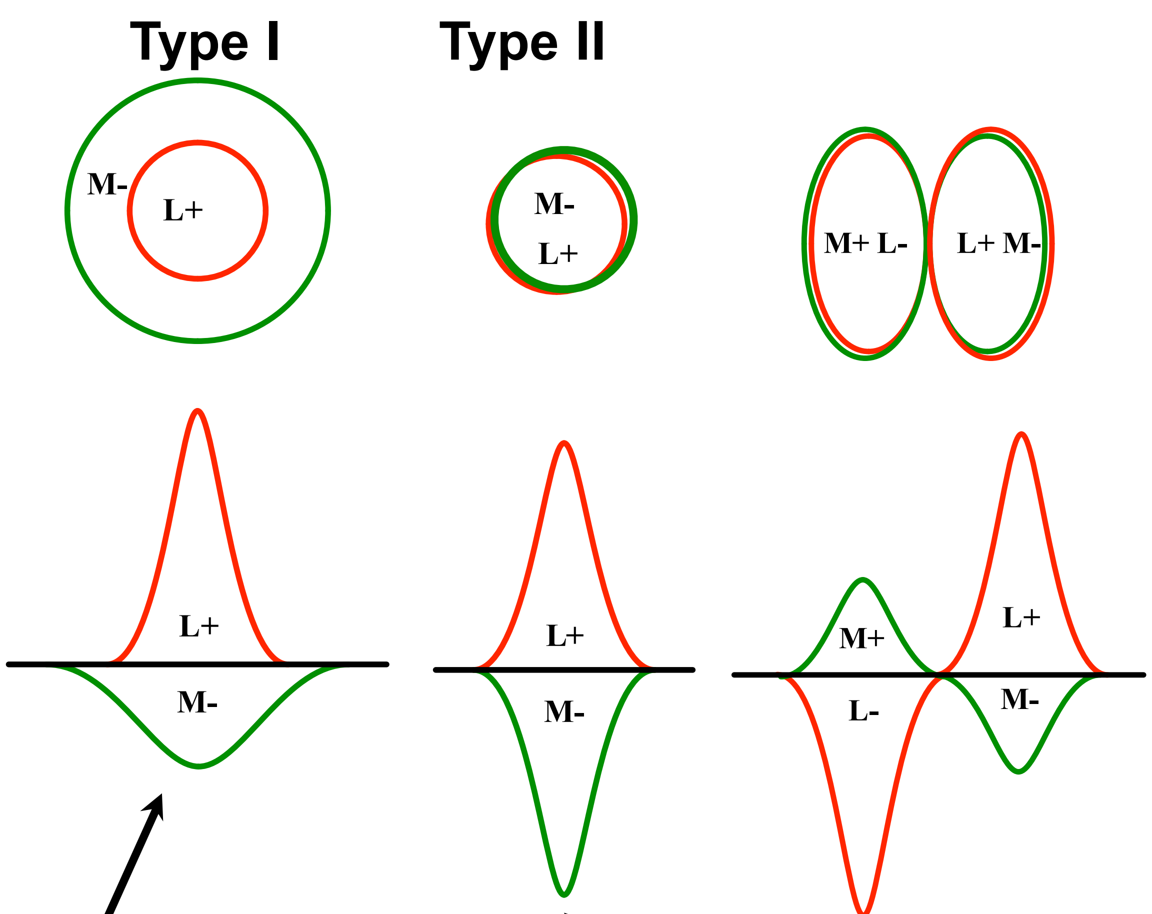
Computational Vision

Primary visual cortex

- Orientation selectivity
- Spatial frequency
- Normalization
- Color opponency

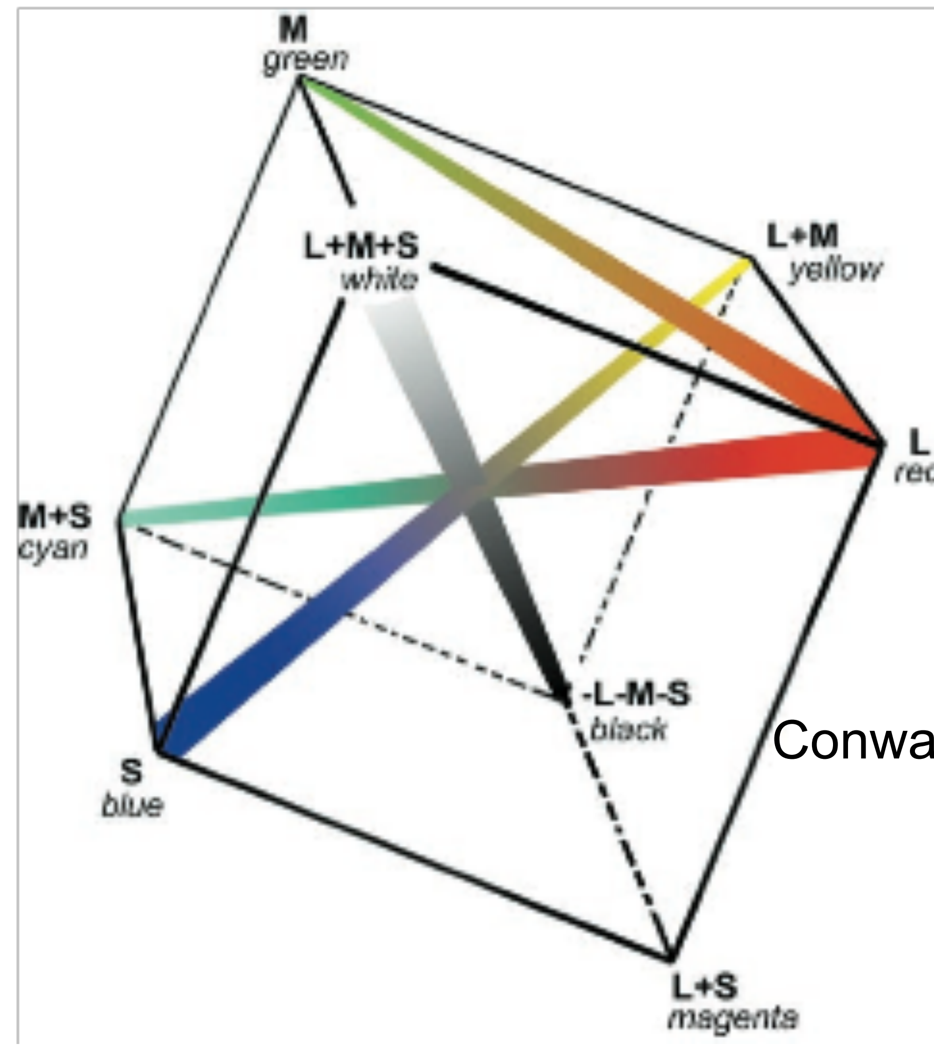
Color selective cells

Single-opponency (SO) **Double-opponency (DO)**



Spatially opponent (major type in parvocellular layers in LGN)

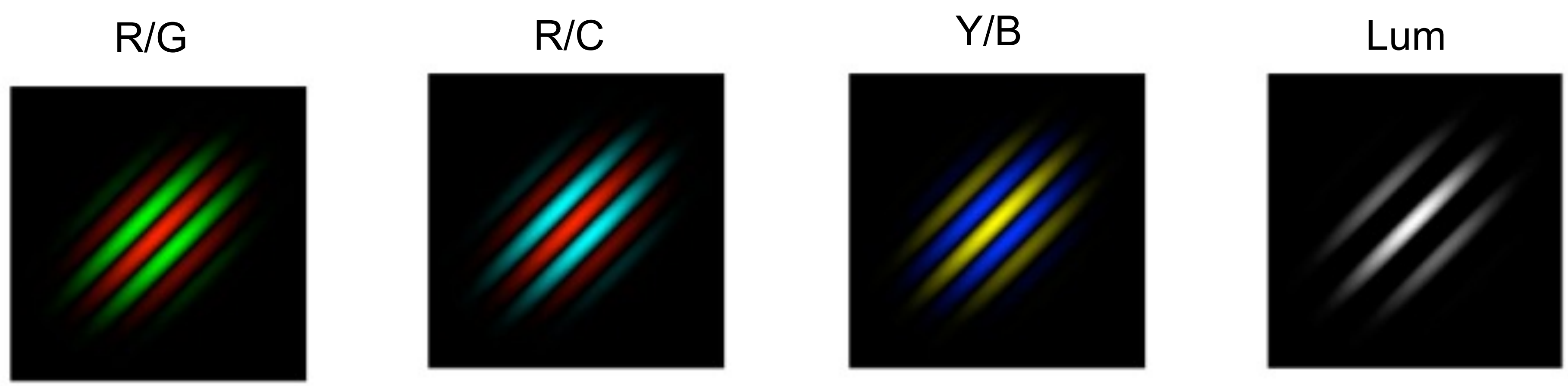
Chromatically opponent (koniocellular layers)

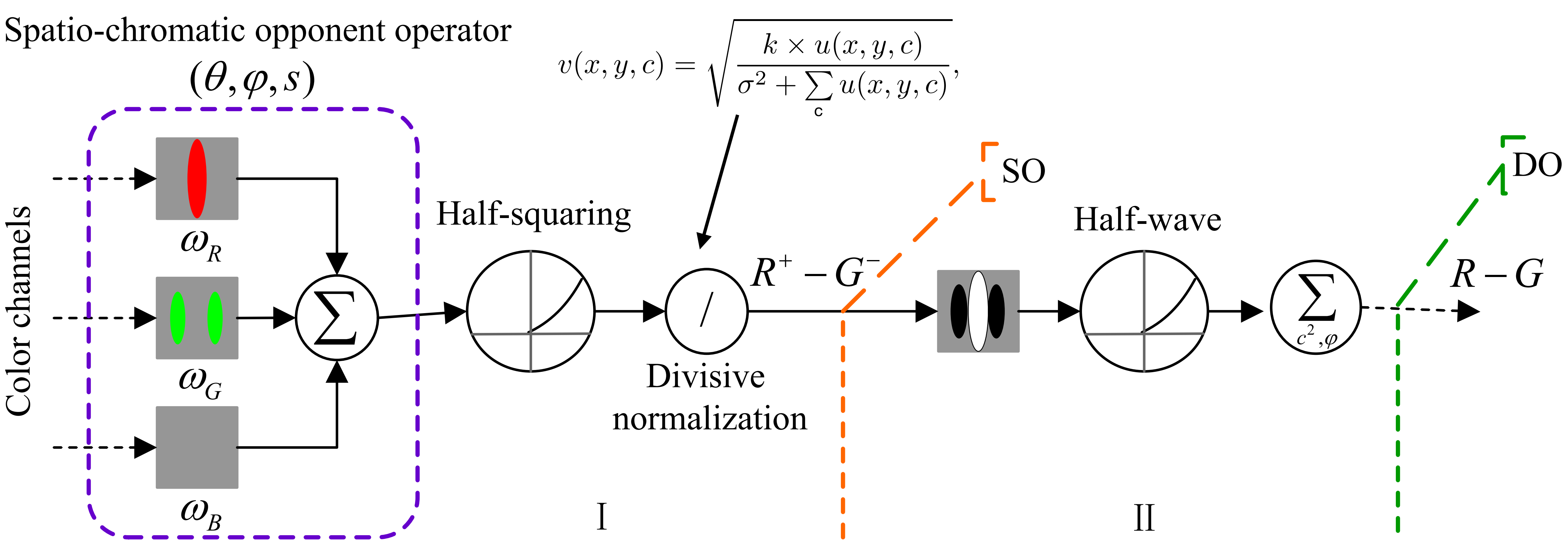


Conway 2001

redrawn from Conway et al. 2010

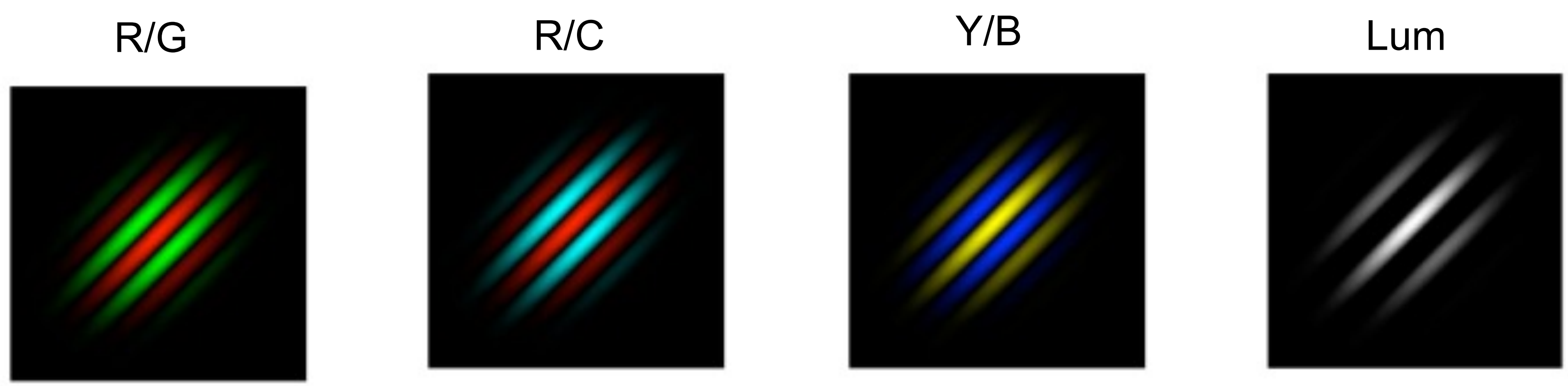
Color processing





Zhang Barhomi & Serre '12

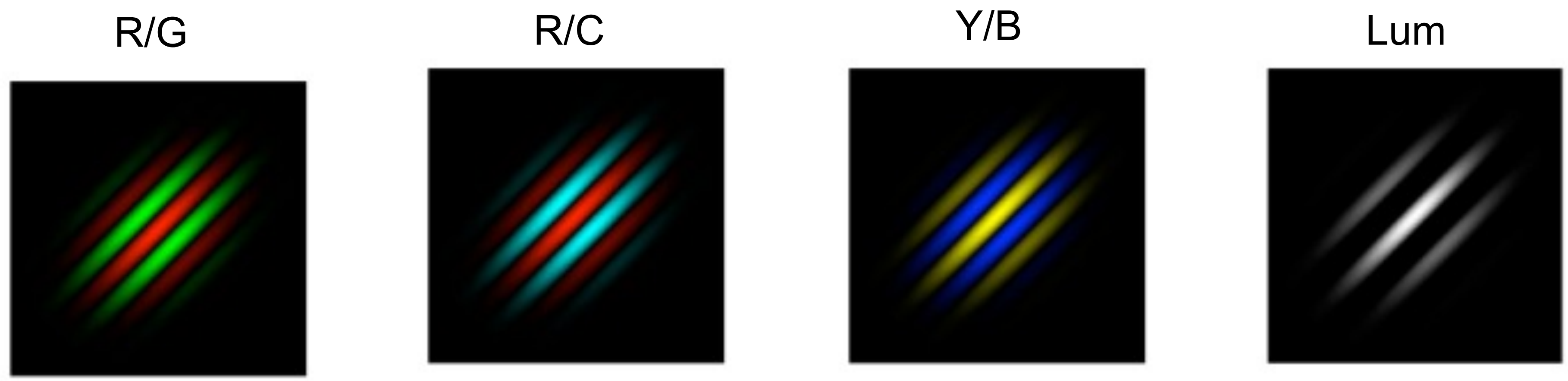
Color processing

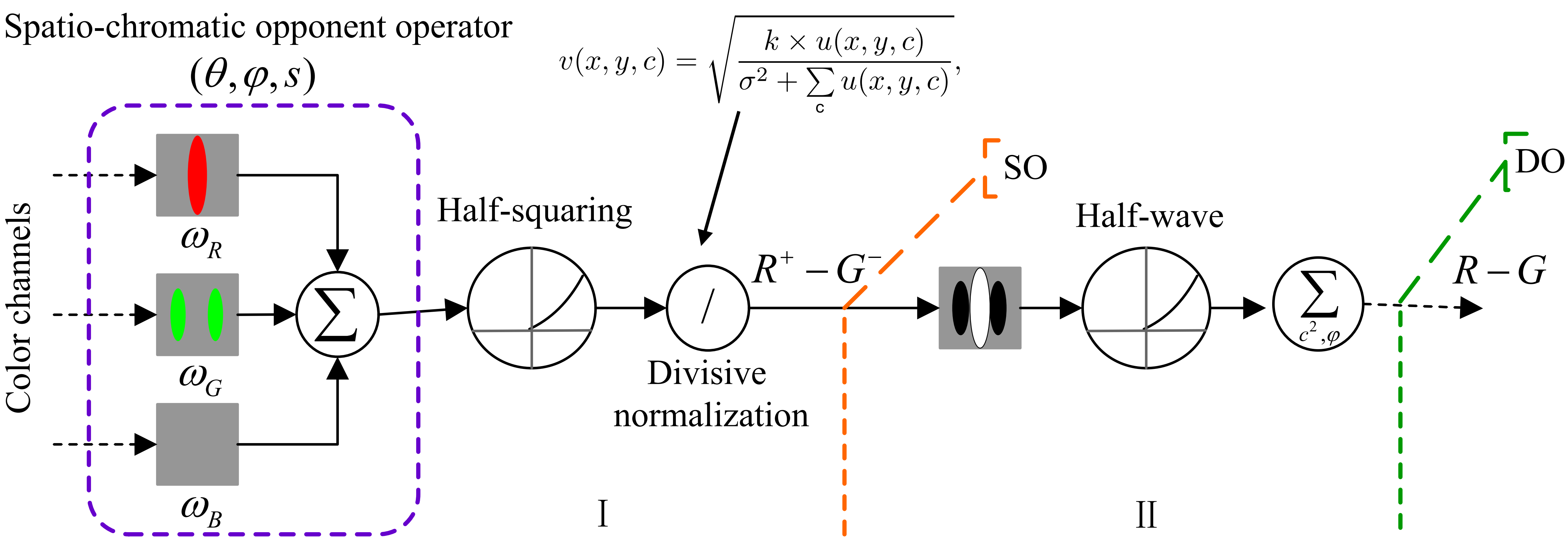


Parameters can be fitted to psychophysics data on color perception

$$\Omega = \begin{pmatrix} \pm 1/\sqrt{2} & \pm 2/\sqrt{6} & \pm 1/\sqrt{6} & \pm 1/\sqrt{3} \\ \mp 1/\sqrt{2} & \mp 1/\sqrt{6} & \pm 1/\sqrt{6} & \pm 1/\sqrt{3} \\ 0 & \mp 1/\sqrt{6} & \mp 2/\sqrt{6} & \pm 1/\sqrt{3} \end{pmatrix}$$

