

Visual Perception



CS 7450 - Information Visualization
November 18, 2015
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*

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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

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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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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

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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

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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

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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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How Many 3's?



12817687561**3**8976546984506985604982826762
980985845822450985645894509845098094**3**585
90910**3**0209905959595772564675050678904567
8845789809821677654876**3**64908560912949686

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What Kinds of Tasks?



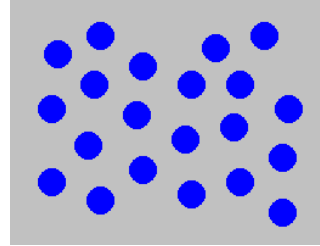
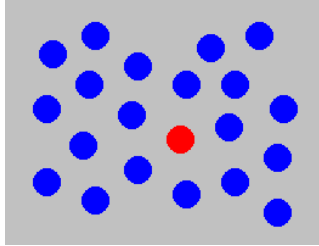
- Target detection
 - Is something there?
- Boundary detection
 - Can the elements be grouped?
- Counting
 - How many elements of a certain type are present?

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"

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Example



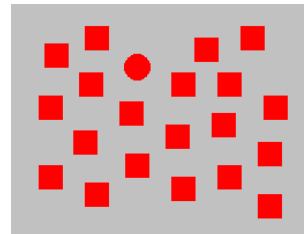
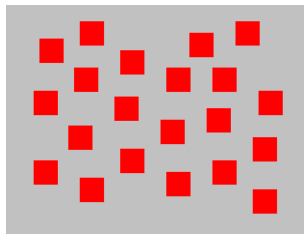
- Determine if a red circle is present

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Shape



Can be done preattentively by people

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Example



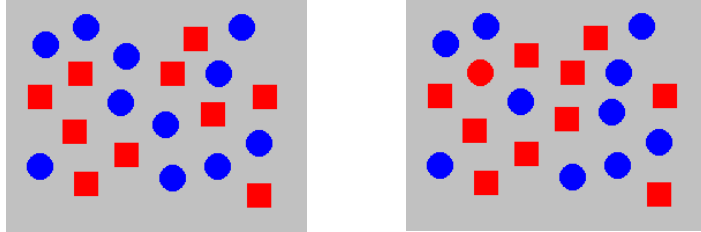
- Determine if a red circle is present

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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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Example



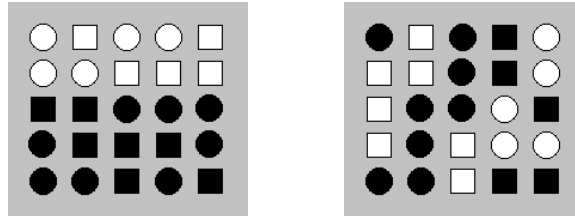
- Is there a boundary in the display?

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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



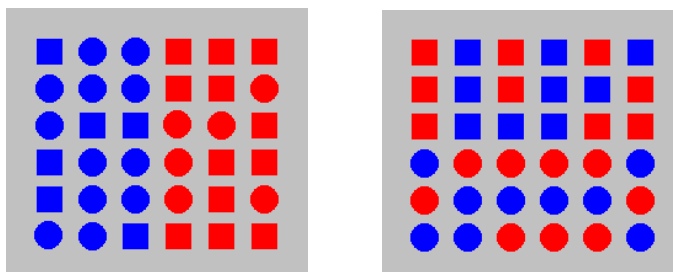
- Is there a boundary in the display?

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Hue versus Shape



Left: Boundary detected preattentively based on hue regardless of shape

Right: Cannot do mixed color shapes preattentively

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Example



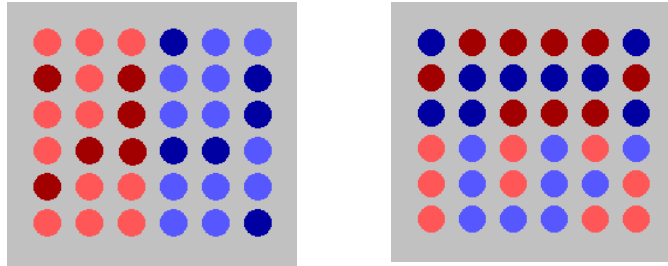
- Is there a boundary?

