Lecture 1, InfoVis MiniCourse

Perception, Frameworks, Color

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Information visualization

interactive visual representation of abstract data
- help human perform some task more effectively

external representation
- reduces load on working memory

External representation example

book topic relationships

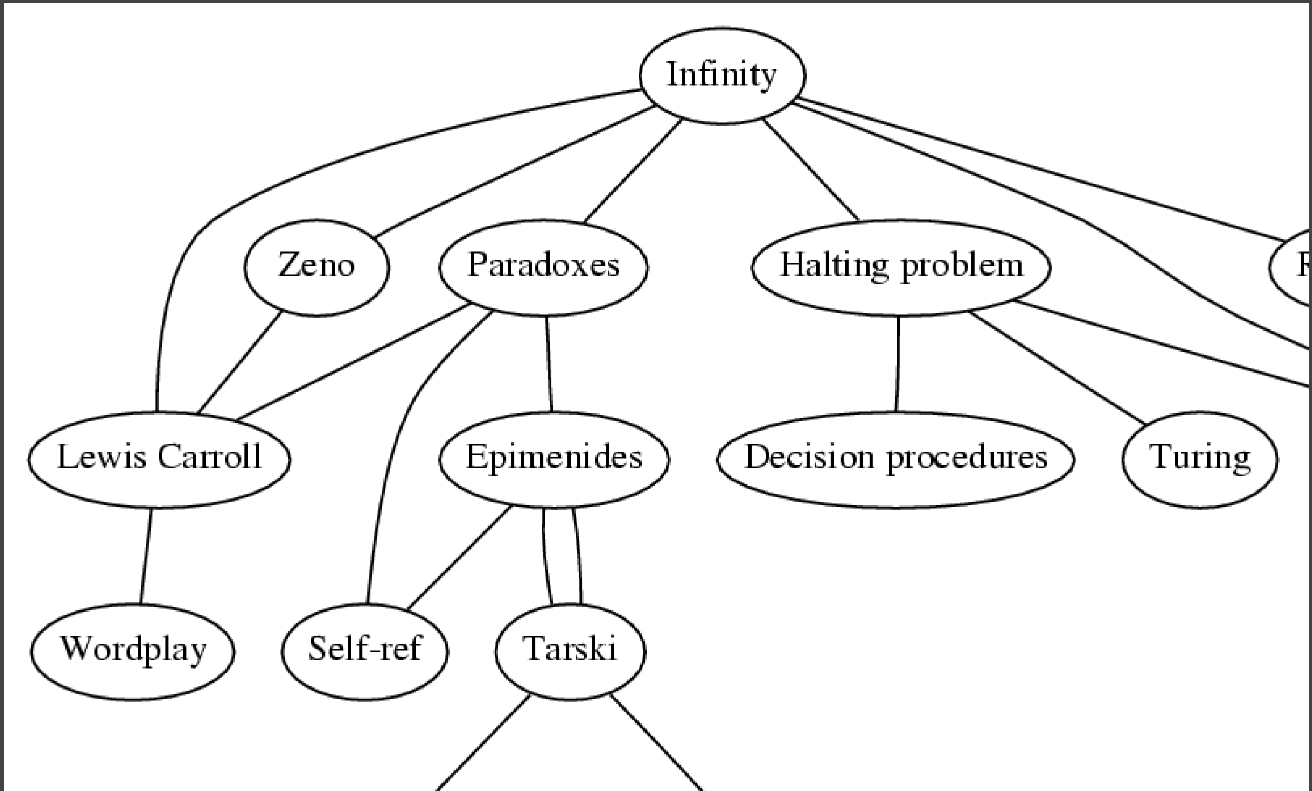
- [Godel, Escher, Bach. Hofstadter 1979]

Paradoxes – Lewis Carroll
Turing – Halting problem
Halting problem – Infinity
Paradoxes – Infinity
Infinity – Lewis Carroll
Infinity – Unpredictably long searches
Infinity – Recursion
Infinity – Zeno
Infinity – Paradoxes
Lewis Carroll – Zeno
Lewis Carroll – Wordplay

Halting problem – Decision procedures
BlooP and FlooP – AI
Halting problem – Unpredictably long searches
BlooP and FlooP – Unpredictably long searches
BlooP and FlooP – Recursion
Tarski – Truth vs. provability
Tarski – Epimenides
Tarski – Undecidability
Paradoxes – Self-ref
[...]

External representation example

offload cognition to visual systems
read off answer



Mini-Course Outline

- Perception
- Frameworks
- Color
- Space/Order
- Depth/Occlusion
- High Dimensionality
- Interaction
- Navigation/Zooming
- Focus+Context
- Graphs/Trees
- Scalability
- Task-Centered Design

Human Perception

sensors/transducers

- psychophysics: determine characteristics

relative judgements: strong
absolute judgements: weak

- continuing theme

different optimizations than most machines

- eyes are not cameras
- perceptual dimensions not nD array
- (brains are not hard disks)

Psychophysical Measurement

JND: just noticeable difference

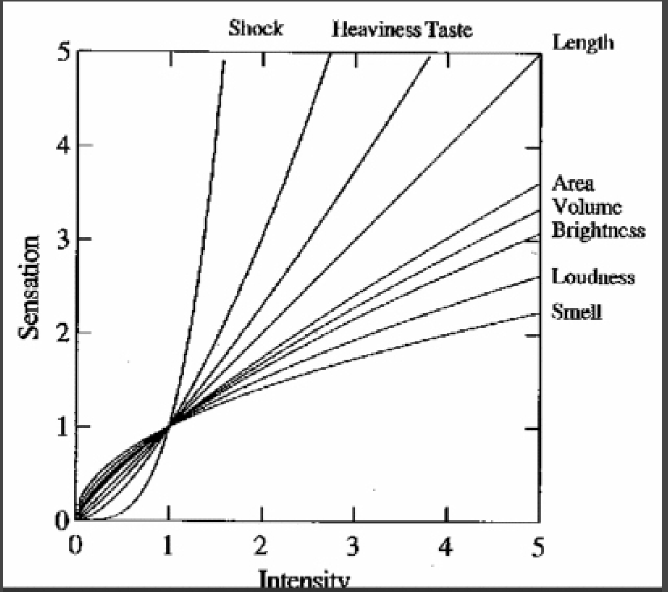
increment where human detects change

average to create "subjective" scale

Nonlinear Perception of Magnitudes

sensory modalities not equally discriminable

- Stevens power law

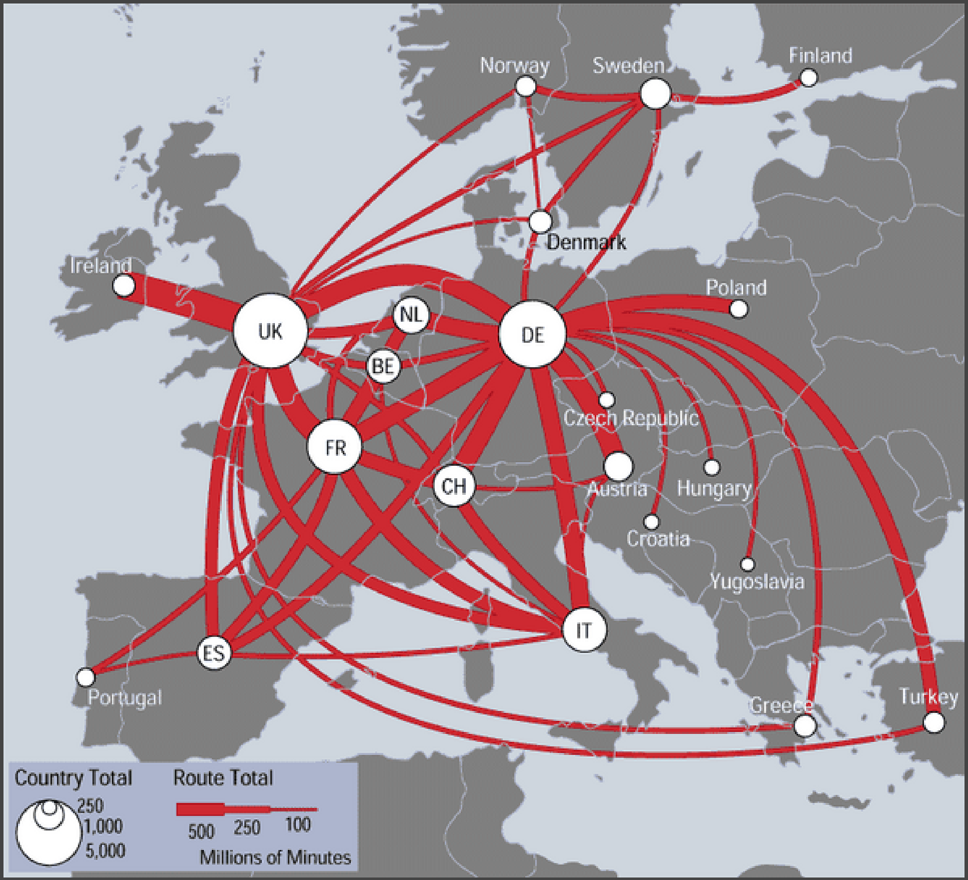


$$S = I^p$$

[Stevens, On the Theory of Scales of Measurement, Science 103:2684, 1946]

