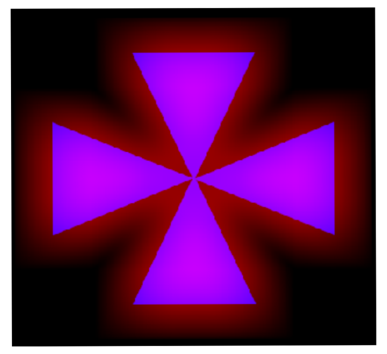
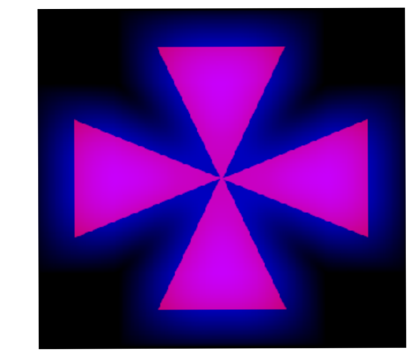


Bringing color into focus: accommodative state varies with the spectral content of light



Benjamin M. Chin[1], Martin S. Banks[1], Derek Nankivil[2], Austin Roorda[1], and Emily A. Cooper[1]
[1]University of California, Berkeley [2]Johnson & Johnson Vision Care

Introduction

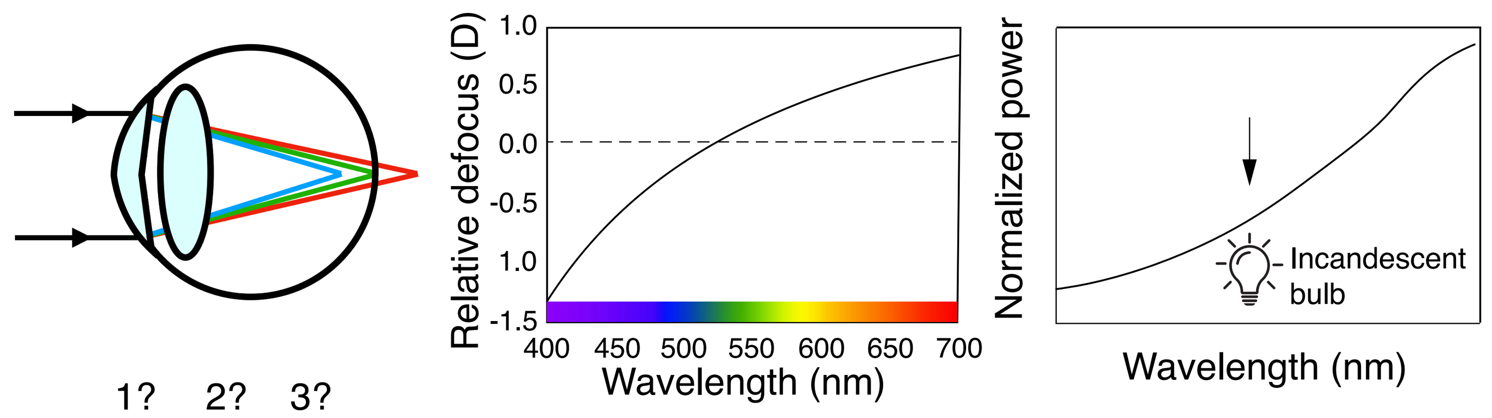
Accommodation: changing power of lens in eye to obtain clear images