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Hue versus brightness



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

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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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Preattentive Features



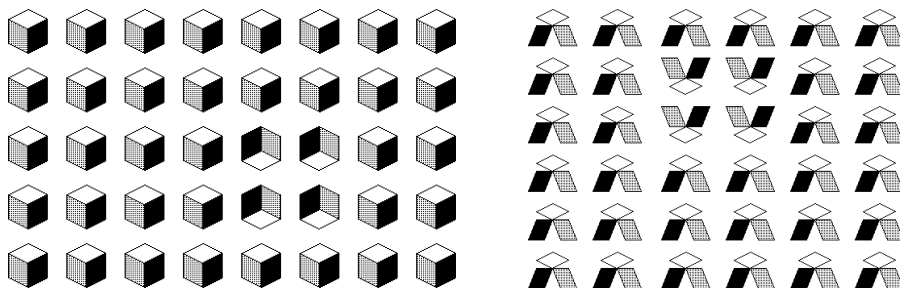
- Certain visual forms lend themselves to preattentive processing
- Variety of forms seem to work

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3-D Figures



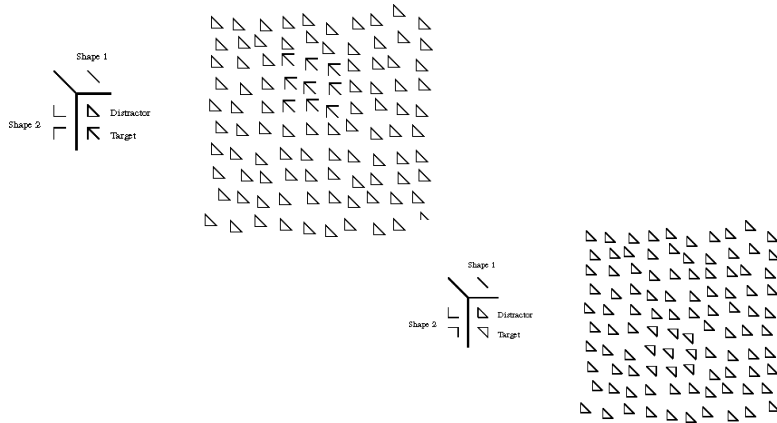
3-D visual reality has an influence

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Emergent Features



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Potential PA Features



- | | |
|--------------|---------------------|
| length | hue |
| width | intensity |
| size | flicker |
| curvature | direction of motion |
| number | binocular lustre |
| terminators | stereoscopic depth |
| intersection | 3-D depth cues |
| closure | lighting direction |

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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

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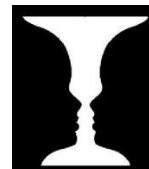
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Gestalt Laws



- 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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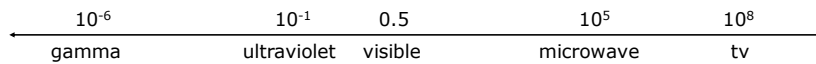
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Color



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



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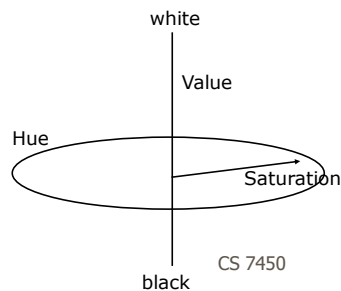
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Color Models



- 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>

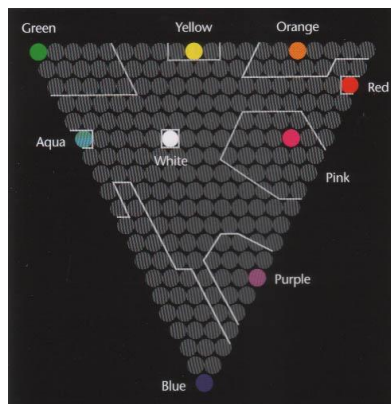
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Color Categories

- 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

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Maybe Not All the Same?



<http://www.boreme.com/posting.php?id=30670>



It took me a long time to figure out which color was different (it complicates matters that the TV program pointed to the wrong square). I used the eyedropper tool in Adobe Illustrator to confirm which square had the different color. [Click here](#) to see the RGB value for each square.

The Himba had a much harder time pointing out the square that English speakers would categorize as a shade of blue.

Himba tribe

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Article Discussion



Choosing Colors for Data Visualization
by Maureen Stone
Originally published January 17, 2006

- Printer-friendly
- Email to a friend
- Email to myself
- Comments

The problem of choosing colors for data visualization is expressed by this quote from information visualization guru Edward Tufte:

"... avoiding catastrophe becomes the first principle in bringing color to information: Above all, do no harm." (Envisioning Information, Edward Tufte, Graphics Press, 1990)

Color used well can enhance and clarify a presentation. Color used poorly will obscure, muddle and confuse. While there is a strong aesthetic component to color, using color well in information display is essentially about function: what information are trying to convey, and how (or whether) color can enhance it.

