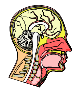


3. Perception

A Rose is still a rose by any other name

Aim

How does the brain process attended sense data?

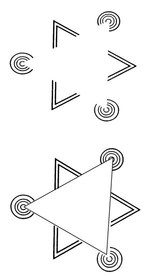
How does this affect the design of multi-media systems?

Link: Illusory figures

Can you see the triangle?

- Most of the triangle boundary is not black/white contrast. i.e. *most of the boundary isn't there!*
- The triangle (foreground) looks brighter than the rest
- When you outline the triangle, the perceived brightness disappears

The brain enhances reality



Kanizsa's triangle

The blind spot

+ ●

- Cover one eye
- Hold the page up with *cross on outside*
- Fix your focus on the **dot**
- Move the paper back and forth
- At some point the cross will entirely disappear from view!

Print this slide

The blind spot

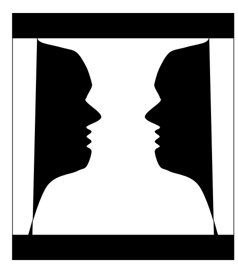
- There are no light receptors where retinal nerves leave the eye as the optic nerve
- Hence each eye has a very large "hole" in the visual field information received
- Why do we not see this hole when we look with one eye? (eg as a "gap" in our visual field)

The brain "fills in" information deficiencies

Figure-ground

- *What do you see?*
- Can you see a *vase*?
- Can you see *faces*?
- Can you see both?
- The ambiguity arises from deciding what is "figure" and what is "ground"

The brain resolves ambiguity



Illusions

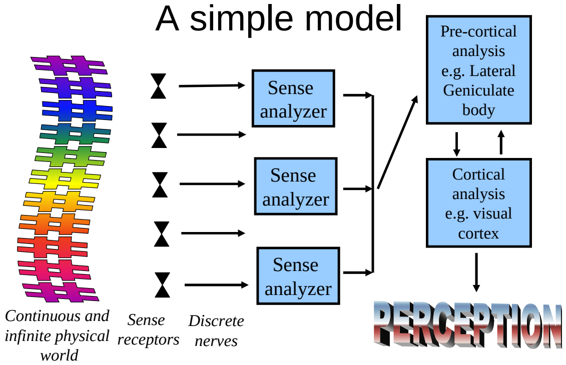
- Are not *exceptions but* “business as usual” for the visual system i.e. this is how our visual system *normally and always operates*
- Illusions are the rare cases where the assumptions of our perception don’t work
- Perception cannot *reflect* physical reality, it must *construct* it

Application

- *Realism* is not necessary for perceptual effect
  - E.g. cartoons
  - Icons must *represent* rather than be realistic
- *Completeness* is not necessary for effect and details omitted may be presumed there
  - A face without a nose will still be seen as a face
  - Disney hands have three fingers
- *Feature enhancement* is normal in perceptual processing. Use it to improve your effect

Link: Receptive field

A simple model



Link: Color Vision: Eye mechanisms

An example: Color vision

- Light is less than 1% of an *electro-magnetic spectrum* (EMS) that includes radio waves, x-rays and cosmic rays.
  eg a radio can receive radio waves but we cannot
- Color derives from EMS wave frequency, and brightness from EMS wave amplitude
  - **We see “Green” when EMS waves vibrate about a million times per half meter**

Link: Black, Brown, Yellow

Color and light frequency

- A combination of *all frequencies* (colors) appears to us as “white” - we see white as “without color”
- *No light* at all appears to us as a color (Black)
- Some colors are “non-spectral” - ie correspond to no particular frequency (Brown)
- Yellow is not one frequency but a combination (red+green)

Color is not just the light frequency

Link: Perception

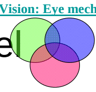
What is “redness”?

