

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

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Perceptual Processing



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

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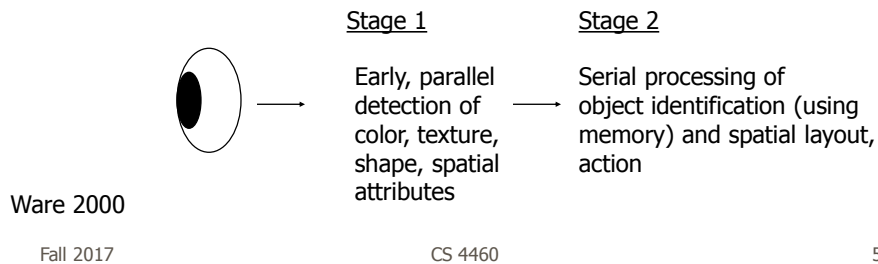
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One (simple) Model



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



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

How Many 3's?



1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

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



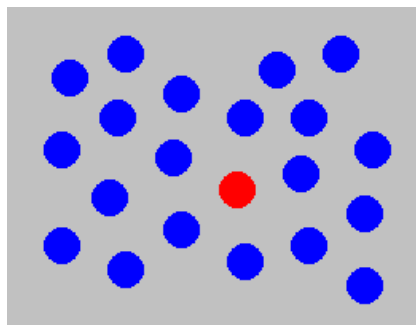
- Determine if a red circle is present

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Hue



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

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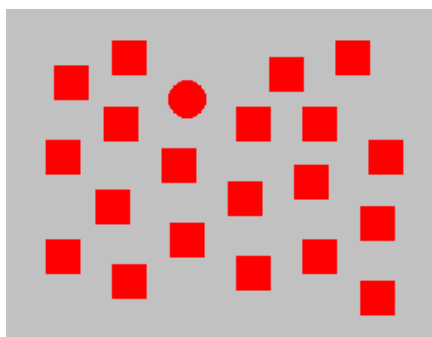
Distractor

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Shape



Can be done preattentively by people

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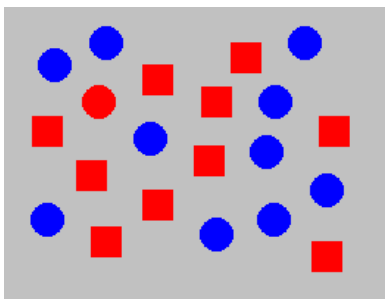
Distractor

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Hue and Shape



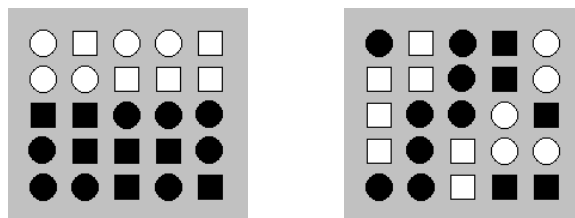
- Cannot be done preattentively
- Must perform a sequential search
- Conjunction of features (shape and hue) causes it

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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)

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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

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Discussion



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

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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

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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

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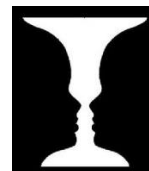
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Gestalt Laws



- 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



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Key Perceptual Properties



- Brightness
- Color
- Texture
- Shape

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Luminance/Brightness



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

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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

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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

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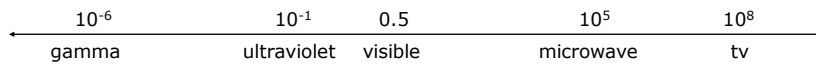
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Color



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



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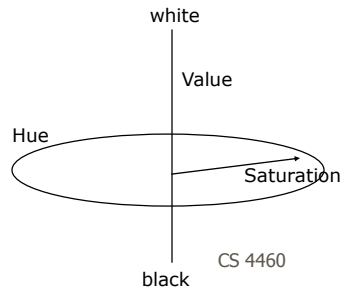
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Color Models



