Topic Notes

Visual Perception

CS 7450 - Information Visualization
August 26, 2013
John Stasko

Agenda

- Visual perception
  - Pre-attentive processing
  - Color
  - Etc.

Semiotics

- The study of symbols and how they convey meaning

- Classic book:
  - J. Bertin, 1983, *The Semiology of Graphics*

Related Disciplines

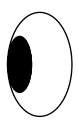
- Psychophysics
  - Applying methods of physics to measuring human perceptual systems
    - How fast must light flicker until we perceive it as constant?
    - What change in brightness can we perceive?
- Cognitive psychology
  - Understanding how people think, here, how it relates to perception

Perceptual Processing

- Seek to better understand visual perception and visual information processing
  - Multiple theories or models exist
  - Need to understand physiology and cognitive psychology

One (simple) Model

- Two stage process
  - Parallel extraction of low-level properties of scene
  - Sequential goal-directed processing



Stage 1

Early, parallel detection of color, texture, shape, spatial attributes

Stage 2

Serial processing of object identification (using memory) and spatial layout, action

Ware 2000

Stage 1 - Low-level, Parallel

- Neurons in eye & brain responsible for different kinds of information
  - Orientation, color, texture, movement, etc.
- Arrays of neurons work in parallel
- Occurs "automatically"
- Rapid
- Information is transitory, briefly held in iconic store
- Bottom-up data-driven model of processing
- Often called "pre-attentive" processing

Stage 2 - Sequential, Goal-Directed

- Splits into subsystems for object recognition and for interacting with environment
- Increasing evidence supports independence of systems for symbolic object manipulation and for locomotion & action
- First subsystem then interfaces to verbal linguistic portion of brain, second interfaces to motor systems that control muscle movements

Stage 2 Attributes

- Slow serial processing
- Involves working and long-term memory
- More emphasis on arbitrary aspects of symbols
- Top-down processing

Preattentive Processing

- How does human visual system analyze images?
  - Some things seem to be done preattentively, without the need for focused attention
  - Generally less than 200-250 msecs (eye movements take 200 msecs)
  - Seems to be done in parallel by low-level vision system

Drawn from
C. Healey web article

How Many 3's?

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

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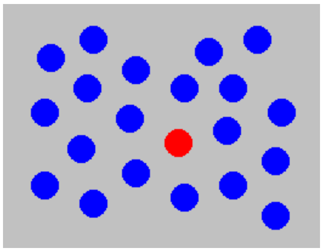
What Kinds of Tasks?

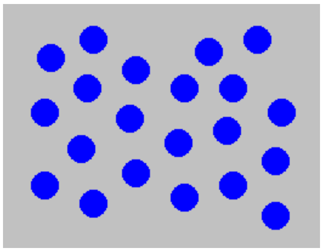
- Target detection
  - Is something there?
- Boundary detection
  - Can the elements be grouped?
- Counting
  - How many elements of a certain type are present?

Example

- Determine if a red circle is present
- (2 sides of the room)

Hue



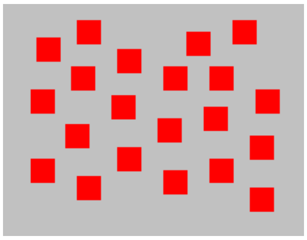


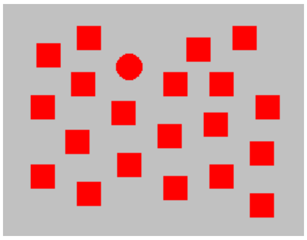
Can be done rapidly (preattentively) by people
Surrounding objects called "distractors"

