Modeling Adult Visual Function

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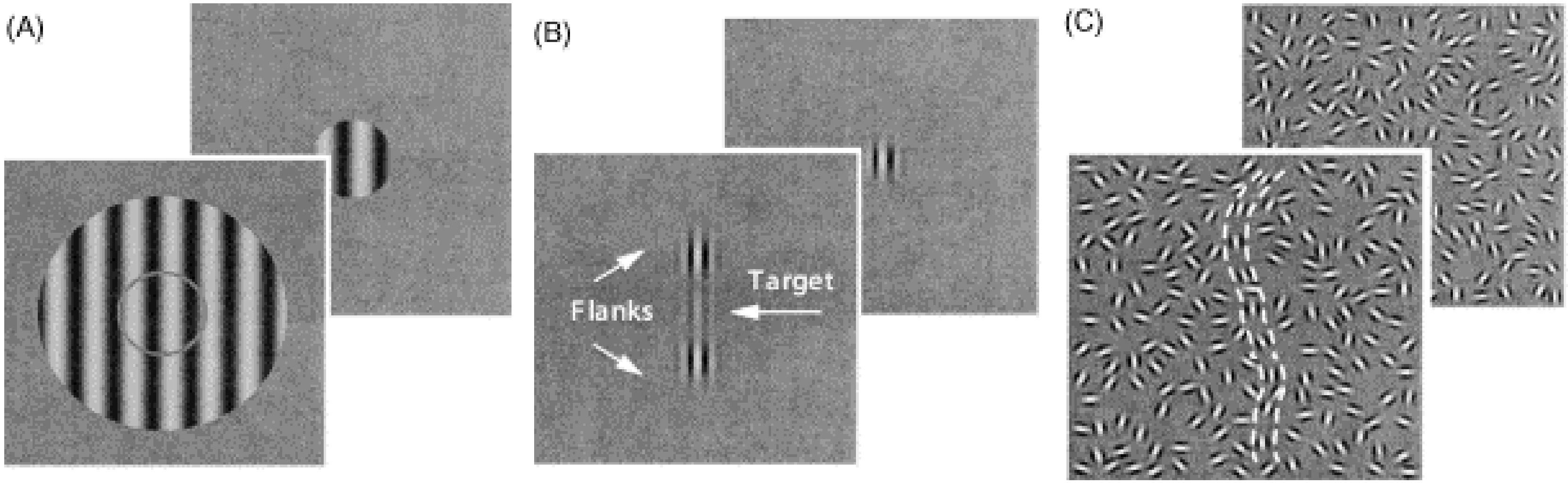
Surround modulation



(Series et al. 2003)