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



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How Not to Use Color



<http://www.cc.com/video-clips/w066sz/the-daily-show-with-jon-stewart-full-color-coverage>

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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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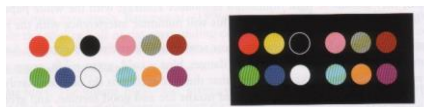
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Color for Categories



- 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

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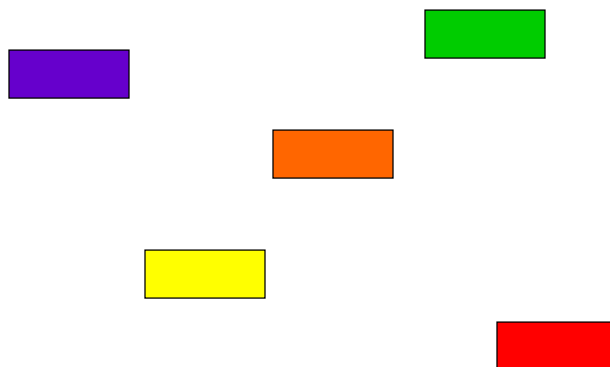
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Color for Sequences



Can you order these (low->hi)

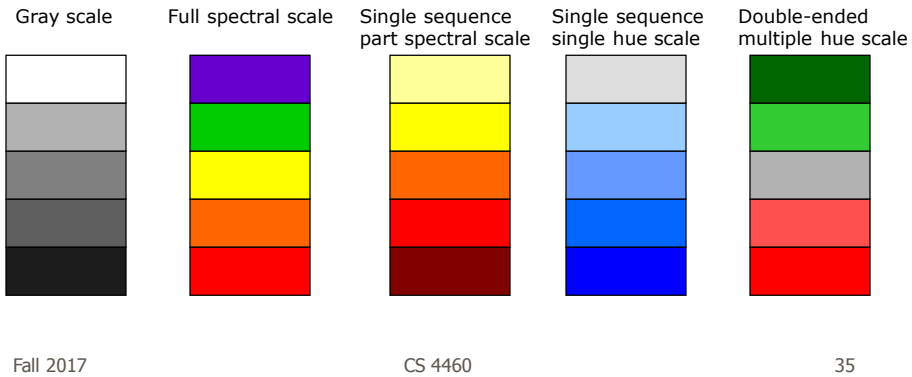


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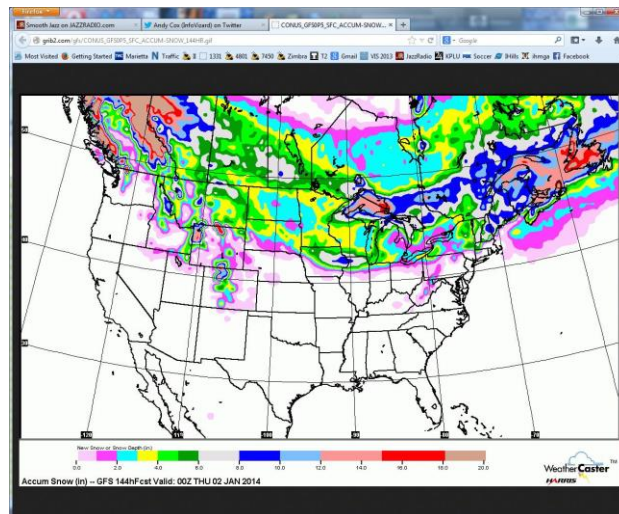
Possible Color Sequences



