CS448B :: 5 Oct 2009

Graphical Perception

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Graphical Perception

Graphical Perception

The ability of viewers to interpret visual (graphical) encodings of information and thereby decode information in graphs.

Which best encodes quantities?

Position
Length
Area
Volume
Value (Brightness)
Color Hue
Orientation (Angle)
Shape

Mackinlay's ranking of encodings

QUANTITATIVE	ORDINAL	NOMINAL
Position	Position	Position
Length	Density (Val)	Color Hue
Angle	Color Sat	Texture
Slope	Color Hue	Connection
Area (Size)	Texture	Containment
Volume	Connection	Density (Val)
Density (Val)	Containment	Color Sat
Color Sat	Length	Shape
Color Hue	Angle	Length
Texture	Slope	Angle
Connection	Area (Size)	Slope
Containment	Volume	Area
Shape	Shape	Volume

Topics

- Signal Detection
- Magnitude Estimation
- Pre-Attentive Visual Processing
- Using Multiple Visual Encodings
- Gestalt Grouping
- Change Blindness

Detection

Detecting Brightness

Which is brighter?

Detecting Brightness

(128, 128, 128)

(144, 144, 144)

Which is brighter?

Detecting Brightness

Which is brighter?

Detecting Brightness

(134, 134, 134)

(128, 128, 128)

Which is brighter?

Just Noticeable Difference

JND (Weber's Law)

$$\Delta S = k\frac{\Delta I}{I}$$

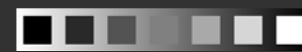
Ratios more important than magnitude

Most continuous variation in stimuli perceived in discrete steps

Information in color and value

Value is perceived as ordered

∴ Encode ordinal variables (O)



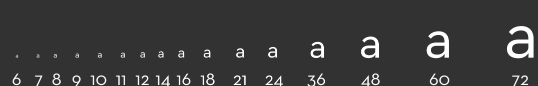
∴ Encode continuous variables (Q) [not as well]

Hue is normally perceived as unordered

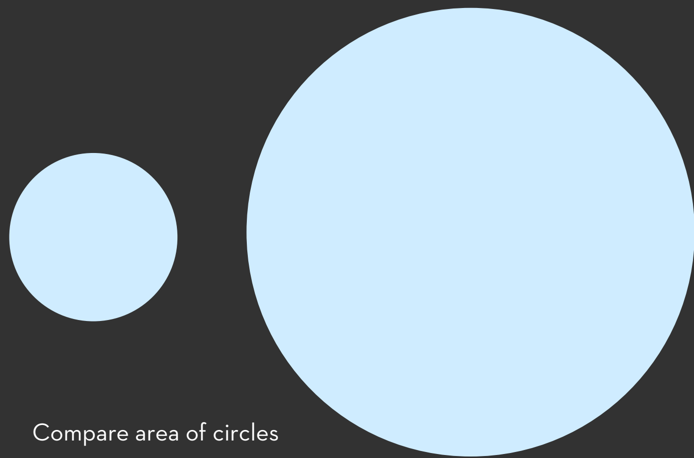
∴ Encode nominal variables (N) using color

Steps in font size

Sizes standardized in 16th century



Estimating Magnitude

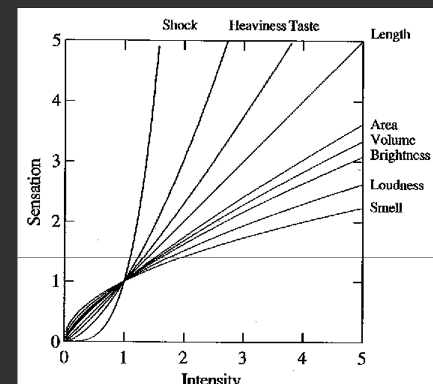


Compare area of circles

Steven's Power Law

$$S = I^p$$

p < 1 : underestimate
p > 1 : overestimate



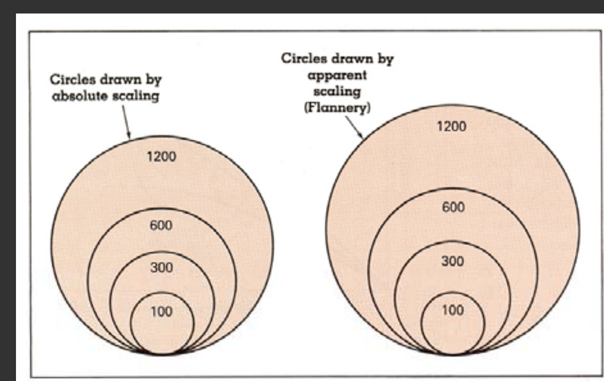
[graph from Wilkinson 99, based on Stevens 61]

Exponents of power law

Sensation	Exponent
Loudness	0.6
Brightness	0.33
Smell	0.55 (Coffee) - 0.6 (Heptane)
Taste	0.6 (Saccharine) -1.3 (Salt)
Temperature	1.0 (Cold) – 1.6 (Warm)
Vibration	0.6 (250 Hz) – 0.95 (60 Hz)
Duration	1.1
Pressure	1.1
Heaviness	1.45
Electic Shock	3.5