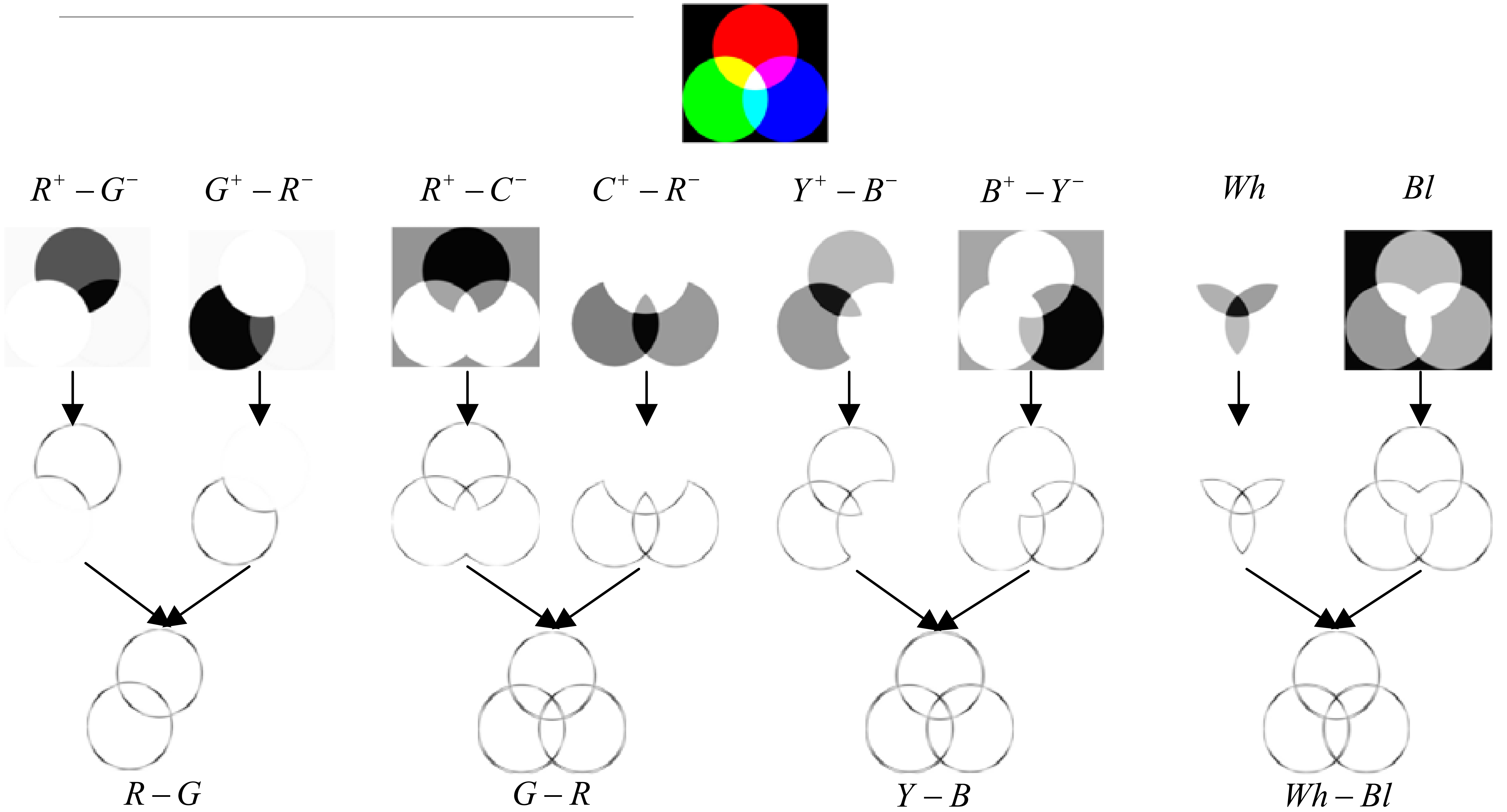
Color processing





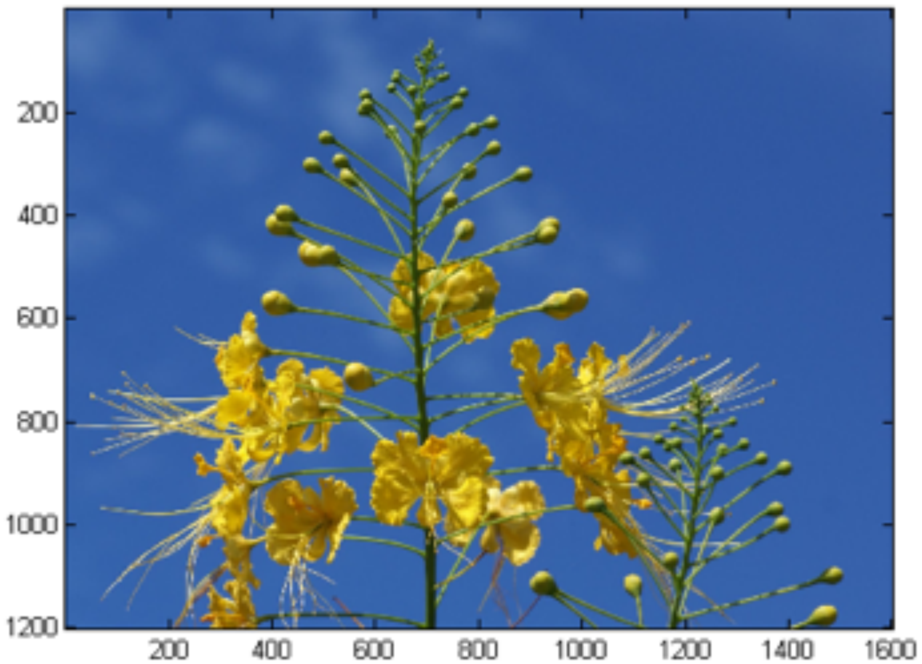
Zhang Barhomi & Serre '12

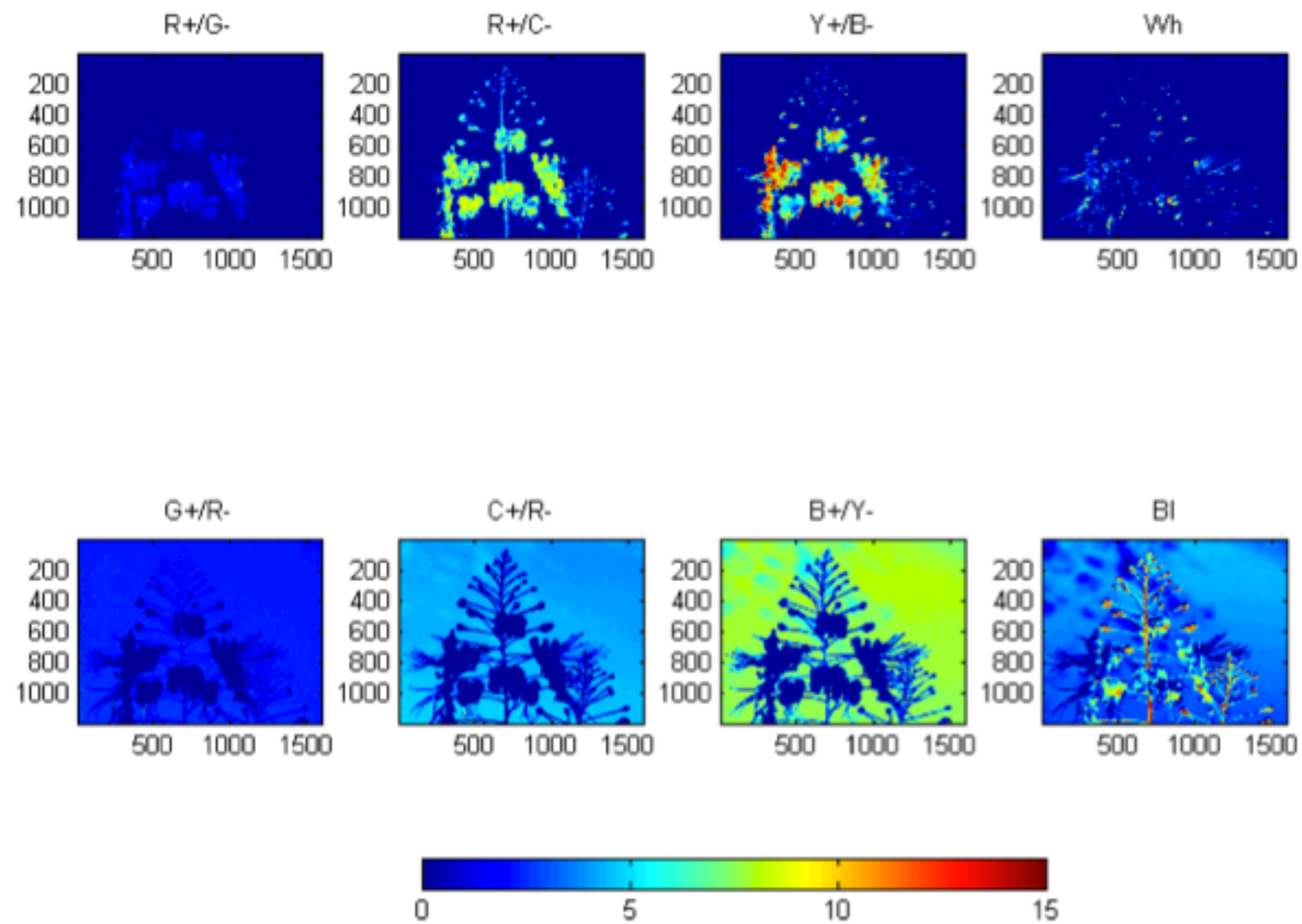
Color processing



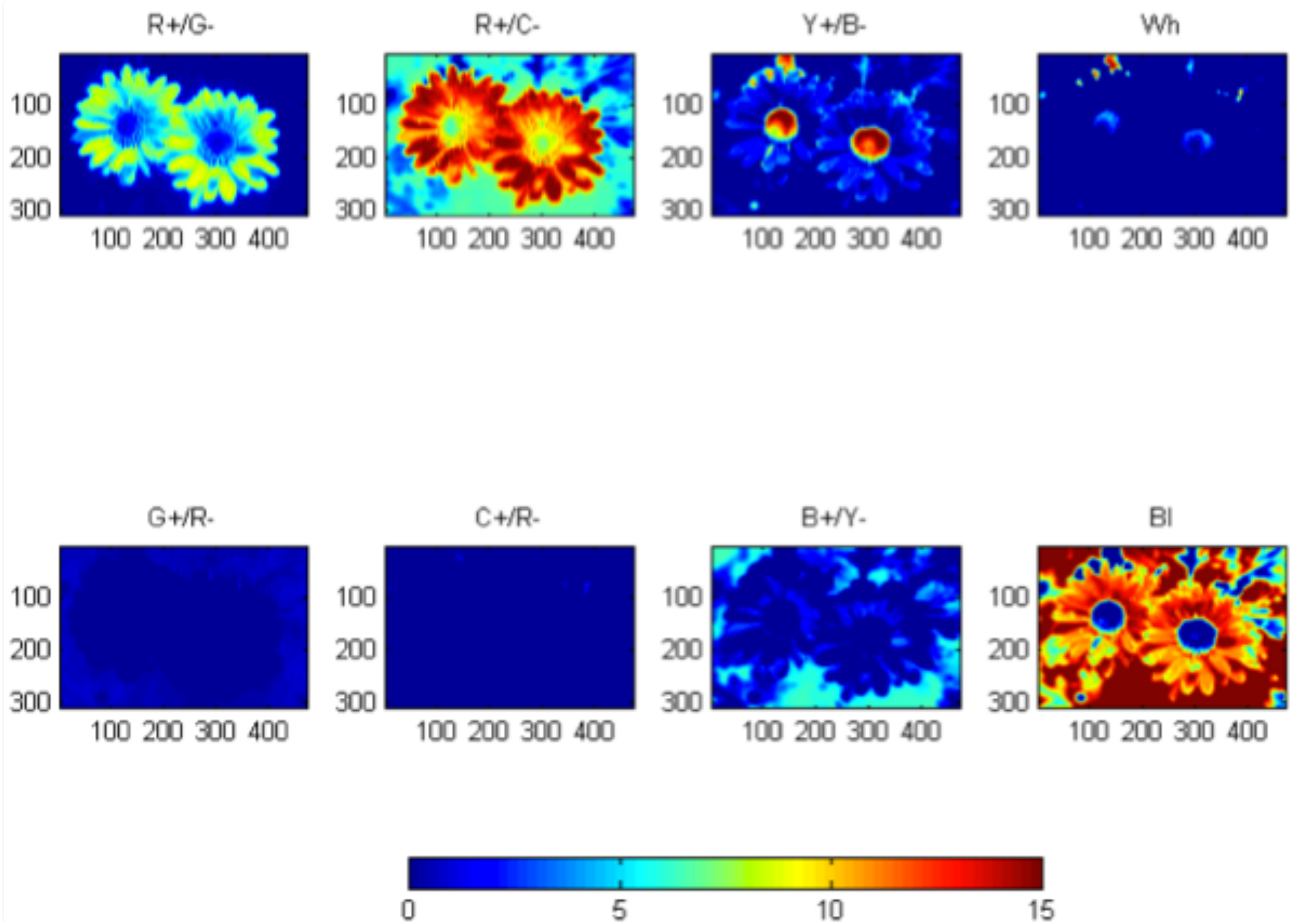
Zhang Barhomi & Serre '12

Computer Vision

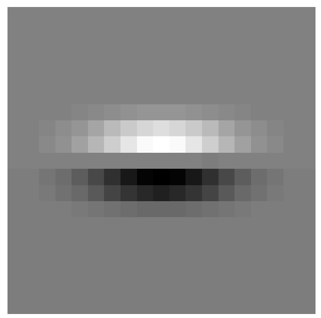


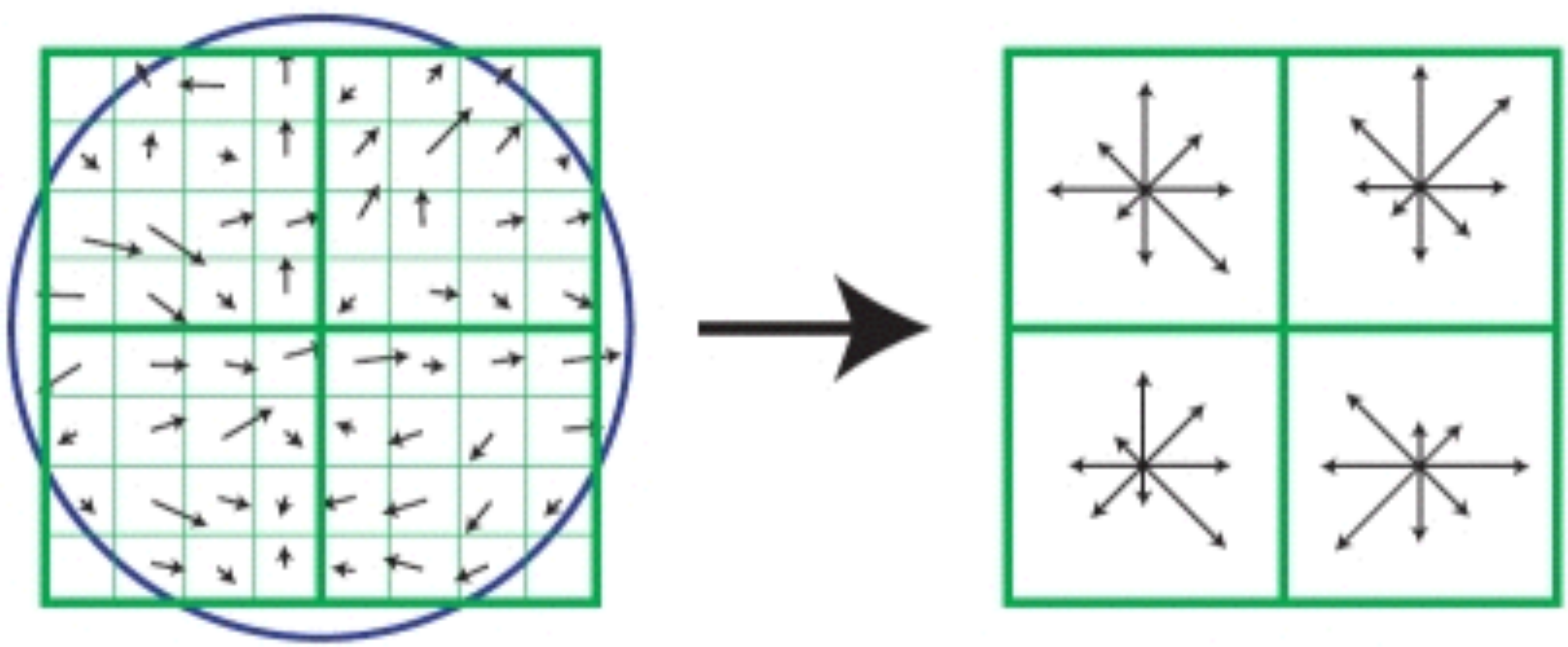


Computer Vision



Color descriptors in computer vision



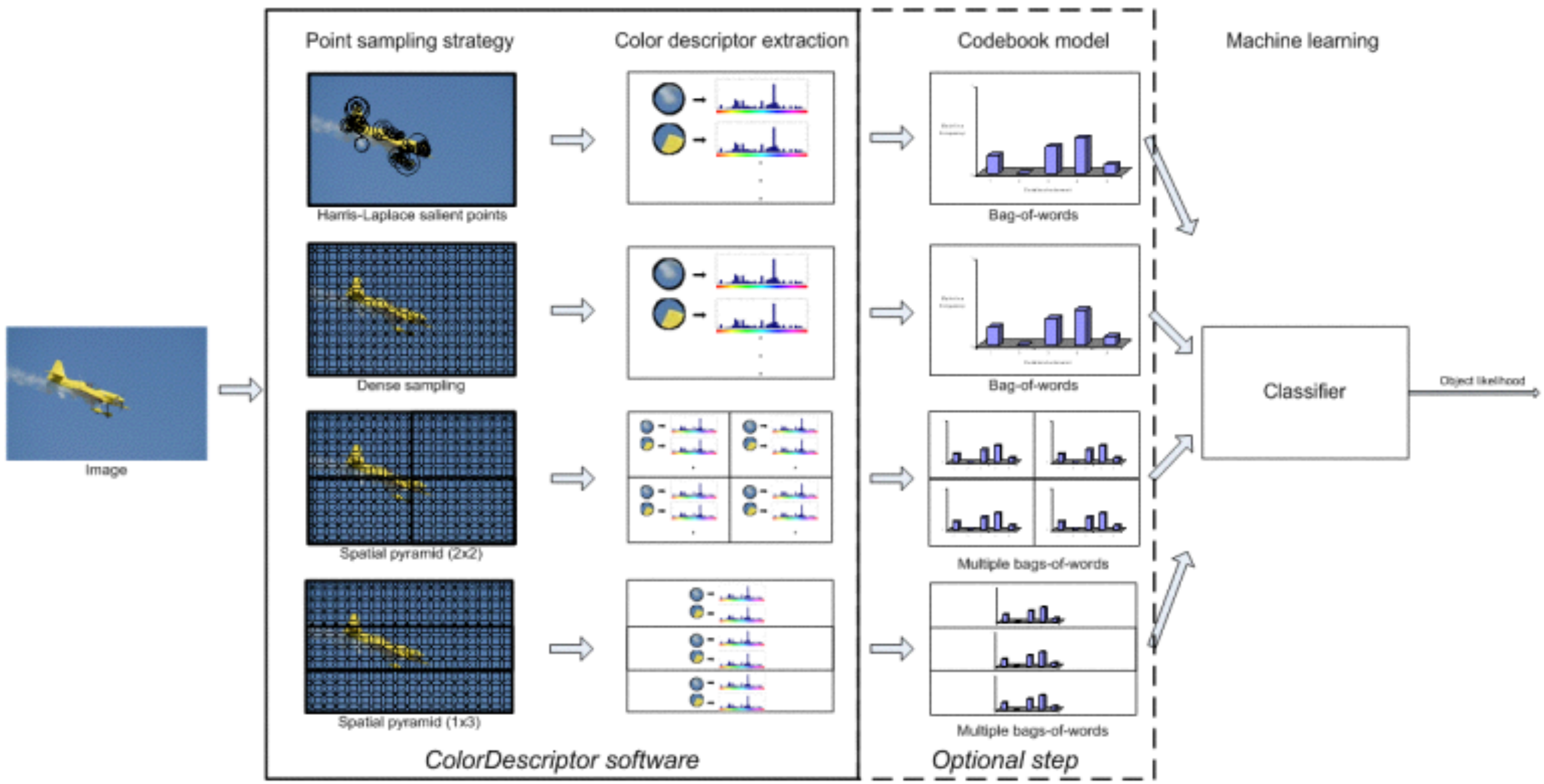


source: David Lowe

Color descriptors in computer vision

ColorDescriptor software

for object and scene categorization



Created by Koen van de Sande
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Available from
http://www.colordescriptors.com

Contours detection with DO

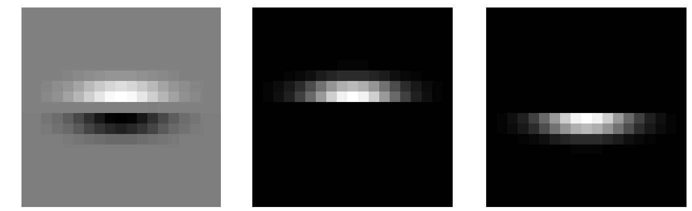
A. Original images B. Double-Opponent gradient C. Specular invariant gradient D. Specular and shadow-shading invariant gradient E. Shadow-shading invariant gradient

Computer Vision

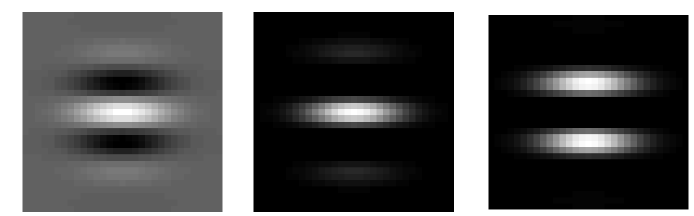
- SO/DO approach improves on all recognition and segmentation datasets tested as compared to existing color representations

Soccer team

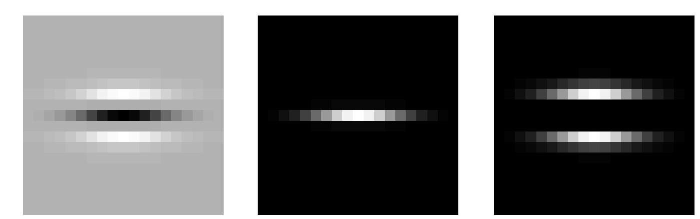
17-category flowers



A. Gradient used in SIFT



B. Gabor filters used in HMAX



C. Gaussian derivatives used in segmentation

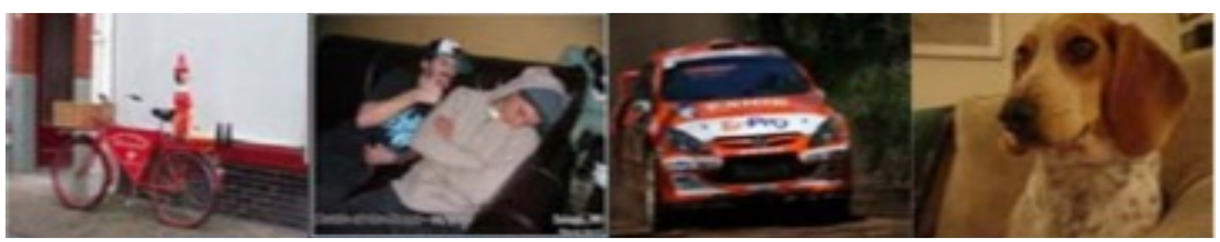
- Color datasets

	Soccer team			Flower		
Method	Color	Shape	Both	Color	Shape	Both
Hue/SIFT	69 (67)	43 (43)	73 (73)	58 (40)	65 (65)	77 (79)
Opp/SIFT	69 (65)	43 (43)	74 (72)	57 (39)	65 (65)	74 (79)
SOSIFT/DOSIFT	82	66	83	68	69	79
SOHMAX/DOHMAX	87	76	89	77	73	83

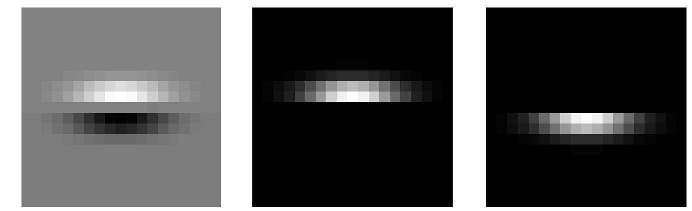
Zhang Barhomi & Serre '12

Computer Vision

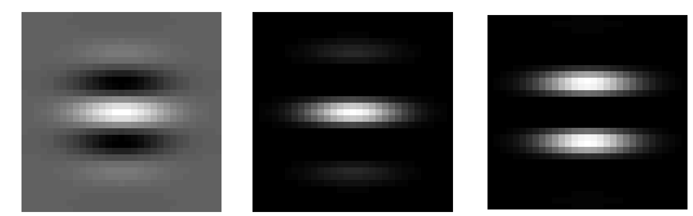
- SO/DO approach improves on all recognition and segmentation datasets tested as compared to existing color representations



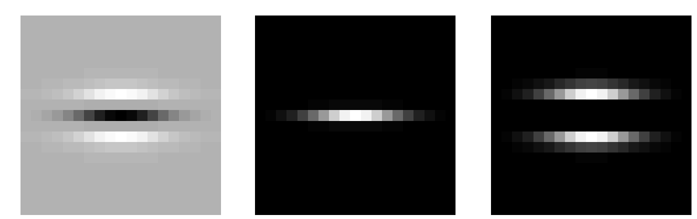
PASCAL VOC 2007



A. Gradient used in SIFT



B. Gabor filters used in HMAX



C. Gaussian derivatives used in segmentation

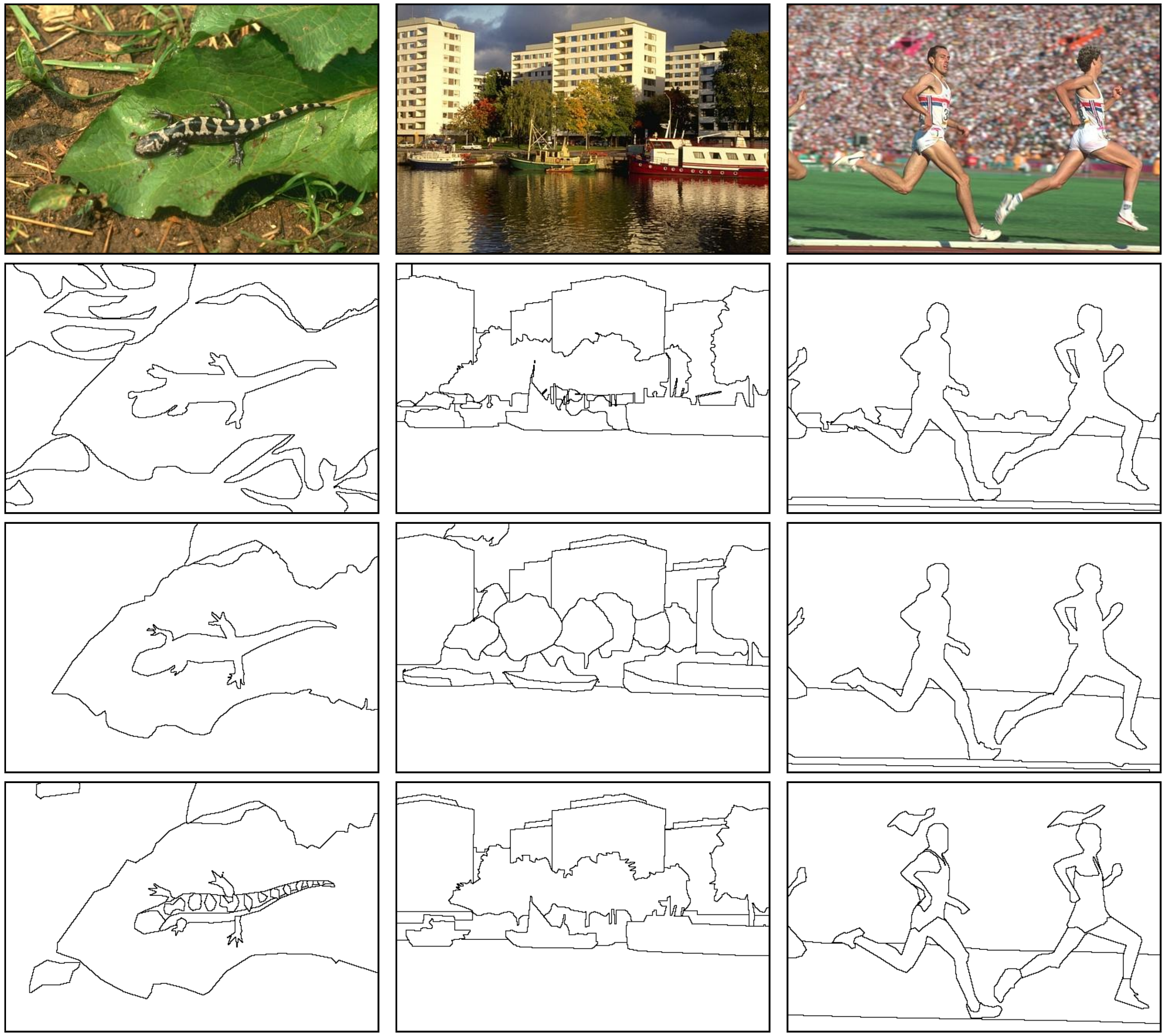
- Pascal challenge

Method	SIFT	HueSIFT	OpponentSIFT	CSIFT	SODOSIFT	SODOHMAX
AP	40 (38.4)	41	43 (42.5)	43 (44.0)	46.5 **(33.3/39.8)**	46.8 **(30.1/36.4)**

