Perception

Lecture 6 CPSC 533C, Fall 2004

29 Sep 2004

Tamara Munzner

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

```
  57
x 48
____
```


External Representation: multiplication

paper mental buffer

```
  57
x 48
____
```

[7*8=56]

External Representation: multiplication

paper mental buffer

```
   5
  57
x 48
____

   6
```

[7*8=56]

External Representation: multiplication

paper mental buffer

```
   5
  57
x 48
----
   6
```

[5*8=40 + 5 = 45]

External Representation: multiplication

paper mental buffer

```
  57
x 48
----
 456
```

[5*8=40 + 5 = 45]

External Representation: multiplication

paper mental buffer

```
  57
x 48
----
 456
```

[7*4=28]

External Representation: multiplication

paper mental buffer

```
   2
  57
x 48
----
 456
   8
```

[7*4=28]

External Representation: multiplication

paper mental buffer

```
   2
  57
x 48
----
 456
   8
```

[5*4=20 + 2 =22]

External Representation: multiplication

paper mental buffer

```
  57
x 48
----
 456
228
```

[5*4=20 + 2 =22]

External Representation: multiplication

paper mental buffer

```
  57
x 48
----

 456
228
----
  6
```


External Representation: multiplication

paper mental buffer

```
  57
x 48
----

 456
228          [8+5 = 13]
----
  6
```


External Representation: multiplication

paper mental buffer

```
  57
x 48
----
 1
 456
228          [8+5 = 13]
----
  36
```


External Representation: multiplication

paper mental buffer

```
  57
x 48
----
 1
 456
228          [4+2+1=7]
----
  36
```


External Representation: multiplication

paper mental buffer

```
  57
x 48
----

 456
258          [4+2+1=7]
----
 736
```


External Representation: multiplication

paper mental buffer

```
  57
x 48
----

 456
258
----
2736
```

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

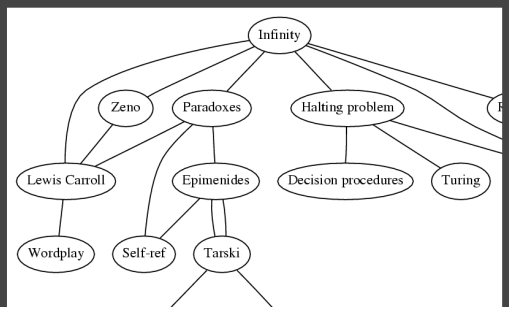
External Representation: topic graphs

[Godel, Escher, Bach. Hofstadter 1979]

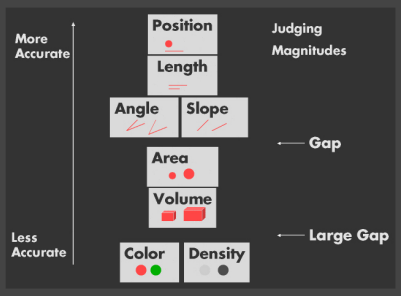
Paradoxes – Lewis Carroll
Turing – Halting problem
Halting problem – Infinity
Paradoxes – Infinity
Infinity – Lewis Carroll
Infinity – Unpredictably long searches
Infinity – Recursion
Infinity – Zeno
Infinity – Paradoxes
Lewis Carroll – Zeno
Lewis Carroll – Wordplay
Halting problem – Decision procedures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



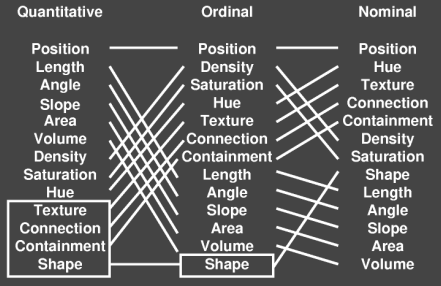
Dimensional ranking



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

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	volume, curvature
Density	shading, color saturation
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

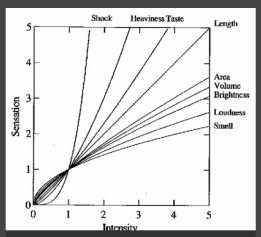
JND: just noticeable difference

increment where human detects change

average to create "subjective" scale

Nonlinear perception of magnitudes

sensory modalities not equally discriminable
- Stevens power law

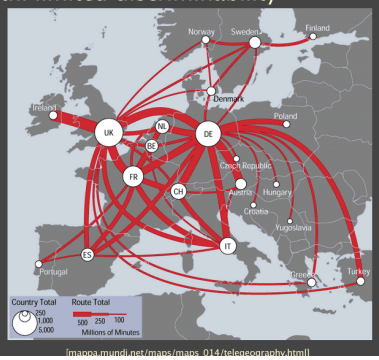


$$S = I^p$$

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

Dimensional dynamic range

linewidth: limited discriminability



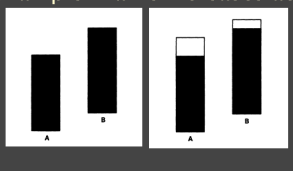
[mappa.mundi.net/maps/maps_014/telegeography.html]