Dimensional Dynamic Range

linewidth: limited discriminability



[mappa.mundi.net/maps/maps_014/telegeography.html]

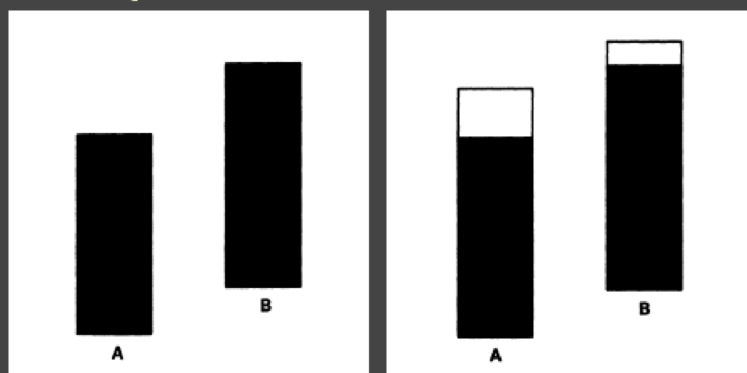
Weber's Law

ratio of increment threshold to background intensity is constant

- relative judgements within modality

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

Cleveland example: frame increases accuracy

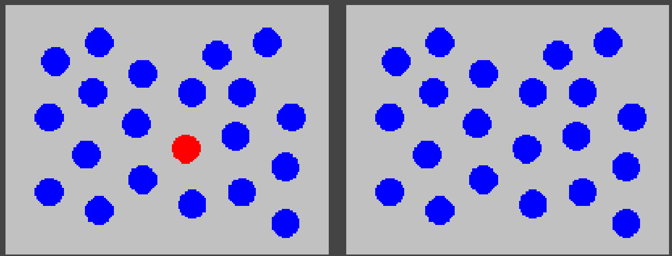


[Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models

Preattentive Visual Dimensions

color (hue) alone: preattentive

- attentional system not invoked
- search speed independent of distractor count

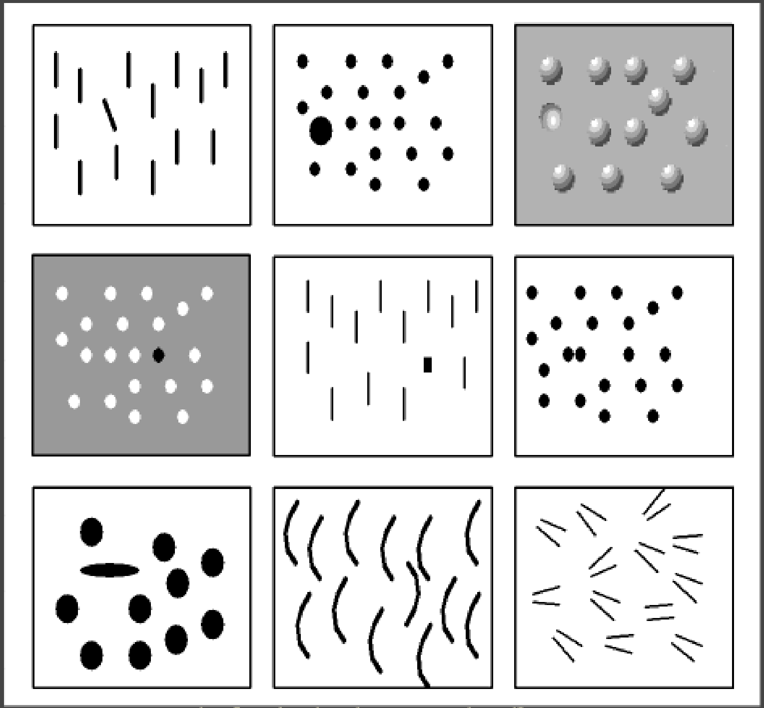


[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive Visual Dimensions

many preattentive dimensions of visual modality

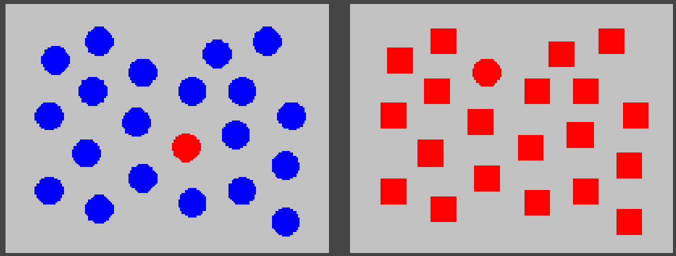
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction



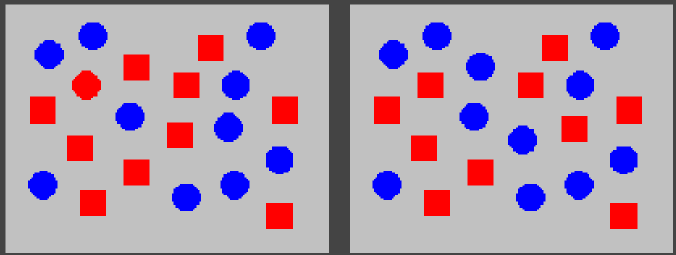
[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive Visual Dimensions

color alone: preattentive
shape alone: preattentive



combined hue and shape: multimodal



- requires attention
- search speed linear with distractor count

Integral vs. Separable Dimensions

red-green yellow-blue | x-size y-size | size orientation | color shape | color motion | color location

[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

Gestalt Laws

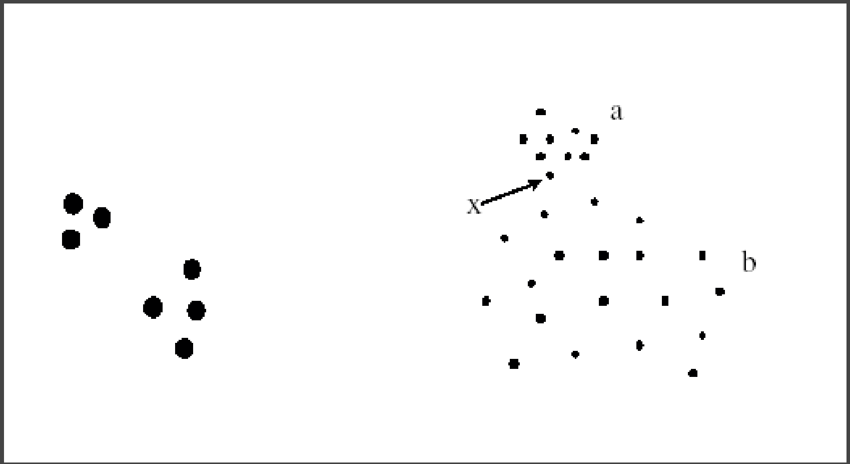
principles of pattern perception

- "gestalt": German for "pattern"
- original proposed mechanisms wrong
- rules themselves still useful
- "Pragnatz": simplest possibility wins

principles

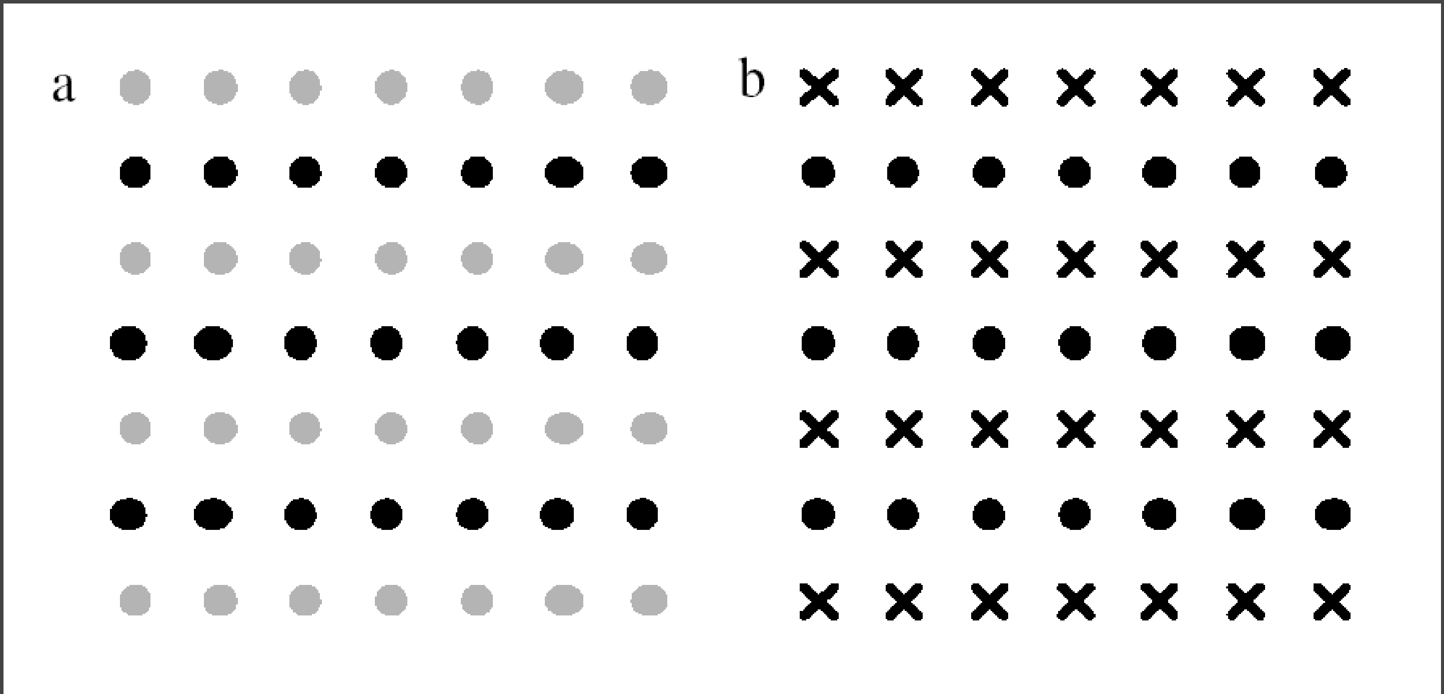
- proximity
- similarity
- continuity/connectedness/good continuation
- closure
- symmetry
- common fate (things moving together)
- relative sizes