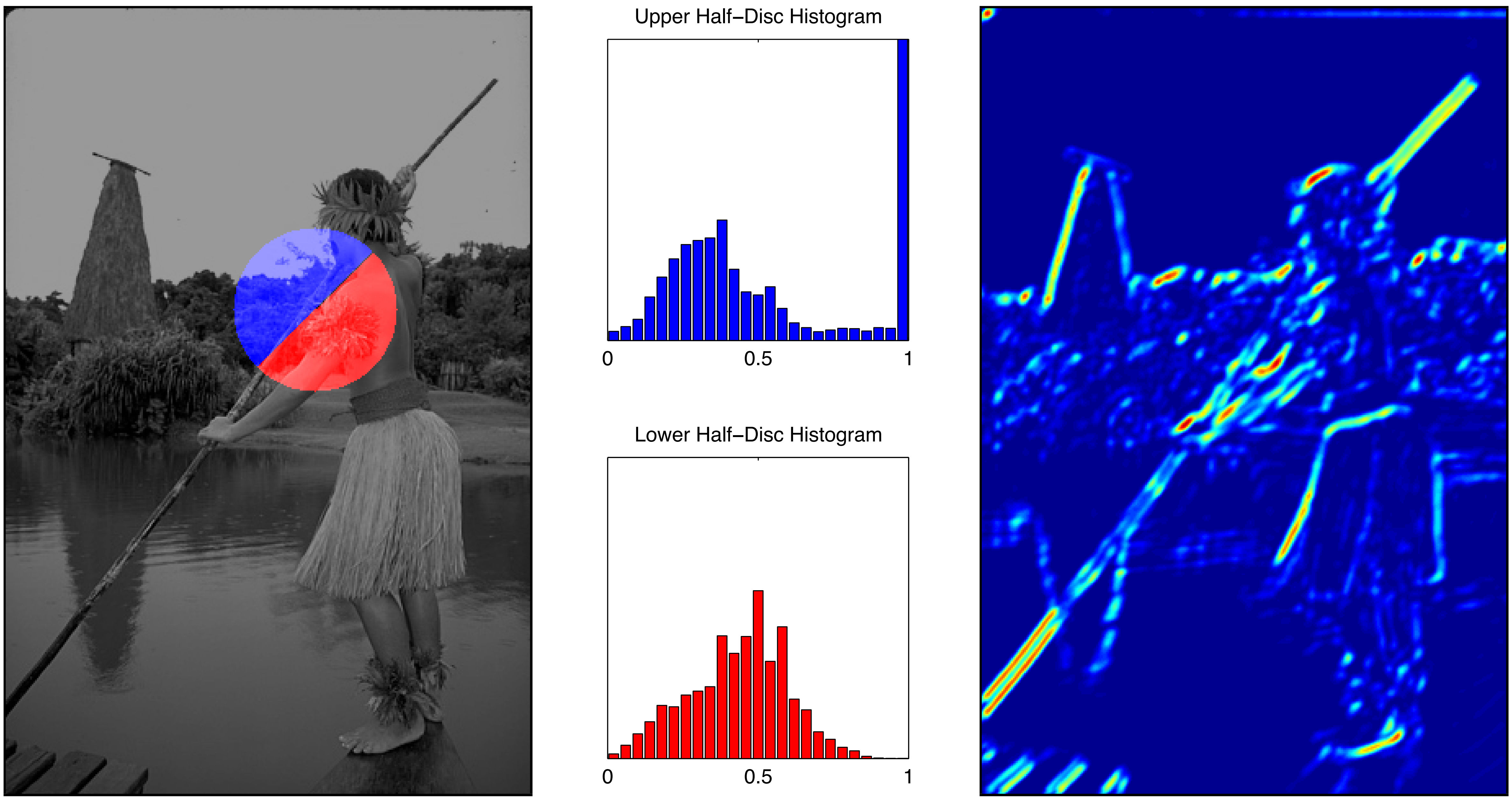
Zhang Barhomi & Serre ’12

Contours detection

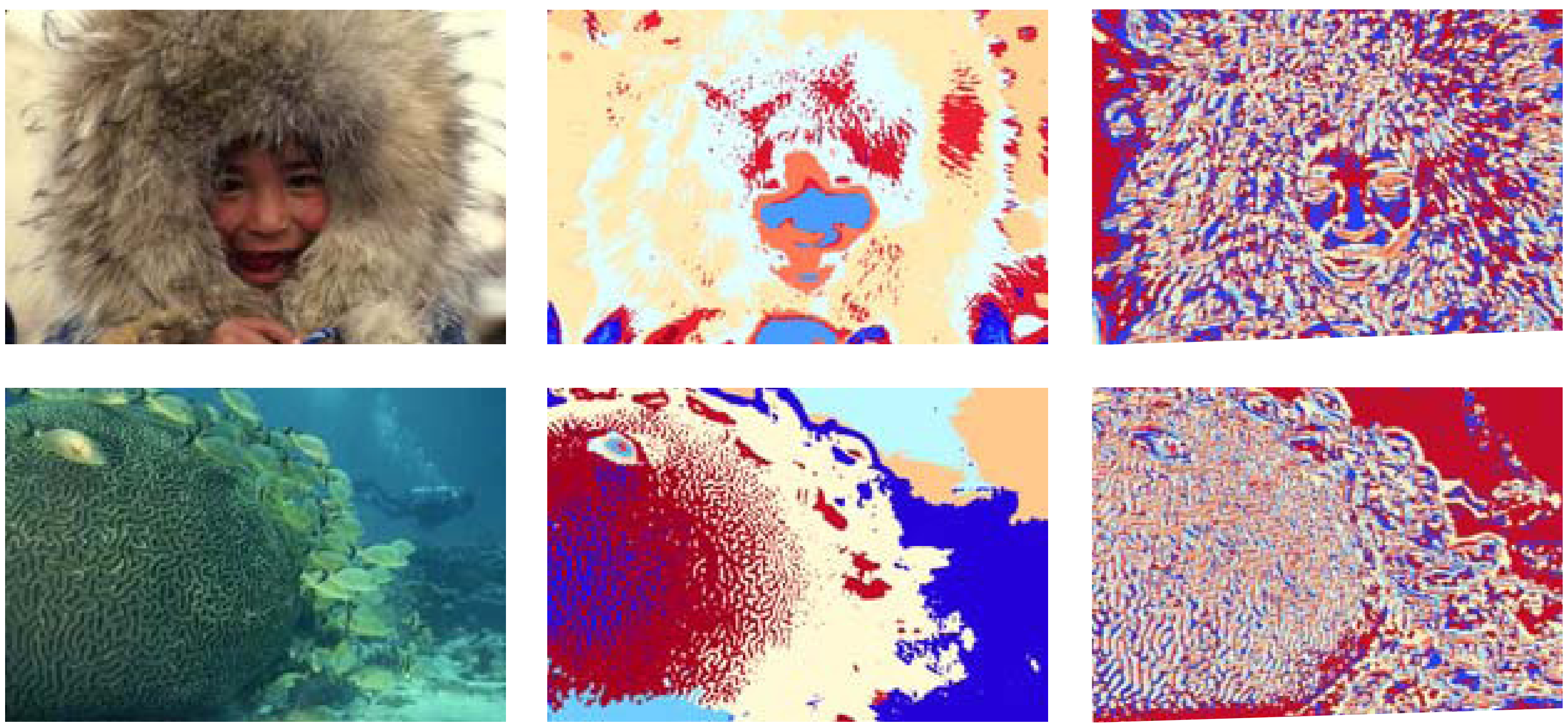
Berkeley segmentation dataset



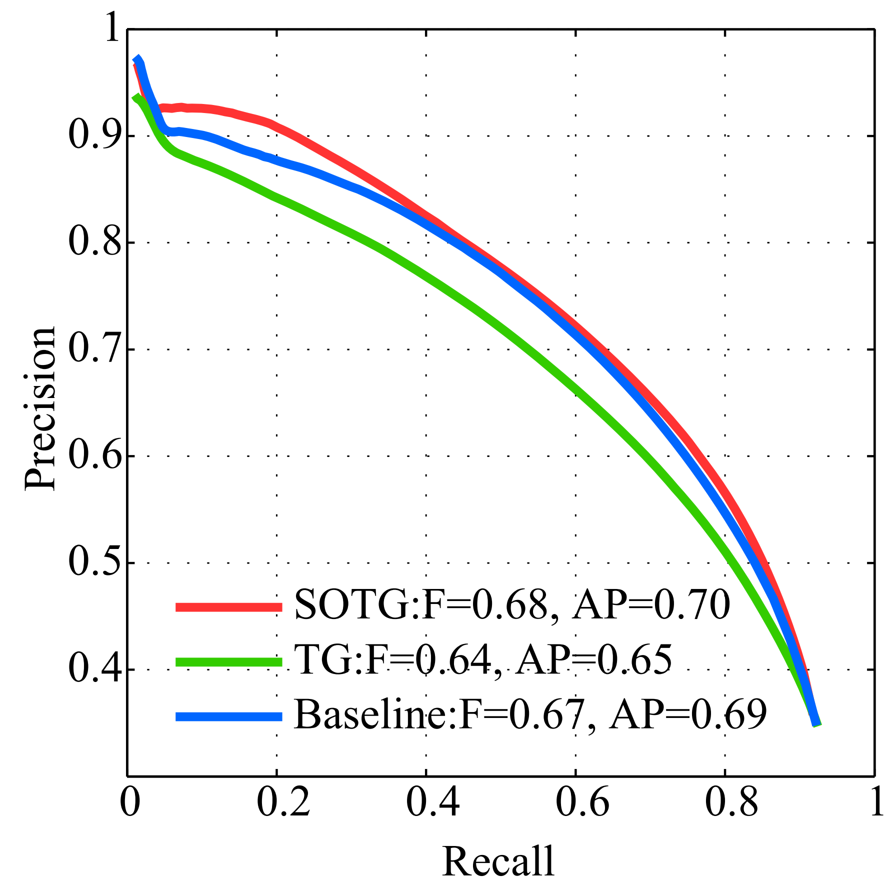
Contours detection



Contours detection



A. Color-texton map vs. grayscale texton map



B. Precision-recall curves

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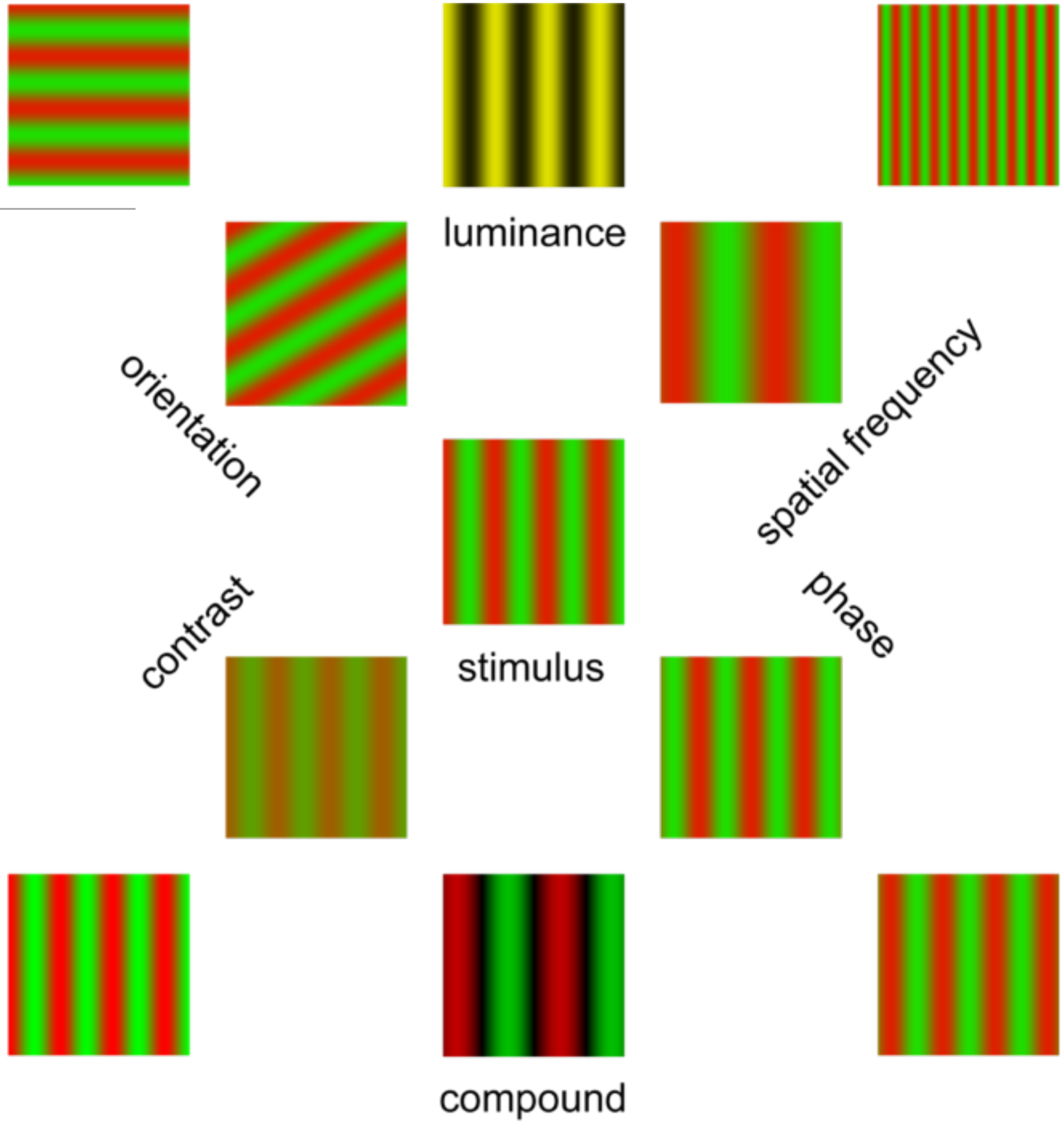
Color gratings



SO cells

L-increment excitatory

M-decrement excitatory

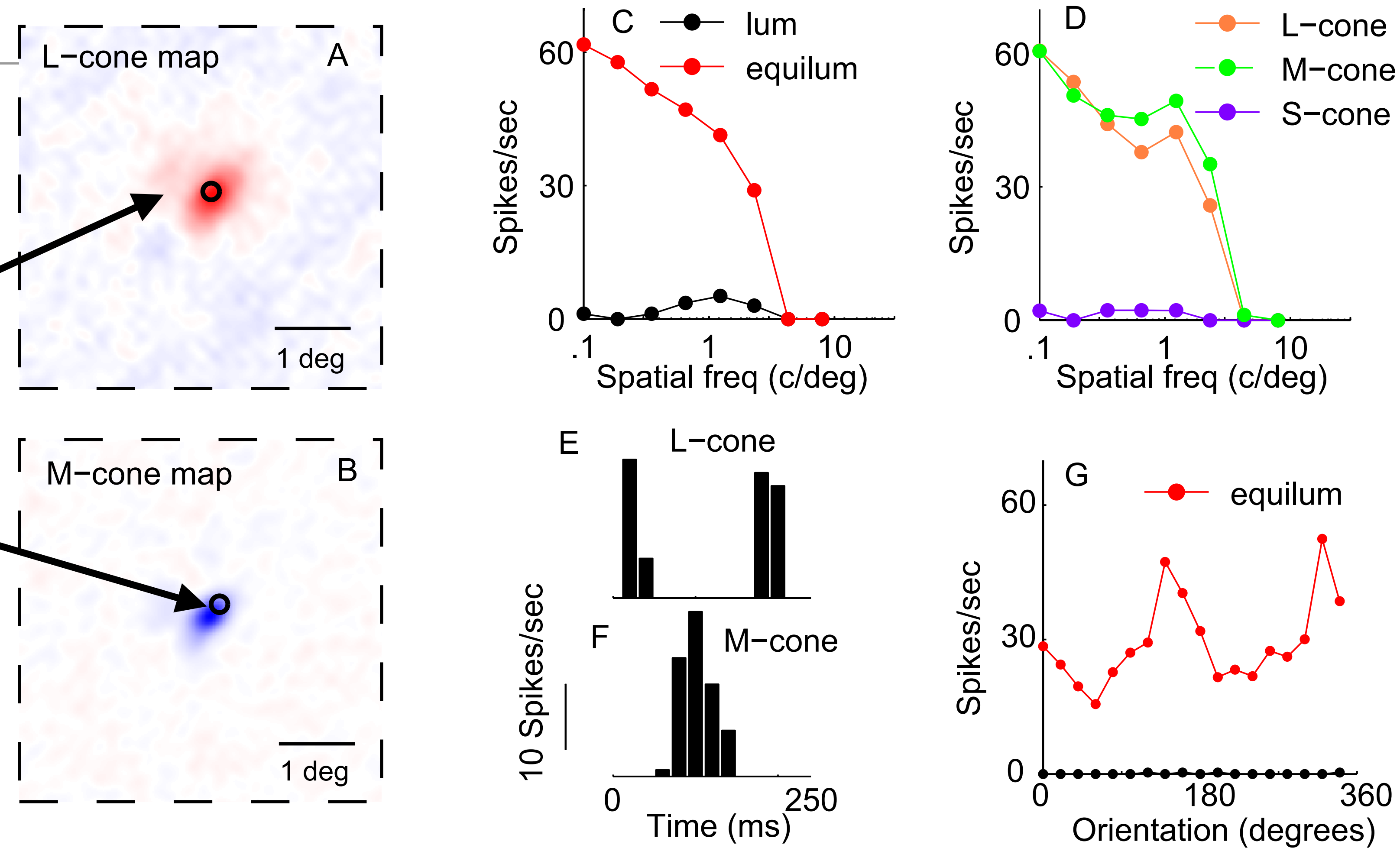
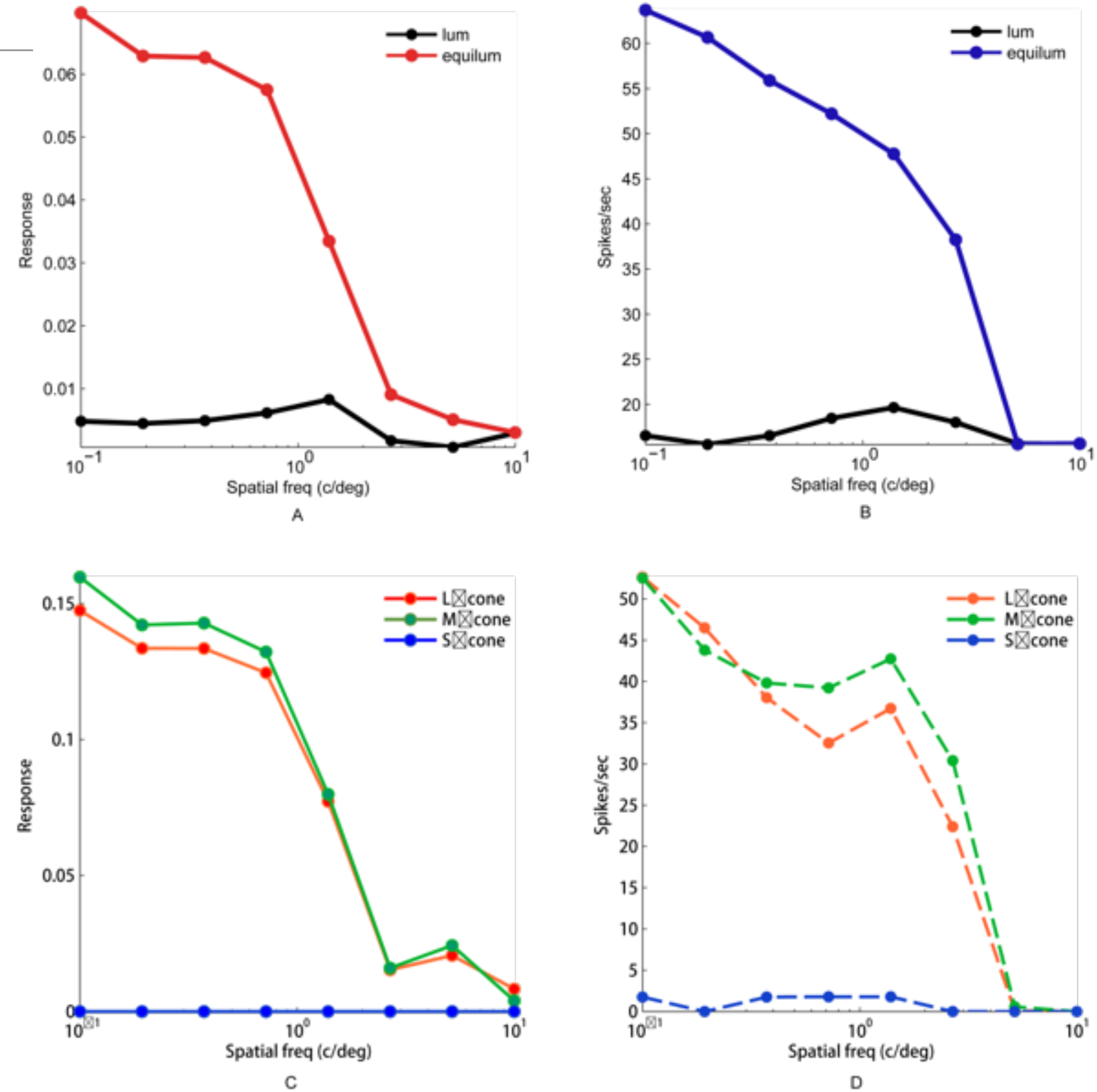


Figure 3. An example of a V1 single-opponent neuron from layer 6. ***A***, ***B***, Two-dimensional maps (from subspace reverse correlation) of the sensitivity of this cell for L- (***A***) and M- (***B***) cone-isolating patterns. Plotting conventions are as in Figure 1. ***C***, Spatial-frequency (freq) responses for luminance (lum) and equiluminant (equilum) red–green gratings. This cell responded very weakly to luminance patterns of 0.2 contrast and was spatially low-pass for red–green equiluminant patterns (rms cone contrast = 0.14). ***D***, Spatial-frequency responses for L-, M-, and S-cone-isolating patterns. The low-pass tuning curve data to L- and M-cone-isolating gratings are consistent with the absence of spatial opponency of the spatial maps of cone inputs to this neuron shown in ***A*** and ***B***. This L+M− single-opponent cell had very weak responses to S-cone-isolating stimuli. L-, M-, and S-cone contrasts were 0.13, 0.15, and 0.24, respectively. ***E***, ***F***, Temporal phase of L- and M-cone inputs. PSTHs of the responses to L- (***E***) and M- (***F***) cone-isolating, drifting grating patterns of optimal spatial frequency and orientation. The PSTHs to M-cones and L-cones are precisely out of phase, meaning the cone inputs are of opposite sign. ***G***, Orientation tuning for equiluminant and luminance patterns. Responses to equiluminant red–green drifting gratings of optimal spatial frequency are plotted in red (rms cone contrast = 0.14; O/P ratio = 0.56; CV = 0.87). The responses to luminance patterns (0.15 contrast stimuli; points plotted in black) were negligible.

