Lecture 5: Visual Encoding Principles

Information Visualization
CPSC 533C, Fall 2011

Tamara Munzner

UBC Computer Science

Wed, 21 September 2011

Required Readings

Chapter 3: Visual Encoding Principles
(this time: first 25 pages, Sec 3.1-3.4)
(next time: last 11 pages, Sec 3.5)

Representing Colors as Three Numbers, Maureen Stone, IEEE CG&A 25(4):78-85, Jul 2005.

Further Reading

The Psychophysics of Sensory Function. S. S. Stevens, Sensory Communication, MIT Press, 1961, pp 1-33.

Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models. William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.

Automating the Design of Graphical Presentations of Relational Information. Jock Mackinlay, ACM Transaction on Graphics, vol. 5, no. 2, April 1986, pp. 110-141.

Semiology of Graphics. Jacques Bertin, Gauthier-Villars 1967, EHESS 1998

The Grammar of Graphics. Leland Wilkinson, Springer-Verlag 1999

Further Reading

Stone. Color In Information Display. IEEE Visualization 2006 Course Notes. http://www.stonesc.com/Vis06

A Field Guide To Digital Color, Maureen Stone, AK Peters 2003.

Tufte, Envisioning Information. Chapter 5: Color and Information

Ware, Information Visualization: Perception for Design:

Ch 3: Lightness, Brightness, Contrast, and Constancy

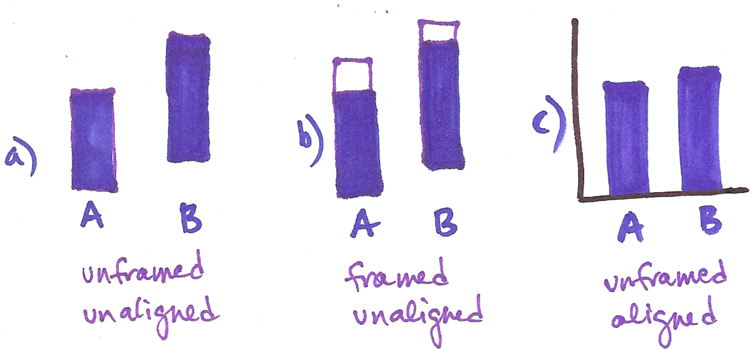
Ch 4: Color

Ch 5: Visual Attention and Information That Pops Out

Ch 6: Static and Moving Patterns

Ch 8: Space Perception and the Display of Data in Space

Relative vs Absolute Perception: Length

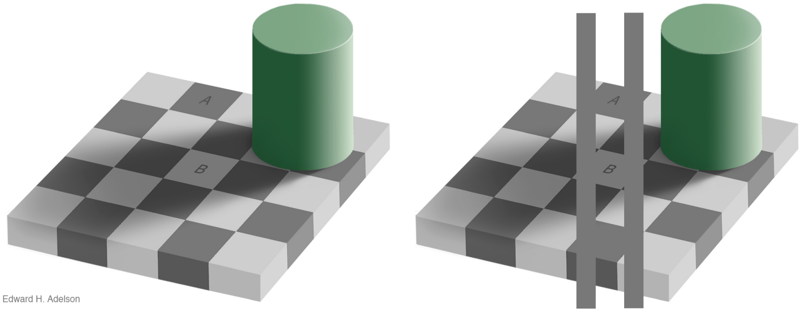


- Weber's Law: relative judgements
  - ratio of increment threshold to background intensity is constant

$$\frac{\Delta I}{I} = K$$

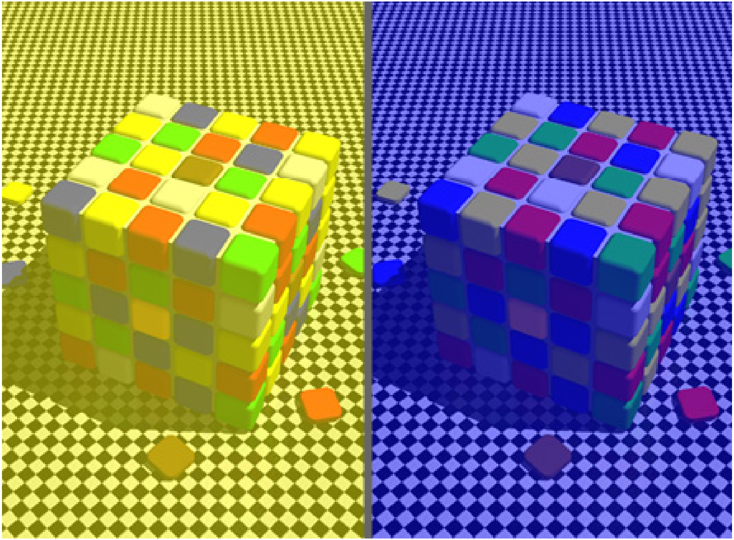
  - filled rectangles vs white rectangles

Relative vs Absolute Perception: Lightness



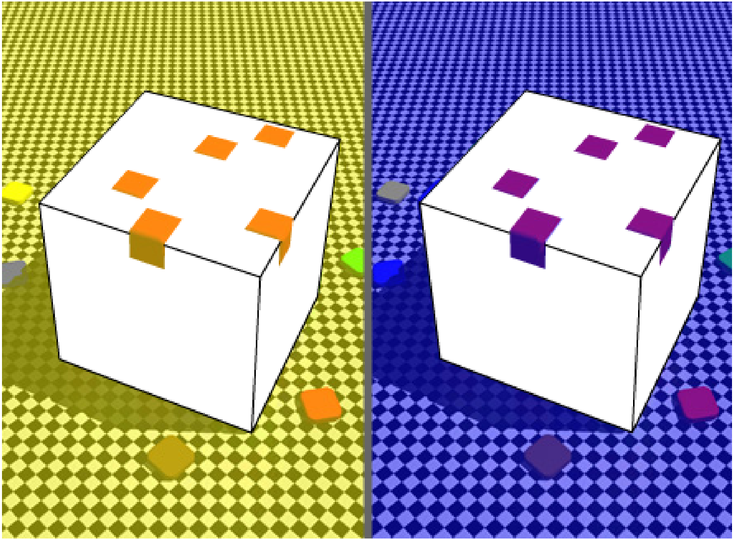
[Edward H. Adelson,
http://persci.mit.edu/_media/gallery/checkershadow_double_full.jpg]