[Psychophysics of Sensory Function, Stevens 61]

Apparent magnitude scaling

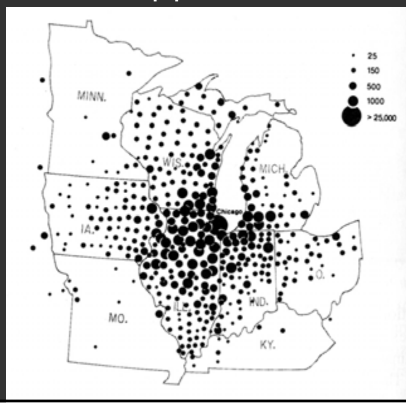


[Cartography: Thematic Map Design, Figure 8.6, p. 170, Dent, 96]

$S = 0.98A^{0.87}$ [from Flannery 71]

Proportional symbol map

Newspaper Circulation



[Cartography: Thematic Map Design, Figure 8.8, p. 172, Dent, 96]

Graduated sphere map

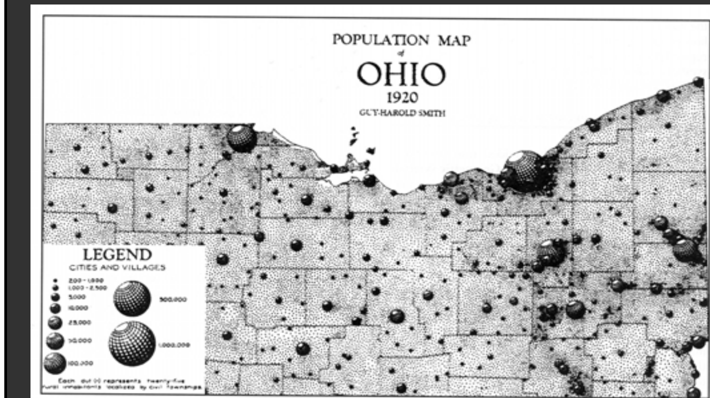


FIGURE 7.4. An eye-catching map created using three-dimensional geometric symbols. (After Smith, 1928. First published in *The Geographical Review*, 18(3), plate 4. Reprinted with permission of the American Geographical Society.)

Cleveland and McGill

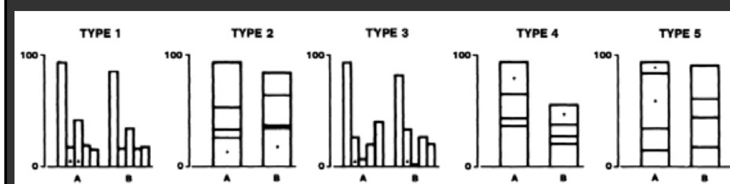


Figure 4. Graphs from position–length experiment.

[Cleveland and McGill 84]

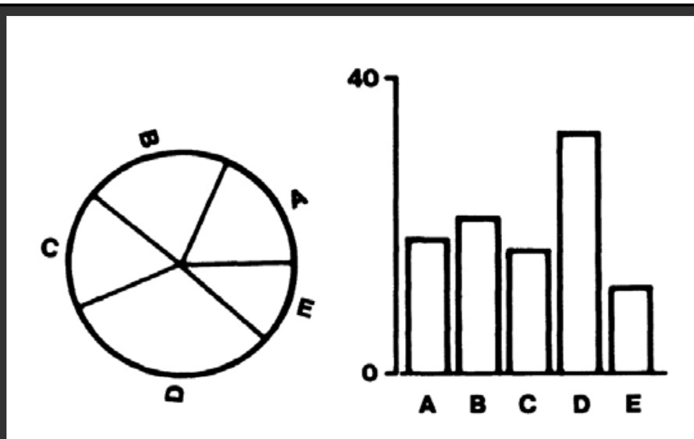


Figure 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]

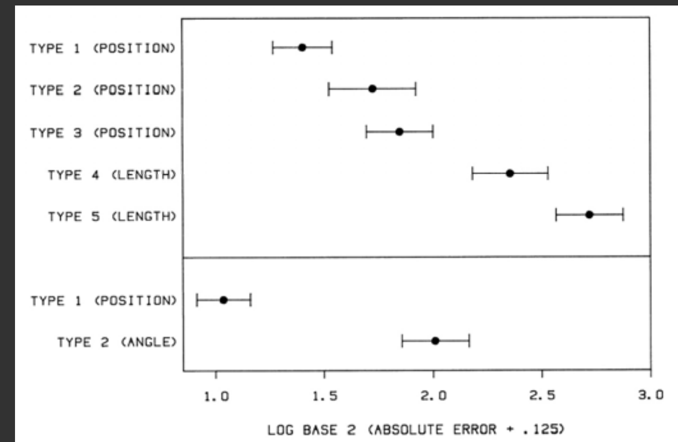


Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

[Cleveland and McGill 84]

Relative magnitude estimation

Most accurate

- Position (common) scale
- Position (non-aligned) scale
- Length
- Slope
- Angle
- Area
- Volume
- Color hue-saturation-density