Johnson et al 2008

Model SO

Model | **Johnson et al 2008**



DO cells

L-decrement excitatory

M-increment excitatory

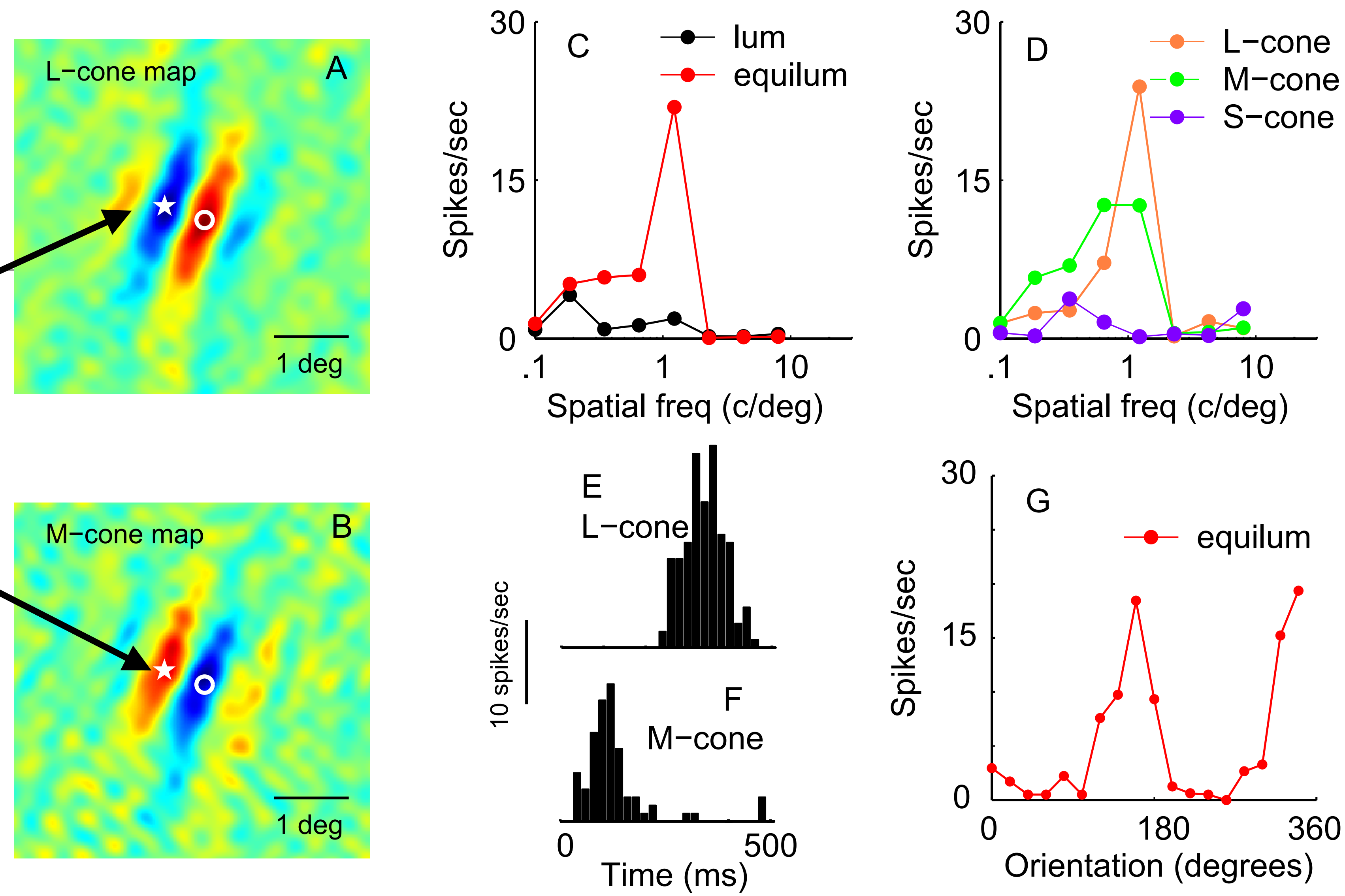
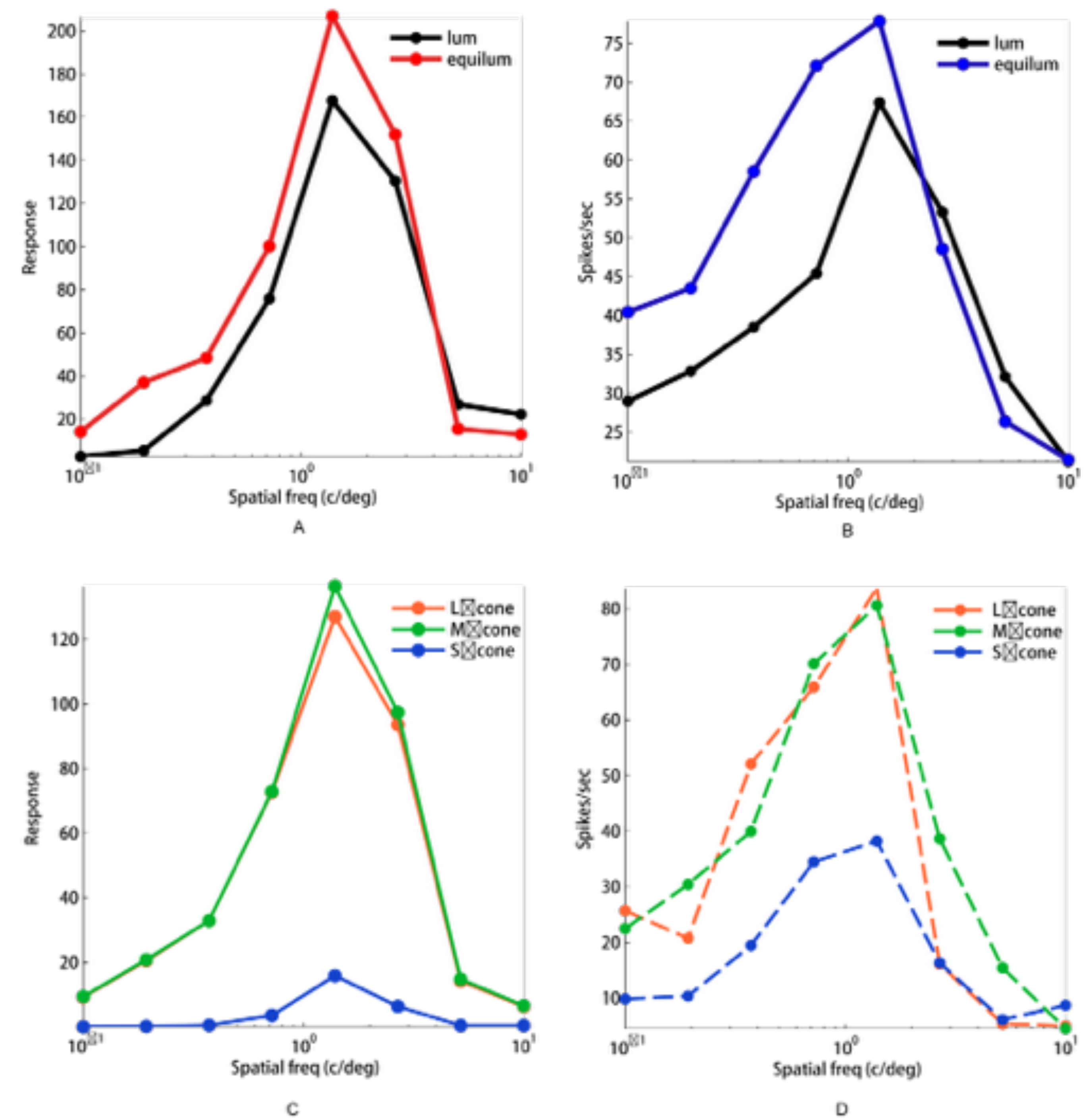


Figure 1. Double-opponent simple cell from layer 2/3. ***A***, ***B***, Two-dimensional maps (from subspace reverse correlation) of the sensitivity of this cell for L- (***A***) and M- (***B***) cone-isolating patterns. The pseudocolor maps depict excitation to increments in red and excitation to decrements in blue. Fixed points in the visual field are designated with a star and with an open circle to facilitate comparison between the L- and M-cone maps. At the star location, the L-cone map is decrement excitatory, whereas the M-cone map is increment excitatory, and vice versa for the location marked by the open circle. ***C***, Spatial-frequency (freq) responses for luminance (lum) and equiluminant (equilum) red–green gratings. This cell responded very weakly to luminance patterns of 0.2 contrast, and was spatial-frequency tuned for red–green equiluminant patterns (rms cone contrast = 0.14). ***D***, Spatial-frequency responses for L-, M-, and S-cone-isolating patterns. The bandpass tuning curve data to L- and M-cone-isolating gratings are consistent with the spatial opponency of the cone inputs to this neuron shown in ***A*** and ***B***. L-, M-, and S-cone contrasts were set at 0.13, 0.15, and 0.24, respectively. ***E***, ***F***, Temporal phase of L- and M-cone inputs. PSTHs of the responses to L- (***E***) and M- (***F***) cone-isolating, drifting grating patterns with a temporal frequency of 2 Hz and optimal spatial frequency and orientation are shown. The PSTHs to M-cones and L-cones are precisely out of phase, meaning the cone inputs are of opposite sign. ***G***, Orientation tuning in response to equiluminant red–green drifting gratings of optimal spatial frequency (rms cone contrast = 0.14; O/P ratio < 0.01; CV = 0.32).