Proximity



[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

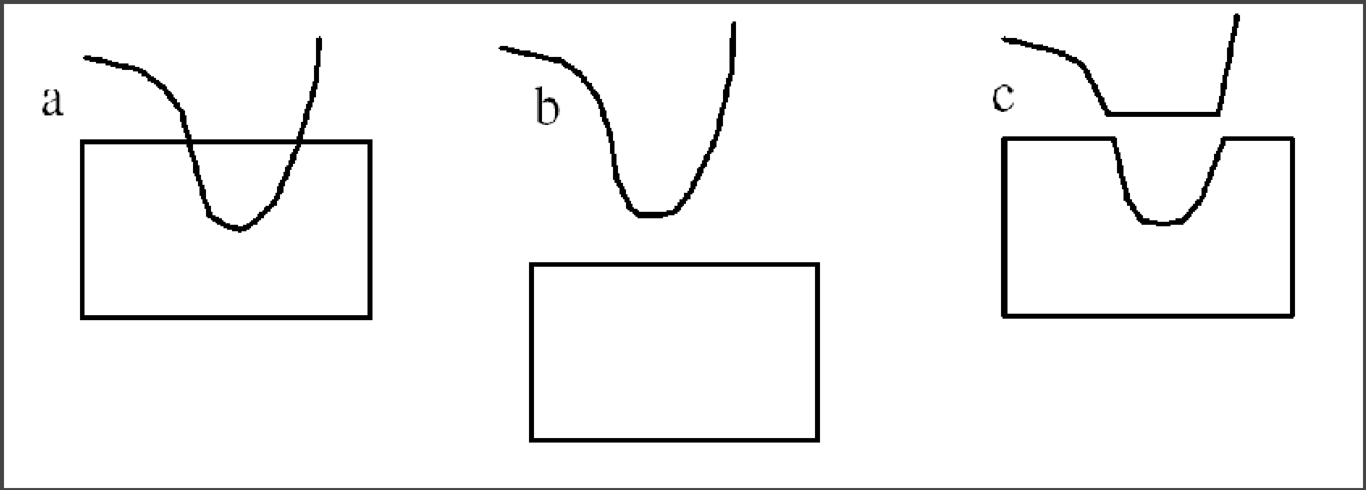
Similarity



[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

Continuity

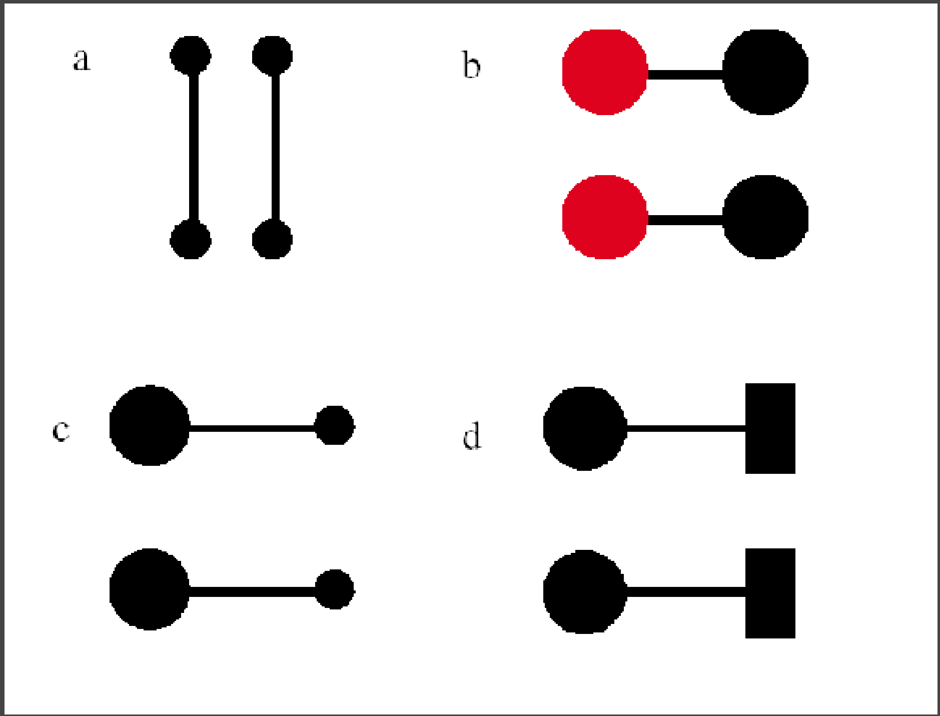
smooth not abrupt change
overrules proximity