Example

- Determine if a red circle is present

Shape



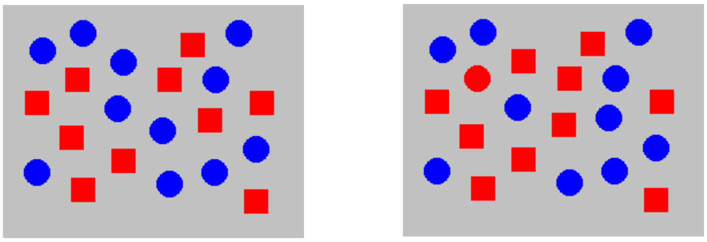


Can be done preattentively by people

Example

- Determine if a red circle is present

Hue and Shape

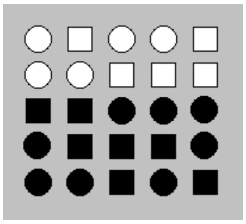


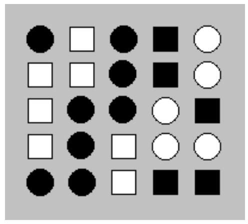
- Cannot be done preattentively
- Must perform a sequential search
- Conjuction of features (shape and hue) causes it

Example

- Is there a boundary in the display?

Fill and Shape



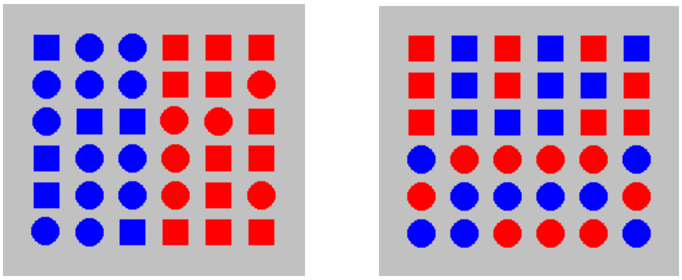


- Left can be done preattentively since each group contains one unique feature
- Right cannot (there is a boundary!) since the two features are mixed (fill and shape)

Example

- Is there a boundary in the display?

Hue versus Shape

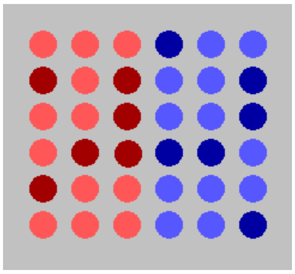


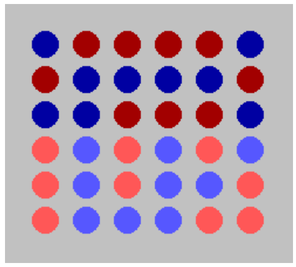
Left: Boundary detected preattentively based on hue regardless of shape
Right: Cannot do mixed color shapes preattentively

Example

- Is there a boundary?

Hue versus brightness





Left: Varying brightness seems to interfere
Right: Boundary based on brightness can be
done preattentively

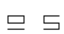
Example Applet

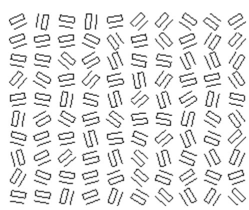
- Nice on-line tutorial and example applet
  - http://www.csc.ncsu.edu/faculty/healey/PP/index.html
  - Chris Healey, NC State
  - Prior pictures taken from site

Preattentive Features

- Certain visual forms lend themselves to preattentive processing
- Variety of forms seem to work