Johnson et al 2008

Model DO

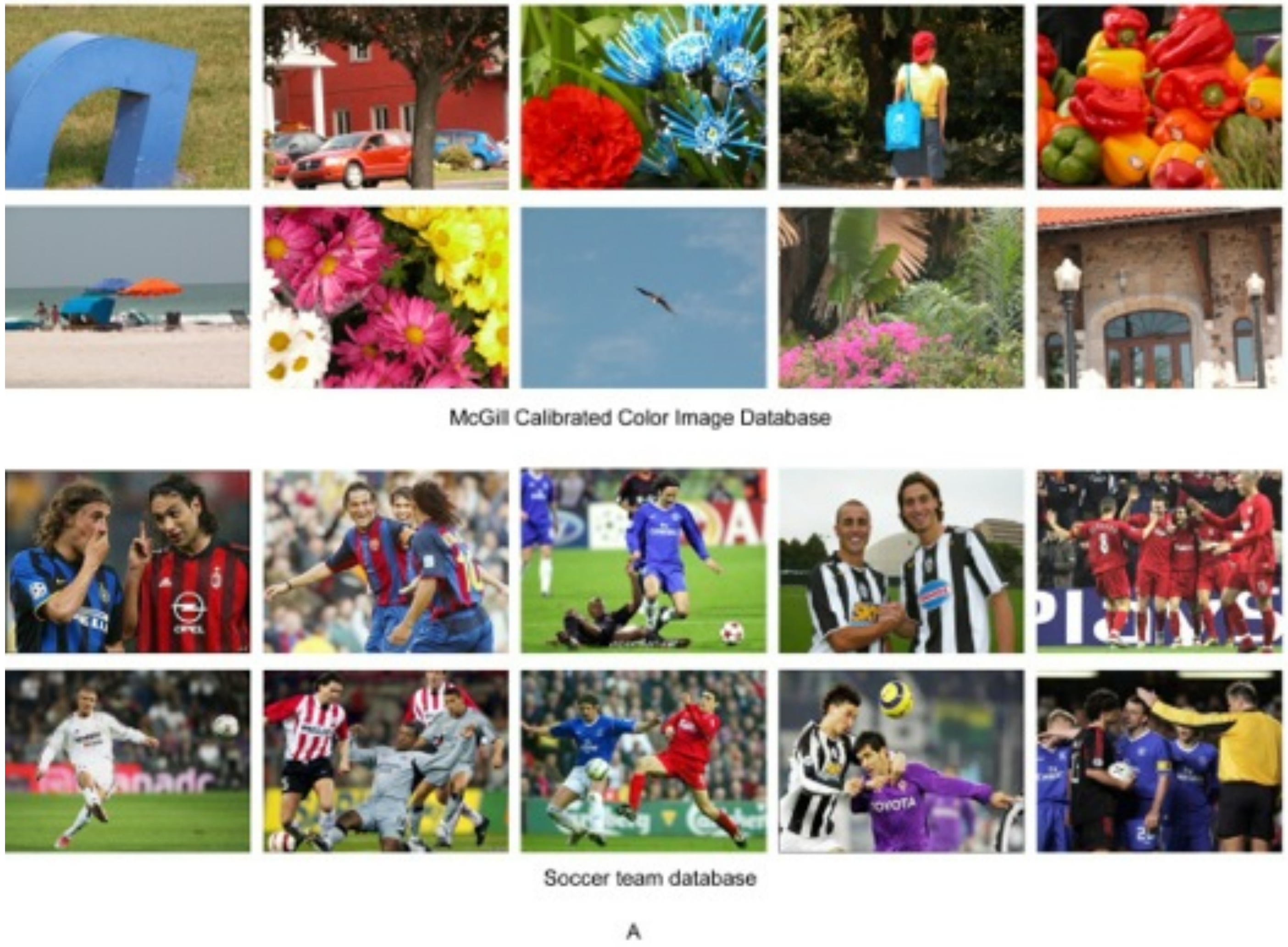
Model **Johnson et al 2008**



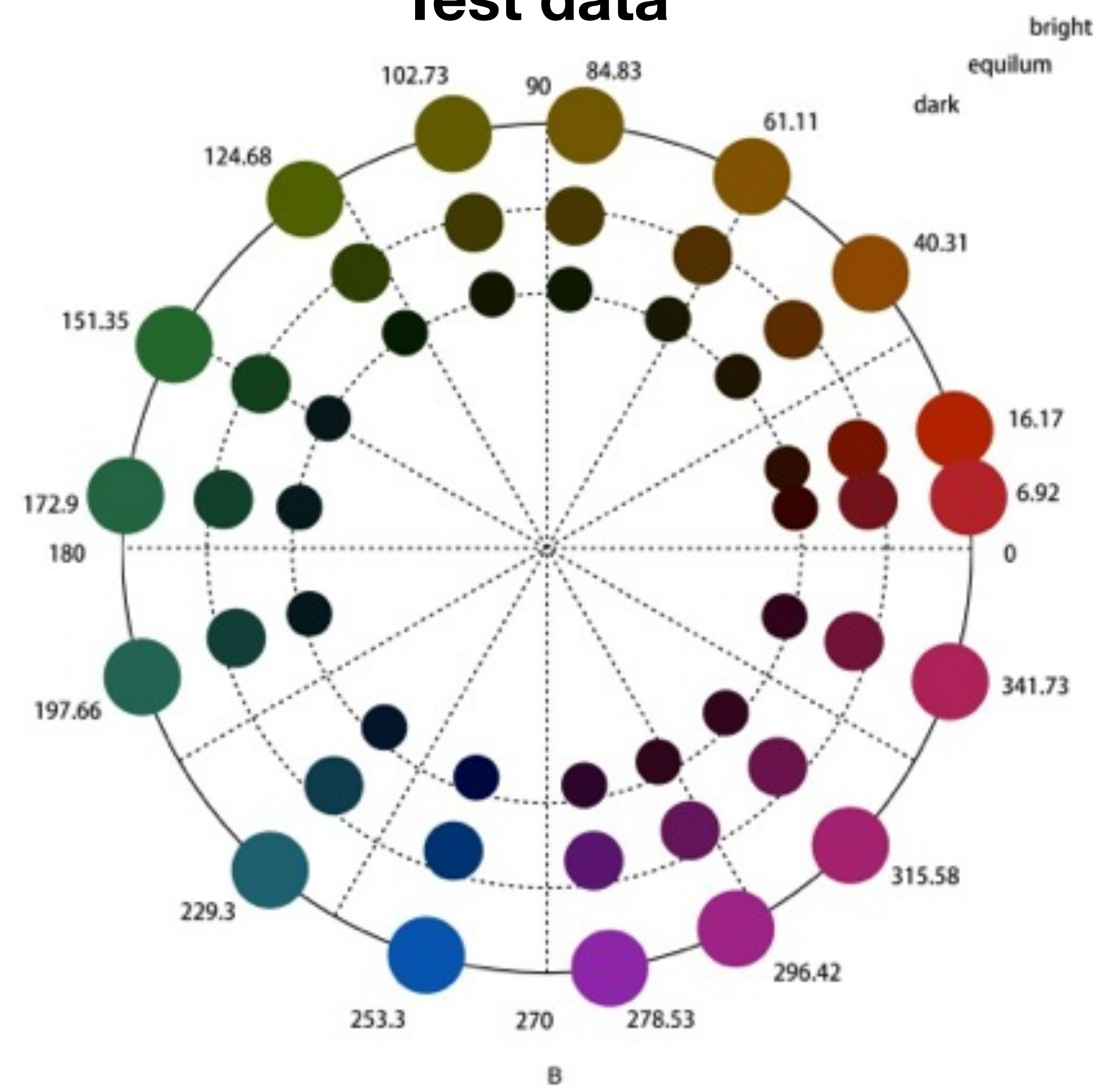
Johnson et al 2008

Beyond V1: Comparison with glob cells in V4/PIT

Model training data



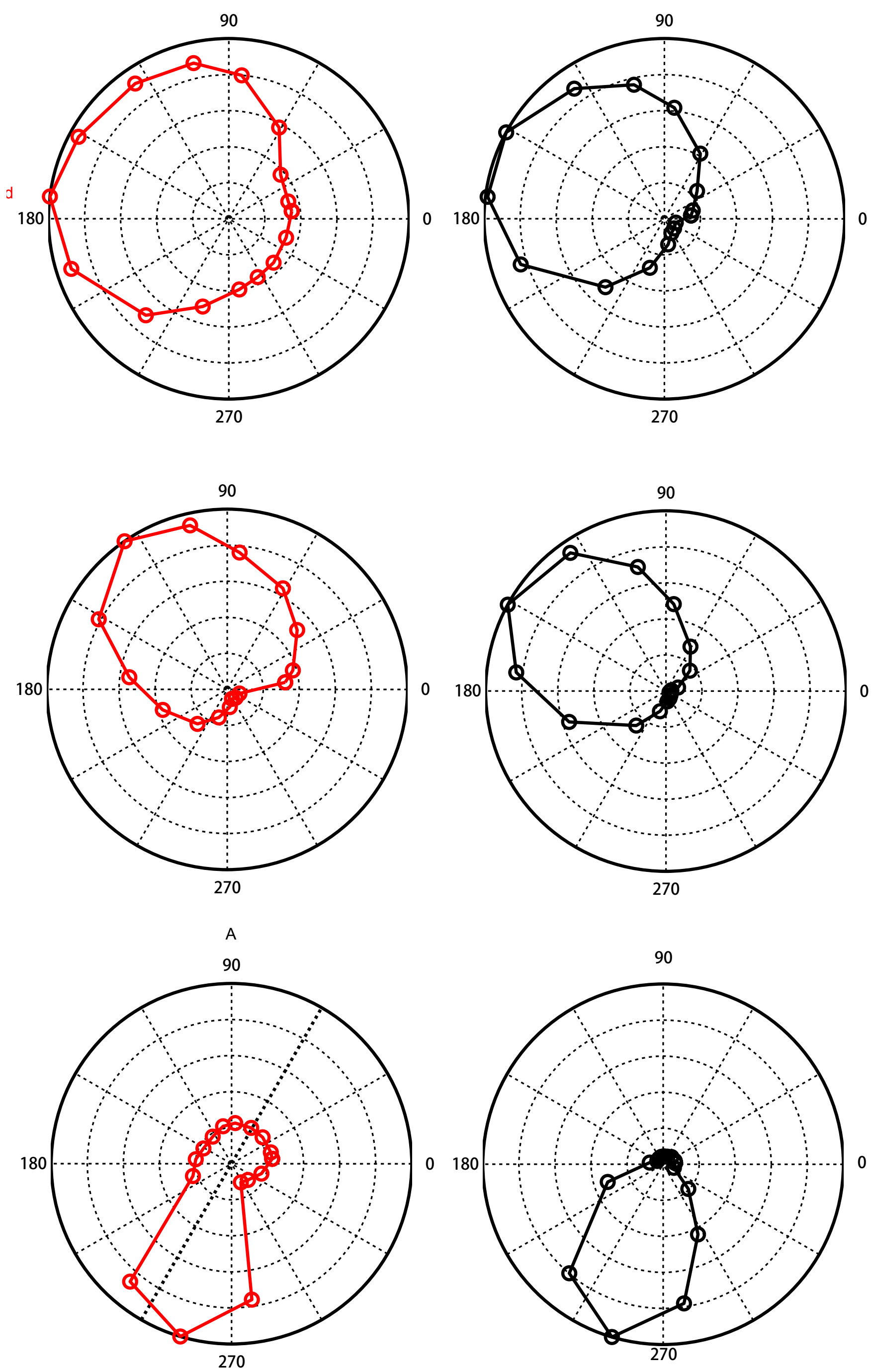
Test data

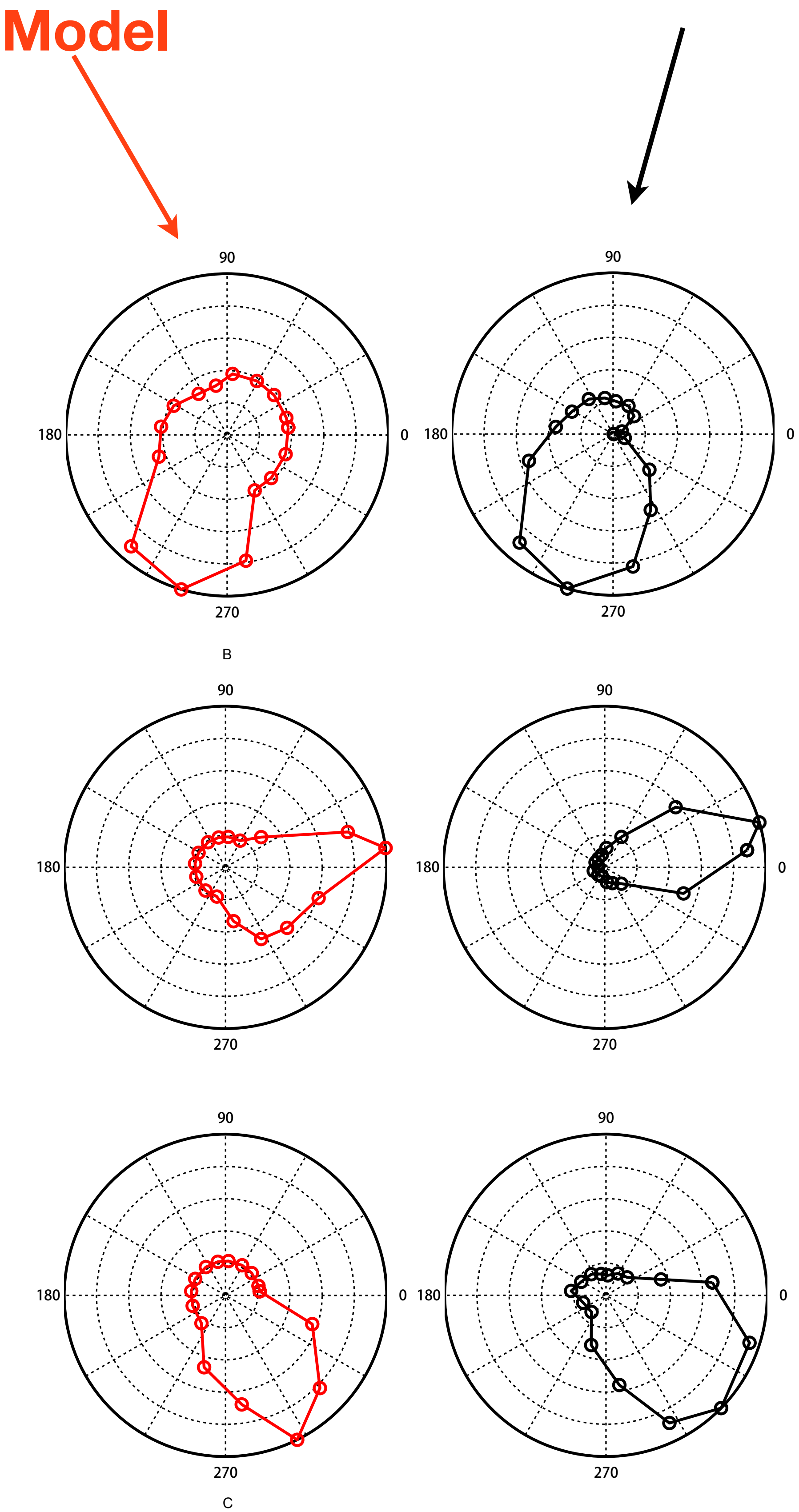


Beyond V1: Comparison with glob cells in V4/PIT

Glob cells (Conway & Tsao '09)

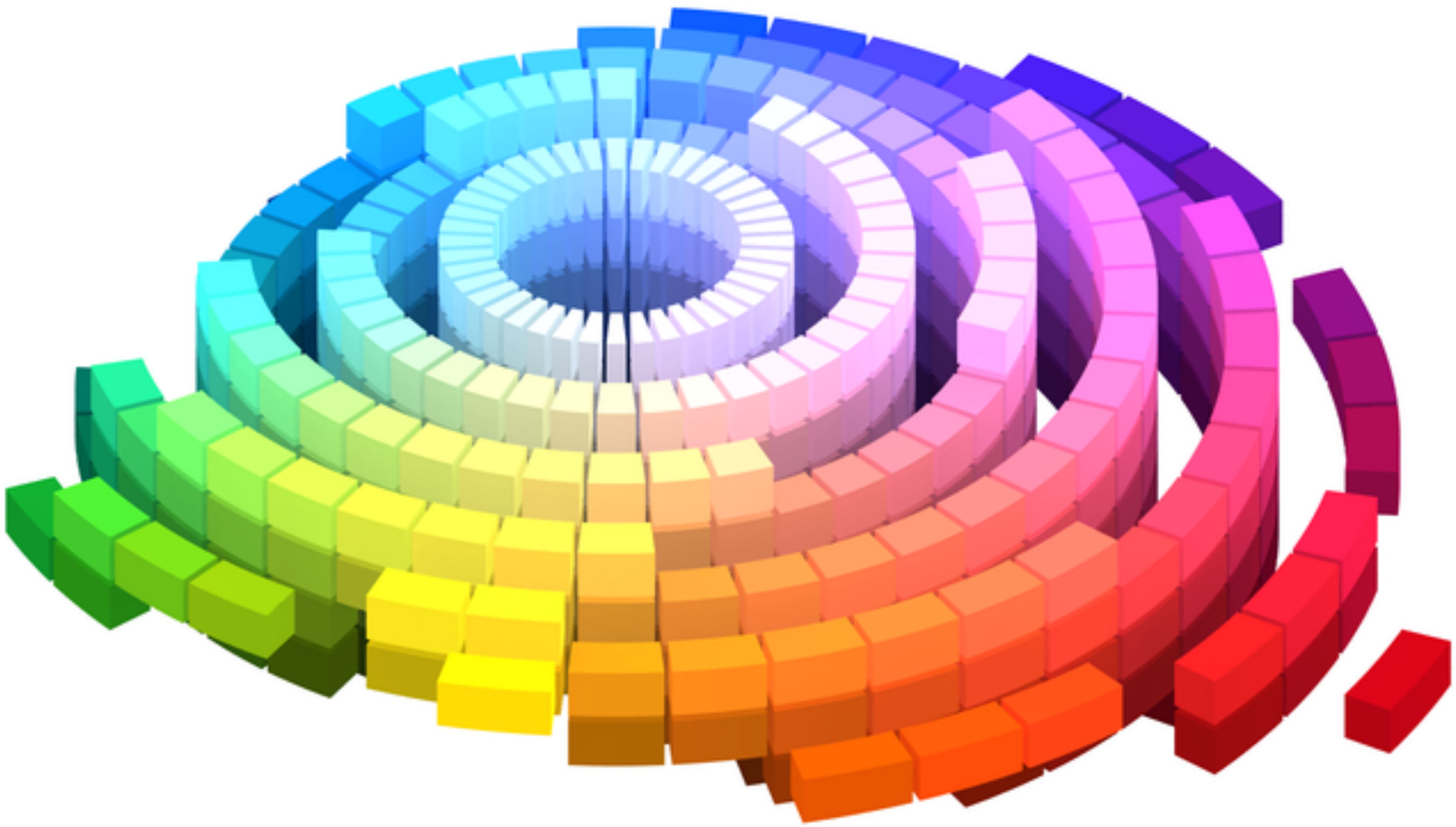
Model





