

Perception

Lecture 6 CPSC 533C, Fall 2004

29 Sep 2004

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Readings

Ware, Chapter 5: Visual Attention and Information That Pops Out

Ware, Chapter 6: Static and Moving Patterns

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.

External Representation

reduces load on working memory

- offload cognition

familiar example: multiplication/division

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline \hline \end{array}$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline \hline \hline \end{array}$$

$$[7 * 8 = 56]$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 5 \\ 57 \\ \times 48 \\ \hline \end{array}$$

$$[7 * 8 = 56]$$

6

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 5 \\ 57 \\ \times 48 \\ \hline \end{array}$$

$$[5 * 8 = 40 + 5 = 45]$$

6

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline \hline \hline \end{array}$$

$$[5 * 8 = 40 + 5 = 45]$$

456

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline \hline \hline \end{array}$$

$$[7*4=28]$$

456

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 2 \\ 57 \\ \times 48 \\ \hline \end{array}$$

$$[7*4=28]$$

$$\begin{array}{r} 456 \\ 8 \end{array}$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 2 \\ 57 \\ \times 48 \\ \hline \end{array}$$

$$[5 * 4 = 20 + 2 = 22]$$

$$\begin{array}{r} 456 \\ 8 \end{array}$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline \hline \hline \end{array}$$

$$[5*4=20 + 2 =22]$$

$$\begin{array}{r} 456 \\ 228 \end{array}$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline \end{array}$$

$$\begin{array}{r} 456 \\ 228 \\ \hline 6 \end{array}$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline \hline \hline \end{array}$$

$$\begin{array}{r} 456 \\ 228 \\ \hline 6 \end{array}$$

$$[8+5 = 13]$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline 1 \\ 456 \\ 228 \\ \hline 36 \end{array}$$

$$[8+5 = 13]$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline 1 \\ 456 \\ 228 \\ \hline 36 \end{array}$$

$$[4+2+1=7]$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline \hline \hline \end{array}$$

$$\begin{array}{r} 456 \\ 258 \\ \hline 736 \end{array}$$

$$[4+2+1=7]$$

External Representation: multiplication

paper

mental buffer

$$\begin{array}{r} 57 \\ \times 48 \\ \hline \hline \hline \end{array}$$

$$\begin{array}{r} 456 \\ 258 \\ \hline \hline 2736 \end{array}$$

External Representation

reduces load on working memory

- offload cognition

familiar example: multiplication/division

synthetic example: information visualization

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

External Representation: topic graphs

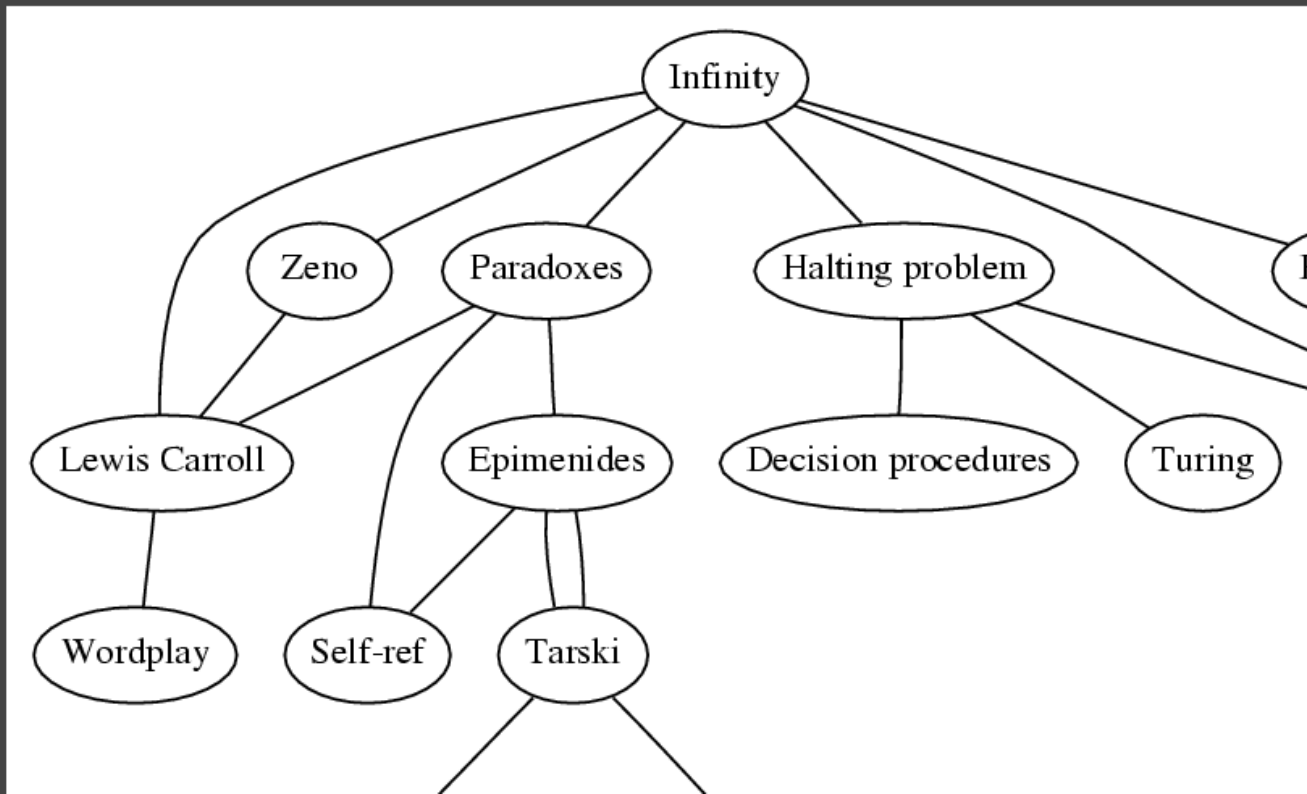
[Godel, Escher, Bach. Hofstadter 1979]

