Perception

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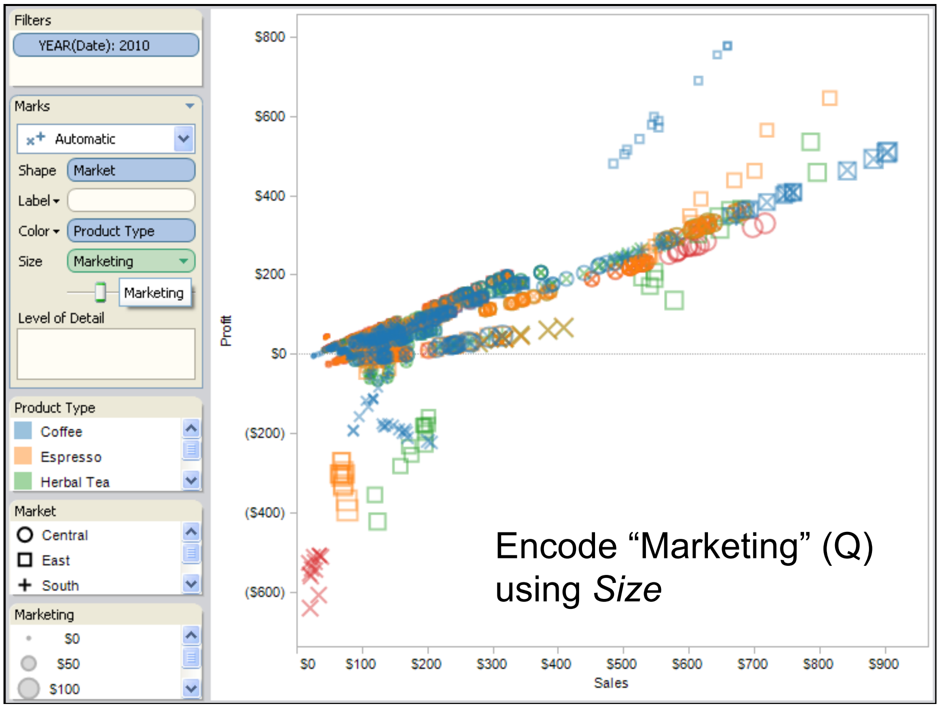
CS 294-10: Visualization
Fall 2014

Multidimensional Visualization

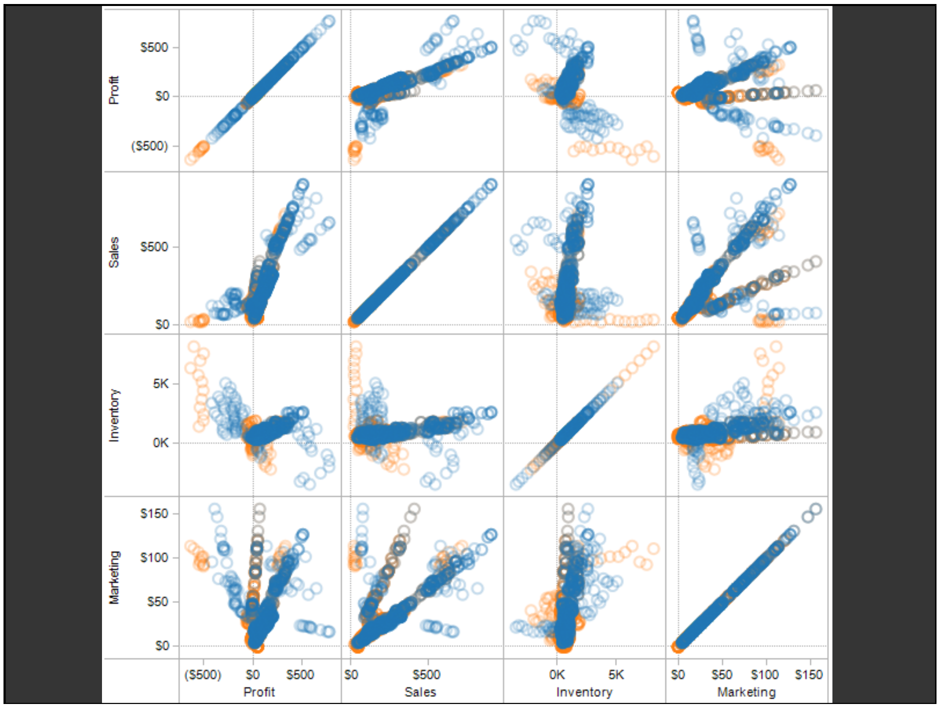


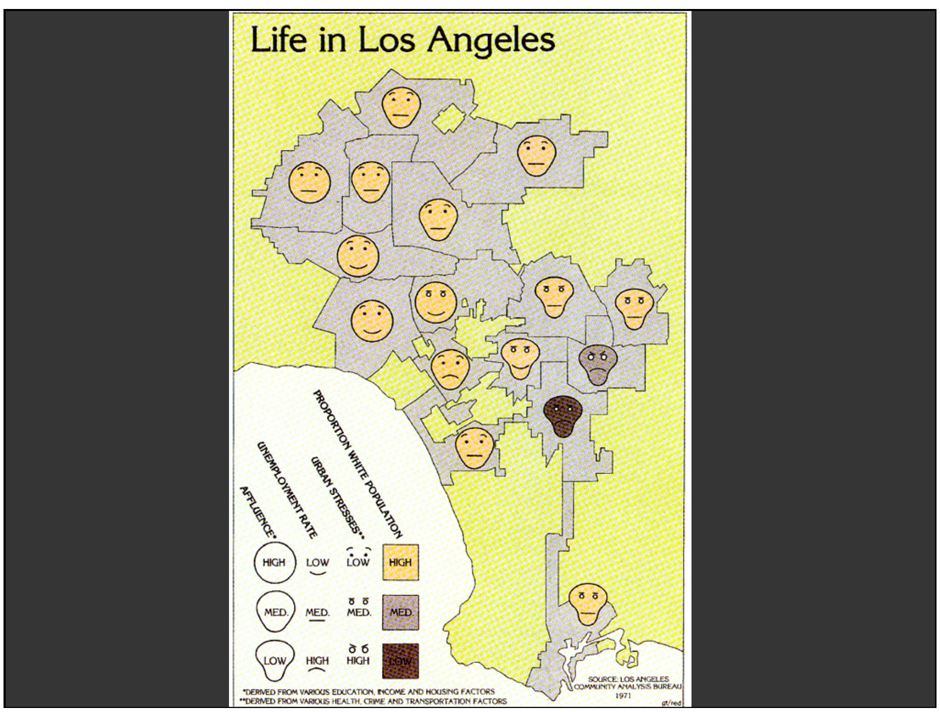
Visualizing Multiple Dimensions

Strategies

- **Avoid “over-encoding”**
- **Use space and small multiples intelligently**
- **Reduce the problem space**
- **Use interaction to generate *relevant* views**