Relative vs Absolute Perception: Color



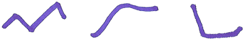
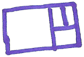
[Purves. http://www.purveslab.net/seeforyourself/]

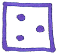
Relative vs Absolute Perception: Color



[Purves. http://www.purveslab.net/seeforyourself/]

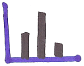
Image Theory

- marks : geometric primitives
  - points 
  - lines 
  - areas 

- visual channels : control appearance of marks
  - position
    horizontal , vertical , both 
  - color 
  - shape 
  - tilt 
  - size 

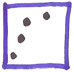
Visual Encoding

- analyze as combination of marks and channels showing abstract data dimensions



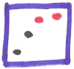
1: vertical position

mark: line



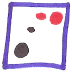
2: vertical position, horizontal position

mark: point



3: vertical position, horizontal position, color

mark: point



4: vertical position, horizontal position, color, size

mark: point

Visual Channel Types and Rankings

what / where

How much

Visual Channel Types and Rankings

what / where

planar position 

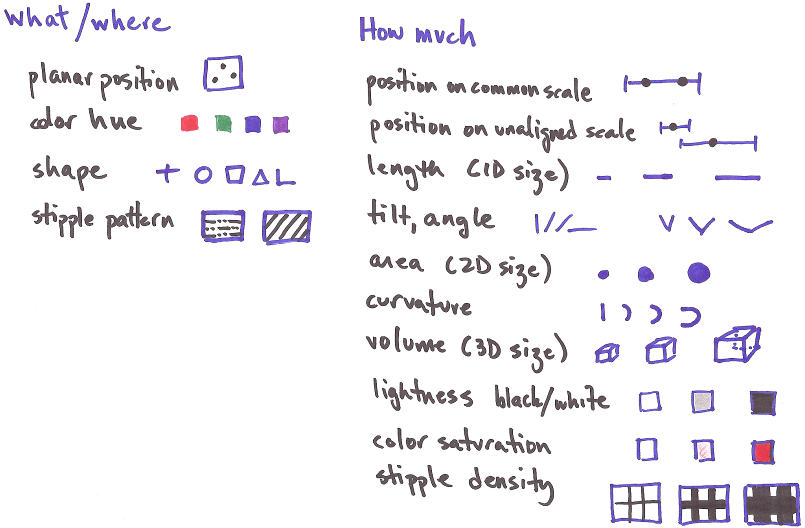
color hue 

shape 

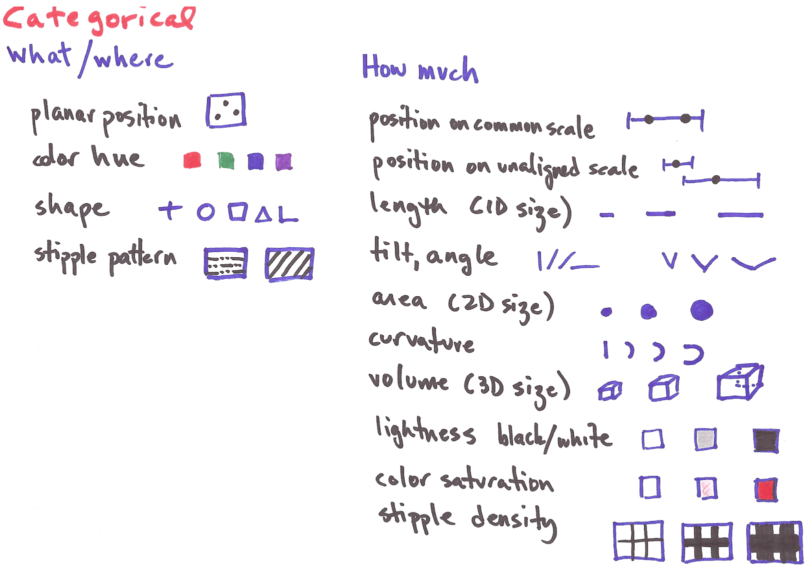
stipple pattern 

How much

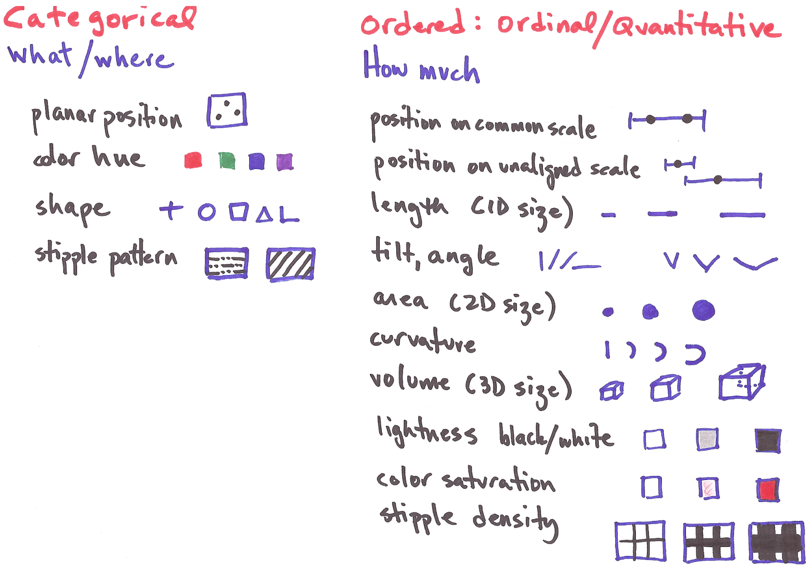
Visual Channel Types and Rankings



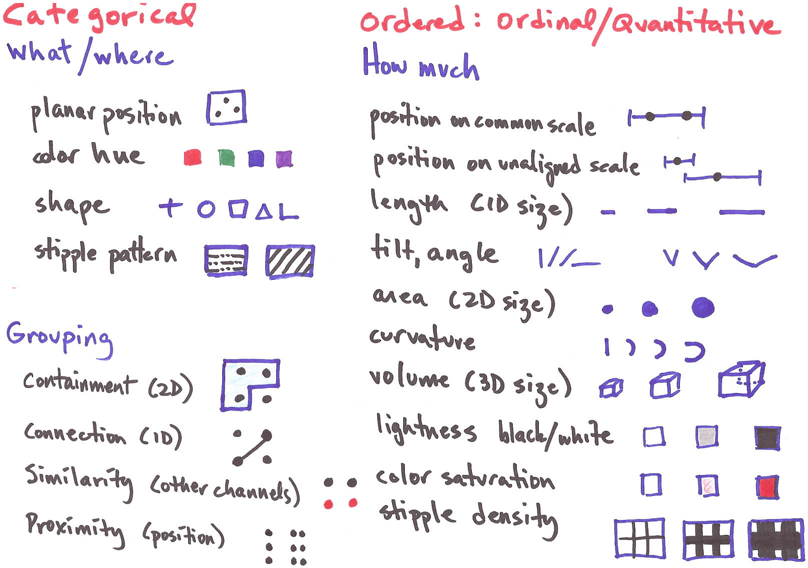
Visual Channel Types and Rankings