- The EMS spectrum is continuous - there is no basis to make a certain range “red”
- Red exists because *we have receptors specialized to respond to that frequency*
- If our receptors responded to other frequencies (eg UV like bees) we would see the world in new “colors”
- If we had **four** types of cones, our “reality” would have more colors (frequency combinations)
- Colors are not in the world - *they are in us*

Perception is a species specific window on reality

Link: Color Vision: Eye mechanisms

Tri-chromatic model



- Every color *seen by humans* is a mixture of red + green + blue frequencies
- Because we have three types of *cone* receptors in the retina
  - one sensitive to a *high* frequency range (*blue*)
  - one sensitive to a *middle* frequency range (*green*)
  - one sensitive to a *low* frequency range (*red*)
- "Color" is a *perception* created by the combined output of three types of retina cells

Link: Color Vision: Eye mechanisms

Application: color blindness

- Some people only form colors from *two* primaries (eg red & green) because the other cone type (blue) doesn't work
- *Blue/Green color blindness* occurs in 8% of men from an X chromosome defect. (Women with 2 X's are only color blind if both are defective)

COLOR **COLOR** ← **Don't do this**

Hue

- In computing, three numbers in the range 0-255 of R,G,B values define a color's *hue* e.g. this hue is R=255, G=255, B=0 (perfect yellow)
- *Application*: To experiment yourself, in Word Insert a text box, then choose Format/ TextBox/ Colors/ More Colors/ Custom
- Two other HCI values are calculated from light - *luminance* and *saturation*

Link: Color Vision: Eye mechanisms

Luminance

- Luminance is our version of brightness. Is it the sum of the three amplitudes: i.e. L = R + G + B?
- In fact, our weighting is mainly based on the green and red amplitudes: L = 0.3R + 0.6G + 0.1B
- When you alter a computer's RGB values you set the user's luminance, based on all three

L = 100 *L = 150* *L = 200*

- *Application*: Luminance affects the background sense of light or darkness and its associations

Gregory: Retinex theory and color constancy

Saturation

- Vision also analyzes the "degree of whiteness", where equal RGB frequencies are *saturated*
- *Saturation*, like luminance, is an aspect of color our eyes create, e.g. we distinguish pure vs pastel colors

S = 90 *S = 150* *S = 200* *S = 255*

- *Application*: Children prefer bright colors and clear, loud noises (e.g. a drum) but adults prefer pastel colors and combinations. Their analysis is more advanced.

Link: Retina

Black and white vision - rods

- Cones proliferate around fovea to give visual acuity - there are no rods at the fovea
- Twilight has too little light for cones to operate, so the 100 million *black and white sensitive* "rods" in retina dominate (cf 1-5M cones)
- In daylight the rods are "bleached" so in darkness we are at first "blind", then they generate a light sensitive chemical (1/2 hour for full sensitivity)
- *Application*: Black vs White is a more fundamental distinction than red vs green

Summary: Color = H + S + L

- If the eye were a camera, it would have two types of film (color and B/W). It can adapt over a million-fold brightness range
- Computers represent **hue**, **luminance** and **saturation** because this is the way our brains analyze light

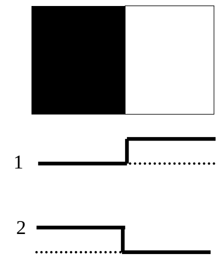
S = 200, L=100  *S = 100, L=200* 

- *Application: Color matching.* Certain colors balance or complement each other, as the color wheel illustrates.

Link: Visual system organization

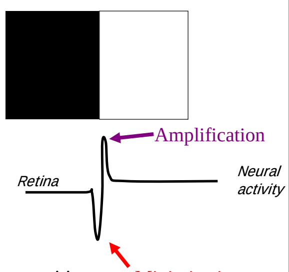
Retinal boundary analysis

- One type of retinal cell (1) responds to light increases *above background level*
- One type of retinal cell (2) responds to light increase *below background level*



Edge amplification

- Result is *boundary or edge* detection
- Retinal cells interact laterally to *excite* or *inhibit* nearby cells
- Gives amplification of boundaries

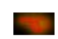


Boundaries are the basis of shape recognition

Application

- *Boundary detection* is critical to all higher visual processing (e.g shape recognition)
  - Especially for smaller figures, ensure the figure boundary is clear
  - If necessary enhance important boundaries - thicken the lines, increase color contrast, change the background