There is rarely a single visualization that answers all questions. Instead, the ability to generate appropriate visualizations quickly is key


Profit
$500
$0
($500)
Sales
$500
$0
Inventory
5K
0K
Marketing
$150
$100
$50
$0
($500) $0 $500
Profit
$0 $500
Sales
0K 5K
Inventory
$0 $50 $100 $150
Marketing


Life in Los Angeles
PROPORTION WHITE POPULATION
URBAN STRESSES**
UNEMPLOYMENT RATE
AFFLUENCE*
HIGH
LOW
LOW
HIGH
MED.
MED.
MED.
MED.
LOW
HIGH
HIGH
LOW
*DERIVED FROM VARIOUS EDUCATION, INCOME AND HOUSING FACTORS
**DERIVED FROM VARIOUS HEALTH, CRIME AND TRANSPORTATION FACTORS
SOURCE: LOS ANGELES COMMUNITY ANALYSIS BUREAU 1971
gt/red

Parallel Coordinates [Inselberg]

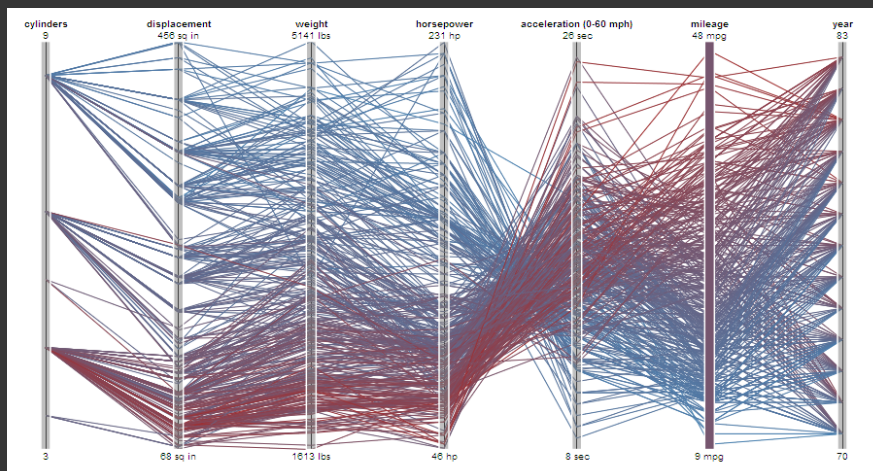
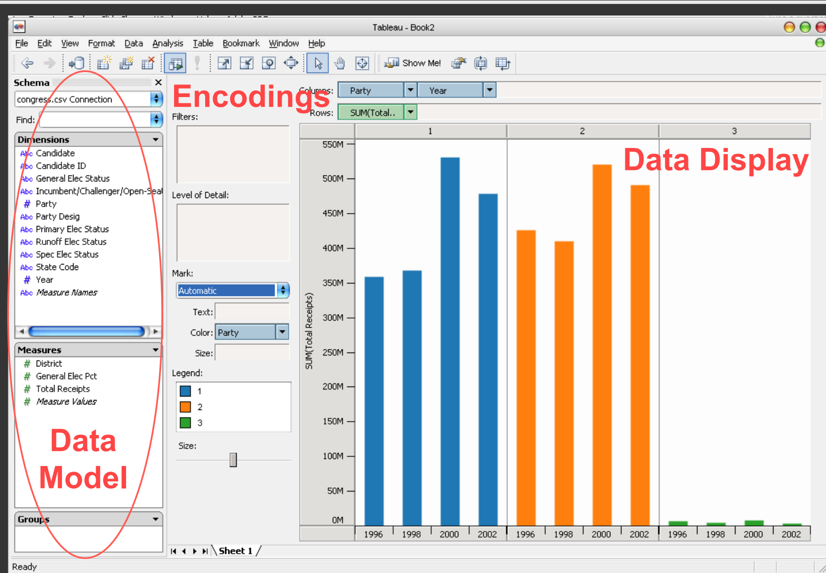


Tableau / Polaris

Tableau



Specifying Table Configurations

Operands are names of database fields

Each operand interpreted as a set {…}

Quantitative and Ordinal fields treated differently

Three operators:

- concatenation (+)
- cross product (x)
- nest (/)

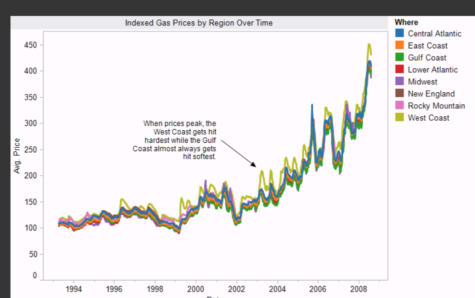
Announcements

Assignment 2: Exploratory Data Analysis

Use existing software to formulate & answer questions

First steps

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



Create visualizations

- Interact with data
- Question will evolve
- Tableau

Make wiki notebook

- Keep record of all steps you took to answer the questions

Due before class on Sep 29, 2014

Perception

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

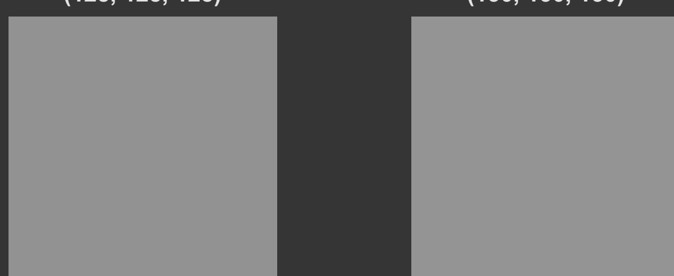
Detection

Detecting brightness

Which is brighter?