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

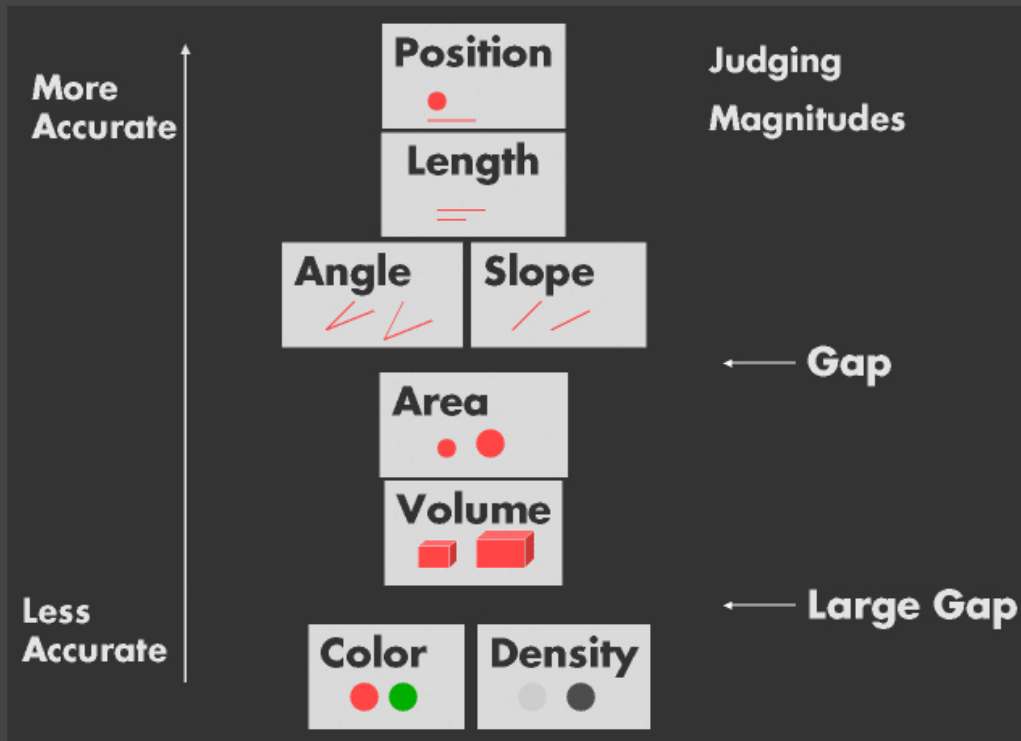
Halting problem – Decision procedures
BlooP and FlooP – AI
Halting problem – Unpredictably long searches
BlooP and FlooP – Unpredictably long searches
BlooP and FlooP – Recursion
Tarski – Truth vs. provability
Tarski – Epimenides
Tarski – Undecidability
Paradoxes – Self-ref
[...]

