

# Visual Perception

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CS 7450 - Information Visualization  
August 29, 2012  
John Stasko

## Agenda

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- 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

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## 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

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## 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?

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## Example



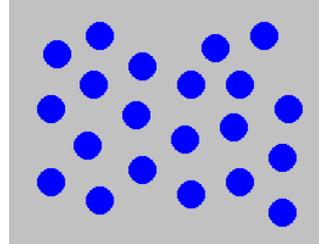
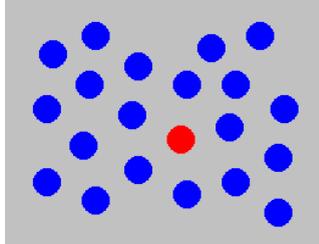
- Determine if a red circle is present
- (2 sides of the room)

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# Hue



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

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# Example



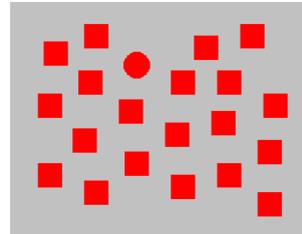
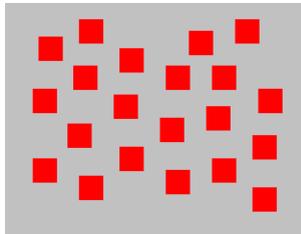
- Determine if a red circle is present

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# Shape



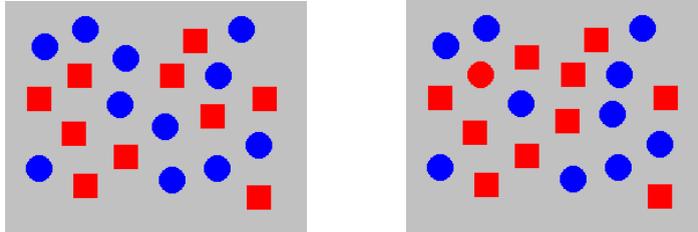
Can be done preattentively by people

# Example



- Determine if a red circle is present

# 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



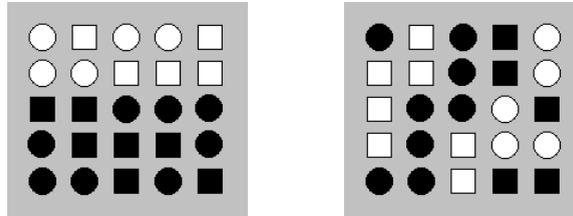
- Is there a boundary in the display?

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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



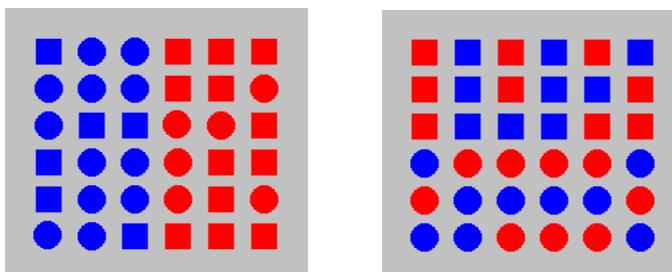
- Is there a boundary in the display?

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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



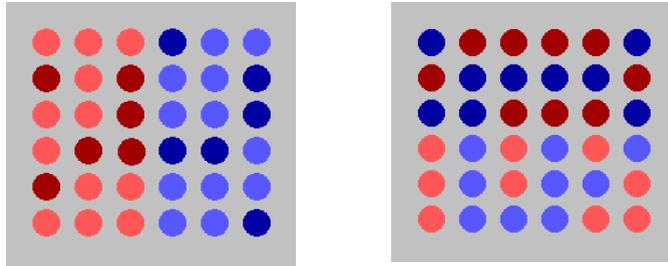
- Is there a boundary?

