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Comparison of models for chromatic discrimination

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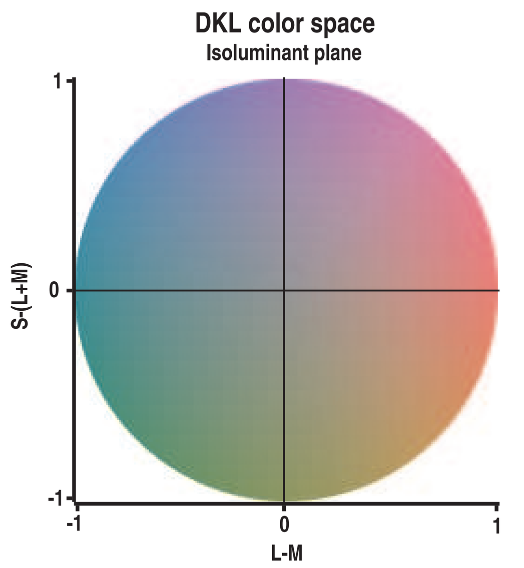
Introduction

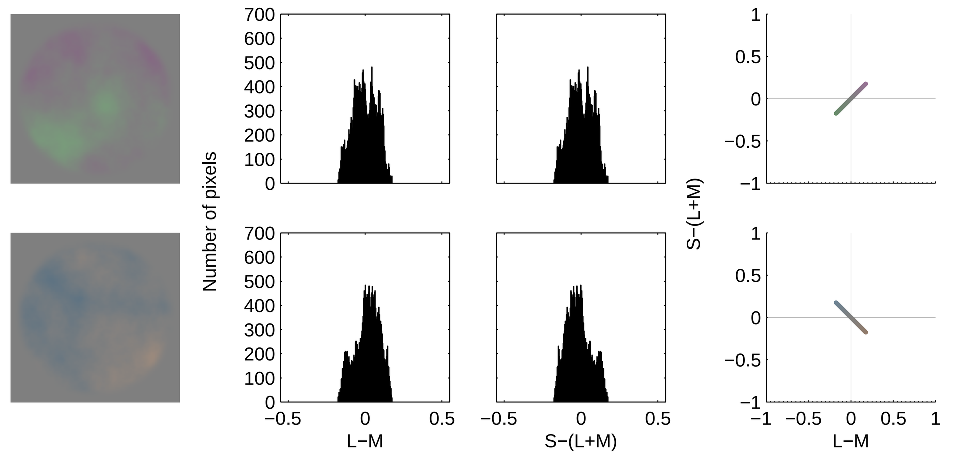
Cardinal models of chromatic discrimination assume that chromatic discrimination is mediated by four mechanisms lying along the cone-opponent axes. For discrimination at test locations intermediate to the cardinal axes, they predict that the discrimination ellipses at these locations are either circular or elongated along one of the cardinal axes.

Previously, we presented data showing discrimination ellipses that were elongated along non-cardinal directions [1]. We also found differences between the discrimination ellipses for stimuli chromatically variegated along orthogonal directions in color space at intermediate test locations. A model with eight mechanisms provided a good fit to the data [2]. Here we investigate whether a cardinal model could predict these results by fitting various variants of a model with four and with eight mechanisms to the data.



