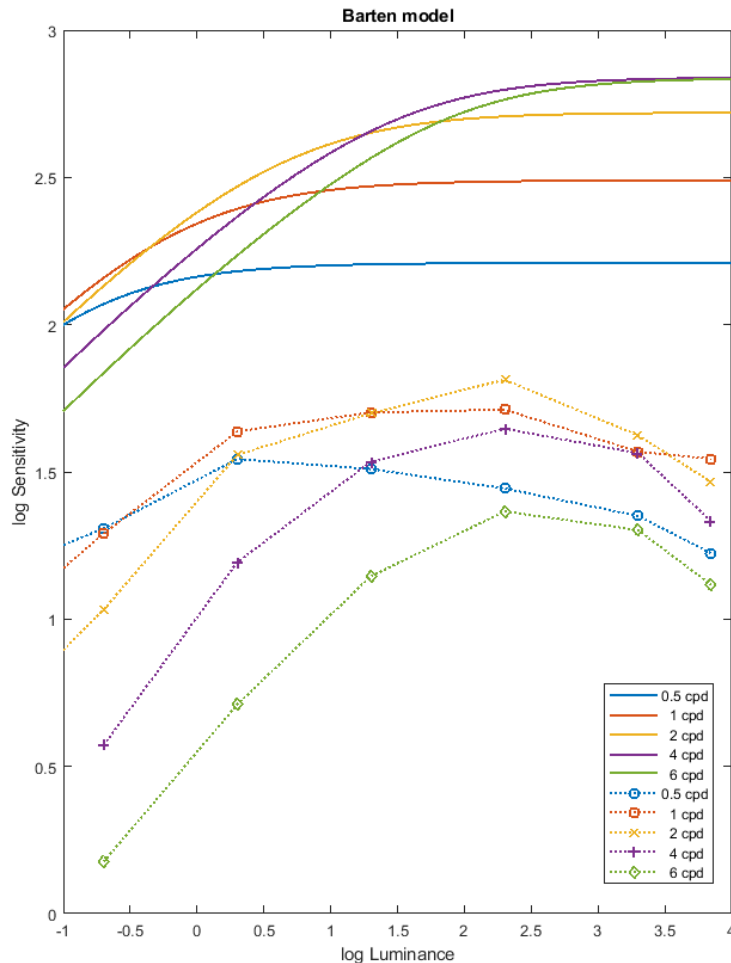
Contrast sensitivity as a function of background luminance



Achromatic CSF: peak sensitivity (y_{max}) at 20-200cd/m², then decreases rapidly

Chromatic CSFs: peak sensitivity (y_{max}) at higher bg lum (~ 200-2000); decrease at 7000cd/m²

