

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*

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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 msec (eye movements take 200 msec)
 - 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?



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

What Kinds of Tasks?



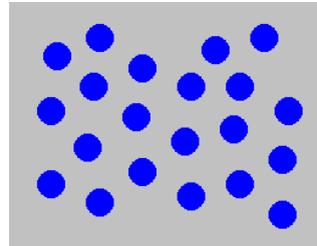
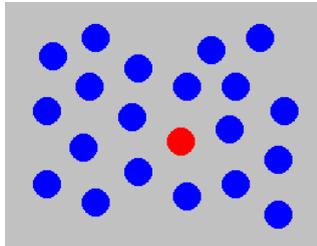
- Target detection
 - Is something there?
- Boundary detection
 - Can the elements be grouped?
- Counting
 - How many elements of a certain type are present?

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



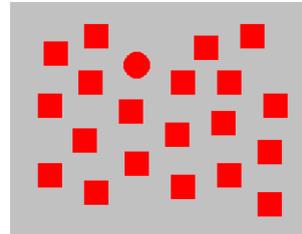
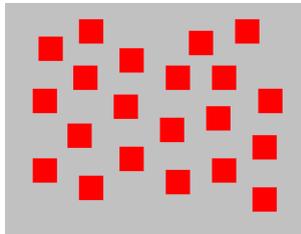
- Determine if a red circle is present

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Shape



Can be done preattentively by people

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Example



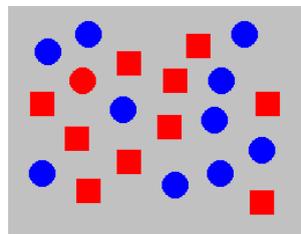
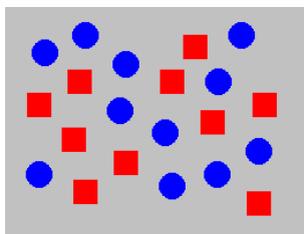
- Determine if a red circle is present

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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



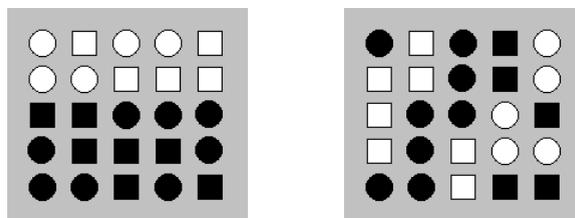
- Is there a boundary in the display?

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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



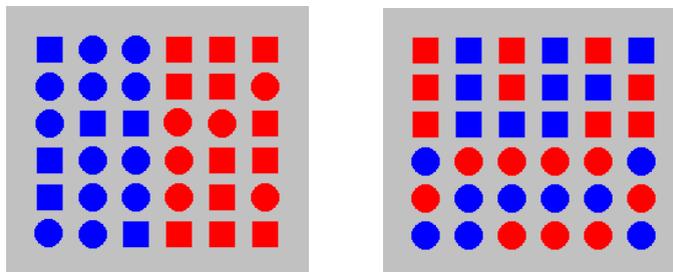
- Is there a boundary in the display?

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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

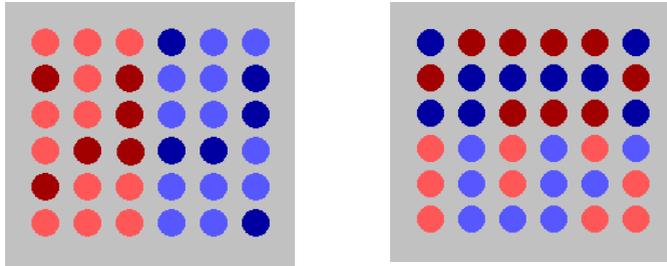
- Is there a boundary?

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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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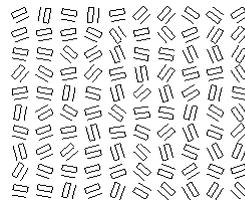
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Textons



