

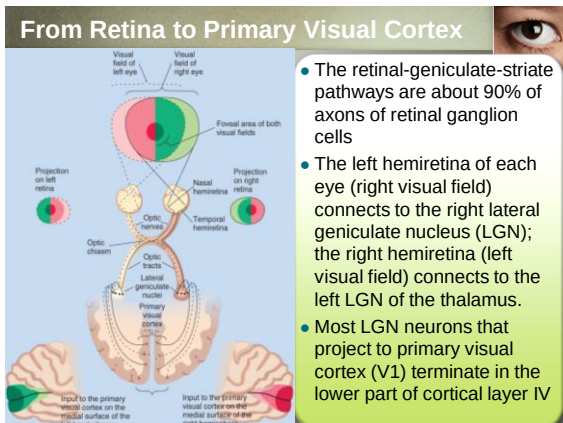


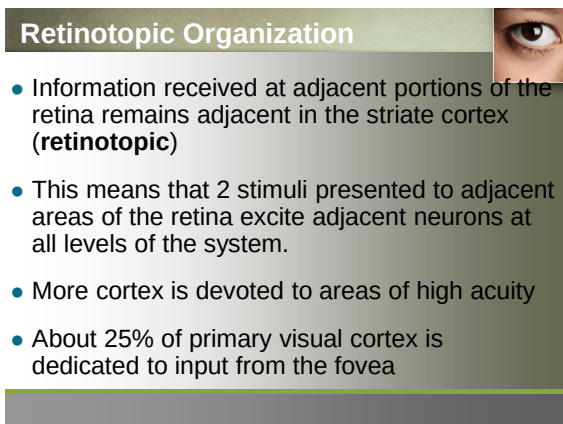
The Brain, Biology and Cognition (BBC)

Lecture 3: Vision & Perception

Dr Kate Williams







The M and P channels of communication that flow through each LGN.



Magnocellular layers

- Big cell bodies, bottom two layers of LGN
- Particularly responsive to movement
- Input primarily from rods

M

Parvocellular layers

- Small cell bodies, top four layers of LGN
- Color, detail, and still or slow objects
- Input primarily from cones

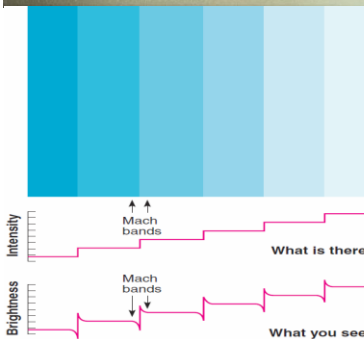
P

Seeing Edges



- Edges are informative because they define the extent and position of all objects in the world.
- An edge is where 2 different areas of a visual image meet.
- Perception of an edge is perception of contrast between 2 adjacent areas in the visual field.
- To enhance these contrasts our visual system creates nonexistent stripes called:
 - **Mach bands** for contrast enhancement
 - Makes edges easier to see
 - A consequence of lateral inhibition

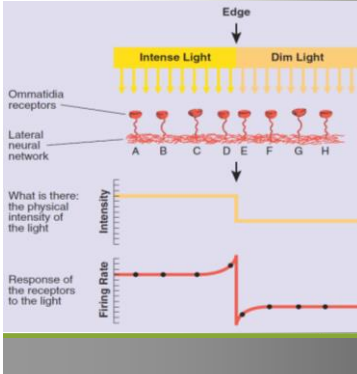
Lateral Inhibition and Contrast Enhancement



The illusory Mach bands

- Intensity graph shows what is actually there:
- a series of stripes of differing intensities.
- But what we see is the brightness changing from darker to lighter.
- Next to each edge the brighter stripe looks brighter than it actually is and the darker stripe looks darker.
- Mach bands enhance the contrast at each edge enabling us to see the edge easier.

Lateral Inhibition and Contrast Enhancement



How lateral inhibition produces contrast enhancement (Adapted from Ratliff, 1972)

- When receptor is illuminated by light, it fires & inhibits other receptors around it from firing.
- Contrast enhancement is firing rate of receptors on each side of edge
- E.g., receptor D fires more than others that are intensely illuminated (A,B,C) because it's next to the edge between intense & dim light.
- While receptor E fires less than others (F,G,H) because it's next to the edge between 2 types of lighting but on the dim side.

