Visual Perception

CS 7450 - Information Visualization September 1, 2011 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

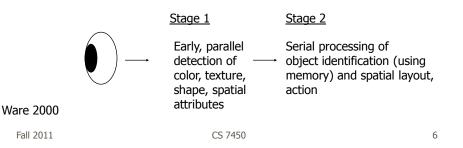
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One (simple) Model

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



Stage 1 - 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

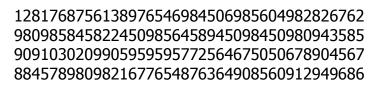
- Splits into subsystems for object recognition and for interacting with environment
- Increasing evidence supports independence of systems for symbolic object manipulation and for locomotion & action
- First subsystem then interfaces to verbal linguistic portion of brain, second interfaces to motor 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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Preatte	ntive Process	sing
images? – Some thi	human visual system ngs seem to be done p the need for focused at	preattentively,
moveme	y less than 200-250 ms nts take 200 msecs) o be done in parallel by stem	
		Drawn from C. Healey web article
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How Many 3's?

3980985845822450985645894509845098094**33**0209905959595772564675050678904567 **3**

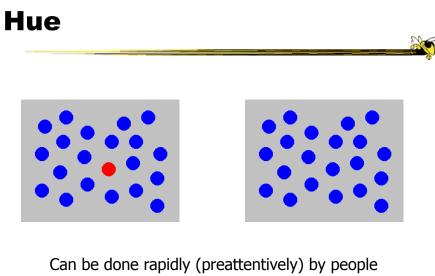
What Kinds of Tasks?

- 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)



Surrounding objects called "distractors"

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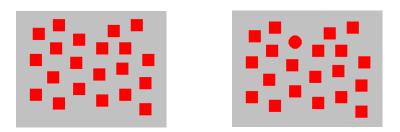
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• Determine if a red circle is present





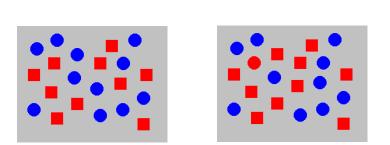
Can be done preattentively by people

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• Determine if a red circle is present

Hue and Shape



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

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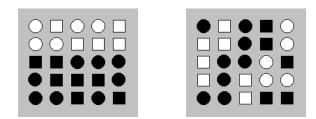
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• Is there a boundary in the display?

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)

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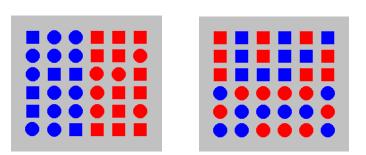
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• Is there a boundary in the display?

Hue versus Shape



Left: Boundary detected preattentively based on hue regardless of shape Right: Cannot do mixed color shapes preattentively

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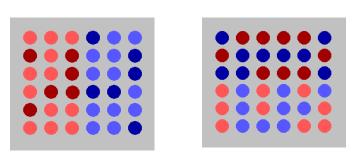
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• Is there a boundary?

Hue versus brightness



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

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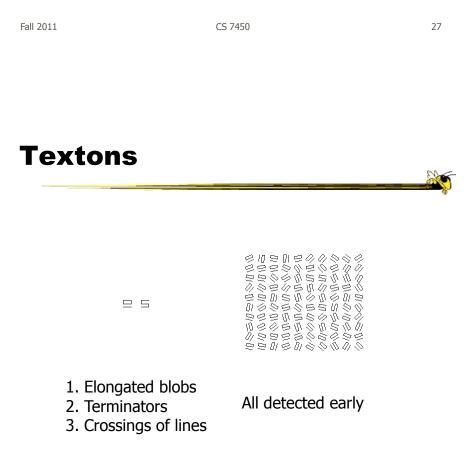
Example Applet

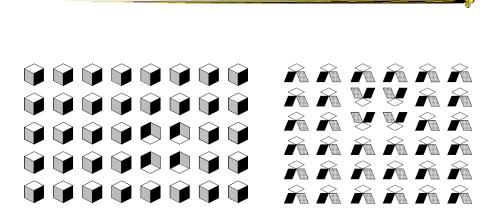
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- Nice on-line tutorial and example applet
 - http://www.csc.ncsu.edu/faculty/healey/PP/index.html
 - Chris Healey, NC State
 - Prior pictures taken from site

