

Visual Perception



CS 7450 - Information Visualization
January 17, 2006
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*

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

Perceptual Processing

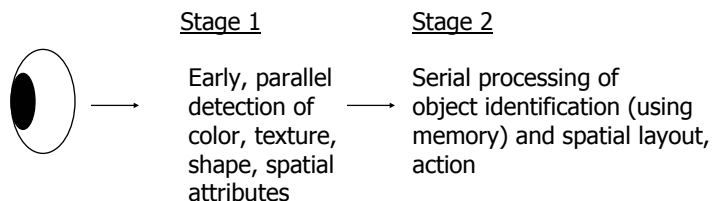


- Seek to better understand visual perception and visual information processing
 - Multiple theories or models exist
 - Need to understand physiology and cognitive psychology

One (simple) Model



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



Stage 1 - Low-level, Parallel



- Neurons in eye & brain responsible for different kinds of information
 - Orientation, color, texture, movement, etc.
- Arrays of neurons work in parallel
- Occurs “automatically”
- Rapid
- Information is transitory, briefly held in iconic store
- Bottom-up data-driven model of processing
- Often called “pre-attentive” processing

Stage 2 - Sequential, Goal-Directed



- Splits into subsystems for object recognition and for interacting with environment
- Increasing evidence supports independence of systems for symbolic object manipulation and for locomotion & action
- First subsystem then interfaces to verbal linguistic portion of brain, second interfaces to motor systems that control muscle movements

Stage 2 Attributes



- Slow serial processing
- Involves working and long-term memory
- More emphasis on arbitrary aspects of symbols
- Top-down processing

Healey Article



- Discuss

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

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?



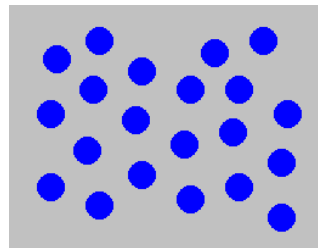
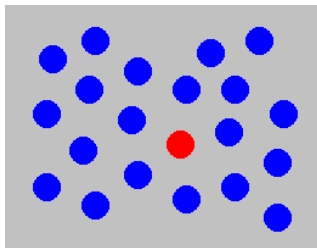
- Target detection
 - Is something there?
- Boundary detection
 - Can the elements be grouped?
- Counting
 - How many elements of a certain type are present?

Example



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

Hue



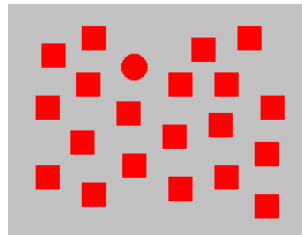
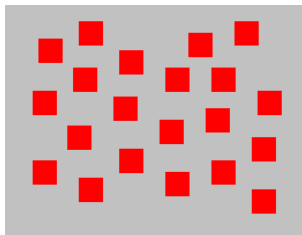
Can be done rapidly (preattentively) by people
Surrounding objects called "distractors"

Example



- Determine if a red circle is present

Shape



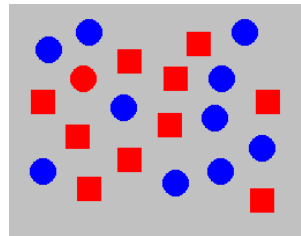
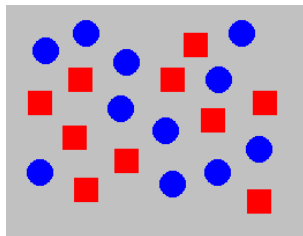
Can be done preattentively by people

Example



- Determine if a red circle is present

Hue and Shape



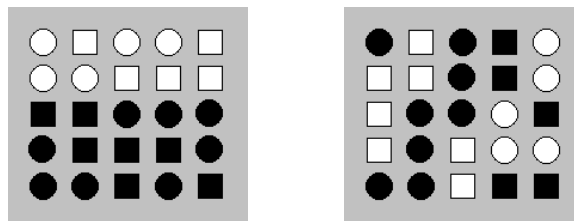
- Cannot be done preattentively
- Must perform a sequential search
- Conjunction of features (shape and hue) causes it

Example



- Is there a boundary in the display?

Fill and Shape



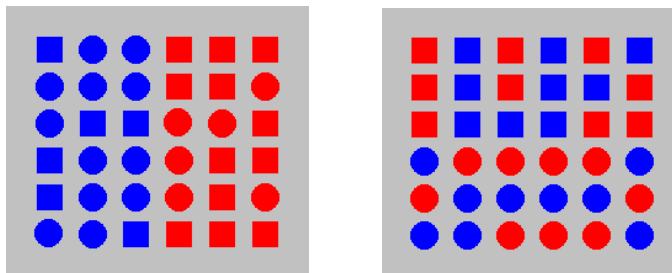
- Left can be done preattentively since each group contains one unique feature
- Right cannot (there is a boundary!) since the two features are mixed (fill and shape)

Example



- Is there a boundary in the display?