Least accurate

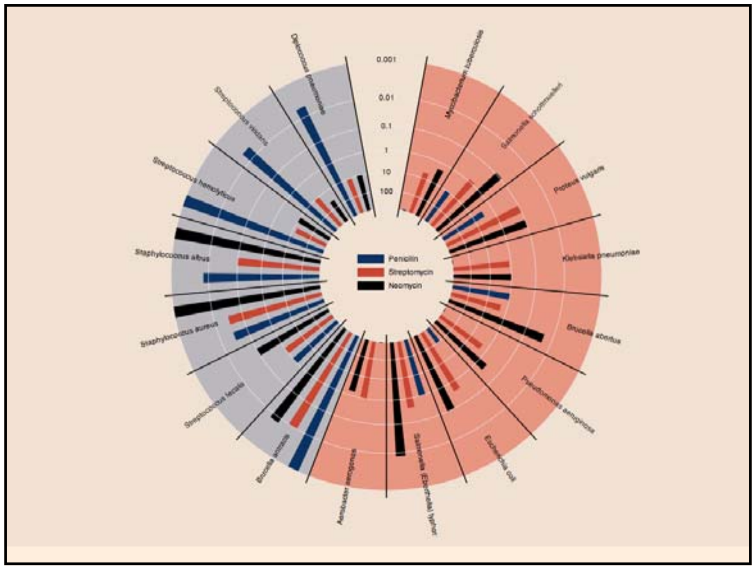
Mackinlay's ranking of encodings

QUANTITATIVE	ORDINAL	NOMINAL
Position	Position	Position
Length	Density (Value)	Color Hue
Angle	Color Sat	Texture
Slope	Color Hue	Connection
Area (Size)	Texture	Containment
Volume	Connection	Density (Value)
Density (Value)	Containment	Color Sat
Color Sat	Length	Shape
Color Hue	Angle	Length
Texture	Slope	Angle
Connection	Area (Size)	Slope
Containment	Volume	Area
Shape	Shape	Volume

Administrivia

Assignment 1

Scores and comments will be returned shortly

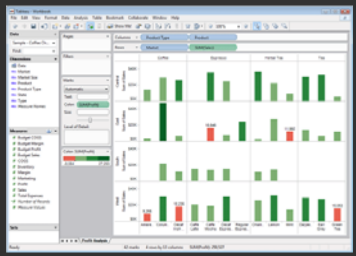


Assignment 2: Visual Data Analysis

Use visualization software (Tableau) to form & answer questions

First steps:

- Step 1: Pick a domain
- Step 2: Pose questions
- Step 3: Find Data
- Iterate



Create visualizations

- Interact with data
- Refine your questions

Make wiki notebook

- Keep record of your analysis
- Prepare a final graphic and caption

Due by *end of day* on **Monday, October 12**

Protovis Tutorial

Creating interactive visualizations in JavaScript using the Protovis framework (protovis.org)

Friday October 9, 4-5:30pm

104 Gates

Led by Mike Bostock

Next Week (10/12 & 10/14)

Jeff and Mike will out attending VisWeek.

Mon 10/12: **Color**

Guest lecturer: Jason Chuang, Stanford CS

Wed 10/14: **Flash/Flare Tutorial**

Tutorial leader: Jason Chuang, Stanford CS

Pre-attentive vs. Attentive Visual Processing

How many 3's

```
12817687561389765469845069856049828267628
98098584582245098564589450984509809435858
90910302099059595957725646750506789045679
88457898098216776548763649085609129496868
```

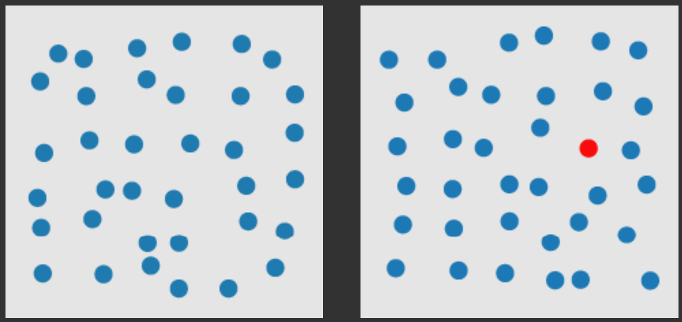
[based on slide from Stasko]

How many 3's

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

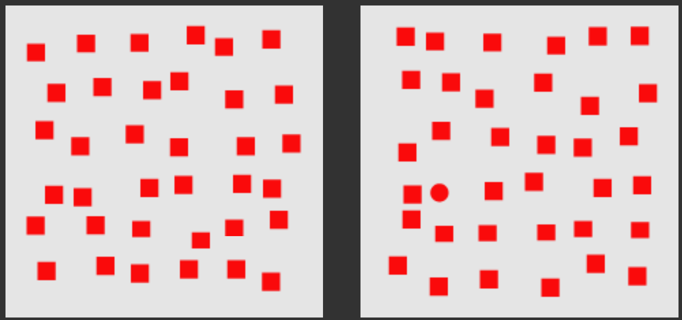
[based on slide from Stasko]

