Administrivia

Reminders:
- Do analysis and write the abstract together, write the rest of the report individually
- The report should closely follow the research reports you’ve seen in the readings
- Methodology needs to be updated from previous milestones
  – enough info for someone to fully replicate exactly what you did (past tense)

Administrivia

Some (hints at) things I like to see in reports:
- Sub-themes of observations with illustrative quotes
  – E.G. We noticed X participants felt y was an issue. For example, participant Z said “…”
- Strong motivation for the problem and why the experiment was designed the way it was
- Exploring why you found the statistical results you did with subjective data
TODAY

- color perception (stage 1)
- pre-attentive processing (stage 1)
- guidelines for design
- gestalt theories (stage 2)

many of the slides in this lecture are courtesy of Colin Ware “Information Visualization: Perception for Design”, 2000

MACHINERY OF PERCEPTION

this is a more detailed version of figure by Ware, 2003 Design as applied perception

HUMAN VISUAL SYSTEM

- light passes through lens
- focused on retina

RETINA:

COVERED WITH LIGHT-SENSITIVE RECEPTORS

- rods
  - sensitive to broad spectrum of light
  - unable to resolve detail
  - over-stimulated in all but the dimmest light
  - can’t discriminate between colors
  - sense intensity or shades of gray
  - primarily for night vision & perceiving movement
  - 120 million per eye

- cones
  - less sensitive to light
  - used to sense color
  - 6 million per eye
**RETINA**

- center of retina (fovea) has most of the cones – allows for high acuity of objects focused at center

- edge of retina (periphery) is dominated by rods – allows detecting motion in periphery

**PERIPHERAL ACUITY**

With strict fixation of the center spot, each letter is equally legible because it is about ten times its threshold size. This is true at any viewing distance. Chart shows the increasingly coarse grain of the retinal periphery. Each letter is viewed by an equal area of visual cortex.


**WHY STUDY COLOR?**

- color can substantially improve user interfaces...

- but inappropriate use can severely reduce usability
COLOR COMPONENTS

- **hue**
  - property of the wavelengths of light (i.e., “color”)

- **intensity**
  - also luminance, lightness, brightness, value
  - how much light appears to be reflected from a surface
  - some hues are inherently lighter or darker

- **saturation**
  - purity of the hue
    - e.g., red is more saturated than pink
  - color is mixture of pure hue & achromatic color
    - portion of pure hue is the degree of saturation

VISIBLE SPECTRUM

TRICROMACY THEORY

- cone receptors used to sense color
- 3 types: Short, Medium, Long (really more yellow)
  - each sensitive to different band of spectrum
  - balance of activity between 3 types to achieve all colours in visible spectrum

DISTRIBUTION OF CONES

- not distributed evenly
  - mainly reds (64%) and greens (32%) & very few blues (4%)
    - insensitive to short wavelengths, e.g. cyan to deep-blue
- center of retina (high acuity) has no blue cones
  - small blue objects you fixate on disappear (or so the theory goes)
COLOR SENSITIVITY (CONT.)

implications:
- Blue text on a dark background to be avoided. We have few short-wavelength sensitive cones in the retina and they are not very sensitive. Older users need brighter colors.
- Blue text on a dark background to be avoided. We have few short-wavelength sensitive cones in the retina and they are not very sensitive.
- Older users need brighter colors.
- Blue text on a dark background to be avoided. We have few short-wavelength sensitive cones in the retina and they are not very sensitive.
- Older users need brighter colors.

Blue text on a dark background to be avoided. We have few short-wavelength sensitive cones in the retina and they are not very sensitive.
- Older users need brighter colors.

Showing small yellow text on a white background is a bad idea. Pure yellow excites both our M and L cones, making yellow the brightest of colours. Need a lot of luminance contrast.

As we age...
- lens yellows & absorbs shorter wavelengths
  - sensitivity to blue is even more reduced
- fluid between lens and retina absorbs more light
  - perceive a lower level of brightness
  - thus older users often need even brighter colours (more luminance contrast) to see differences

COLOR SENSITIVITY & IMAGE DETECTION

- most sensitive to the center of the spectrum
- brightness determined mainly by L+M
- implications?
  - harder to deal with blue edges & blue shapes
  - avoid blue text is a widely mentioned guideline, but is it true?

