Lecture 11 – Human Abilities
Visual Processing
Joanna McGrenere
ADMINISTRIVIA

Project

– MSIV – Part A was just due
– MSIV – Part B due on Thurs
– MSIV – Part C (Video) due next Thursday
– design reviews on Friday
  • be prepared to show your prototype (if we have questions about how it changed)
  • be prepared to talk about presentations/video
Design Competition (next Tues) will be held in this room (DMP 110)

- Main presentations: 3:30 - 5:30 (mandatory)
- Might go slightly past 5:30, social with nibblies, and judging to follow
  - If you have a team member who cannot stay past 5:30, you need to let me know (via piazza) by Friday

testing presentation is required – availability of DMP 110 for testing will be posted on Piazza
MSV

• fantastic design jury:
  – **Barry Po:** Senior Director, Product and Business Development, NGRAIN (PhD in Computer Science, HCI, 2005)
  – **Nicole Arksey:** User Experience Researcher & Interaction Designer, IQmetrix (MSc in Computer Science, HCI, 2007)
  – **Antoine Ponsard:** UX Designer, PDFTron Systems Inc. (MSC in Computer Science, HCI, 2015)

• will be a short break ~ halfway through – opportunity to chat with jury members, as well as at social afterwards (once judging is done)
TODAY (AND NEXT TIME)

– 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

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

this is a more detailed version of Fig 2.1 in Ware reading
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
RETINA

• interplay of rods/cones with **ganglion cells**: specialized nerve cells, 2 types

• **X-cells**
  – concentrated in fovea
  – responsible for early detection of pattern

• **Y-cells**
  – widely distributed in the retina
  – Responsible for early detection of movement
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
TRICHRROMACY 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

from Ware (2013). Information Visualization, Perception for design
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
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.

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.

reproduced from Ware (2013). Information Visualization, Perception for design
COLOR SENSITIVITY (CONT.)

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

reproduced from Ware (2013). Information Visualization, Perception for design
TRICROMACY 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
- 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...
Opponent colors

B  R
B  Y
Y  R
G  R
COLOR CHANNELS: OPPONENT PROCESS THEORY

From Ware (2008). Visual Thinking for Design. p68
can you identify the unique hues?
(blue, green, yellow . . . what about red?)
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
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
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
SATURATION

• how ‘pure’ a color is to the viewer
  – high-saturation colours are more pure (vivid)
    • strong signal on red/green or yellow/blue chromatic channels
  – low-saturation colours close to black/white/grey

• strong signals attract attention better than weak signals
  – 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
RELATION OF OPPOSING CHANNELS

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

how to use color effectively?
COLOR IS GREAT FOR CLASSIFICATION:

– rapid visual segmentation
– helps determine type
• 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)
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?
Modo's Business Development Manager Sylvain is testing one of the new City of Vancouver - Local Government bikes. 1,000 bikes at 150 stations will soon make it even easier to get around the city! http://ow.ly/Y1kvy
PRE-ATTENTIVE PROCESSING
MACHINERY OF PERCEPTION

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

stage 2
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stage 3
Object Identification, Working Memory

this is a more detailed version of Fig 2.1 in Ware reading
PERCEPTION PRIMITIVES

– whole visual field processed in parallel
– can tell us what kinds of information is easily/quickly distinguished
– popout effects (prior to conscious attention)
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
897390570927940579629765098294
08028085080830802809850–802808
567847298872ty4582020947577200
21789843890r455790456099272188
897594797902855892594573979209
PRE-ATTENTIVE PROCESSING

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

• the time taken to search for target is independent of the number of distractors
IDENTIFY “SPECIAL” OBJECT IN UPCOMING SLIDES

• how fast can you do it?
MOTION
SIZE
SIMPLE SHADING
CONJUNCTION (DOES NOT POP OUT)
CONJUNCTIONS OF FEATURES

• 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
COMPOUND FEATURES (DO NOT POP OUT)
MORE PREATTENTIVE CHANNELS

Shape

Length

Width

Parallelism

Enclosure

Curvature

Spatial grouping

Added marks

Number

...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.
Top New Releases

The Nest
Cynthia D'Aprix Sweeney
MARCH 2016
$13.99
Pre-order

Fool Me Once
Harlan Coben
MARCH 2016
$18.99
Pre-order

Jane Steele
Lyndsay Faye
MARCH 2016
$18.99
Pre-order

The Summer Before the War
Helen Simonson
MARCH 2016
$15.99
Pre-order

Shadow on the Mountain
Stephen Singular and Joyce Singular
MARCH 2016
$15.99
Pre-order

The Way of the Gun
Ian Overton
APRIL 2016
$15.99
Pre-order

DAILY DEAL
Shopping for a Billionaire Boxed Set (Parts 1-5)
Now $0.99 (Was $6.99)
Ever meet a hot billionaire while your hand’s in a toilet in the men’s room of one of his stores?
No? So it really is just me. Hm. When you’re a mystery shopper, you get paid to humiliate yourself, all in the name of improving customer service.

by Julia Kent
$79 in Romance, Contemporary
$128 in Romance
$13 in Fiction & Literature, Humorous
4.2/5 249 ratings

$0.99
Add to cart
To: Jessica Dawson  
Subject: Self-Defining Memory Cues

http://dl.acm.org/citation.cfm?id=2732842

Sent from my iPhone
Gestalt Laws
MACHINERY OF PERCEPTION

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

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stage 2

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this is a more detailed version of Fig 2.1 in Ware reading
PATTERN PERCEPTION AND GESTALT LAWS

• 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
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

[diagram]

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

[diagram]

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

**symmetry:** symmetrical objects are more readily perceived

![Symmetry Example](image)

**common region:** objects within an enclosed space are grouped

![Common Region Example](image)

**connectedness:** objects connected by continuous contours are perceived as related

![Connectedness Example](image)
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?
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MACHINERY OF PERCEPTION

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stage 3

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Stage 3

- where more complex visual objects can be stored in visual working memory
- where actually problem solving, reasoning, etc. about visual objects occurs