Perception

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CS 448B: Visualization
Winter 2020

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Announcements

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Assignment 3: Dynamic Queries

Create a **small** interactive dynamic query application similar to Homefinder, but for South Bay Restaurant Data.

1. Implement interface
2. Submit the application and a short write-up on canvas

Can work alone or in pairs

Due before class on **Feb 10, 2020**

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Perception

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Mackinlay' s effectiveness criteria

Effectiveness

A visualization is more effective than another visualization if the information conveyed by one visualization is more readily *perceived* than the information in the other visualization.

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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

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Topics

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

8

Detection

9

Detecting brightness

Which is brighter?

10

Detecting brightness

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

Which is brighter?

11

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

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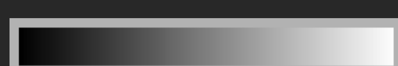
Information in color and value

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

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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

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

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Estimating Magnitude

16

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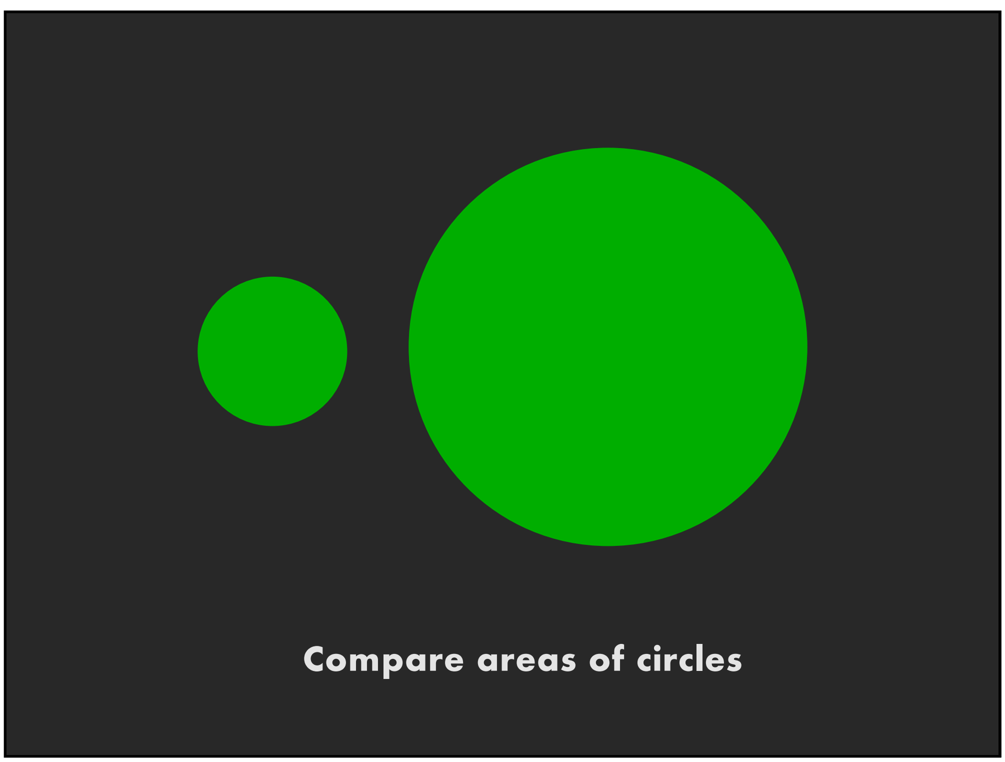
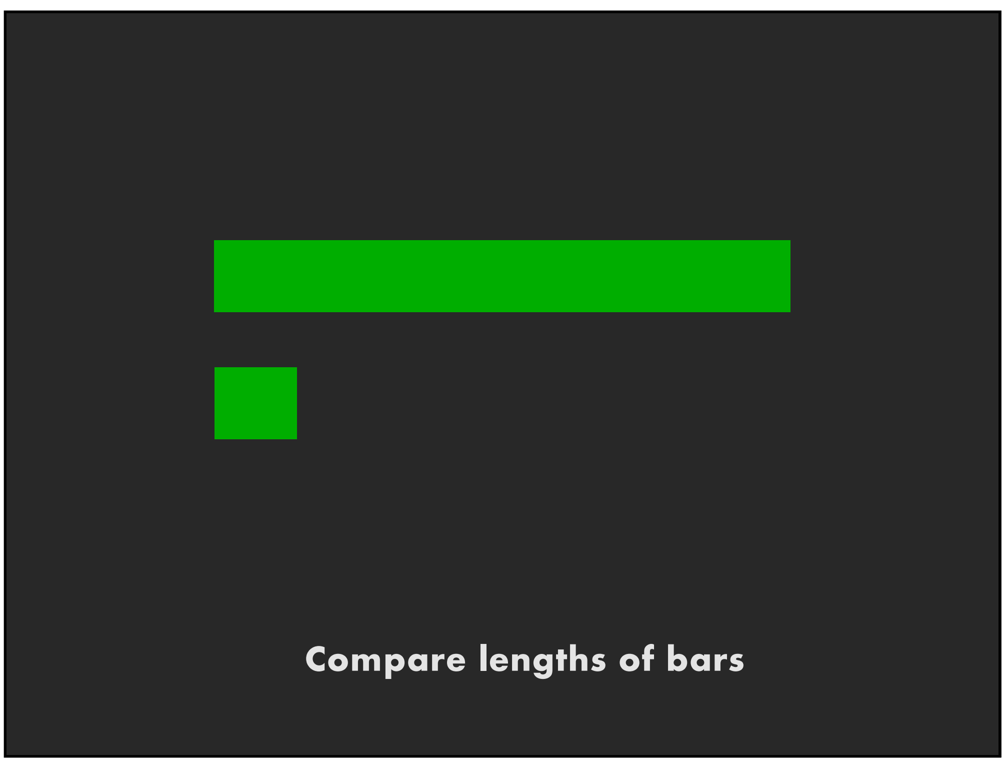