Visual pop-out: Color



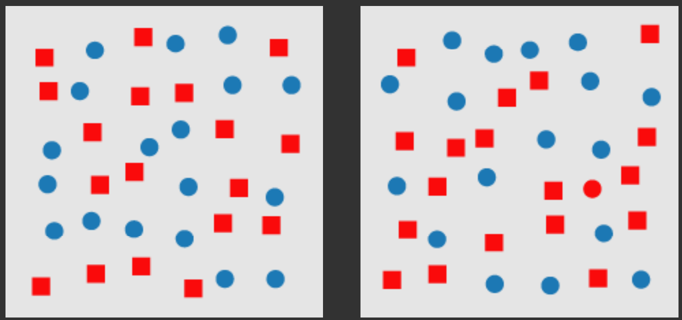
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Visual pop-out: Shape



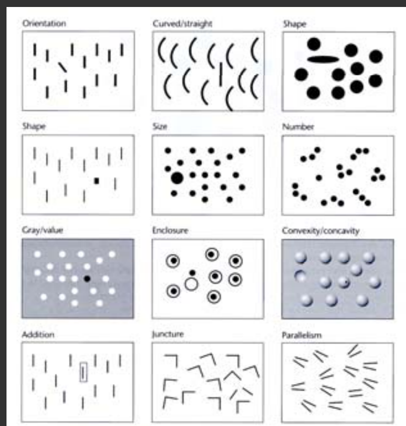
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Feature Conjunctions



http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Pre-Attentive features



[Information Visualization. Figure 5. 5 Ware 04]

More Pre-attentive Features

Line (blob) orientation	Julesz & Bergen [1983]; Wolfe et al. [1992]
Length	Triesman & Gormican [1988]
Width	Julesz [1985]
Size	Triesman & Gelade [1980]
Curvature	Triesman & Gormican [1988]
Number	Julesz [1985]; Trick & Pylyshyn [1994]
Terminators	Julesz & Bergen [1983]
Intersection	Julesz & Bergen [1983]
Closure	Enns [1986]; Triesman & Souther [1985]
Colour (hue)	Nagy & Sanchez [1990, 1992]; D'Zmura [1991]; Kawai et al. [1995]; Bauer et al. [1996]
Intensity	Beck et al. [1983]; Triesman & Gormican [1988]
Flicker	Julesz [1971]
Direction of motion	Nakayama & Silverman [1986]; Driver & McLeod [1992]
Binocular lustre	Wolfe & Franzel [1988]
Stereoscopic depth	Nakayama & Silverman [1986]
3-D depth cues	Enns [1990]
Lighting direction	Enns [1990]

http://www.csc.ncsu.edu/faculty/healey/PP/index.html

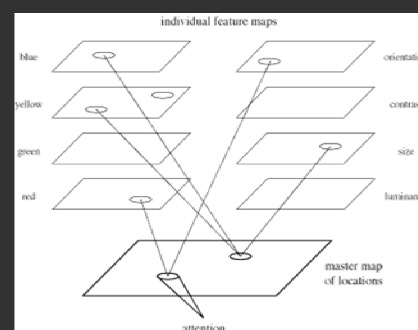
Pre-attentive conjunctions

Spatial conjunctions are often pre-attentive

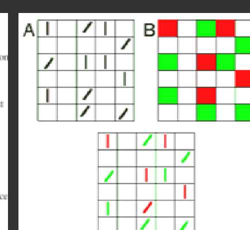
- Motion and 3D disparity
- Motion and color
- Motion and shape
- 3D disparity and color
- 3D disparity and shape

Most conjunctions are not pre-attentive

Feature-integration theory



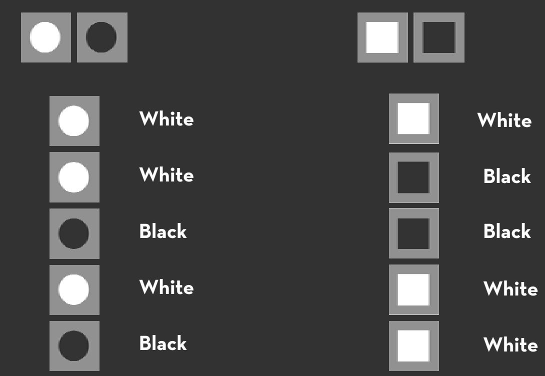
Treisman's feature integration model [Healey 04]



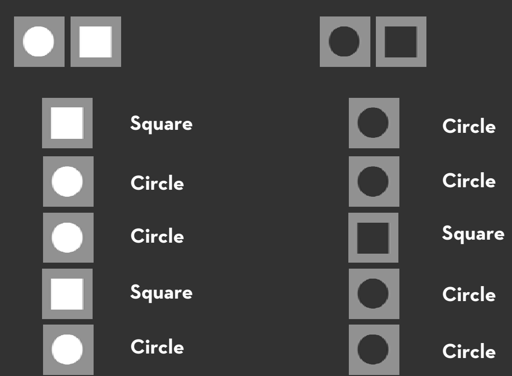
Feature maps for orientation & color [Green]

