260-2017-04-12-vision

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Prelude

Today's topics

- Vision

How vision informs

- What's out there?
  - Shape, form, color
- Where is it?
  - Position, orientation, motion

Electromagnetic (EM) radiation

http://en.wikipedia.org/wiki/File:EM_Spectrum_Properties_edit.svg

Features of EM radiation

- Wavelength/frequency
- Intensity
- Location/position of source
- Reflects off some materials
- Refracted (bent) moving through other materials

EM radiation provides information across space (and time)

Reflectance spectra differ by surface

http://http://www.vgt.vito.be/userguide/book_1/4/42/ie42bd.gif

Optic array specifies geometry of environment

Color == categories of wavelength

- Eyes categorize wavelength into relative intensities within wavelength bands
- RGB ~ **R**ed, **G**reen, **B**lue
  - Long, medium, short wavelengths
- *Color is a neural/psychological construct*

RGB monitors

How a camera works

The biological camera

The biological camera

Parts of the eye

- *Cornea* - refraction (2/3 of total)
- *Pupil* - light intensity; diameter regulated by Iris.
- *Lens* - refraction (remaining 1/3; focus)

Parts of the eye

- *Retina* - light detection
  - ~ skin or organ of Corti
- *Pigment epithelium* - regenerate photopigment
- *Muscles* - move eye, reshape lens, change pupil diameter

Eye forms image on retina

- Image inverted (up/down)
- Image reverseed (left/right)
- Point-to-point map (*retinotopic*)
- Binocular and monocular zones

Retinal image

Eyes views overlap

The *fovea*

http://www.brainhq.com/sites/default/files/fovea.jpg

The fovea

- Central 1-2 deg of visual field
- Aligned with visual axis
- *Retinal ganglion cells* pushed aside
- Highest *acuity* vision == best for details

Acuity varies across fovea

Acuity varies across fovea

http://michaeldmann.net/pix_7/blndspot.gif

What part of the skin is like the fovea?

Photoreceptors detect light

Photoreceptors detect light

- *Rods*
  - ~120 M/eye
  - Mostly in periphery
  - Active in low light conditions
  - One wavelength range

Photorceptors detect light

- *Cones*
  - ~5 M/eye
  - Mostly in center
  - 3 wavelength ranges

Photoreceptors "specialize" in particular wavelengths

Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013.

How photoreceptors work

- Outer segment
  - Membrane disks
  - *Photopigments*
    - Sense light, trigger chemical cascade
- Inner segment
  - Synaptic terminal
- Light *hyperpolarizes* photoreceptor!
  - The *dark current*

Retina

- Physiologically *backwards*
  - How?
- Anatomically *inside-out*
  - How?

Retina

- Physiologically *backwards*
  - Dark current
- Anatomically *inside-out*
  - Photoreceptors at back of eye

Retinal layers

http://www.retinareference.com/anatomy/

Retinal layers

- Bipolar cells
  - Horizontal cells
- Retinal ganglion cells
  - Amacrine cells

Center-surround receptive fields

Center-surround receptive fields

- Center region
  - Excites (or inhibits)
- Surround region
  - Does the opposite
- Bipolar cells & Retinal Ganglion cells ->
- Most activated by "donuts" of light/dark
  - Local contrast (light/dark differences)

What's a reddish-green look like?

What's a reddish-green look like?

Opponent processing

http://www.visualexpert.com/sbfaqimages/RGBOpponent.gif

Opponent processing

- Black vs. white (achromatic)
- Long (red) vs. Medium (green) wavelength cones
- (Long + Medium) vs. Short cones
- Can't really see reddish-green or bluish-yellow

From eye to brain

From eye to brain

- Retinal ganglion cells
- 2nd/II cranial (optic) nerve
  - Optic chiasm
- *Lateral Geniculate Nucleus (LGN)* of thalamus (90% of projections)

From eye to brain

- Hypothalamus
  - Suprachiasmatic n.
- Superior colliculus & brainstem

LGN

LGN

- 6 layers + intralaminar zone
  - Parvocellular (small cells): chromatic
  - Magnocellular (big cells): achromatic
  - Koniocellular (chromatic - short wavelength?)
- Retinotopic map of opposite visual field

From LGN to V1

From LGN to V1

- Via optic radiations
- *Primary visual cortex (V1)* in occipital lobe

Human V1

http://www.scholarpedia.org/w/images/3/3a/03-Human-V1.png

Measuring retinotopy in V1

(Dougherty et al. 2003)

Retinotopy in V1

- Fovea overrepresented
  - Analogous to somatosensation
  - High acuity in fovea vs. lower outside it
- Upper visual field/lower (ventral) V1 and *vice versa*

V1 has laminar, columnar organization

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- 6 laminae (layers)
  - Input: Layer 4
  - Output: Layers 2-3 (to cortex), 5 (to brainstem), 6 (to LGN)

V1 has laminar, columnar organization

- Columns
  - Orientation/angle
  - Spatial frequency

Orientation/angle tuning

https://foundationsofvision.stanford.edu/wp-content/uploads/2012/02/dir.selective.png

From center-surround receptive fields to line detection

Spatial frequency tuning

Low == gist || high == details

(Panichello, Cheung, and Bar 2013)

V1 has laminar, columnar organization

- Columns
  - Color/wavelength
  - Eye of origin, *ocular dominance*

Ocular dominance columns

Ocular dominance signals retinal disparity

http://www.scholarpedia.org/w/images/9/99/11-Hubel-Wiesel-model.png

Beyond V1

Beyond V1

- Larger, more complex receptive fields
- *Dorsal stream* (where/how)
  - Toward parietal lobe
- *Ventral stream* (what)

What is vision for?

- What is it? (form perception)
- Where is it? (space perception)
- How do I get from here to there (action control)
- What time (or time of year) is it?

References

Dougherty, R. F., V. M. Koch, A. A. Brewer, B. Fischer, J. Modersitzki, and B. A. Wandell. 2003. "Visual Field Representations and Locations of Visual Areas V1/2/3 in Human Visual Cortex." *Journal of Vision* 3 (10): 1–1. doi:10.1167/3.10.1.

Panichello, Matthew F., Olivia S. Cheung, and Moshe Bar. 2013. "Predictive Feedback and Conscious Visual Experience." *Perception Science* 3: 620. doi:10.3389/fpsyg.2012.00620.