19

20



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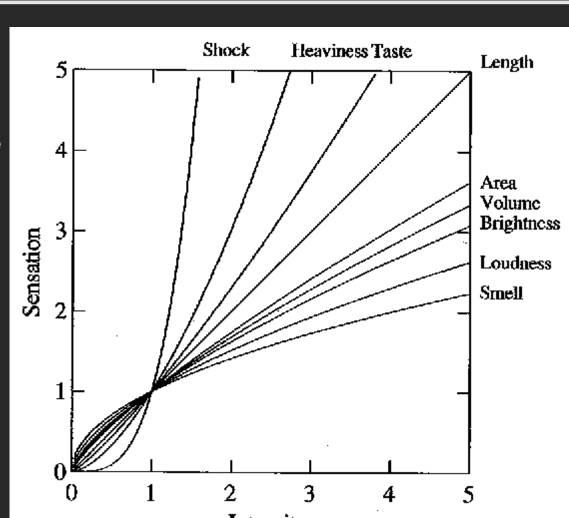
Steven's power law

$$S = I^p$$

p < 1 : underestimate
p > 1 : overestimate



[graph from Wilkinson 99, based on Stevens 61]

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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]

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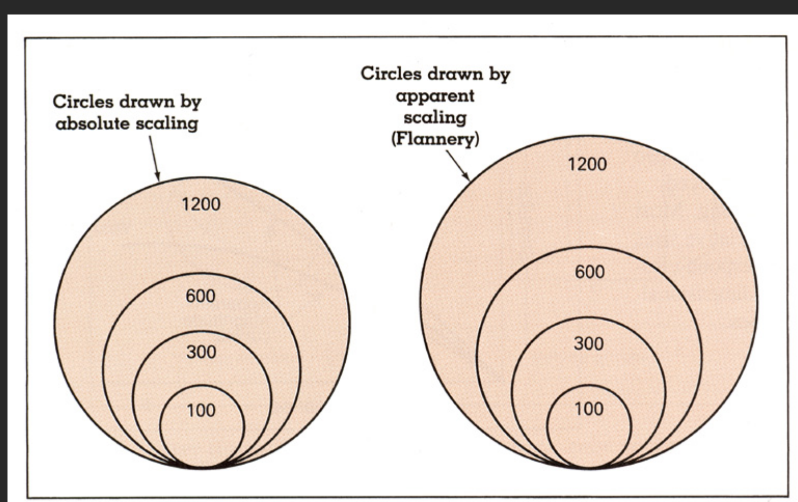
Apparent magnitude scaling