Preattentive Features

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





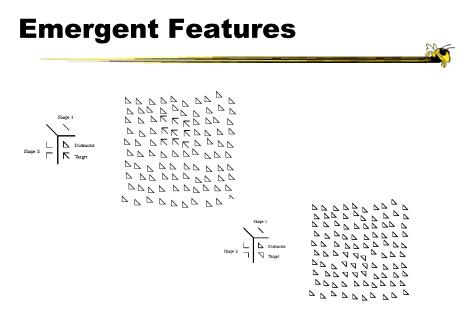
3-D visual reality has an influence

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3-D Figures

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Potential PA Features

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

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

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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Color

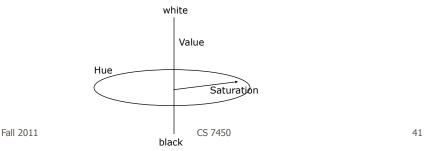
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 Sensory response to electromagnetic radiation in the spectrum between wavelengths 0.4 - 0.7 micrometers

10-6	10-1	0.5	105	10 ⁸	
gamma	ultraviolet	visible	microwave	tv	

Color Models

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



How Not to Use Color

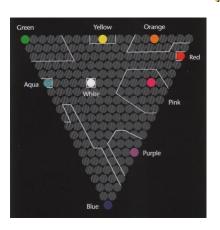


http://www.thedailyshow.com/video/index.jhtml?videoId=156230&title=full-color-coverage

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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



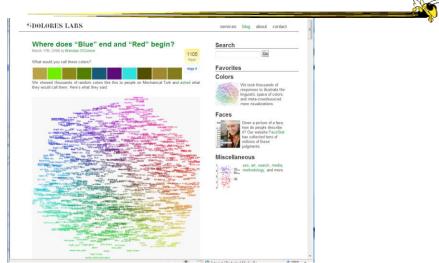
From Ware '04

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Using Mechanical Turk



http://blog.doloreslabs.com/2008/03/where-does-blue-end-and-red-begin/

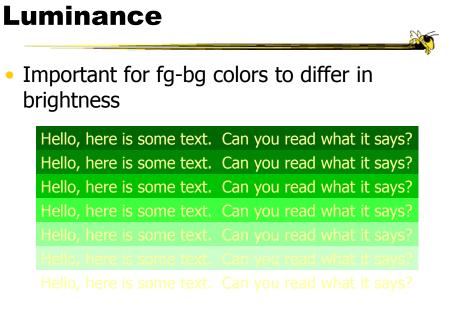
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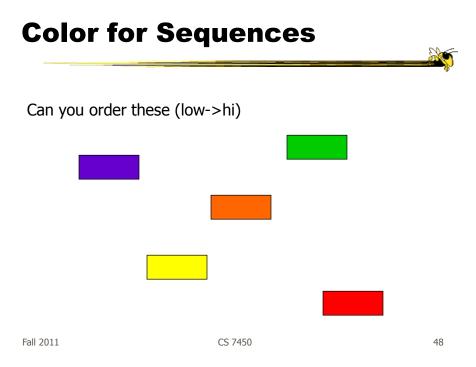
Color for Categories

- 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

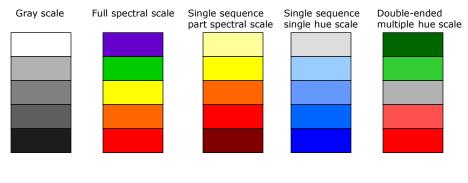


From Ware **`04**

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Possible Color Sequences



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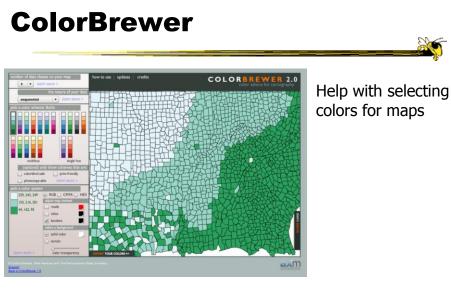
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HeatMap

