



The Brain, Biology and Cognition (BBC)

Lecture 3: Vision & Perception

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What Do We See?

When information enters the eye, its projected to the back of the eye called the retina.

The projected image is not an accurate internal copy of the external world.

It is a distorted & upside-down 2D image that gets transformed into the 3D world we perceive

Vision Research:

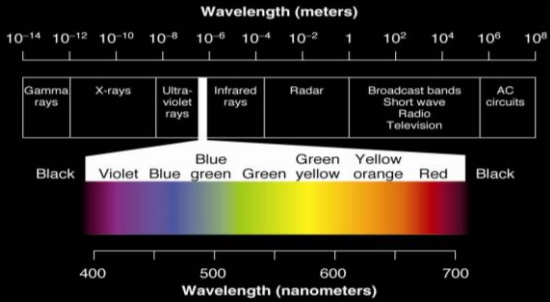
1. probes components of the visual system
2. Aims to assess what we see



We can see because light bounces off objects and that light enters the eye

- Light can be thought of in two ways:
 1. Particles of energy (photons)
 2. Waves of electromagnetic radiation (energy)
- Humans see light between 380-760 nanometers

The Electromagnetic Spectrum



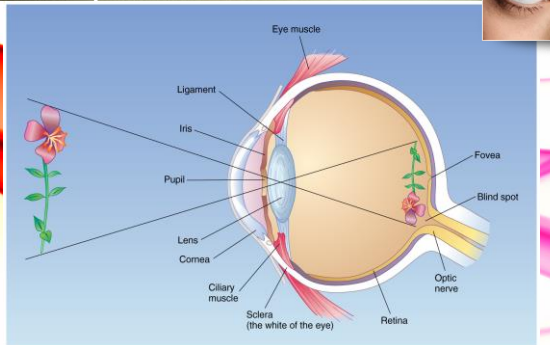
Some animals see other wavelengths, e.g., rattlesnakes thought to see infrared rays, which allows them to see warm-blooded prey in darkness.

The Pupil and the Lens



- Amount of light reaching retina is controlled by the **iris** (gives our eyes their colour).
- Light enters through the **pupil** (size changes in response to changes in illumination).
- This comes from compromise between:
 - **Sensitivity of eye** – ability to see when light is dim, and
 - **Acuity of eye** – ability to see details of objects.
- Behind pupil is the **Lens** – focuses light on the **retina**
- **Ciliary muscles** alter the shape of the lens as needed
 - This increases ability of the lens to bend (refract) light and brings close objects in to sharp focus.
 - When we focus on the distance the lens is flattened.
 - This process is called **accommodation**.

The Pupil and the Lens



The Human Eye

Eye Position and Binocular Disparity

- We have 2 eyes – so why do we not end up seeing 2 of everything?
- Movement of our eyes are coordinated so each point in the world is projected to corresponding points on the both retinas.
- To do this our eyes **Converge**: turn slightly inward when objects are close.
- But the position of images on the 2 retinas are never going to be the same because our eyes do not view the world from exactly the same position.
- This results in: **Binocular disparity** – difference in position of same image on the two retinas
- The visual system uses this to construct & provide the brain with a 3-D image and distance information



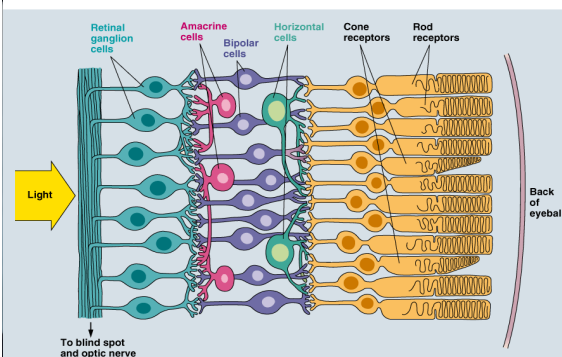
The Retina and Translation of Light into Neural Signals

- Light landing on the retina is then transferred in to neural signals to be processed by the CNS.
- The retina is considered “inside-out”
 - Light passes through several cell layers before reaching receptors
- The retina is composed of 5 layers of different types of neurons: receptors, horizontal cells, bipolar cells, amacrine cells, and retinal ganglion cells.
- Vertical pathway – receptors > bipolar cells > retinal ganglion cells
- Lateral communication - Horizontal cells & Amacrine cells



The Retina and Translation of Light into Neural Signals

Cellular Structure of the Mammalian Retina



The Retina and Translation of Light into Neural Signals

- Inside-out arrangement creates 2 visual problems:
- Incoming light is distorted by retinal tissue through which it must pass before reaching the receptors.

- Dealt with by the fovea: indentation about 0.33 cm in diameter at the centre of the retina.

- Thinning of the retinal ganglion cell layer at the fovea reduces the distortion of the incoming light.



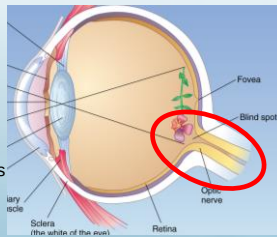
The Retina and Translation of Light into Neural Signals

2. For the bundle of retinal ganglion cell axons to leave the eye there is a gap in the receptor layer - **blind spot**.

- Section where there are no receptors so anything that falls on the area is not picked up.