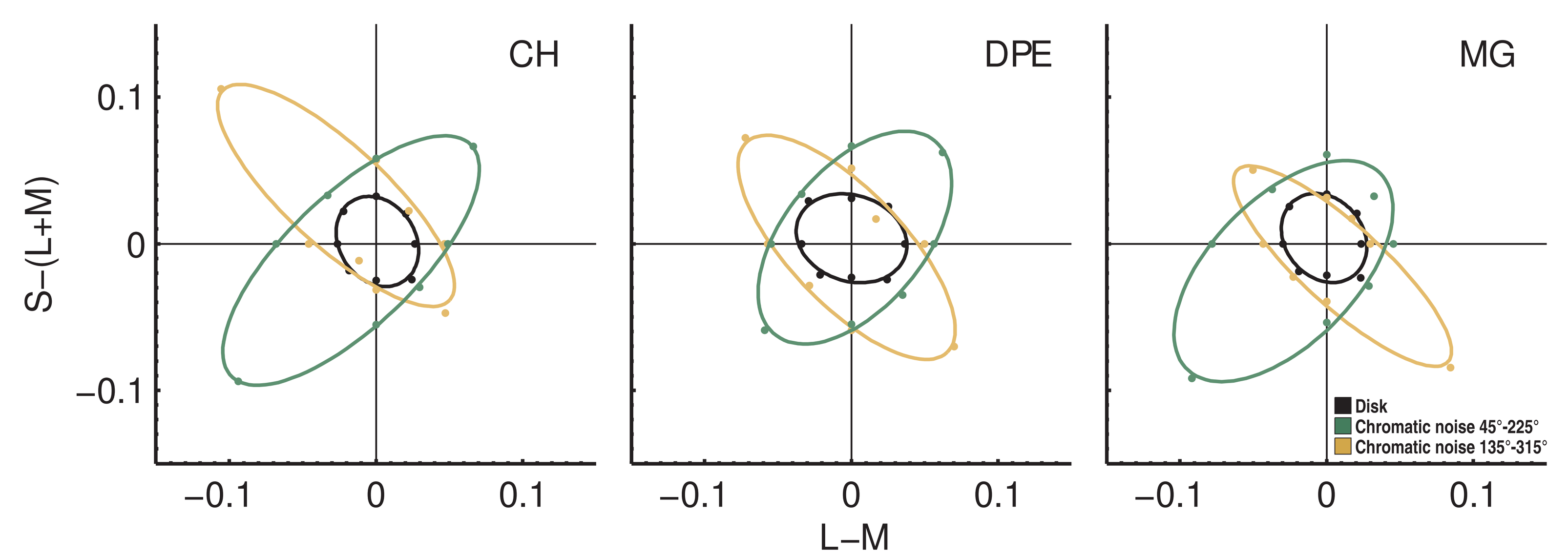
Chromatic noise 45°– 225°

Chromatic noise 135°– 315°

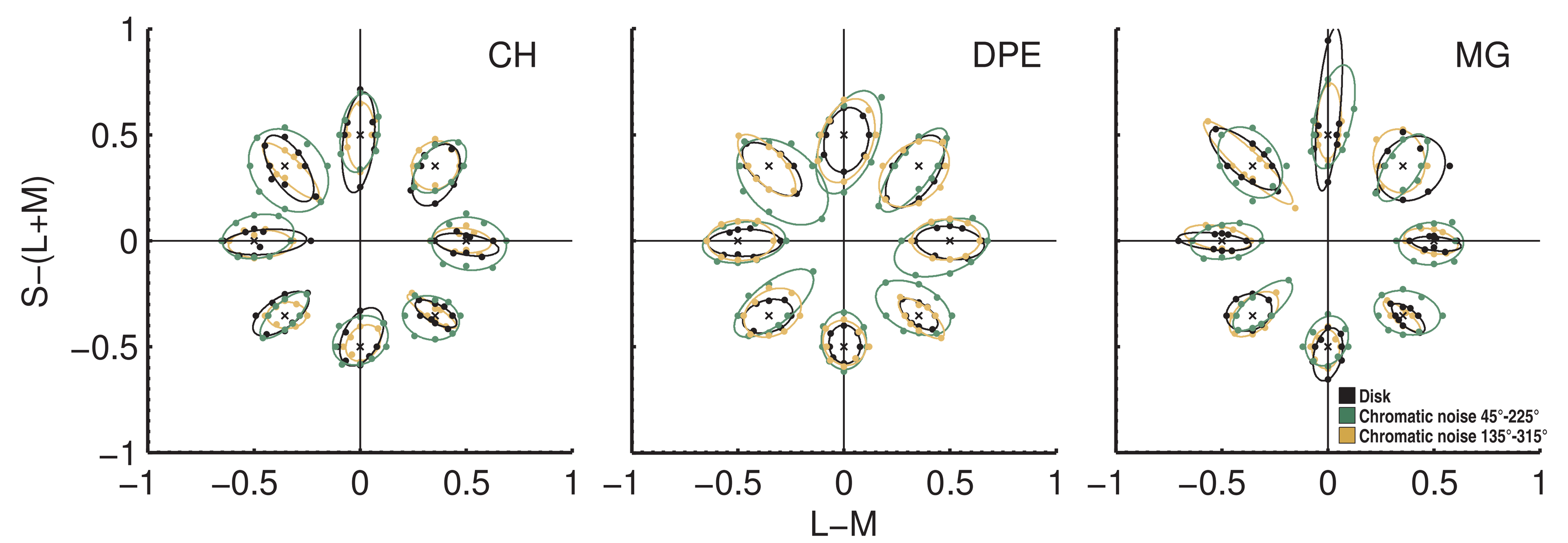


Data

Discrimination at the adaptation point



Discrimination away from the adaptation point



References

[1] Hansen, T., Giesel, M., & Gegenfurtner, K. R. (2008). Chromatic discrimination of natural objects. *Journal of Vision*, 8(1):2, 1–19.