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

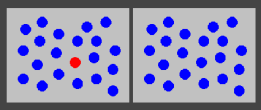
dot chart over pie or bars

direct differences over superimposed curves

framed rectangles over shading on maps

Preattentive visual dimensions

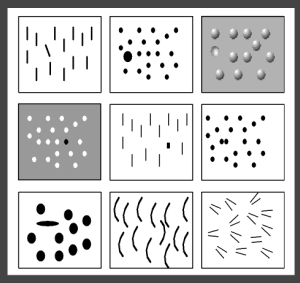
color (hue) alone: preattentive
- attentional system not invoked
- search speed independent of distractor count



[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]

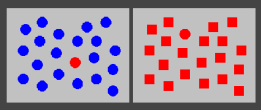
Non-preattentive: parallelism

many preattentive dimensions of visual modality
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction

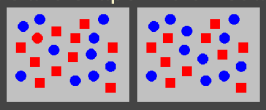
[Chris Healey, Preattentive Processing, www.csc.ncsu.edu/faculty/healey/PP/PP.html]

Preattentive visual dimensions

color alone: preattentive
shape alone: preattentive



combined hue and shape: multimodal



- requires attention
- search speed linear with distractor count

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

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

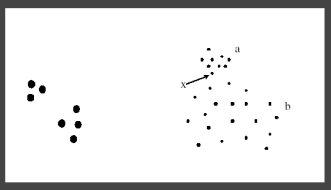
subsequent examples from
- Information Visualization: Perception for Design
- Colin Ware
- Morgan Kaufmann, 2000

Gestalt Principles

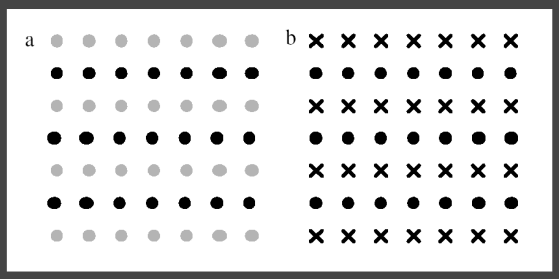
proximity, similarity,
continuity/connectedness/good continuation
closure, symmetry
common fate (things moving together)
[psychlab1.hanover.edu/classes/Sensation/sld013.htm]

figure/ground, relative sizes

Proximity

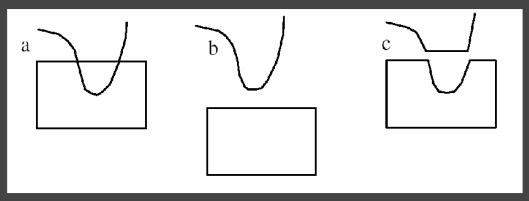


Similarity



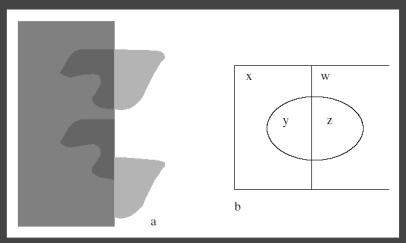
Continuity

smooth not abrupt change
overrules proximity



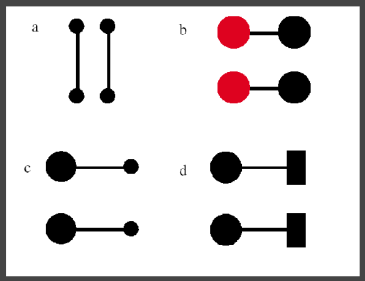
Transparency

needed for perception
- continuity
- color correspondence



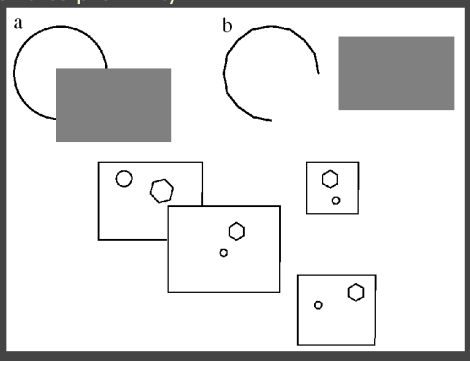
Connectedness

can overrule size, shape



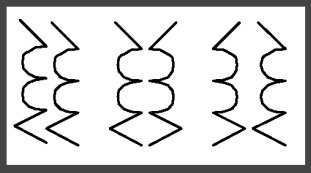
Closure

overrules proximity

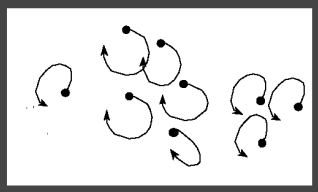


Symmetry

emphasizes relationships

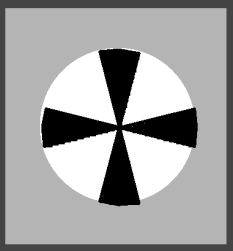


Common Fate



Relative Size

smaller components perceived as objects



Figure/Ground

determined by combination of previous laws

Graph Drawing Tension

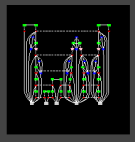
node placement

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

[www.cs.nyu.edu/~yap/visual/home/proj/foveation.html
cat.cpc.utexas.edu/examples_foveated.html]

Equal Legibility

if fixated on center point

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

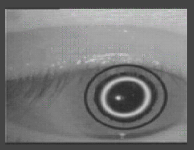
Foveal Touch

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