Multiple Attributes

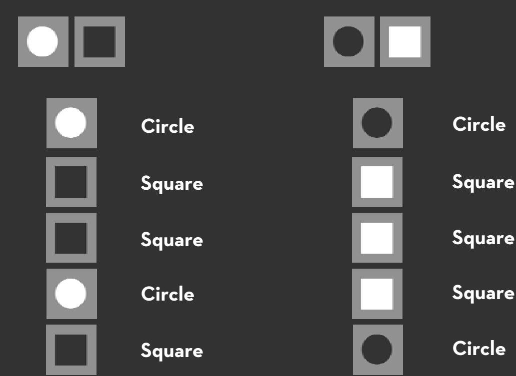
One-dimensional: Lightness



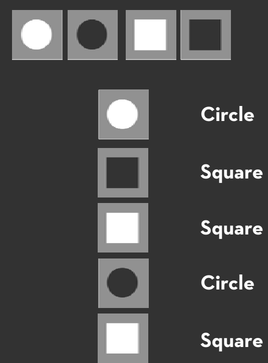
One-dimensional: Shape



Correlated dims: Shape or lightness



Orthogonal dims: Shape & lightness



Speeded Classification

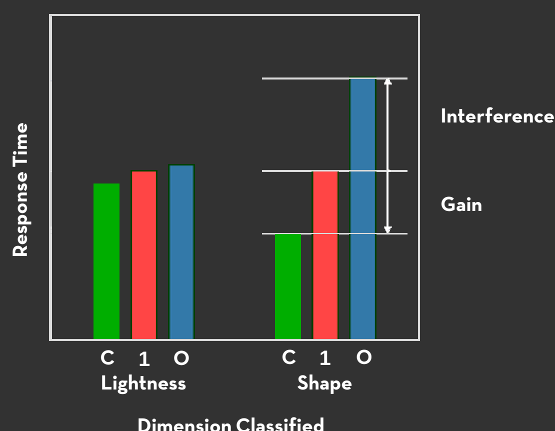
Redundancy Gain

Facilitation in reading one dimension when the other provides redundant information

Filtering Interference

Difficulty in ignoring one dimension while attending to the other

Speeded Classification



Types of Dimensions

Integral Filtering interference and redundancy gain

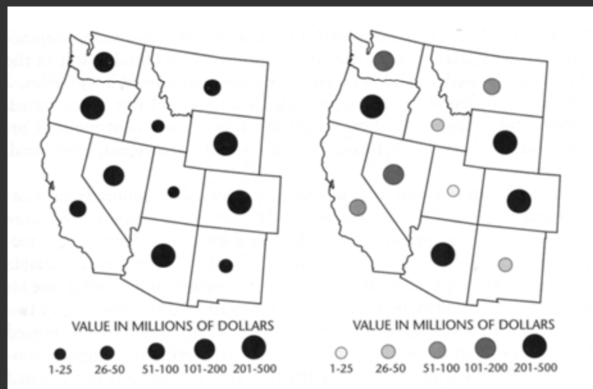
Separable No interference or gain

Configural Interference, “condensation”, no redundancy gain

Asymmetrical One dim separable from other, not vice versa

- Example: The Stroop effect – color naming is influenced by word identity, but word naming is not influenced by color

Size and Value



W. S. Dobson, Visual information processing and cartographic communication: The role of redundant stimulus dimensions, 1983 (reprinted in MacEachren, 1995)

Orientation and Size (Single Mark)

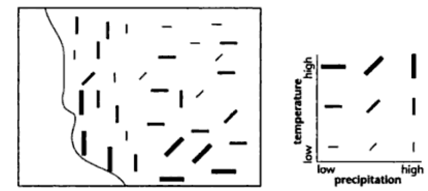


FIGURE 3.36. A map of temperature and precipitation using symbol size and orientation to represent data values on the two variables.

How well can you see temperature or precipitation?

Is there a correlation between the two?

[MacEachren 95]

Shape and Size (Single Mark)

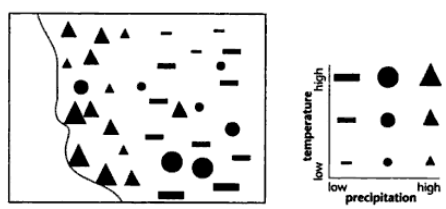


FIGURE 3.40. The bivariate temperature–precipitation map of Figure 3.36, this time using point symbols that vary in shape and size to represent the two quantities.

Easier to see one shape across multiple sizes than one size of across multiple shapes?

