Announcements

• 1st exam (next Thursday):
  • Multiple choice (about 22), short answer and short essay
  • don’t list everything you know for the essay questions
  • lectures vs. readings
    • exam will mostly be from lectures
    • expect 1 multiple choice question per reading
  • PPT files are on Blackboard only. PDFs are both on BB & on the class page
  • Review session: TBD, mostly likely Wednesday evening

1. Which of the following is NOT a factor that can affect a person’s criterion in yes-no tasks?
   a. Strength of the signal
   b. Costs associated with hits and false alarms
   c. Signal frequency
   d. Personal biases

2. Functional Magnetic Resonance Imaging (fMRI):
   a. Directly measures the electrical neural activity of the brain
   b. Approximates neural activity via a measurement of blood flow
   c. Cannot be used to study neural activity
   d. Is easily interpretable

3. Which structure of the eye is responsible for most of the eye’s refractive power? [2 pts] _______

4. Name and describe one advantage and one disadvantage of the method constant stimuli? [4 pts]

Early visual processing: retina & LGN

• Retina
  • rods and cones
  • spatial layout

• Receptive fields
  • center-surround organization
  • perceptual consequences of center surround organization

• Beginning of parallel pathways in vision
  • M and P cells

Visual Photoreceptors: rods and cones

Light hits the outer segment of rods and cones which contain photosensitive chemicals (photopigments).
The light changes the molecular properties of the photopigments, which in turn changes the electrical state of these cells – this is called transduction.

• 5 million cones vs. 120 million rods
• Rods = precursors to motion perception & sensitivity
• Cones = precursors to color vision & resolution
Convergence

- There are:
  - 5 million cones and 120 million rods
  - Only 2 million ganglion cells

- Therefore, many receptors must send signals to each ganglion cell. This is called **convergence**.

- The **extent of convergence** on different parts of the retina determines a tradeoff between:
  - **sensitivity** to low light levels
  - **resolution** of fine spatial detail.

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Perception...**involves competing demands**

- **Sensitivity** - being able to detect “faint” signals
- **Resolution** - being able to distinguish among multiple signals (e.g., their location)

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Rod vision is more sensitive to light than cone vision

- Greater convergence of rods than cones onto ganglion cells
- Thus, greater summation of rod signals
- Thus, less stimulation per rod is required.

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Cone vision can see finer details than rod vision

...and cones are specialized for high resolution vision

- Greater convergence of rods than cones onto ganglion cells limits rod spatial resolution.
- Cone vision can see finer details than rod vision.
**Cones and color vision**

- Humans have 3 different cone types, each with a different photopigment.
- Photopigments are maximally sensitive to specific wavelengths.
  - Short wavelength sensitive
  - Mid-wavelength sensitive
  - Long wavelength sensitive

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**Fovea**

- 1 mm pit at the center of the retina, high acuity
- Reduced light distortion
- Its cortical representation is magnified

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**Ocular albinism**

- Cone density greatest in fovea
- Rod density greatest at about 15 degrees.
What retina sees……

Night Sky: why are there more stars off-center?

Day: cone vision
Night: rod vision

Blind spot

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The Retina

- Rods and cones connect with horizontal and bipolar cells (collector cells).
  - Lateral interaction takes place at horizontal cells.
  - Amacrine cells connect adjacent bipolar cells (lateral interactions again).
  - Bipolar cells are connected to retinal ganglion cells.

Retinal Ganglion Cells

- Retinal ganglion cells have receptive fields that are responsive to light stimulation.
  - Receptive field
    - STRICT definition: that area of the retina over which a ganglion cell is sensitive to light stimulation. I.e., an area of the retina that the cell monitors.
    - PRACTICAL definition: that area of the world over which a ganglion cell is sensitive to light stimulation. I.e., an area of the world that the cell monitors.
Neural circuit with convergence. Neuron B now receives inputs from all of the receptors, so increasing the size of the stimulus increases the size of neuron B's response.

Neural circuit with convergence and inhibition. Because stimulation of the receptors on the side (1, 2, 6, and 7) sends inhibition to neuron B, neuron B responds best when just the center (3-5) are stimulated.