Textons

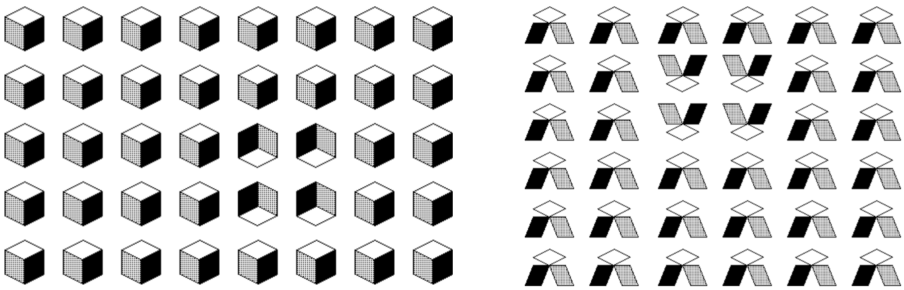




1. Elongated blobs
2. Terminators
3. Crossings of lines

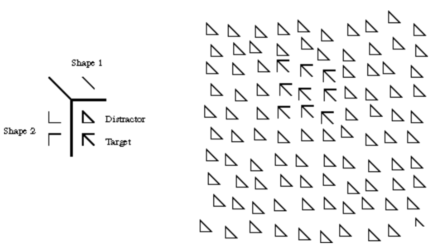
All detected early

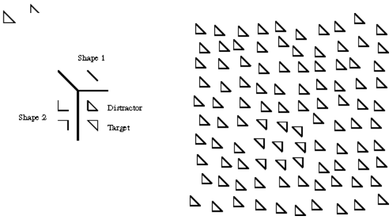
3-D Figures



3-D visual reality has an influence

Emergent Features





Potential PA Features

length
width
size
curvature
number
terminators
intersection
closure

hue
intensity
flicker
direction of motion
binocular lustre
stereoscopic depth
3-D depth cues
lighting direction

Discussion

- What role does/should preattentive processing play in information visualization?

Gestalt Laws

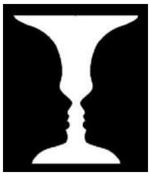
- Background
  - German psychologists, early 1900's
  - Attempt to understand pattern perception
  - Founded Gestalt school of psychology
  - Provided clear descriptions of many basic perceptual phenomena
    - → Gestalt Laws of Pattern Perception

Gestalt Laws

- Proximity
  - Things close together are perceptually grouped together
- Similarity
  - Similar elements get grouped together
- Connectedness
  - Connecting different objects by lines unifies them
- Continuity
  - More likely to construct visual entities out of smooth, continuous visual elements

Gestalt Laws

- Symmetry
  – Symmetrical patterns are perceived more as a whole
- Closure
  – A closed contour is seen as an object
- Relative Size
  – Smaller components of a pattern as perceived as objects
- Figure & Ground
  – Figure is foreground, ground is behind



Key Perceptual Properties

- Brightness
- Color
- Texture
- Shape

Luminance/Brightness

- Luminance
  - Measured amount of light coming from some place
- Brightness
  - *Perceived* amount of light coming from source

Brightness

- Perceived brightness is non-linear function of amount of light emitted by source
  - Typically a power function
  - $S = aI^n$

    S - sensation

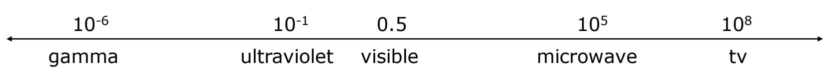
    I - intensity
- Very different on screen versus paper

Grayscale

- Probably not best way to encode data because of contrast issues
  - Surface orientation and surroundings matter a great deal
  - Luminance channel of visual system is so fundamental to so much of perception
    - We can get by without color discrimination, but not luminance

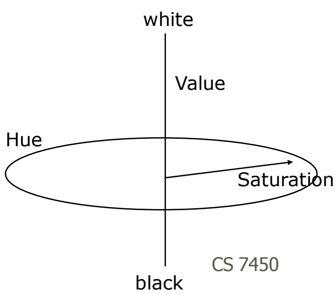
Color

- Sensory response to electromagnetic radiation in the spectrum between wavelengths 0.4 - 0.7 micrometers



Color Models

- HVS model
  - Hue - what people think of color
  - Value - light/dark, ranges black<-->white
  - Saturation - intensity, ranges hue<-->gray

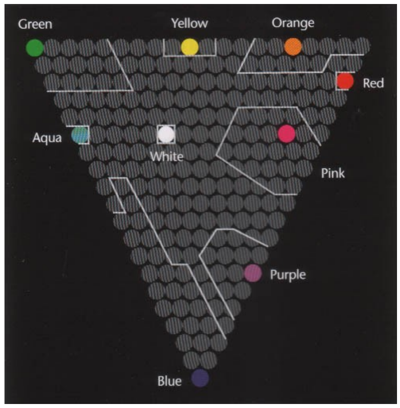


How Not to Use Color

http://www.thedailyshow.com/video/index.jhtml?videoId=156230&title=full-color-coverage

