Information Visualization

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Visual Perception

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Semiotics

- The study of symbols and how they convey meaning
- Sensory vs. Arbitrary symbols
- Sensory representation
  - Understanding without training
  - Resistance to instructional bias
  - Sensory immediacy
  - Cross-cultural validity
- Arbitrary representation
  - Hard to learn
  - Easy to forget
  - Embedded in culture and applications
  - Formally powerful
  - Capable of rapid change
- Most visualizations are hybrids!

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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

- Dr. John Stasko, Slides of CS7500 at Gatech

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Visual Perception

- What is visual perception?
  - process of knowing or being aware of information through the eyes.
  - process of acquiring, interpreting, selecting, and organizing sensory information.

    http://en.wikipedia.org/wiki/Perception

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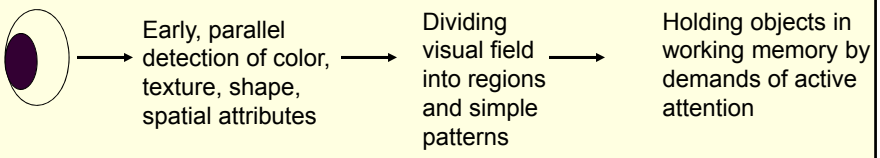
One Simple Model of Perceptual Processing

- Three stage process
  - Parallel extraction of low-level properties of scene
  - Pattern perception
  - Sequential goal-directed processing



Ware 2004

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Stage 1 - Low-level, Parallel

- Neurons in eye & brain are 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

- Dr. John Stasko, Slides of CS7500 at Gatech

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Stage 2 – Pattern Perception

- Slow serial processing
- Involves working and long-term memory
- A combination of bottom-up feature processing and top-down attentional mechanisms
- Different pathways for object recognition and visually guided motion

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Stage 3 – Sequential Goal-Directed

- A few objects are constructed from the available patterns to provide answers to visual queries
- Top-down attention-driven model of processing
- Slow serial processing

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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
  - **Luminance** is a photometric measure of the density of luminous intensity in a given direction. It describes the amount of light that passes through or is emitted from a particular area, and falls within a given solid angle. -wikipedia
- **Brightness**
  - Perceived amount of light coming from source
  - **Brightness** is the perception elicited by the luminance of a visual target. This is a subjective attribute/property of an object being observed. -wikipedia

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Brightness

- Perceived brightness is non-linear function of amount of light emitted by source
- $S = aI^n$
  - S – sensation
  - I - intensity

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Grayscale

- A series of shades from white to black
- 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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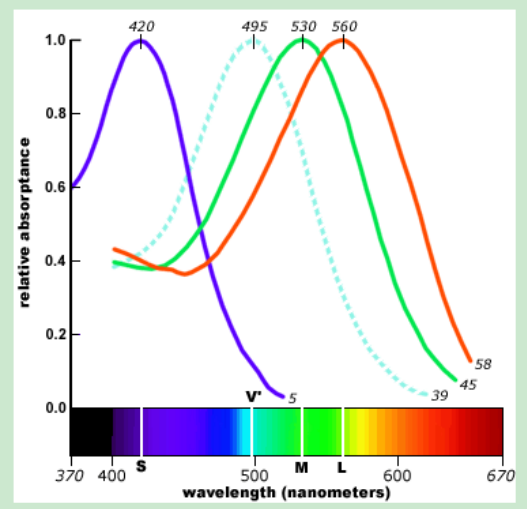
Trichromacy Theory

- Fact: we have 3 distinct color receptors
- Color space: three dimensional
- Color blindness: lack of the receptors for the long or medium wavelength
  - Can't distinguish green and red



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http://www.handprint.com/HP/WCL/color1.html#receptors

RGB Color Space

- C ≡ rR + gG + bB
  - C: color
  - R, G, B: the primary light sources to be used to create a match
  - r, g, b: the amounts of each primary light
  - ≡ : perceptual match

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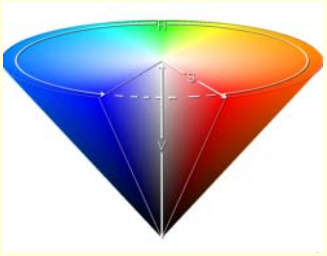
HVS Color Space

- HVS encapsulates information about a color in terms that are more familiar to humans: *What color is it? How vibrant is it? How light or dark is it?*