≡ 5



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

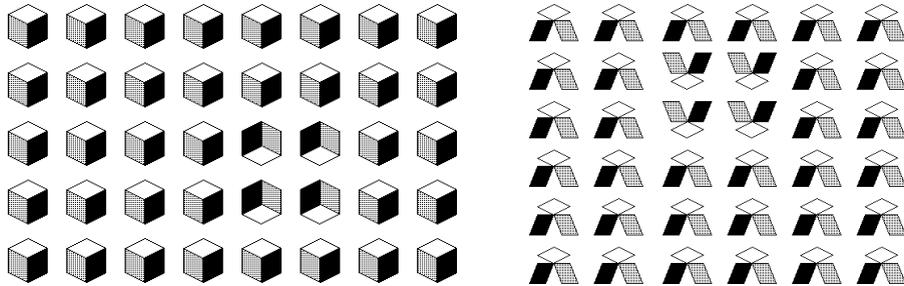
All detected early

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3-D Figures



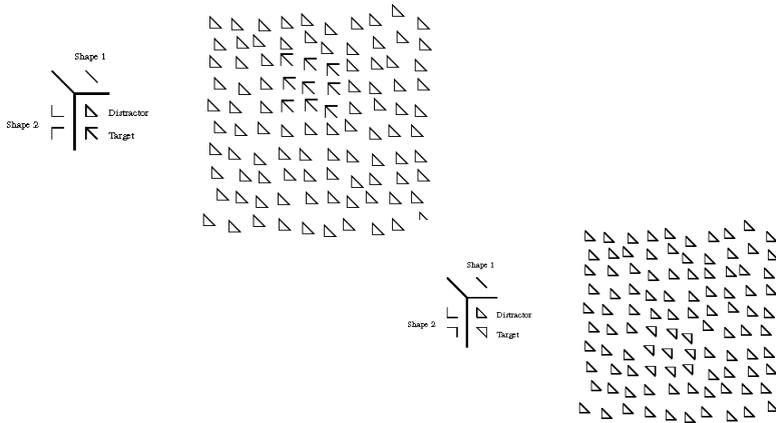
3-D visual reality has an influence

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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?

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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

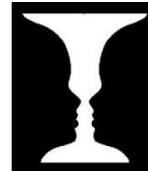
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Gestalt Laws

- 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

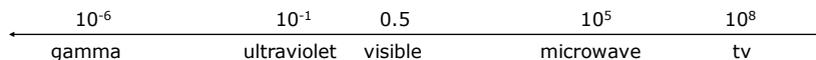


- Probably not best way to encode data because of contrast issues
 - Surface orientation and surroundings matter a great deal
 - Luminance channel of visual system is so fundamental to so much of perception
 - We can get by without color discrimination, but not luminance

Color

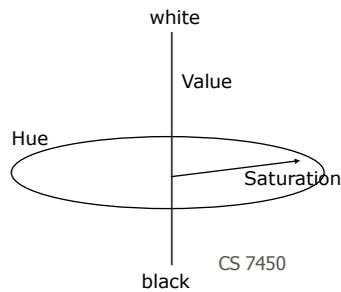


- Sensory response to electromagnetic radiation in the spectrum between wavelengths 0.4 - 0.7 micrometers



Color Models

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



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How Not to Use Color

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

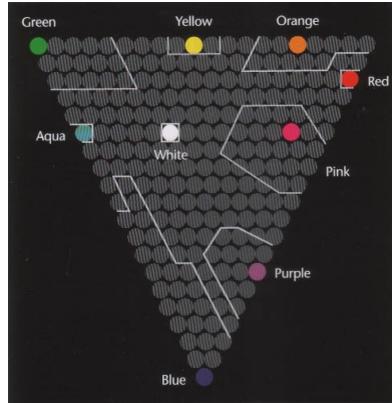
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Color Categories

- 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

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/>



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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?

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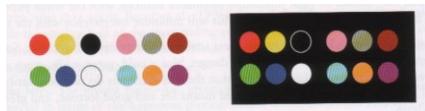
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Color for Categories



- 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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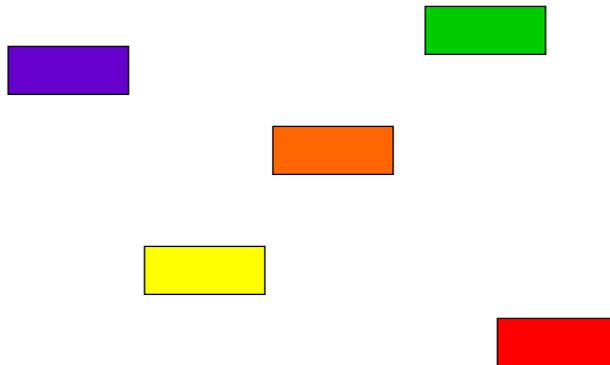
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Color for Sequences



Can you order these (low->hi)