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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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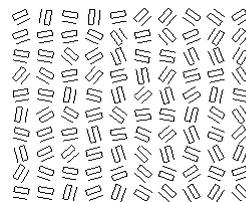
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# Textons



≡ 5



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

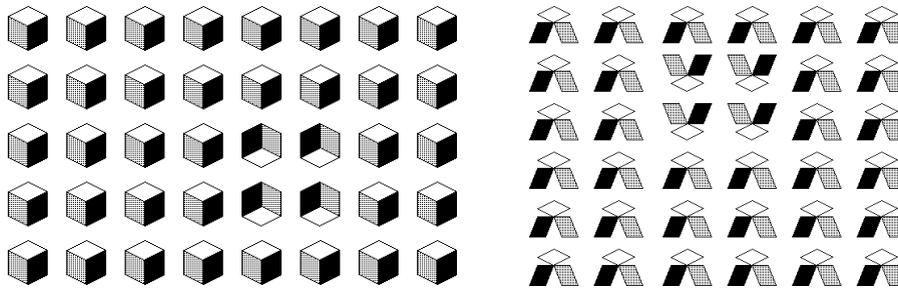
All detected early

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# 3-D Figures



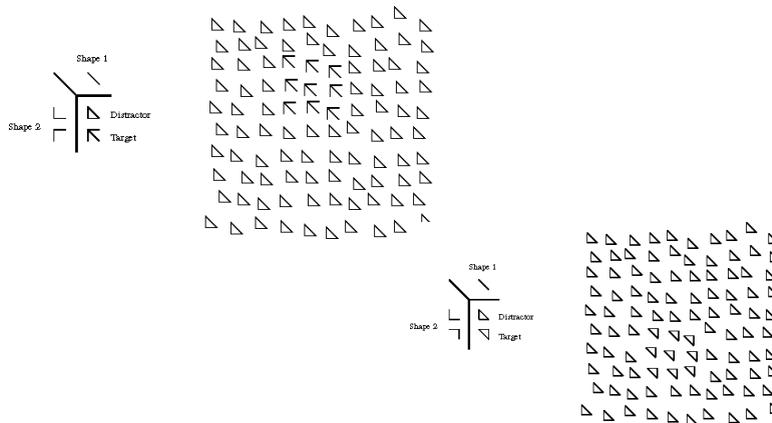
3-D visual reality has an influence

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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

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- 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

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- 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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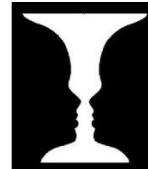
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# Gestalt Laws



- 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

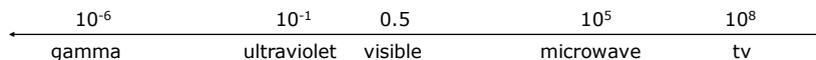


- Probably not best way to encode data because of contrast issues
  - Surface orientation and surroundings matter a great deal
  - Luminance channel of visual system is so fundamental to so much of perception
    - We can get by without color discrimination, but not luminance

# Color



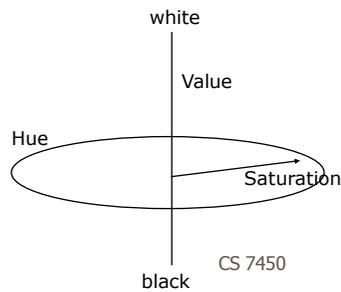
- Sensory response to electromagnetic radiation in the spectrum between wavelengths 0.4 - 0.7 micrometers



# 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



The screenshot shows a video player interface for a video titled "February 6, 2008: Full Color Coverage". The video content shows Jon Stewart on the set of the Daily Show. A quote box is overlaid on the video: "Earlier in the day I had wanted to paint my bedroom McCain, but I already have Romney drapes and they clash." - Jon Stewart. The video player includes a play button, a progress bar at 00:01:04.42, and a volume icon. Below the video player, the video title "Full Color Coverage" is displayed, along with a description: "Jon shuffles through the colors assigned to the candidates and compares the gadgets of the cable news teams." The video has 113030 views, was posted on February 6, 2008, and has 5 comments and 17 thumbs up. The video player also shows a progress bar at 100% and a volume icon.

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

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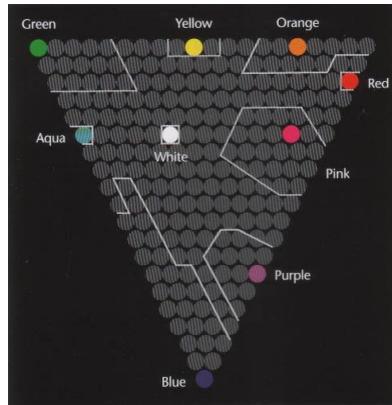
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# Color Categories