External representation example

offload cognition to visual systems
read off answer

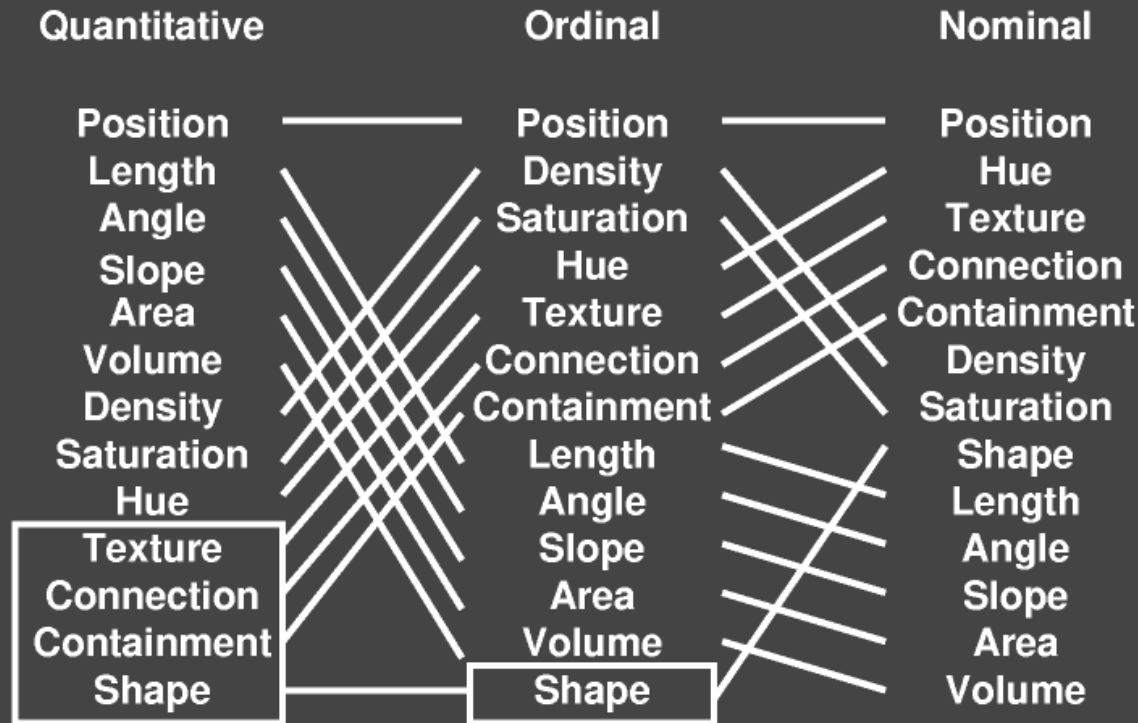


Dimensional ranking



Dimensional 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]

Cleveland's study

Position	position along common scale
Length	positions along nonaligned scales
Angle	length, direction, angle
Slope	area
Area	volume, curvature
Volume	shading, color saturation
Density	
Saturation	
Hue	
Texture	
Connection	
Containment	
Shape	