Detecting brightness

(128, 128, 128) (130, 130, 130)



Which is brighter?

Just noticeable difference

JND (Weber's Law)

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

- Ratios more important than magnitude
- Most continuous variations in stimuli are 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

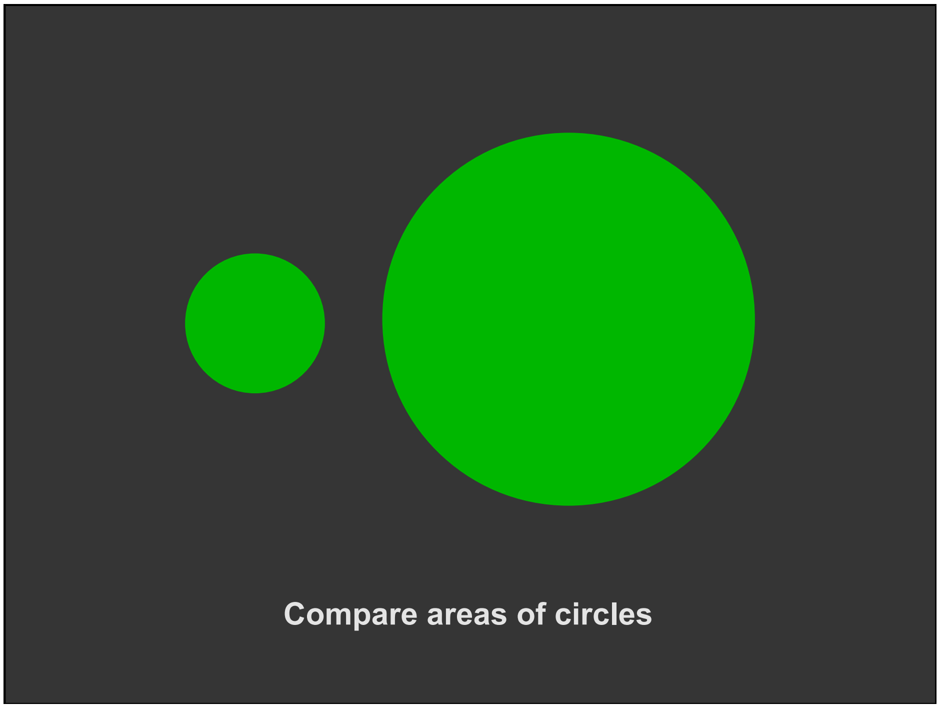
Steps in font size

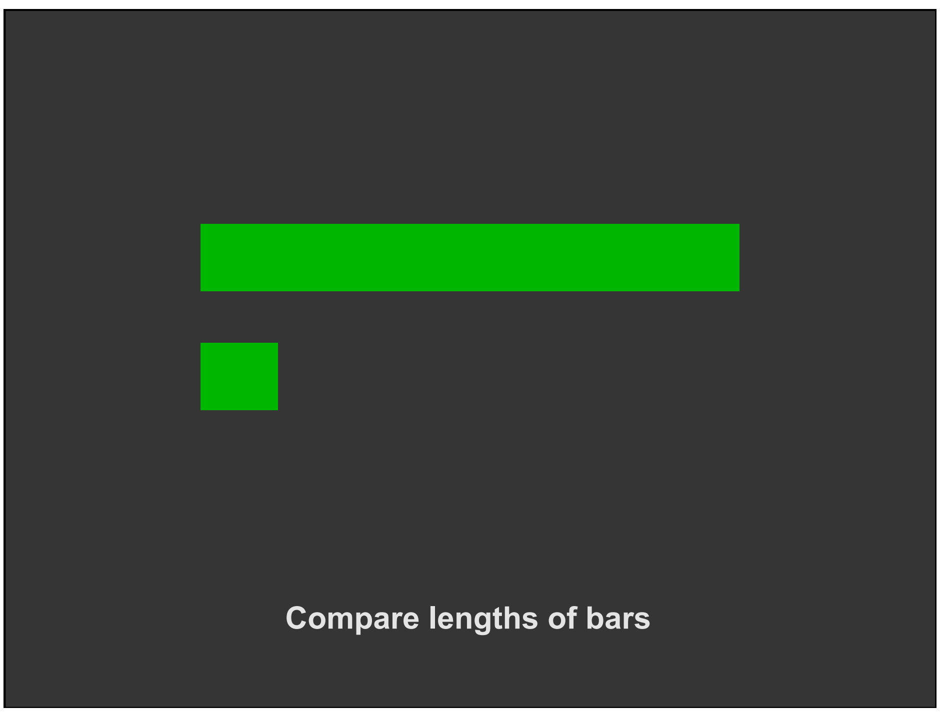
Sizes standardized in 16th century

a a a a a a a a a a a a a a a a a

6 7 8 9 10 11 12 14 16 18 21 24 36 48 60 72

Estimating Magnitude

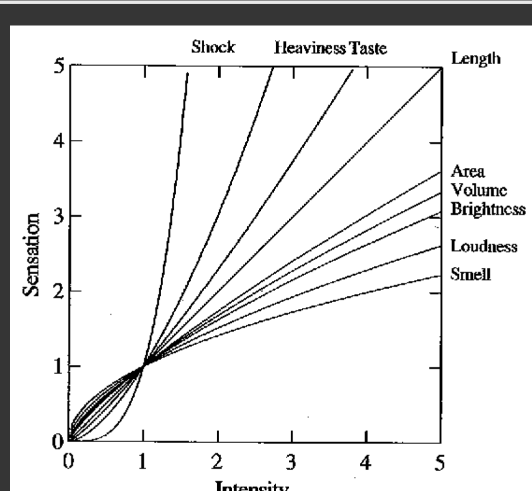

Compare areas of circles


Compare lengths of bars

Steven's power law

$$S = I^p$$

p < 1 : underestimate
p > 1 : overestimate



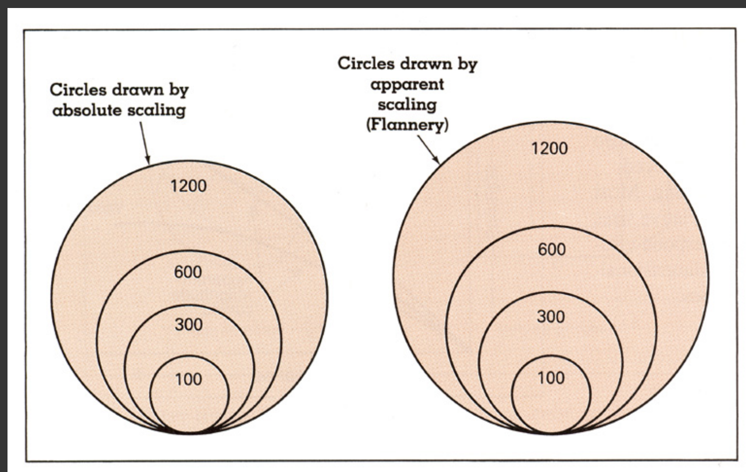
[graph from Wilkinson 99, based on Stevens 61]