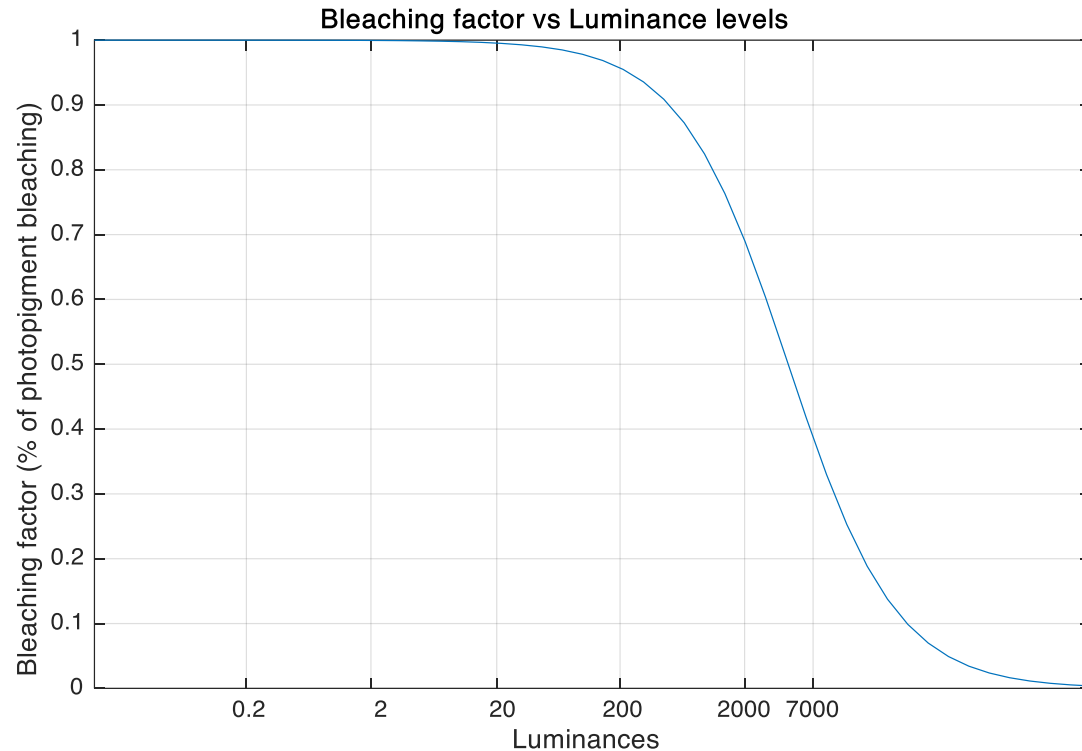
Comparison with Barten's model



$$S(u) = \frac{1}{m_t(u)} = \frac{M_{\text{opt}}(u)/k}{\sqrt{\frac{2}{T} \left(\frac{1}{X_o^2} + \frac{1}{X_{\text{max}}^2} + \frac{u^2}{N_{\text{max}}^2} \right) \left(\frac{1}{\eta p E} + \frac{\Phi_0}{1 - e^{-(u/u_0)^2}} \right)}}$$

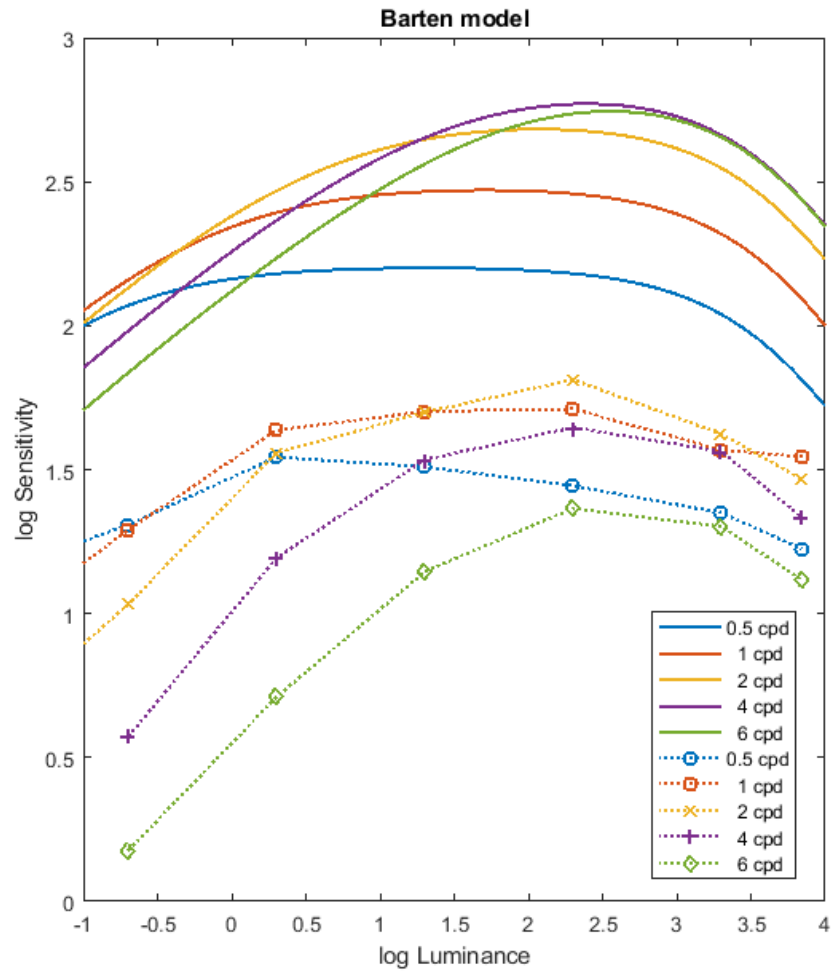
- A qualitative model relating sensitivity to external and internal noises, optical modulation function, and lateral inhibition
- The shape of the predicted curve is fairly consistent with measured data
- However, the magnitude of measured sensitivities are much lower than the predicted values
- The model predicts the sensitivity curve to flatten out at high luminance levels
- Measured data shows decrease in sensitivity after exceeding certain luminance values

Modelling the effect of bleaching



- The fraction of unbleached pigment decrease logarithmically with increasing luminance levels which could be linked to the observed drop in sensitivity

Modification of Barten's model



- Barten's model modulated with the bleaching factor function
- The new model mimics the sensitivity drop in measured data

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- We have extended achromatic and chromatic contrast sensitivity measurements to background luminances ranging from 0.02 to 7000 cd/m².
- Consistent with previous achromatic CSF measurements (e.g. van Ness, 1991; max lum=280cd/m²), the achromatic CSF is lowpass ≤ 0.2 cd/m² and bandpass at intermediate luminances.