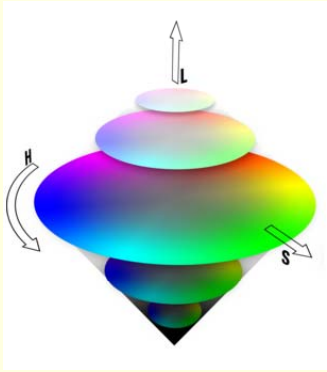
- Hue: the color type (such as red, blue, or yellow)
- Value (brightness): light/dark of the color
- Saturation: the "vibrancy" of the color



http://en.wikipedia.org/wiki/HSV_color_space

HSL Color Space

- Hue: the color type (such as red, blue, or yellow)
- Saturation: the "vibrancy" of the color
- Luminance: measured amount of light coming from some place



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Luminance

- What if the color space has only the luminance dimension?
  - Grayscale
- We can get by 99% of time
- Luminance channel of visual system is so fundamental to so much of perception

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Luminance

- Important for foreground -background 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?

Slide courtesy of John Stasko

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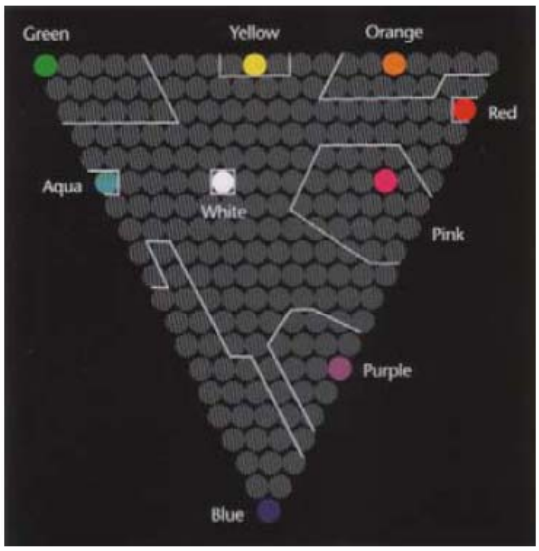
Color Categories

- 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

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

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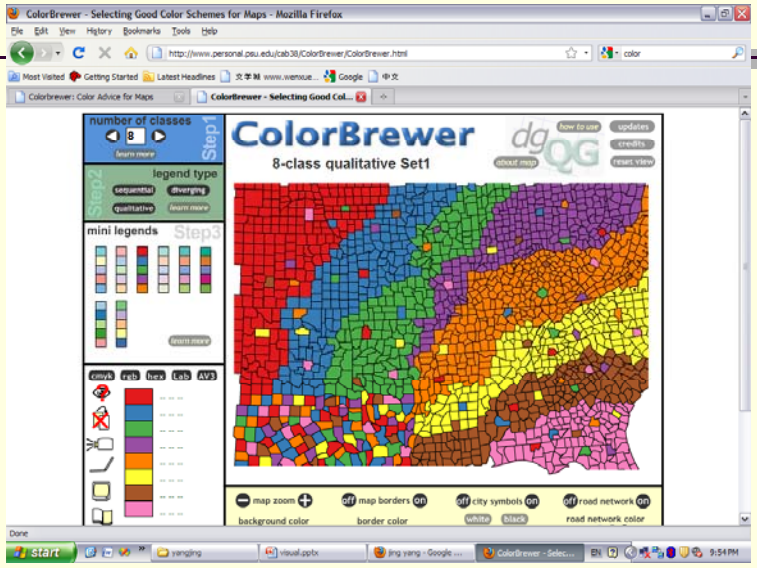
ColorBrewer Qualitative Set



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http://www.personal.psu.edu/cab38/ColorBrewer/ColorBrewer.html

Example - Newdle

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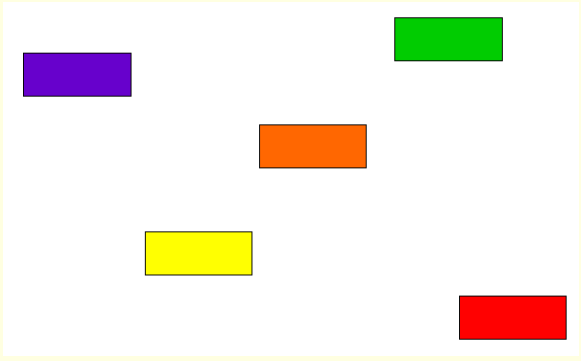
Color for Sequences

- Can you order these (low->hi)