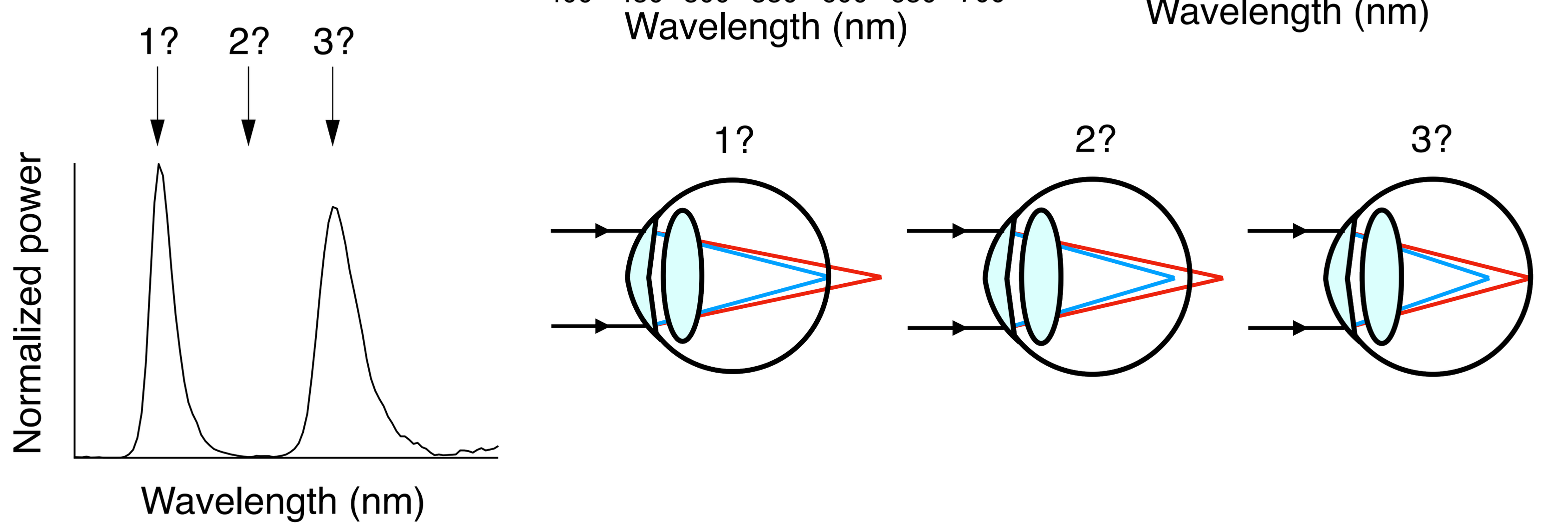
Different wavelengths refracted by different amounts: longitudinal chromatic aberration (LCA)

Thus, with broadband light spectra, there are many different accommodative demands

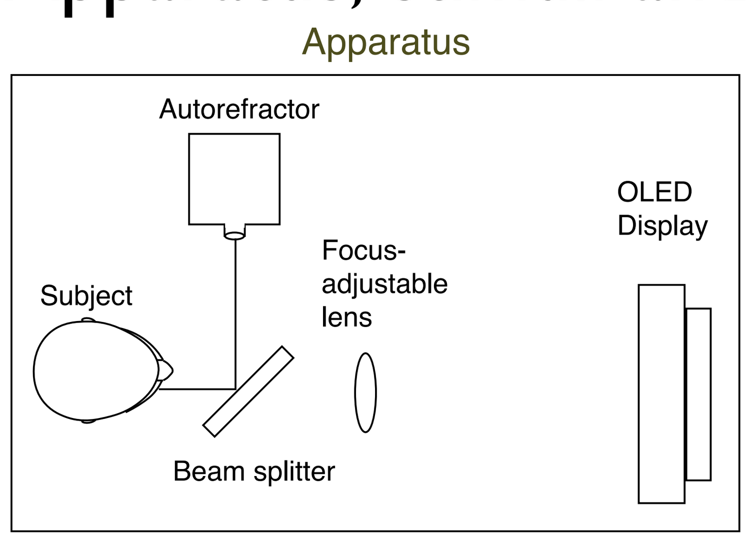
For white light, humans accommodate middle wavelengths (Coe et al., 2004; Ivanoff, 1949)