[2] Giesel, M., Hansen, T., & Gegenfurtner, K. R. (2009) The discrimination of chromatic textures. *Journal of Vision*, in press.

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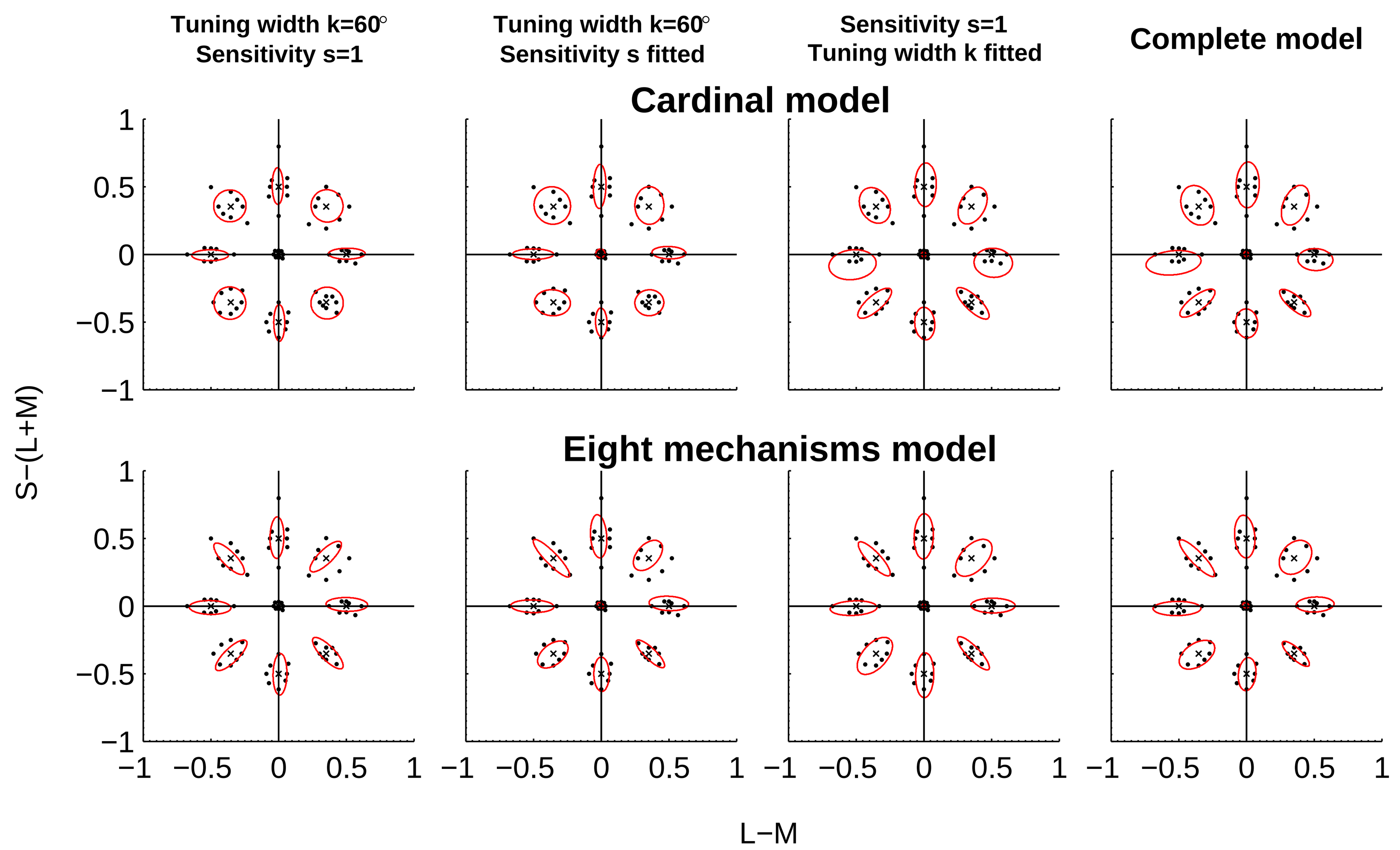
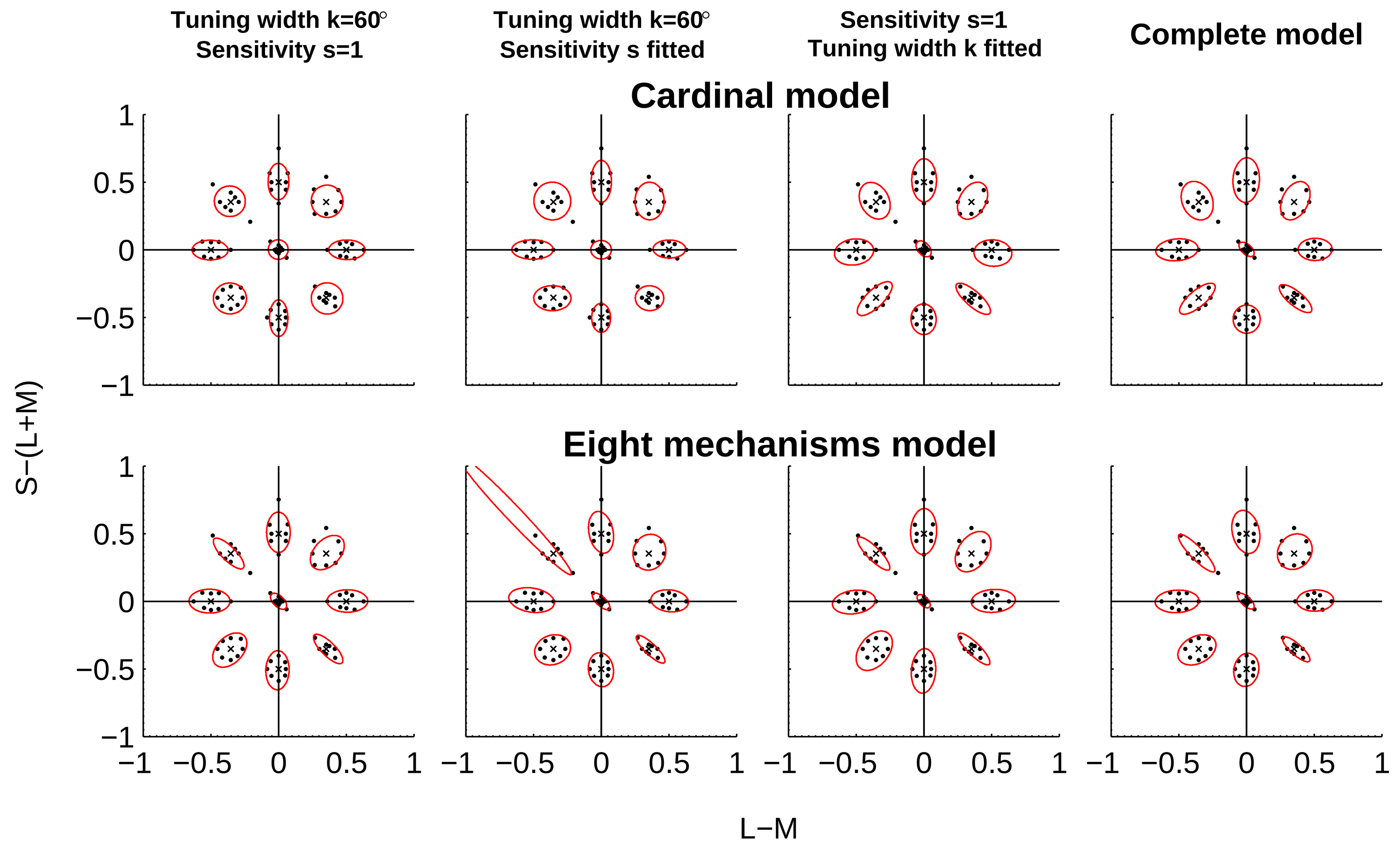
Model predictions