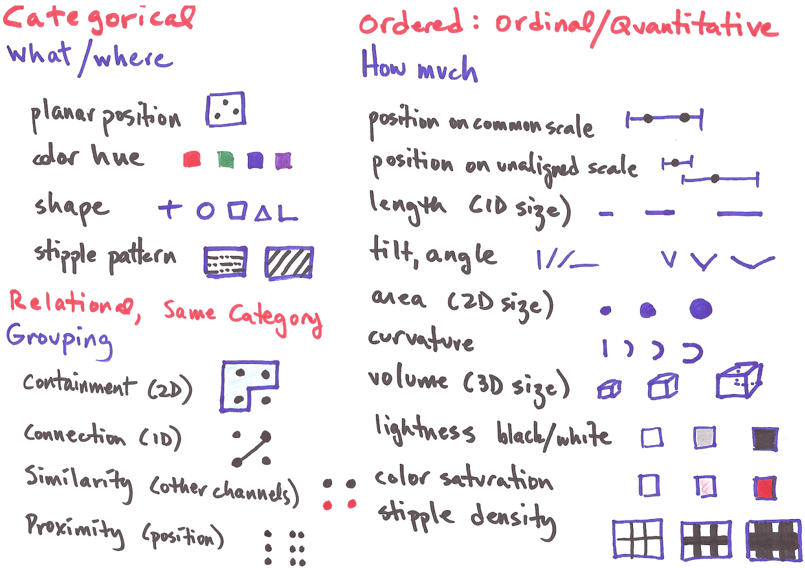
Visual Channel Types and Rankings



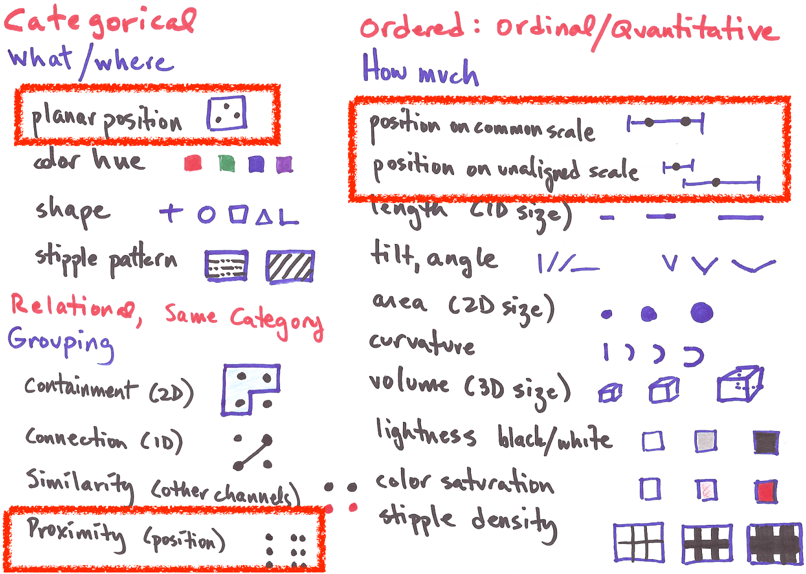
Visual Channel Types and Rankings



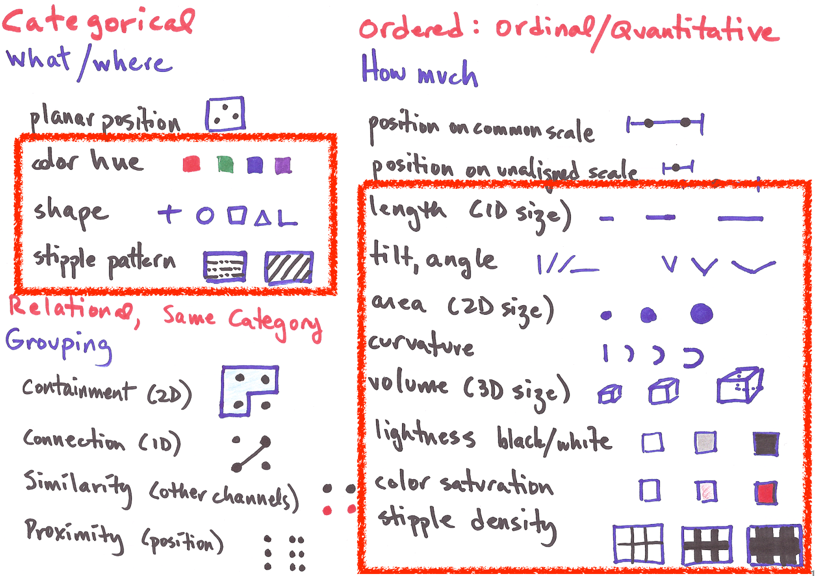
Visual Channel Types and Rankings



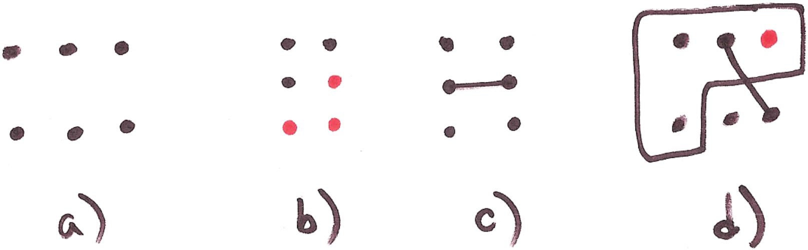
Only Planar Position Works For All!



Ranking Differs For All Other Channels



Grouping Channels



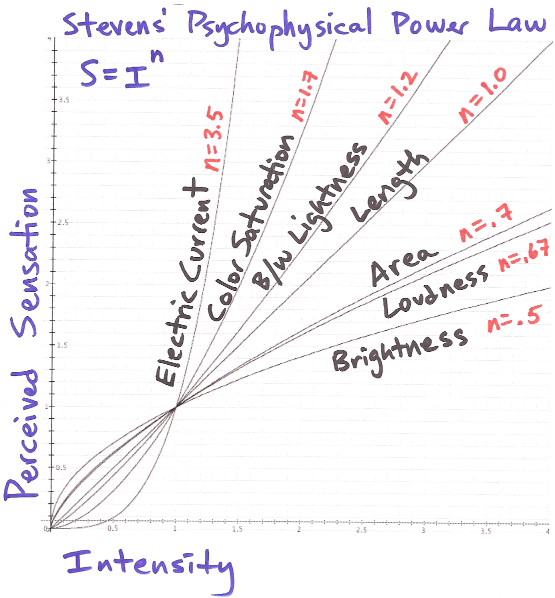
proximity similarity (color) connection containment

Expressiveness and Effectiveness

- expressiveness principle
  - pick visual channel to express all of and only information in dataset
- effectiveness principle
  - ranking of channel should match importance of attribute

- what criteria determine channel ranks?
  - accuracy, discriminability, separability, popout
  - grouping precedence

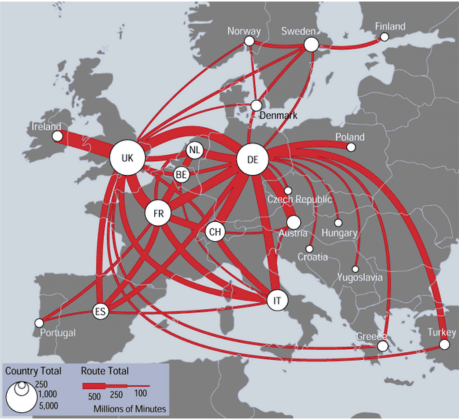
Accuracy



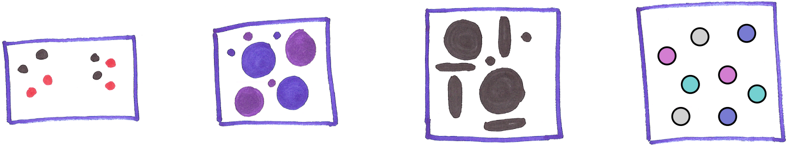
Stevens' Psychophysical Power Law
$S = I^n$
Electric Current
n=3.5
Color Saturation
n=1.7
B/w Lightness
n=1.2
Length
n=1.0
Area
n=.7
Loudness
n=.67
Brightness
n=.5
Perceived Sensation
Intensity
0.5
1
1.5
2
2.5
3
3.5
4

Discriminability

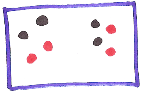
- limits on available dynamic range

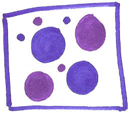


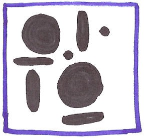
Separability vs. Integrality

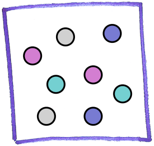


Separability vs. Integrality