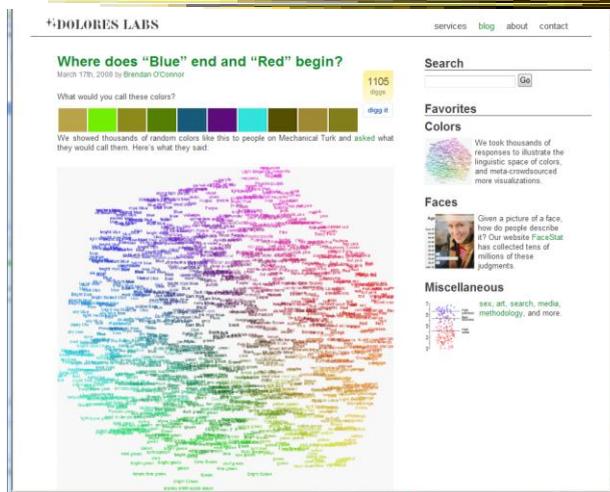


- Are there certain canonical colors?
  - Post & Greene '86 had people name different colors on a monitor
  - Pictured are ones with > 75% commonality



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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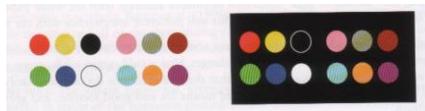
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## Color for Categories



- 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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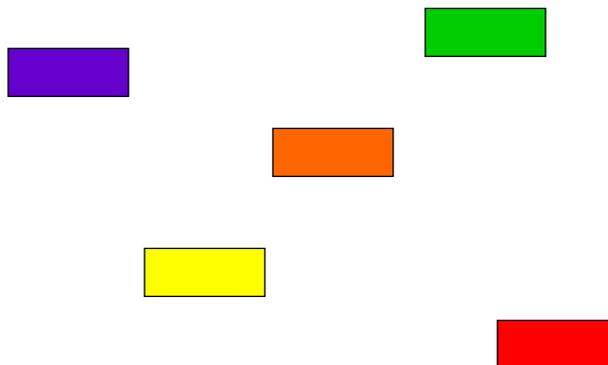
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## Color for Sequences



Can you order these (low->hi)

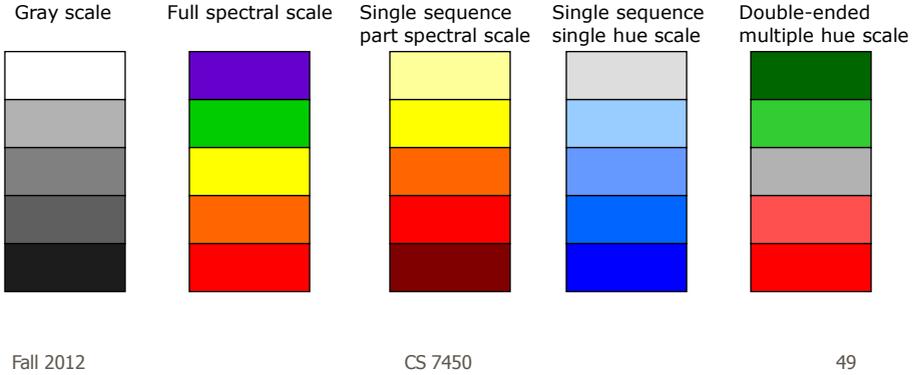


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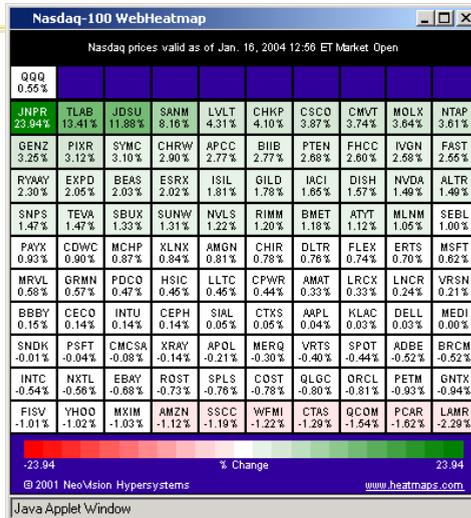
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# Possible Color Sequences

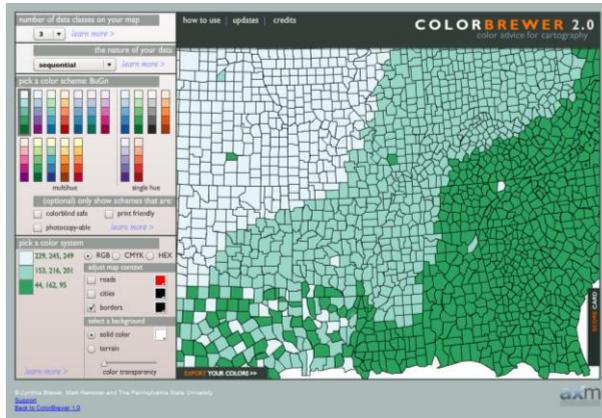


# HeatMap



• [http://screening.nasdaq.com/heatmaps/heatmap\\_100.asp](http://screening.nasdaq.com/heatmaps/heatmap_100.asp)

# 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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# 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.