FOCUS

- wavelengths of light focus at different distances behind eye’s lens
  - need for constant refocusing (causes fatigue)
  - Aside: another reason why blue is harder to see, especially if there’s bright red or white nearby!

Most people see the red closer than the BLUE but some see the opposite effect
TRICHROMACY THEORY INSUFFICIENT

doesn’t explain:
- why we can read small blue text
- why there is no such thing as a reddish-green or greenish-red, blueish-yellow or yellowish-blue
- yellowish-red, yes; Bluish-red, yes
- after image effects (see next...)

Stare at the white dot in the middle of next slide for 5 seconds...
COLOR CHANNELS:
Opponent Process Theory

From Ware (2008). Visual Thinking for Design, p68

OPPONENT COLORS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>B</td>
<td>R</td>
</tr>
<tr>
<td>B</td>
<td>Y</td>
</tr>
<tr>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>G</td>
<td>R</td>
</tr>
</tbody>
</table>

can you identify the unique hues?
(blue, green, yellow ... what about red?)


RELATION OF OPPOSING CHROMATIC CHANNELS

From Ware (2008). Visual Thinking for Design, p68
**LUMINANCE & BRIGHTNESS**

- **luminance** is the *measured* amount of light coming from some region of space
  - but humans are not light meters
  - receptors bleach and become less sensitive with more light
  - takes up to half an hour to recover sensitivity

- **brightness** refers to *perception* of amount of light coming from a source
  - brightness perception is non-linear

---

**SIMULTANEOUS LUMINANCE CONTRAST**

Contrast occurs because our brain is better at determining differences in the amount of light than measuring absolute light emitted.

---

**SIMULTANEOUS CHROMATIC CONTRAST**

Both yellow bars are the same.

---

**CONTRAST**

Implications:

- because colours are changed by appearance of adjacent colours
  - therefore can only use a small number of very different colours to symbolically label effectively
  - otherwise contrast effect causes color confusion
SHAPE FROM SHADING

- we understand 3D surfaces via shading patterns
- the luminance channel can determine shape from shading; chromatic channels cannot
- what are we seeing in the image below?

![NASA image of Surface of Mars, From Ware (2008). Visual Thinking for Design. p68](image1)

LUMINANCE “CHANNEL”

- carries ~2/3 more details than either of the chromatic channels
- therefore chromatic channels alone not suitable for fine details, small fonts, etc.

implications:
- luminance contrast critical for fine details
- harder to focus on edges created by color alone
  - best to use both luminance & color differences

![RRR](image2)

SATURATION

- high-saturation colours are more pure (vivid)
- low-saturation colours close to black/white/grey
- saturated colours will stand out against unsaturated ones
- easier to detect in small areas
- unsaturated colours will have less dramatic contrast effects

COLOR BLINDNESS

- trouble discriminating colors
  - around 9% of population (8% males, 1% females)
- different photopigment response
  - reduces ability to discern color diffs
    - particularly those of low luminance contrast
- red-green deficiency is best known
  - lack of either green or red photopigment
    - can’t discriminate colors dependent on R & G
- luminance contrast and careful color selection
  - e.g., avoid having reds and greens with similar luminance
- simulators available online can help you check your designs against most common deficiencies
  - E.g., http://www.color-blindness.com/coblis-color-blindness-simulator/
how to use color effectively?

COLOR IS GREAT FOR CLASSIFICATION:

– rapid visual segmentation
– helps determine type
**COLOR GREAT FOR CLASSIFICATION**

 colour mapping can be used to extend the number of displayable data dimensions to 5 or 6 in a single scatter plot.

---

**COLOR GUIDELINES**

recommended colors for encoding categories of information:

- widely agreed upon names
- entire set correspond to most common color names across cultures
- when learnability matters: choose from set of first six (unique hues), then from second set of six

---

**COLOR GUIDELINES**

- large areas: low saturation
- small areas: high saturation (strong contrast with background)

---

**COLOR GUIDELINES**

- generally want to avoid single-color distinctions and encodings
  - e.g. 🔺🔻 better than 🟢🔴
- blue text is actually okay
  - so long is there is high luminance contrast
COLOR GUIDELINES

to increase contrast
pick non-adjacent colors on hue circle:

COLOR GUIDELINES

• take advantage of (and don’t go against) common symbolic uses or natural orderings of color
• e.g., color gradients generally understood to indicate an order (e.g., increasing/decreasing amount)