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

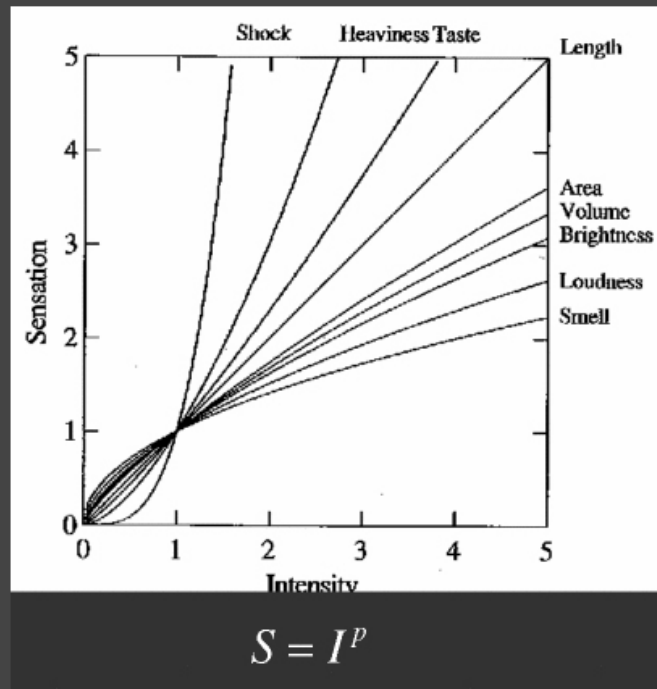
increment where human detects change

average to create "subjective" scale

Nonlinear perception of magnitudes

sensory modalities **not** equally discriminable

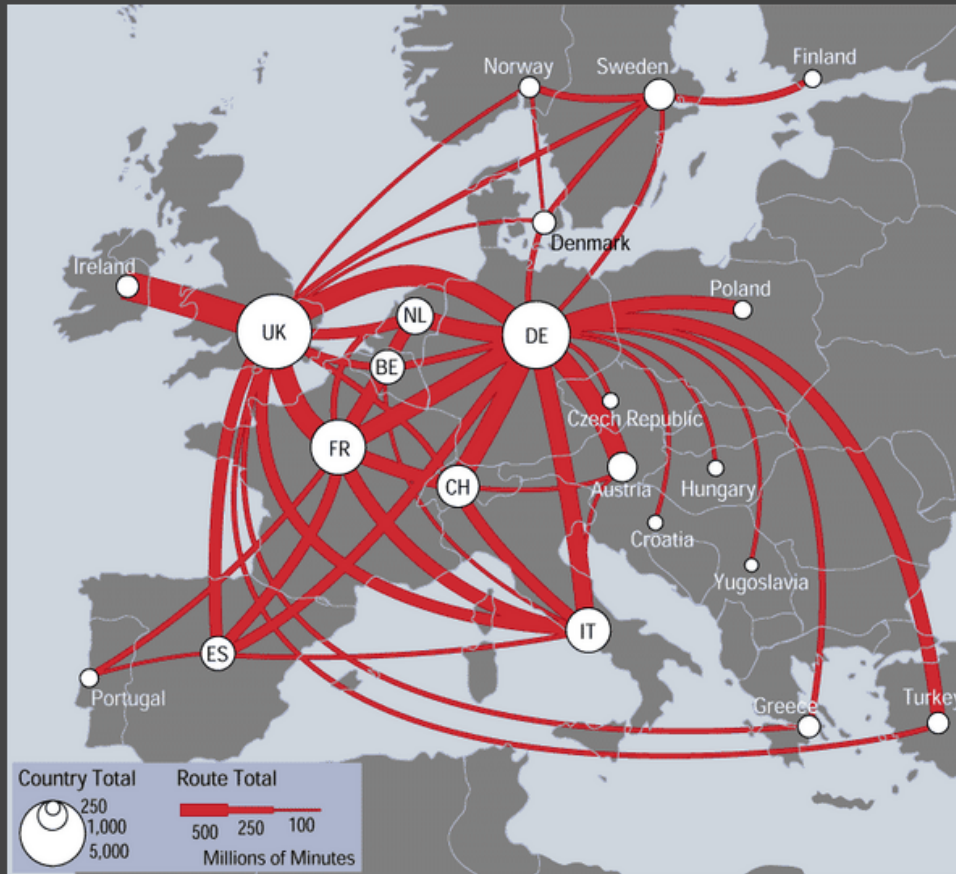
- Stevens power law



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

Dimensional dynamic range

linewidth: limited discriminability



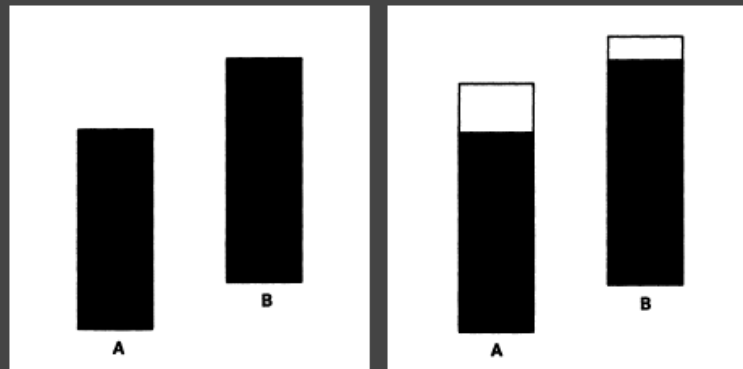
Weber's Law

ratio of increment threshold to background intensity is constant

- relative judgements within modality

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

Cleveland example: frame increases accuracy



Cleveland suggestions

dot chart over pie or bars

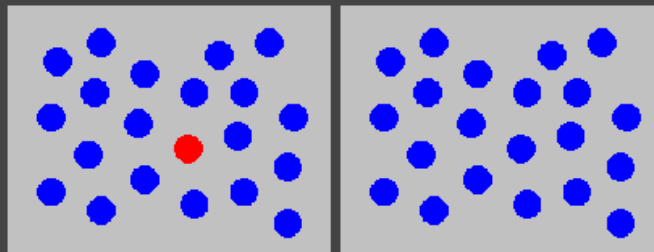
direct differences over superimposed curves

framed rectangles over shading on maps

Preattentive visual dimensions

color (hue) alone: preattentive

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

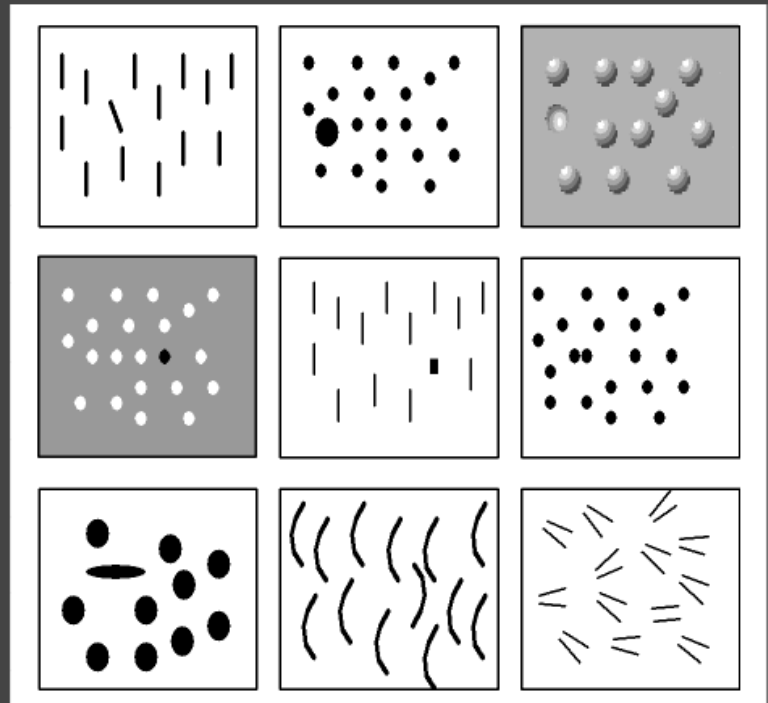


[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive visual dimensions

many preattentive dimensions of visual modality

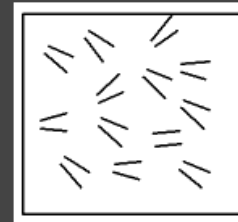
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction