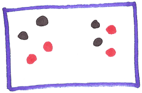
position

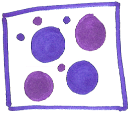
hue (color)

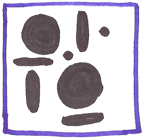
fully separable

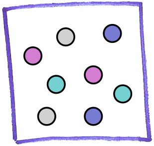
2 groups each

Separability vs. Integrality









position
hue (color)

size
hue (color)

fully separable

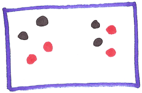
some interference

difficult to discriminate small items

2 groups each

{2 groups each}

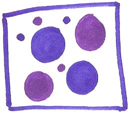
Separability vs. Integrality



position
hue (color)

fully separable

2 groups each

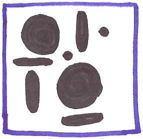


size
hue (color)

some interference

difficult to discriminate small items

{2 groups each}

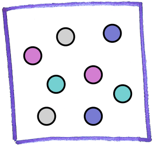


size: width
size: height

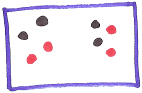
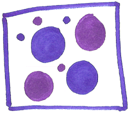
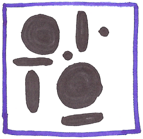
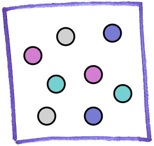
some/significant interference

integral percept: area (planar size)

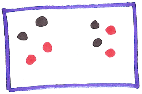
3 groups



Separability vs. Integrality

			
position hue (color)	size hue (color)	size: width size: height	red green
fully separable	some interference	some / significant interference	major interference
	difficult to discriminate small items	integral percept: area (planar size)	integral percept: color / hue
2 groups each	{ 2 groups each }	3 groups	4 groups

