Visual Perception

CS 4460 – Intro. to Information Visualization
September 11, 2017
John Stasko

Perception Challenge

http://www.simonslab.com/videos.html

Learning Objectives

- Describe the visual processing pipeline
- Define pre-attentive processing
  - Identify visual features that are and are not pre-attentive
- Describe Gestalt principles and their application to visualization
- Explain how luminance and brightness relate
- Learn about and use principles of color in visualization
- Explain which perception factors best encode different communication goals
- Define change blindness
- Describe key limitations of visual channel

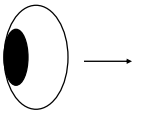
- Ultimately, critique and apply perception principles to designs

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?

12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496869

How Many 3's?

128176875613897654698450698560498282676298098584582245098564589450984509809435859091030209905959595772564675050678904567884578980982167765487636490856091294968 6

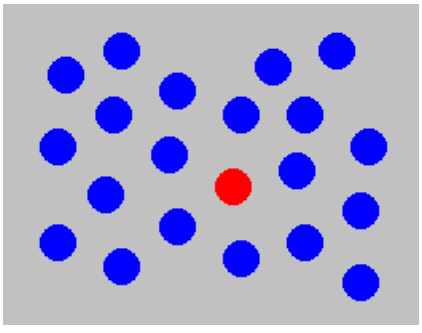
What Kinds of Tasks?

- 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

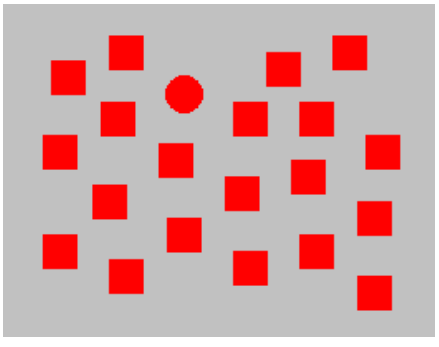
Hue



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

Distractor

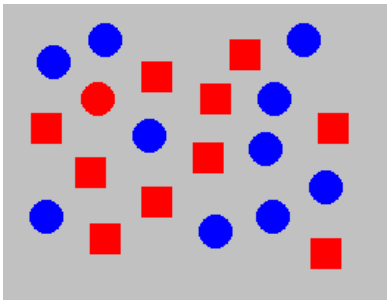
Shape



Can be done preattentively by people

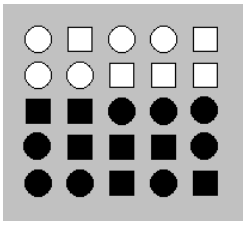
Distractor

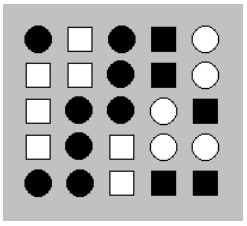
Hue and Shape



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

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 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

Discussion

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

Gestalt Laws

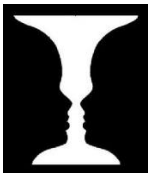
- Background
  - German psychologists, early 1900's
  - Attempt to understand pattern perception
  - Founded Gestalt school of psychology
  - Provided clear descriptions of many basic perceptual phenomena
    - → Gestalt Laws of Pattern Perception

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

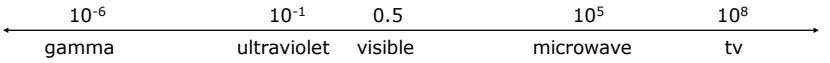
- Perceived brightness is non-linear function of amount of light emitted by source
  - Typically a power function
  - $S = aI^n$
    - S - sensation
    - I - intensity
- Very different on screen versus paper

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

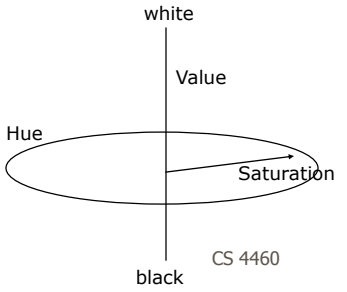
Color

- 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.cc.com/video-clips/w066sz/the-daily-show-with-jon-stewart-full-color-coverage

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?
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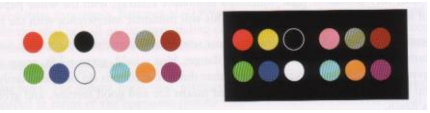
Color for Categories

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

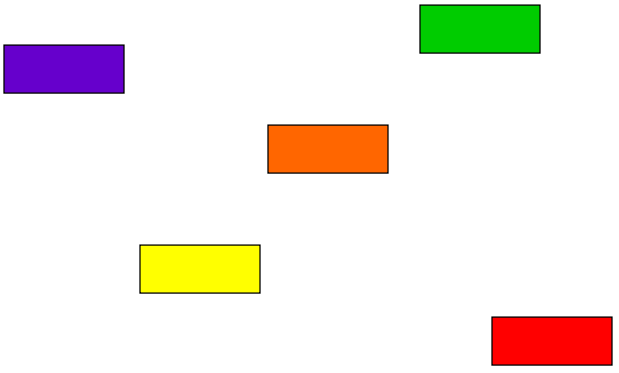
    red, green, yellow, blue, black, white, pink, cyan, gray, orange, brown, purple