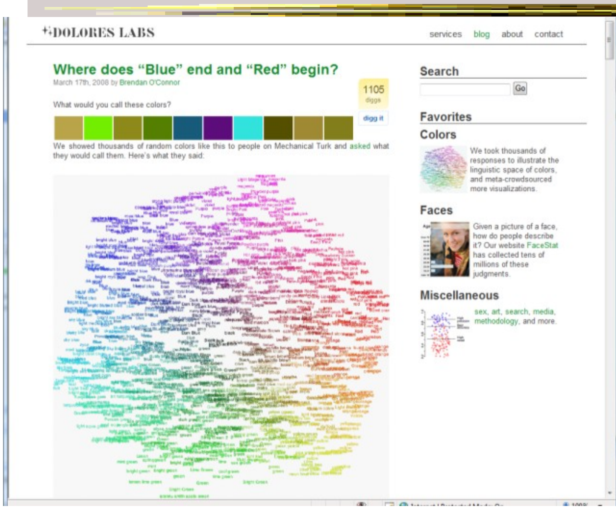
Color Categories

- Are there certain canonical colors?
  - Post & Greene '86 had people name different colors on a monitor
  - Pictured are ones with > 75% commonality



From Ware '04

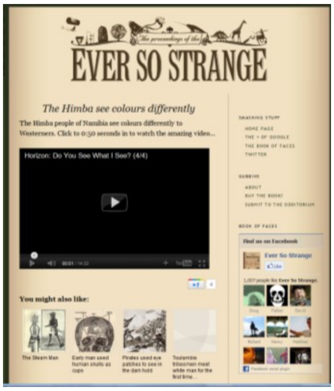
Using Mechanical Turk

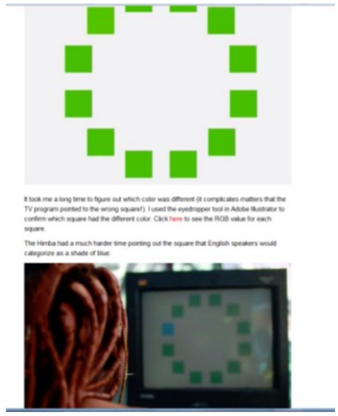


http://blog.doloreslabs.com/2008/03/where-does-blue-end-and-red-begin/

Maybe Not All the Same?

http://www.eversostrange.com/2011/08/11/himba-colours-differently/





Luminance

- Important for fg-bg colors to differ in brightness

Hello, here is some text. Can you read what it says?
Hello, here is some text. Can you read what it says?
Hello, here is some text. Can you read what it says?
Hello, here is some text. Can you read what it says?
Hello, here is some text. Can you read what it says?
Hello, here is some text. Can you read what it says?
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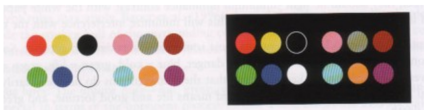
Color for Categories

- Can different colors be used for categorical variables?
  - Yes (with care)
  - Ware's suggestion: 12 colors

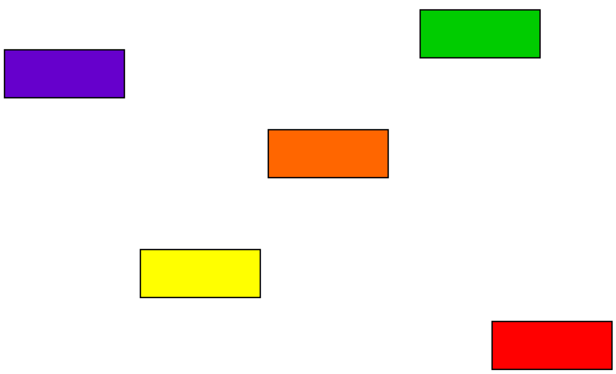
    red, green, yellow, blue, black, white, pink, cyan, gray, orange, brown, purple