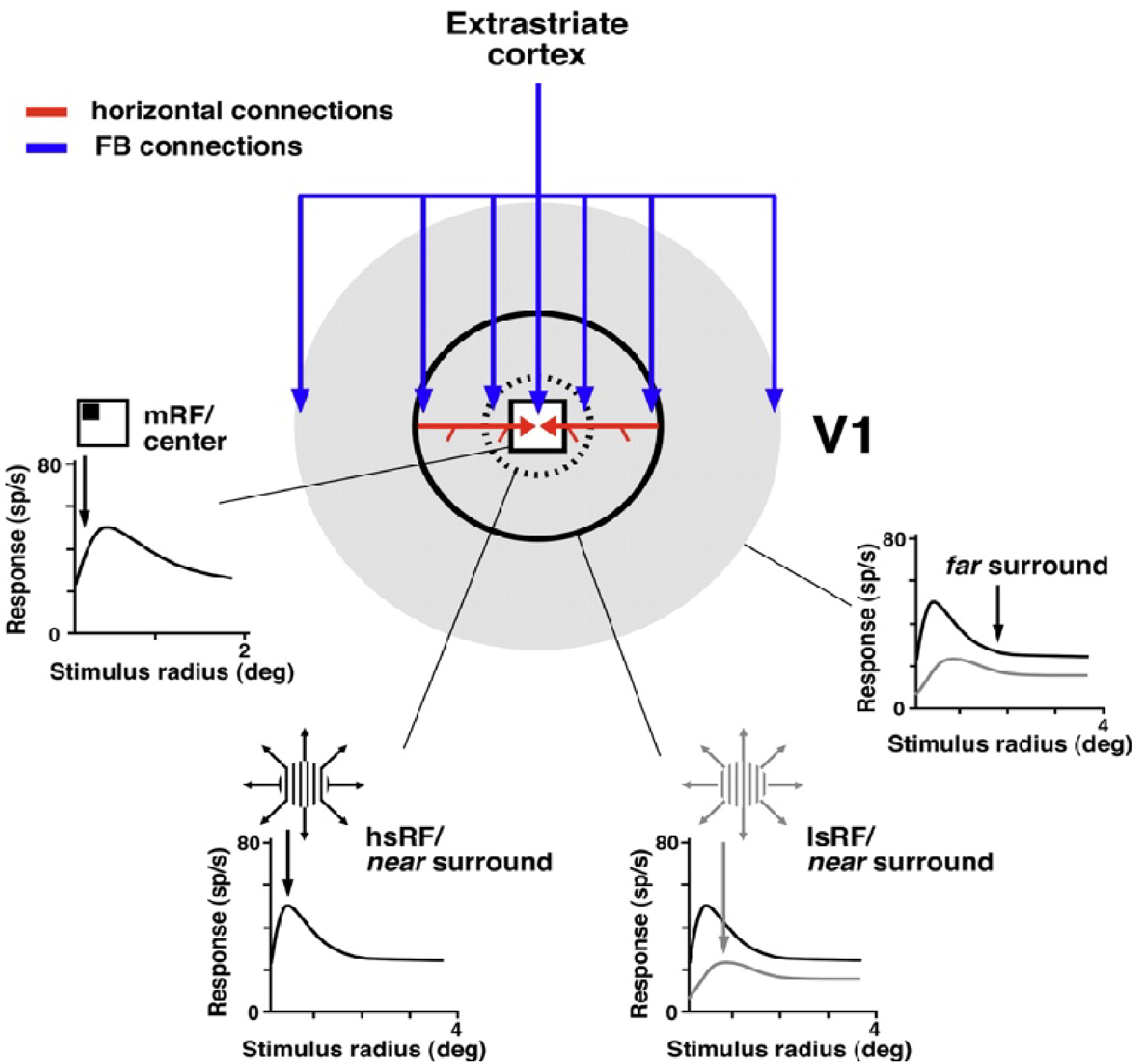
Apparent contrast reduces

Detection facilitated

Contour pops out

Many types of contextual interactions are known

Surround modulation

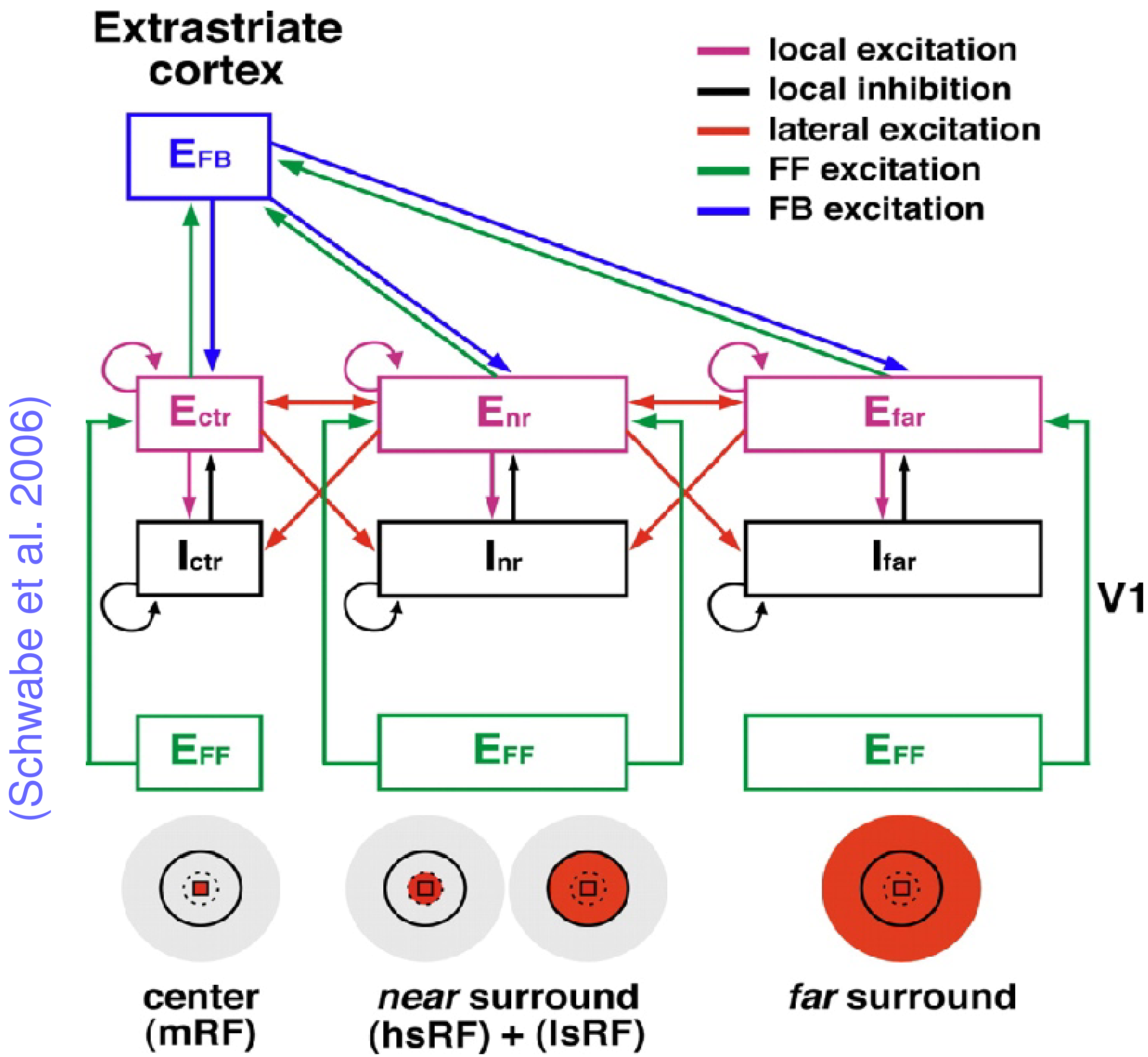


(Schwabe et al. 2006)

Effects depend strongly on contrast (Hirsch & Gilbert 1991), (Weliky et al. 1995) and on distance

Distance-related effects match both lateral and feedback connections

Proposed model circuit



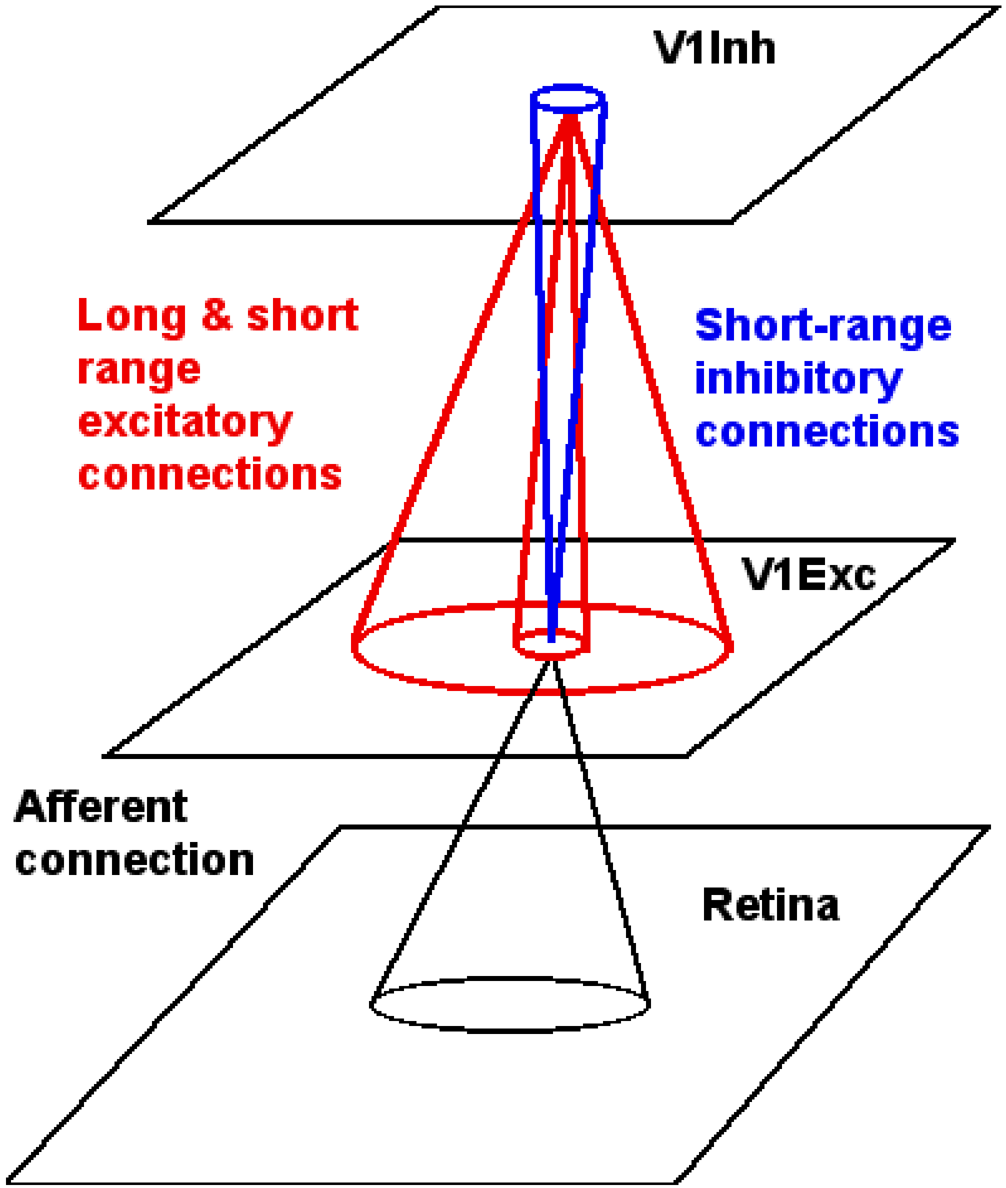
From Schwabe et al. (2006):