[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

Connectedness

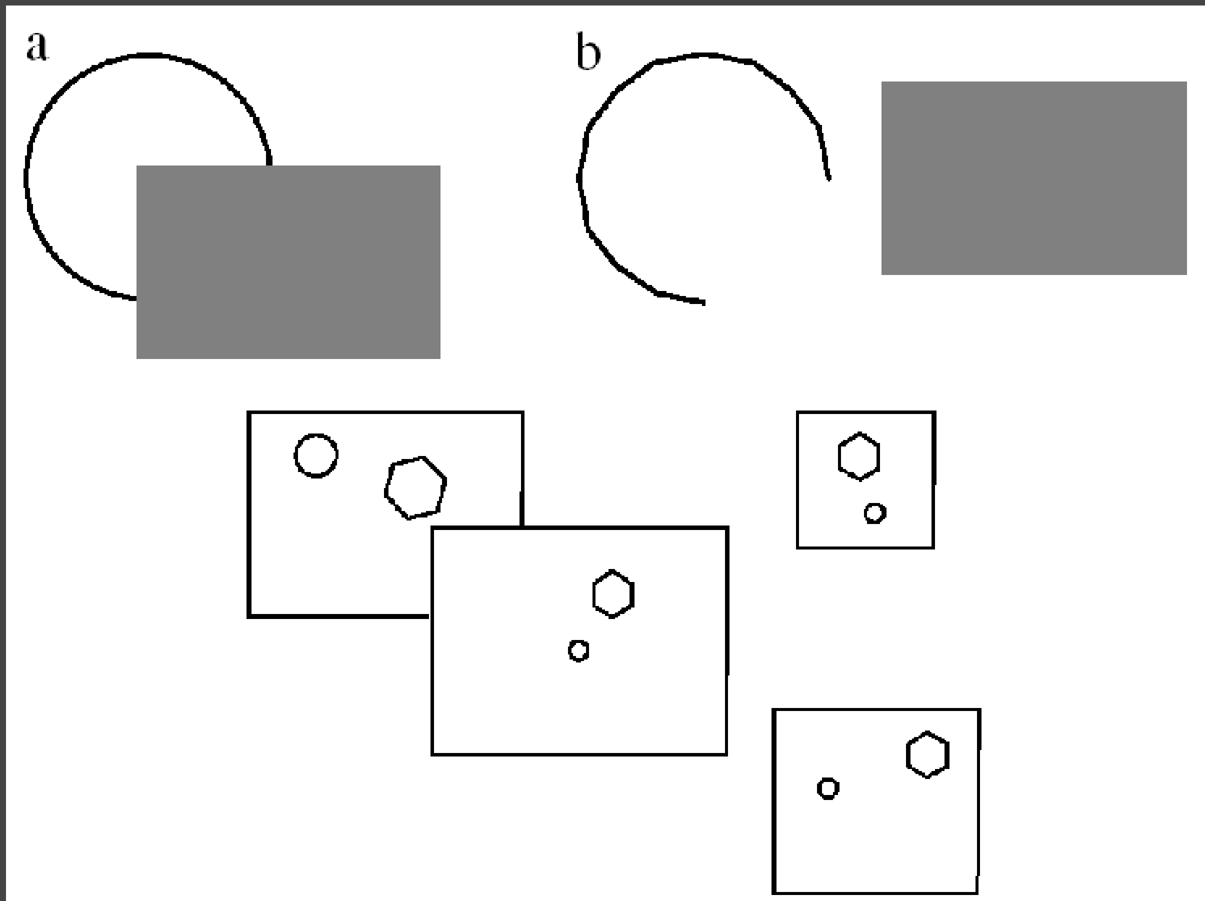
can overrule size, shape



[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

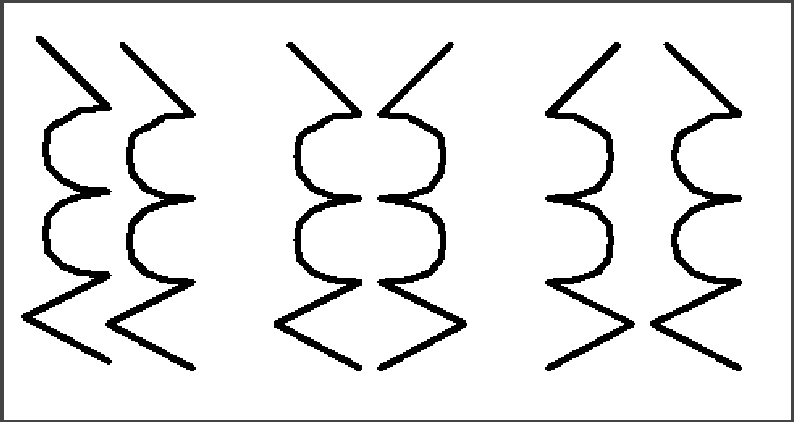
Closure

overrules proximity



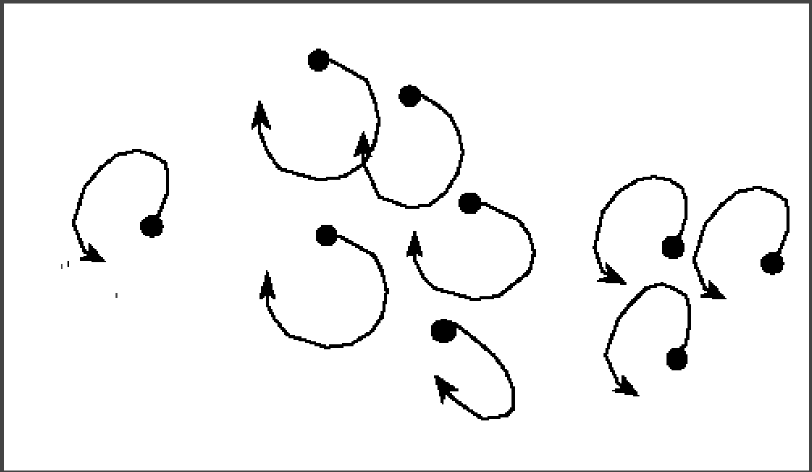
Symmetry

emphasizes relationships



[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

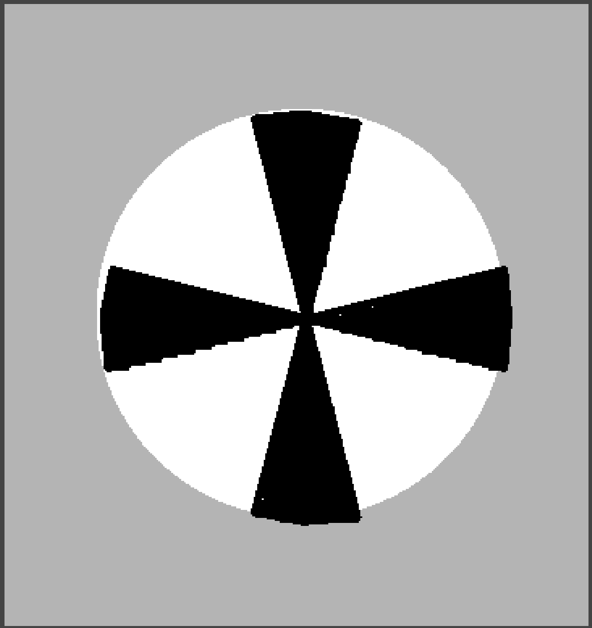
Common Fate



[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

Relative Size

smaller components perceived as objects



[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999.]

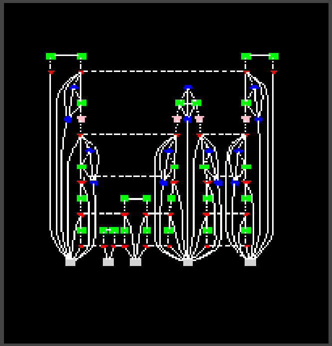
Graph Drawing Tension

node placement

close
- proximity

far
- visual popout of long edge

either
- connectedness



[www.research.att.com/sw/tools/graphviz]

tradeoffs abound in infovis!

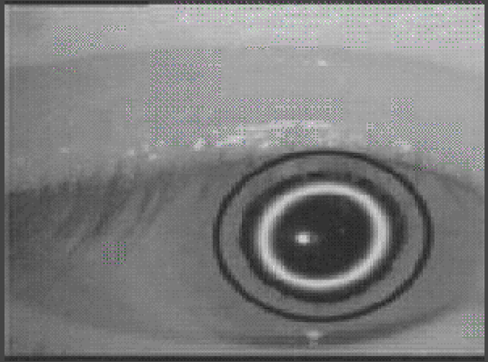
Eyes

fovea

- thumbnail at arm's length
- small high resolution area

saccades [video]

- high-resolution samples
- brain makes collage
- vision perceived as entire simultaneous field
- fixation points: dwell 200-600ms
- moving: 20-100ms



[vision.arc.nasa.gov/personnel/jbm/home/projects/osa98/osa98.html/

Ears

perceived as temporal stream

- but also samples over time
- hard to filter out when not important
  - visual vs auditory attention

implications

- harder to create overview?
- hard to use as separable dimension?

'sonification' still very niche area

- alternative: supporting sound enhances immersion

More Reading

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 5: Visual Attention and Information That Pops Out

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999.
Chapter 6: Static and Moving Patterns

The Psychophysics of Sensory Function, S. S. Stevens, Sensory Communication, MIT Press, 1961, pp 1-33.
http://www.cs.ubc.ca/~tmm/courses/cpsc533c-03-spr/readings/ss.pdf

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.

http://www.jstor.org/cgi-bin/jstor/printpage/01621459/di985961/98p1201a/0.pdf?userID=8e670917@ubc.ca/01cc99333c0050103e7f4
&backcontext=citation&config=jstor&dowhat=Acrobat&0.pdf

Perception in Visualization. Christopher G. Healey
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

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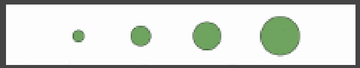
Data Types

categorical (nominal)

- apples, oranges, bananas

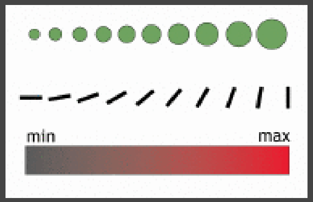
ordered (ordinal)

- small, medium, large
- days: Sun, Mon, Tue, Wed, Thu, Fri, Sat



continuous (quantitative)

- 10 inches, 17 inches, 23 inches



[graphics.stanford.edu/papers/polaris]

Mackinlay, Card Framework

Data Types

- nominal, ordered, quantitative

Marks

- point, line, area, surface, volume
- geometric primitives

Retinal Properties / Perceptual Dimensions

- size, brightness, color, texture, orientation, shape,...
- parameters that control the appearance of geometric primitives
- separable channels of information flowing from retina to brain