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

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

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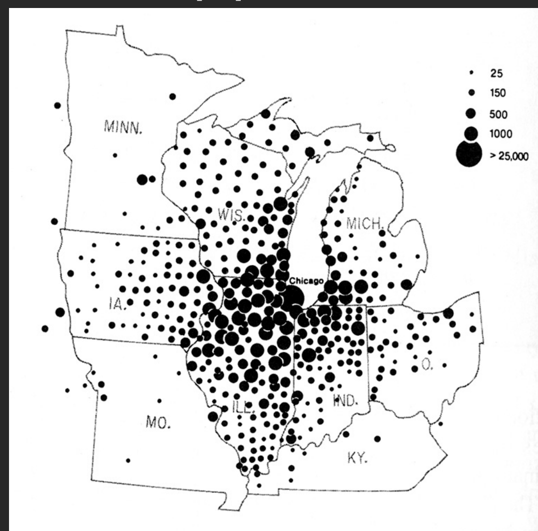
Proportional symbol map

Newspaper Circulation



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

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Graduated sphere map

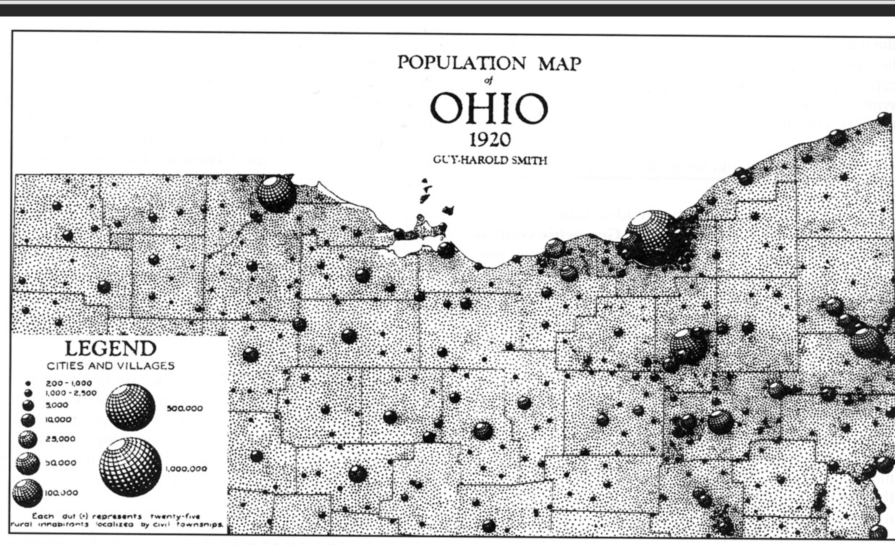

FIGURE 7.4. An eye-catching map created using three-dimensional geometric symbols. (After Smith, 1928. First published in *The Geographical Review,* 18(3), plate 4. Reprinted with permission of the American Geographical Society.)

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Cleveland and McGill

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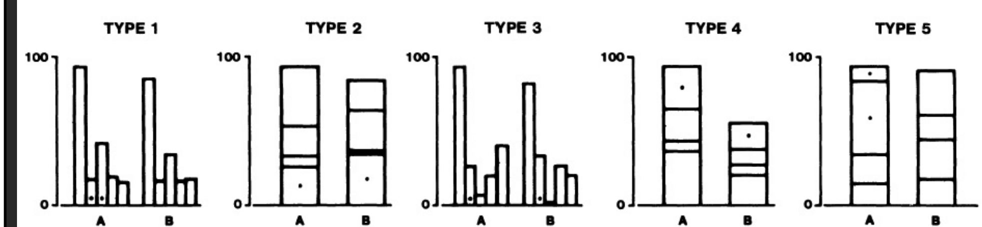

Figure 4. Graphs from position–length experiment.

[Cleveland and McGill 84]

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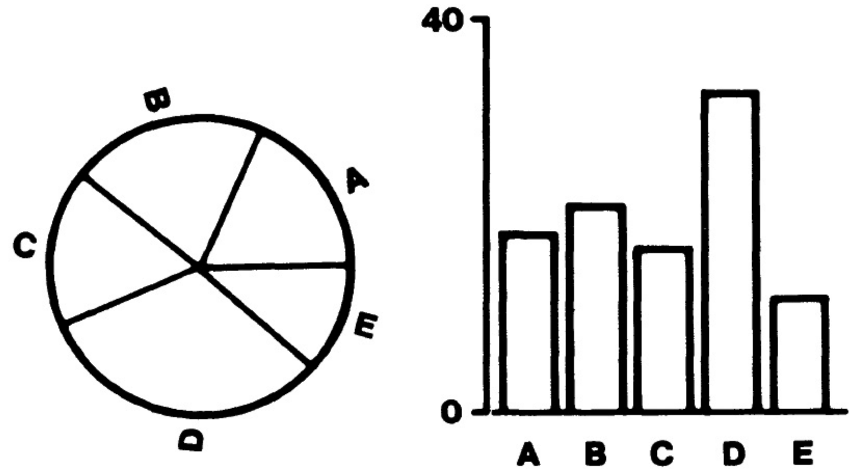