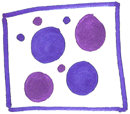
Separability vs. Integrality



position
hue (color)

fully separable

2 groups each

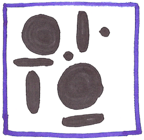


size
hue (color)

some interference

difficult to discriminate small items

2 groups each

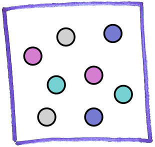


size: width
size: height

some/significant interference

integral percept: area (planar size)

3 groups



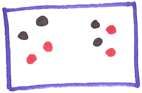
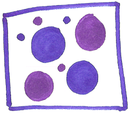
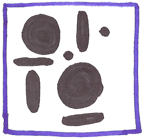
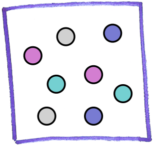
red
green

major interference

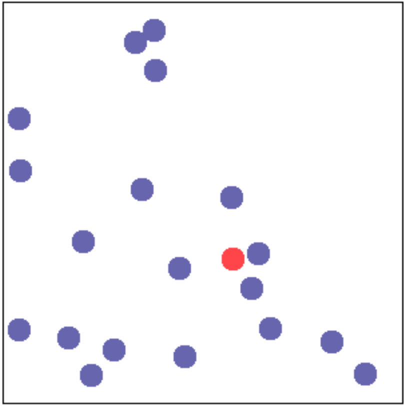
integral percept: color/hue

4 groups

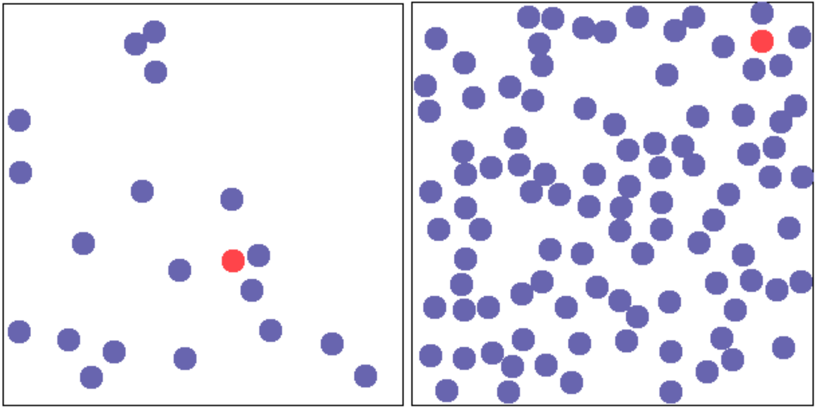
Separability vs. Integrality

			
position hue (color)	size hue (color)	size: width size: height	red green
fully separable	some interference	some/significant interference	major interference
	difficult to discriminate small items	integral percept: area (planar size)	integral percept: color/hue
2 groups each	2 groups each	3 groups	4 groups