The most important use of color in information presentation is to distinguish one element from another, a function Edward Tufte calls "to label." In Figure 1, for example, the different colors in the scatter plot label different products. But the use of color as a label goes beyond the distinctive data colors, for color in this discussion includes black, white and shades of gray.

Your thoughts?

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

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Luminance



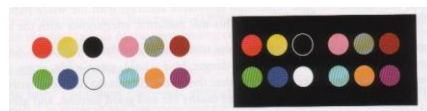
- Important for fg-bg colors to differ in brightness

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

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

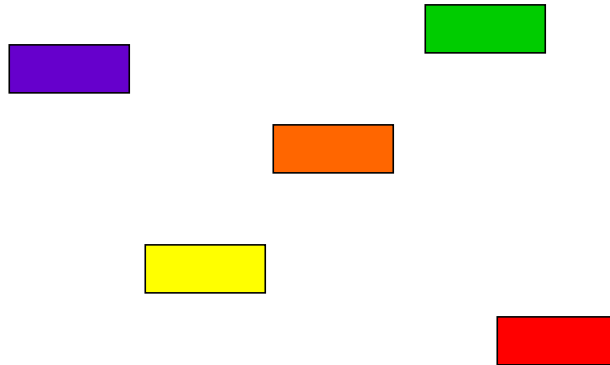


From Ware '04

Color for Sequences



Can you order these (low->hi)

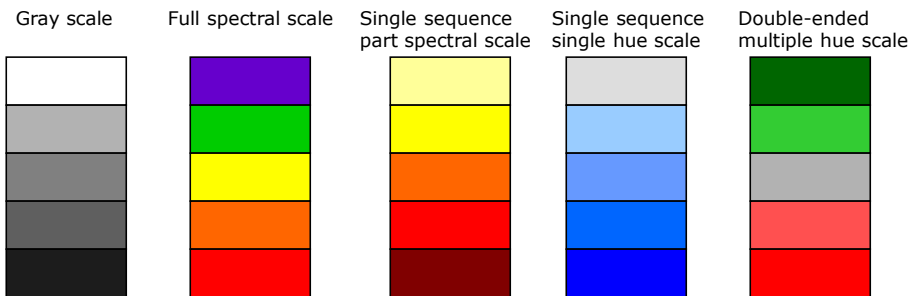


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Possible Color Sequences



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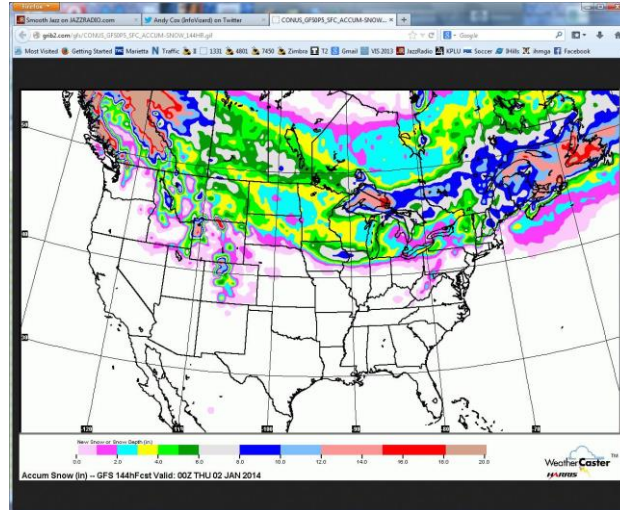
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Advice



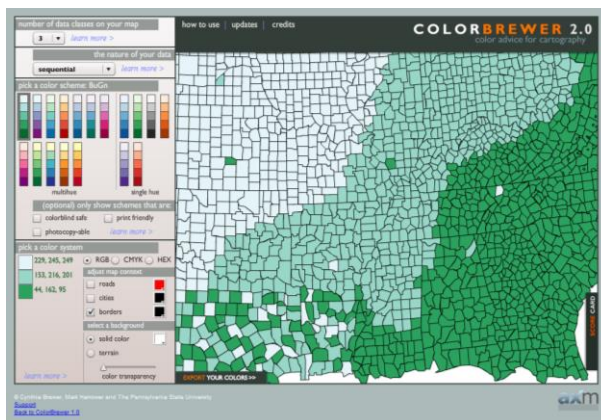
Don't use the rainbow color scale for quantitative data



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ColorBrewer



Help with selecting colors for maps

<http://colorbrewer2.org/>

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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

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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