Zhang & Serre in prep

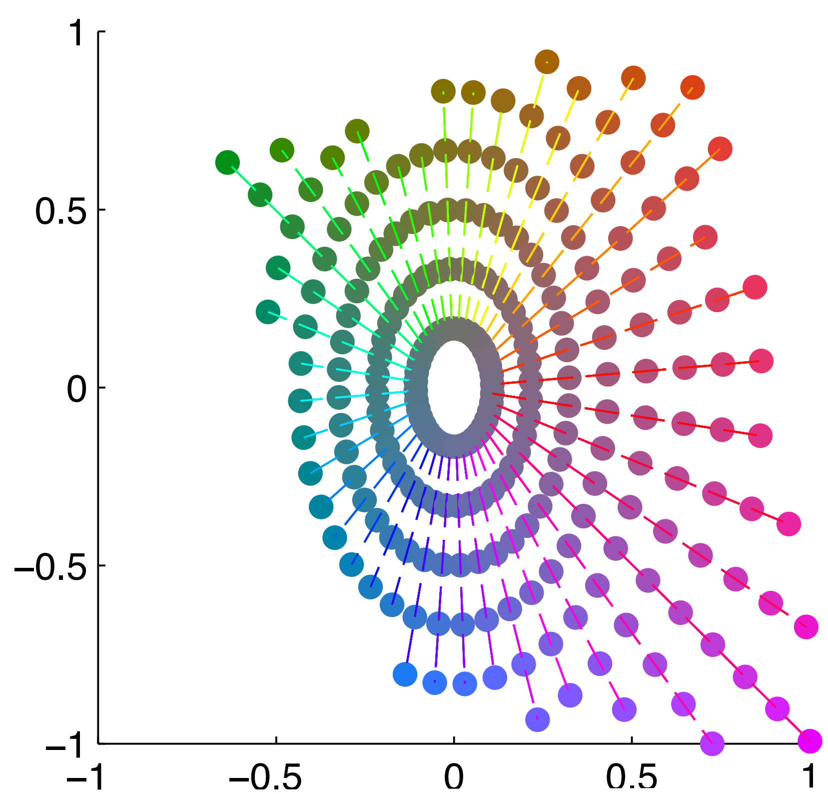
Munsell space



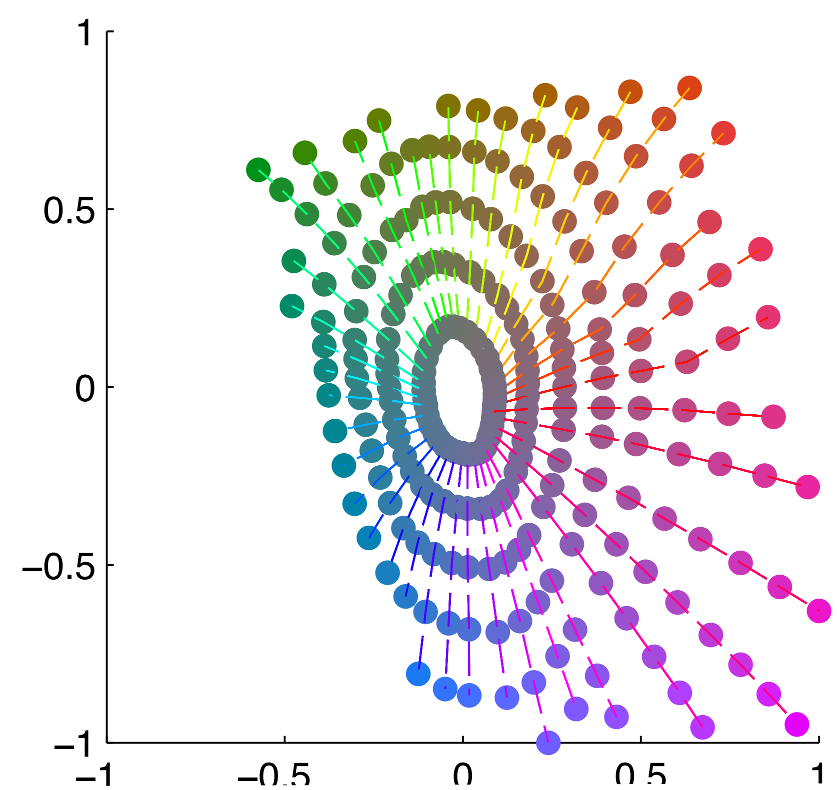
source: wikipedia

Munsell space

Munsell data



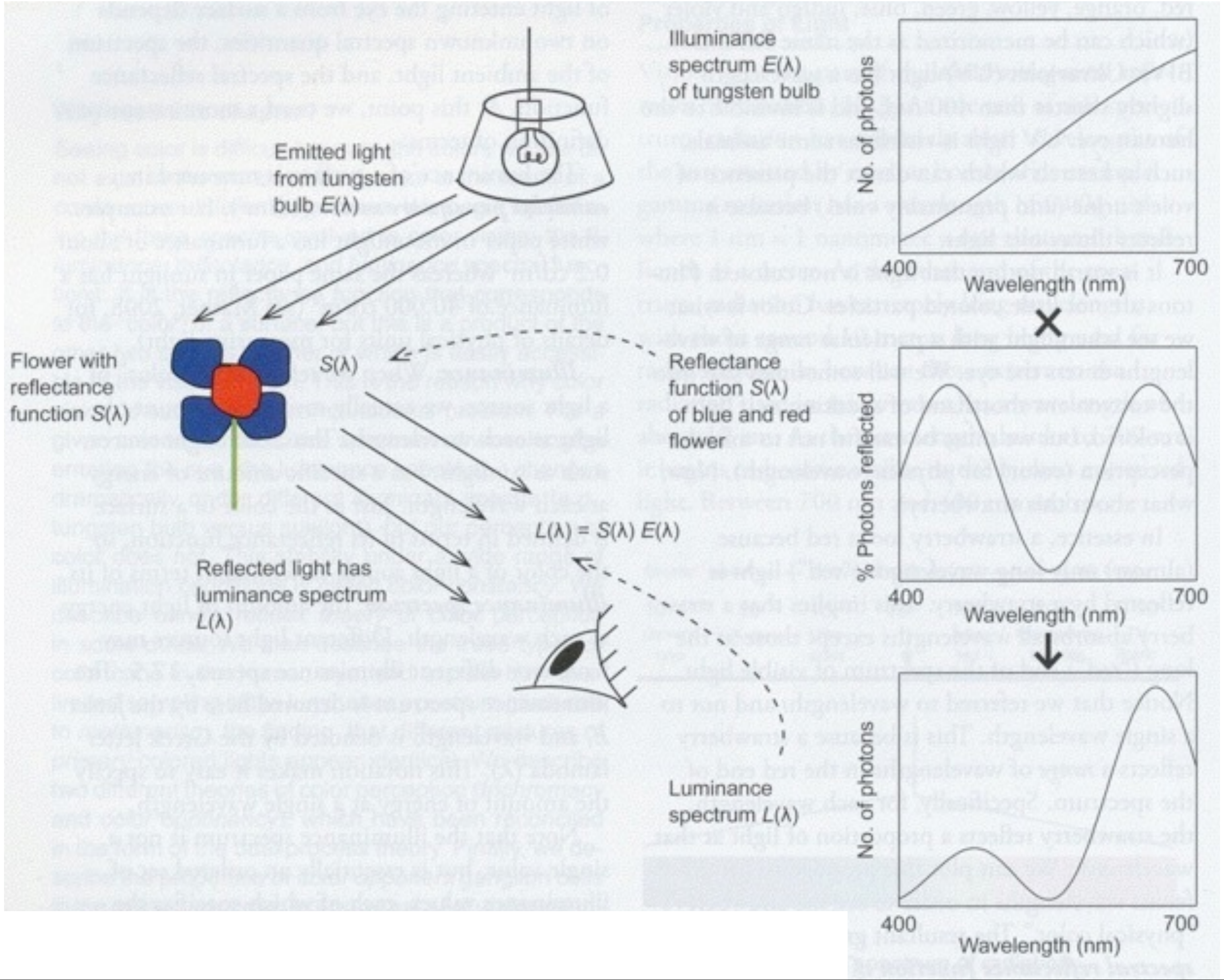
Model



Zhang & Serre in prep

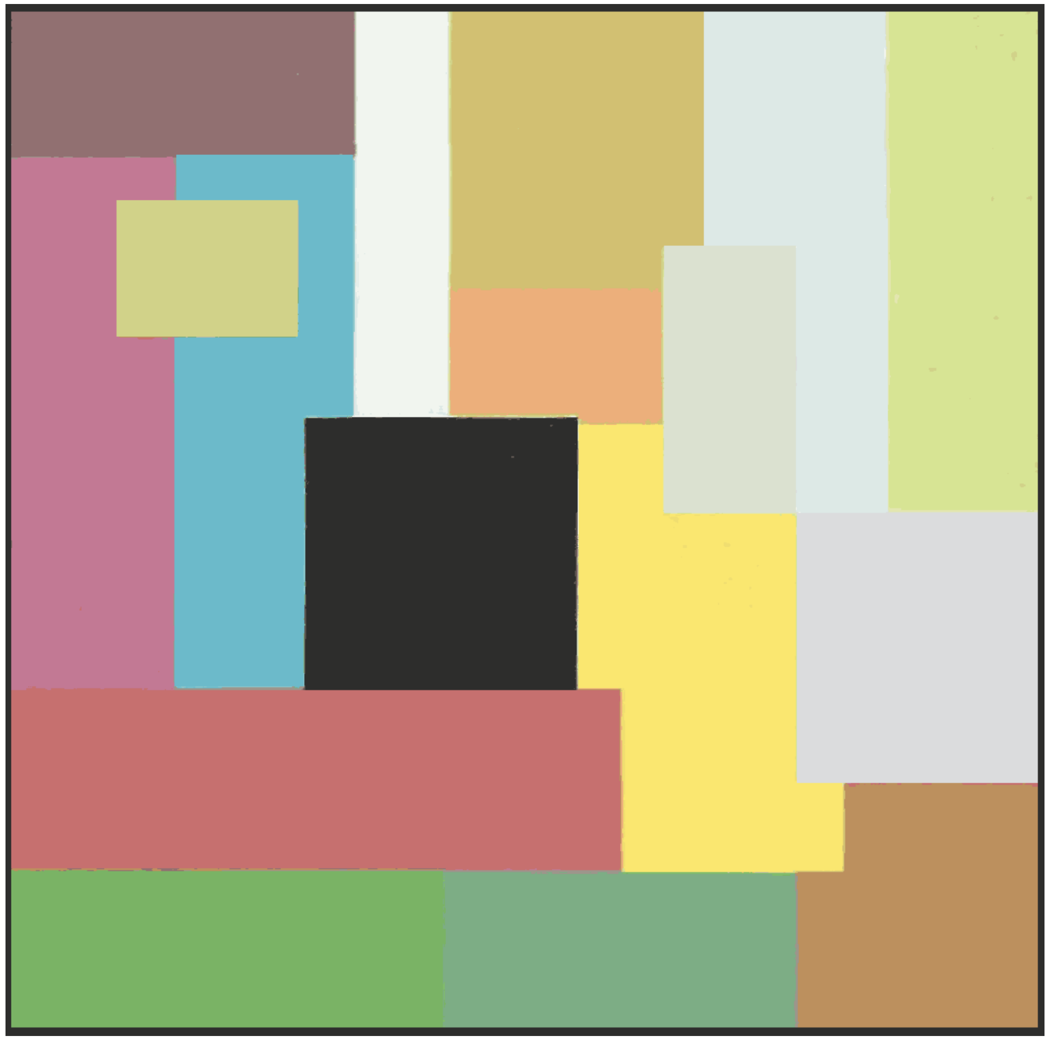
Color constancy

- Color constancy: Perceived colors highly tolerant to light source (eg green or red)



source: Frisby & Stone

The Land-Mondrian experiments (1964)