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

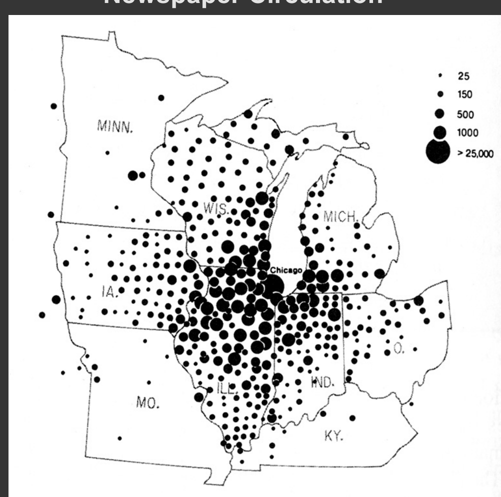


[Cartography: Thematic Map Design, Figure 8.6, p. 170, Dent, 96]

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

Proportional symbol map

Newspaper Circulation



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

Graduated sphere map

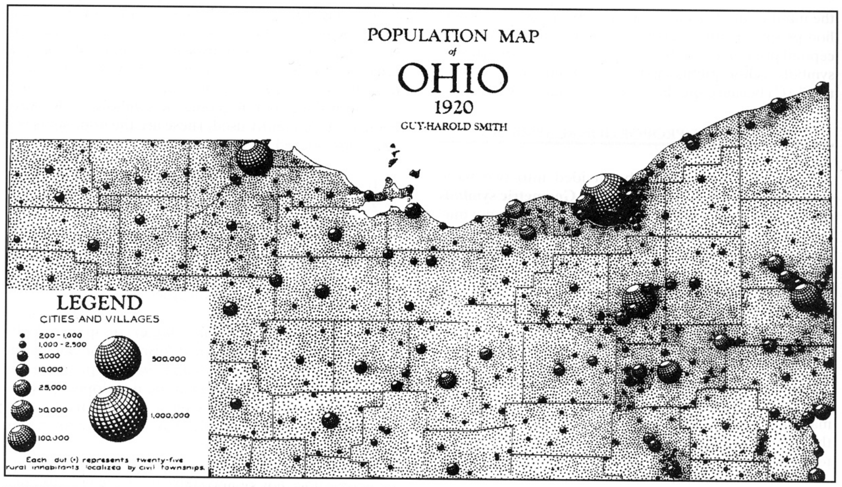


FIGURE 7.4. An eye-catching map created using three-dimensional geometric symbols. (After Smith, 1928. First published in *The Geographical Review,* 18(3), plate 4. Reprinted with permission of the American Geographical Society.)

Cleveland and McGill

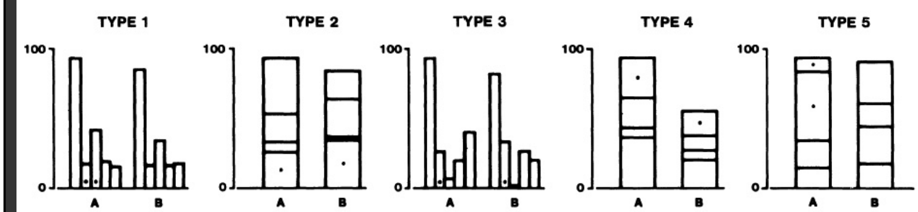


Figure 4. Graphs from position–length experiment.

[Cleveland and McGill 84]

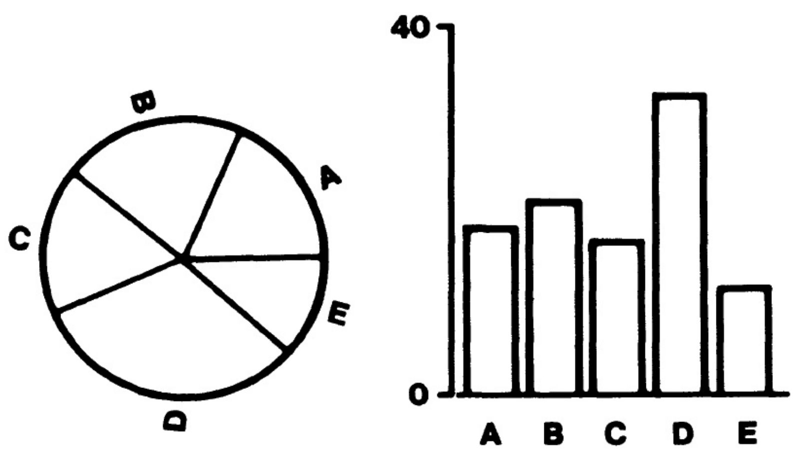


Figure 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]