Non-preattentive: parallelism

many preattentive dimensions of visual modality

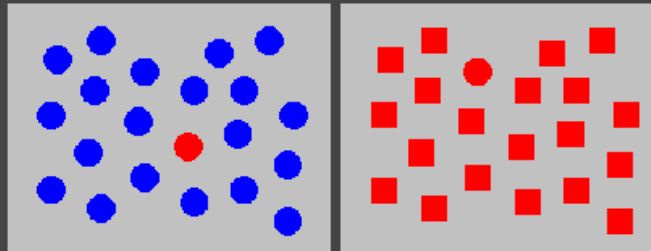
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction



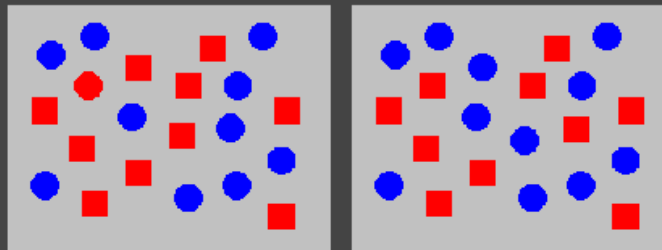
Preattentive visual dimensions

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

Gestalt Laws

principles of pattern perception

- "gestalt": German for "pattern"
- original proposed mechanisms wrong
- rules themselves still useful

Pragnatz

- simplest possibility wins

subsequent examples from

- Information Visualization: Perception for Design
- Colin Ware
- Morgan Kaufmann, 2000

Gestalt Principles

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

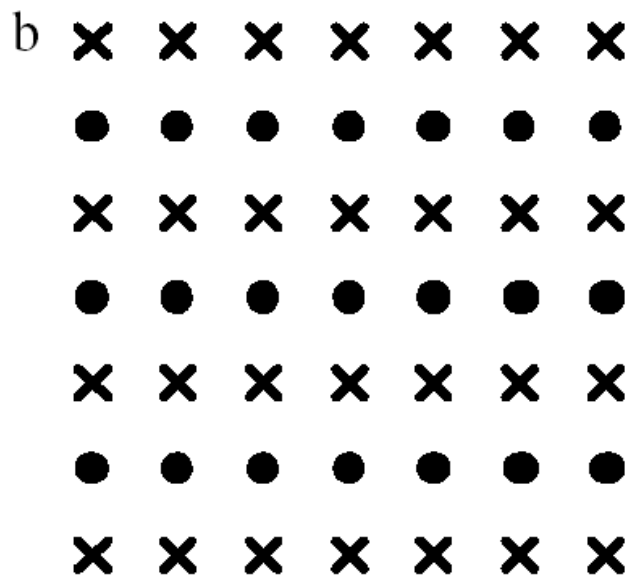
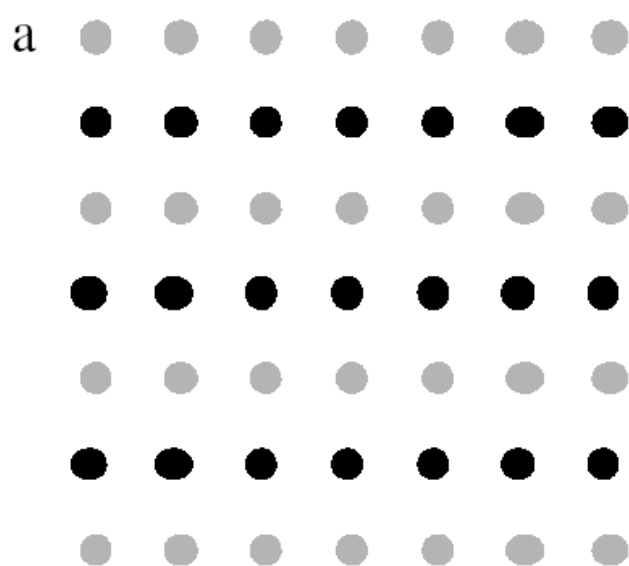
[psychlab1.hanover.edu/classes/Sensation/sld013.htm]