The boundaries are clear and the colors match 

This: 

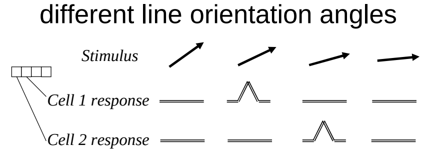
vs this: 

The LGB relay station

- Information from each eye divides!
- *Each cortex receives **all** visual input for the **opposite** half of the visual field, via the lateral geniculate body*
- *Somehow,* the corpus collosum joins these halves into a single visual perception!
- Even though each eye has different capabilities and gives information from a different perspective (see HCI5 on 3D)

Cortical visual processing

- Each square mm contains 250,000 cells
- The visual cortex operates in layers (simple/complex/hyper-complex cells)
- In one layer, different cells respond to different line orientation angles



Visual cortex structure

- It is not just an upward processing hierarchy: simple→ complex→ hyper-complex cells
- There are also:
  - *Lateral interactions* (to enhance or inhibit)
  - *Downward interactions*: Projections from the visual cortex influence the LGB, i.e. *the cortex can alter its source of information*
- *Our vision is a negotiation between higher and lower brain processing*

Summary

- Are <u>two</u> types of processing:
  - *Color, boundary and object detection and recognition* (HCI3&4)
  - *Object location, orientation and movement* (HCI5)
  - Different analyzers handle movement and location in visual space and object recognition
- *Application*: With different cues for depth and object recognition, a system must manage both
  - Can see where an object is but not recognize it
  - Can recognize an object but not know its distance

Link: Retinex theory and color constancy

Color constancy

- The frequencies of light reflected by an object vary with illumination, e.g.
  - View a banana in fluorescent light then in sunlight
  - It is the same color, *but it shouldn't be if color depends on light frequencies, as they changed!*
- Our visual system maintains *color constancy*: It adjusts perceived color to background illumination

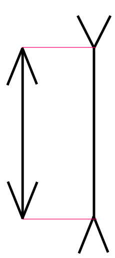
Link: Emmerts law

Size constancy

- Retinal image size varies with distance
- But try this:
  - View a bright light for a while, then look elsewhere to see an after-image
  - Look nearby at a bright book then view a far-away wall - the after-image appears larger though *it is the same size on your retina*
- The visual system keeps *size constancy*: an object's size is adjusted according to its distance

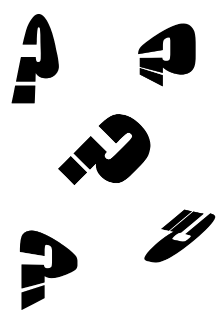
Example: Which line is bigger?

- The angle lines are used as cues to imply depth
- So right figure seems further away, and left figure seems closer
- Size of right figure is adjusted so it appears bigger



Shape constancy

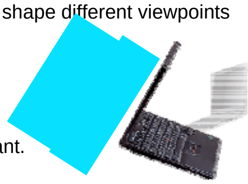
- Recognize the same shape
  - rotated
  - tilted
  - Compressed
- Our vision maintains shape constancy regardless of the angle we view from (observer position)



Perceptual constancy

- Our perception automatically adjusts to changes that don't really change the external object:
  - *Color constancy* - same color different illumination
  - *Size constancy* - same size different distances
  - *Shape constancy* - same shape different viewpoints
- It adjusts for
  - Background light
  - Distance
  - Observer position

  as they aren't *really* important.



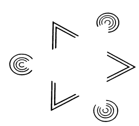
Application

- Objects are recognized despite changes in color, distance or orientation
  - What color is the baby?
  - How big is the plane?
  - Are we seeing front or back?

Link: Perception as hypothesis

Perception is a "best fit" hypothesis

- The visual system *deduces* what is "out there" by rejecting unlikely coincidences in favor of likely causes
  - That many lines terminate abruptly in a linear fashion is unlikely - more likely it is an edge
- Our vision *is a "best guess" based on evolutionary heuristics. So we* may "know" an illusion is false, but it does not change what we "see"



We see an edge - whose brightness is enhanced by the visual system

Perception is valid

- Our vision's "tricks" make perceptions *more real*
- *In fact,* objects:
  - *Don't* change color going from artificial to natural light
  - *Don't* change size when they become more distant
  - *Don't* change shape when we move around them
- The business of perception is rightly the constant objects of the world, not the variations in their light signals.
- So for good reason our sensory systems "trick" us!