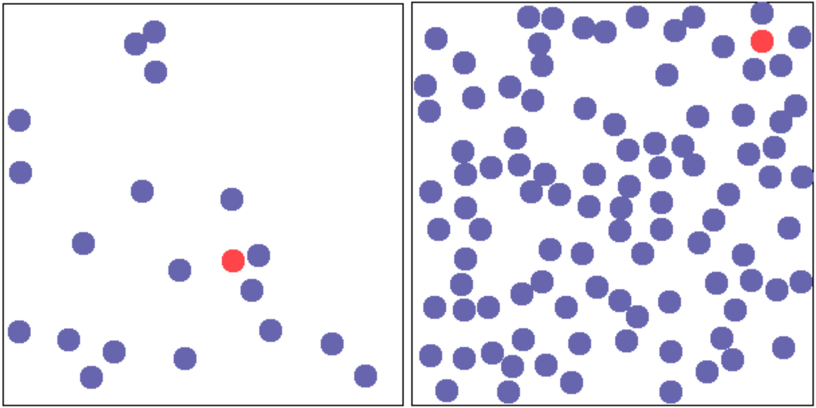
Visual Popout



Visual Popout

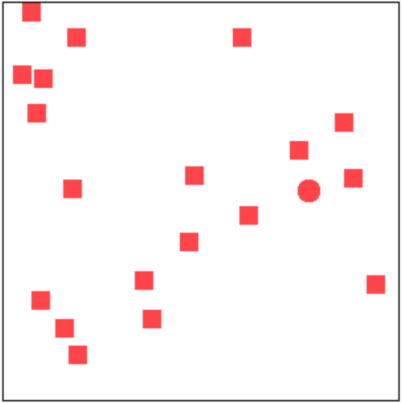


Visual Popout

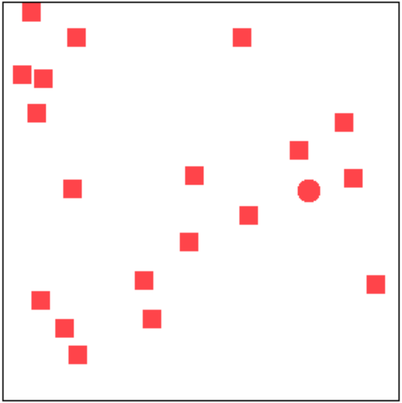


- parallelism: independent of distractor count

Visual Popout

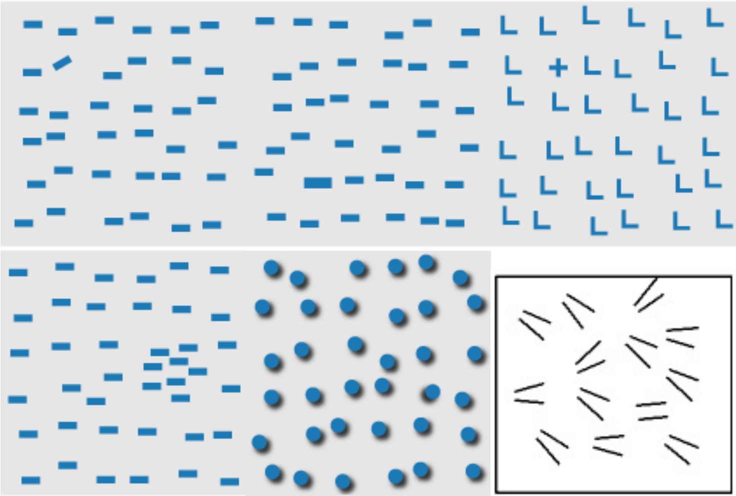


Visual Popout

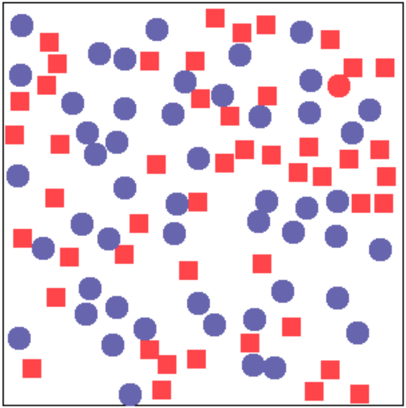


- speed depends on: which channel, difference from surroundings
  - 'sufficiently different' is context dependent

Popout Channels: Many But Not All

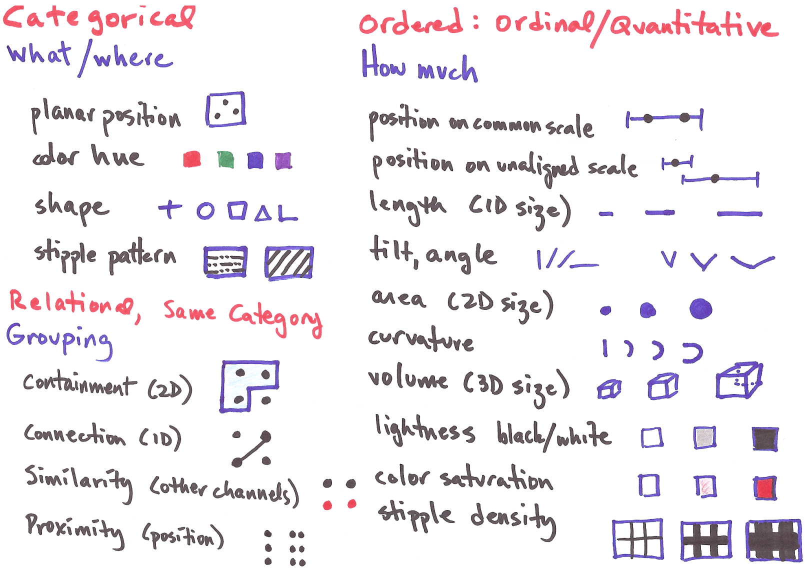


Popout Limits



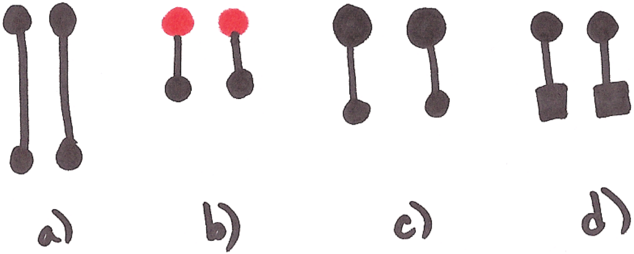
- combination searches are serial
    - exception: a few pairs

Visual Channel Types and Rankings



Grouping: Precedence Not Effectiveness

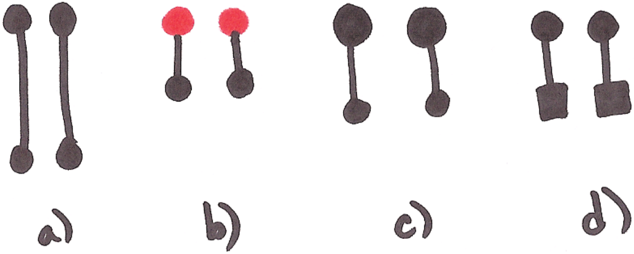
- all channels effective; rank is order of precedence



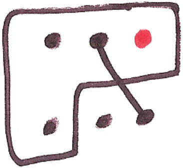
proximity similarity (color) sim (size) sim (shape)

Grouping: Precedence Not Effectiveness

- all channels effective; rank is order of precedence

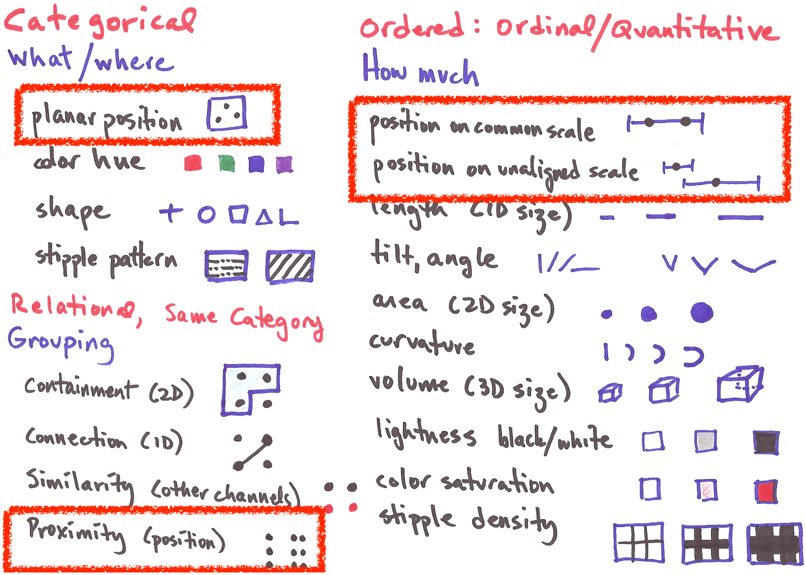


proximity similarity (color) sim (size) sim (shape)



