



Spatial Summation and Receptive Field Structure of Color Vision Mechanisms

Yung-Chun Lin and Chien-Chung Chen

Department of Psychology, National Taiwan University, Taipei, Taiwan



Purpose

- While the receptive field structure of luminance mechanisms is well understood, those of color vision mechanisms are not yet clear.
- We investigated the extent and the shape of the receptive fields of chromatic detectors by observing the **detection thresholds** for spatial patterns with different **spatial extent**, **shape** and **chromaticity**.

Method

Length

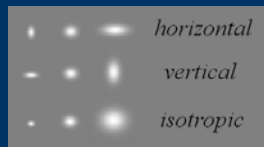
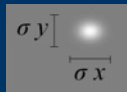
In both experiments, every stimulus has two spatial extent parameters: σ_x (horizontal scale) and σ_y (vertical scale). Each of them could vary from 0.01 to 0.60 visual angle degree.

Shape

Horizontal condition: Varying σ_x

Vertical condition: Varying σ_y

Isotropic condition: Varying **both** σ_x and σ_y



Chromaticity

Stimuli are modulated in the three cardinal axes of DKL space (Derrington et al., 1984), i.e. **(a) L-M** **(b) S** **(c) L+M**

Thresholds were measured with a 2AFC paradigm and QUEST adaptive threshold seeking algorithm (Watson & Pelli, 1983).

Experiment 1: Spatial summation of Gaussian spots

In order to estimate the excitatory area of the receptive field, the stimuli were Gaussian spots.

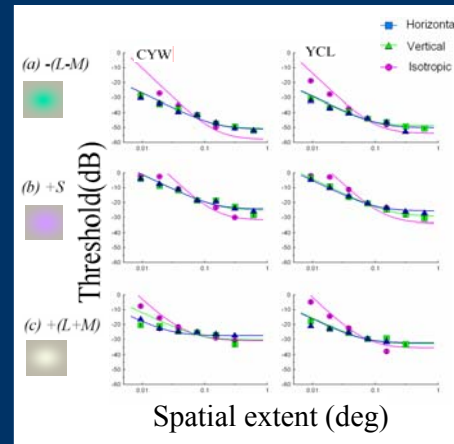
Experiment 2: Spatial summation of Gabor patches

In order to simulate the receptive field structure of **VI** simple cells, the stimuli were Gabor patches (4 cyc/deg, sine phase, horizontal).

Result

Experiment 1

- These data points of threshold are fitted by the convolution of a Gaussian spot and a Gabor filter.



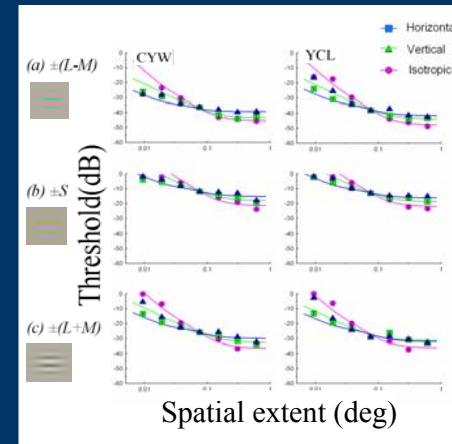
- Model parameters are listed below.

Direction	Subject	σ_x	σ_y	σ_x / σ_y	spa. freq.	RMSE
-(L-M)	CYW	0.1499	0.1588	0.943955	0.0588	1.857287
	YCL	0.0899	0.1124	0.799822	0.0611	1.770518
+S	CYW	0.1608	0.1435	1.120557	0.0013	2.075734
	YCL	0.1796	0.1043	1.721956	0.031	1.542739
+(L+M)	CYW	0.0817	0.0289	2.82699	0.6032	1.88517
	YCL	0.0735	0.0638	1.152038	0.106	2.216032

- The average detection threshold is the highest for S cone modulation followed by L+M, and (L-M) in that order.
- As the spatial extent increased, the detection threshold decreased to a critical point and then leveled out.
- The slope of threshold decrement as a function of spatial extent change in one dimension was about -0.5 for achromatic spots and -1 for isoluminant spots.

Experiment 2

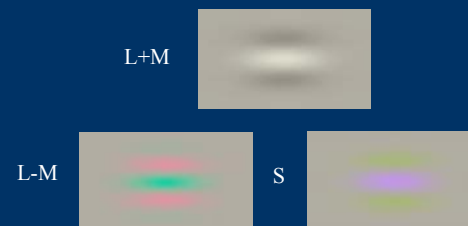
- These data points of threshold are fitted by the convolution of a Gabor patch and a Gabor filter. (Chen & Tyler, 1999)



- Model parameters are listed below.

Direction	Subject	σ_x	σ_y	σ_x / σ_y	spa. freq.	RMSE
±(L-M)	CYW	0.1348	0.0982	1.372709	4.752	1.895319
	YCL	0.1364	0.0945	1.443386	3.969	2.171691
±S	CYW	0.1357	0.0926	1.465443	3.673	1.571286
	YCL	0.1276	0.0915	1.394536	3.653	1.033071
±(L+M)	CYW	0.1421	0.0999	1.422422	3.709	2.325081
	YCL	0.0944	0.1169	0.807528	3.752	2.209163

- The slope of threshold decrement was about -0.5 for Gabor patches.
- Gabor receptive field structure according to model parameters. (For one observer CYW)



Conclusion

- The best detectors for achromatic Gaussian spots is smaller than those for isoluminant spots. On average, the detector for achromatic spots is 46.5% smaller than that for isoluminant spots in horizontal direction and 64.2% in vertical direction.
- The best detectors for isoluminance Gaussian spots are isotropic but not those for achromatic spots.
- The best detectors for Gaussian spots tuned to very low spatial frequencies (<0.1 cyc/deg for most cases).
- The best detectors for achromatic and isoluminant Gabor patches are about the same size (average half high full width is 0.303 deg for the parallel or horizontal direction and 0.233 deg for the orthogonal or vertical direction).
- The best detectors for achromatic and isoluminant Gabor patches have the horizontal-vertical ratio around 1.4. This implies that the shape of the receptive field is elongated rather than isotropic.
- The best detectors for Gabor patches have a peak spatial frequency tuning around 3.7 cyc/deg for most cases.

Reference

- Chen, C. C., & Tyler, C. W. (1999). Spatial pattern summation is phase-insensitive in the fovea but not in the periphery. *Spatial Vision*, 12(3), 267-285.
- Derrington, A. M., Krauskopf J., Lennie P. (1984). Chromatic mechanisms in lateral geniculate nucleus of macaque. *Journal of Physiology*, 357, 241-265.
- Watson, A. B., Pelli, D. G. (1983). QUEST: a Bayesian adaptive psychometric method. *Percept Psychophysics*, 33(2), 113-20.

Acknowledgement

- This study is supported by NSC93-2815-C-002-081H.