Slide courtesy of John Stasko

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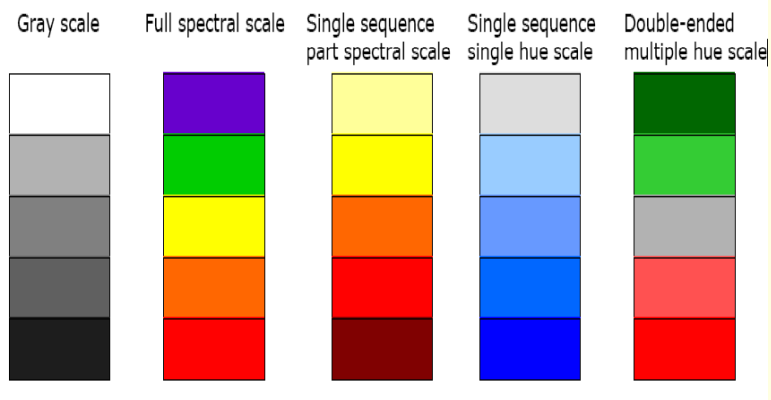
Possible Color Sequences



Slide courtesy of John Stasko

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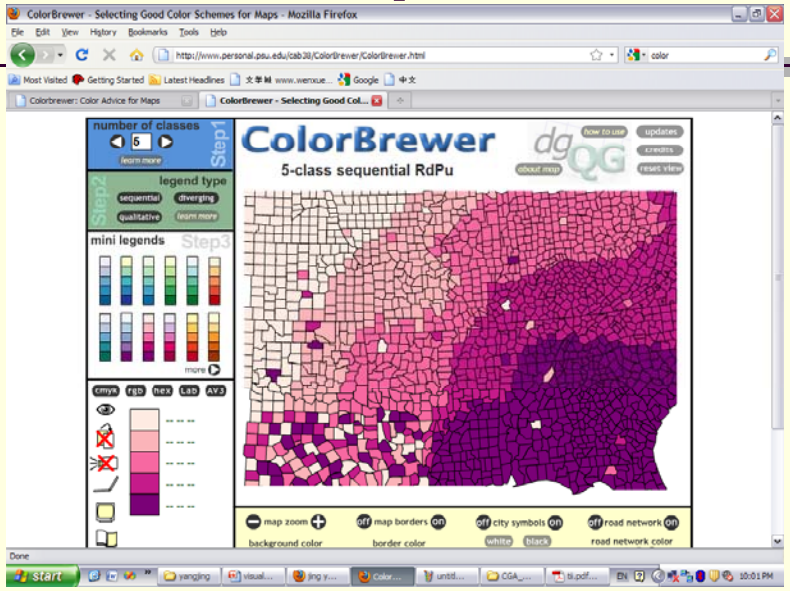
ColorBrewer Sequential Set



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http://www.personal.psu.edu/cab38/ColorBrewer/ColorBrewer.html

Show Variations Above and Below Zero

- Use a neutral value to represent zero
- Increase in saturation (?) toward opposite colors to show positive and negative values

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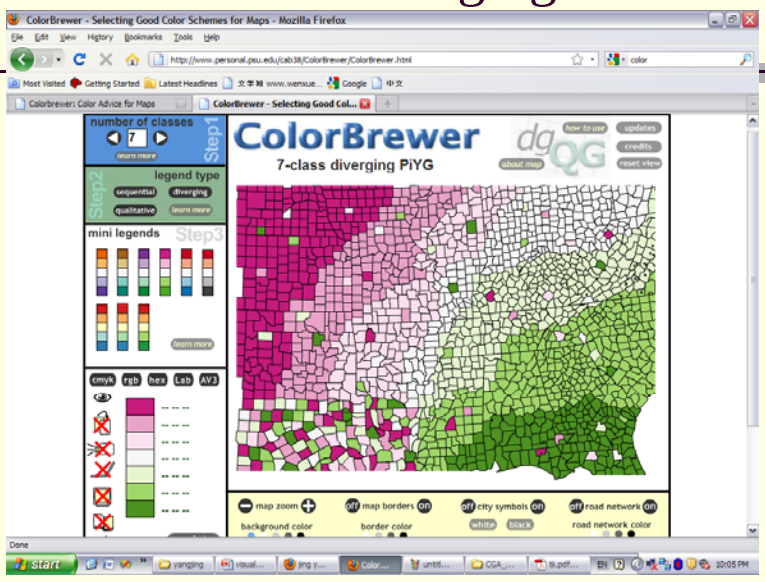
ColorBrewer Diverging Set