Advice



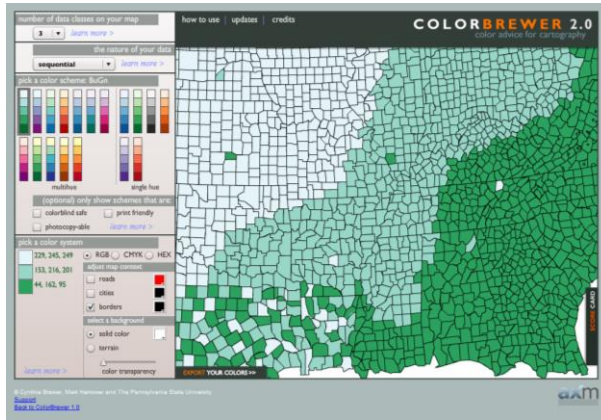
Don't use the rainbow color scale for quantitative data



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ColorBrewer



Help with selecting colors for maps

<http://colorbrewer2.org/>

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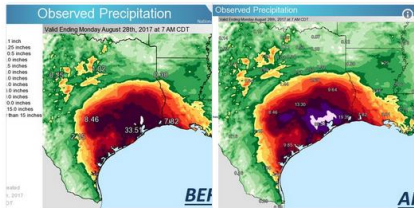
AMERICA

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



August 28, 2017 · 1:50 PM ET

BILL CHAPPELL



NWS @NWS

#Harvey in perspective. So much rain has fallen, we've had to update the color charts on our graphics in order to effectively map it.

10:21 AM - Aug 28, 2017

251 replies 15,571 retweets 12,976 likes

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

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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



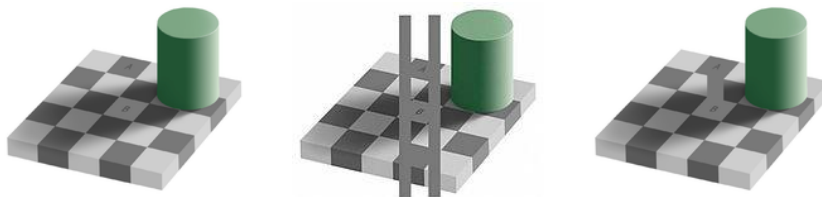
- For large regions, don't use highly saturated colors (pastels a good choice)
- Do not use adjacent colors that vary in amount of blue
- Don't use high saturation, spectrally extreme colors together (causes after images)
- Use color for grouping and search
- Beware effects from adjacent color regions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

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



Are regions A and B the same color?

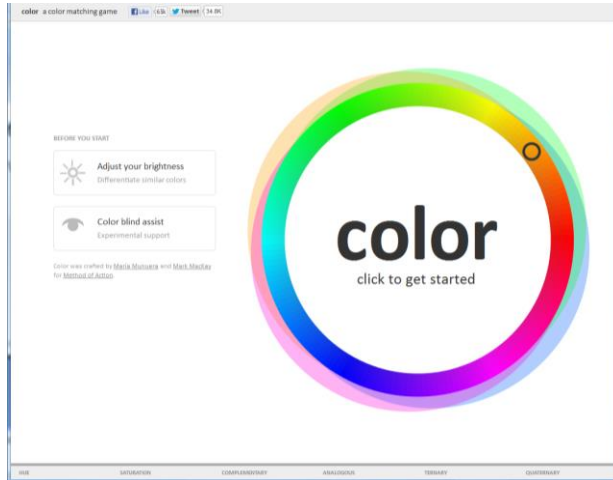
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Color Challenge

