Perception, Part 3
Gleitman *et al.* (2011), Chapter 5

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Psych 9A / Psy Beh 11A
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• Visual neuroscience and perception
• More on shape processing
• Visual neuroscience and perception
• More on shape processing
• But first, let’s finish up our look at motion perception
**Motion Cues to Depth: Structure From Motion**

We are quite good at interpreting biological motion, and can recover object identity from very sparse descriptions of its motion.

Gunnar Johannson was the first to explore this systematically.

Try this flash shockwave:

[http://www.journalofvision.org/content/suppl/2011/01/13/2.5.2.DCSupplementaries/genderclass.swf](http://www.journalofvision.org/content/suppl/2011/01/13/2.5.2.DCSupplementaries/genderclass.swf)
Eye movements and motion perception

*Saccade* – extremely rapid movement of the eyes of which we are usually not aware.
Eye movements and motion perception

*Saccade* – extremely rapid movement of the eyes of which we are usually unaware

Our visual systems *compensate* for eye movements so that the world does not appear to move when the eyes move.

What caused the retinal image motion?
Eye movements and motion perception

*Saccade* – extremely rapid movement of the eyes of which we are usually not aware.

Our visual systems *compensate* for eye movements so that the world does not appear to move when the eyes move.

Cover one eye, jiggle the other eye by pressing gently on its corner, and watch the world move. Contrast the jiggling visual scene to what you see when voluntary eye movements are made.

Voluntary eye movements involve not only signals to eye muscles but also feedback signals to visual mechanisms concerning the resulting eye movement. This lets the visual mechanisms shift the world appropriately so that it appears stable.
Induced Motion

The moon, when seen behind moving clouds, sometimes appears to move while the clouds appear stationary. The visual system appears to favor the interpretation that small pieces of the visual field move in the real world, large areas do not.

Traffic standstill on a freeway: have you ever had the experience that your car is drifting toward the car in front and stamped on the brakes, only to find that your foot was on the brake anyway and that your car was not moving at all? If all of the cars next to you start moving and they are perceived as stationary, then it must be you that are moving!
Visual Neuroscience and Perception

Retinal Circuitry

- Rod
- Cone
- Horizontal cell
- Bipolar cell
- Amacrine cell
- Ganglion cell
- Optic nerve
- Light
Retinal Ganglion Cells

Several different kinds, including *parvo* (small) and *magno* (large) cells
Retinal Ganglion Cells

Parvo (small) and magno (large) cells

<table>
<thead>
<tr>
<th>anatomical</th>
<th>parvo</th>
<th>magno</th>
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</thead>
<tbody>
<tr>
<td>small</td>
<td>majority of cells</td>
<td>large minority of cells</td>
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<table>
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<tr>
<th>physiological</th>
<th>slow, sustained, color-sensitive</th>
<th>fast, transient high sensitivity</th>
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<tr>
<th>functional</th>
<th>form/color</th>
<th>time/motion/depth</th>
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Mapping of the visual field

Optic Chiasm

Retinal ganglion cell axons cross in a way that projects
the *left* side of the visual field to the *right* side of the brain
the *right* side of the visual field to the *left* side of the brain
Mapping of the visual field

The lateral geniculate nucleus (LGN) receives information from both eyes. The left half of the LGN receives information from the right side of the visual field. The right half of the LGN receives information from the left side of the visual field. This also holds true for neurons in primary visual cortex (area V1).
Lateral Geniculate Nucleus (LGN)

Layered topographic maps of the visual field

*Figure 11. The projections of the small (P cells), and large (M cells) ganglion cells from the two eyes to parvocellular and magnocellular layers of the LGN respectively. Each eye projects to alternating layers as seen in the autoradiogram (right).*
Lateral Geniculate Nucleus (LGN)

M – magnocellular
P - parvocellular

c – contralateral
i - ipsilateral
Neurons in LGN project (via their axons) to primary visual cortex (area V1) via the optic radiation
There are also *extrastriate* visual areas of cortex engaged in visual processing, such as V2, V3, V4 and V5 (MT)

So let's start with V1...
Parallel Processing of Visual Information

• Different neurons in visual cortex respond to different aspects of a stimulus.
• These different analyses go on in parallel; they proceed simultaneously at all locations across the visual field.
• For example, neurons that analyze forms are doing their work at the same time that other cells are analyzing motion and still others are analyzing color.
• In primary visual cortex (V1), these neurons are organized according to the visual field locations of their receptive fields.
Primary Visual Cortex – V1

Retinotopic Mapping

Many more neurons are devoted to processing information from the central visual field, especially in the fovea.

Neurons have receptive fields laid out retinotopically, so that sensitivity to visual field directions changes smoothly as one moves across visual cortex.

from David Hubel’s Eye, Brain, and Vision, work by Roger Tootell
Primary Visual Cortex

Retinotopic Mapping
Primary Visual Cortex
Six Layers in V1

Figure 10. Nissl (left) and cytochrome oxidase (right) labeled cross sections of the visual cortex of a macaque monkey, showing the individual layers.
Primary Visual Cortex
Six Layers in V1

Primary Input from LGN
Layer 4C
4C α – magno
4C β - parvo
Primary Visual Cortex
Motion Pathway

LGN magno layers ->
4Cα -> 4B
-> V2 thick stripes
Primary Visual Cortex

Color Pathway

Blobs
  color

vs.

Interblobs
  form
Primary Visual Cortex

cytochrome oxidase stain

Blobs

work by Margaret Wong-Riley
Primary Visual Cortex

Blobs
  color
t  parvo

vs.