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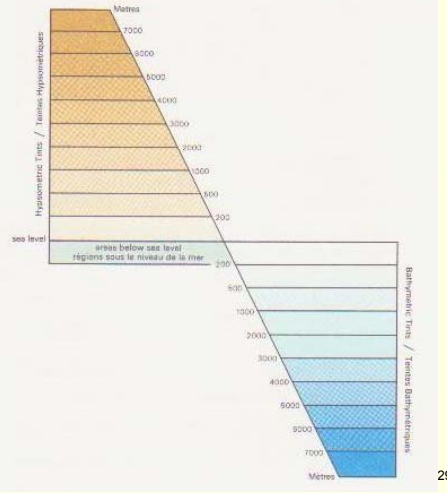
http://www.personal.psu.edu/cab38/ColorBrewer/ColorBrewer.html

Example

- Record ocean depth and land height
- The deeper or higher, the darker

[8] Paul Klee, *On Modern Art* (London, 1948), translated by Paul Findlay from *Über die moderne Kunst* (Bern, 1945), pp. 39–41.

General Bathymetric Chart of the Oceans, International Hydrographic Organization (Ottawa, Canada, 5th edition, 1984), 5.06.



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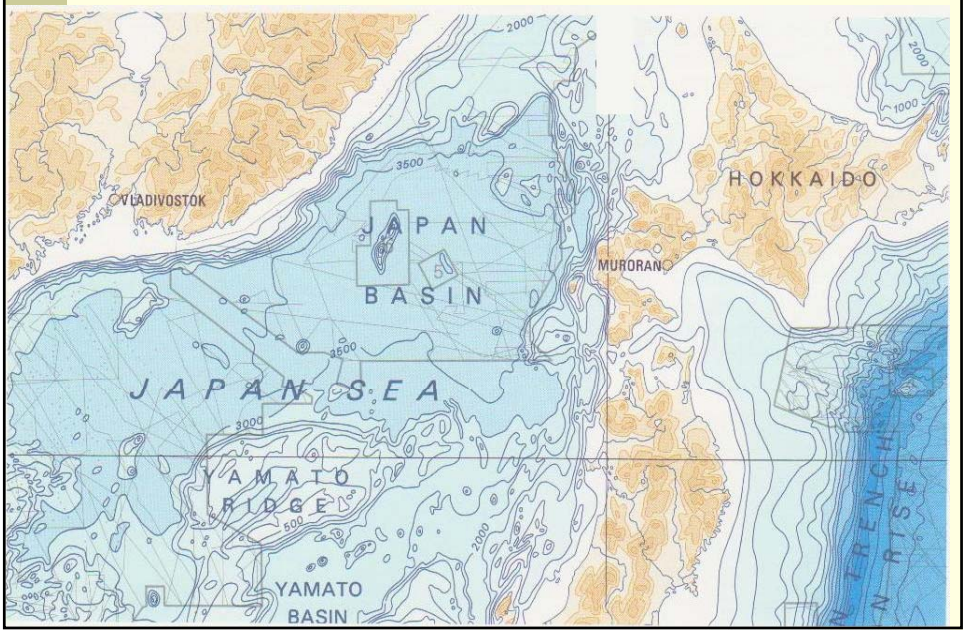
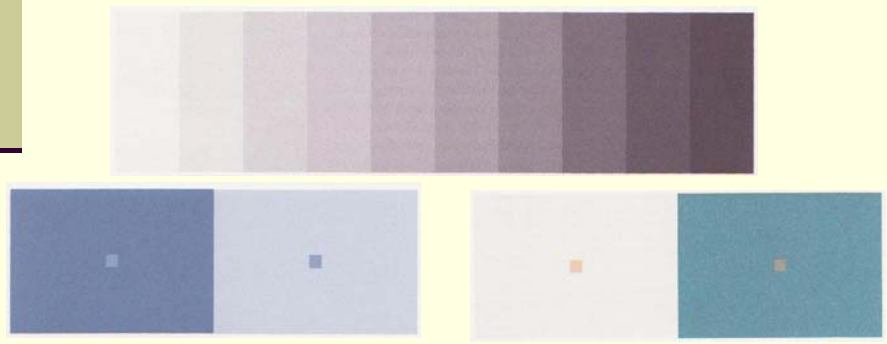
General Bathymetric Chart of the Oceans



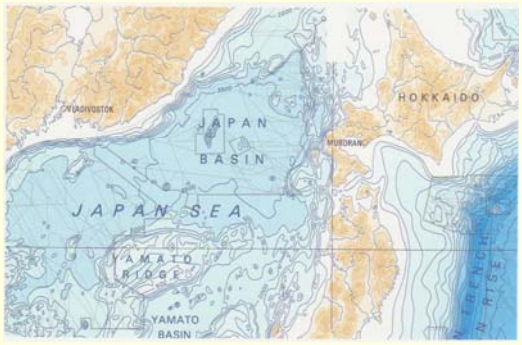
Contextual Effects

- ANY color coding of quantity (whether based on variations on hue, value, or saturation) is potentially sensitive to interactive contextual effects



