# Perception

## Lecture 5 CPSC 533C, Spring 2004

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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

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# 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
[...]

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# External representation example

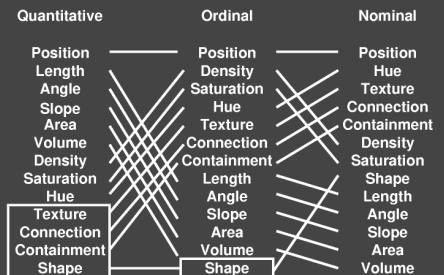offload cognition to visual systems
read off answer



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# Dimensional ranking

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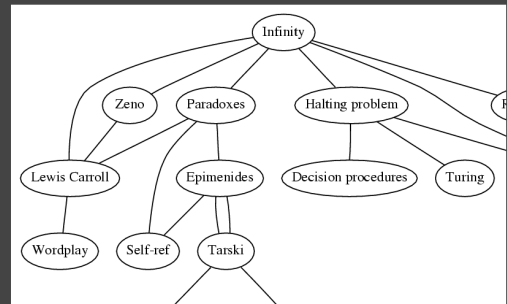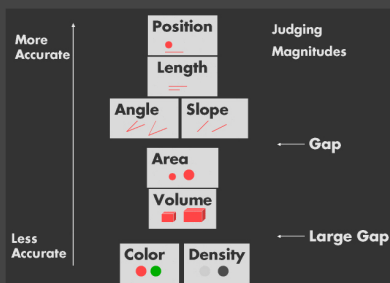
# Dimensional ranking varies by data type

spatial position best for all types



| Quantitative | Ordinal | Nominal |
|---|---|---|
| Position | Position | Position |
| Length | Density | Hue |
| Angle | Saturation | Texture |
| Slope | Hue | Connection |
| Area | Texture | Containment |
| Volume | Connection | Density |
| Density | Containment | Saturation |
| Saturation | Length | Shape |
| Hue | Angle | Length |
| Texture | Slope | Angle |
| Connection | Area | Slope |
| Containment | Volume | Area |
| Shape | Shape | Volume |

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## Cleveland's study

| | |
|---|---|
| **Position** | position along common scale |
| **Length** | positions along nonaligned scales |
| **Angle** | |
| **Slope** | length, direction, angle |
| **Area** | area |
| **Volume** | |
| **Density** | volume, curvature |
| **Saturation** | shading, color 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

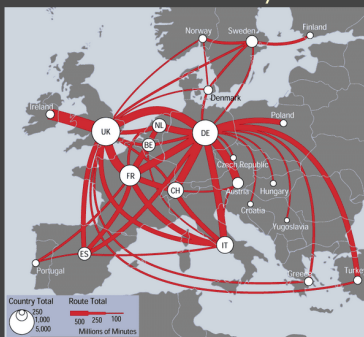sensory modalities not equally discriminable
· Stevens power law



$$S = I^p$$
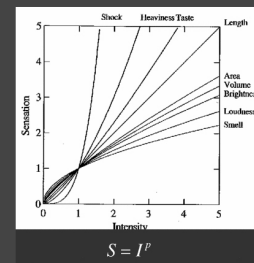
[Stevens, On the Theory of Scales of Measurement, Science 103:2684, 1946]

## Dimensional dynamic range

linewidth: limited discriminability
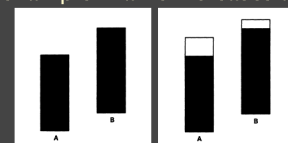


[mappa.mundi.net/maps/maps_014/telegeography.html]

## 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

## Cleveland suggestions

dot chart over pie or bars

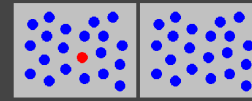direct differences over superimposed curves

framed rectangles over shading on maps

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## Preattentive visual dimensions

color (hue) alone: preattentive
· attentional system not invoked
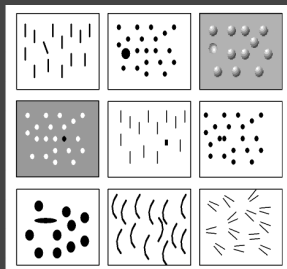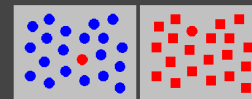· search speed independent of distractor count



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

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## 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