High-threshold inhibitory interneurons

Long-range excitatory lateral connections

Long-range excitatory feedback connections

LESI circuit



(Law & Bednar 2006)

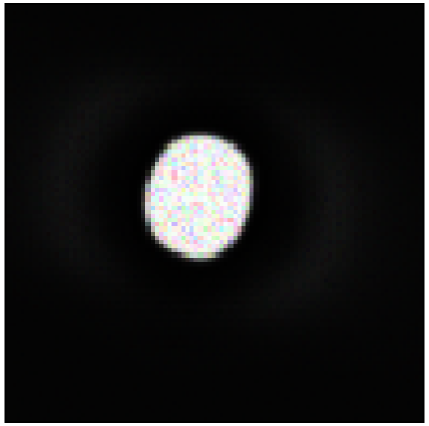
From Law & Bednar (2006):

High-threshold inhibitory interneurons

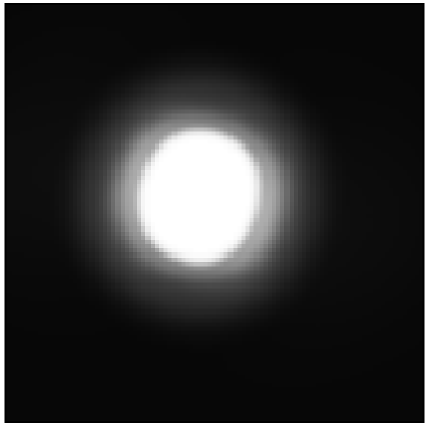
Long-range excitatory lateral connections

No feedback connections yet

Effective lateral inhibition



Excitatory activity



Inhibitory activity

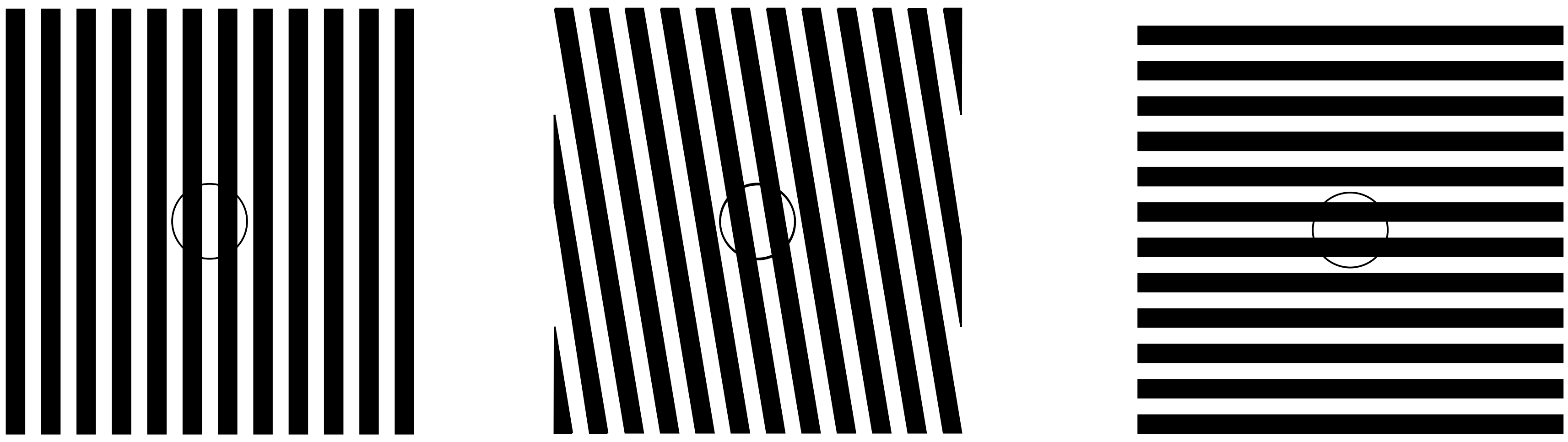
(Law 2009)

At high contrasts, the activity in the inhibitory sheet has wider radius than the activity in the excitatory sheet.

Result: Acts like Mexican-hat lateral interaction function, but using long-range excitatory connections.

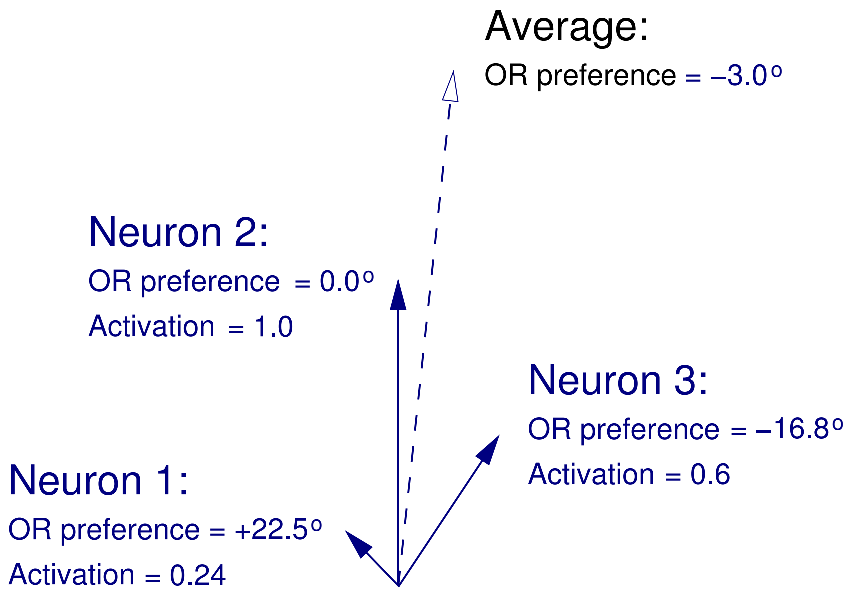
Self-organization thus works as usual (since Hebbian learning is dominated by the high-contrast inputs), but circuitry is correct and low-contrast behavior can be correct.