Reduce Color Contrast Errors

- Use borders to reduce contrast errors
  - They eliminate edge fluting and make each field a more coherent whole



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Color Purposes

- Call attention to specific data
- Increase appeal, memorability
- Increase number of dimensions for encoding data

Slide courtesy of John Stasko

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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, and yellow in periphery
- Use adjacent colors that vary in hue & value

Slide courtesy of John Stasko

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Using Color

- For large regions, don't use highly saturated colors
- Do not use adjacent colors that vary in amount of blue
- Don't use high saturation, spectrally extreme colors together
- Use color for grouping and search
- Beware effects from adjacent color regions

Slide courtesy of John Stasko

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Other Effects of Color

- **Physiological effects** - the effect of color on health and behavior.
- **Color symbolism** - our responses to color are also influenced by color associations from our culture.
- **Personal color preferences** - our own color preferences are important to us.

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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

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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

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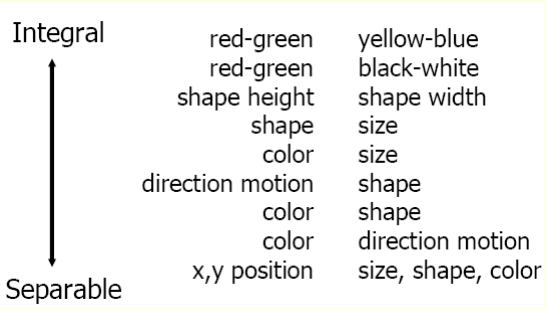
Integral-Separable

- Not one or other, but along an axis



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Pre-attentive Processing

- The most important contribution of vision science to data visualization is that:
  - A limited set of visual properties can be detected very rapidly and accurately by the low-level visual system
- Tasks that can be performed on large multi-element displays in less than 200 to 250 milliseconds (msec) are considered pre-attentive. (Eye movements: 200 msec)

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

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Count 3s

128176875613897654698450698560498282676 2
980985845822450985645894509845098094358 5
909103020990595959577256467505067890456 7
884578980982167765487636490856091294968 6

128176875613897654698450698560498282676 2
980985845822450985645894509845098094358 5
909103020990595959577256467505067890456 7
884578980982167765487636490856091294968 6

- Dr. John Stasko, Slides of CS7500 at Gatech

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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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Pre-attentive Features

- Form
  - Line orientation
  - Line length
  - Line width
  - Line collinearity
  - Size
  - Curvature
  - Spatial grouping
  - Blur
  - Added marks
  - Numerosity
- Color
  - Hue
  - Intensity
- Motion
  - Flicker
  - Direction of motion
- Spatial Position
  - 2D position
  - Stereoscopic depth
  - Convex/concave shape from shading

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Example

- Find the distinct one

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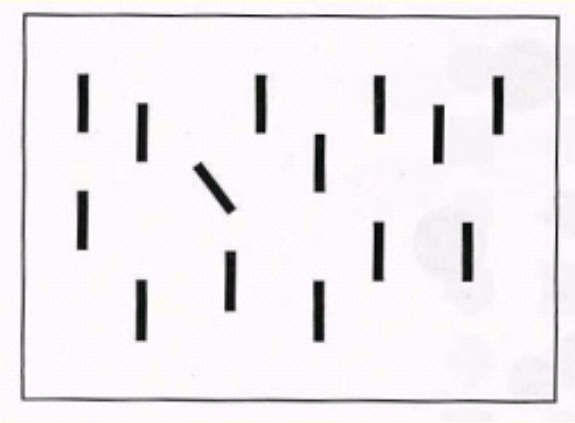
Orientation



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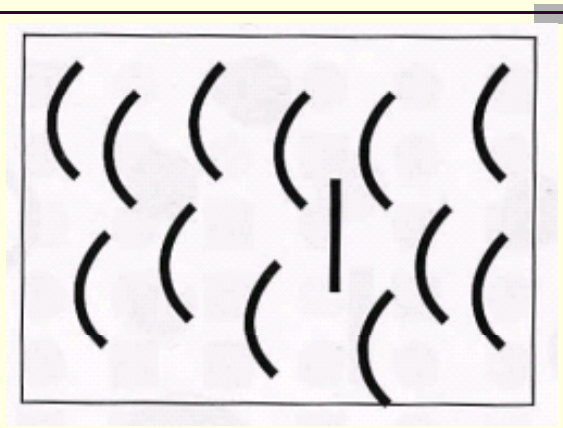
Curved/Straight