Legend:  
Coffee (blue)  
Espresso (orange)  
Smoothie (green)  
Tea (red)

<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

Home About Contact Book Color Flash Publications

**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/IAT).

**Background**  
Before starting StoneSoup in 1999, 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 issue: "Field" lists 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 "Delta: context and the perception of visual attributes," 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 involved 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. There 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



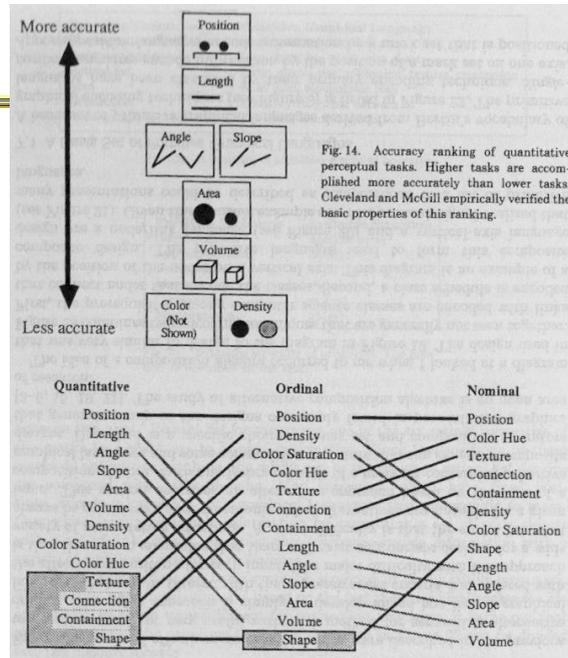
- When you want to communicate one type of variable, which visual property should you use?

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Accuracy ranking of quantitative perceptual tasks



Ranking of perceptual tasks

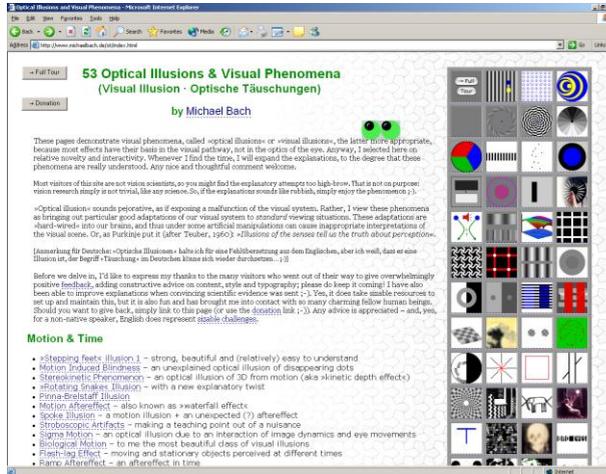
From Jock Mackinlay's 1986 thesis  
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## Change Blindness



- 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](http://viscog.beckman.uiuc.edu/djs_lab/demos.html)

# Optical Illusions



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## Stage 2



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

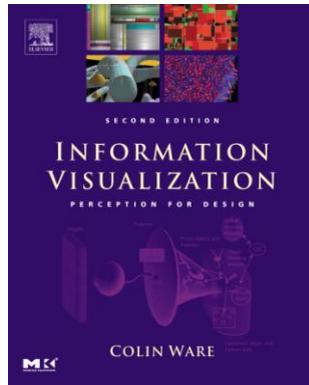
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# Great Book

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*Information Visualization  
Perception for Design*  
2<sup>nd</sup> edition

Colin Ware  
Morgan Kaufmann

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# Design Project

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[More details on website](#)



- Group of 2-4 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 2.5 weeks (Sep 17<sup>th</sup>)

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## HW 2



- Due Wednesday
- Questions?

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## Upcoming



- Labor Day holiday
  - No class
- Cognitive Issues
  - Papers to read
    - Norman book chapter
    - Liu et al '08

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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*