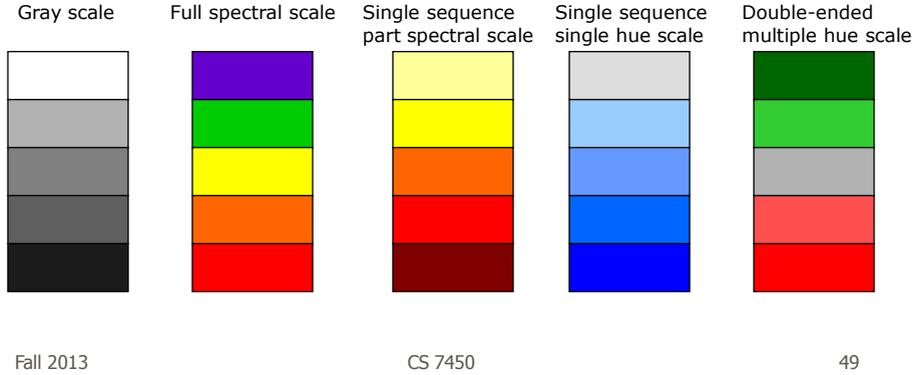


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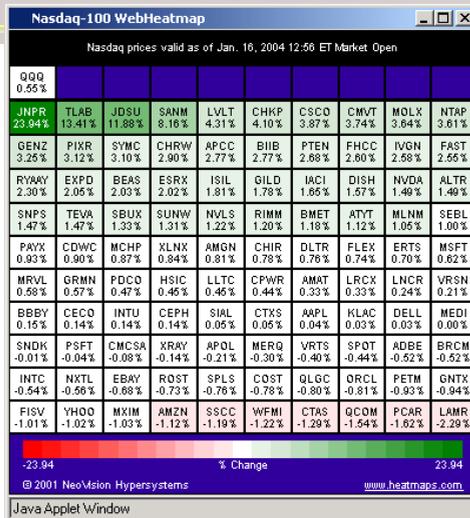
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Possible Color Sequences



HeatMap



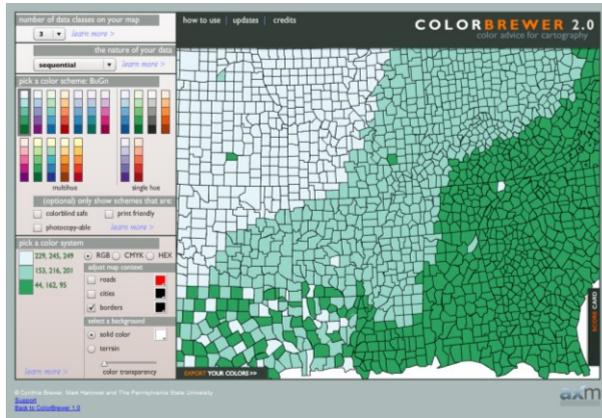
• http://screening.nasdaq.com/heatmaps/heatmap_100.asp

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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



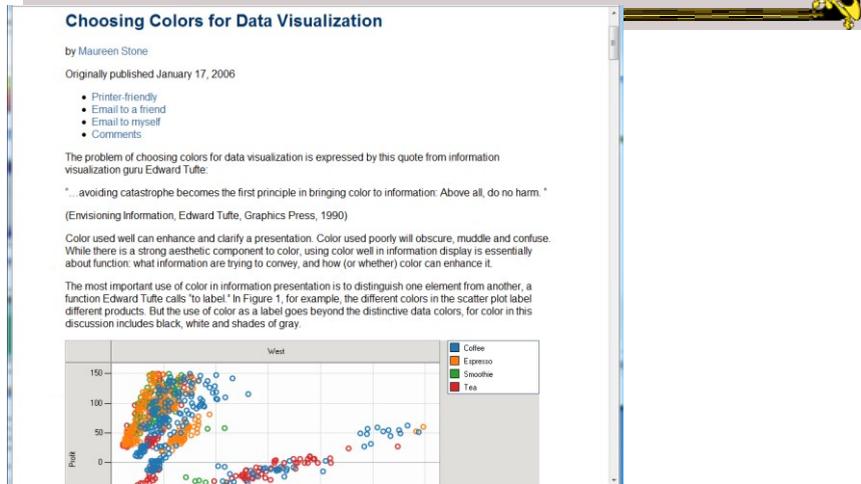
- Modesty! Less is more
- Use blue in large regions, not thin lines
- Use red and green in the center of the field of view (edges of retina not sensitive to these)
- Use black, white, yellow in periphery
- Use adjacent colors that vary in hue & value

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



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

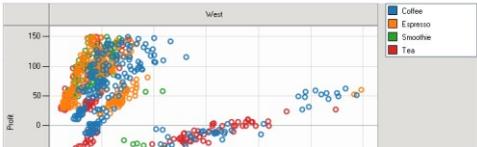
- Printer-friendly
- Email to a friend
- Email to myself
- Comments

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.