Ware 2004

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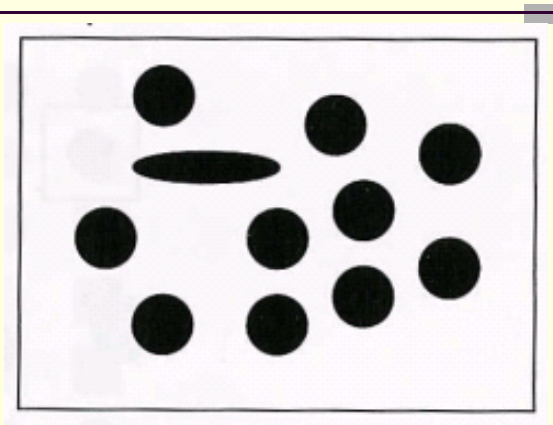
Shape



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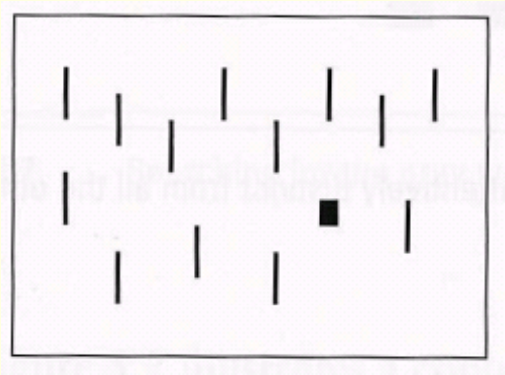
Shape



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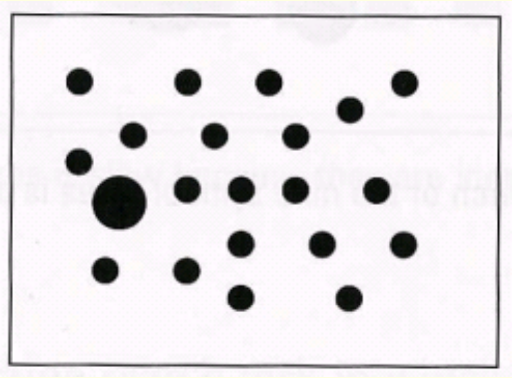
Size



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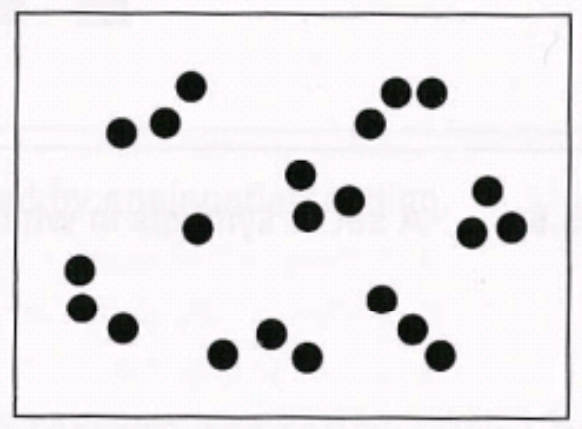
Number



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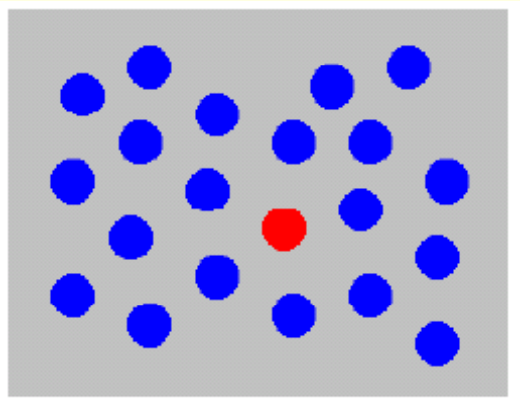
Hue



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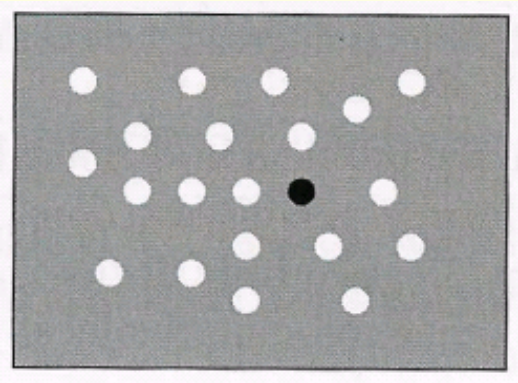
Gray/Value