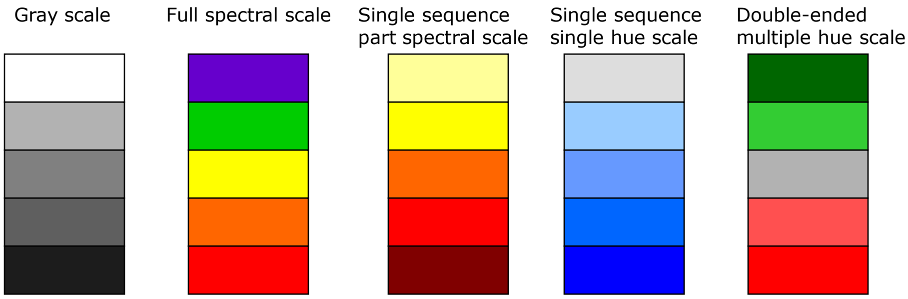
From Ware '04

Color for Sequences

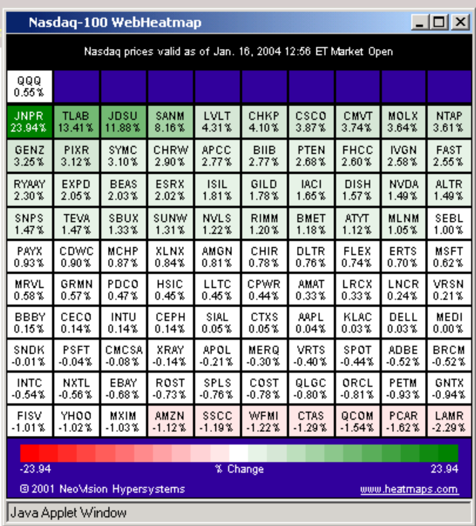
Can you order these (low->hi)



Possible Color Sequences

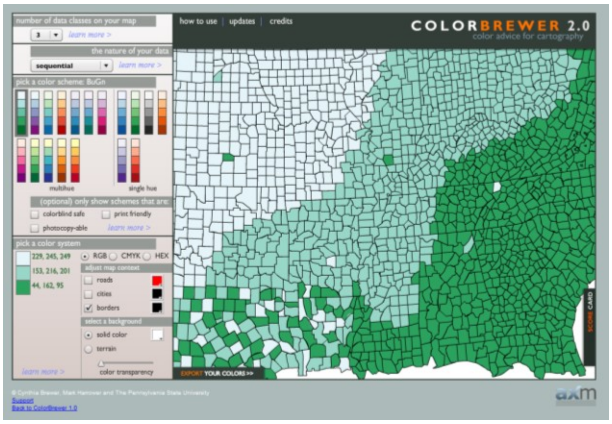


HeatMap



- http://screening.nasdaq.com/heatmaps/heatmap_100.asp

ColorBrewer



Help with selecting colors for maps

http://colorbrewer2.org/

Color Purposes

- Call attention to specific data
- Increase appeal, memorability
- Increase number of dimensions for encoding data
  - Example, Ware and Beatty '88

    x,y - variables 1 & 2

    amount of r,g,b - variables 3, 4, & 5

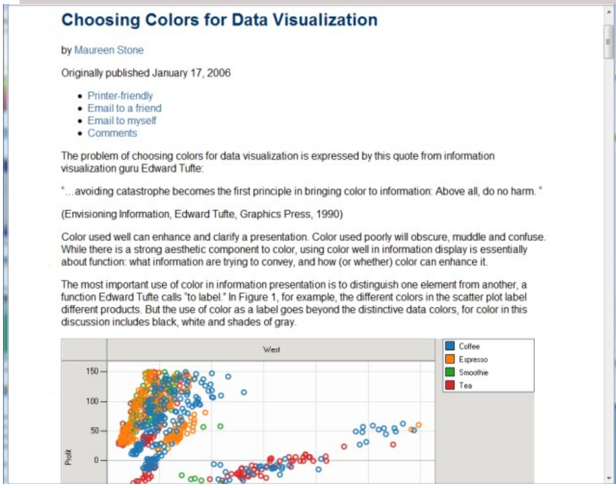
Using Color

- Modesty!   Less is more
- Use blue in large regions, not thin lines
- Use red and green in the center of the field of view (edges of retina not sensitive to these)
- Use black, white, yellow in periphery
- Use adjacent colors that vary in hue & value

