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COLOR VISION: CHAPTER 9

What Are Some Functions Of Color Vision?

What Physical Attributes Are Associated With Color?

- We see objects because of the ____________________________________ from them and that light in the visible spectrum has wavelengths that are associated with ____________________________________.

Quote from you text

- "Colors are created by our perceptual system, and although specific colors are related to specific wavelengths, the connections between wavelength and the experience we call color is an arbitrary one. There is nothing intrinsically blue about short wavelengths or red about long wavelengths. In fact, the light rays are simply energy that has no color at all. Looking at it this way, color is not a property of wavelength but is the brain's way of letting us know what wavelengths are present."

What Physical Attributes Are Associated With Color?

- **<u>Reflectance Curve</u>**:
  - **<u>Achromatic Colors</u>**: light reflection is ______________ across the spectrum – contain no hues.
    - ____
    - ________________________ consists of a combination of different color lights with similar/equivalent reflections.
    - ________________________________: reflecting almost no light

- **<u>Chromatic Colors</u>**: some wavelengths are ______________________ than others.
  - Chromatic color is also referred to as ___________ and is the psychological reaction to wavelengths ranging from about **400 nm** (seen as violet) to about **700 nm** (seen as red).

- **<u>Selective Reflection</u>**:

  - <u>Example</u>: Your **jeans** look blue because their surface is **absorbing** most of the ___________________________________ and **reflecting** to your eyes primarily light from the **blue portion** of the spectrum.

  - <u>Example</u>: **Glaciers** inside do not reflect all wavelengths equally. Instead, the ice selectively reflects ______________________and this causes the ice to appear **deep blue**.

HOW CAN WE DESCRIBE COLOR EXPERIENCE?

- **<u>Basic Colors</u>:**
- **<u>Color Wheel</u>** was proposed by Newton in 1704 as a way to organize colors which matches the order of the colors in the visible spectrum.
- People can discriminate among about ________________________ across the visible spectrum.
- **<u>Saturation</u>**: More colors can be created by changing a color's saturation –
  - e.g., Pink = desaturated red.
- **<u>Intensity</u>** = making a color brighter or dimmer.
- **<u>Munsell Book of Colors</u>** contained **1,225** color samples.

Additive Color Mixing

- Mixing __________________ of different wavelengths
- All wavelengths are available for the observer to see
- Superimposing **blue** and **yellow** lights leads to __________________ percept
- If we were to mix paints of the same color the perception would be ______________.

Subtractive Color Mixing

- Mixing **paints** with different pigments
- Additional pigments (colors) reflect _____________________ wavelengths
- Mixing blue and yellow leads to green

TRICHROMATIC THEORY OF COLOR VISION

- Young (1802) & von Helmholtz (1852) both proposed that the eyes have **3** types of color **receptors** that detect **3** primary colors.

- All other colors can be derived by combining these three.

- **Color Matching Experiments**:

    - Ss were asked to adjust the amounts of ________________________________ of light mixed together in a **"comparison field"** until the color of this mixture matched the color of a single wavelength in a **"test field."**

    - People with **normal color vision** needed to **use at least _______ wavelengths** to make a match.

    - People with **color deficiencies** only needed to mix **_______ wavelengths** to make the match.

Physiological Evidence for the Trichromatic Theory

- **Three Cone Visual Pigments** have been identified and are named for the wavelength that they are most sensitive to:

    - **Short (419 nm):**
        - These were the last to be identified by scientist.
        - They differ from the other cones because their **absolute sensitivity** is lower, they are **more vulnerable to disease**, and they are **almost completely absent in the center of the fovea.**

    - **Medium (531 nm)**

    - **Long (558 nm)**

- The S-, M-, and L- cones occur in a **ratio of 1:5:10** in the retina.

Response of Cones and Color Perception

- Color perception is based on the response of the ________________________________.

    - Responses vary depending on the wavelengths available.
    - Combinations of the responses across all three cone types lead to perception of all colors.
    - Color matching experiments show that colors that are perceptually similar (________________________) can be caused by different physical wavelengths.

Are Three Receptor Mechanisms Necessary for Color Vision?

- **Dichromats** have just 2 types of cone pigment and

- Recent evidence suggests that some humans have **more than three cone** pigments.
  - These different cone systems cause a shift in sensitivity resulting in different color perceptions than people with 3 cone systems.

Trichomatic theory could not explain all color perceptions.

OPPONENT-PROCESS THEORY OF COLOR VISION

- Ewald Hering (1818, 1820): Color vision is caused by opposing responses generated

  by ________________________________ and by ________________________________.

- Support for this theory came from:
  - Color afterimages and simultaneous contrasts.
  - Types of color blindness are red/green and blue/yellow.
  - Trichomatic Theory could not explain these.

SUPPORT FOR THE OPPONENT-PROCESS THEORY

- **Opposing Afterimages**:
  - a _______________ field generates a _______________ after image (paired)
  - a ___________________ field generates a ____________ after image (paired)

- **Simultaneous color contrast**: Surrounding an area with a color changes the appearance of the surrounded area.
  - In the case of the flag the green afterimage surrounds a white area and causes it to appear red.
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- **Visualizing colors:** it is easy to visualize 2 colors that are not opposed (e.g., reddish-yellow) than 2 colors that are opposed (e.g., reddish-green).