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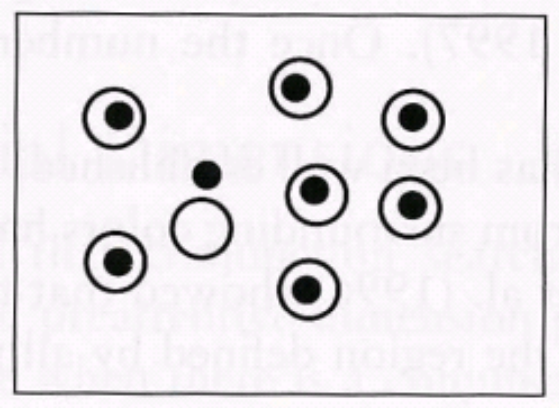
Enclosure



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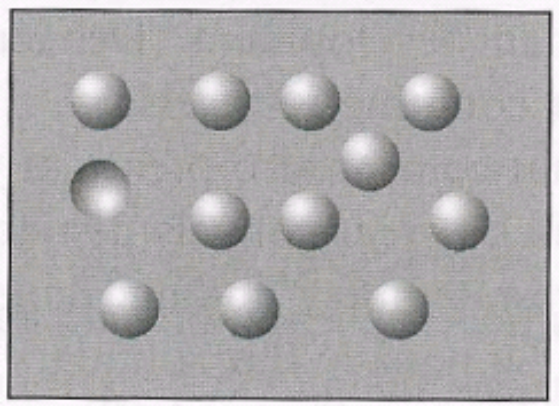
Covexity/Concavity



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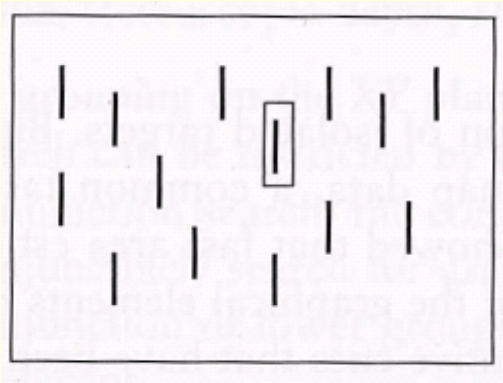
Addition



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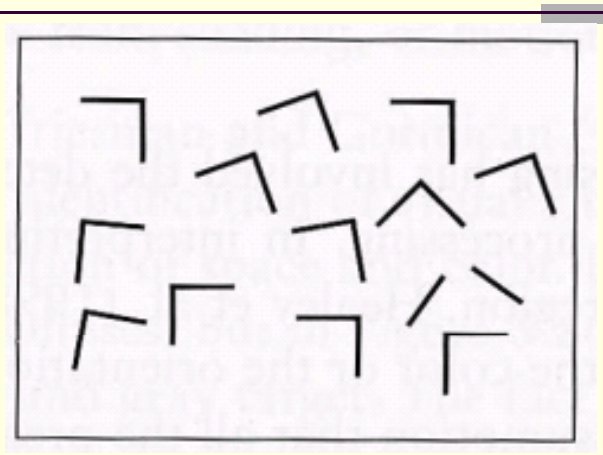
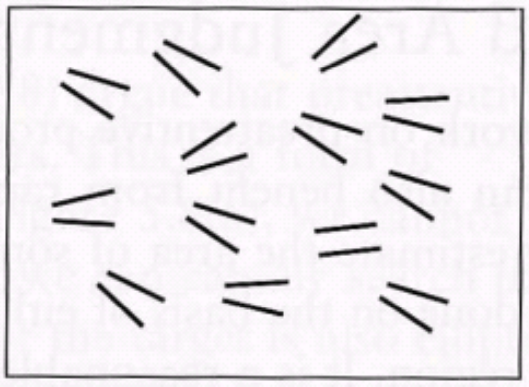
Juncture



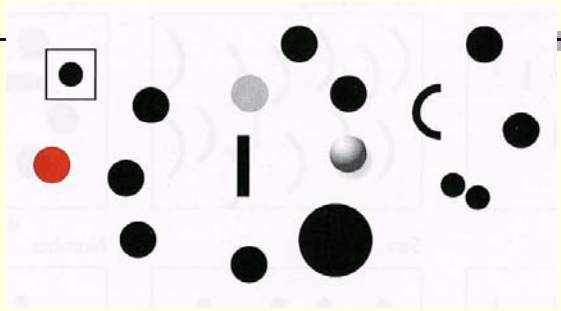
Ware 2004 Not! 57

Parallelism



Ware 2004 Not! 58

Multiple Symbol Types



- Pre-attentive symbols become less distinct as the variety of distracters increase
- Two factors
  - Degree of difference of target from nontargets
  - Degree of difference of nontargets from each other