The Tilt Aftereffect (TAE)



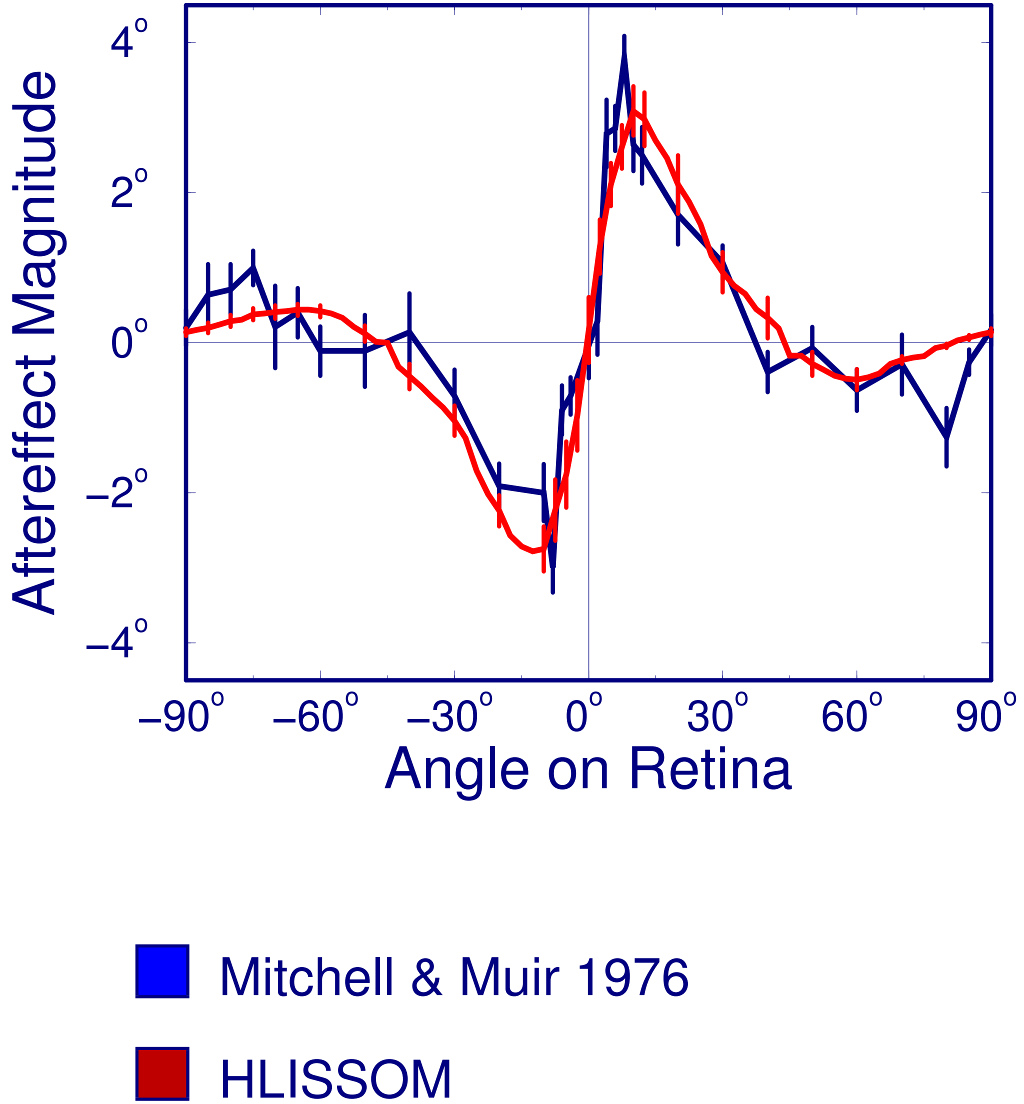
- Bias in orientation perception after prolonged exposure
- Allows model structure to be related to adult function
- Classic explanation: “fatigue” – activated neurons get tired, shifting the population average away

Measuring perceived orientation



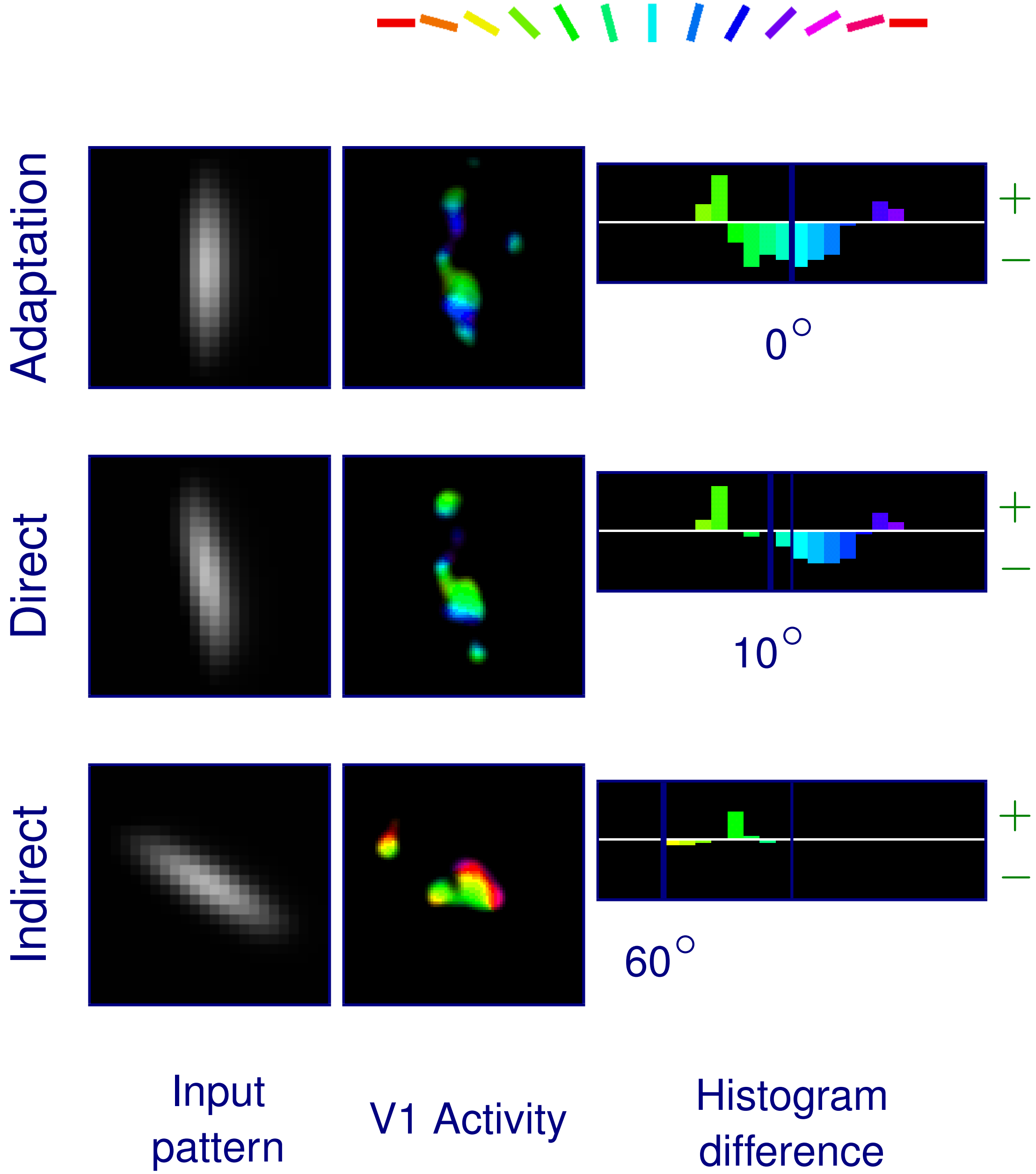
- Assumption: perception based on population average
- Vector average good for cyclic quantities
- Decode perception before and after adaptation