figure/ground, relative sizes

Proximity

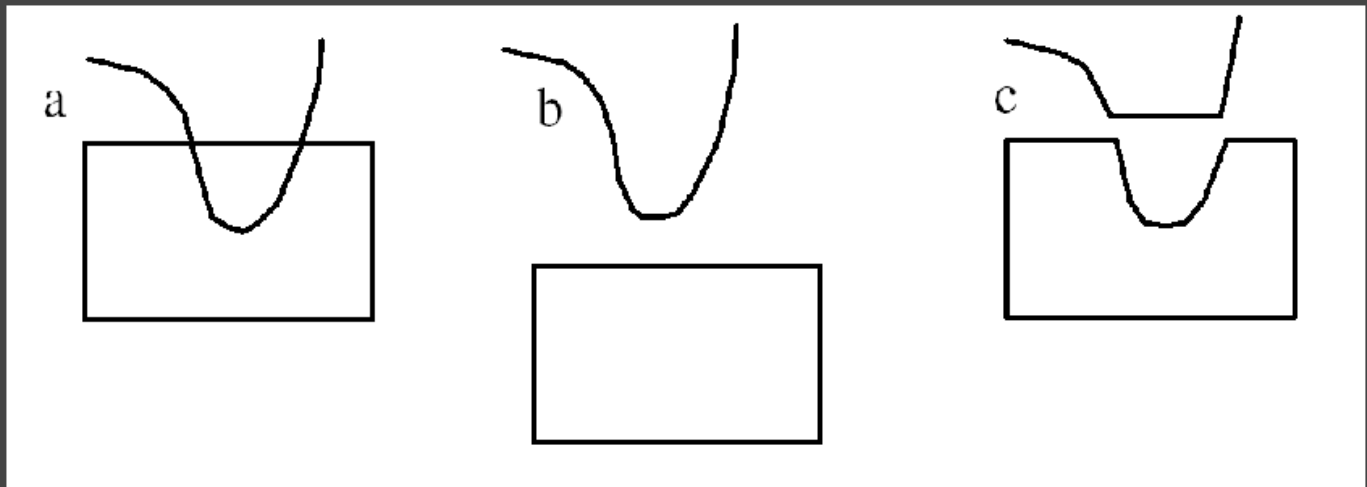


Similarity



Continuity

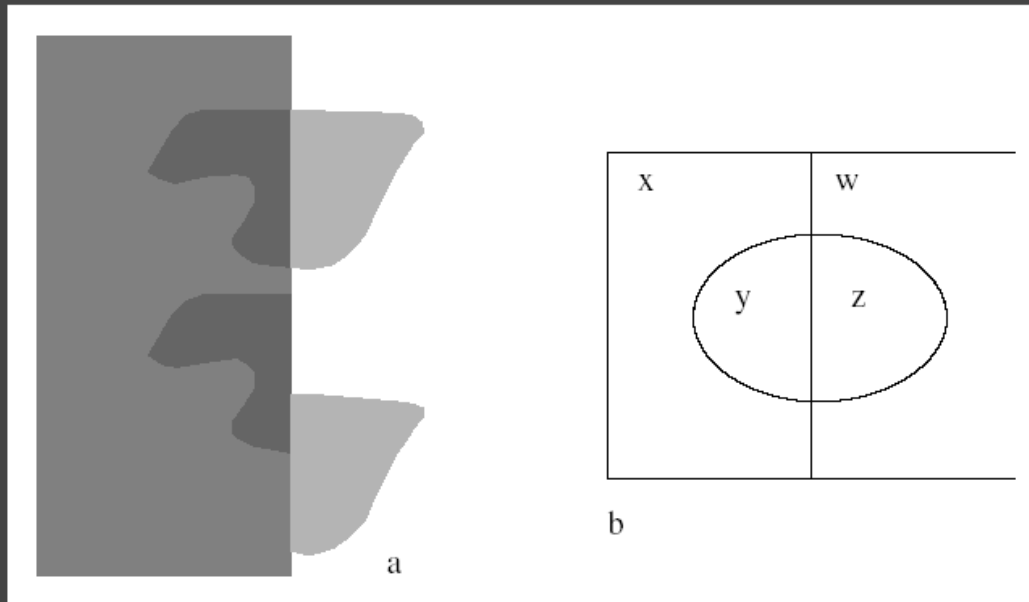
smooth not abrupt change
overrules proximity