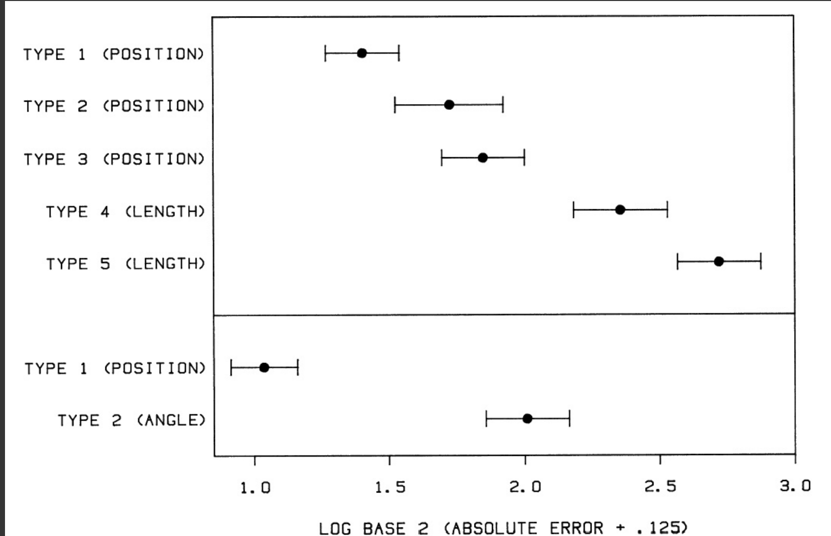


Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

[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 (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

Conjectured *effectiveness* of visual encodings

Preattentive vs. Attentive

How many 3’ s

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

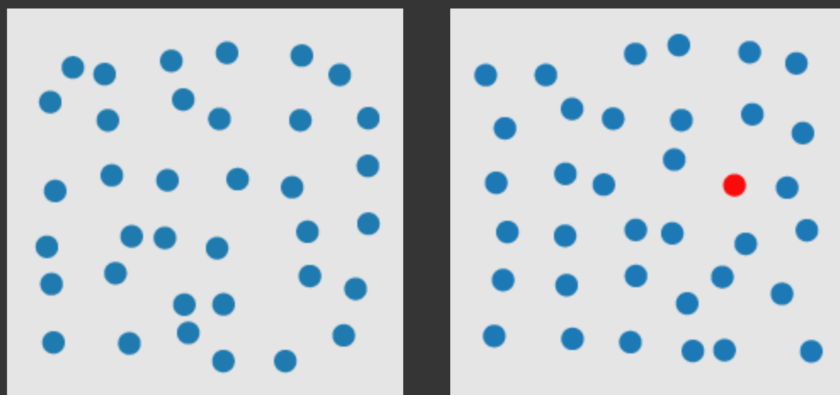
[based on slide from Stasko]

How many 3’ s

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

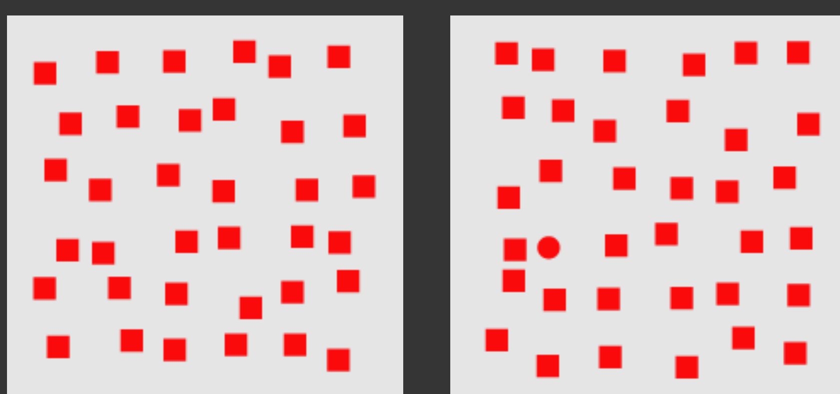
[based on slide from Stasko]

Visual pop-out: Color



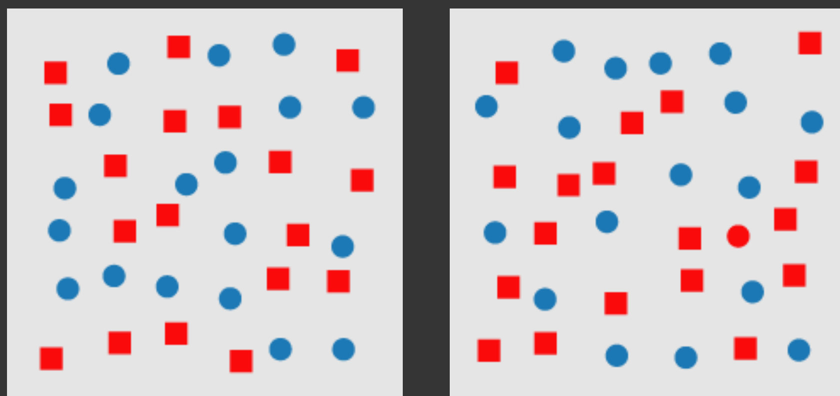
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Visual pop-out: Shape



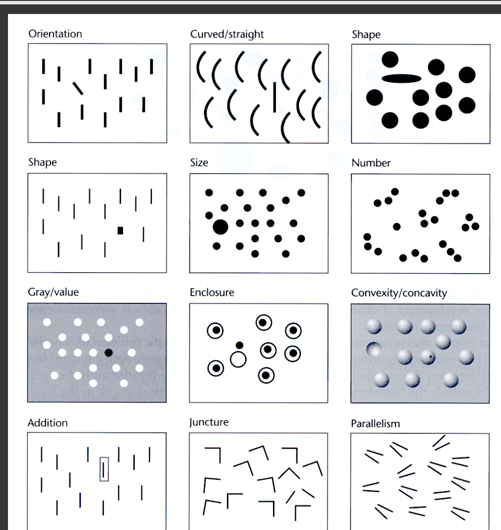
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Feature conjunctions



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

Preattentive features



[Information Visualization. Figure 5. 5 Ware 04]

More preattentive 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

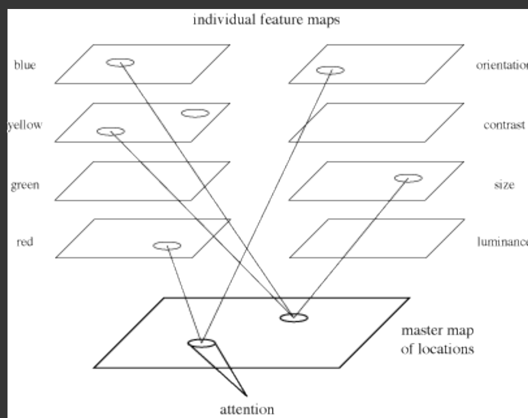
Preattentive conjunctions

Spatial conjunctions are often preattentive

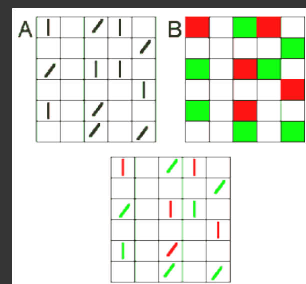
- Motion and 3D disparity
- Motion and color
- Motion and shape
- 3D disparity and color
- 3D disparity and shape