Receptive Fields of Visual Neurons

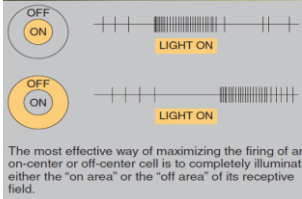
- Examination of brightness Contrast (Hubel & Wiesel)
- Work involved paralyzing eye muscles of animal to place tip of microelectrode near a single neuron in the visual system.
 - Animal shown image on screen to identify receptive field of the neuron
 - Receptive field = area of the visual field within which it is possible for a visual stimulus to influence the firing of that neuron.
- Response of neurons to different stimuli within its receptive field is recorded to characterize the types of stimuli that influences that neurons activity the most.
- Microelectrode pushed further & process repeated for another neuron.
- Recordings taken for 3 levels of the retina-geniculate-striate system: retinal ganglion cells, the lateral geniculate nucleus, & lower layer 4 of the striate cortex.

Receptive Fields: Neurons of the Retina-Geniculate-Striate System

Similarities seen at all three levels:

- Receptive fields of foveal areas are smaller than those in the periphery
- Neurons' receptive fields are circular in shape
- Neurons are monocular (each neuron had a receptive field in one eye but not the other).
- Many neurons at each level had receptive fields with excitatory and inhibitory area that were separated by a circular boundary.

Receptive Fields: Neurons of the Retina-Geniculate-Striate System



- Many cells have receptive fields with a center-surround organization: excitatory and inhibitory regions separated by a circular boundary



- Some cells are "on-center" and some are "off-center"

If both areas of a cell's receptive field are illuminated together, there is little reaction from the cell.

The responses of an on-center cell to contrast

Receptive Fields: Simple and Complex Cortical Cells



- In lower layer IV (4) of the striate cortex, neurons with circular receptive fields (as in retinal ganglion cells and LGN) are rare.
- Most neurons in V1 are either:
 - Simple – receptive fields are rectangular with "on" and "off" regions and respond best to bars of light, or
 - Complex – also rectangular, larger receptive fields, respond best to a particular stimulus anywhere in its receptive field

Figure 6.18 in Pinel book shows an example

Receptive Fields: Simple and Complex Cortical Cells



SIMPLE

- Rectangular
- "On" and "off" regions, like cells in layer IV
- Orientation and location sensitive
- All are monocular

COMPLEX

- Rectangular
- Larger receptive fields
- Do not have static "on" and "off" regions
- Not location sensitive
 - Motion sensitive
- Many are binocular

Columnar Organization of Primary Visual Cortex



- Cells with simpler receptive fields send information on to cells with more complex receptive fields
- Primary visual cortex neurons are grouped in functional vertical columns such that all cells in a column have the same receptive field and ocular dominance:
 - Ocular dominance columns – as electrode moves horizontally, the dominance of the columns changes through areas of left-eye dominance and then right-eye dominance
- Retinotopic organization is maintained

See Figures 6.19 & 6.20 in Pinel

Plasticity of Receptive Fields of Neurons in the Visual Cortex



- **Plasticity is a fundamental property of visual cortex function**
- **Studies examining reactions to simple & individual stimuli (e.g., bars or spots of light) do not provide full understanding of how the visual system works.**
- **Receptive field properties need to be examined within a scene because we do not see things in isolation in the world.**



Seeing Color: Component and Opponent Processing



Component theory (trichromatic theory)

Proposed by Young (1802), refined by Helmholtz (1852)

- Three types of colour cone receptors in the eye, each with a different spectral sensitivity.
- Colour of stimulus encoded by the ratio of activity in the 3 receptors.
- Derived from observation that any colour in the visible spectrum can be matched by mixing together 3 different wavelengths of light in different proportions

Opponent-process theory

Proposed by Hering (1878)

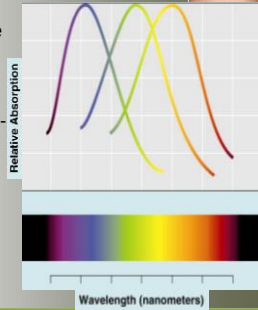
- Two different classes of cells encoding color and another class encoding brightness.
- Each encodes two complementary color perceptions.
 - One class for red & green
 - Another class for blue and yellow
- Accounts for color afterimages and colors that cannot appear together (reddish green or bluish yellow)

Both theories are correct: coding of color by cones seems to operate on a purely component basis, opponent processing of color is seen at all subsequent levels.