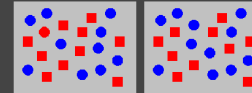[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP/PP.html]

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## Preattentive visual dimensions

color alone: preattentive
shape alone: preattentive



combined hue and shape: multimodal



· requires attention
· search speed linear with distractor count

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

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## Integral vs. separable dimensions



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

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

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## 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
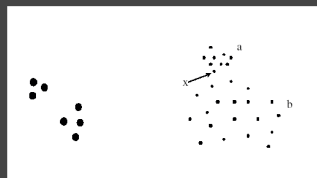· Morgan Kaufmann, 2000

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## Gestalt Principles

proximity, similarity,
continuity/connectedness/good continuation
closure, symmetry
common fate (things moving together)
[psychlab1.hanover.edu/classes/Sensation/sld013.htm]
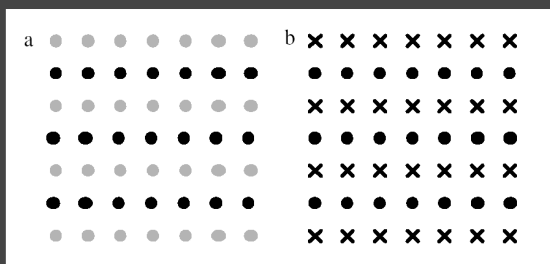
figure/ground, relative sizes
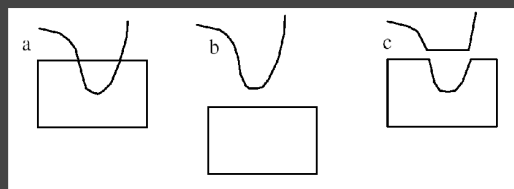
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## Proximity



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## Similarity



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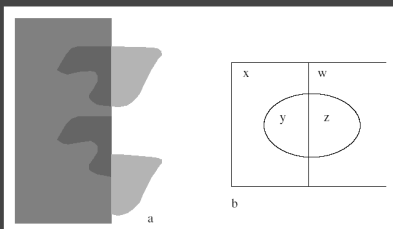## Continuity

smooth not abrupt change
overrules proximity



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## Transparency

needed for perception
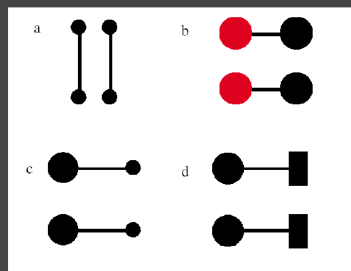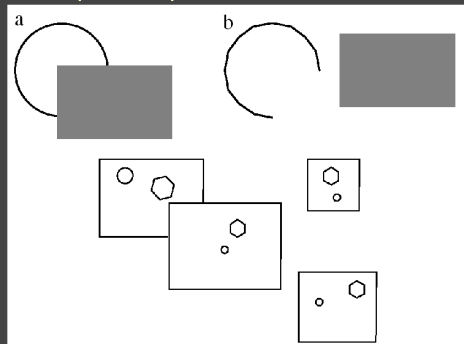· continuity
· color correspondence



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## Connectedness

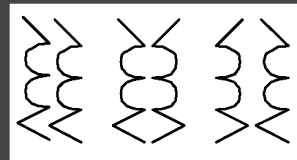can overrule size, shape



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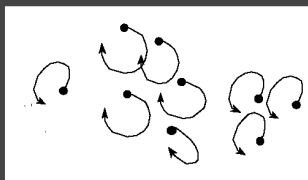
## Closure

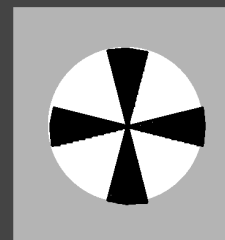overrules proximity

## Symmetry

emphasizes relationships

## Common Fate

## Relative Size

smaller components perceived as objects

## Figure/Ground

determined by combination of previous laws
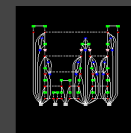
## Graph Drawing Tension

node placement

close
· proximity
far
· visual popout of long edge
either
· connectedness

tradeoffs abound in infovis!



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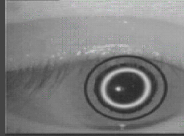
## Eyes

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/

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## Fovea

foveal vision
- · high resolution
- · thumbnail at arm's length

(foveal touch: star-nosed mole)



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

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## 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