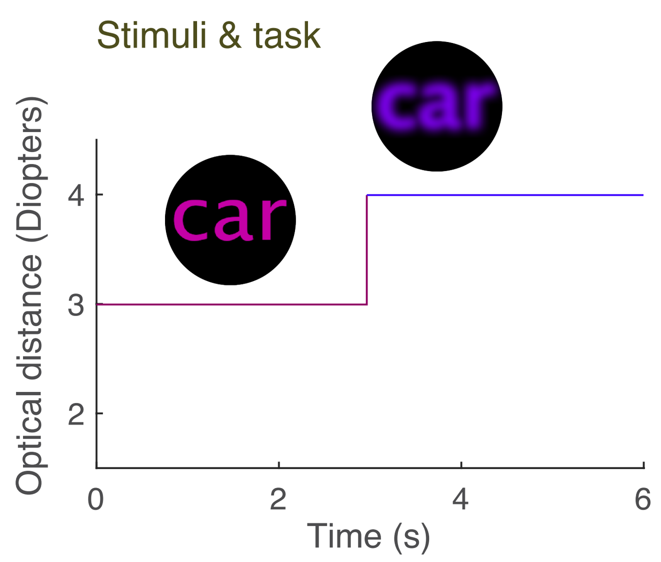
What about arbitrary broadband spectra? For example, ones missing middle wavelengths?

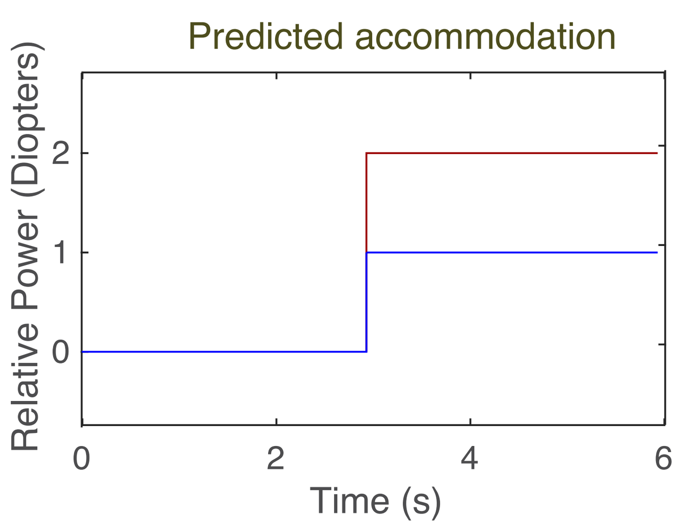


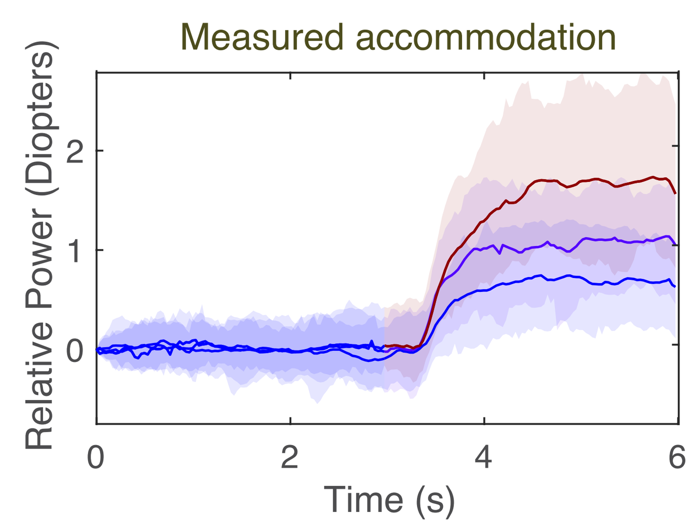


Apparatus, stimuli and task









Present 3-letter word stimulus (24 arcmin per letter) at different optical distances

On each trial, optical distance and color of stimuli change simultaneously

Observer's task is to accommodate. Measure accommodation with autorefractor

Consistent with recent literature, subjects compensate for LCA during accommodation (Fernandez-Alonso et al., 2024). Furthermore, shape of light spectrum influences response!