Most conjunctions are **not** preattentive

Feature-integration theory



Treisman's feature integration model [Healey04]

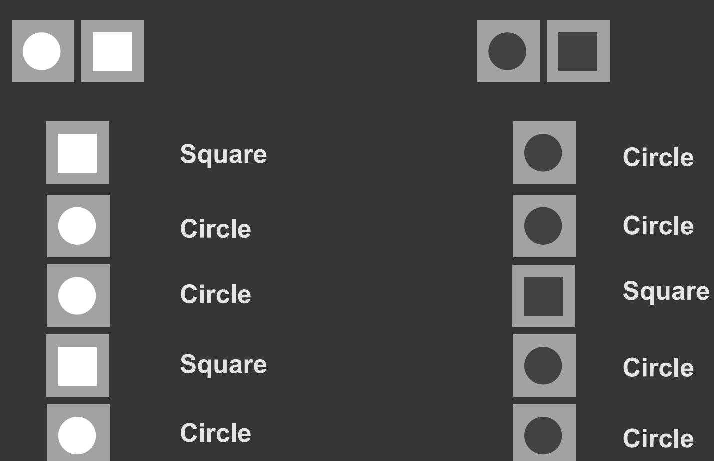


Feature maps for orientation & color [Green]

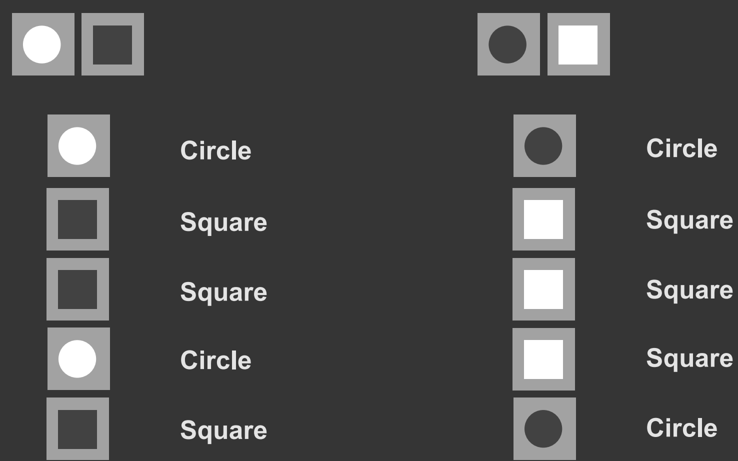
Multiple Attributes

One-dimensional: Lightness

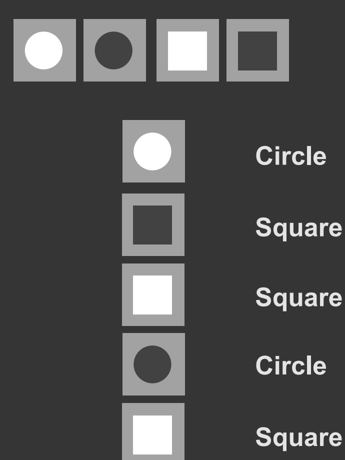
One-dimensional: Shape



Correlated dims: Shape or lightness



Orthogonal dims: Shape & lightness



Speeded classification

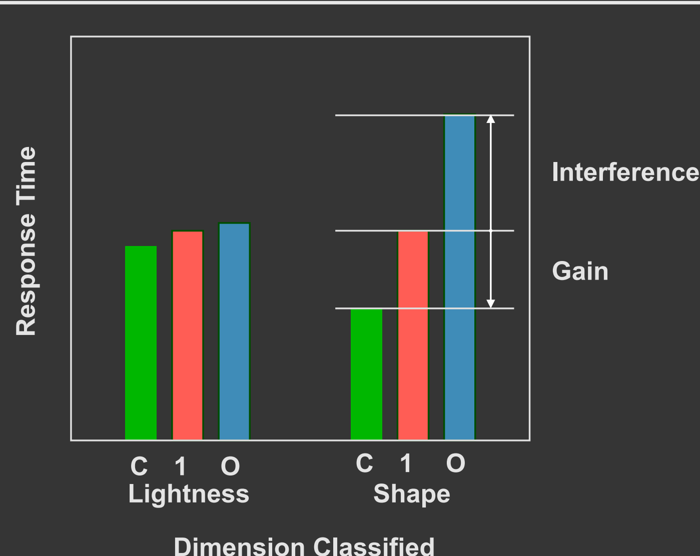
Redundancy gain

- 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**

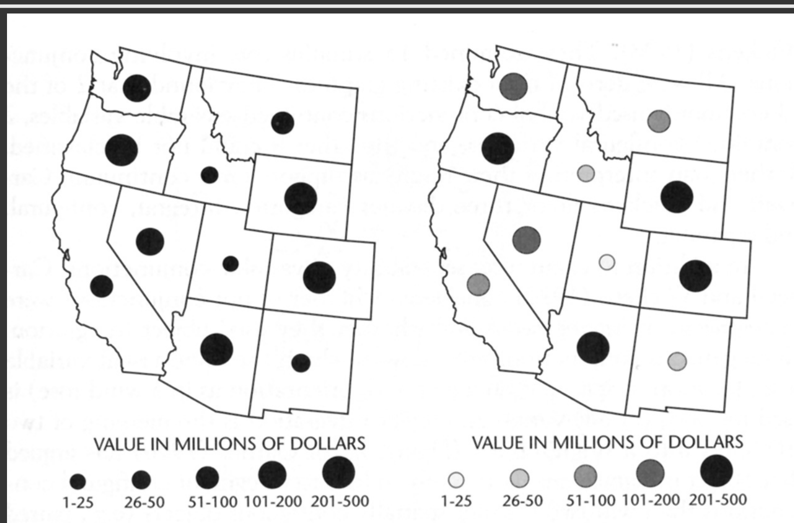
Configural

- **Only interference, but no redundancy gain**

Asymmetrical

- **One dimension separable from other, not vice versa**
  Stroop effect – Color naming influenced by word identity, but word naming not influenced by color