The response properties of retinal ganglion cells can be explained by the neural circuit depicted above. Commonly called lateral inhibition.

Note that the neuron being recorded receives excitatory inputs from one group of receptors and inhibitory inputs from receptors in surrounding regions.

• On-center (off-surround) cell:
  - Light stimulation of the center of the receptive field produces an increase in the firing rate of the ganglion cell.
  - Stimulation of the surround produces decrease in the firing rate of the cell.

• Off-center (on-surround) cell = OPPOSITE
Photoreceptors to Ganglion Cells: Building Receptive Fields

For an on-centered ganglion cell, the response rate is greatest when the stimulus just fills the excitatory central region. When the stimulus covers the entire receptive field, the cell will fire at its background rate.

On-center Off-surround

![Response vs Time Graph](image)

Stimulus condition

Electrical response

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![Response vs Time Graph](image)

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![Response vs Time Graph](image)

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![Response vs Time Graph](image)

Stimulus condition

Electrical response
Photoreceptors to Ganglion Cells: Building Receptive Fields

Works with bars too...

Dark bar

Photoreceptors to Ganglion Cells: Building Receptive Fields: SIZE

What Different Sized RFs “See”

On average, Ganglion cells that receive inputs from the fovea have smaller receptive fields than cells that receive inputs from more peripheral regions.

Position on the retina

More central (more foveal)  More peripheral

Receptive fields and border enhancement

- Borders are the main cue for objects.
- Responses of ON-OFF and OFF-ON receptive fields enhance borders
Receptive fields and **border** enhancement

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**Perceptual consequences of retinal receptive fields**

**Simultaneous Lightness Contrast**

- More surround inhibition
- Less surround inhibition

The right square appears lighter because cells with receptive fields near its border receive less inhibition from the surround.

Thus, what’s happening at border matters!

**Perceptual consequences of retinal receptive fields: Hermann Grid**

Why do spots appear at the junctions, and why do they disappear when a junction is fixated?
The effect is not size dependent

**PROBLEM:** Receptive field size of retinal ganglion cells is fixed

The illusion is effective over a large range of square sizes.

**But!**

The effect can be negated without affecting the assumed relationship between the stimulus and the receptive fields

**But!**

The effect can be negated without affecting the assumed relationship between the stimulus and the receptive fields

Higher level factors also matter!

People see differing brightness of triangles even though ON-OFF (and OFF-ON) receptive filed responses should be equal.

https://www.youtube.com/watch?v=z9Sen1HTu5o
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Retinal Ganglion Cell Types

<table>
<thead>
<tr>
<th></th>
<th>P Cells</th>
<th>M Cells</th>
<th>K Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Size</td>
<td>small</td>
<td>large</td>
<td>very small</td>
</tr>
<tr>
<td>Receptive Field Size</td>
<td>small</td>
<td>large</td>
<td>small</td>
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<tr>
<td>Response Duration</td>
<td>Sustained</td>
<td>Transient</td>
<td>Transient</td>
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<tr>
<td>Responds to Color</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Percentage of Cell Population</td>
<td>80%</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

M Cells

- **M cells** receive input from a relatively large number of photoreceptors (mostly input from rods)
  - Good light sensitivity, but poor spatial resolution
- Transient responses
  - Good temporal resolution (sensitive to motion)
- Large – with broad (thick) axons
  - Consequently faster nerve conduction velocities
  - Good for motion
- Not color-sensitive
- **Origin of the magnocellular pathway**

P Cells

- **P cells** receive input from a relatively small number of photoreceptors (mostly input from cones)
  - Good spatial resolution, but poor sensitivity
- Sustained responses
  - Poor temporal resolution
- Color sensitivity
- **Origin of the parvocellular pathway**

Why parallel pathways?

"Any large computation should be split up and implemented as a collection of small sub-parts that are as nearly independent of one another as the overall task allows.

If a process is not designed in this way, a small change in one place will have consequences in many other places.

This means that the process as a whole becomes extremely difficult to debug or to improve, whether by a human designer or in the course of natural evolution, because a small change to improve one part has to be accompanied by many simultaneous compensating changes elsewhere."

(David Marr, 1976, p. 485)
OPTIONAL - Mach bands