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Using Color



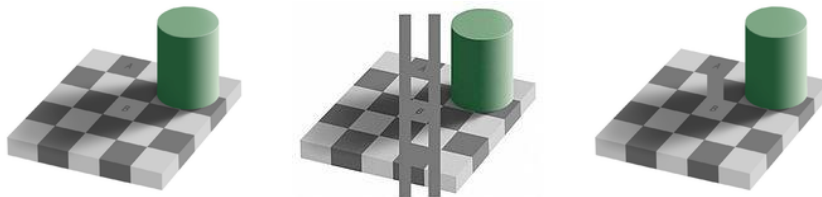
- For large regions, don't use highly saturated colors (pastels a good choice)
- Do not use adjacent colors that vary in amount of blue
- Don't use high saturation, spectrally extreme colors together (causes after images)
- Use color for grouping and search
- Beware effects from adjacent color regions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

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



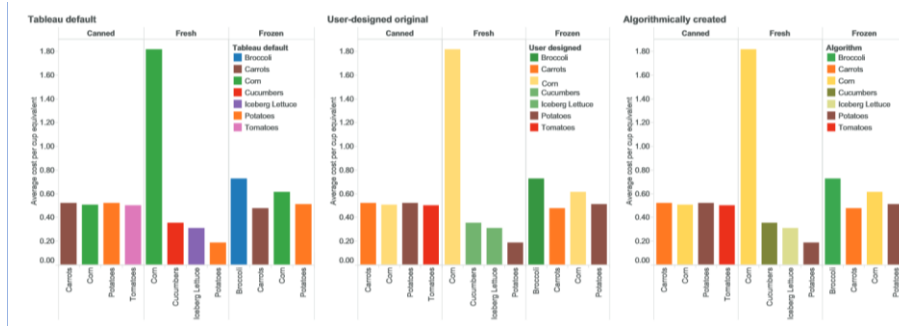
Are regions A and B the same color?

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Tableau's Colors



Provides "default" colors for legend items
Use NLP, Google n-grams & images

Setlur & Stone
TVCG (InfoVis) '15

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<https://vimeo.com/136205858>

More Choices

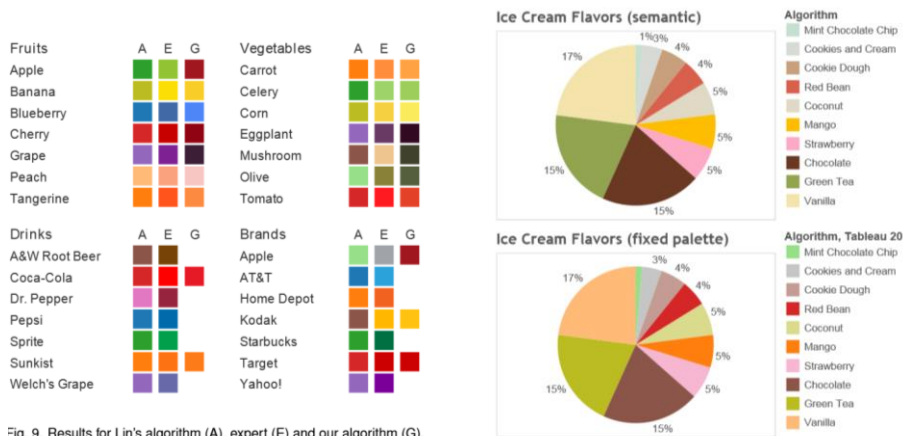


Fig. 9. Results for Lin's algorithm (A), expert (E) and our algorithm (G).

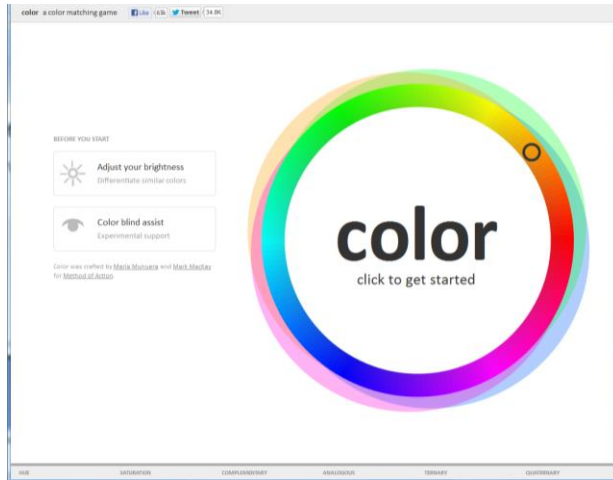
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Color Challenge

<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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Color Resources



