Visual Sensory System

Human Factors Psychology
Dr. Steve

Properties of Light

Light is an electromagnetic wave
Amplitude perceived as brightness
Wavelength (nm) perceived as hue

Physical Measures of Light

Luminous Flux – energy of source (units of candela)
Illuminance – amount of energy that strikes surface of object (foot candle or lux)
Luminance – amount of energy reflecting off the surface of an object (foot lambert)
Reflectance – ratio of luminance/illuminance
Brightness – perceived intensity
Anatomy of the Eye

- Cornea – outer covering of the eye where light is first focused
- Lens – does the fine tuning
- Retina – area in back of eye containing photoreceptors

Accommodation – changing the shape of the lens to focus images on the retina caused by contracting/relaxing ciliary muscles.
- Myopia – nearsightedness caused by inability to flatten the lens enough to focus image on retina (may be due to elongated eye)
- Presbyopia – farsightedness that occurs naturally with age as the lens becomes less flexible.

Color Vision

- CIE Color Space
  - 2-D representation of 3-D color space
  - Hues more saturated (pure) at rim, diluted toward the center (white)
  - X axis – long wavelengths (red)
  - Y axis – medium wavelengths (green)
  - All colors represented by x,y coordinates
  - Center is white – combo of all wavelengths
Color Vision

Types of color deficiencies and color blindness (click to see what color blind see)

- **Protanomaly** (1% of males) – low sensitivity to red (low λs)
- **Deuteranomaly** (6% of males) – low sensitivity to green (med λs shifted to red)
- **Protanopia** (<1% of males) – see in shades of blue and yellow – neutral pt as grey
- **Deuteranopia** (<1% of males) – see in shades of blue and yellow – neutral pt as grey
- **Tritanomaly/Tritanopia** (very rare in both sexes) – blue-yellow deficiency/blindness
- **Monochromacy** (extremely rare) – inability to distinguish any colors

Photoreceptors

- **Rods** – sensitive to dim light (night vision)  
  - found mostly in periphery  
  - why can see a dim star better if look a few degrees to one side
- **Cones** – sensitive to color (daylight vision)  
  - concentrated in fovea  
  - provides fine detail

Color Vision

**Trichromatic Theory**

- Trichromatic Color Theory – color perception is determined by ratio of activity in three different cone mechanisms with different spectral sensitivities (like R B G monitors)
- White curves indicate sensitivity of three types of cones (color vision);
- Black curve indicates sensitivity of rods (night-time vision)
Purkinje Shift

- **Purkinje shift** – as we switch from cone to rod vision (day to night), shorter wavelengths appear brighter (green objects appear brighter, red objects appear darker).

- (Human Factors application) How does the Purkinje shift play a role in the design of fire trucks?

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Color Vision

Opponent Process Theory

Hering’s **Opponent Process Theory**: Eye contains antagonistic responses to 3 pairs of colors

- Blue/Yellow opponent responses
- Red/Green opponent responses
- Black/White opponent responses

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Color Vision

Opponent Process Theory

Stare at center of the flag for 30 sec. Then look at blank white surface. What do you see? How does this support the opponent process theory?
Dark Adaptation

- Takes about 30 minutes to dark adapt, but just a few minutes to light adapt

(Human Factors application: why are red lights used in cockpits and darkrooms?)
- Because rods are insensitive to longer wavelengths, eyes “think” they are in the dark already and adapt more quickly.

Visual Acuity

20/20 Vision – a person can see from 20 feet what a person with “normal” vision can see from 20 feet

20/40 Vision – a person can see from 20 feet what a person with “normal” vision can see from 40 feet

Contrast and Visibility

<table>
<thead>
<tr>
<th>Variable</th>
<th>Effect</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast</td>
<td>Visibility ↓</td>
<td>Black on gray</td>
</tr>
<tr>
<td>Illumination ↓</td>
<td>Contrast Sensitivity ↓</td>
<td>Reading map in poor light</td>
</tr>
<tr>
<td>Polarity</td>
<td>Black on white</td>
<td>Viewgraphs</td>
</tr>
<tr>
<td>Spatial Frequency</td>
<td>Optimum CS at 3 C/D</td>
<td>Font sizes</td>
</tr>
<tr>
<td>Visual Accommodation</td>
<td>CS</td>
<td>Night driving</td>
</tr>
<tr>
<td>Motion</td>
<td>CS</td>
<td>Traffic signs</td>
</tr>
</tbody>
</table>
Contrast, Spatial Frequency (Font Size) and Font Style must be considered in the display of text for optimum legibility (Human Factors Application: While the green background provides good contrast and the font size is highly legible, the font style does not allow for visual separation of letters.)
Monocular Depth Cues

Linear Perspective
- converging parallel lines

Relative Size
- if 2 objects are known to be similar size, the smaller one appears further away

Ames room illusion fools us into thinking that the distance is the same to both people in the photo, therefore their size must be different.

