Rods and cones
PSY 310
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Lecture 04

When we all go color blind.

Ophthalmoscope

- Able to see into an eye
Ophthalmoscope

- Here is what you see

Blood

- The back of your eye is covered in blood vessels
- Why don’t you see them?
  - They do cast shadows!
Blood

- To see the blood vessels in your eyes try the following
- Shine a small pen flashlight into your eye at a steep angle
- Move the light around in jerky motions
- Try to keep your eye still and look for dark lines in your vision
- These are vein shadows!

It takes practice!

Image

- The light coming into your eye projects on to the back of your eye
  - It is, of course, much smaller than the original object
How do we describe the size of visual stimuli?

- A smaller image that is closer is exactly the same on the back of the eye!

- A larger image that is further way is exactly the same on the back of the eye!
Visual angle

- We describe the size of stimuli in terms of visual angle.
- Imagine the world as a sphere around your head.
  - Light comes from the interior surface of the sphere.

Without further information, we cannot say how “big” a stimulus is in absolute size.
- feet, inches, meters

We can only talk about how much of the sphere they cover.
- Visual angle
- Degrees, minutes, seconds, radians
Computing visual angle

- Suppose you want to compute the visual angle, $\theta$, of a line (b,c)

Computing visual angle

- You need to know the distance from your eye to the object, $d$
Computing visual angle

- You need to know the size of the object
  - $2s$

Computing visual angle

- Trigonometry works best with right angles, so we find the middle of $(b,c)$ and work with one triangle (say, the top)
Computing visual angle

- This is a side-angle-side problem from trigonometry
  - You can figure out all other side lengths and angles

\[
\begin{align*}
\tan \left( \frac{\theta}{2} \right) &= \frac{s}{d} \\
\theta &= \frac{d}{2}
\end{align*}
\]
Computing visual angle

- This is a side-angle-side problem from trigonometry
  - You can figure out all other side lengths and angles

\[ \theta = 2 \arctan \left( \frac{s}{d} \right) \]

Be sure to keep units for \( s \) and \( d \) the same!

The \( \arctan \) function (arc tangent) might report in radians or degrees.
Example

- Suppose the snowman is 6 feet tall (s=6 feet) and 20 feet away (d=20 feet)

\[ \theta = 2a \tan \left( \frac{6}{20} \right) \]

Example

- Suppose the snowman is 6 feet tall (s=6 feet) and 20 feet away (d=20 feet)

\[ \theta = 2a \tan(0.3) \]
Example

- Suppose the snowman is 6 feet tall (s=6 feet) and 20 feet away (d=20 feet)
- My calculator gives an atan angle in radians, so I multiply by 180 degrees and divide by Pi radians

\[ \theta = 2 \times 0.29(\text{radians}) \times \frac{180(\text{deg})}{\pi(\text{radians})} \]

\[ \theta = 33.4 \]
Rule of thumb

- A pretty good estimate is found by holding your thumb at arms length
- The width of your thumb is approximately 2 degrees of visual angle

- There are 60 minutes to an angle
- There are 60 seconds to a minute
- I sit about 50 cm from my computer monitor, which is around 31 cm across
  - Visual angle is around 64 degrees

Ophthalmoscope

- The fovea is a special place
Detecting light

- The back of the eye is covered with cells that are sensitive to light
- Photoreceptors

Fig. 13. Tangential section through the human fovea. Larger cones (arrows) are blue cones.

Types of cells

- There are two main classes of photoreceptors
  - Rods: respond well to low light levels
  - Cones: respond well to higher light levels
Photoreceptors

- They are not distributed evenly across the retina
  - Most cones are in the fovea
### Optic disc

- This is where blood vessels and nerves enter and/or leave the eye
- There are no photoreceptors
- Light that falls here cannot be detected

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### CogLab

- In the experiment, you were to stare at a small square on the left with your right eye
- It takes practice to keep it there
On each trial a dot appeared somewhere. Your task was to report whether you saw it or not. Again, it's difficult to keep your eye from moving.

If the gold circle indicates the location of the optic disc, then any dot in here should not be seen.
Here’s the actual data. It’s a plot of the proportion of reports of seeing the dot at different positions. Averaging across subjects makes it blurry. Some subjects move their eyes and so report seeing the dot.

There are three kinds of cones that respond to different wavelengths of light:
- Short (blue)
- Medium (green)
- Long (red)
Cones

- Here’s a small section of the fovea
- Note that most photoreceptors are long wavelength cones (red)
- Why doesn’t most of the world look red?

Color

- Remember
- Color is a perceptual experience, not a property of light
- The magenta and orange have exactly the same wavelength!
Cones vs. Rods

- Cones and rods respond differently in the dark
  - Both become more sensitive to light
  - Rods go further than cones
- You can measure the faintest light someone can detect after dark adaptation
- At some point vision transitions from use of cones to use of rods

Night time vision

- Color vision is based on responses from cones
- For very faint stimuli, only rods respond
- This explains why dimly light rooms appear colorless
  - Or a moonlight night
Color blindness

- Due to a genetic defect, some people do not have all the cones that normals do
- Right: 3 or 5?
- Left: 73 or nothing?

Color blindness

- Color blind people often do see some colors

protanope

deuteranope

tritanope

normal
Conclusions

- Light projects on to the retina of the eye
- Measuring stimulus size by visual angle
- Rods and cones detect light
- Blind spot
- Rods more sensitive to light in dark
- Different cones respond to different wavelengths of light
  - Allows for color perception
  - Color blindness

Next time

- Photoreceptors connect to neurons
- Ganglion cells
- Receptive fields
- Relation to what we see