Transparency

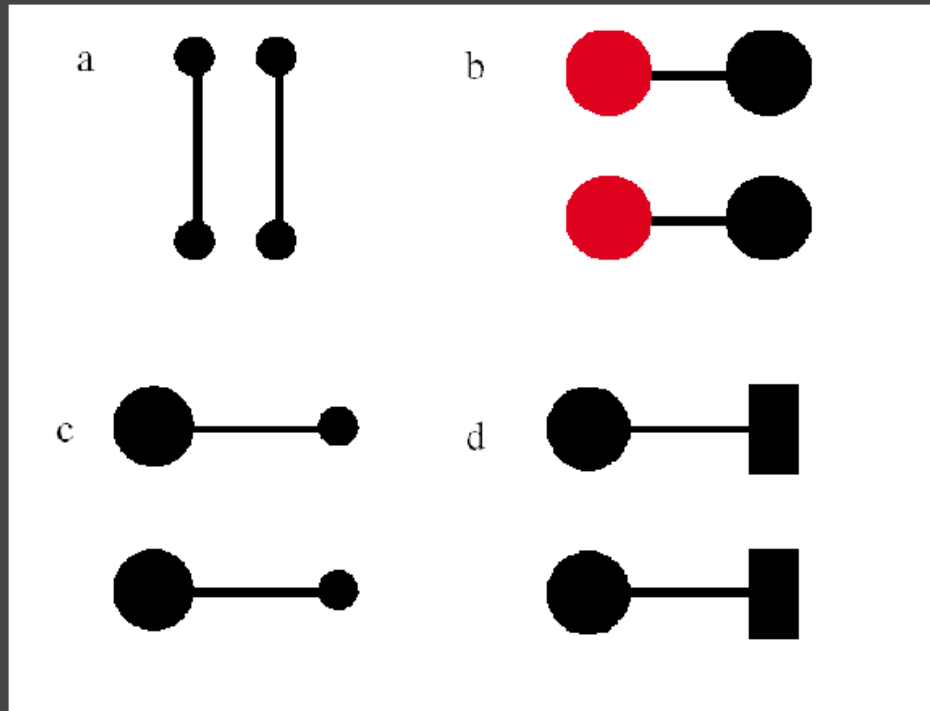
needed for perception

- continuity
- color correspondence



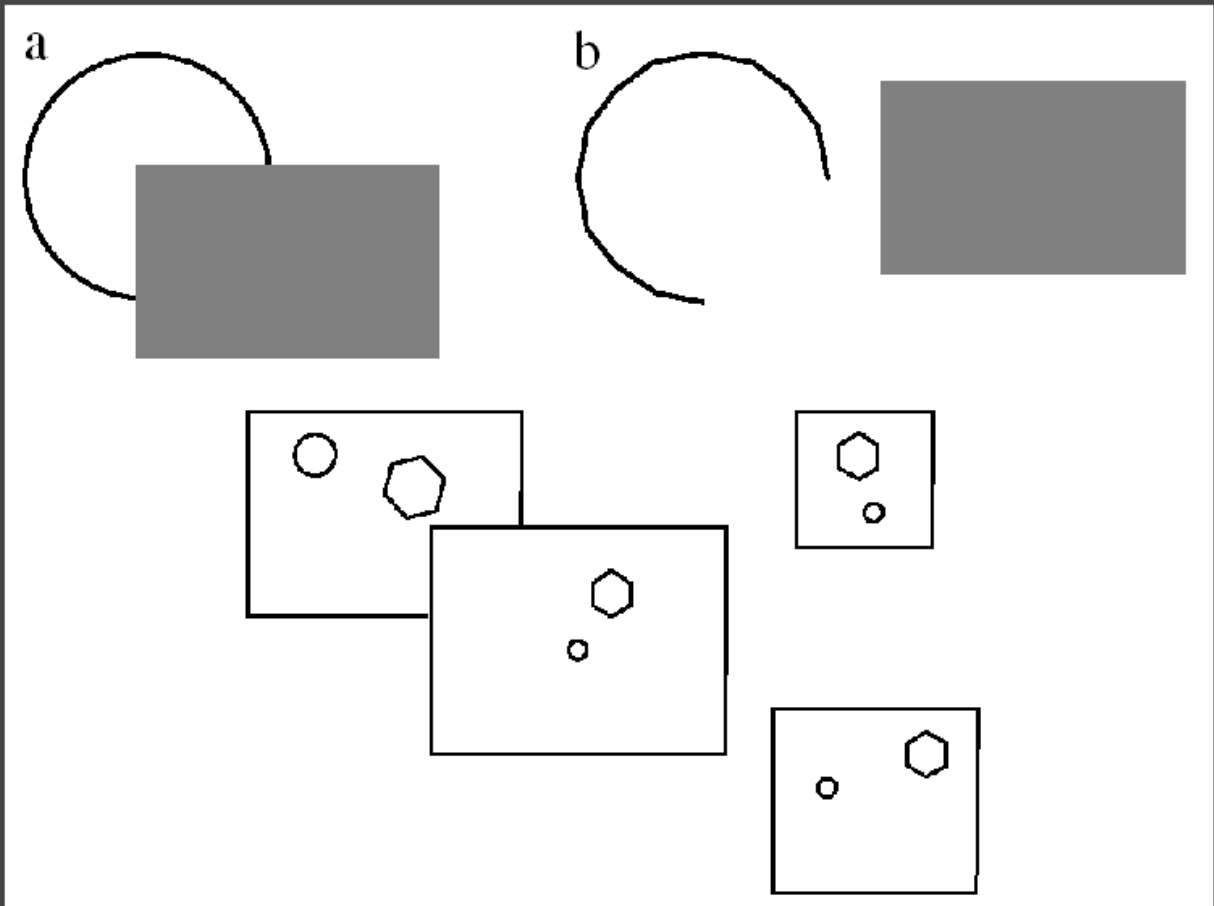
Connectedness

can overrule size, shape



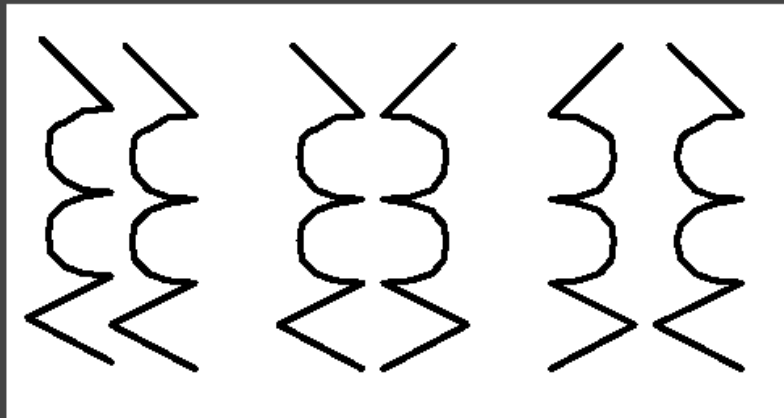
Closure

overrules proximity

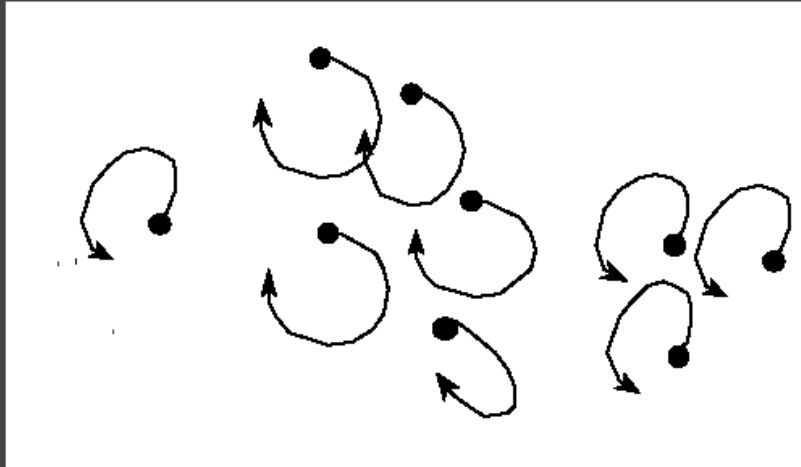


Symmetry

emphasizes relationships

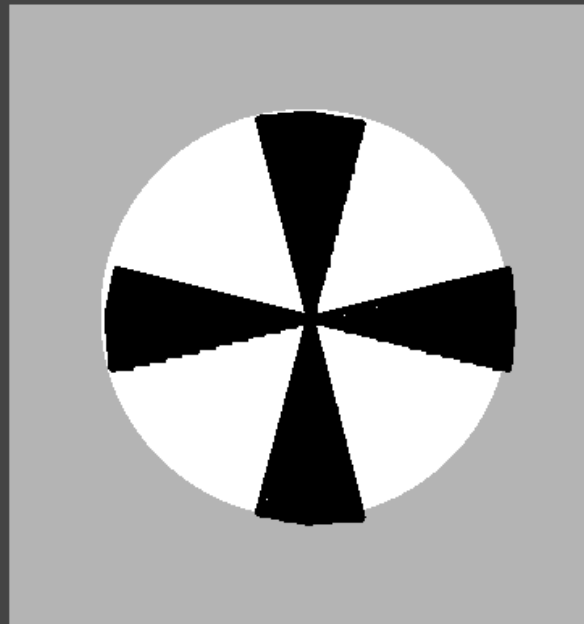


Common Fate



Relative Size

smaller components perceived as objects



Figure/Ground

determined by combination of previous laws



Graph Drawing Tension

node placement

close

- proximity

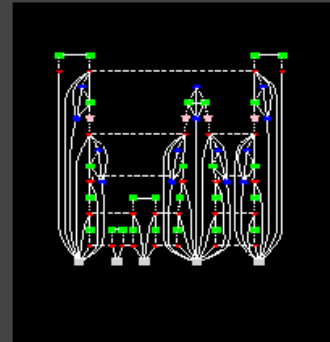
far