Hue versus Shape



Left: Boundary detected preattentively based on hue regardless of shape

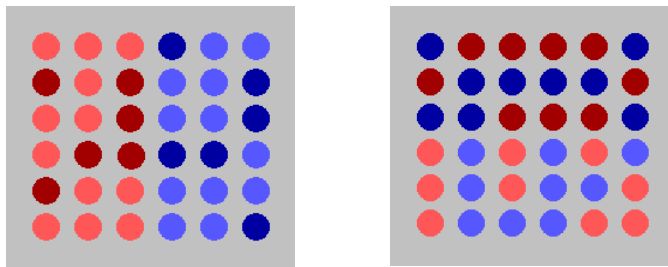
Right: Cannot do mixed color shapes preattentively

Example



- Is there a boundary?

Hue versus brightness



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

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

Preattentive Features

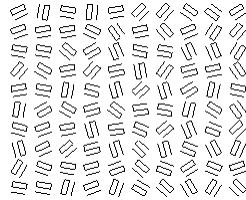


- Certain visual forms lend themselves to preattentive processing
- Variety of forms seem to work

Textons



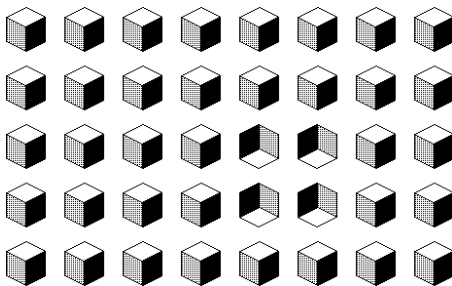
□ S



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

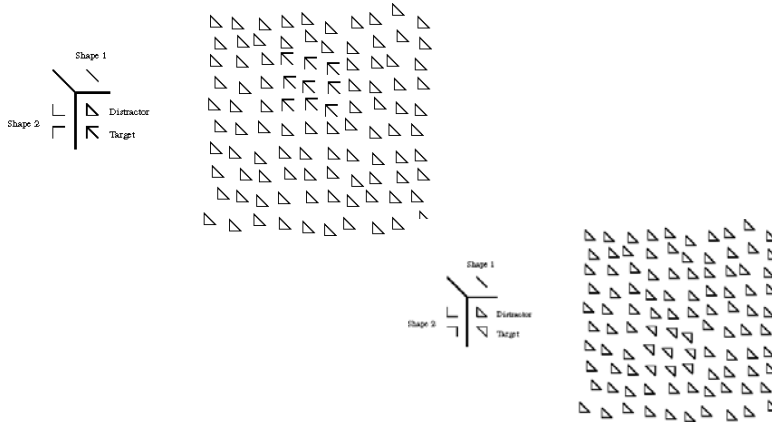
All detected early

3-D Figures



3-D visual reality has an influence

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?

Key Perceptual Properties



- Brightness
- Color
- Texture
- Shape

Luminance/Brightness



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

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

Grayscale

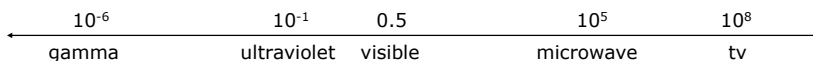


- Probably not best way to encode data because of contrast issues
 - Surface orientation and surroundings matter a great deal
 - Luminance channel of visual system is so fundamental to so much of perception
 - We can get by without color discrimination, but not luminance

Color



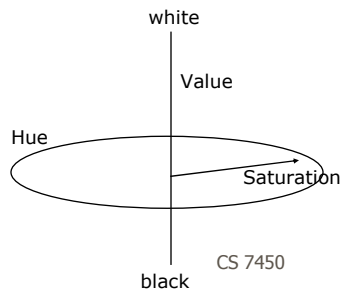
- Sensory response to electromagnetic radiation in the spectrum between wavelengths 0.4 - 0.7 micrometers



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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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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Luminance



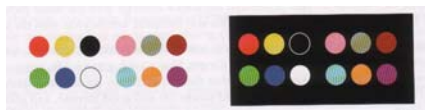
- Important for fg-bg colors to differ in brightness

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



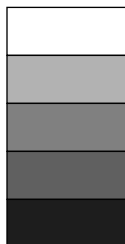
Can you order these (low->hi)