EXAMPLES

in each of the following, try to identify:
• 2 effective uses of color
• 2 ineffective (or less effective) uses of color

For each:
– Think about the reasons(s) for the identified aspects of the design.
– how could you improve the ineffective examples?
MACHINERY OF PERCEPTION

stage 1
Parallel processing of orientation, texture, color and motion features

stage 2
Object Identification, Working Memory

stage 3
Detection of 2D patterns, contours and regions

this is a more detailed version of figure by Ware, 2003 Design as applied perception

PRE-ATTENTIVE PROCESSING
**PERCEPTION PRIMITIVES (STAGE 1)**

- whole visual field processed in parallel
- some information is easily/quickly distinguished
- popout effects (in less than the time it takes for the eye to move from one focus)
- recall MHP: visual information store where information “hits” before moved to short term memory

**PRE-ATTENTIVE PROCESSING (IN STAGE 1)**

- 10 ms or better per item
  - rates for non pre-attentive features 40ms +
- exercise: count all the 3s, say answer aloud

**PRE-ATTENTIVE PROCESSING**

- 10 msec or better
- try the same thing again
PRE-ATTENTIVE PROCESSING

• the time taken to search for target is (mostly) independent of the number of distractors

IDENTIFY “SPECIAL” OBJECT IN UPCOMING SLIDES

• how fast can you do it?

COLOR
ORIENTATION

MOTION

SIZE

SIMPLE SHADING
• when patterns get just a little more complex, search becomes more serial
• conjunctive search: when you have to search for more than one attribute
  – e.g. color AND shape

...except for one, can you tell?
LAWS OF PREATTENTIVE DISPLAY

• must stand out on some simple dimension
  – color
  – simple shape = orientation, size
  – motion
  – depth

DISPLAYING INFORMATION AT A GLANCE:
HIGHLIGHTING

Using color draws attention
So does using Texture
And, yes, underlining works too!

A flying box leads attention
Blinking momentarily attracts attention

Motion elicits an orienting response

to highlight effectively: use a dimension not heavily used in other parts of design

PRE-ATTENTIVE CONJUNCTIONS

• most conjunctions are not pre-attentive
• very small number ARE pre-attentive
  – in general: spatial location and some aspect of form (color or shape)
  – examples:
    • stereo depth and color
    • color and motion
    • color and position
    • shape and position

we can rapidly search for conjunction of 'green circle and right cluster'

EXAMPLES

in each of the following, identify:
• is there an actual pop-out effect?
• how effective is it for the given task?

Note: first two are videos shown in class.
**Gestalt Laws**

**Pattern Perception and Gestalt Laws (Stage 2)**
- by taking advantage of patterns that are easy to see, we can enhance display design and understandability
- **gestalt laws**: basis for most modern theories of pattern perception
  - describes how user see patterns in visual images
  - should be mostly review from 344

**Machinery of Perception**

**Gestalt Laws**
- **proximity**: nearby things are perceived as related
- **similarity**: things that are the same in size, shape, color etc. are perceived to be associated

Redrawn from Tidwell (2012). Designing Interfaces.
**GESTALT LAWS (CONT.)**

closure: groups of things that create shapes/forms are often perceived as whole forms

continuity: users tend to perceive curved or straight lines caused by alignment

**GESTALT LAWS (CONT.)**
symmetry: symmetrical objects are more readily perceived

common region: objects within an enclosed space are grouped

connectedness: objects connected by continuous contours are perceived as related

**GESTALT LAWS (CONT.)**

common fate: objects that move together are perceptually grouped.

**EXAMPLES**

for the following, try to identify:

- 2 effective uses of perceptual groupings
- 2 ineffective (or less effective) uses perceptual groupings

For each:
  - Think about the reasons(s) for the identified aspects of the design.
  - how could you improve the ineffective examples?
MACHINERY OF PERCEPTION

Stage 1
- Parallel processing of orientation, texture, color and motion features

Stage 2
- Detection of 2D patterns, contours and regions

Stage 3
- Object Identification, Working Memory
- Where more complex visual objects can be stored in visual working memory
- Where actually problem solving, reasoning, etc. about visual objects occurs

(this is a more detailed version of figure by Ware, 2003 Design as applied perception)
Next Week…

... Individual Reports!