[MacEachren 95]

Length and Length (Single Mark)

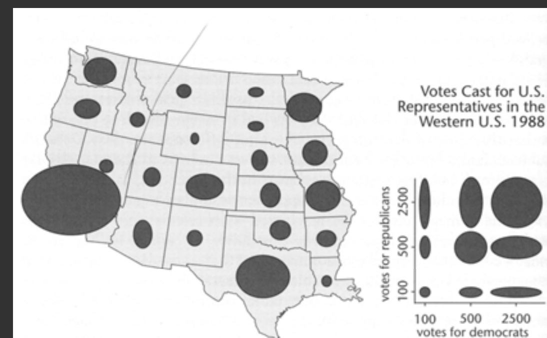


FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

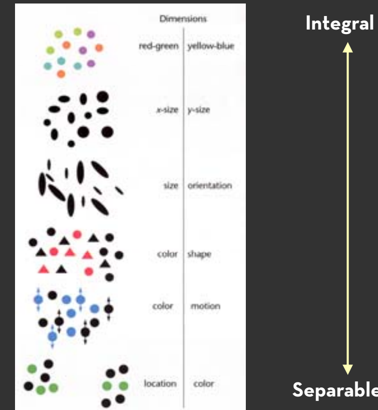
[MacEachren 95]

Angle and Angle (Composed Marks)

FIGURE 3.39. Bivariate map of NO_3 and SO_4 trends. The original Carr et al. version of this map used a wheel with eight spokes, rather than a simple dot, as the center of each glyph. When large enough, this added feature facilitates judgment of specific values. *After Carr et al. (1992, Fig. 7a, p. 234). Adapted by permission of the American Congress on Surveying and Mapping.*

[MacEachren 95]

Summary of Integral-Separable



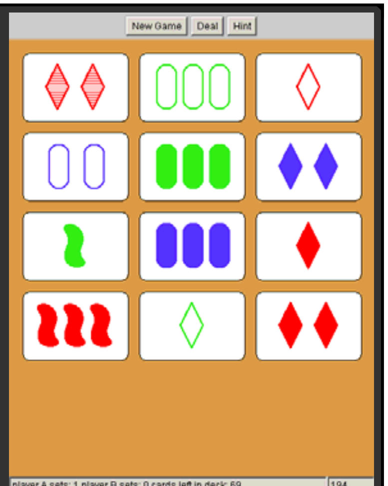
[Figure 5.25, Color Plate 10, Ware 2000]

Set

Each card has 4 features:

- Color
- Symbol
- Number
- Shading/Texture

A set consists of 3 cards in which each feature is the SAME or DIFFERENT on each card.



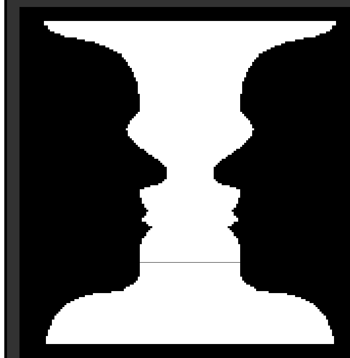
Adrien Treuille's applet
http://www.cs.washington.edu/homes/treuille/resc/set

Gestalt Grouping

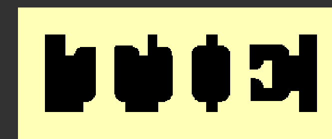
Principles

- Figure/Ground
- Proximity
- Similarity
- Symmetry
- Connectedness
- Continuity
- Closure
- Common Fate
- Transparency

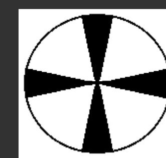
Figure/Ground



Ambiguous



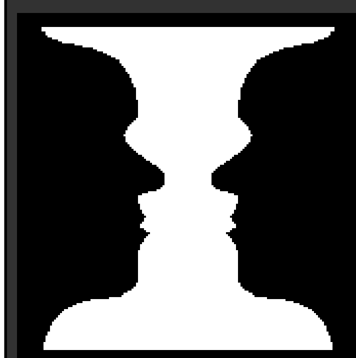
Principle of surroundedness



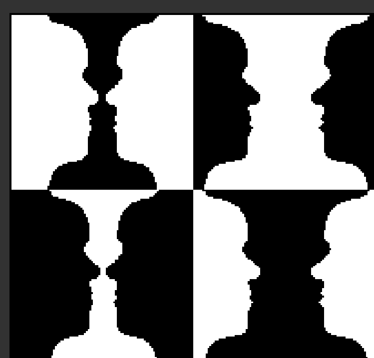
Principle of relative size

http://www.aber.ac.uk/media/Modules/MC10220/visper07.html

Figure/Ground



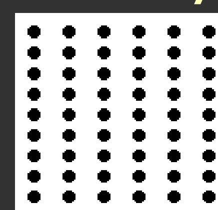
Ambiguous

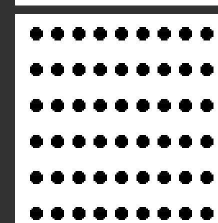


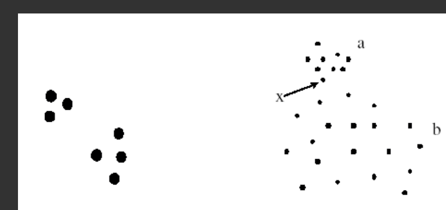
Unambiguous (?)

