Processing the Image
or
Can you Believe what you see?
Light and Color for Nonscientists
PHYS 1230
Optical Illusions
http://www.michaelbach.de/ot/mot_mib/index.html
Vision

We construct images unconsciously and very rapidly. Sometimes our eyes can even deceive us! These “optical illusions reveal the brain’s assumptions about what we are seeing. Our brains are just as fertile when we use our other senses. In moments of anxiety, for instance, we sometimes "hear things" that are not really there. But suppose a leopard approached, half-hidden in the jungle—then our ability to make patterns out of incomplete sights, sounds, or smells could save our lives.

So vision is not merely the act of forming the image of the object on the retina. Our brain must interpret the image.
Previously we learned how the eye forms an image of the object on the retina, how we can correct vision problems, and how we use optical instruments to help see objects.

Next we will talk about the following processes that happen in the retina, the nerve pathways, and the brain. In the following we will talk about lightness and darkness. Then we will discuss depth and color.
Light rays reflected by an object—for example, a pencil—enter the eye and pass through its lens. The lens projects an inverted image of the pencil onto the retina at the back of the eye. Signals produced by rod and cone cells in the retina then start on their way into the brain through the optic nerve and reach a major relay station, the LGN (lateral geniculate nucleus).

Signals about particular elements of the pencil then travel to selected areas of the primary visual cortex, or V1, which curves around a deep fissure at the back of the brain. From there, signals fan out to "higher" areas of cortex that process more global aspects of the pencil such as its shape, color, or motion.

http://www.hhmi.org/senses
• The visual pathway begins in the retina, and signals travel through the following pathway -
  - Photoreceptors
  - Horizontal cells
  - Bipolar cells
  - Amacrine cells
  - Ganglion cells
  - Optic nerve
  - Optic chiasma
  - Visual cortex of brain

• A lot of pre-processing begins in the retina.
• The retina is wired to quickly recognize lines and shapes
• The brain is wired to quickly recognize faces.

http://ligwww.epfl.ch/~fua/vision/3/misc/exam/human/2/
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The response of each point on the retina is influenced by neighboring regions. Each ganglion cell receives signals from rods and cones in a certain area of the retina - this area is called the RECEPTIVE FIELD.
Lightness and Brightness

BRIGHTNESS: Amount of illumination. The opposite is Dim.

LIGHTNESS: Property of a surface e.g. the paper your notes are copied on is lighter than newspaper. The opposite is Darkness.

In everyday life these words are used interchangably, but in this course, brightness is used to describe the light source and lightness to describe the shade of gray. e.g. a surface that reflects 10% of light is a shade of gray, and that shade is INDEPENDENT of the amount of light illumination (or brightness).

LIGHTNESS CONSTANCY: Our eyes and brain correct for the amount of light available so that a newspaper looks the same under bright or dim light.
WEBER’S LAW

We perceive equal steps of lightness (equally spaced shades of gray) when the ratios of lightness are equally spaced.

The percent of light reflected from a surface is a quantitative measure of its lightness. A reflectance of 50% means that 1/2 of the light incident on the surface is reflected, while 1/2 is absorbed.

According to Weber’s Law, reflectances of 1/2, 1/4, 1/8, 1/16, will look equally spaced, but reflectances of 0.9, 0.8, 0.7 etc. will not look equally spaced.

**FIGURE 7.4**

Weber’s law. (a) Reflected light intensity increases by steps of an equal *amount* (1, 2, 3, 4, . . .) — a linear scale. (b) Reflected light intensity increases by steps of an equal *ratio* (1, 2, 4, 8, . . .) — a logarithmic scale. Steps of an equal ratio, (b), are equal steps in lightness.
When light falls on a photoreceptor, it responds by firing more frequently. It also inhibits adjacent cells from firing. This is called lateral inhibition.
In the figure, the green rectangles represent photoreceptors, each generating a signal appropriate for the amount of light falling on it. The red circles represent output neurons of the retina, whose signals will go to the brain through the optic nerve. Each output neuron is shown as receiving input from an overlying photoreceptor (vertical black lines) as well as inhibitory input from adjacent photoreceptors (angled blue lines). It is this laterally spread inhibition that gives "lateral inhibition" networks their name.

http://serendip.brynmawr.edu/bb/latinhib.html
At the bottom of the schematic is a representation of the signals in the output neurons (purple lines). Output neurons well to the right of the dark/light border are excited by an overlying photoreceptor but also inhibited by adjacent, similarly illuminated photoreceptors. The same is true far to the left of the dark/light border. Hence, assuming that the network is organized so that equal illumination of exciting and inhibiting photoreceptors balances out, output neurons far from the edge in either direction will have the same output signals. Only output neurons near the dark/light border will have different output signals.

http://serendip.brynmawr.edu/bb/latinhib.html
As one approaches the dark/light border from the left, the signals will decrease, because inhibition from more brightly lit photoreceptors to the right will outweigh the excitation from the overlying dimly lit photoreceptors. As one approaches the dark/light border from the right, the signals will increase because excitation from brightly lit photoreceptors is not completely offset by inhibition from the dimly lit photoreceptors to the left.

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EXAMPLES OF LATERAL INHIBITION

Uniform white background: all cells are inhibited by adjacent cells, so that all of the white is not as bright.
EXAMPLES OF LATERAL INHIBITION

Gray surrounded by white: this seems darker than gray surrounded by black, where the is no lateral inhibition at work. This is the basis of simultaneous lightness contrast - perceived lightness is affected by surroundings.
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CONCEPT QUESTION ON LATERAL INHIBITION

The reason that the gray surrounded by black appears lighter than the gray surrounded by white is -

A. The photoreceptors compare the two gray dots and think the right one is lighter

B. The black adjacent to the right gray dot eliminates lateral inhibition and so that gray appears lighter

C. The white adjacent to the left gray dot causes lateral inhibition so it appears darker
CONCEPT QUESTION ON LATERAL INHIBITION

Which specific white area causes lateral inhibition?