Linear weighting vs. switching strategies

Linear model with 3 variables: changes in red luminance, blue luminance, and optical distance

$$\Delta A = w_S \Delta S + w_R \Delta L_R c_R + w_B \Delta L_B c_B$$

Switching model: accommodate whichever wavelength has higher luminance

if $L_{R1} < L_{B1}$ and $L_{R2} > L_{B2}$

$$\Delta A = w_S \Delta S + c$$

if $L_{R1} > L_{B1}$ and $L_{R2} < L_{B2}$

$$\Delta A = w_S \Delta S - c$$

otherwise

$$\Delta A = w_S \Delta S$$

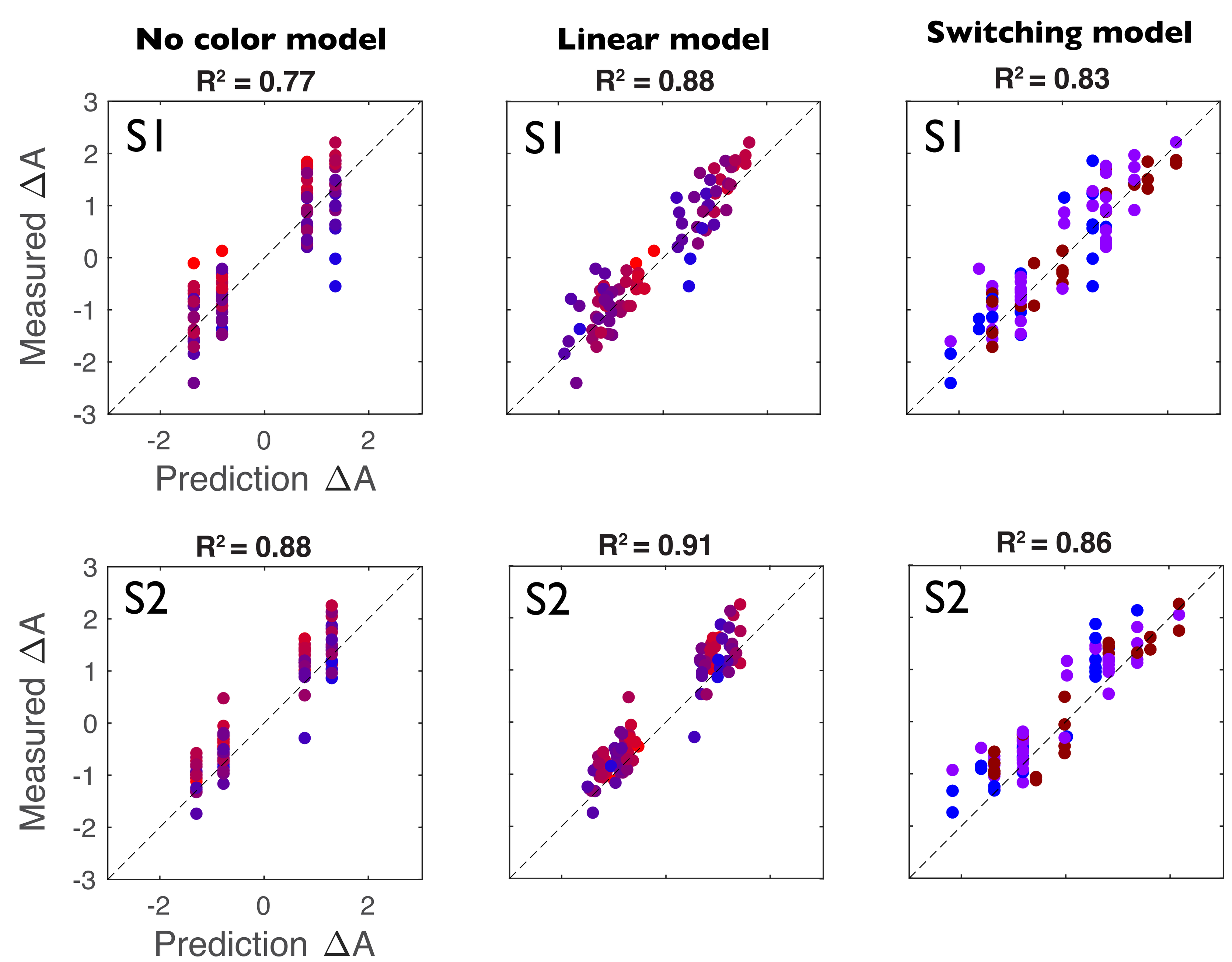
Condition construction

Red luminance (cd/m²)	Blue luminance (cd/m²)	Optical distance step (D)
0.40	0.40	1.50
0.20	0.20	0.75
0.10	0.10	-0.75
0.05	0.05	-1.50

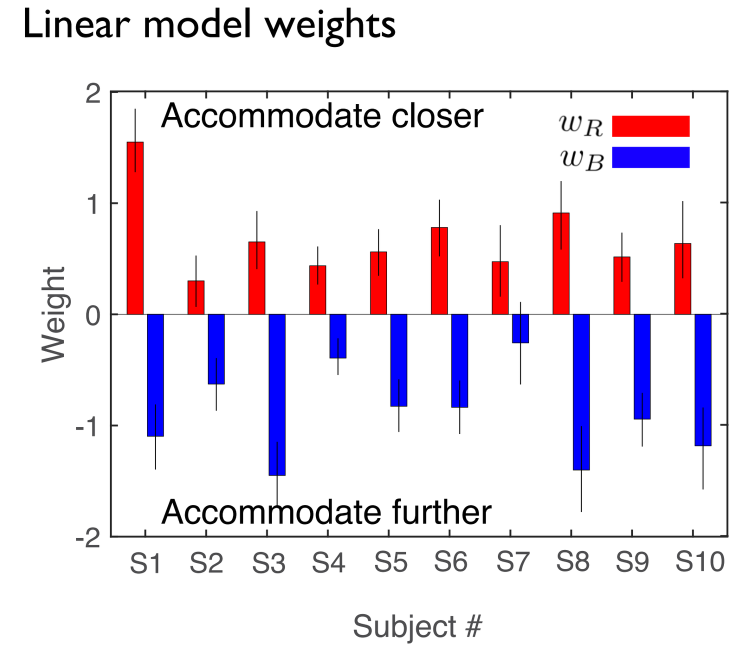
Color 1, Color 2

Randomly pair colors and optical distance step: 80 trials per subject (n=10)