TAE in Humans and LISSOM



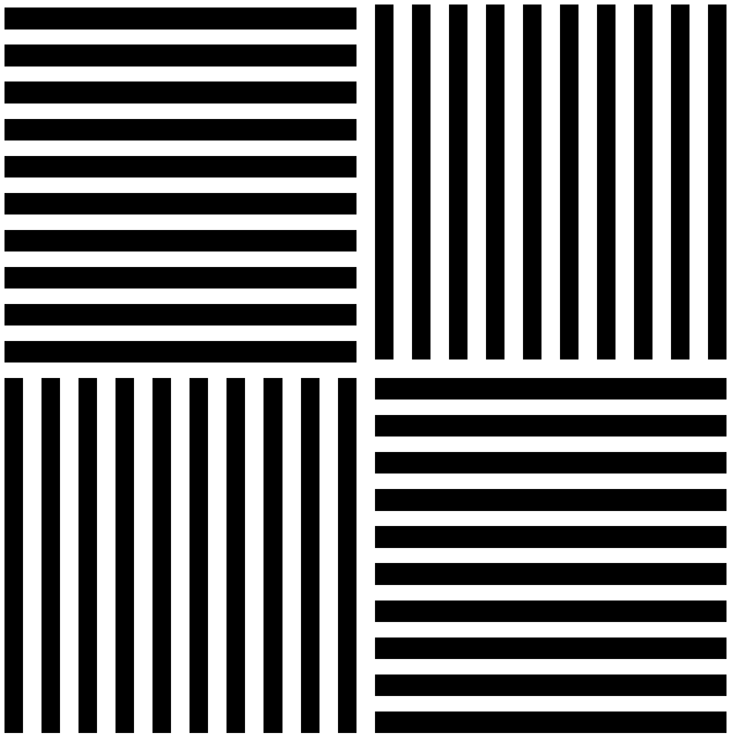
- Direct effect for small angles
- Indirect effect for larger angles
- Null effect at training angle
- Human, model match closely

TAE Adaptation in LISSOM



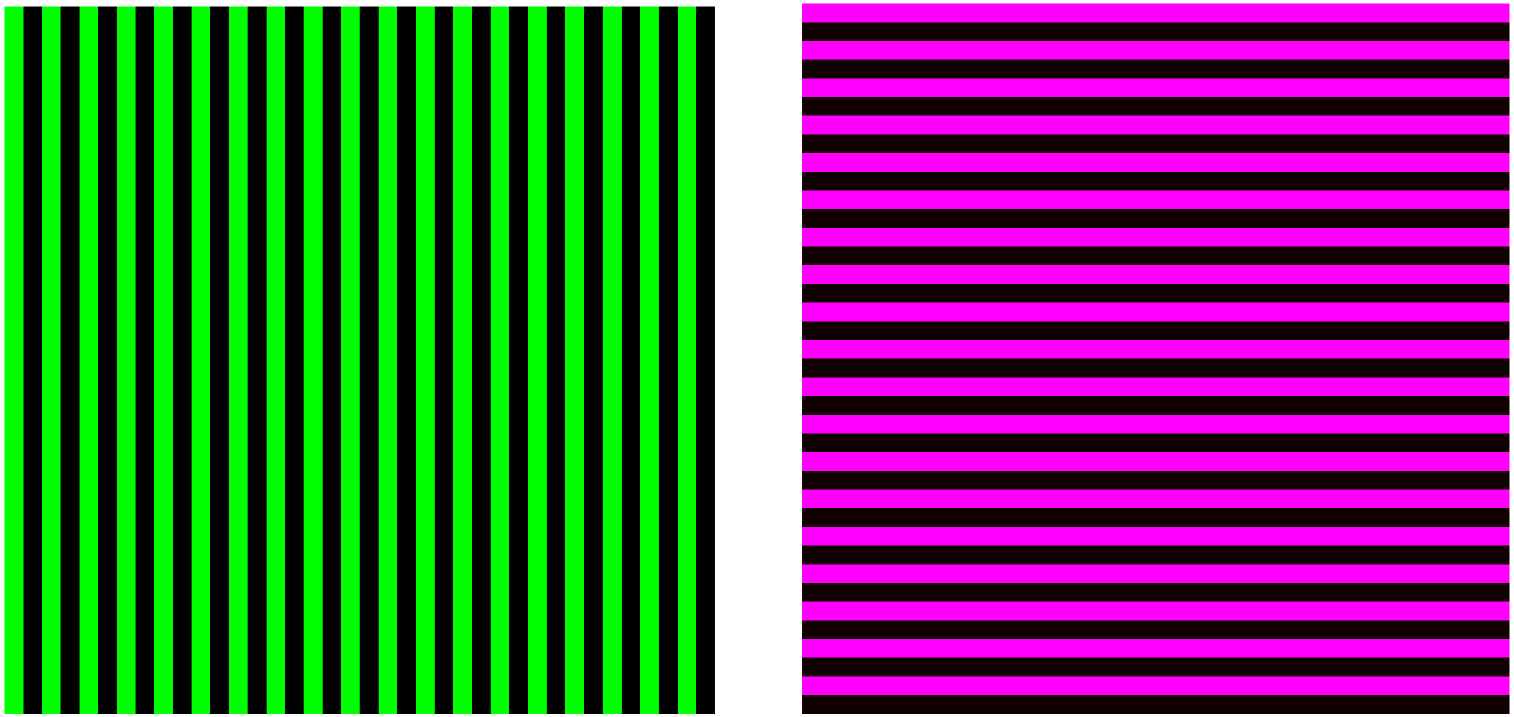
- **Null at zero**: More inhibition, but no net change in perception
- **Direct effect:** More inhibition for angles $<10^\circ$
  - Perception shifts from 10 to 14°
- **Indirect effect:** Less inhibition for angles $<60^\circ$
  - Perception shifts from 60 to 58°
- Due to synapses, not tired neurons!