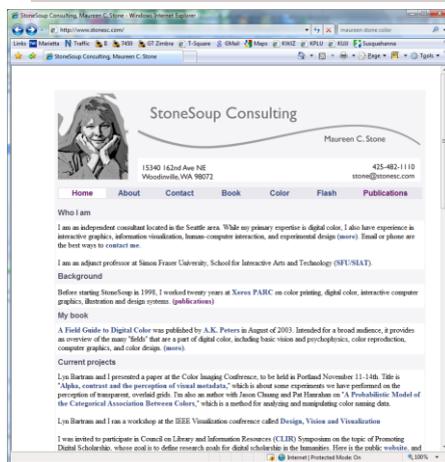
<http://www.b-eye-network.com/newsletters/ben/2235>

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Good Color Advice



StoneSoup Consulting
Maureen C. Stone

15340 162nd Ave NE
Microsoft, WA 98072

425-482-1110
stone@stonesc.com

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Who I am
I am an independent consultant located in the Seattle area. While my primary expertise is digital color, I also have experience in interactive graphics, information visualization, human-computer interaction, and experimental design (www). Email or phone are the best ways to contact me.

I am an adjunct professor at Simon Fraser University, School for Interactive Arts and Technology (SFI/NIAT).

Background
Before starting StoneSoup in 1998, I worked twenty years at Xerox PARC on color printing, digital color, interactive computer graphics, illustration and design systems. (publications)

My book
A Field Guide to Digital Color was published by A.K. Peters in August of 2003. Intended for a broad audience, it provides an overview of the many "fields" that are a part of digital color, including basic vision and psychophysics, color reproduction, computer graphics, and color design. (www)

Current projects
Lyn Bartram and I presented a paper at the Color Imaging Conference, to be held in Portland November 11-14th. Title is "A field guide to the perception of visual materials," which is about some experiments we have performed on the perception of transparent, overlaid grids. I'm also an author with Jason Chang and Pat Hanrahan on "A Probabilistic Model of the Categorical Association Between Colors," which is a method for modeling and manipulating color naming data.

Lyn Bartram and I ran a workshop at the IEEE Visualization conference called Design, Vision and Visualization.

I was invited to participate in Council on Library and Information Resources (CLIR) Symposium on the topic of Promoting Digital Scholarship, whose goal is to define research needs for digital scholarship in the humanities. Here is the public website, and

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

<http://www.stonesc.com>

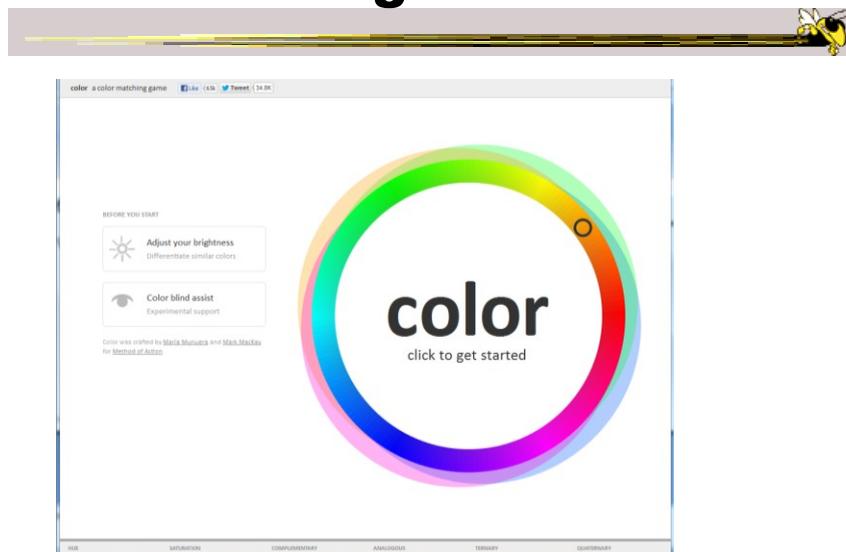
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Color Challenge