Figure 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]

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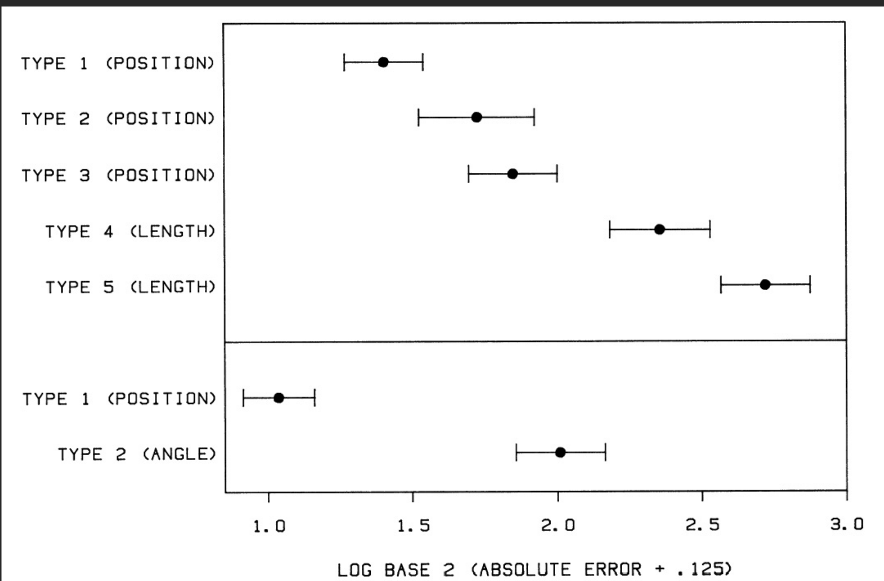

Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

[Cleveland and McGill 84]

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Relative magnitude estimation

Most accurate

Least accurate

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

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Mackinlay' s ranking of encodings

QUANTITATIVE	ORDINAL	NOMINAL
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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

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Preattentive vs. Attentive

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How many 3’s

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

[based on slide from Stasko]

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How many 3's

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

[based on slide from Stasko]

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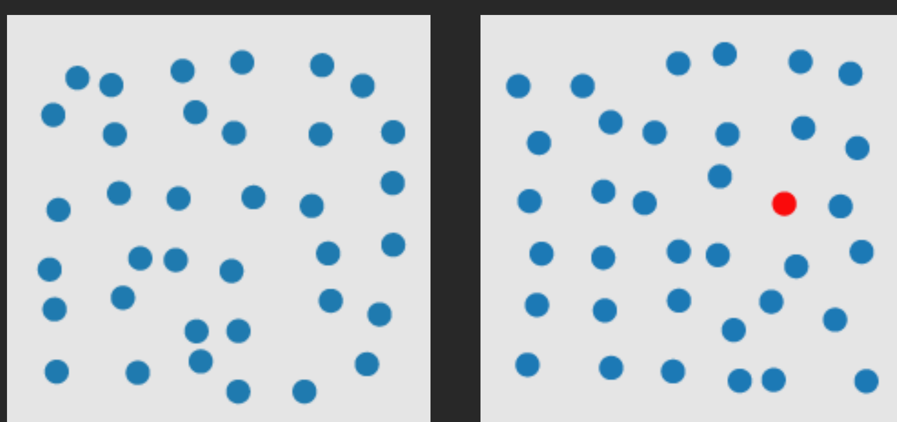
Visual pop-out: Color



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

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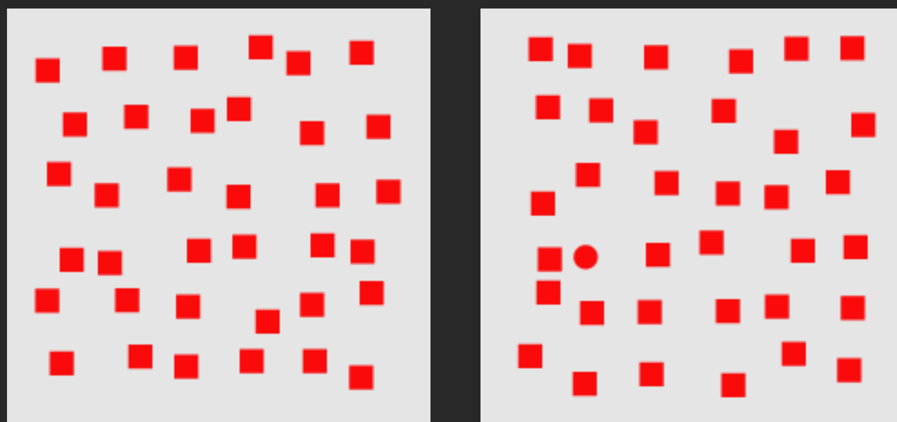
Visual pop-out: Shape



