Early Visual Processing: Receptive Fields & Retinal Processing (Chapter 2, part 2)

Lecture 5

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Sensation & Perception (PSY 345 / NEU 325)
Princeton University, Fall 2017
the eye (viewed from above)
• **Cornea**: The transparent “window” into the eyeball (carries 2/3 of eye’s total refractive power)

• **Aqueous humor**: watery fluid in behind cornea

• **Lens**: allows changing of focus

• **Pupil**: The dark circular opening at the center of the iris in the eye, where light enters the eye

• **Vitreous humor**: transparent fluid that fills main cavity of the eye (gel-like; may contain “floaters”)

• **Retina**: light-sensitive membrane in the back of the eye that contains rods and cones.
- **photic sneeze reflex** (“sun sneezing”) tendency to sneeze when walking from a dark room into bright light

**topic of debate:**
- Aristotle - “sun heats the nose.”
- Bacon - closed eyes and didn’t sneeze!
- current thinking: “crossed wiring”
Image formation with a lens

Goal is to focus the light rays emanating from a single point to a single point on the imaging surface.
lenses

converging

diverging
**Refraction:** necessary to focus light rays, carried out by lens

- **Accommodation:** process in which the lens changes its shape, altering its refractive power

- **Emmetropia:** no refractive error
Figure 2.3  Optics of the human eye

(a) Emmetropia

(b) Myopia

• too fat / powerful
• eye is too long

(c) Myopia with correction

(d) Hyperopia

• too thin / not enough accommodation
• eye is too short

(near-sightedness)

(far-sightedness)
normal eye - accommodation

far away object

min

Good

max
normal eye - accommodation

far away object

near object

(min) Good

(max) Good

(courtesy ben backus)
**myopic (near-sighted) eye**

- lens too powerful

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- far away object
- can’t get far objects in focus
myopic (near-sighted) eye

- lens too powerful

- far away object
  - min: Good
  - max: can’t get far objects in focus

- near object
  - min: Good
  - max: Good
hyperopic (farsighted) eye

- lens not powerful enough

far away
object

min

max

Good
hyperopic (farsighted) eye

- lens not powerful enough

min

far away object

max

near object

Good

can’t get near objects in focus

• lens not powerful enough
• **Astigmatism**: visual defect caused by the unequal curving of one or more of the refractive surfaces of the eye, usually the cornea.

• if you have an astigmatism, some lines will have lower contrast.
Camera analogy for the eye

- **Aperture** (F-stop) = **Iris/pupil**. Regulates the amount of light coming into the eye

- **Focus** = **Lens**. Changes shape to change focus

- **Film** = **Retina**. Records the image
the retina
(“smart” film in your camera)
What does the retina do?

1. **Transduction**
   - Conversion of energy from one form to another (i.e., “light” into “electrical energy”)

2. **Processing**
   - **Amplification** of very weak signals (1-2 photons can be detected!)
   - **Compression** of image into more compact form so that information can be efficiently sent to the brain
     - optic nerve = “bottleneck”
     - analogy: jpeg compression of images

this is a major, important concept
Basic anatomy: photomicrograph of the retina

- Sclera
- Pigment epithelium
- 
  - Photoreceptor layer
  - External limiting membrane
  - Outer nuclear layer
  - Outer plexiform layer
- Inner nuclear layer
- Inner plexiform layer
- Ganglion cell layer
- Nerve fiber layer
- Inner limiting membrane

- Outer segments
- Inner segments
- Photoreceptor nuclei
- Photoreceptor axons (Henle’s fiber layer)
- Outer synaptic layer
- Horizontal cells
- Amacrine cells

Light

Scale: 50 μm
retina

cone

bipolar cell

retinal ganglion cell

optic disc
(blind spot)

optic nerve

inner

outer

optic nerve

retina

retinal ganglion cell

bipolar cell

cone

optic disc
(blind spot)
What’s crazy about this is that the light has to pass through all the other junk in our eye before getting to photoreceptors!

Cephalopods (squid, octopus): did it right.
• photoreceptors in innermost layer, no blind spot!

Debate:
1. accident of evolution?
   OR
2. better to have photoreceptors near blood supply?
retina

RPE (retinal pigment epithelium)

optic disc (blind spot)

optic nerve

inner

outer

retinal ganglion cell

bipolar cell

cone

RPE (retinal pigment epithelium)
blind spot demo

(a)

F

(b)

F