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Example

- Determine if a red circle is present

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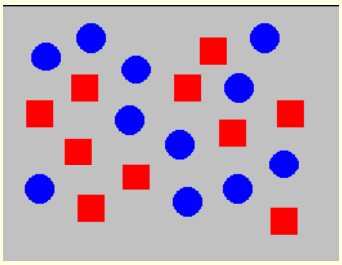
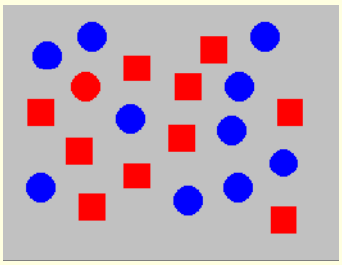
Conjunction of Features





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

- Dr. John Stasko, Slides of CS7500 at Gatech

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Example

- Is there a boundary in the display?

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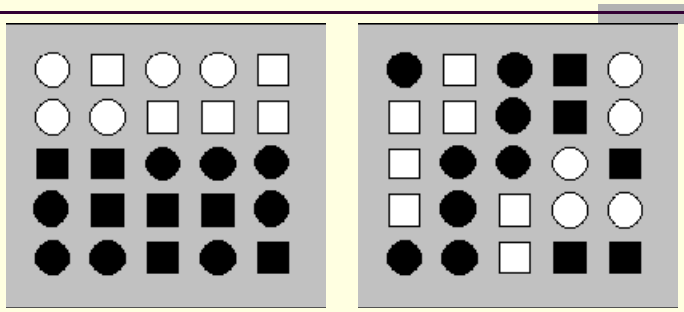
Mixed Features



- Left can be done pre-attentively since each group contains one unique feature
- Right cannot (there is a boundary!) since the two features are mixed (fill and shape)

- Dr. John Stasko, Slides of CS7500 at Gatech

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Example

- Is there a boundary in the display?

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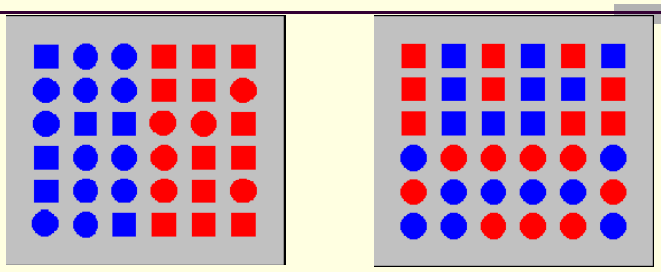
Feature Hierarchy: Hue vs. Shape



- Left: Boundary detected pre-attentively based on hue regardless of shape
- Right: a horizontal form boundary cannot be pre-attentively identified when hue varies randomly in the background
- Visual systems favor hue over shape

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

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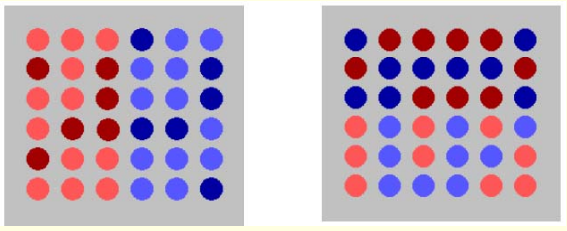
Feature Hierarchy: Hue vs. Brightness



- Left: Boundary detected pre-attentively based on hue regardless of brightness
- Right: a horizontal form boundary cannot be pre-attentively identified when hue varies randomly in the background
- Visual systems favor hue over brightness

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

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Discussion

- What can we do using pre-attentive features?

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Stage 2

- Missing!
- Maybe in the future

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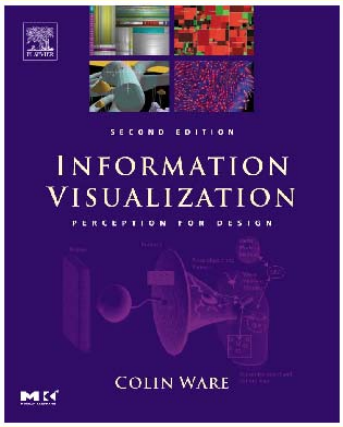
References

- Dr. Colin Ware



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References

- Edward Tufte: Envisioning Information
- Also, lots of slides from John Stako's infovis class were used!

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