Correlated dims: Size and value



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

Othogonal dims: Aspect ratio

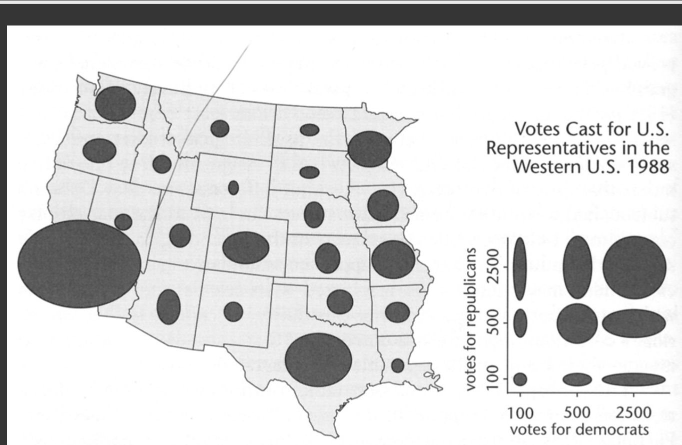


FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

[MacEachren 95]

Orientation and Size (Single Mark)

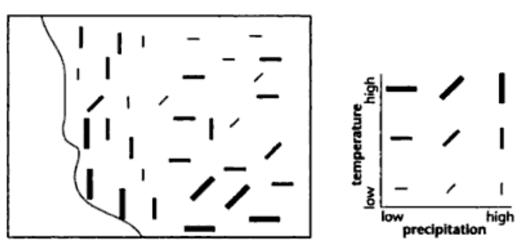


FIGURE 3.36. A map of temperature and precipitation using symbol size and orientation to represent data values on the two variables.

How well can you see temperature or precipitation?
Is there a correlation between the two?

[MacEachren 95]

Shape and Size (Single Mark)

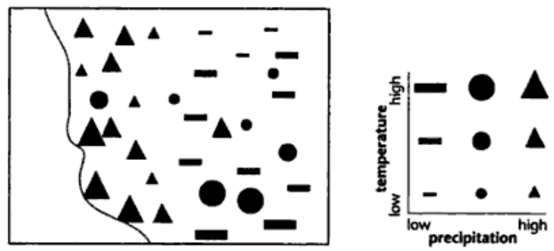
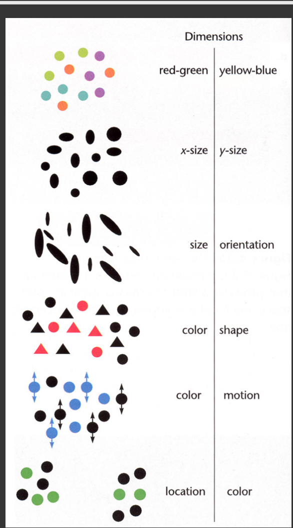


FIGURE 3.40. The bivariate temperature–precipitation map of Figure 3.36, this time using point symbols that vary in shape and size to represent the two quantities.

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

[MacEachren 95]

Summary of Integral-Separable



Integral

Separable

[Figure 5.25, Color Plate 10, Ware 00]

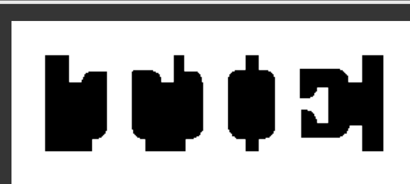
Gestalt

Principles

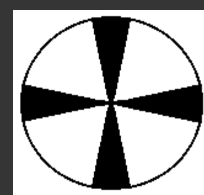
- figure/ground
- proximity
- similarity
- symmetry
- connectedness
- continuity
- closure
- common fate
- transparency