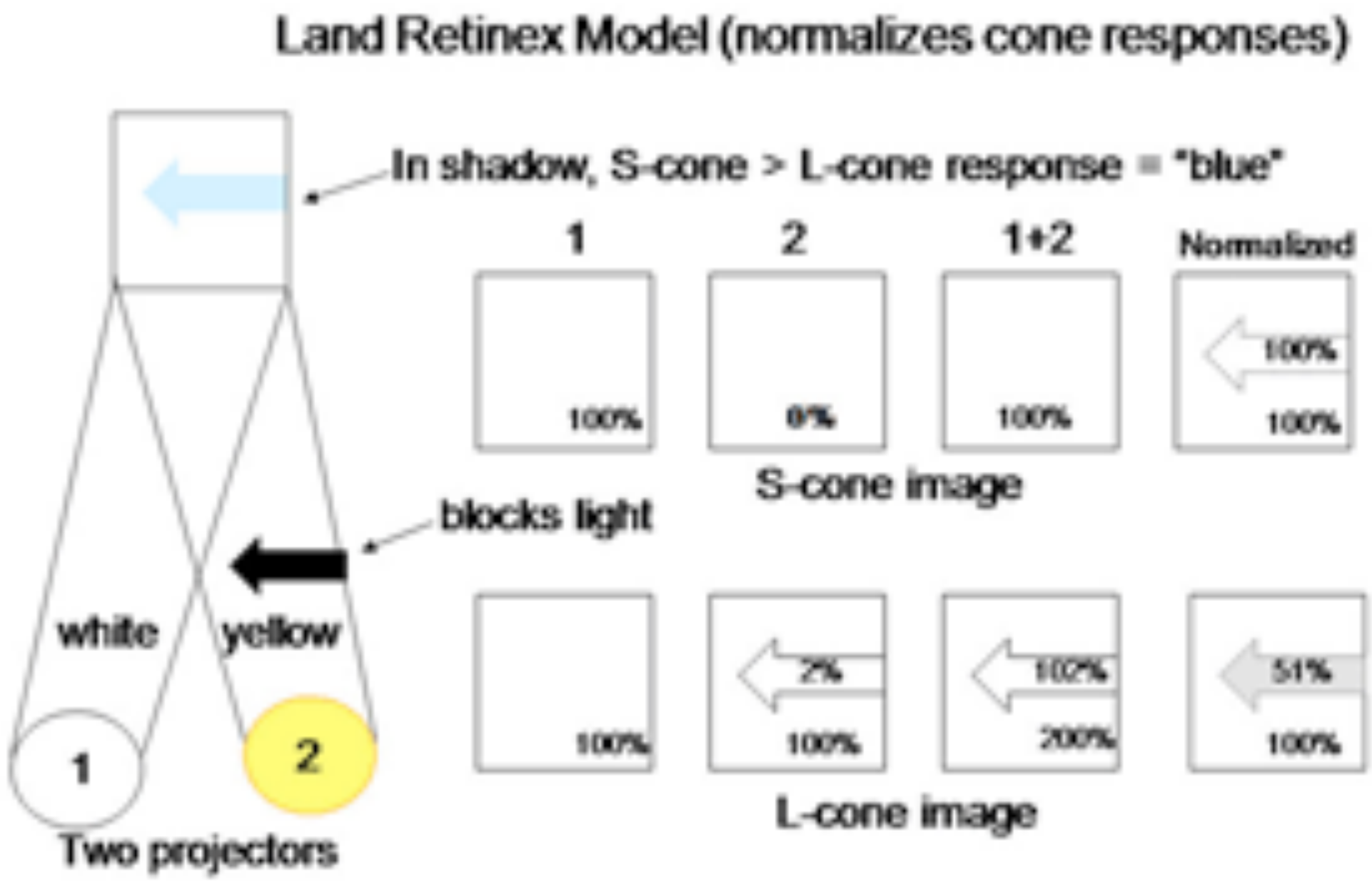
The Land-Mondrian experiments (1964)

- Subjects view a multicolored display (Color Mondrian)
- Display with patches of different size, shape and color
  - No patch surrounded by another of a single color
  - Patches surrounding another patch differed in color
  - Patches were matte
- Lighting
  - Illuminated by 3 projectors with filters for Red, Green and Blue
  - Intensity was measured using a photometer

The Land-Mondrian experiments (1964)

- Experiment 1: Light reflectance from a “green” patch (60 units red | 30 units green | 10 units blue) when other patches are visible
  - Subjects observation ⇒ GREEN
- Experiment 2: Light reflectance from a “green” patch (60 units red | 30 units green | 10 units blue) when viewed in isolation
  - Subjects observation ⇒ RED
- Conclusion: Perceived color is not determined by dominant reflected wavelength
  - Perceived color depends upon the colors of other nearby objects

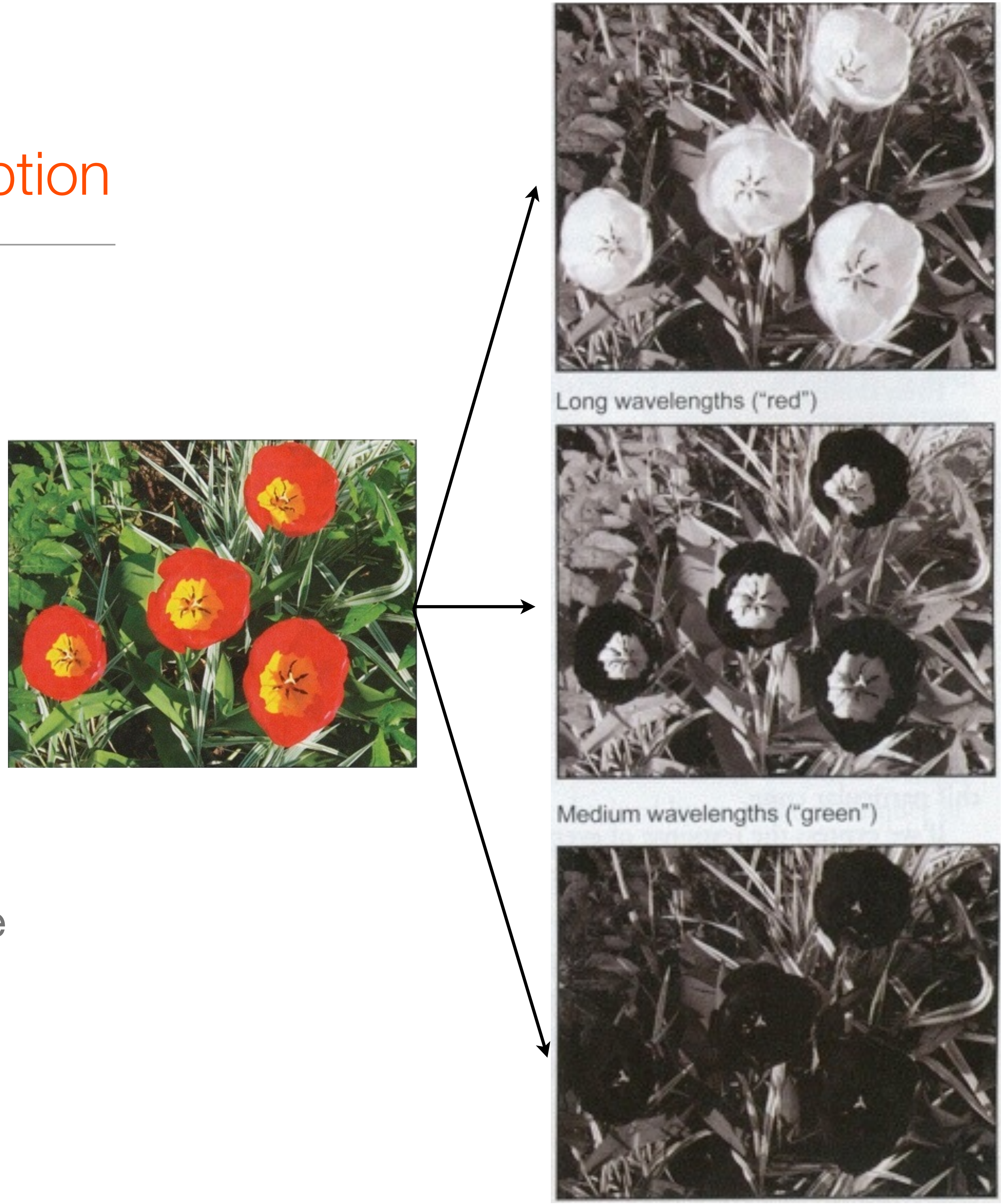
Color correction as an anchoring problem



unknown source

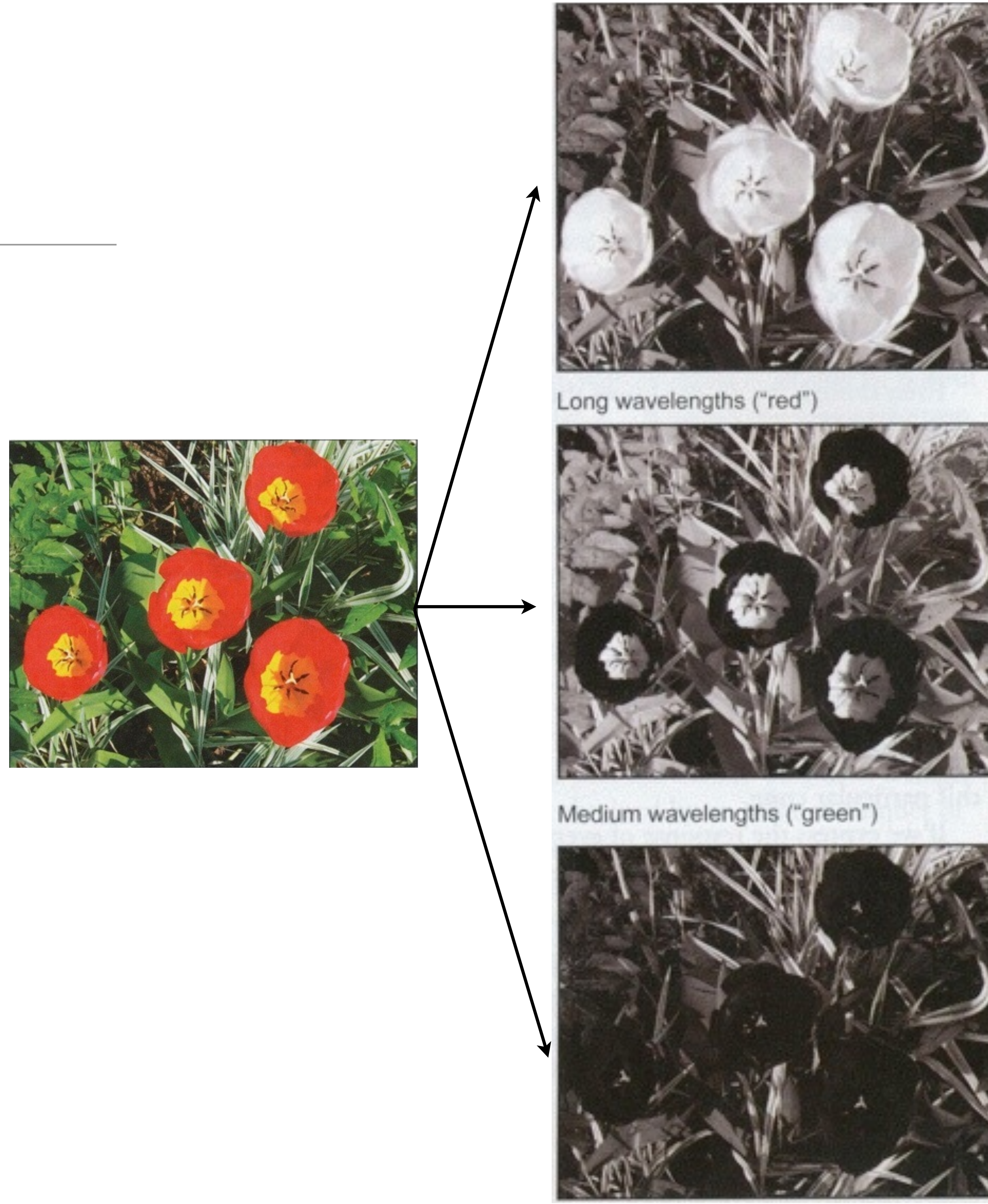
Gray-world assumption

- Given image with sufficient color variations, average of RGB components should average out to common gray value
- True for variations in color that are random and independent
- Given a large enough amount of samples, the average should tend to converge to the mean value (which is gray)