McCollough effect test pattern



Before adaptation, this pattern should appear monochrome

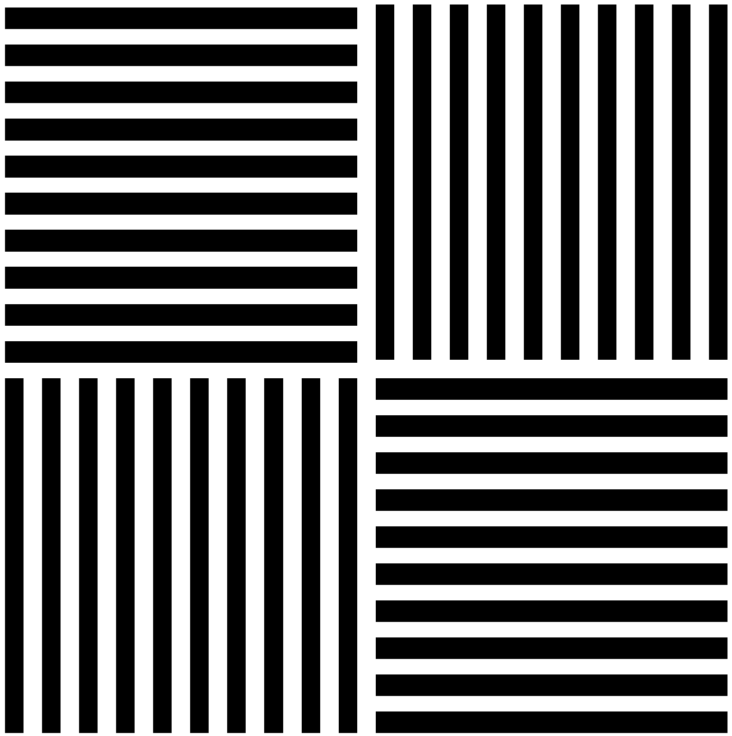
Adaptation pattern



Stare alternately at the two patterns for 3 minutes,

moving your gaze to avoid developing strong afterimages

McCollough effect



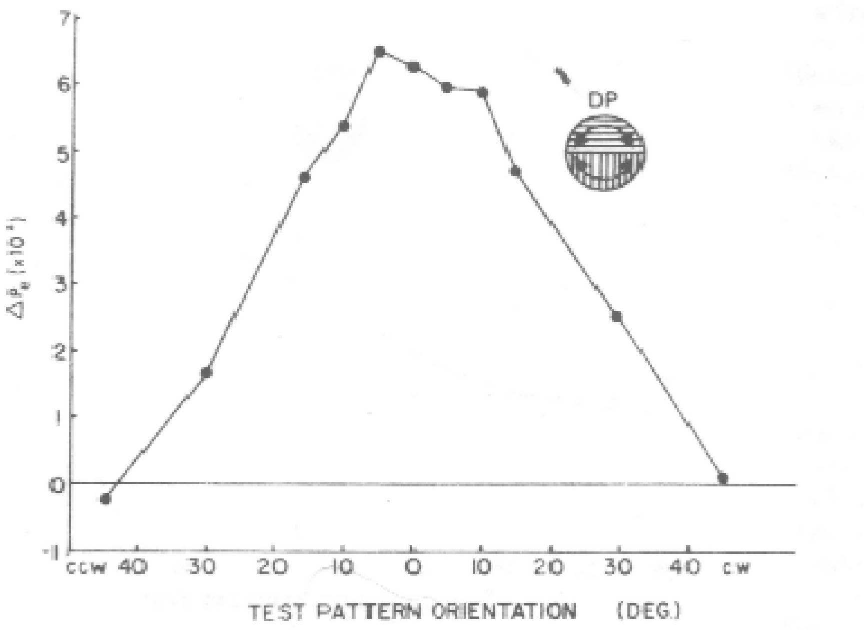
(McCollough 1965)

After adaptation:

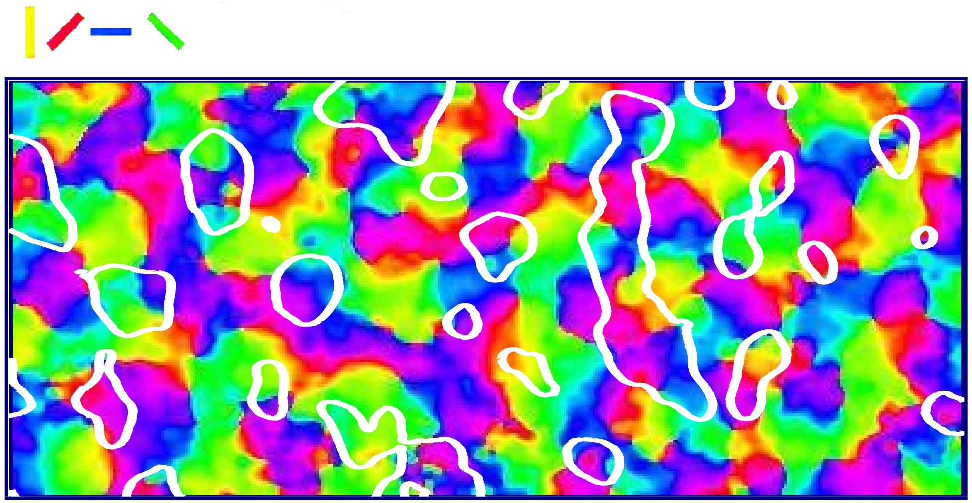
- Vertical bars should be slightly magenta
- Horizontal bars should be slightly green

- The effect should reverse if you tilt your head 90°, and disappear if you tilt 45°.

McCollough effect: data



(Ellis 1977)