- People who are colorblind to _______________ are also color-blind to _____________

  and people who can't see ________________ also cannot see ___________________.

OPPONENT-PROCESS THEORY

- Three Mechanisms of Opponent Process Theory, each of which responds in opposite ways to different intensities or wavelengths of light:
  - Black (-) & White (+)
  - Red (+) & Green (-)
  - Blue (-) & Yellow (+)

  - These responses ***were*** believed to be the result of chemical reactions in the retina

Physiology of Opponent-Process Theory

- **<u>Opponent Neurons</u>** were found in the ________________________________
- They respond with an ________________________ response to light from one end of the spectrum and with an _____________________ response to light from the other end.
  - The **B+Y-** cell
  - The **G+R-** cell
  - The **Y+B-** & **R+G-** cell

Opponent Process & Trichromatic Theories Combined

- Both theories are supported by physiological evidence.
- Each theory describes physiological activity at ________________________ in the visual system.

Processing Of Color Information Takes Place in 2 Stages

- First, the cones in the retina respond with different patterns to different wavelengths ____.
- Second, neurons in the LGN integrate the inhibitory and excitatory signals from the receptors ____.
- Color vision also involves a number of different ______________________________, but more research is needed to examine how color is coded in the cortex.

COLOR DEFICIENCY TESTING

- **Color Vision Tests called Ishihara Plates**: color deficient people either perceive different numbers than those with normal color vision or no numbers at all.

COLOR DEFICIENCY

- **Color Matching Tests** determine the minimum number of wavelengths needed to match another wavelength in the spectrum.

- This procedure has revealed **3 types of color deficiencies**:
  - **Monochromat**: Need only ___________ wavelength
  - **Dichromat**: Need _____________ wavelengths
  - **Anomalous Trichromat**: Needs ______________ wavelengths
    - Mixes wavelengths in different proportions than trichromats and will not be as good at discriminating between wavelengths that are very close together.

- **Monochromatism = color blind**
  - They see everything in shades of lightness ____________________________
  - rare genetic disorder that occurs in __________________________________.
  - Only _______________and no functioning _____________________.
  - ____.
  - Ability to see only ____.
  - Very sensitive to ________________________.

Gene Disorders & Dichromatism

- **Sex or X–linked disorders** occur when a __________________ allele is carried on the X chromosome.

- ____________________are more likely to be affected, since they only have ________ chromosome and therefore do not have a corresponding dominant gene to override the recessive gene.
  - **Red-green color blindness**
    - for son to be color-blind, what must mother be?
    - for daughter to be color blind what must parents be?

COLOR DEFICIENCY

- **3 Forms of Dichromatism**:
  - **Protanopia**: sex-linked recessive disorder inherited through a gene on the X chromosome.
    - Affects 1 % of males & .02 % of females.

  - **Deuteranopia**: sex-linked recessive disorder inherited through a gene on the X chromosome.
    - Affects 1 % of males & .01 % of females.

  - **Tritanopia**: very rare, affecting only .002% of males & .001 % of females.

COLOR DEFICIENCY

- **Cortical Color Blindness**: The disorders just described are color deficiencies resulting from receptor problems, but color deficiency can be caused by cortical problems resulting from injury or stroke.

  - **Cerebral Achromatopsia**: color vision loss due to brain injury and people with this condition typically see the world without color.

  - The cone systems are not affected in these individuals. Therefore, processing information about wavelength is not the same as perception of color.

  - Cortical areas are needed to change this stimulation into something meaningful.

What Does a Person with Color Vision Deficiencies Perceive When He/She Views Various Colors?

- To answer this question we must use a **Unilateral Dichromat** who is a person with trichromatic vision in one eye and dichromatic vision in the other.

  - This person can look at a color with his/her dichromatic eye and then determine which color it corresponds to with his/her trichromatic eye.

Perceiving Colors Under Changing Illumination

- Color constancy - perception of colors as relatively constant in spite of changing light sources.
  - Sunlight has approximately equal amounts of energy at all visible wavelengths

    (________________________)

  - Tungsten lighting has more energy in the long-wavelengths (______________)

  - Objects _________________________________ from these two sources

Why does color constancy occur?

- **Chromatic Adaptation**: prolonged exposure to chromatic color such as red light _______________________________your long-wavelength cone pigment, which decreases your _____________________ to red light.

- When in a tungsten lit room your eyes become adapted to the yellow/long-wavelength-rich tungsten light, which will decrease your eyes' sensitivity to long wavelengths.
  - This decreased sensitivity causes the long-wavelength light reflected from objects to have less effect than before adaptation and this compensates for the greater wavelengths in the tungsten light.

- **The effect of the surroundings**: color constancy works best when the object is surrounded by objects of different colors and works less well if the surroundings are masked.