Modeling Adult Visual Function

Dr. James A. Bednar
jbednar@inf.ed.ac.uk
http://homepages.inf.ed.ac.uk/jbednar
Surround modulation

Apparent contrast reduces

Detection facilitated

Contour pops out

Many types of contextual interactions are known

(Series et al. 2003)
Surround modulation

Effects depend strongly on distance and contrast.

Distance-related effects match both lateral and feedback connections.

(Schwabe et al. 2006)
Proposed model circuit

From Schwabe et al. (2006):
High-threshold inhibitory interneurons
Long-range excitatory lateral connections
Long-range excitatory feedback connections

CNV Spring 2008: Modeling adult function
LESI circuit

From Law & Bednar (2006):
- High-threshold inhibitory interneurons
- Long-range excitatory lateral connections
- No feedback connections yet
Effective lateral inhibition

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.
Stable development

If the manual thresholds of standard LISSOM are replaced with homeostatic plasticity, excitatory radius shrinking can be eliminated. Result: map shape remains stable over time.
The Tilt Aftereffect (TAE)

- Bias in orientation perception after prolonged exposure
- Allows model structure to be related to adult function
TAE in Humans and LISSOM

- Direct effect for small angles
- Indirect effect for larger angles
- Model perception: vector average of orientations
- Human, model match closely

Aftereffect Magnitude

Angle on Retina

Mitchell & Muir 1976
HLISSOM
TAE Adaptation in LISSOM

- **Adaptation**: 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°
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

- 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

2.3 × 5.3mm macaque V1

Ellis 1977

Landisman & Ts’o 2002
LISSOM Color V1 Model

- 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

- 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

- Strength of the ME (in the model)
- Orientation of the test pattern

CNV Spring 2008: Modeling adult function
Compared with human

![Graph showing the orientation of the test pattern vs. the strength of the ME. The graph compares simulated ME with human data.]
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?
References


Landisman, C. E., & Ts’o, D. Y. (2002). Color processing in macaque
striate cortex: Relationships to ocular dominance, cytochrome oxidase, and orientation. *Journal of Neurophysiology, 87* (6), 3126–3137.