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



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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

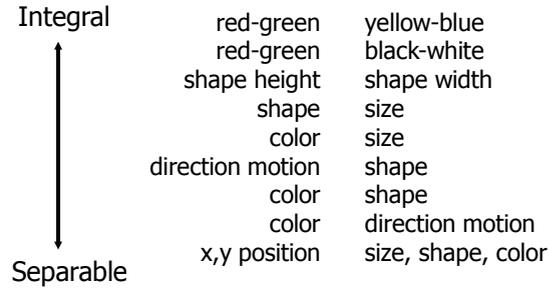


- Suppose that we use two different visual properties to encode two different variables in a discrete data set
 - color, size, shape, lightness
- Will the two different properties interact so that they are more/less difficult to untangle?
 - Integral - two properties are viewed holistically
 - Separable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

Integral-Separable



- Not one or other, but along an axis



Ware '04

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Encodings



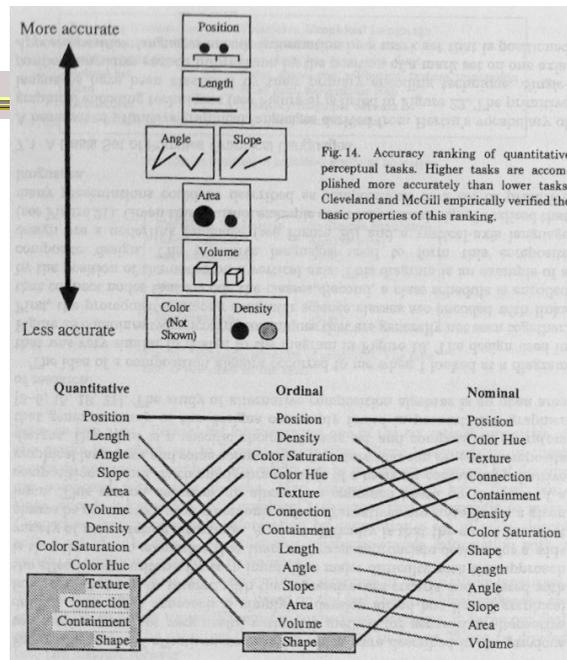
- When you want to communicate one type of variable, which visual property should you use?

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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

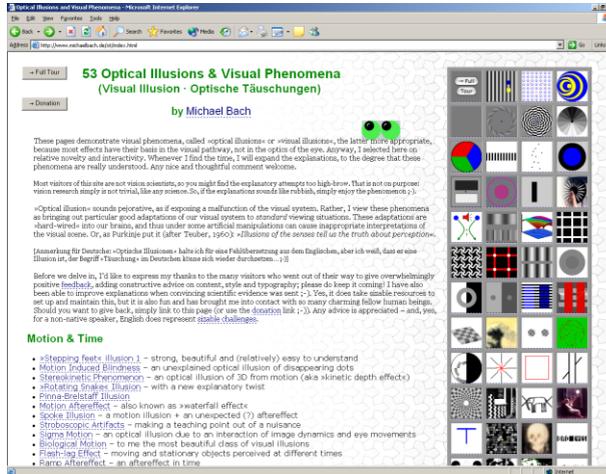
- Is the viewer able to perceive changes between two scenes?
 - If so, may be distracting
 - Can do things to minimize noticing changes
- Fun examples
 - Static pictures (Ron Rensink, UBC)
 - <http://www.psych.ubc.ca/~rensink/flicker/download/>
 - Videos (Dan Simons, Illinois)
 - http://viscog.beckman.uiuc.edu/djs_lab/demos.html

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Optical Illusions



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Stage 2



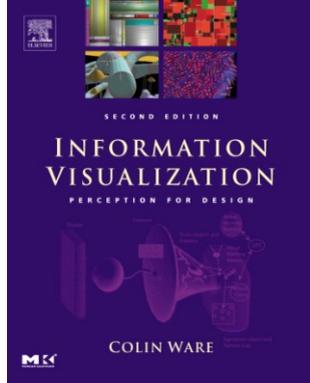
- Missing here!
- Object recognition and locomotion/action
- Maybe in the future... :^)

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Great Book



*Information Visualization
Perception for Design*
2nd edition

Colin Ware
Morgan Kaufmann

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HW 1 Discussion

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

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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*