- To deal with this, the system uses information by receptors around the blind spot to fill in gaps in the retinal image.

- Referred to as **completion** and suggests the visual system does more than just create a copy of the external world.



Cone and Rod Vision

Duplexity theory of vision – cones and rods mediate different kinds of vision



Cones:

Photopic (daytime) vision

- High-acuity color information in good lighting
- Only cones are found at the fovea

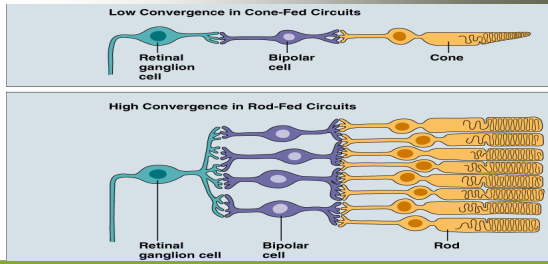
Rods:

Scotopic (nighttime vision)

- High-sensitivity, allowing for low-acuity vision in dim light, but lacks detail and color information
- More convergence than cone system, increase sensitivity, decrease acuity

Cone and Rod Vision

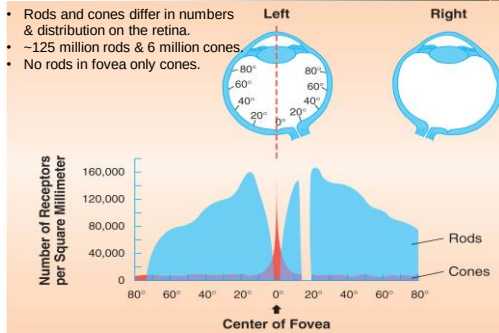
Difference comes from the way they are wired (convergence)
 Photopic system has few cones converging on each RGC
 Scotopic has several hundred rods converge on single RGC



A schematic representation of the convergence of cones and rods on retinal ganglion cells.

Cone and Rod Vision

- Rods and cones differ in numbers & distribution on the retina.
- ~125 million rods & 6 million cones.
- No rods in fovea only cones.



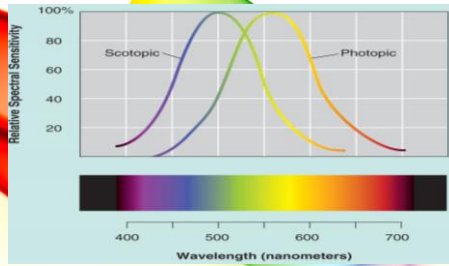
The distribution of cones and rods over the human retina. (Adapted from Lindsay & Norman, 1977.)

Spectral Sensitivity

- Lights of the same intensity but different wavelengths may not all look as bright
- A **spectral sensitivity curve** shows the relationship between wavelength and brightness
- There are different spectral sensitivity curves for photopic (cone) vision and scotopic (rod) vision

Spectral Sensitivity

Human photopic (cone) and scotopic (rod) spectral sensitivity curves.



- Under photopic conditions, the visual system is maximally sensitive to wavelengths of ~560 nanometers so a light at 500 nanometers would have to be more intense than one at 560 to be seen as equally bright.
- Under scotopic conditions the visual system is maximally sensitive to wavelengths of ~500 nanometers so a light of 560 nanometers would have to be more intense than one at 500 to be seen as equally bright.

Eye Movement



- Cones are responsible for mediating high-acuity colour vision under photopic conditions – but how do they do this when so many of them are crammed in to the fovea?
- Our eyes continually scan the visual field.
- So, our visual perception at any one time is the summation of recent visual information.
- This is why the world remains there even when we blink.
- Even when we fix our eyes on one object our eyes constantly move – and these involuntary fixational eye movements are of 3 types: tremor, drift, and saccades.



Visual Transduction: The Conversion of Light to Neural Signals



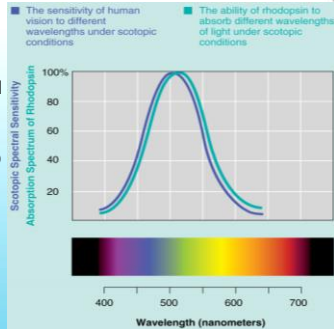
- **How does light turn to neural signals?**
- **Transduction:** conversion of 1 form of energy to another
- **Visual transduction:** conversion of light to neural signals by rods & cones.
- They contain chemicals called photopigments that absorb light and transduce it to neural activity.
- Red pigment (pigment is any substance that absorbs light) called rhodopsin was extracted from rods in 1876.
- When exposed to a continuous intense light it was bleached (lost its colour and its ability to absorb light)
- When put back in darkness, red colour & light-absorbing capability returned.

Visual Transduction: The Conversion of Light to Neural Signals



- Figure shows relationship between absorption spectrum of rhodopsin (green) & human scotopic spectral sensitivity curve (blue).

- The fact that they are so close shows that in dim light our sensitivity to various wavelengths is a direct consequence of rhodopsin's ability to absorb them.



Visual Transduction

The inhibitory response of rods to light