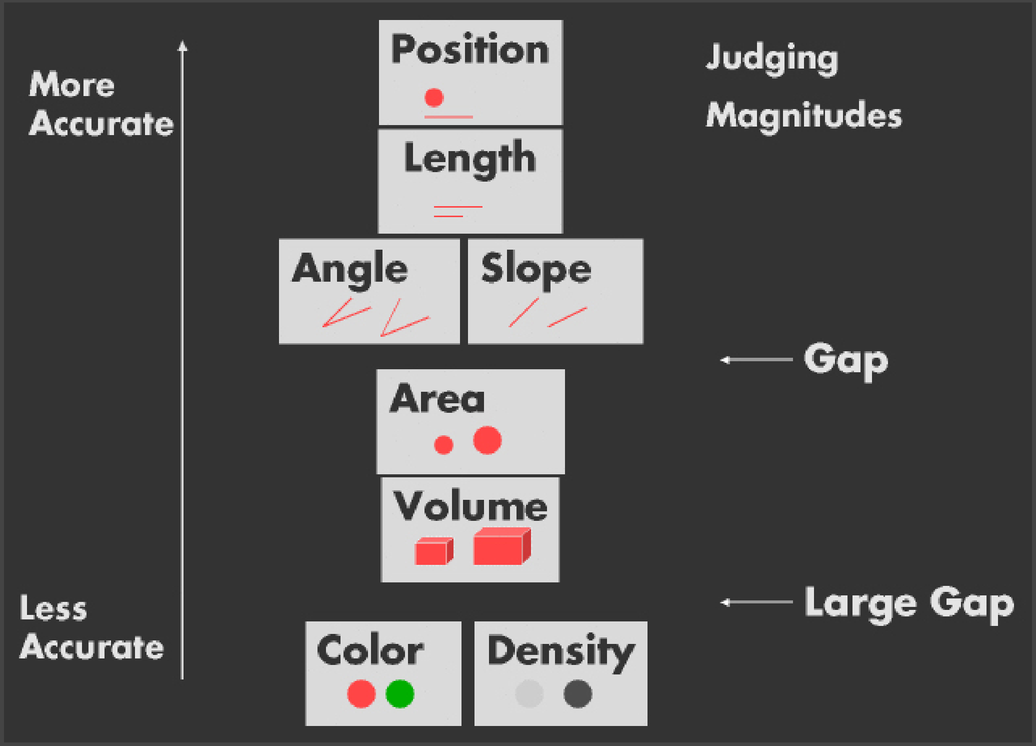
Data Variables

- 1D, 2D, 3D, 4D, 5D, etc

Bertin; Wilkinson; Stolte et al

- closest thing to central dogma we've got

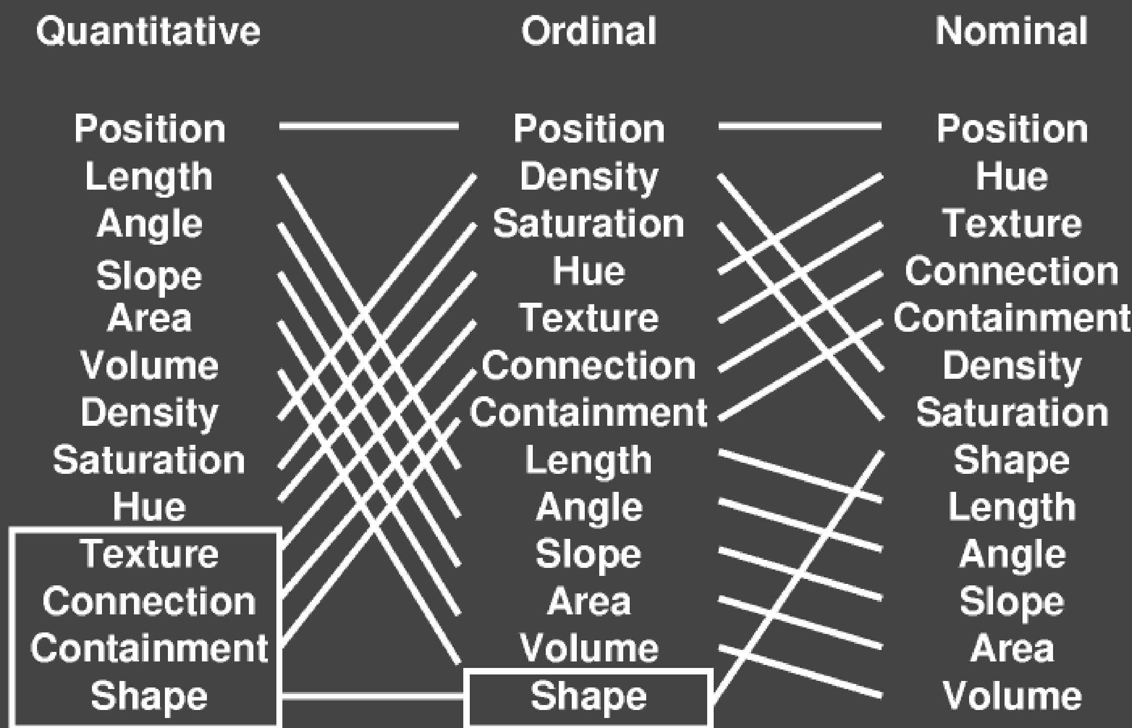
Ranking Perceptual Dimensions



[graphics.stanford.edu/courses/cs448b-02-spring/lectures/encoding/walk015.html]

Ranking Varies by Data Type

spatial position best for all types



[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]

More Reading

Chapter 1, Readings in Information Visualization: Using Vision to Think. Stuart Card, Jock Mackinlay, and Ben Shneiderman, Morgan Kaufmann 1999.

The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. Ben Shneiderman, Proc. 1996 IEEE Visual Languages, also Maryland HCIL TR 96-13
ftp://ftp.cs.umd.edu/pub/hcil/Reports-Abstracts-Bibliography/96-13html/96-13.html

The Structure of the Information Visualization Design Space. Stuart Card and Jock Mackinlay, Proc. InfoVis 97
http://citeseer.nj.nec.com/card96structure.html

The Grammar of Graphics, Leland Wilkinson, Springer 1999

Semiology of Graphics: Diagrams, Networks, Maps. Jaques Bertin.University of Wisconsin Press, Madison (WI), 1983. W. J. Berg (Translator).

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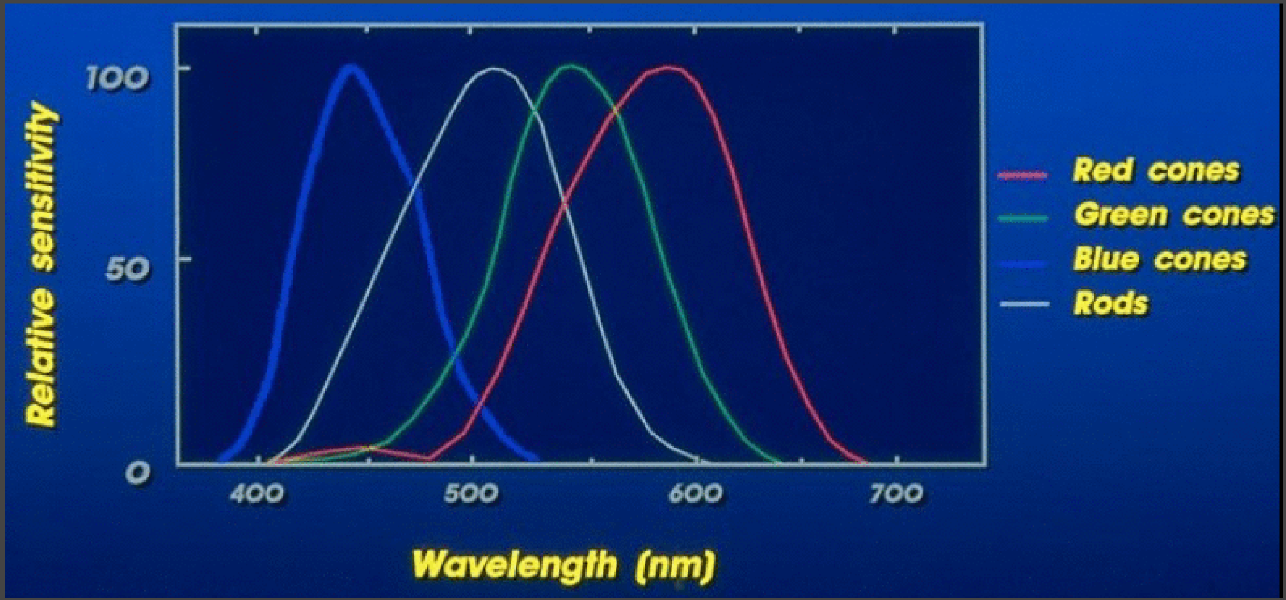
Trichromacy

cone response is a function of wavelength
for a given spectrum

- multiple by response curve
- integrate to get response

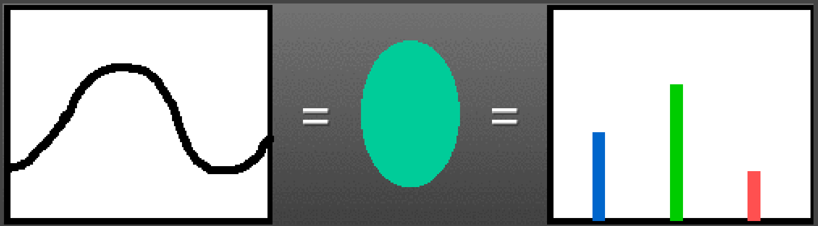


[Stone, SIGGRAPH 2001 course notes,
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf

Metamerism

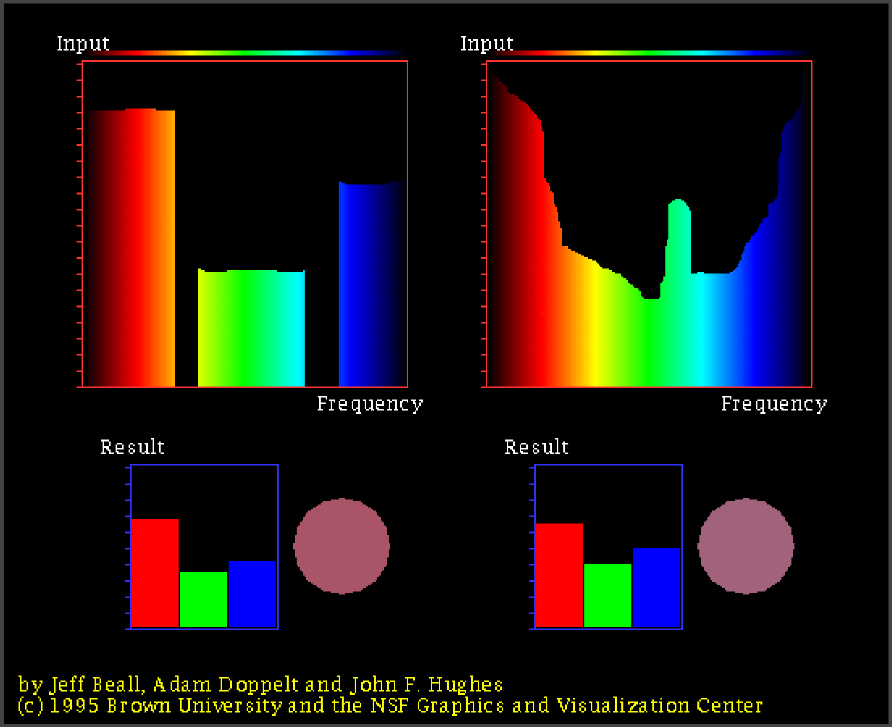
brain sees only cone response

different spectra appear the same



[Stone, SIGGRAPH 2001 course notes,
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf

Metamerism



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

Color Rules of Thumb

nominal
- bad: > 12 hues
- good: use <= ~12 hues

ordinal
- bad: using hue
- good: saturation/brightness

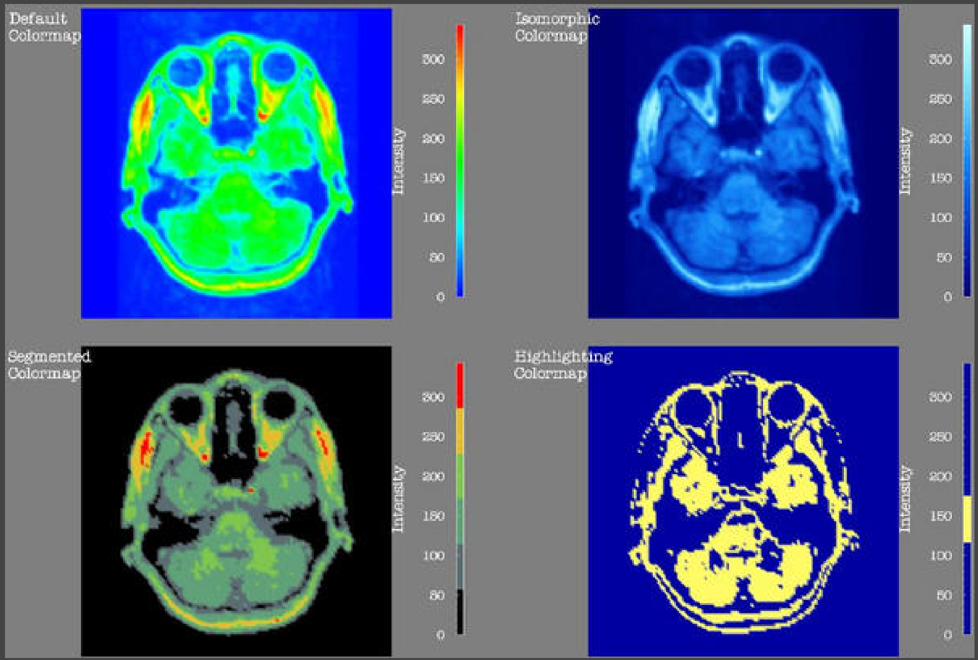
quantitative
- bad: rainbow colormaps
- good: interpolate between two hues

[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999. Figure 4.21]

Colormaps

rainbow colormaps usually bad idea

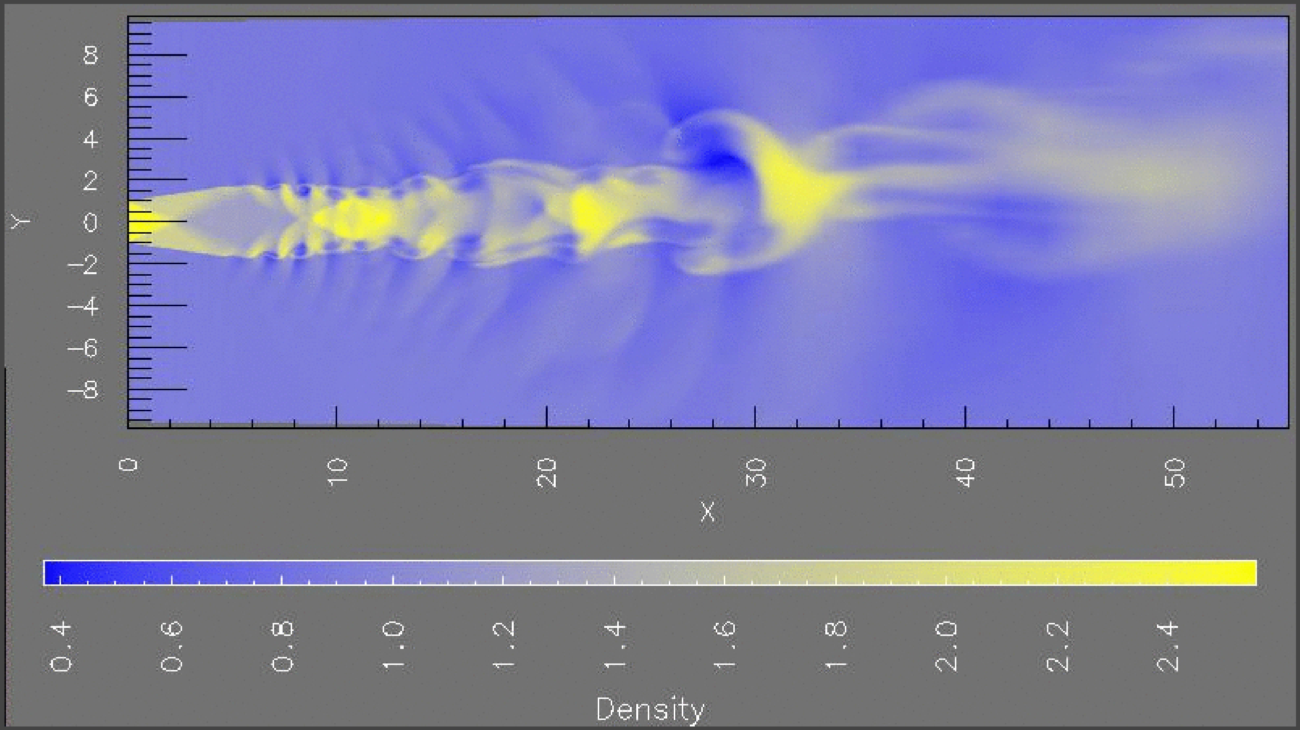
- hue is mediocre for showing order
- not perceptually linear!



[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm

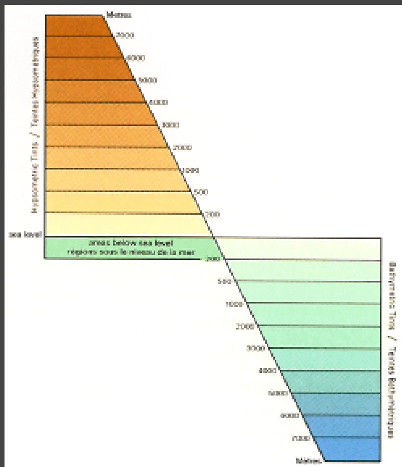
Colormaps

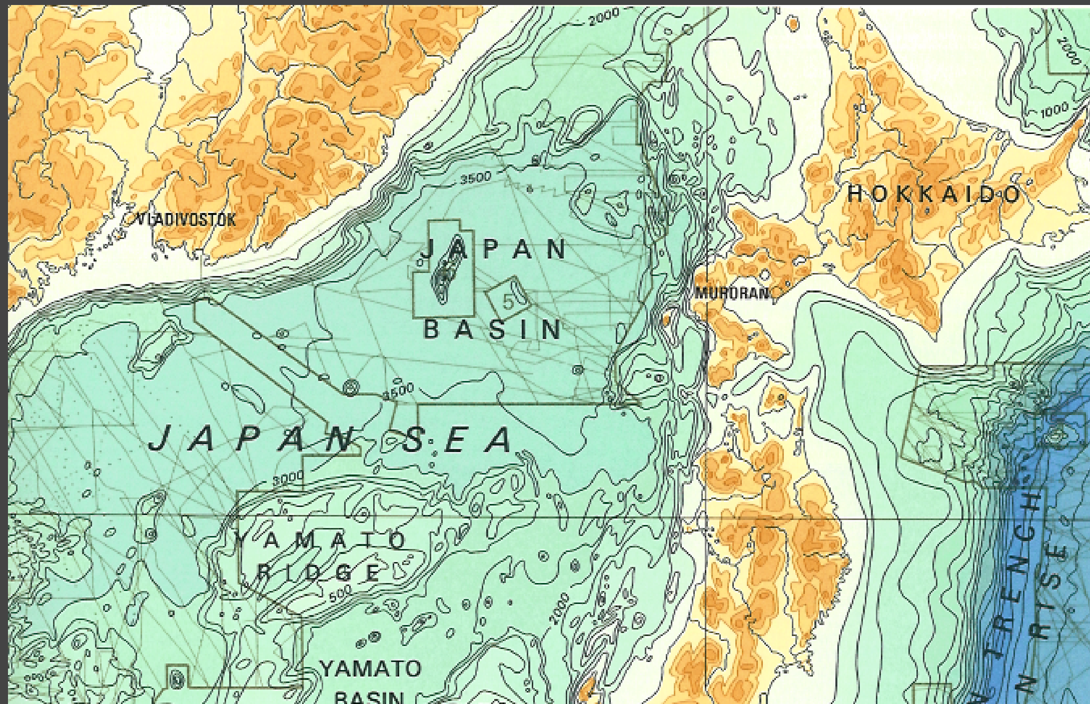
interpolating between two hues usually safe