containment overrides connection

Power of Planar Position



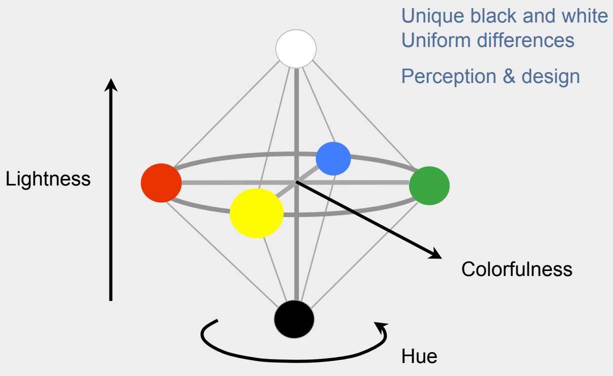
Color Vision Process

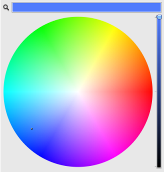
- rods
  - B/W info in low-light conditions
  - not discussed further
- 3 cone types
  - sensors: RGB
- 3 opponent color channels
  - one luminance: black/white
  - two "color": red/green, blue/yellow

  - color deficiency
    - one hue channel collapsed
    - sex-linked mutation: 8% of men, .5% of women

Luminance, Saturation, Hue

- luminance: how much
- saturation: how much
- hue: what

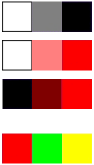


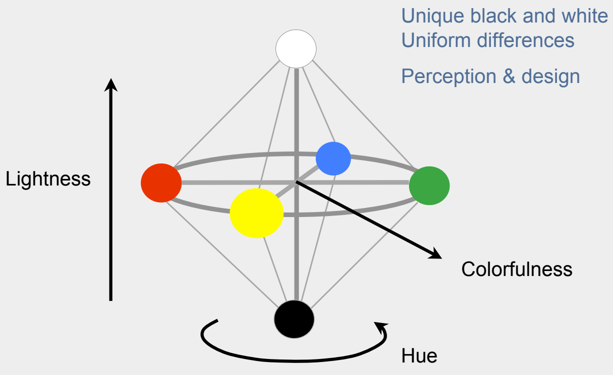


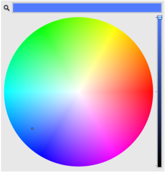
[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85]

Ordered: Lum/Sat, Unordered: Hue

- luminance: how much
- saturation: how much
- hue: what



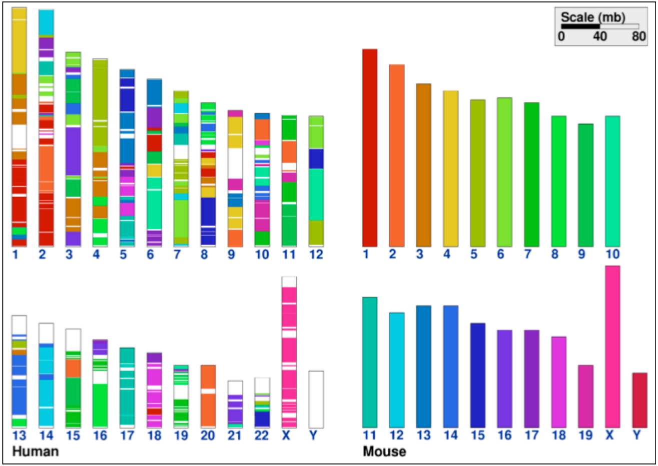




[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85]

Discriminablity: Categorical Color

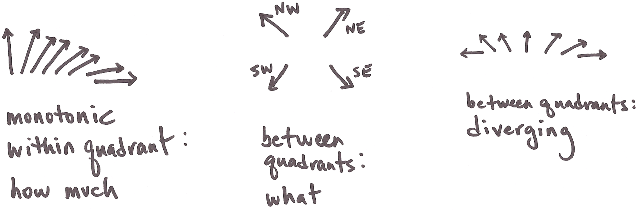
- noncontiguous small regions: 6-12 bins



[Sinha and Meller. Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Bioinformatics 2007]

Other Channels

- size: how much
  - small sizes interfere with many other channels
- tilt/angle: both



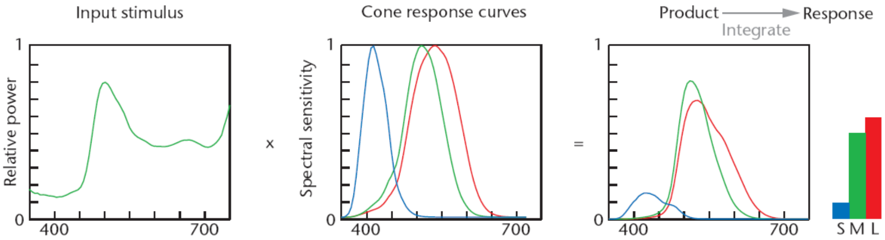
- shape: what
- stipple: how much
  - interferes with luminance
- motion: how much
  - grabs attention, difficult to attend to other channels

Color As Three Numbers

Stone
Representing Color As Three Numbers, CG&A 25(4):78-85

Trichromacy

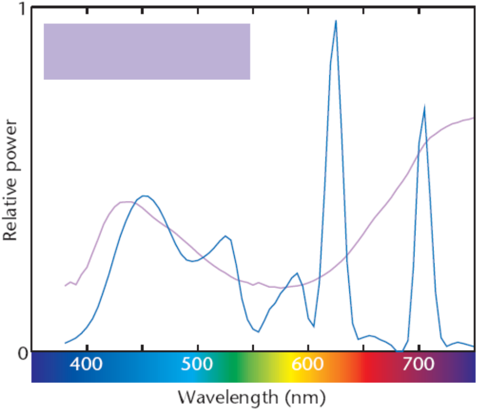
- different cone responses area function of wavelength
- for a given spectrum
  - multiply by response curve
  - integrate to get response