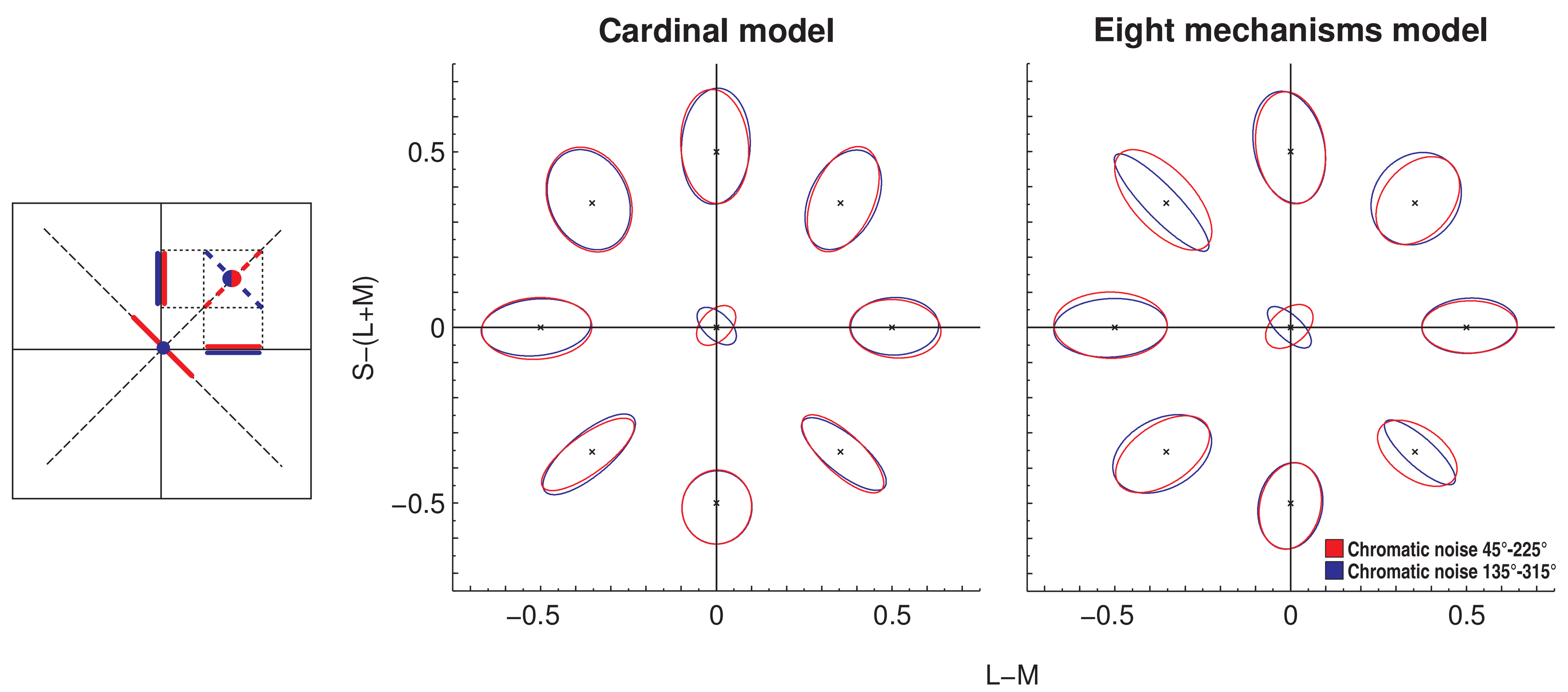
Disk



Chromatic noise 135°–315°

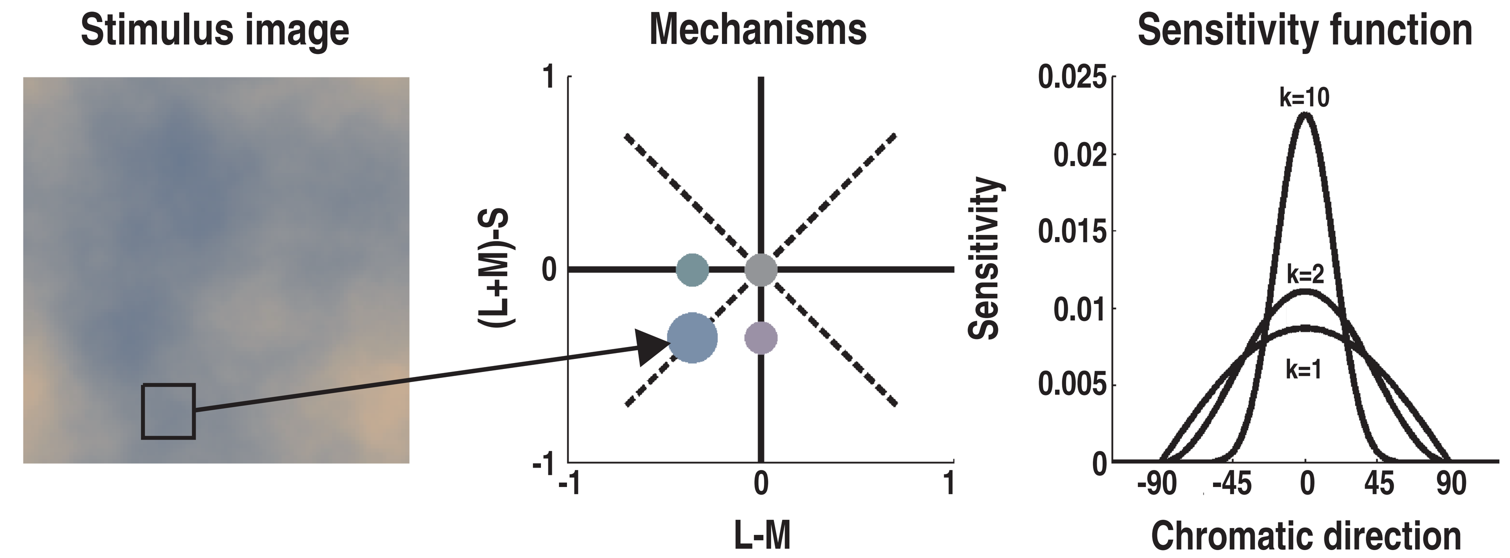


Chromatic noise 45°–225° vs. Chromatic noise 135°– 315°



Model

We fitted a chromatic discrimination model simultaneously to the discrimination data for the disk and the chromatically variegated stimuli averaged across subjects. Each of the M mechanisms has a preferred chromatic direction μ_i to which its sensitivity is maximal. The excitatory response E_i of mechanism i to an image is computed by projecting the chromatic coordinates r_j and θ_j of each pixel j of the image onto the mechanism. The sensitivity profile of each mechanism is determined by the tuning width k_i and the sensitivity parameter s_i.



1. Excitatory stage

Sensitivity S_i of mechanism i to chromatic direction θ:

$$S_i(\theta) = s_i[\cos^{k_i}(\theta - \mu_i)]^+$$

The excitatory response E_i of mechanism i to the image is given by:

$$E_i = \frac{1}{N}\left(\sum_{j=1}^{N} r_j S_i(\theta_j)\right)$$

2. Response function

$$R_i = gE_i^p$$

3. Decision variable

The decision variable D is computed using the responses to the comparison image R_{C_i} and the responses to the test image R_{T_i}. Threshold is reached when $D = 1$.