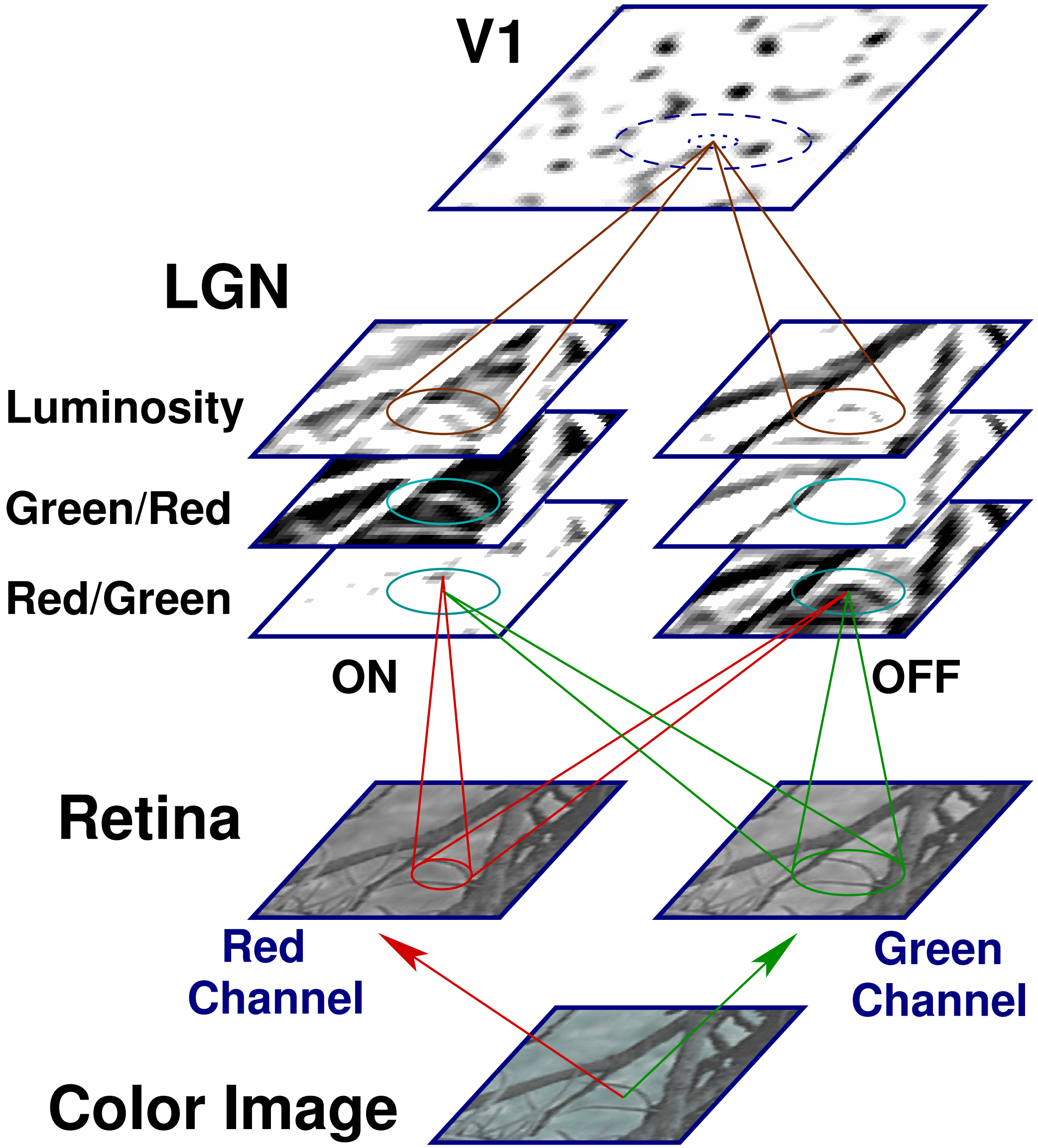


(Landisman & Ts'o 2002)

2.3×5.3mm macaque V1

- Effect measured in humans at each angle between adaptation and test
- Strength falls off smoothly with angle
- V1 is earliest possible substrate – first area showing OR selectivity; has color map

LISSOM Color V1 Model

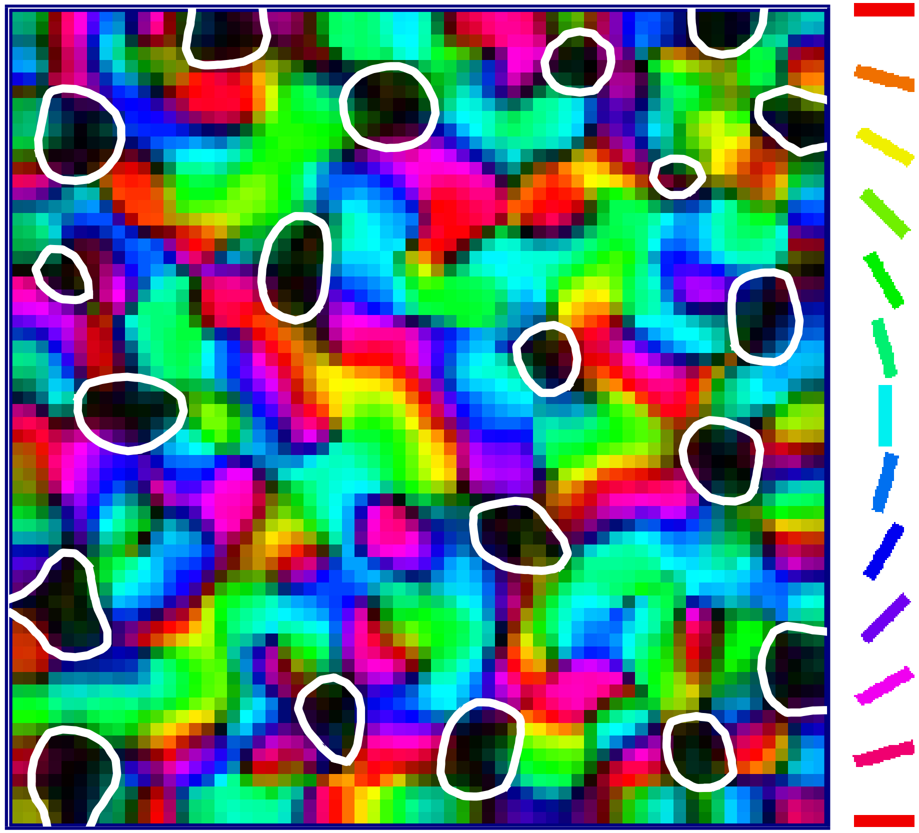


(Bednar et al. 2005)

- Input: RGB images
- Decomposed into Red, Green channels (no blue in central fovea, Calkins 2001)
- Processed by color opponent retinal ganglia

LISSOM OR + Color map

(Bednar et al. 2005)



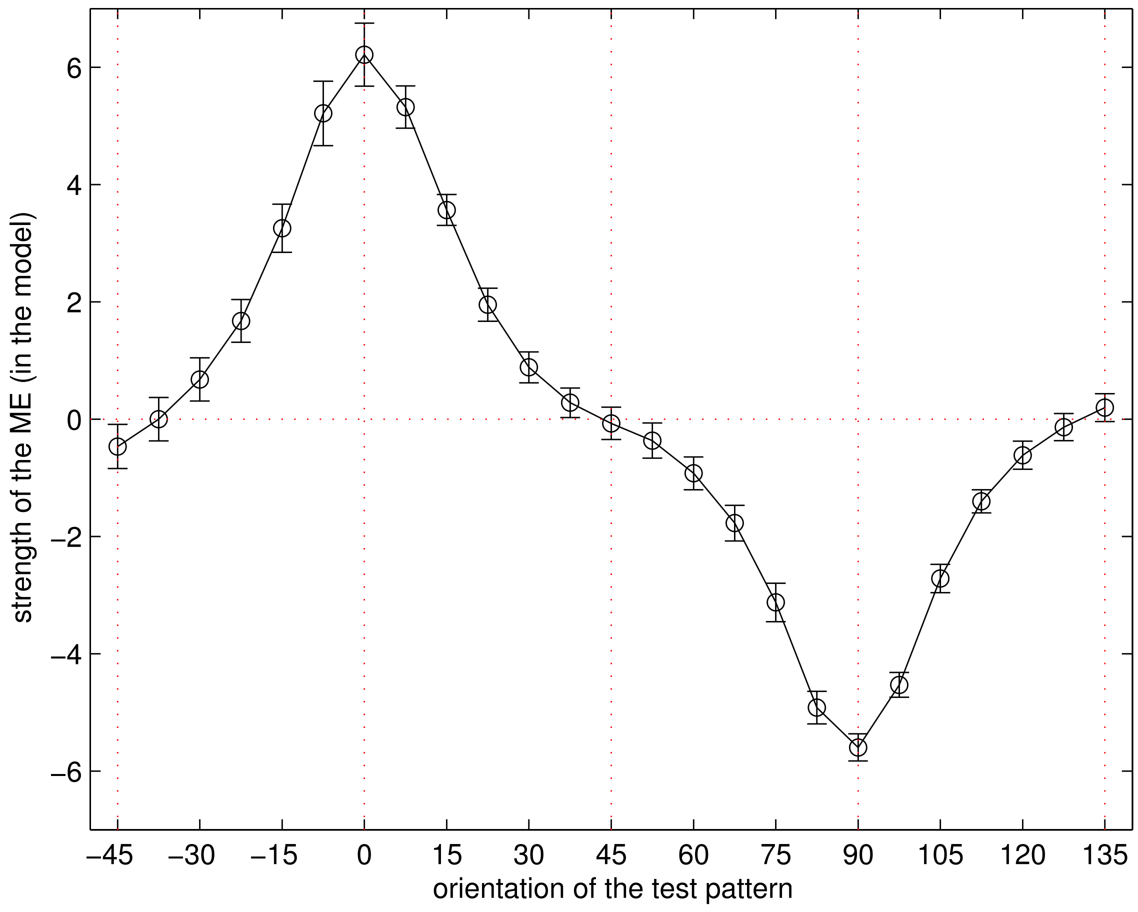
- Orientation map similar to animal maps
- Color-selective cells occur in blobs
- Each blob prefers either red or green