http://www.aber.ac.uk/media/Modules/MC10220/visper07.html

Proximity

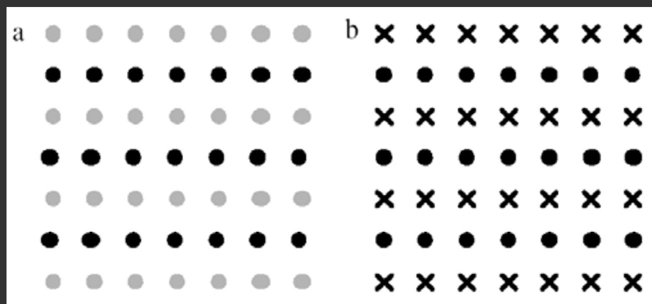






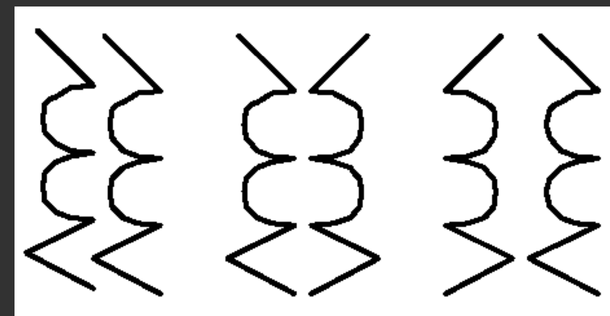
[Ware 00]

Similarity



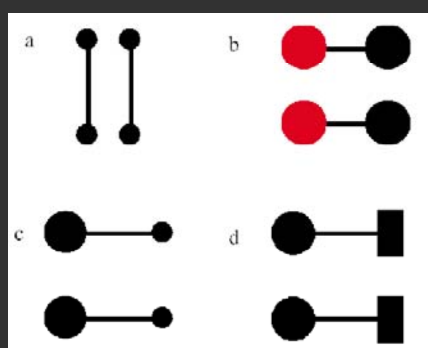
Rows dominate due to similarity [from Ware 04]

Symmetry



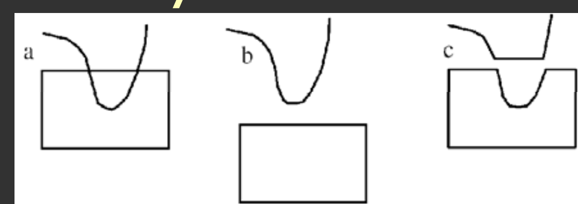
Bilateral symmetry gives strong sense of figure [from Ware 04]

Connectedness

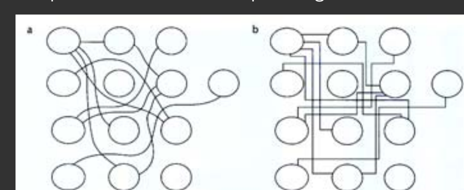


Connectedness overrules proximity, size, color shape [from Ware 04]

Continuity

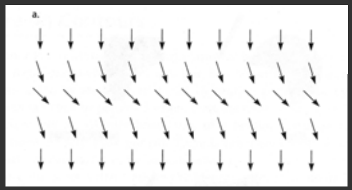


We prefer smooth not abrupt changes [from Ware 04]

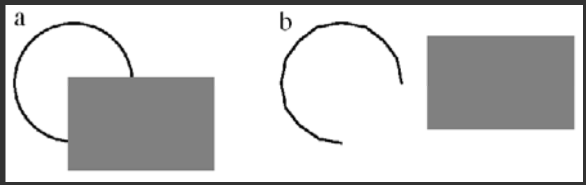


Connections are clearer with smooth contours [from Ware 04]

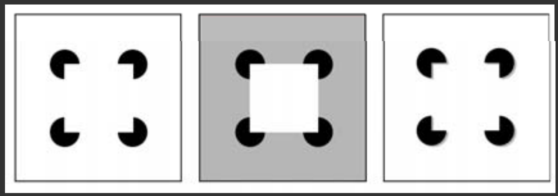
Continuity: Vector fields



Closure

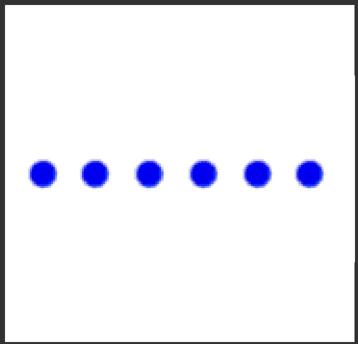


We see a circle behind a rectangle, not a broken circle [from Ware 04]



Illusory contours [from Durand 02]