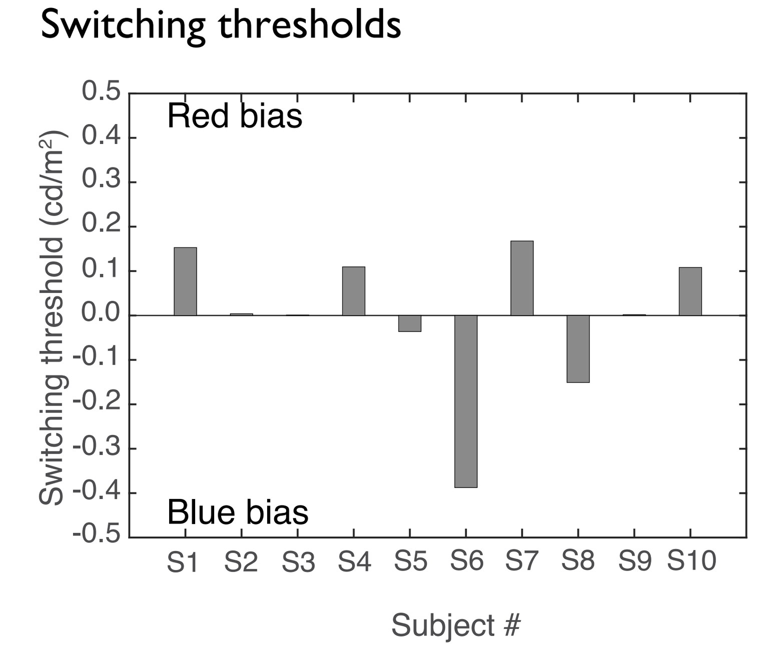
Results



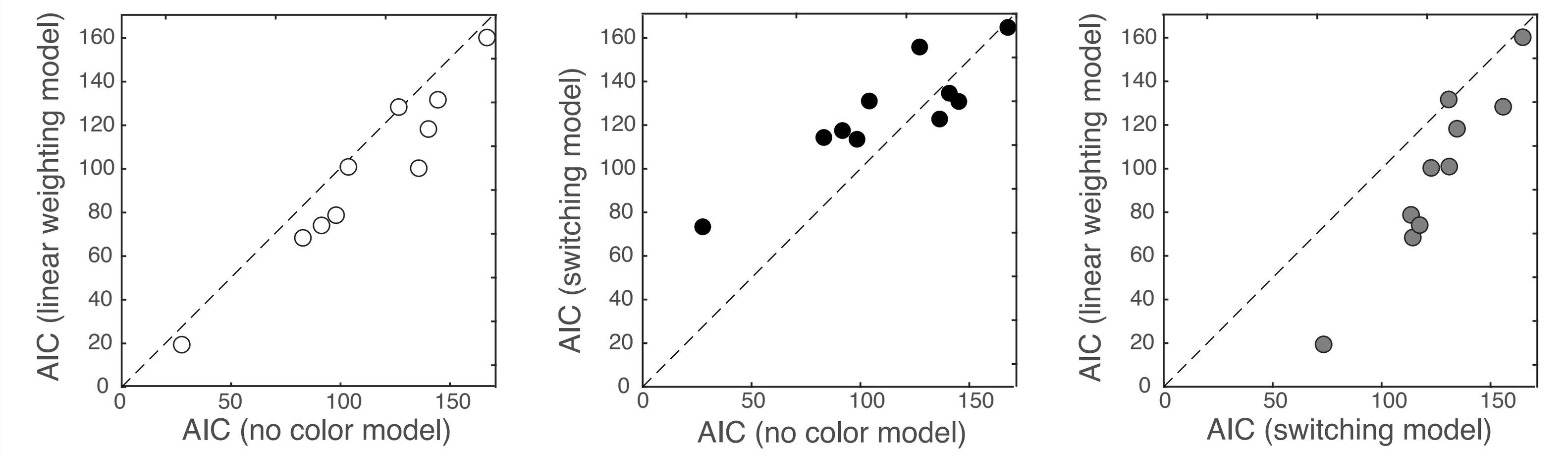
Linear model weights



Switching thresholds



Comparison using Akaike Information Criterion

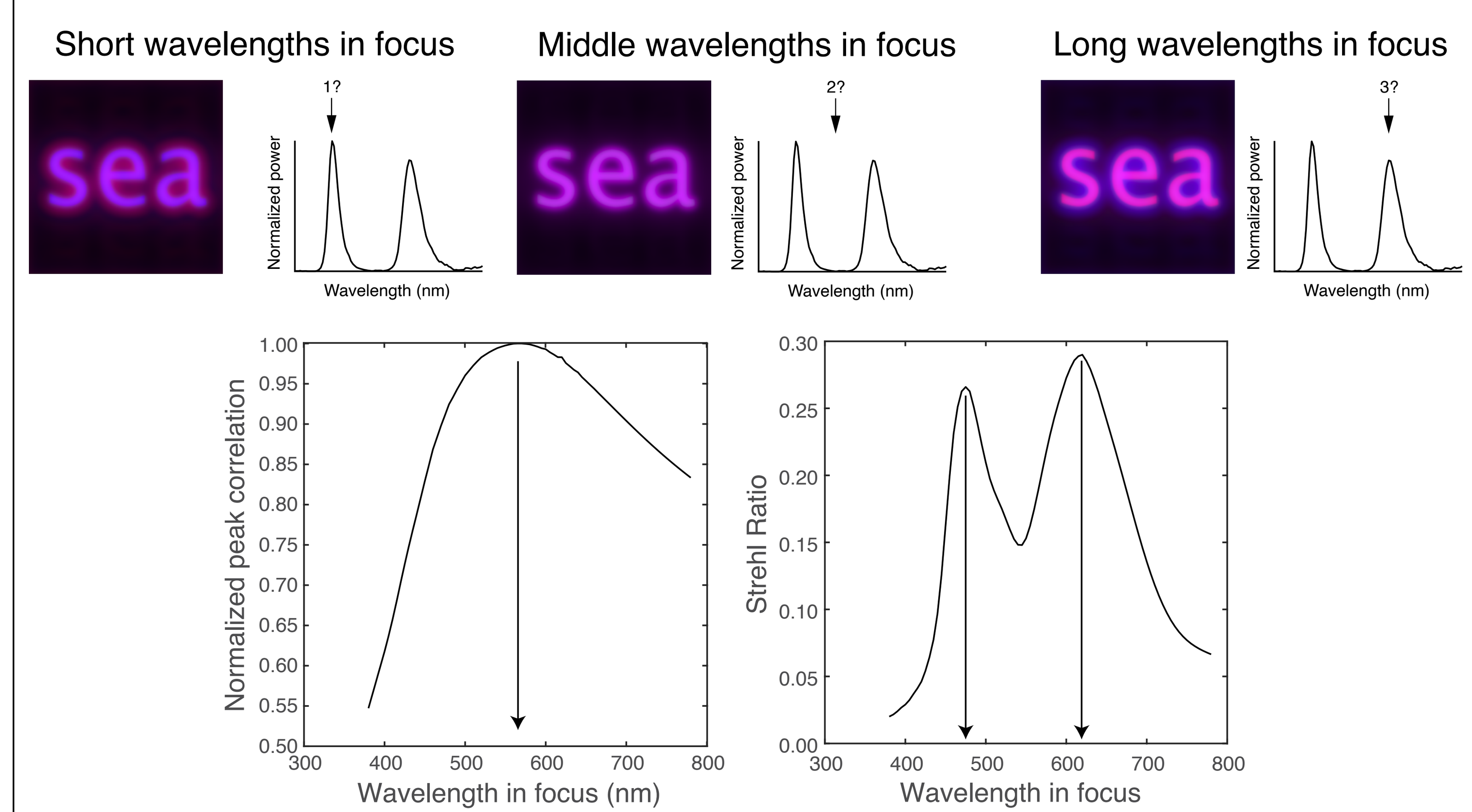


Akaike Information Criterion (AIC): common model comparison metric

Lower AIC = better fit. Penalizes larger number of parameters to make comparison fair

Weighting model outperforms switching and 'no color' models for 9/10 subjects

Does linear weighting maximize image quality?



$\rho_{max} = max(I_{retinal} \star I_{original})$ $\quad Strehl = \frac{max(PSF_{human})}{max(PSF_{DL})}$

Weighting model implies humans accommodate in-between long and short wavelengths

Behavior maximizes image quality according to cross-correlation metric, but not Strehl ratio

Conclusions

Most subjects follow a 'weighting' rather than a 'switching' strategy during accommodation

Increasing proportion of red luminance causes closer accommodation

Increasing proportion of blue luminance causes farther accommodation

Future experiments: determine whether subjects maximize acuity during accommodation

References

Coe, C., Bradley, A., & Thibos, L. (2004). Polychromatic Refractive Error from Monochromatic Wavefront Aberrometry. *Optometry and Vision Science, 91*(10). 1167-1174.

Fernandez-Alonso, M., Finch, A. P., Love, G. D., & Read, J. C. A., (2024). Ocular accommodation and wavelength: The effect of longitudinal chromatic aberration on the stimulus–response curve. *Journal of Vision, 24*(11).

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Acknowledgements: National Science Foundation Award #2041726, and the UC Berkeley Center for Innovation in Vision and Optics