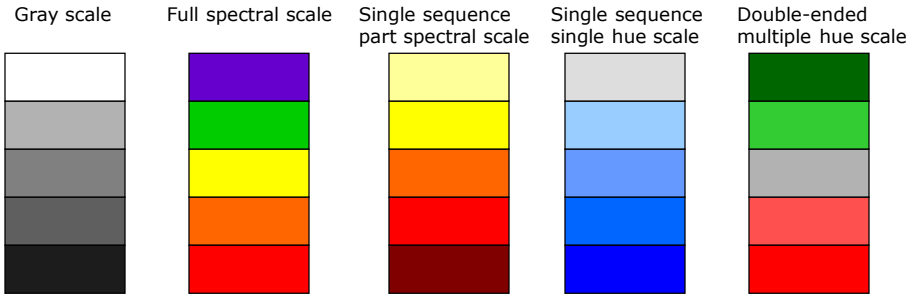
From Ware '04

Color for Sequences

Can you order these (low->hi)

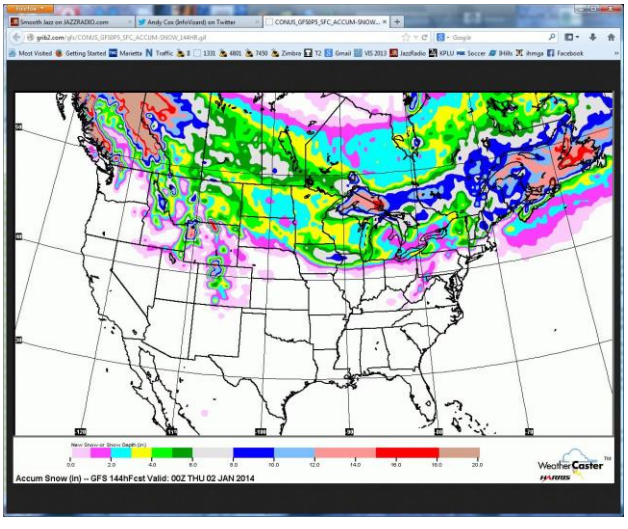


Possible Color Sequences

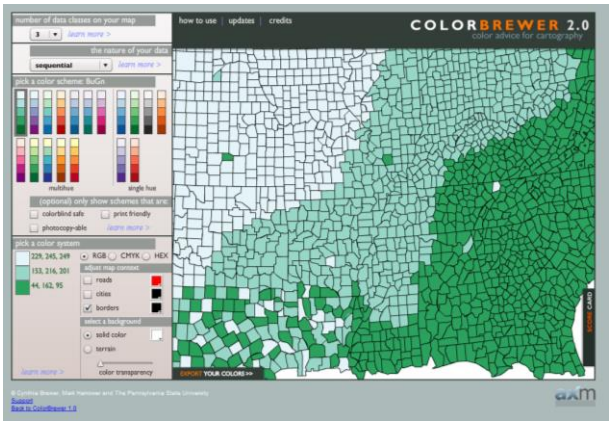


Advice

Don’t use the rainbow color scale for quantitative data



ColorBrewer



Help with selecting colors for maps

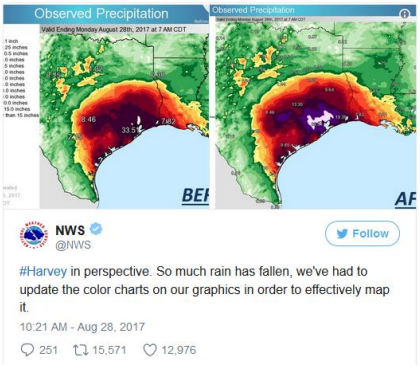
http://colorbrewer2.org/

AMERICA

National Weather Service Adds New Colors So It Can Map Harvey's Rains

August 28, 2017 · 1:50 PM ET

BILL CHAPPELL



http://www.npr.org/sections/thetwo-way/2017/08/28/546776542/national-weather-service-adds-new-colors-so-it-can-map-harveys-rains

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

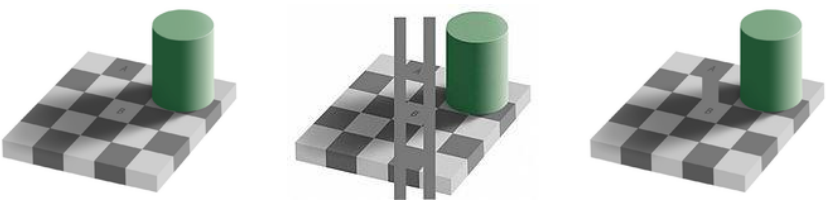
Using Color

- 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)