Perception is an output

- NOT an undistorted window on reality
- It is a best fit "model" of reality "out there"
- Even simple perceptions are sophisticated analyses, e.g. constancy adjustments
- Perceptions are complex visual analyzer outputs
- *Application:* Design screens to fit how people see rather than how the world is physically

Perception is affected by

- Physical signal (e.g. light amplitude/frequency)
- Receptor type (e.g. RGB)
- Brain analysis based on
  - Prior history (habituation)
  - Background (object brightness vs background)
  - Contrast effects (local enhancement)
  - Context effects (effects of the whole on the part)
  - Expectations (top down alterations)

Application: Total effect

- All analyzers are affected by others, as the brain is highly inter-connected
  - What counts is the total *holistic* effect
  - cf the "Frankenstein effect"
    (Dr Frankenstein created a monster by choosing the best of each body part from a graveyard and sewing them together)
  - Effects should harmonize not clash
  - A good effect can't compensate for a bad whole
  - In HCI, every aspect counts and all interact

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Application: Minimalism

- When there are few useful signals, small signals have big effects if :
  - All signals are consistent with an effect (hypothesis)
  - No signals contradict the effect
- What do you see? Is there depth? Is something there?

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Summary: Perception is …

- Always ambiguous as the input data is *equivocal*
- The *likely hypothesis* of analyzers hypothesizing on *objects*
- A hypothesis once formed may be "smoothed", "enhanced" or "filled in" (by the brain)
- Only by eliminating external variations due to external light, orientation and distance, *plus* by using past experience, can *objects be identified*
- Analysis involves various channels, e.g. for object *recognition* and object *location* in space
- It is based on recognizing *boundary changes*

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Homework: **Read**

- *Illusory figures* - understand illusions as what our eyes do all the time
  - http://www.jstor.org/stable/1423472?seq=1
  - http://www.iovs.org/content/11/6/540.full.pdf
  - http://en.wikipedia.org/wiki/Ehrenstein_illusion
  - http://en.wikipedia.org/wiki/Illusory_contours
- Retina - get an idea of what goes on at this level
  - http://en.wikipedia.org/wiki/Retina
- Visual system organization, - understand from an information processing perspective
  - http://www.answers.com/topic/visual-system-organization
  - http://en.wikipedia.org/wiki/Visual_system
- Color vision, eye mechanisms,
  - http://en.wikipedia.org/wiki/Color_vision#Cone_cells_in_the_human_eye
- Emmerts Law - Explains size constancy
  - http://en.wikipedia.org/wiki/Emmert%27s_law
- Perception - skim this so you know what a big thing perception is, that we all take so much for granted
  - http://en.wikipedia.org/wiki/Perception
- Perception as hypothesis - this is the main conclusion of the lesson
  - http://www.answers.com/topic/perceptions-as-unconscious-influences
  - http://www.users.totalise.co.uk/~kbroom/Lectures/gestalt.htm
  - http://www.simplypsychology.org/perception-theories.html

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OTHER LINKS

- *Retinex theory and color constancy*
  - http://en.wikipedia.org/wiki/Color_constancy#Retinex_Theory
- *Receptive Field*
  - http://en.wikipedia.org/wiki/Receptive_field
- *Black*
  - http://en.wikipedia.org/wiki/Black
- *Brown*
  - http://en.wikipedia.org/wiki/Brown
- *Yellow*
  - http://en.wikipedia.org/wiki/Yellow

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- Do you recognize these patterns?
- How does pattern recognition occur?

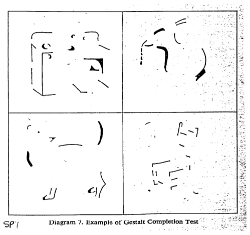

Diagram 7. Example of Gestalt Completion Test

What do you see here?

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