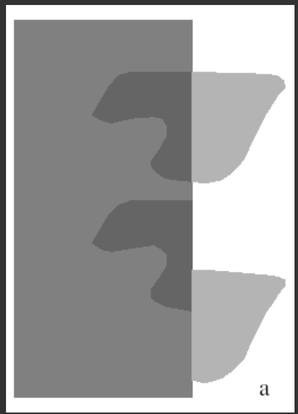
Common Fate



Dots moving together are grouped

http://coe.sdsu.edu/eet/articles/visualperc1/start.htm

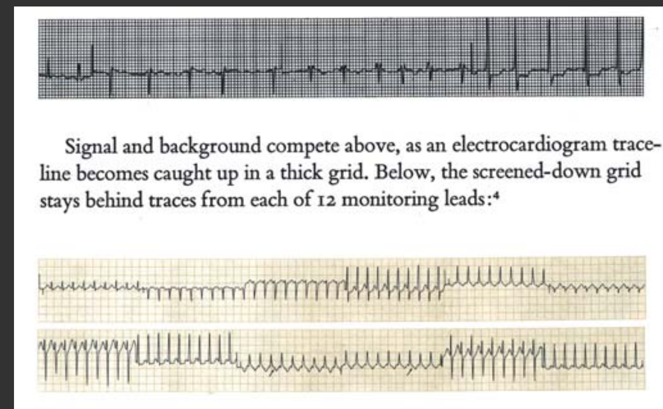
Transparency



Requires continuity and proper color correspondence [from Ware 04]

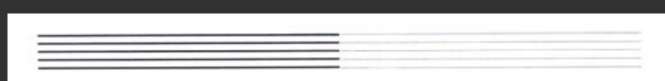
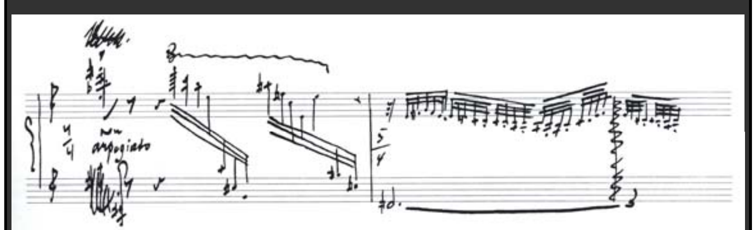
Layering and Small Multiples

Layering: Gridlines


Signal and background compete above, as an electrocardiogram trace-line becomes caught up in a thick grid. Below, the screened-down grid stays behind traces from each of 12 monitoring leads:[4]

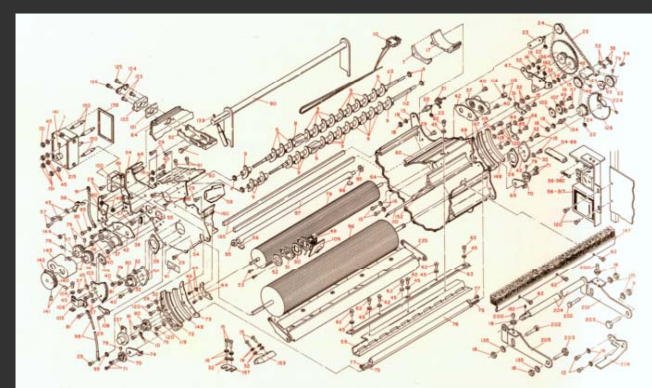
Electrocardiogram tracelines [from Tufte 90]

Layering: Gridlines



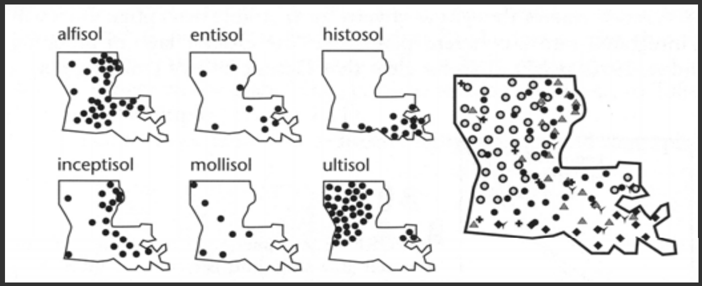
Stravinsky score [from Tufte 90]

Layering: color and line width



IBM Series III Copier [from Tufte 90]

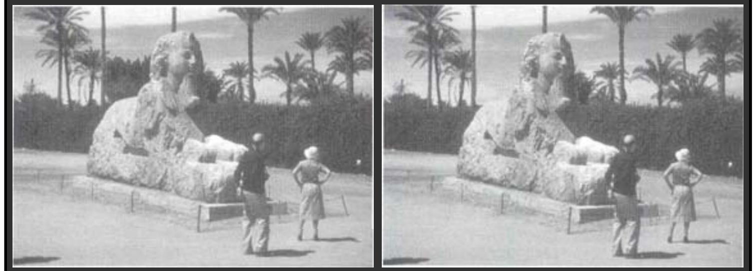
Small Multiples



[Figure 2.11, p. 38, MacEachren 95]

Change Blindness

Change Blindness



[Example from Palmer 99, originally due to Rock]

Change detection

Change detection

Demonstrations

http://www.psych.ubc.ca/~rensink/flicker/download/
http://www.dothetest.co.uk/

Summary

Choosing effective visual encodings requires knowledge of visual perception

Visual features/attributes

- Individual attributes often pre-attentive
- Multiple attributes may be separable, often integral

Gestalt principles provide high-level guidelines

We don't always see everything that is there