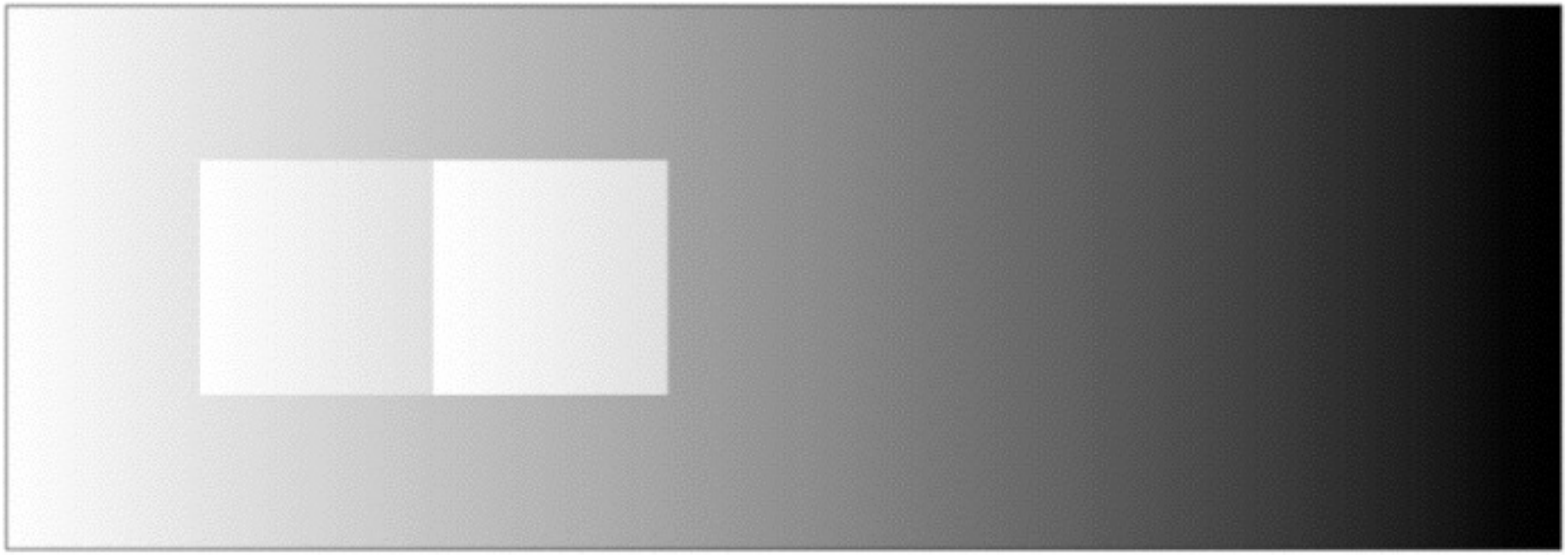
White-world assumption

- Brightest patch is white

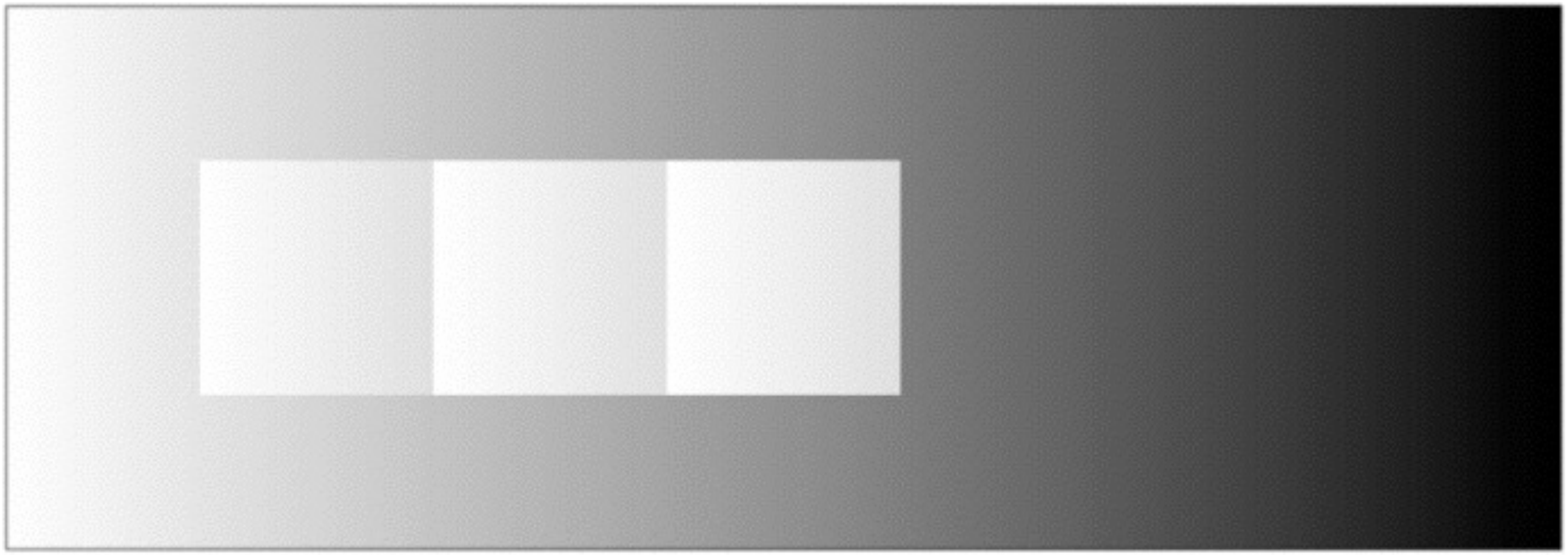


Gelb / Gilchrist demo

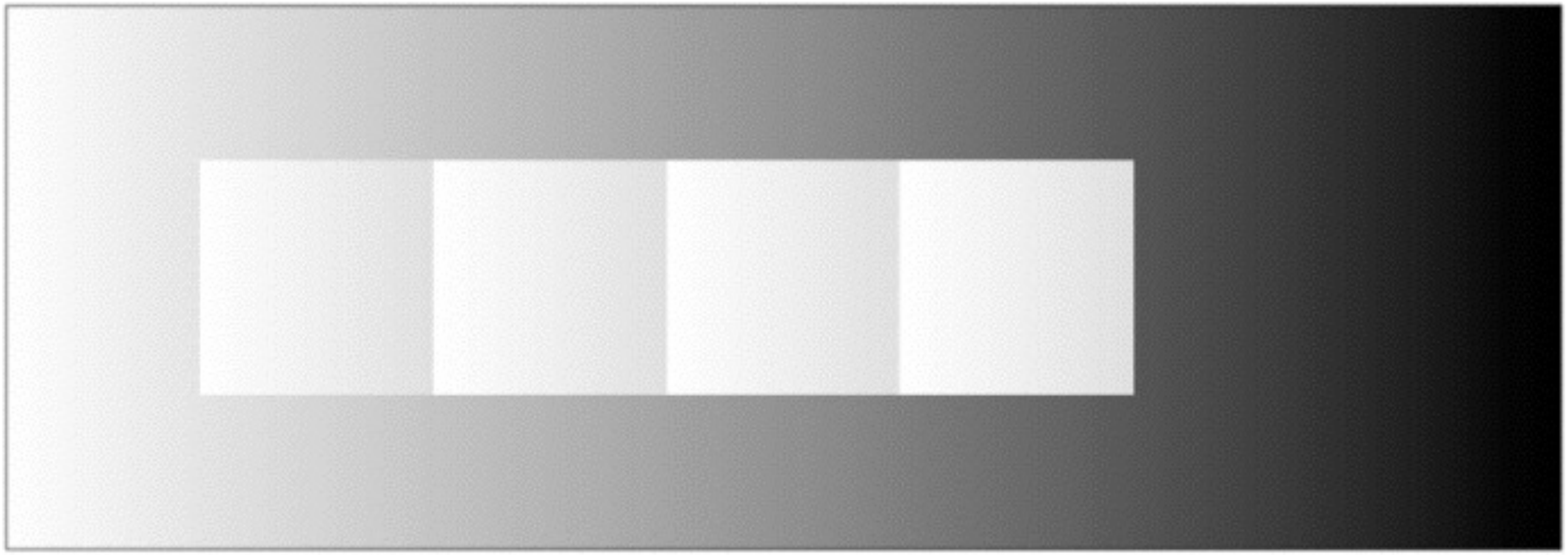
Gelb / Gilchrist demo



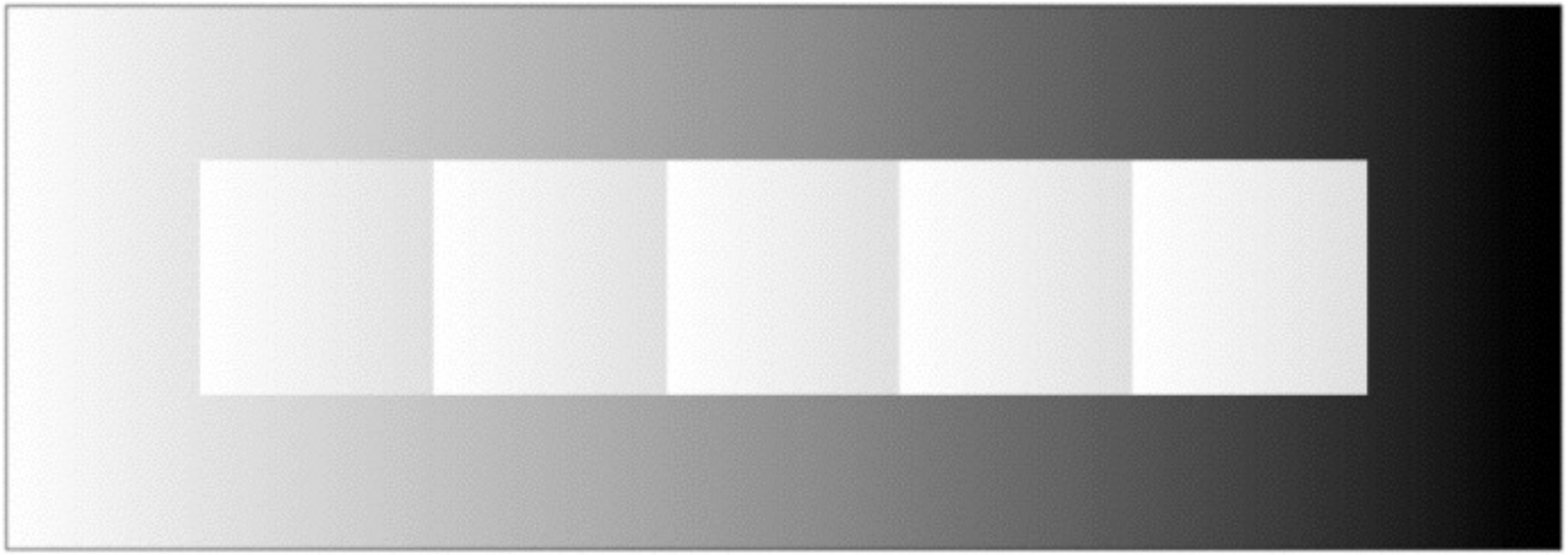
Gelb / Gilchrist demo



Gelb / Gilchrist demo

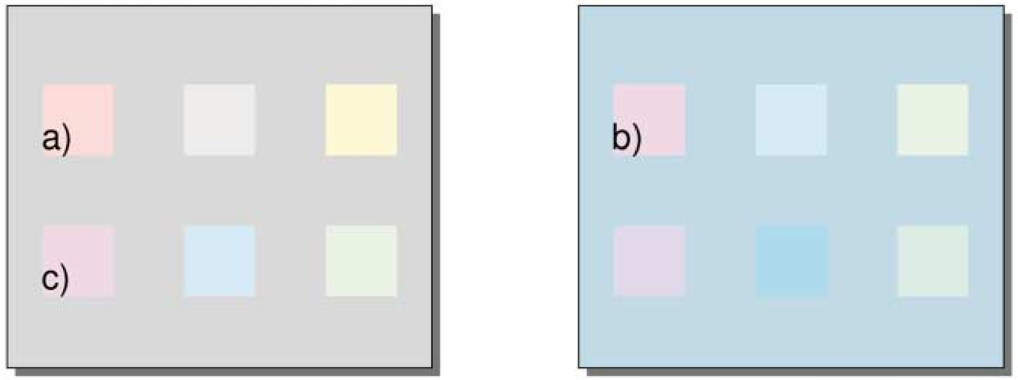


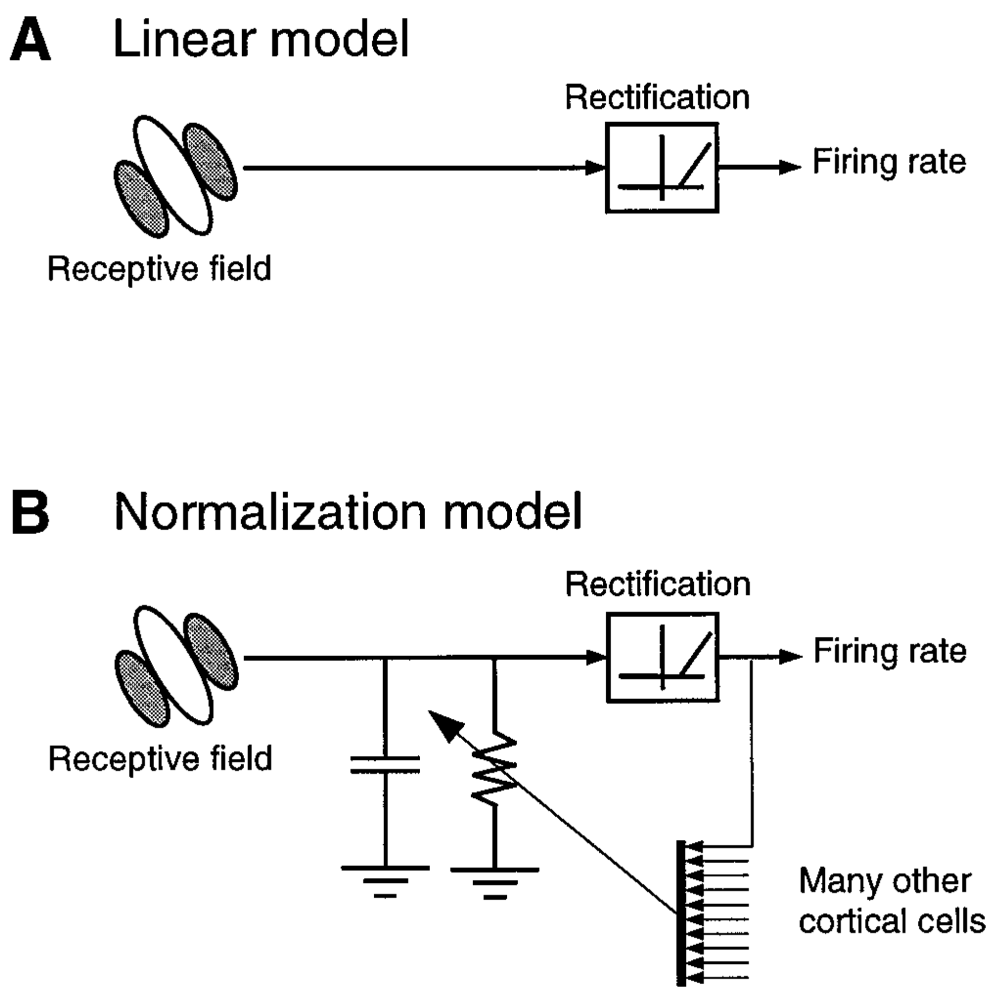
Gelb / Gilchrist demo

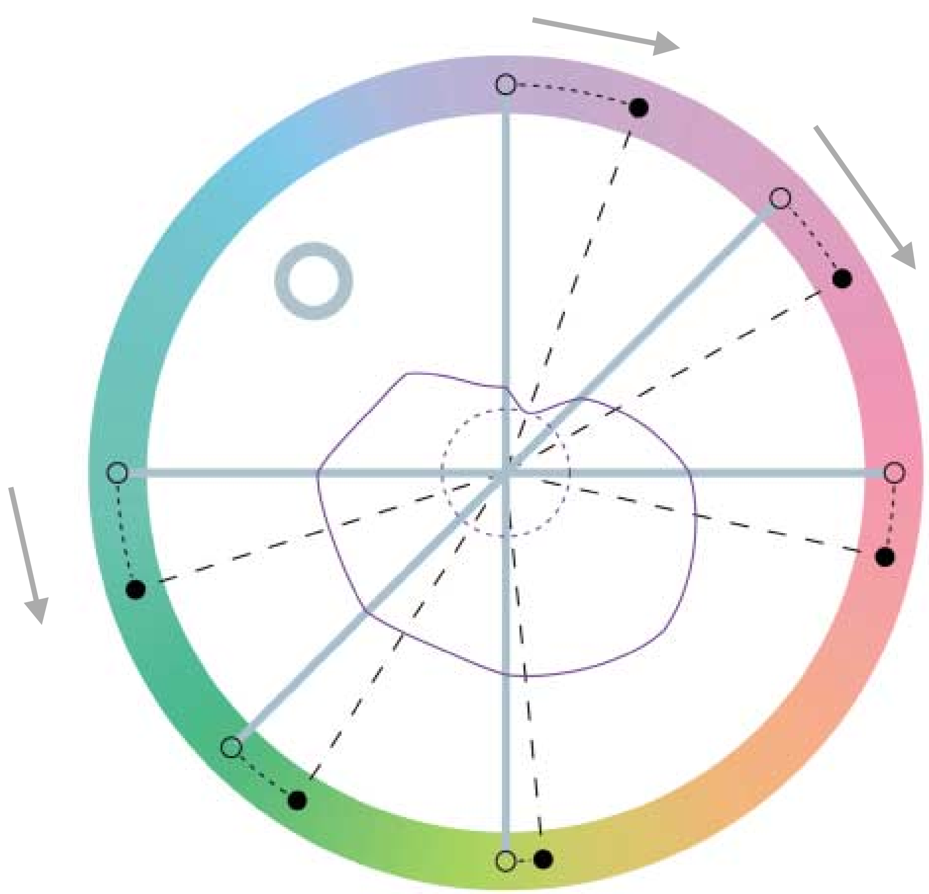


Gelb / Gilchrist demo

Color processing





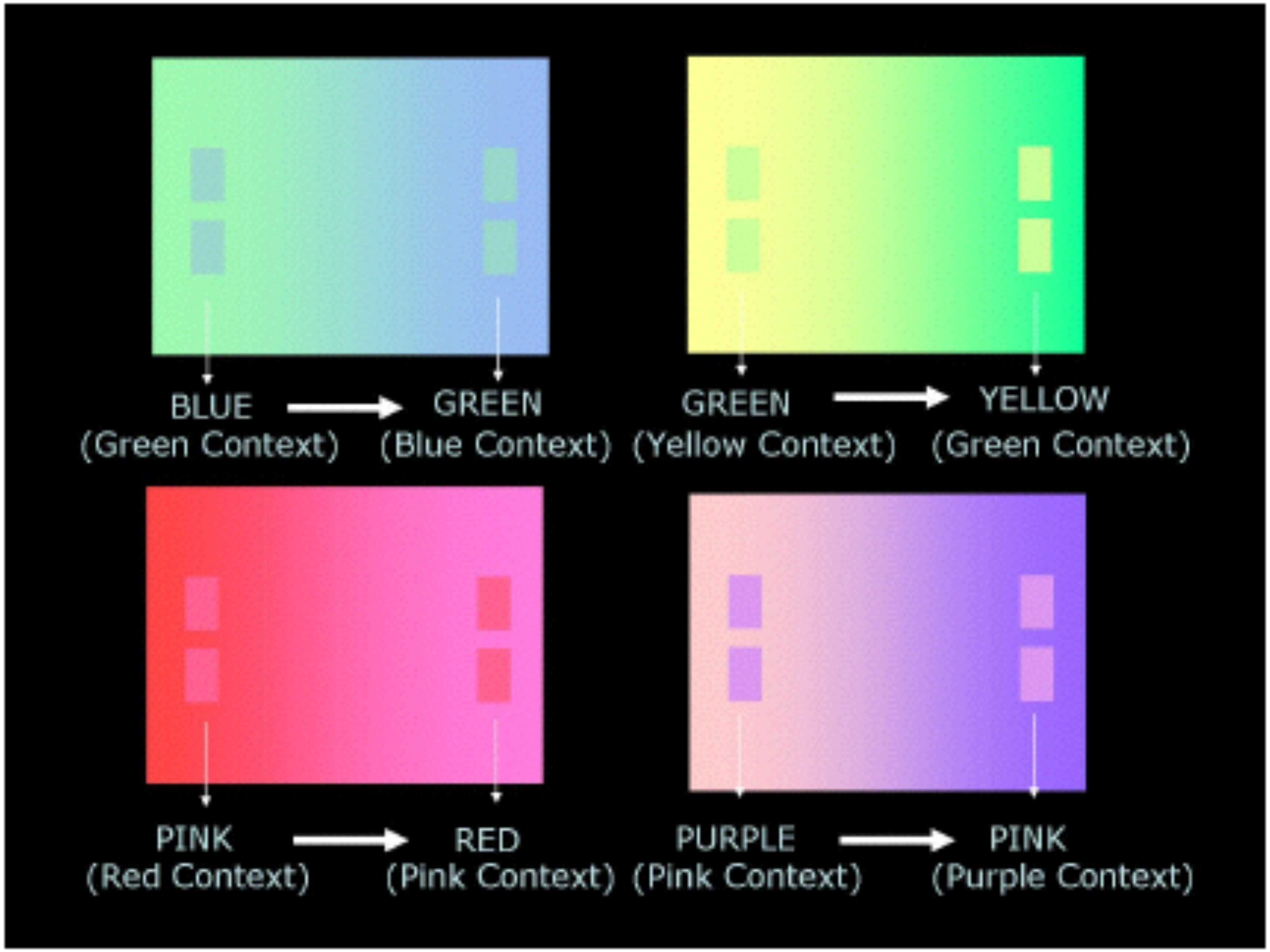


Other color channels

Wachtler et al 2003

Zhang & Serre in prep

Color contrast and divisive normalization



Color contrast and divisive normalization