A. The entire white area

B. The white directly surrounding the gray dot
The four squares in the middle of these grey backgrounds are, in fact, all the same brightness intensity. The reason that the one on a black background looks lighter in shade than the ones on lighter backgrounds is because of the brightness contrast between the foreground and background.
MORE LATERAL INHIBITION

If you don't believe it, here is proof.
The gray spots that you perceive result from lateral inhibition. The effect is greater in your peripheral vision, where lateral inhibition acts over greater distances. Why?
The gray spots that you perceive result from lateral inhibition. Why do you see dark squares at the center of the white crosses?

A. When light falls on a photoreceptor, adjacent cells are inhibited from firing. The four surrounding dark squares cause the dim response in the center of the white cross bars.

B. When light falls on a photoreceptor, adjacent cells are inhibited from firing. The four white cross bars thus inhibit the response in the center of the white cross bars.

C. When light falls on a photoreceptor, adjacent cells are inhibited from firing. The large area of white cross bars inhibits the response throughout the image, that appears as dark spots in the center of the white cross bars.
The gray spots that you perceive result from lateral inhibition. Why do they appear mainly in your peripheral vision?

A. When light falls on a photoreceptor, adjacent cells are inhibited from firing. The rods are sensitive to light and dark, so the effect is strongest in your peripheral vision.

B. When light falls on a photoreceptor, adjacent cells are inhibited from firing. The cones are sensitive to color, so you do not see this effect in the center of the image.

C. When light falls on a photoreceptor, adjacent cells are inhibited from firing. The rods are spaced farther apart in your peripheral vision, making the effect stronger for a large pattern such as shown here in the Hermann Grid.
The white spots that you perceive result from lateral inhibition. Why do you see white spots at the center of the black crosses?

A. When no light falls on a photoreceptor, adjacent cells are un-inhibited. The four surrounding white squares cause the dim response in the center of the black cross bars.

B. When no light falls on a photoreceptor, adjacent cells are un-inhibited from firing. The four black cross bars thus encourage a response in the center of the black cross bars.

C. When no light falls on a photoreceptor, adjacent cells are un-inhibited from firing. The large area of black cross bars accentuate the response throughout the image, that appears as white spots in the center of the black cross bars.
MODERN GRID ILLUSION

Although the Hermann Grid illusion is pretty well understood, where the effect is due to lateral inhibition, the Scintillating Grid illusion, is much more complex. This Scintillating Grid illusion is distinct from the Hermann Grid illusion in that eye movements are important. Although there was a pretty comprehensive article on this illusion in Vision Research, the underlying mechanism behind it is not yet fully understood.

LATERAL INHIBITION IN ART

Georges Seurat’s “La Poseuse en Profil”. By exaggerating the edge enhancement due to lateral inhibition, Seurat makes the difference between the actual light intensity in each region appear greater.
MORE LATERAL INHIBITION IN ART

Victor Vasarely’s “Arcturus II”. The four X’s results entirely from image processing in your visual system. Each concentric square is of uniform intensity and reflectance. But because the corners of the square are directly bounded by two sides of darker hue, lateral inhibition makes the corners appear lighter, giving rise to an X.
Take two small pieces of paper and place them on the paper so that you can see only one of the steps. You will probably notice that this step appears uniformly bright across its horizontal extent. However, when you view all the steps at once, each one appears lighter on the left and darker on the right.
This effect is due to edge enhancement - at an edge between light and dark, the dark is made darker due to lateral inhibition of the cells that are seeing the lighter region.
Although each vertical band has equal color across the width, we perceive that the grayscale has a gradient in each region.
CRAIK O’BRIEN ILLUSION

Contrast at the edge of a region is transferred to the whole region. E.g. if a rug is darker than the floor at its edge, then the whole rug is thought to be darker than the floor, even if it is lighter in the center.
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Optical illusion showing that perception of brightness depends on contrast rather than absolute intensity of light.

The center gray stripe reflects exactly the same amount of light on the left side as on the right; the right side looks brighter because of contrast.
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CENTER SURROUND OF GANGLION CELLS

When light strikes any of the cones in the center of the receptive field, the ganglion is excited (++)

When light strikes any of the cones in the surroundings, the ganglion is inhibited (-)
RESPONSE OF EYE DEPENDS ON THE PATTERN OF THE LIGHT
RESPONSE OF EYE DEPENDS ON THE PATTERN OF THE LIGHT

(a) When a uniform gray area is imaged on the receptive field, a small background response occurs
(b) When bright light is imaged on the receptive field, a large response occurs
(c) When bright light is imaged on the surround of the receptive field, the response is decreased below background
(d) When bright light is imaged on the center and surround of the receptive field, a small background response occurs - excitation and inhibition balance
(e) When bright bars are imaged on the center and surround of the receptive field, a very large response occurs - the dark bars reduce inhibition
(e) When closely spaced bars are imaged on the center and surround of the receptive field, a small background response occurs - there is no net excitation or inhibition
CONCEPT QUESTION ON EYE RESPONSE

Which of the following receptive field illuminations will get the biggest response?

A  B  C
The shaded circles seem to form an X made of spheres. But if you rotate the image 180°, the same circles form an X made of cavities, since the brain assumes that light comes from above.

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The two lines appear to have different lengths. They are actually the same length, but the arrow heads make them look different. This is the Muller-Lyer illusion and originates from the similarity with perspective of the side of a building (if they were on their sides). The top one would be the inside of a building and so looks smaller, the other is the outside of a building so looks bigger.