Sensation & Perception

• Ch. 3: Vision

© Takashi Yamauchi (Dept. of Psychology, Texas A&M University)

• Main topics
  – convergence
  – Inhibition, lateral inhibition and lightness perception
  – Interactions between neurons
  – Feature detectors
Question 1

- What do these devices have in common?
These devices make use of electromagnetic waves.

Capture electromagnetic waves and transform them into various forms.
What does the eye do?

→ Transducing light energy into electrical energy
Transduction

• → Light enters the eye
• → A photon hits a receptor
• → changes the shape of pigment molecules
• → triggers massive chemical reactions
• → generate electrical signals
- Solar cells (photovoltaics) produce electricity in a similar way as our eyes do.
Rods and cones

• Morphology
• Distribution on the retina
• Dark adaptation
• Spectral sensitivity
Photo receptors: Rods and cones

- Rods have bigger outer segments than cones.
- Why?
Outer segments capture photons

- Bigger outer segments can capture more light.
- Rods have bigger outer segments.
  - Rods allow us to see in the dark.
  - Cones are mainly for day vision.
  - Cones are for color perception.
How can we see objects?

• How can we see a book?
• How can we see a desk?
• Why don’t we see light?
Reflection of light

• What we see is a reflection of light.
• Different objects reflect different wavelengths,
  - → different objects show different colors
• Photo receptors in the eye are geared to capture different wavelengths
**Lens:** focuses light rays.

**Iris:** control the size of the pupil → regulating the amount of light reaching the retina

**Retina:** a layer of receptor cells

**Receptor cells** → **rods and cones**
Retina:

Rod and cone receptors (R)

Horizontal cells (H)

Bipolar cells (B)

Amacrine cells (A)

Ganglion cells (G)

Receptor outer segments

Receptor inner segments

Receptor cell bodies

Optic nerve fibers

Light rays
• Photo receptors are facing away from the light source.
• The optic nerve carries neural information to this spot.
• What happens?
  – No receptors, no vision \( \rightarrow \) blind spot
Some messages: how to improve your vision

- Massage your eye muscles
- Eat carrots
- Massage the back of your head.
Rods and cones

- Morphology
- Distribution on the retina
- Dark adaptation
- Spectral sensitivity
The distribution of cones and rods on the retina

- Cones are concentrated mainly on the fovea.
- There are no rods on the fovea.
- We move eyes to capture images on the fovea.
Rods and cones are different

• In their dark adaptation rates
Dark adaptation rates of rods and cones

• When you enter a dark room from outside, you can’t see well at first. But gradually, your eyes are adjusted to the dark, and see better.
• In terms of the activity of neurons, what is the difference between A and B? Any guess?

A. 

B.
Measuring the electrical activity of a neuron directly by inserting a thin needle into animal brains.
The frequency of action potential emitted by a neuron is correlated with the intensity of the stimulus.
Neural Processing by Convergence

• Why are rods more sensitive to light than cones?

• Because rods are bigger than cones.

• Because rods and cones are connected to ganglion cells in different manners.
Activities of neurons can be schematically shown as

The firing rate of neuron B is determined by the activation sent by neurons a1-a4.
Ganglion cell
• Convergence:
• The ratio of connections with two groups of neurons.
• Rods vs. Ganglion cells
  – 120:1
• Cones vs. Ganglion cells
  – 6:1
Why does this matter?

- How is this related to the higher sensitivity of rods?
The cones result in better detail vision than the rods

• Visual acuity
  – How far apart are two dots?
The frequency of action potential

The number of action potential emitted by a neuron is correlated with the intensity of the stimulus.
Fig. 2.11, p.53
• Demonstration:
  • On a scratch paper, draw two vertical lines of about 2 inches (1/2 inch apart).
  • Close your left eye, and focus your right eye on your index figure, and move the figure.
  • At some point, you can’t distinguish the two vertical lines.
The distribution of cones and rods on the retina

- Cones are concentrated mainly on the fovea.
- There are no rods on the fovea.
- We move eyes to capture images on the fovea.
The cones result in better detail vision than the rods

- Visual acuity
  - How far apart are two dots?
Neurons

• How do you detect there are two separate dots (lights)?
• How do you detect there are two separate dots (lights)?
• Rods are bigger than cones
• Convergence:
Lateral Inhibition & Mach bands
Herman grid
The frequency of action potential

The number of action potential emitted by a neuron is correlated with the intensity of the stimulus.
Questions: What happens to B?
Questions: What happens to B?
Receptive field

• The receptive field of a neuron in the visual system is the area on the retina that influences the firing rate (action potential) of the neuron.

• Measuring the receptive field of a ganglion cell
Receptive field of a ganglion cell

Measuring the frequency of action potentials elicited by this ganglion cell.

Cones

Ganglion cell
Receptive field of a ganglion cell
Questions: What happens to B?
Measuring the receptive field of a ganglion cell

Change the size of the stimulus and see the way a ganglion cell respond
Excitatory-monocoupled inhibitory-surround receptive field

Excitatory

Inhibitory
Questions: What happens to B?
Excitatory and inhibitory connections

- What neurons transmit is electricity.
- Some neurons send positive (excitatory) signals (+) → increase the firing rate of the target neuron.
- Some neurons send negative (inhibitory) signals (-) → depress the firing rate of the target neuron.
Spatial Summation

The firing rate of neuron B can be expressed by the overall summation of the signals that B receives.
How does this happen?
=\text{sum}(B)
Fig. 3-7, p. 51
Why is this important?

- help you to detect the edge of a figure
Physical stimuli

Your perception
Lateral inhibition

Figure 2.43
White’s illusion

• Can you explain this by lateral inhibition?
Are the horizontal lines parallel or do they slope?
Application: Machine vision

- Implementing the mechanism of lateral inhibition to a computer program.
• Edge detection algorithm
  – Zero-crossing