Monocular Depth Cues

Interposition
- Nearer objects obscure the view of further objects

Light & Shading
- 3-D objects cast shadows and shade on opposite side of illumination source, and reflections on same side

Monocular Depth Cues

Textual Gradients
- Texture appears more fine with increasing distance

Aerial Perspective
- Objects in the distance appear hazy or bluish
Monocular Depth Cues

Motion Parallax
- As perceiver moves, objects in foreground appear to move by faster than objects in background

Binocular Cues

Convergence
- Eyes rotate inward as object gets closer

Retinal Disparity
- Slightly different image to each eye, brain combines them

Retinal Disparity (3D T-Rex)

Click for more anaglyphs:
**Depth Perception**

Identify the monocular cues to depth perception in this photo. How does top-down processing affect your perception?

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**Visual Search**

<table>
<thead>
<tr>
<th>Serial Search</th>
<th>Parallel Search</th>
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</thead>
<tbody>
<tr>
<td>Q Q Q Q Q Q Q</td>
<td>O O O O O O O</td>
</tr>
<tr>
<td>Q Q Q Q Q Q Q</td>
<td>O O X O O O O</td>
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<tr>
<td>Q Q Q Q Q O Q</td>
<td>O X O O O O O</td>
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<tr>
<td>Q Q Q Q Q Q Q</td>
<td>O O O O O O O</td>
</tr>
<tr>
<td>Q Q Q Q Q Q Q</td>
<td>O O O O X O O</td>
</tr>
</tbody>
</table>

Search time: \( T = \frac{(N \times I)}{2} \)

I = inspection time per object

N = total number of objects

**Pop-out Effect**

- conspicuities

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**Signal Detection Theory**

- hit rate 7%
- false alarm rate 8%
- “no” region
- “yes” region
- sensory continuum

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Signal Detection Theory

<table>
<thead>
<tr>
<th>Actual State</th>
<th>Signal Present (Strike)</th>
<th>Signal Absent (Ball)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hit</td>
<td>P(H)</td>
<td>False Alarm</td>
</tr>
<tr>
<td></td>
<td>Base Hit!</td>
<td>P(FA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Swinging Strike</td>
</tr>
<tr>
<td>Miss</td>
<td>1 – P(H)</td>
<td>Correct Rejection</td>
</tr>
<tr>
<td></td>
<td>Called Strike</td>
<td>1 – P(FA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ball</td>
</tr>
</tbody>
</table>

Operator Response

Yes (Swing)

No (Hold up)

Signal Detection Theory

Receiver Operating Characteristic Curve

SDT Application

Think of some situation to which you can apply signal detection theory.

1. What do each of the outcomes (hit, miss, false alarm, correct rejection) mean in the context you are thinking about? What are their consequences?
2. How great do you think d’ (the sensitivity) is in this situation (is there a lot or little overlap between the ‘signal’ and ‘noise’ curves)? How might we change d’ in this situation?
3. What might cause people to adopt a certain b (the criterion) in this situation? Is a risky or a conservative criterion preferable? How might we change b in this situation?
4. What might be a consequence of examining the situation using signal detection theory rather than simply monitoring with one standard assessment measure (hits, false alarms...)?
Applications of SDT

- Medical diagnosis
- Police identification line-ups
- Monocular and binocular depth perception
- Items on a radar screen on collision paths
- Discriminating smells [gas leak detection]
- Parapsychology -- extra sensory perception
- Drug testing in personnel selection
- Baseball -- swing at a pitch or not
- Military detection (camouflaged objects)
- Effectiveness of radar & night vision
- Driving -- safe to go through a gap
- Emergency / fire detection -- dispatch of ambulances