Seeing Color

The absorption spectra of the three classes of cones

- 1960s: technique to measure absorption spectrum of photopigment contained in single cone developed & confirmed Young's findings.
- 3 different types of cones in the retina & each has different photopigment with its own characteristic absorption spectrum.
- Diagram shows some cones are more sensitive to short wavelengths, some to medium and some to long.
- 3 cones are red, green, & blue.



Color Constancy & the Retinex Theory

- One aspect the theories could not account for was **Color constancy**: colour perception is not altered by varying reflected wavelengths.
- **Retinex theory** (Land): color determined by proportion of light of different wavelengths that surface reflects
 - Although wavelengths of light reflected by surface change with changes in illumination, efficiency which a surface absorbs wavelength & reflects unabsorbed portion does not change
- Relative wavelengths are constant, so perception is constant
 - Dual-opponent colour cells are sensitive to colour contrast
 - Found in cortical "blobs", the peg-like dual-opponent colour columns in the primary visual cortex

Figure 6.23 in Pinel



Color Constancy and the Retinex Theory



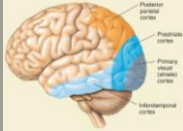
- Method of Land's (1977) color-vision experiments:
- Ps viewed Mondrians illuminated by various proportions of three different wavelengths from projectors:
 - short wavelength,
 - middle wavelength, and
 - long wavelength.
- Adjusting amount of light emitted from each projector (therefore adjusting amount of light of each wavelength) had no effect on the perception of the colours on the Mondrian display.



Cortical Mechanisms of Vision and Conscious Awareness



- Occipital & areas of temporal cortex also involved in vision.
- Visual cortex is of 3 different types:
 1. Primary visual cortex (striate): receives input from visual relay nuclei of thalamus & located in posterior region of occipital lobe,
 2. Secondary visual cortex: receives input from primary visual cortex & located in pre-striate & inferotemporal cortex,
 3. Association cortex: receives input from secondary visual cortex & located in several parts of cerebral cortex but mainly in posterior parietal cortex.
- As information flows up visual hierarchy the neurons have larger receptive fields and the stimuli to which neurons respond are more specific and complex.



The visual areas of the human cerebral cortex.

Functional Areas of Secondary and Association Visual Cortex



Neurons in each area respond to different visual cues, such as color, movement, or shape

Lesions of each area results in specific deficits



Anatomically distinct (about 12 functionally distinct areas identified so far)

Retinotopically organized

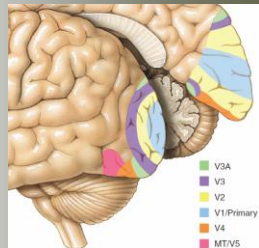


Visual Functional Specialization theory



- Different cortical areas in the brain are specialised for processing different visual attributes/functions (Zeki).

- V1 and V2: Early stage/initial processing of items
- V3 AND V3a: Cells respond to form (especially shape)
- V4: Cells respond to colour and some to line orientation
- V5/MT: Processes visual motion

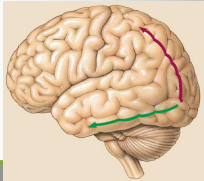


However, this leads to the binding problem(s) (Feldman)

Dorsal and Ventral Streams



- Most visual info enters V1 via lateral geniculate nuclei
- Info from the two LGNs is received in V1 combined.
- Then separated to various functional areas of secondary & association cortex (See Horton & Sincich, 2004).



dorsal stream
ventral stream

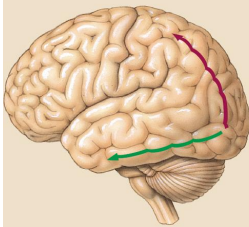
Dorsal and Ventral Streams



“Where” vs. “What” Theory – Ungerleider and Mishkin (1982)

“Control of behavior” vs. “conscious perception” theory - Goodale & Milner (1992)

Dorsal and Ventral Streams: Two Theories and What They Predict



“Where” vs. “What” Theory

Dorsal stream specializes in visual spatial perception
Ventral stream specializes in visual pattern recognition

Predicts

- Damage to dorsal stream disrupts visual spatial perception
- Damage to ventral stream disrupts visual pattern recognition

“Control of Behavior” vs. “Conscious Perception” Theory

Dorsal stream specializes in visually guided behavior
Ventral stream specializes in conscious visual perception

Predicts

- Damage to dorsal stream disrupts visually guided behavior but not conscious visual perception
- Damage to ventral stream disrupts conscious visual perception but not visually guided behavior
