Vision III: Cortical mechanisms of vision

Please sit where you can examine a partner.

Michael E. Goldberg, M.D.

First you tell them what you’re gonna tell them

- The cortical visual system is composed of multiple visual areas with different functions.
- V1 neurons describe object features.
- The principle of columnar organization.
- Two visual streams – ‘what’ and ‘how’ (or ‘where’).
- MT neurons describe motion and depth (dorsal stream).
- IT neurons describe objects (ventral stream).

See the triangle?
See the white bar?

See the wavy line?

Which small square is darker?
So

- Your visual system does not measure and report the exact physical nature of the visual world.
- It collects some data, and makes guesses.
- Optical illusions take advantage of the guessing strategies.

Roughly 40% of cerebral cortex is involved in vision

Remember

- Receptive fields in the retina and the lateral geniculate are circular, with center – surround organization.
  - Off surround - inhibits
  - On center - excites
The striate cortex – V1 – builds more sophisticated receptive fields from these basic building blocks. Cells describe specific

- Contour orientations.
- Binocular interaction.
- Speed and direction of motion.
- Color.

David Hubel and Torsten Wiesel won a Nobel Prize in 1981 for describing the properties of striate cortical neurons.

V1 simple cell is most responsive to an oriented line.
Orientation tuning in a V1 simple cell

V1 complex cells are sensitive to orientation of stimuli

But not particularly to stimulus position within the receptive field
Complex cells can be constructed from an array of similarly oriented simple cells

The cerebral cortex is organized in a columnar manner

Within a column

- Information is processed and transformed from monocular, center-surround, non-directionally selective input to
  - Orientation
  - Binocular disparity
  - Direction-selective output
- Processed information is distributed
  - Layers 2-3 to other cortical areas
  - Layer 5 to the superior colliculus
  - Layer 6 to the lateral geniculate nucleus
- This general arrangement of columnar processing is maintained throughout the cortex, not just visual cortex.
Cells with similar orientation preferences lie in the same column.

Geniculate cells representing the same area of the visual field but arising from different eyes project to adjacent areas of V1.

Orientation columns with the same monocular lateral geniculate input lie in the same ocular dominance column.
The actual topology of orientation and ocular dominance columns

Color sensitive cells lie at the center of the pinwheels, in cytochrome oxidase containing 'blobs.'

Color sensitive cells are mostly unoriented

Depth perception starts with the detection of binocular disparity
Random dot stereograms generate structure from disparity

Disparity selectivity in a V1 neuron

Motion selectivity in a V1 neuron
V2 (Area 18) also is divisible by cytochrome oxidase staining

Stripes in Area 18

Blobs in Area 17

Two cortical visual streams subserve two different visual functions.

Where/how?

What

Functional separation begins in the retina and continues through the LGN

LGN Parvocellular cells

Retinal P cells: color, longer latency, fine detail

LGN Magnocellular cells

Retinal M cells: broadband, shorter latency, courser detail
And continues in V1

And V2

After V2, different functions are performed by anatomically different areas:
The dorsal stream provides vision for action — “where and how”
After V2, different functions are performed by anatomically different areas:
The ventral stream provides vision for object identification.

MT – the analysis of motion

- Neurons in MT are selective for speed and direction of motion, and retinal disparity.
- Neurons in MT report the perceptual aspects of motion.
- Electrical stimulation of MT affects the perception of motion.
Human MT

Structure from motion

MT Cells are tuned for direction
Perceived motion in a plaid

Striate neurons respond to the components of the plaid

MT responds to the direction of the plaid, and not the components
MT has columns for direction of motion

MT has disparity columns

Electrically stimulating an orientation column in MT induces the perception of motion described by that column.

100% coherence
Electrically stimulating an orientation column in MT induces the perception of motion described by that column.

50% coherence

Electrically stimulating an orientation column in MT induces the perception of motion described by that column.

No coherence

Electrically stimulating an orientation column in MT induces the perception of motion described by that column.
The parietal lobe describes the world for action, location, and attention.

There are multiple representations of the visual field in the intraparietal sulcus

Within the dorsal stream there is further functional segregation –

- MT is specialized for depth and motion.
- LIP is specialized for attention in far space.
- MIP is specialized for providing visual information to the arm-reaching area.
- AIP is specialized for providing visual information for grasping.
- VIP is specialized for providing visual information for mouth and head movements.
Patients demonstrate this functional segregation

- Patients with V1 lesions generally have total visual field deficits in the affected field.
- Patients with more anterior lesions can have loss of specific functions:
  - Color agnosia
  - Blindness for motion
  - Dissociation of object vision and vision for action
  - Neglect

The inferior temporal lobe describes the visual world for object recognition

Where/how?

What?

Neurons in inferior temporal cortex are selective for complex patterns like faces
Visuomotor function: Intact – but patient can’t name the object

Draw an anchor. Patient cannot conceptualize the anchor.

Patients with inferior temporal lesions have visual agnosia

Prosopagnosia “face blindness”

- Term first used by Bodamer, 1947
- Inability to recognize familiar faces
- Visual acuity is normal
- Caused by lesion to right inferior temporal lobe
- May be congenital (“developmental prosopagnosia”)
- Patients compensate by using other recognition cues: clothing, gait, voice, etc.
Finally, you tell them what you told them

- The striate cortex (V1) uses unoriented, monocular input from the lateral geniculate to assemble cells selective for orientation, motion, and retinal disparity.
- Striate cortex is organized in columns with similar orientation and ocular dominance.
- Two visual streams emanate from V1: a dorsal stream concerned with analyzing the visual world for location and action, and a ventral stream concerned with analyzing the nature of objects in the visual world. Different areas subsume different spatial and object attribute functions.
- Clinical deficits include specific deficits for color, faces, motion, visual targeting of motion, and spatial localization.