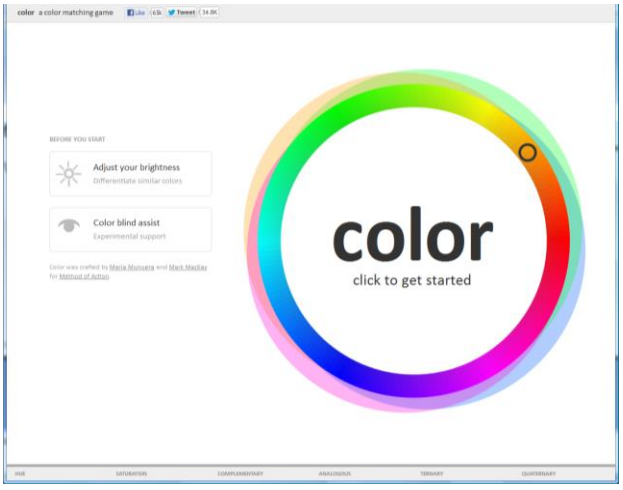
https://en.wikipedia.org/wiki/Checker_shadow_illusion



Are regions A and B the same color?

Color Challenge

http://color.method.ac/



Test your color abilities

Good Color Advice

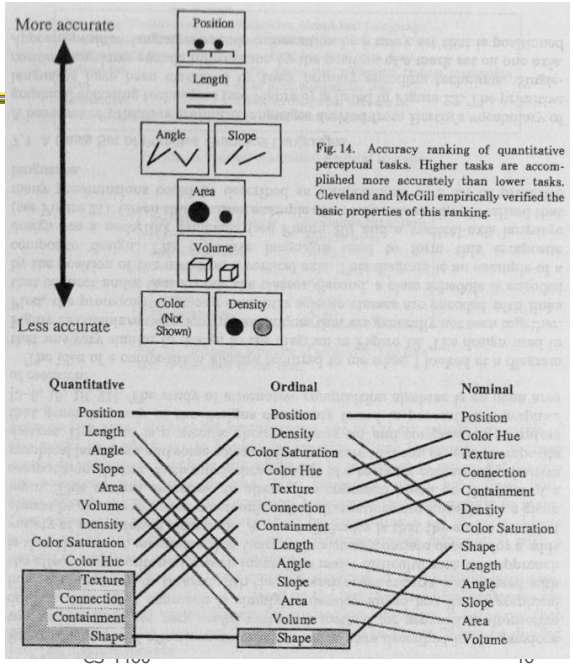
Maureen Stone's website
Many references and links
She frequently offers tutorials about color at conferences

http://www.stonesc.com

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

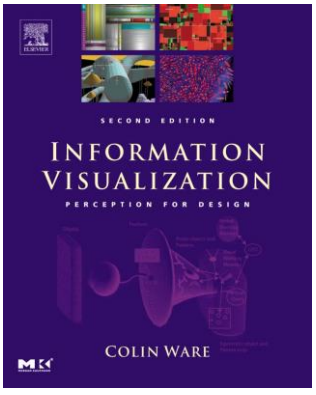
Change Blindness

- 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://www.simonslab.com/videos.html`

Stage 2

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

Great Book

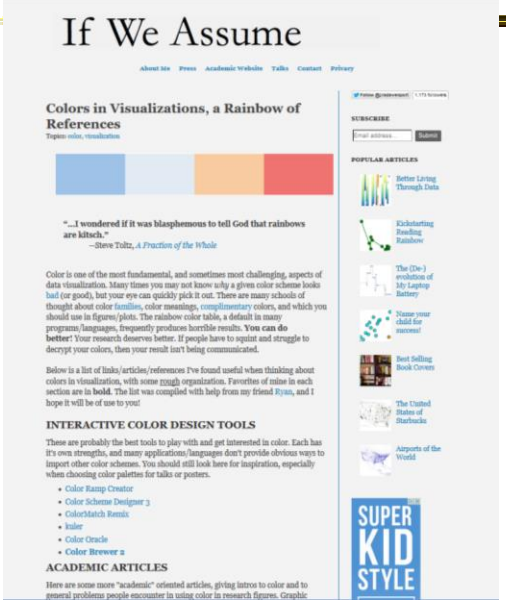


Information Visualization Perception for Design
2nd edition

Colin Ware
Morgan Kaufmann

http://www.ifweassume.com/2012/12/colors-in-visualizations-rainbow-of.html

Color Resources



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- Ultimately, critique and apply perception principles to designs

HW 1 Return

- Observations

Upcoming

- Case Study: Jigsaw system
  - Prep: Read Jigsaw flier, Watch 2 videos
- (Will push Lab 2 to next week)
- Multivariate visual representations 1

Sources Used

Healey website and article

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

C. Ware, *Information Visualization*