[Rogowitz and Treinish, How NOT to Lie with Visualization, www.research.ibm.com/dx/proceedings/pravda/truevis.htm

Colormaps, Tufte



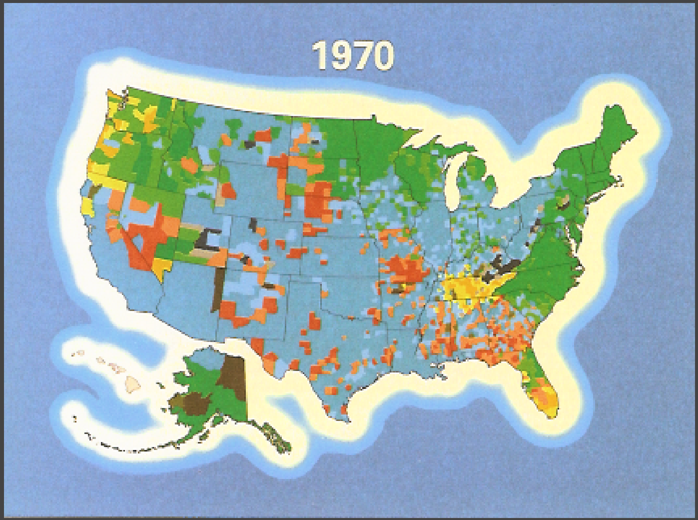


[Tufte, Envisioning Information, p. 91]

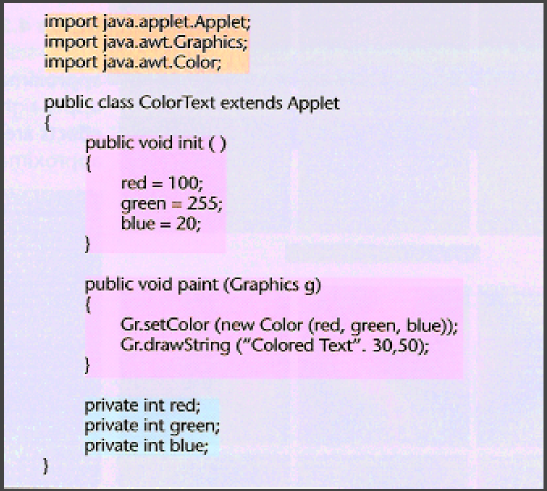
Color In Large Areas

Ware and Tufte agree: desaturate!

"excessively exuberant"



pastels for text bg



[Edward Tufte, Envisioning Information, p.82]
[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann 1999. Figure 4.20]

Color Deficiency

deutanope
protanope

- has red/green deficit
- 10% of males!

tritanope

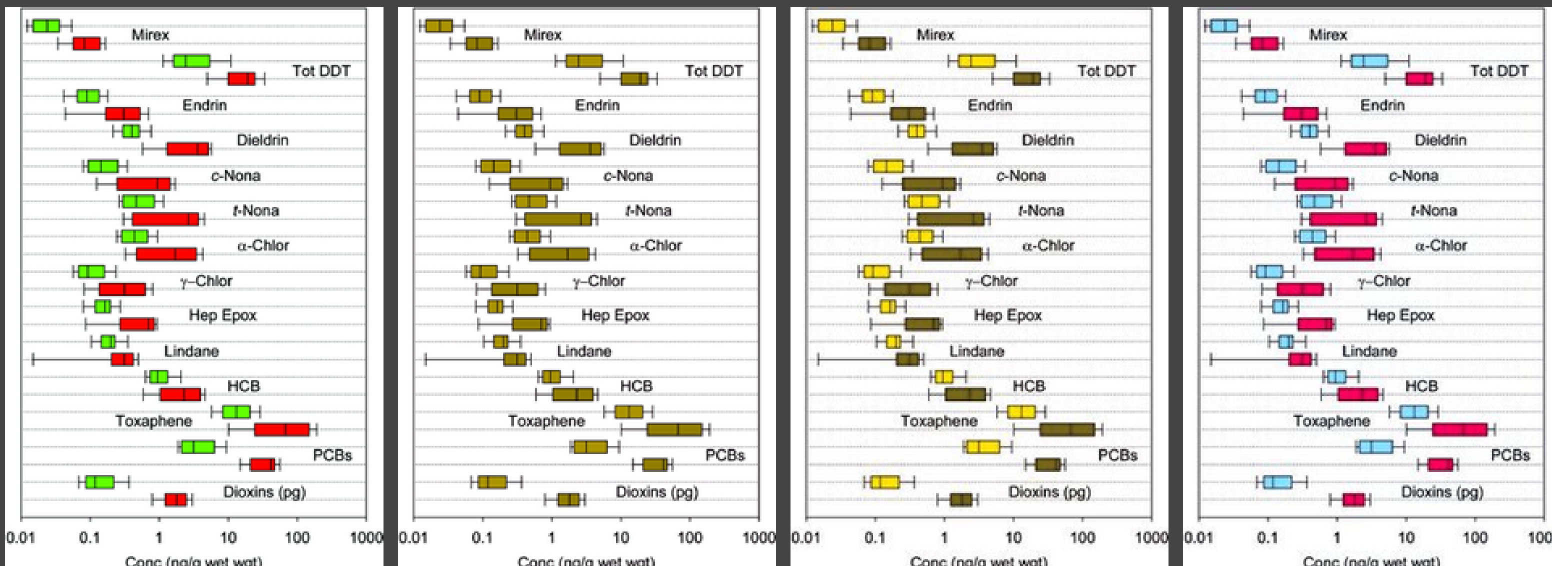
- has yellow/blue deficit

http://www.vischeck.com/vischeck

- test your images

Color Deficiency Examples: vischeck

original deuteranope protanope tritanope



[www.cs.ubc.ca/~tmm/courses/cpsc533c-04-spr/a1/dmitry/533a1.html, citing Global Assessment of Organic Contaminants in Farmed Salmon, Ronald A. Hites, Jeffery A. Foran, David O. Carpenter, M. Coreen Hamilton, Barbara A. Knuth, and Steven J. Schwager, Science 2004 303: 226-229.]

Designing Around Deficiencies

red/yellow/green could have domain meaning
then distinguish by more then hue alone

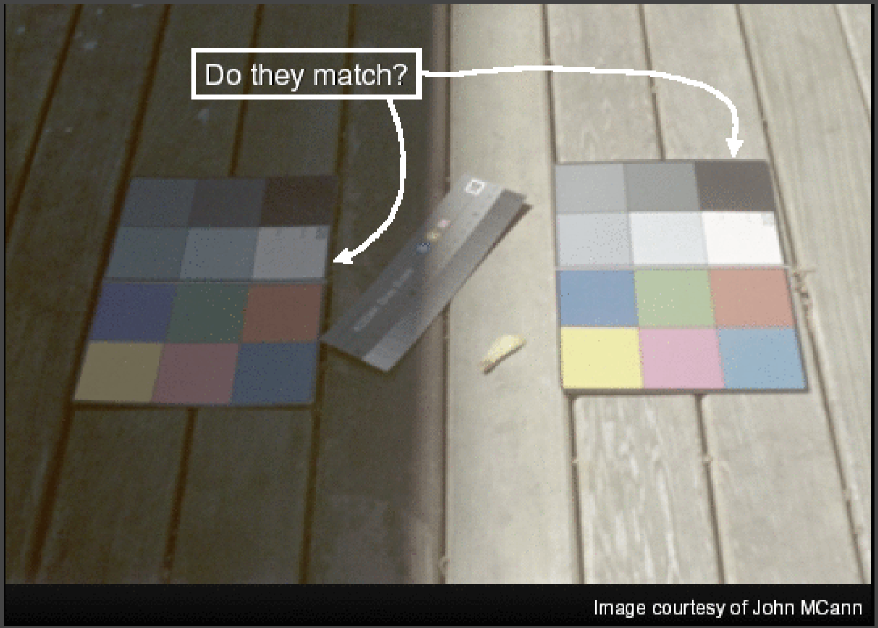
- saturation, brightness

original | deuteranope | protanope | tritanope

[Courtesy of Brad Paley]