<http://color.method.ac/>



Test your color abilities

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Good Color Advice



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

<http://www.stonesc.com>

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Encodings



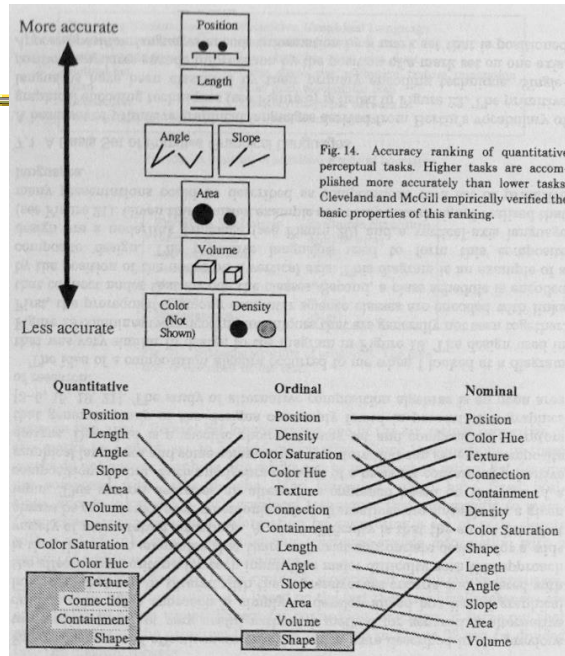
- When you want to communicate one type of variable, which visual property should you use?

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Accuracy ranking of quantitative perceptual tasks



Ranking of perceptual tasks

From Jock Mackinlay's 1986 thesis

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Change Blindness



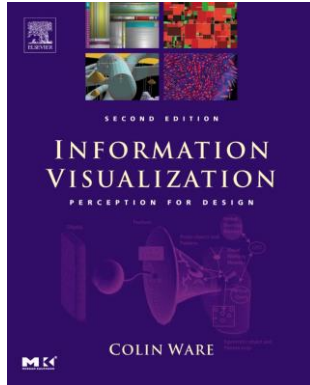
- Is the viewer able to perceive changes between two scenes?
 - If so, may be distracting
 - Can do things to minimize noticing changes
- Fun examples
 - Static pictures (Ron Rensink, UBC)
<http://www.psych.ubc.ca/~rensink/flicker/download/>
 - Videos (Dan Simons, Illinois)
<http://www.simonslab.com/videos.html>

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

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

Color Resources



If We Assume

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Colors in Visualizations, a Rainbow of References

Tags: color, visualization

...I wondered if it was blasphemous to tell God that rainbows are klutzy."
—Steve Toltz, *A Fraction of the Whole*

Color is one of the most fundamental, and sometimes most challenging, aspects of data visualization. Many times you may not know why a given color scheme looks bad (or good), but your eye can quickly pick it out. There are many schools of thought about color families, color meanings, complementary colors, and which you should use in figures/plots. The rainbow color table, a default in many program languages, frequently produces horrible results. You can do better! Your research deserves better. If people have to squint and struggle to decrypt your colors, then your result isn't being communicated.

Below is a list of links/articles/references I've found useful when thinking about colors in visualization, with some rough organization. Favorites of mine in each section are in bold. The list was compiled with help from my friend Ryan, and I hope it will be of use to you!

INTERACTIVE COLOR DESIGN TOOLS

These are probably the best tools to play with and get interested in color. Each has its own strengths, and many applications/languages don't provide obvious ways to import other color schemes. You should still look here for inspiration, especially when choosing color palettes for talks or posters.

- [Color Ramp Creator](#)
- [Color Scheme Designer 3](#)
- [ColorMatch Remote](#)
- [kuler](#)
- [Color Oracle](#)
- [Color Brewer 2](#)

ACADEMIC ARTICLES

Here are some more "academic" oriented articles, giving intro to color and to general problems people encounter in using color in research figures. Graphic

SUBSCRIBE

Your address:

POPULAR ARTICLES

- [Better Living Through Data](#)
- [Kickstarting Finding Rainbow](#)
- [The \(De-\) evolution of My Laptop Battery](#)
- [Save your child for screen!](#)
- [Best Selling Book Covers](#)
- [The United States of Statistics](#)
- [Airports of the World](#)

SUPER KID STYLE

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Learning Objectives



- Describe the visual processing pipeline
- Define pre-attentive processing
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HW 1 Return



- Observations

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Upcoming



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

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Sources Used



Healey website and article

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

C. Ware, *Information Visualization*

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