- visual popout of long edge

either

- connectedness

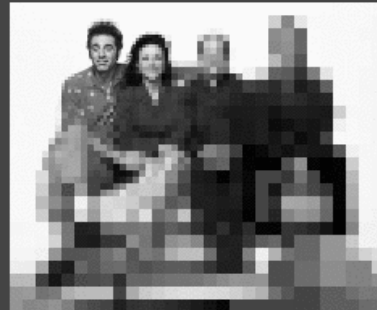
tradeoffs abound in infovis!



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

Foveal Vision

thumbnail at arm's length
small high resolution area on retina



Equal Legibility

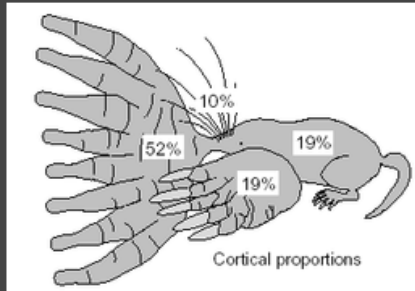
if fixated on center point



[psy.ucsd.edu/~sanstis/SABlur.html]

Foveal Touch

star-nosed mole

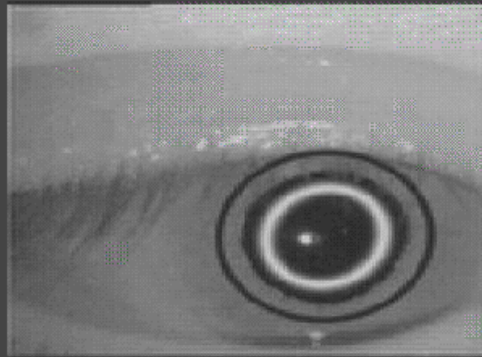


[www.nature.com/nsu/010329/010329-6.html
brain.nips.ac.jp/event/work131030/Catania_and_Kaas,_1997.pdf]

Eyes

saccades [video]

- fovea: 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