Color/Brightness Constancy

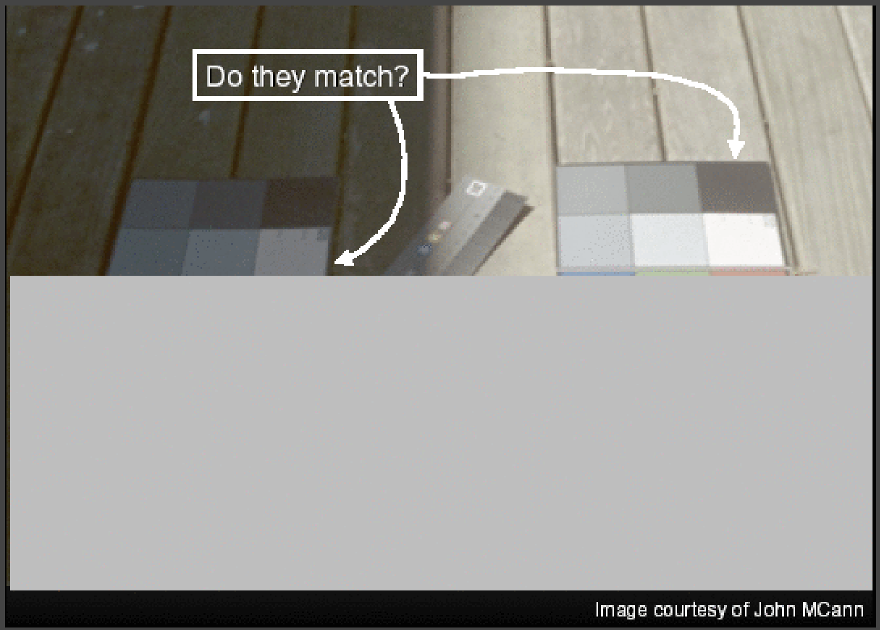
relative judgements



[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Color Constancy

relative judgements



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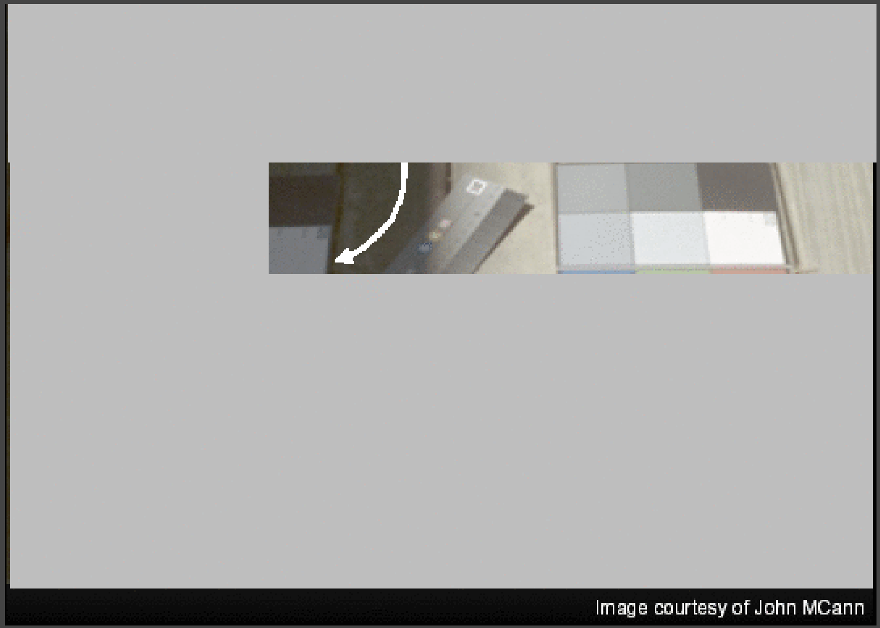

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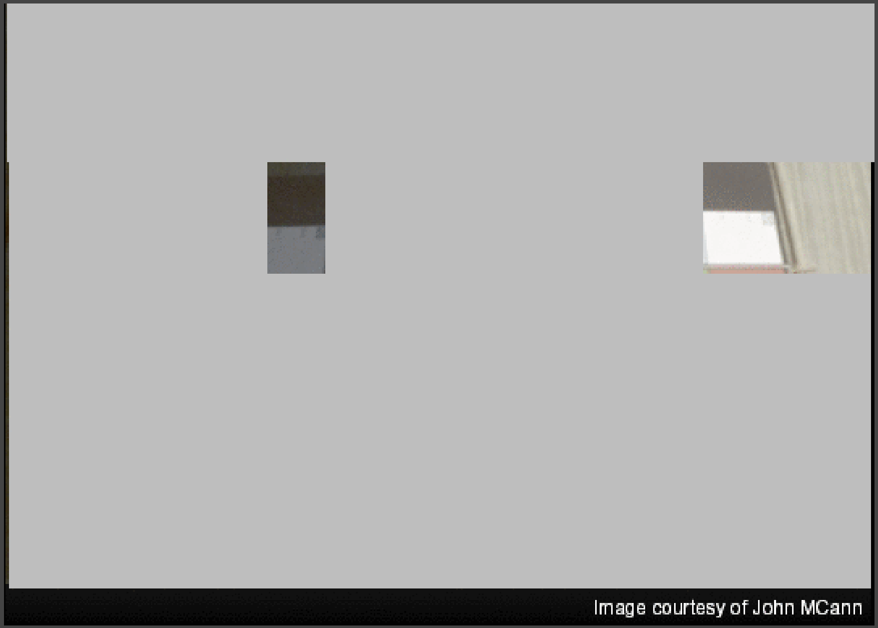

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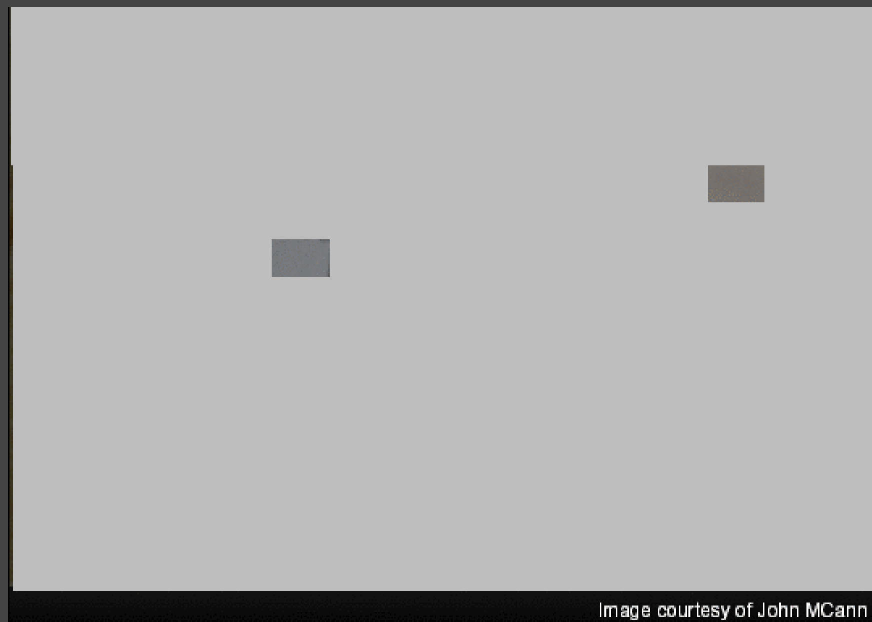
relative judgements



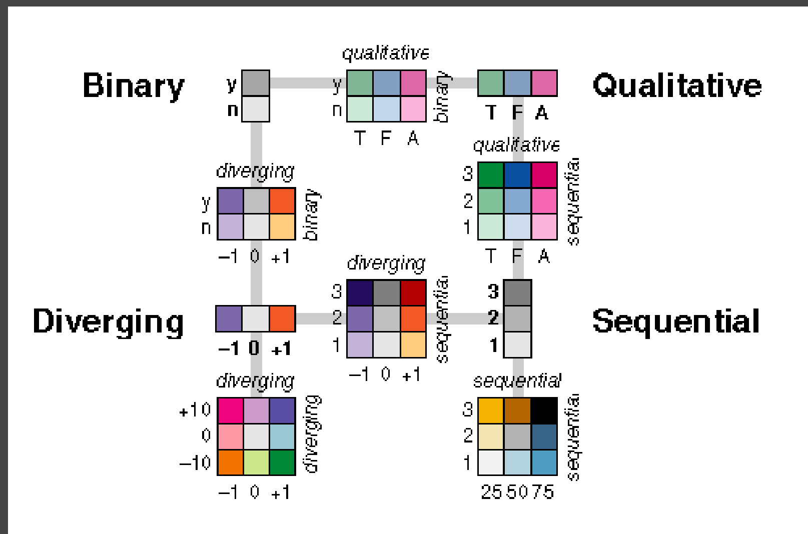
[courtesy of John McCann, from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Context Matters

Bezold effect: outlines

[from Stone 2001 SIGGRAPH course
graphics.stanford.edu/courses/cs448b-02-spring/04cdrom.pdf]

Cartographic Color Advice



[Brewer, www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html]

More Reading

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999. Chapter 3: Lightness, Brightness, Contrast, and Constancy

Information Visualization: Perception for Design. Colin Ware. Morgan Kaufmann 1999. Chapter 4: Color

Envisioning Information. Edward Tufte. Graphics Press, 1990. Chapter 5: Color and Information

How Not to Lie with Visualization, Bernice E. Rogowitz and Lloyd A. Treinish, Computers In Physics 10(3) May/June 1996, pp 268-273.
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Color use guidelines for data representation. C. Brewer, 1999.
http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/ASApaper.html

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