[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

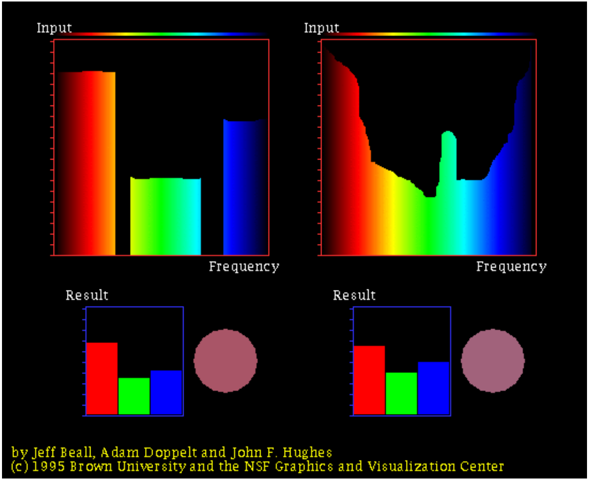
Metamerism

- brain sees only cone response
- different spectra appear the same



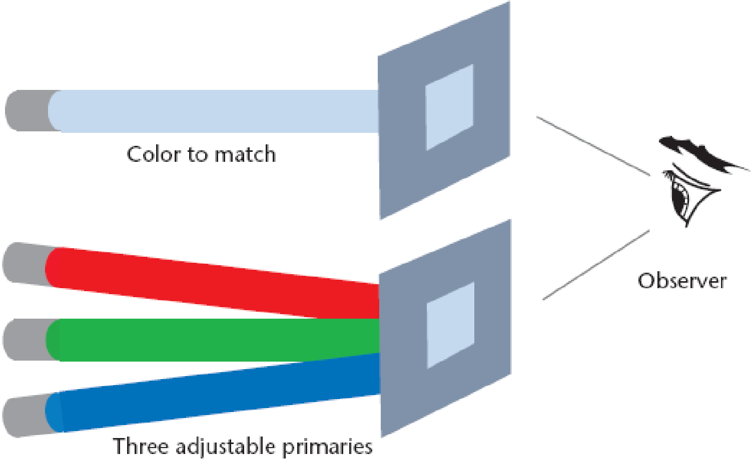
[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

Metamerism Demo



[www.cs.brown.edu/exploratories/freeSoftware/repository/edu/brown/cs/exploratories/applets/spectrum/metamers_java_browser.html]

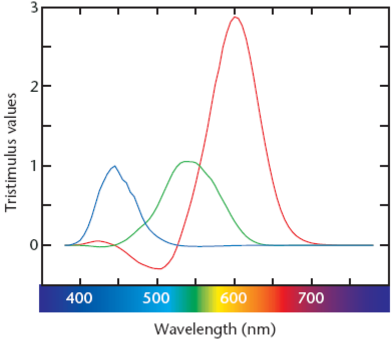
Color Matching Experiments



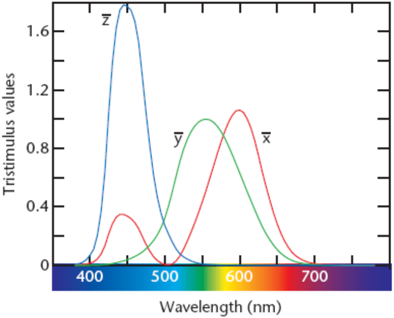
[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

Color Matching Functions

Stiles-Burch, negative lobe



CIE standard, all positive

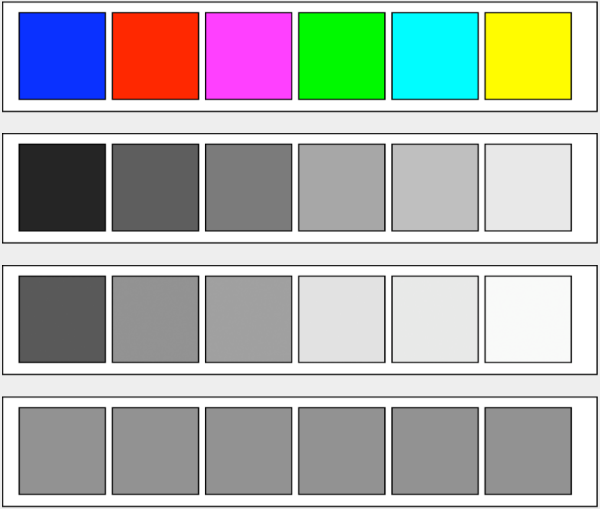


[Stone, Representing Color As Three Numbers, CG&A 25(4):78-85, www.stonesc.com/pubs/Stone%20CGA%2007-2005.pdf]

Color Spaces

- RGB: convenient for machines
  - these three channels **not** separable
- CIE XYZ: from color matching functions
  - perceptually based
- L*a*b*: from XYZ + reference whitepoint
  - perceptually linear, safe to interpolate
- HLS: simple transformation of RGB
  - good: separates out lightness, hue, saturation channels
  - bad: lightness **not** true luminance
  - careful: only **pseudo**-perceptual!

Lightness vs Luminance



Corners of the RGB color cube

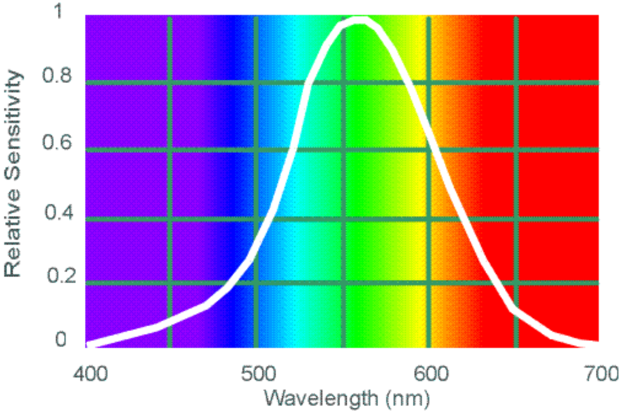
Luminance values

L* values

L from HLS
All the same

[Stone. Color In Information Display. IEEE Visualization 2006 Course Notes. http://www.stonesc.com/Vis06]

Spectral Sensitivity



[Joy of Visual Perception, Peter Kaiser. http://www.yorku.ca/eye/photopik.htm]