Possible Color Sequences



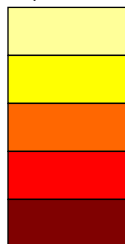
Gray scale



Full spectral scale



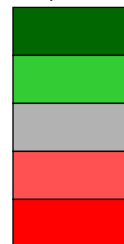
Single sequence
part spectral scale



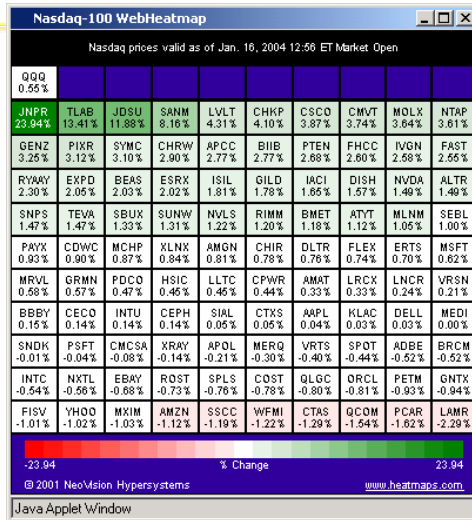
Single sequence
single hue scale



Double-ended
multiple hue scale

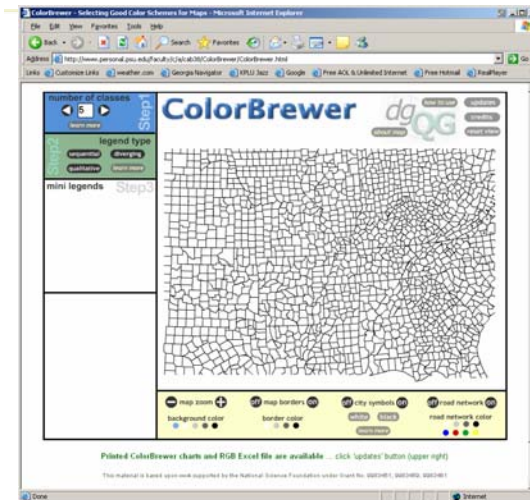


HeatMap



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

ColorBrewer



Help with selecting colors for maps

Color Purposes



- Call attention to specific data
- Increase appeal, memorability
- Increase number of dimensions for encoding data
 - Example, Ware and Beatty '88
 - x,y - variables 1 & 2
 - amount of r,g,b - variables 3, 4, & 5

Using Color



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

Using Color



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

Texture



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

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

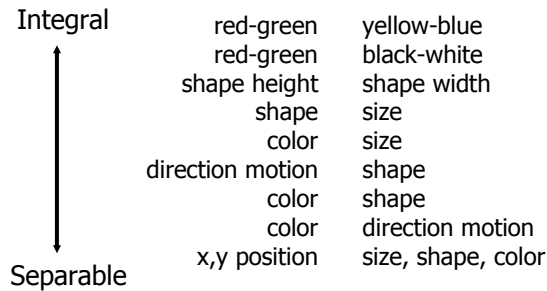


- Suppose that we use two different visual properties to encode two different variables in a discrete data set
 - color, size, shape, lightness
- Will the two different properties interact so that they are more/less difficult to untangle?
 - Integral - two properties are viewed holistically
 - Separable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

Integral-Separable



- Not one or other, but along an axis



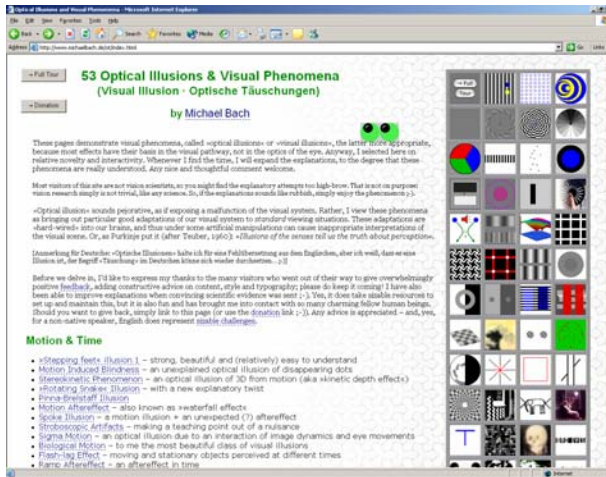
Ware '04

Change Blindness



- Is the viewer able to perceive changes between two scenes?
 - If so, may be distracting
 - Can do things to minimize noticing changes
- Look at Healey's page again

Optical Illusions

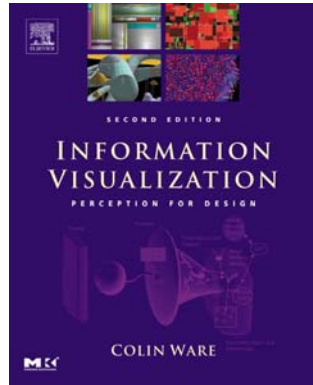


Stage 2



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

Great Book



*Information Visualization
Perception for Design*
2nd edition

Colin Ware
Morgan Kaufmann

HW Reminder



- HW 1 due Thurs
- HW 2 due Tues
- Any questions?

Upcoming



- Social Visualization
 - Reading
 - Xiong & Donath, UIST '99
- Cognitive Issues
 - Papers to discuss...

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*