Figure/Ground

Ambiguous



Principle of surroundedness

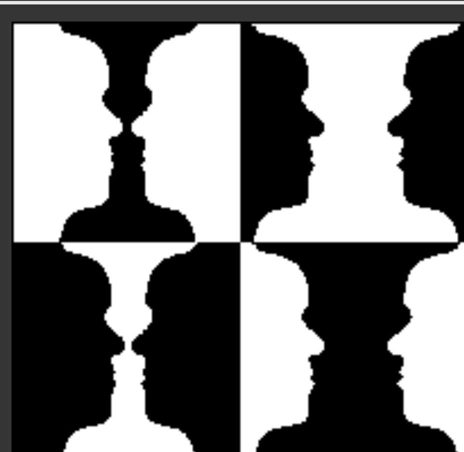


Principle of relative size

http://www.aber.ac.uk/media/Modules/MC10220/visper06.html

Figure/Ground

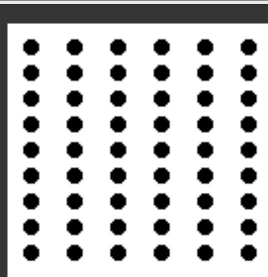
Ambiguous

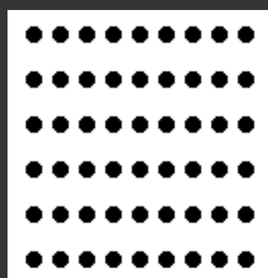


Unambiguous

http://www.aber.ac.uk/media/Modules/MC10220/visper06.html

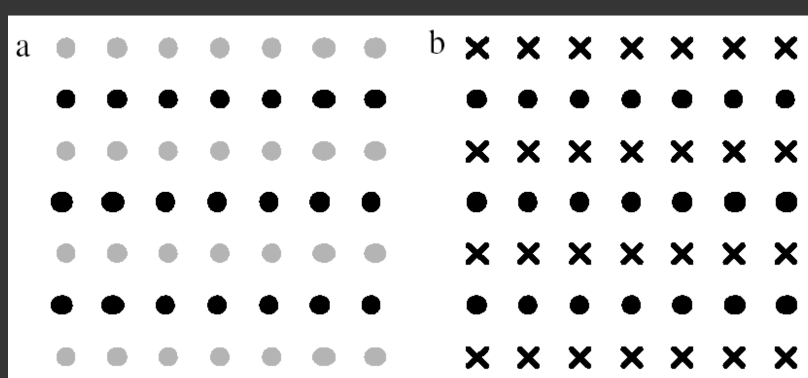
Proximity





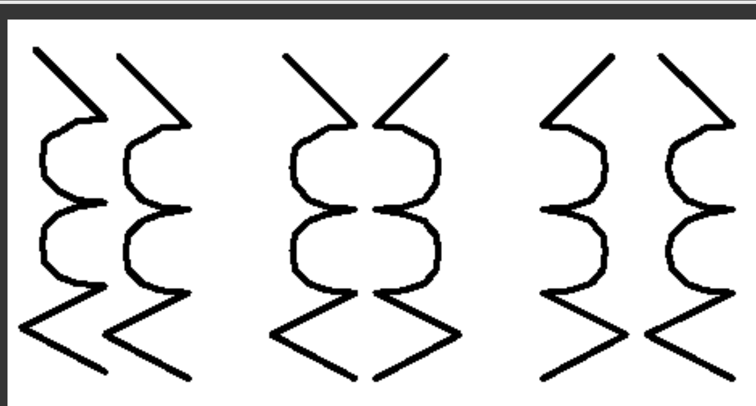
[Ware 00]

Similarity



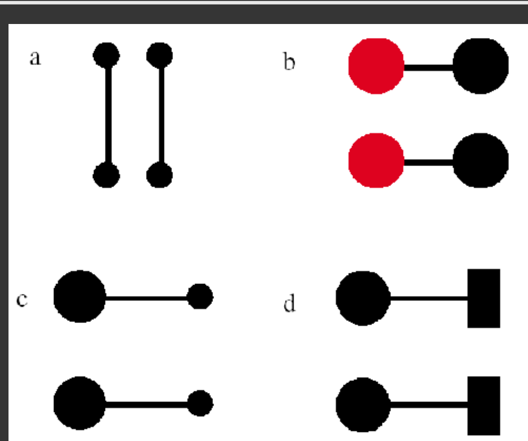
Rows dominate due to similarity [from Ware 04]

Symmetry



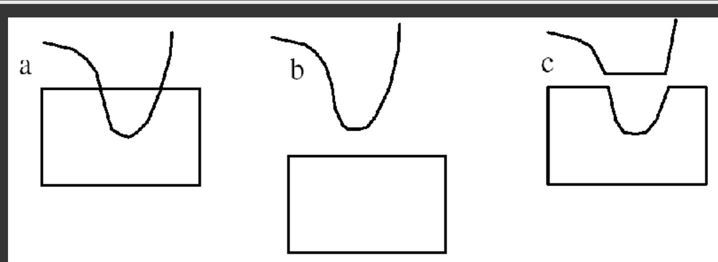
Bilateral symmetry gives strong sense of figure [from Ware 04]

Connectedness

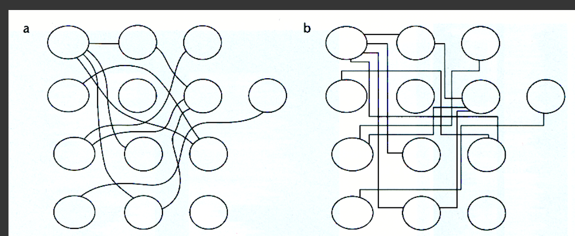


Connectedness overrules proximity, size, color shape [from Ware 04]

Continuity

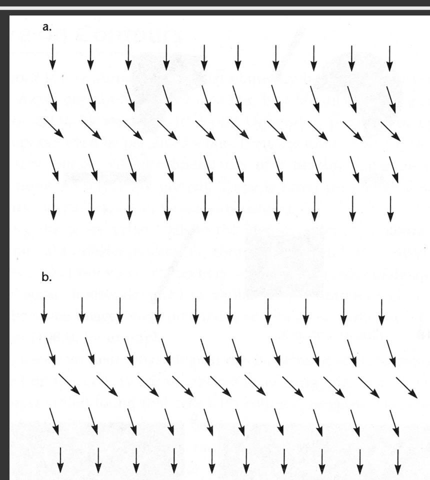


We prefer smooth not abrupt changes [from Ware 04]



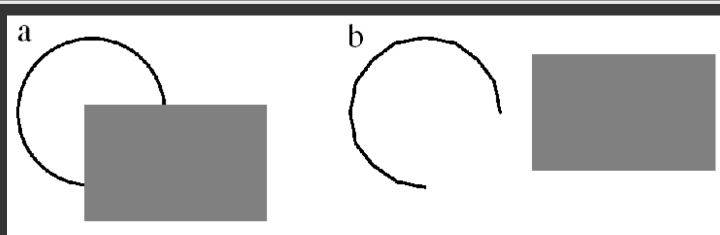
Connections are clearer with smooth contours [from Ware 04]

Continuity: Vector fields

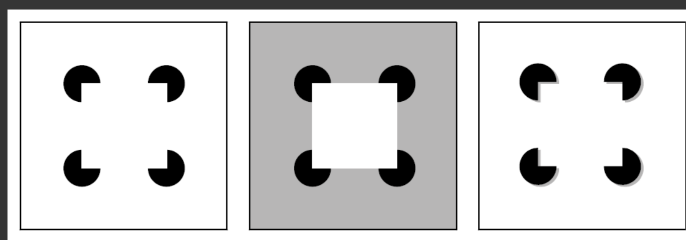


Prefer field that shows smooth continuous contours [from Ware 04]

Closure

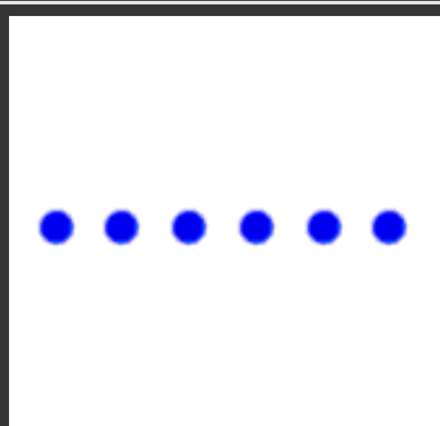


We see a circle behind a rectangle, not a broken circle [from Ware 04]



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]