Using Color

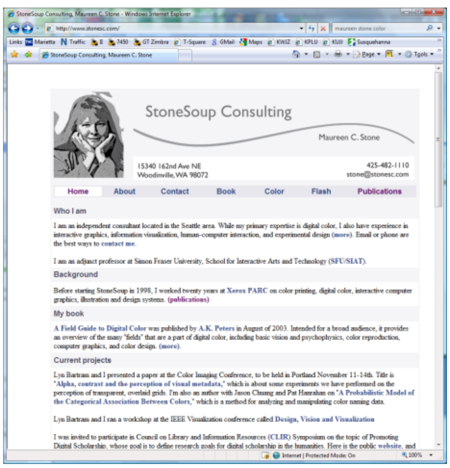
- For large regions, don't use highly saturated colors (pastels a good choice)
- Do not use adjacent colors that vary in amount of blue
- Don't use high saturation, spectrally extreme colors together (causes after images)
- Use color for grouping and search
- Beware effects from adjacent color regions (my old house - example)

Article Discussion



http://www.b-eye-network.com/newsletters/ben/2235

Good Color Advice

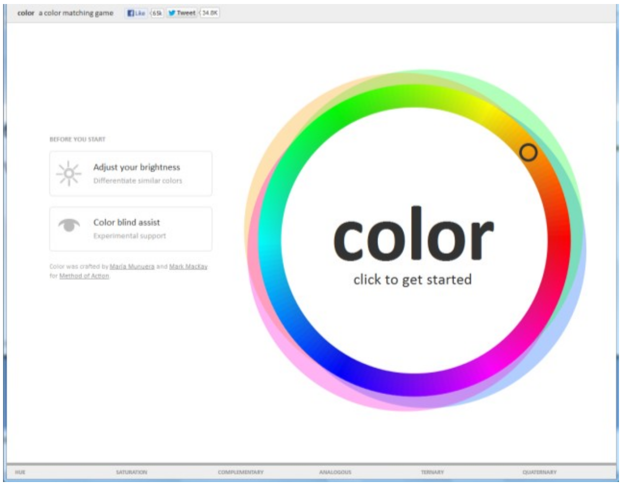


Maureen Stone's website
Many references and links
She frequently offers tutorials about color at conferences

http://www.stonesc.com

Color Challenge

http://color.method.ac/



Texture

- Appears to be combination of
  - orientation
  - scale
  - contrast
- Complex attribute to analyze

Shape, Symbol

- Can you develop a set of unique symbols that can be placed on a display and be rapidly perceived and differentiated?
- Application for maps, military, etc.
- Want to look at different preattentive aspects

Glyph Construction

- Suppose that we use two different visual properties to encode two different variables in a discrete data set
  - color, size, shape, lightness
- Will the two different properties interact so that they are more/less difficult to untangle?
  - Integral - two properties are viewed holistically
  - Separable - Judge each dimension independently

Integral-Separable

- Not one or other, but along an axis

Integral

↕

Separable

red-green	yellow-blue
red-green	black-white
shape height	shape width
shape	size
color	size
direction motion	shape
color	shape
color	direction motion
x,y position	size, shape, color