Calculating McCollough Effect

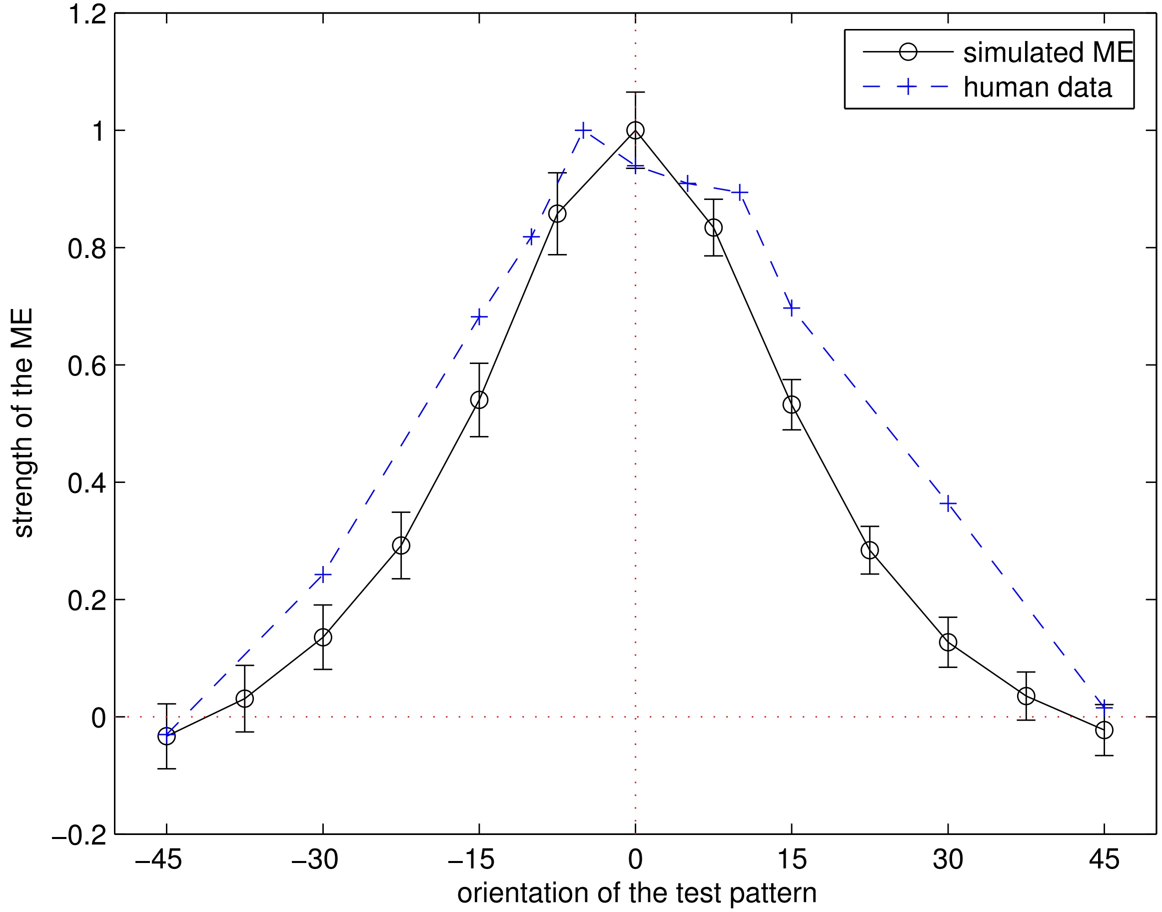
- Perceived color estimated as a vector average of all units
- Vector direction: + for red-selective units, - for green-selective units
- Weighted by activation level and amount of color selectivity

Result is a number from extreme red (positive) to extreme green (negative), with approximately 0 being monochrome.

Model McCollough Effect



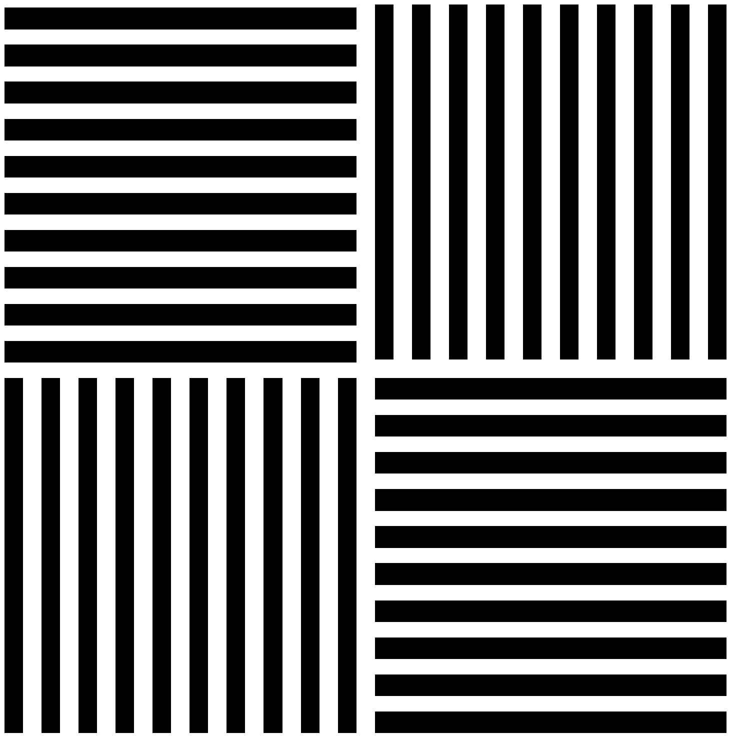
Compared with human



Summary

- LISSOM can be compatible with actual circuit
- May explain surround modulation
- Afteffects arise from Hebbian adaptation of lateral inhibitory connections
- The same self-organizing processes can drive both development and adaptation: both structure and function
- **Novel prediction:** Indirect effect due to weight normalization

McCollough Effect



Is the effect still present?

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