Interblobs
  form

Fig. 27. Diagram of a slab of striate cortex (V1) of primate brain to show the composition of a hypercolumn. A hypercolumn consists of two ocular dominance columns (one from each eye) each containing stacks of orientation columns. A blob is a cylinder of cells running from I to IVB which receives direct input from blue/yellow cells of the koniocellular layers of the LGN, and the color-opponent red and green cells of the parvocellular layers of the LGN. The latter projections are secondary to the first synapses in layer IVCb. Magnocellular cells from the LGN project to layer IVCa.
Primary Visual Cortex
Form/Color

LGN parvo layers -> 4Cβ -> Layers 2+3,1 -> extrastriate areas
Primary Visual Cortex

Back Projections (modulate input to cortex)

Layers 5,6 not only receive some input from superior colliculus (SC) and LGN but also project back to these areas
Primary Visual Cortex

Ocular Dominance Columns

Figure 14. The signals from each eye are segregated within the LGN and go into different ocular dominance columns within area V1, layer 4C.
Primary Visual Cortex

Ocular Dominance Columns

from David Hubel’s *Eye, Brain, and Vision*
Simon LeVay’s reconstruction

V1 fovea
Primary Visual Cortex

Change in Orientation Sensitivity as one traverses the cortical surface

from David Hubel’s *Eye, Brain, and Vision*
Primary Visual Cortex

Orientation and Ocular Dominance Relationship

Figure 23. The ice-cube model of the cortex. It illustrates how the cortex is divided, at the same time, into two kinds of slabs, one set of ocular dominance (left and right) and one set for orientation. The model should not be taken literally: Neither set is as regular as this, and the orientation slabs especially are far from parallel or straight.
Primary Visual Cortex

Hypercolumn
Fig. 27. Diagram of a slab of striate cortex (V1) of primate brain to show the composition of a hypercolumn. A hypercolumn consists of two ocular dominance columns (one from each eye) each containing stacks of orientation columns. A blob is a cylinder of cells running from I to IVB which receives direct input from blue/yellow cells of the koniocellular layers of the LGN, and the color-opponent red and green cells of the parvocellular layers of the LGN. The latter projections are secondary to the first synapses in layer IVB. Magnocellular cells from the LGN project to layer IVCa.
What about V2?
Extrastriate Cortex

V2 –
* some LGN input
* lots of V1 input
* retinotopically mapped
* thin stripes (color)
* thick stripes (motion)
* interstripes (form)
* projects to V3, V4, V5 (MT)
Extrastriate Cortex

V3 – V1 and V2 input

two retinotopic maps of foveal region

specialized for detailed visual processing

specialized for analysis of moving form

+ color sensitivity

+ depth sensitivity
Extrastriate Cortex

V4 – specialized for color, among other things

cerebral achromatopsia
cannot see color!
-often accompanied by visual scotoma and visual agnosia

large receptive fields

thought to be sensitive to color of surface
Extrastriate Cortex

**V5** – specialized for motion
also called area MT

cerebral akinetopsia
cannot see motion!

inputs – V2 thick stripes

V5 neurons sensitive to
motion of object
V3 neurons sensitive to
motion of edges

large receptive fields
“Where” Visual Pathway

Occipital to Parietal Lobe

“What” Visual Pathway

Occipital to Temporal Lobe
After Mishkin and colleagues (1983)

Multiple Parallel Visual Pathways

Figure 19. Much of V1 is located in the calcarine sulci and its relationship to other brain areas is best shown by unfolding the brain and showing it flattened open. The visually responsive areas of the macaque monkey are shown in color. From Van Essen et al. (1992).
Visual object recognition

Binding problem: how are results determined by different systems (color, form, motion) bound together to provide a percept of a unified object?

Some people say that neurons in different visual areas fire synchronously to indicate that they have information concerning the same object.

Here are two proposals for how different parts of a shape are brought together.
Visual object recognition

Divide things up into “generalized cylinders” (Marr & Nishihara)
Visual object recognition

Divide things up into “geons” (Biederman)
Visual object recognition

Some of the best current work on the topic comes from the field of computer vision.

Goal: have the computer process image or video input delivered by a camera (like a webcam) in a way that correctly detects and identifies things seen in the video.

Human, car, truck, bus, tree, grass, bush, road, sidewalk, traffic light, etc.—depends on the kind of scenery that is presented to the computer.

Most successful approaches use what are known as “machine learning” methods in which one trains a computer program to recognize various classes of objects.

Having received this training, the computer program is then able to detect and categorize objects presented in new images or video.
Visual agnosia – inability to recognize objects

two forms

1. apperceptive
   cannot recognize by shape
   cannot copy drawings
   often involves *prosopagnosia* (face blindness)

2. associative
   can copy but cannot recognize
   difficulty transferring visual information
   into verbal descriptions

both forms are typically associated with some sort of trauma to the brain
Face Recognition
-lots of research!

Thatcher illusion
Face Recognition

Thatcher illusion
Face Recognition

Inverted Face Illusion
Face Recognition

Fusiform Face Area – lots of work done by Nancy Kanwisher

Many people think that there is at least one area in the brain, the fusiform gyrus, located in the temporal lobes, specialized for processing face information and recognizing faces. Its damage can lead to prosopagnosia.
Impossible Figures

Many of these suggest that our visual systems
1. use local information to try to infer 3D shape
2. glue the local descriptions together into a global shape without checking for consistency
3. can switch between global shape hypotheses

devil’s tuning fork
http://www.michaelbach.de/ot/cog_imposs1/index.html
Impossible Figures

M.C. Escher...
Impossible Figures

another Escher...
Impossible Figures

a final Escher...

oldest known impossible figure (ca 1025 AD)

http://naute.com/illusions/magi.phtml