$$D = (\sum_{i=1}^{M} |R_{C_i} - R_{T_i}|^2)^{\frac{1}{2}}$$

Parameter of the complete model

	g	p	k_0	k_{45}	k_{90}	k_{135}	k_{180}	k_{225}	k_{270}	k_{315}	s_0	s_{45}	s_{90}	s_{135}	s_{180}	s_{225}	s_{270}	s_{315}
$M = 4$	21.964	0.552	45.613	–	63.194	–	49.524	–	35.464	–	22.008	–	18.741	–	16.958	–	25.984	–
$M = 8$	17.810	0.562	58.162	57.032	70.832	52.168	61.585	61.239	50.873	46.648	10.751	24.745	9.678	12.228	7.841	20.343	21.325	22.228

Conclusions

- A chromatic discrimination model based on the cardinal mechanisms predicted discrimination ellipses elongated along directions intermediated to the cardinal directions if the mechanisms were more narrowly tuned than given by a linear combination of cone inputs.
- The discrimination model based on the cardinal mechanisms did not predict the different discrimination ellipses at intermediate test locations for stimuli chromatically variegated along orthogonal directions in color space.
- A discrimination model assuming additional mechanisms along intermediate directions predicted different discrimination ellipses for stimuli chromatically variegated along orthogonal directions in color space without requiring narrowly tuned chromatic mechanisms.