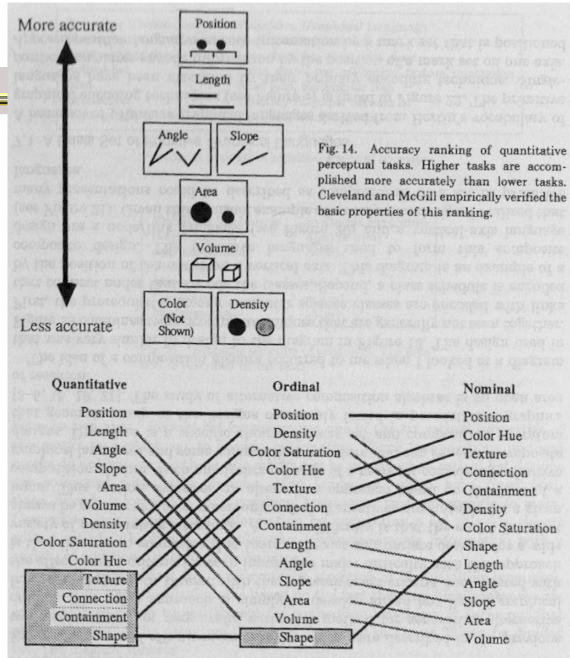
Ware ‘04

Encodings

- When you want to communicate one type of variable, which visual property should you use?

Accuracy ranking of quantitative perceptual tasks

Ranking of perceptual tasks

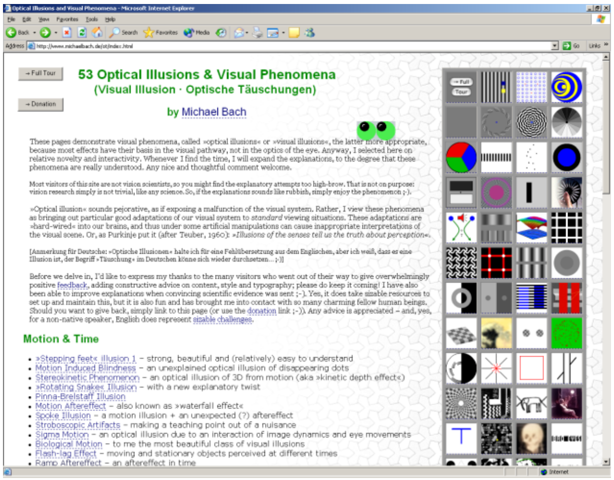


From Jock Mackinlay's 1986 thesis

Change Blindness

- Is the viewer able to perceive changes between two scenes?
  - If so, may be distracting
  - Can do things to minimize noticing changes
- Fun examples
  - Static pictures (Ron Rensink, UBC)
    http://www.psych.ubc.ca/~rensink/flicker/download/
  - Videos (Dan Simons, Illinois)
    http://viscog.beckman.uiuc.edu/djs_lab/demos.html

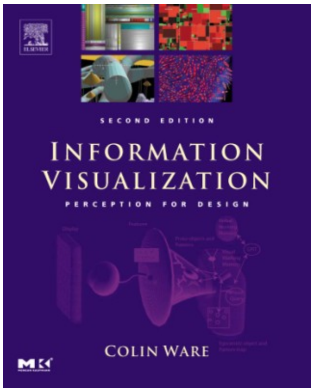
Optical Illusions



Stage 2

- Missing here!
- Object recognition and locomotion/action
- Maybe in the future… :^)

Great Book



Information Visualization
Perception for Design
2nd edition

Colin Ware
Morgan Kaufmann

HW 1 Discussion

- What findings did you make?
- What was difficult?
- What help did you want?

More details on website

Design Project

- Group of 3-5 students
- Understand problem, design, build
- You pick the topic/domain/data
  - **Absolutely crucial!!!**
  - NY Times vizs are nice examples
  - Be creative!
- First milestone: Teams and topics in 3 weeks (Sep 17th)

Upcoming

- Value/Benefits of Visualization
  - Papers
    - Fekete et al '08
    - Norman book chapter
    - van Wijk '05
- Labor Day holiday
  - No class

Sources Used

Healey website and article

http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Marti Hearst SIMS 247 lectures
C. Ware*, Information Visualization*