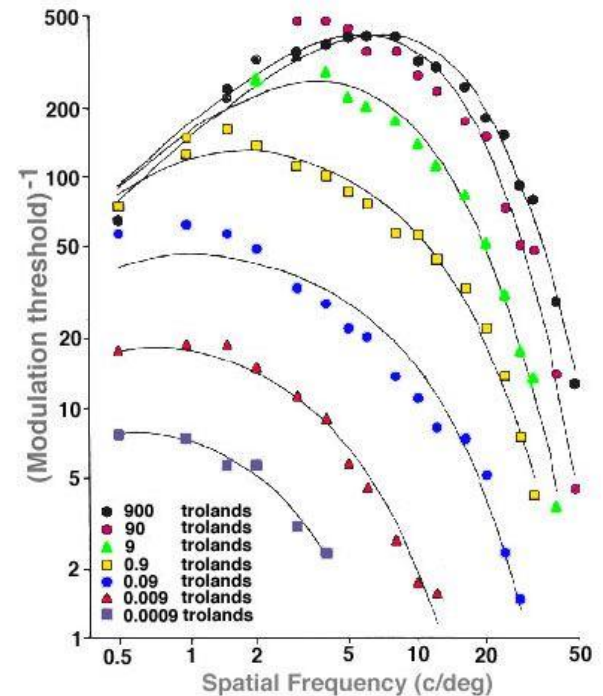


Figure 24. Contrast sensitivity function showing a change in shape from low pass at low luminances and bandpass at high luminances. van Ness' data from Lamming D., *Contrast Sensitivity*. Chapter 5. In: Cronly-Dillon, J., *Vision and Visual Dysfunction*, Vol 5. London: Macmillan Press, 1991.

Comparison with Literature

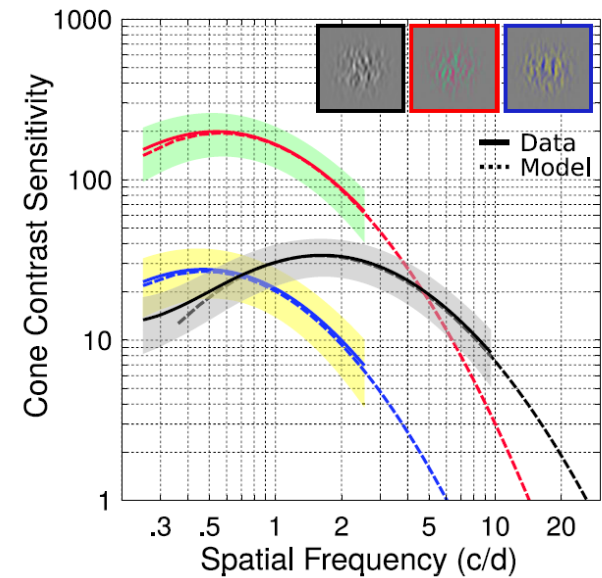


FIGURE 2. Measured CCS as a function of spatial frequency for the Ach (solid black line), RG (solid red line), and BY (solid blue line) conditions under monocular viewing. The average across the 51 subjects is shown. The dotted lines indicate the log-parabola model estimation, which is reconstructed with the average estimated values for each of the three parameters by the *qCSF*. The averaged model parameters are reported in the Table. The shaded regions represent \pm SD.

Comparison with Literature

- The chromatic contrast sensitivity functions are lowpass at all luminance levels. Our cone contrast sensitivities for intermediate luminances are commensurate with previous measurements (e.g. Mullen, 1985; Kim et al, 2017).

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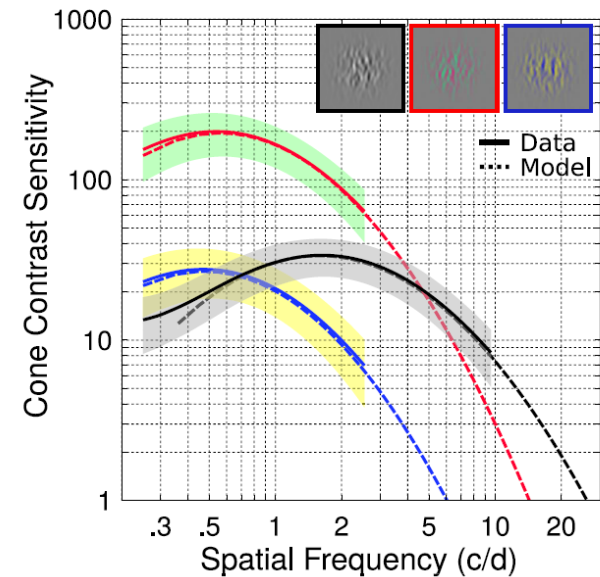


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Thank you!

Acknowledgements

Collaborators:

Sophie Wuerger

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