Nasdaq-1	00 Webl	leatma	p				_		
,	lasdaq price	es valid as	s of Jan.	16, 2004	12:56 ET I	vlanket Op	en		
QQQ 0.55%									
JNPR TLAE 23.94% 13.41		SANM 8.16%	LVLT 4.31%	CHKP 4.10%	CSCO 3.87%	CMVT 3.74%	MOLX 3.64%	NTAP 3.61%	
GENZ PIXR 3.25% 3.12%		CHRW 2.90%	APCC 2.77%	BIIB 2.77%	PTEN 2.68%	FHCC 2.60%	IVGN 2.58%	FAST 2.55%	
RYAAY EXPE 2.30% 2.05%		ESRX 2.02%	ISIL 1.81%	GILD 1.78%	IACI 1.65%	DISH 1.57%	NVDA 1.49%	ALTR 1.49%	
SNPS TEV 1.47% 1.47%		SUNW 1.31%	NVLS 1.22%	RIMM 1.20%	BMET 1.18%	ATYT 1.12%	MLNM 1.05%	SEBL 1.00%	
PAYX CDW 0.93% 0.90%		XLNX 0.84%	AMGN 0.81%	CHIR 0.78%	DLTR 0.76%	FLEX 0.74%	ERTS 0.70%	MSFT 0.62%	
MRVL GRMI 0.58% 0.57%		HSIC 0.45%	LLTC 0.45%	CPWR 0.44%	AMAT 0.33%	LRCX 0.33%	LNCR 0.24%	VRSN 0.21%	
BBBY CEC0 0.15% 0.14%		CEPH 0.14%	SIAL 0.05%	CTXS 0.05%	AAPL 0.04%	KLAC 0.03%	DELL 0.03%	MEDI 0.00%	
SNDK PSFT -0.01% -0.041		XRAY -0.14%	APOL -0.21%	MERQ -0.30%	VRTS -0.40%	SPOT -0.44%	ADBE -0.52%	BRCM -0.52%	
INTC NXTL -0.54% -0.561		R0ST -0.73%	SPLS -0.76%	COST -0.78%	QLGC -0.80%	0RCL -0.81%	PETM -0.93%	GNTX -0.94%	
FISV YH00 -1.01% -1.021		AMZN -1.12%	SSCC -1.19%	WFMI -1.22%	CTAS -1.29%	QCOM -1.54%	PCAR -1.62%	LAMR -2.29%	
-23.94			% Ch	ange				23.94	
@ 2001 Neo V	sion Hypers	systems				www	i.heatmar	os.com	

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



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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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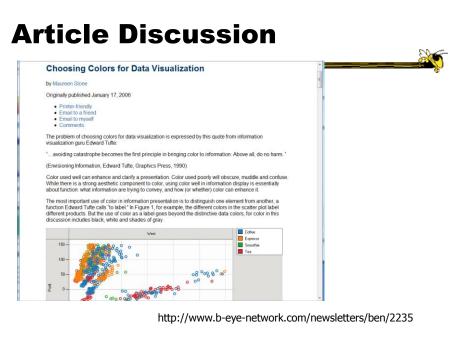
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Using Color

• 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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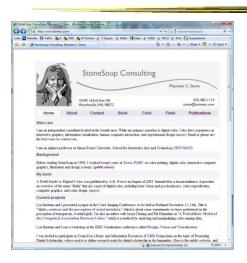


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Good Color Advice



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

http://www.stonesc.com

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Texture

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

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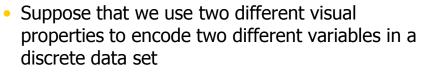
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Shape, Symbol

- 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



- 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

Integral	red-green	yellow-blue
t	red-green	black-white
	shape height	shape width
	shape	size
	color	size
	direction motion	shape
	color	shape
	color	direction motion
Separable	x,y position	size, shape, color

Ware '04

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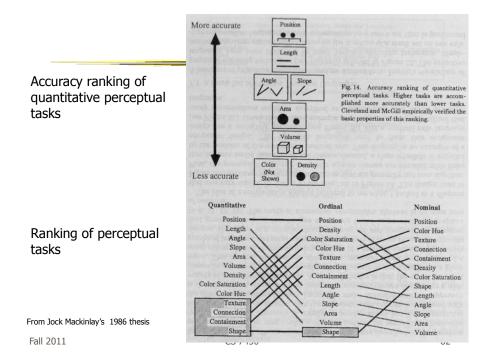
Encodings

1

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

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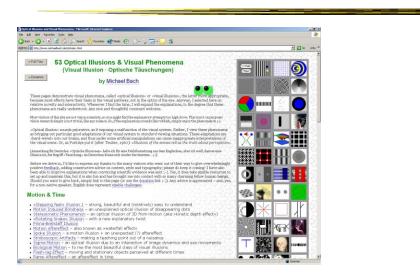
Change Blindness

- 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

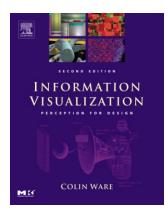
- Missing here!
- Object recognition and locomotion/action
- Maybe in the future... :^)

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Great Book



Information Visualization Perception for Design 2nd edition

Colin Ware Morgan Kaufmann

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More details on website

Design Project

- 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 weeks (Sep 15th)

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HW 2

- Due Tuesday
- Questions?

Upcoming

Cognitive Issues

Papers to read
 Norman book chapter
 Liu et al

Storytelling

 Papers to read
 Segel & Heer

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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*