If We Assume

Colors in Visualizations, a Rainbow of References

Types: color, visualizations

“...I wondered if it was blasphemous to tell God that rainbows are kitsch.”
—Steve Tubb, *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 programs/languages, frequently produces horrible results. You can do better! Your research deserves better. If people have to agonize 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 Items](#)
- [Isler](#)
- [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

POPULAR ARTICLES

- [Better Learning Through Data](#)
- [Kickstarting Reading Rainbows](#)
- [The \(De-\) evolution of My Laptop Battery](#)
- [Name your child for success!](#)
- [Not Selling Book Covers](#)
- [The United States of Starbucks](#)
- [Airports of the World](#)

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SUPER KID STYLE

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Texture



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

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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



Ware '04

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Encodings



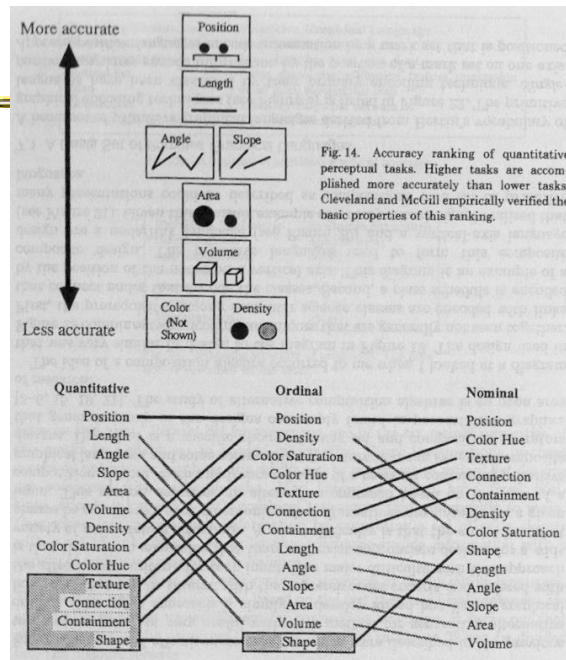
- When you want to communicate one type of variable, which visual property should you use?

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Accuracy ranking of quantitative perceptual tasks



Ranking of perceptual tasks

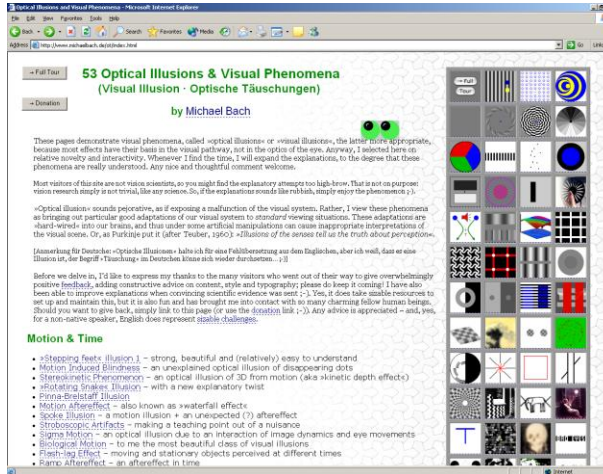
From Jock Mackinlay's 1986 thesis
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Change Blindness



- 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>

Optical Illusions



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Stage 2



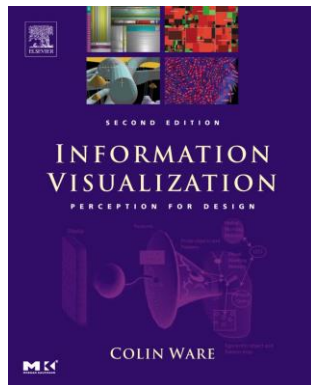
- Missing here!
- Object recognition and locomotion/action
- Maybe in the future... :^)

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Great Book



*Information Visualization
Perception for Design*
2nd edition

Colin Ware
Morgan Kaufmann

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HW 6 Return



- Plus some other older ones

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Project



- Deliverables
 - Demo to Ramik, Iulian & John
Final exam week, sign up on t-square
 - Video
5 minutes max, show in final exam period
Wednesday 9th

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Video Advice



- Use Camtasia
- Process
 - 1. Develop script (rehearse timing)
 - 2. Record script
 - 3. Capture video of demo to script
 - 4. Add effects
- You've seen examples all semester
 - eg, <http://www.cc.gatech.edu/gvu/ii/videos.html>

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Upcoming



- Evaluation
 - Papers
 - Carpendale '08
- Thanksgiving holiday
 - No class
- Review
 - Papers
 - Now You See It*, chapter 13
 - Heer et al '10

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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*

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