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

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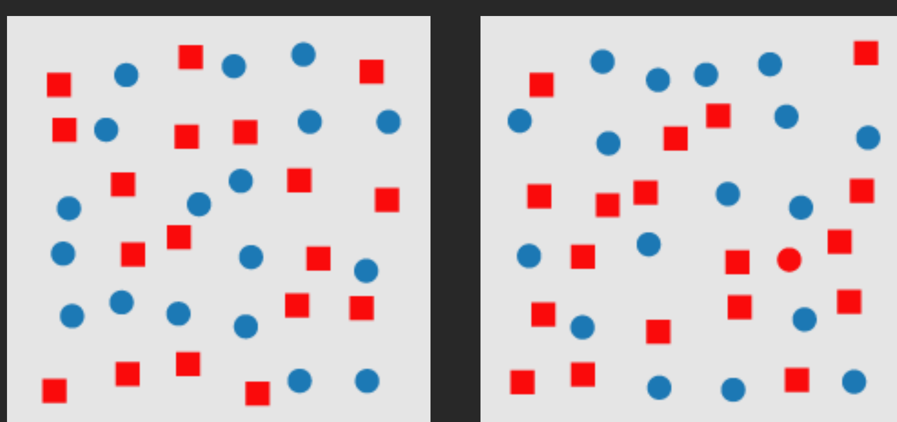
Feature conjunctions



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

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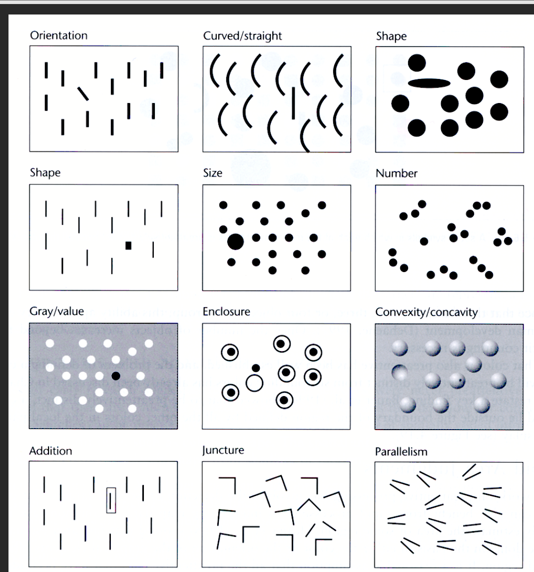
Preattentive features



[Information Visualization. Figure 5. 5 Ware 04]

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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

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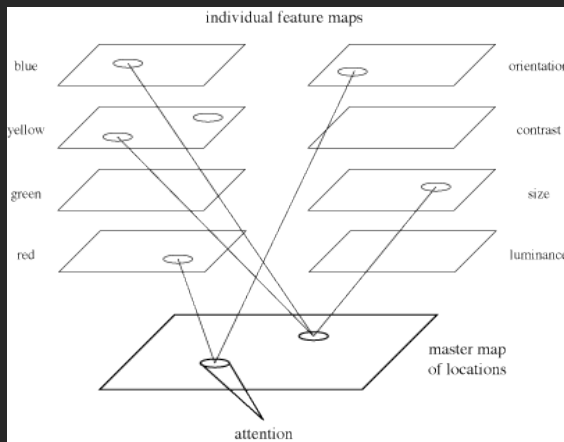
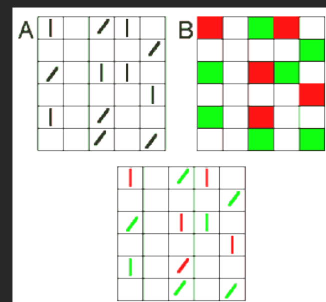
Feature-integration theory





Feature maps for orientation & color [Green]

Treisman's feature integration model [Healey04]

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Multiple Attributes

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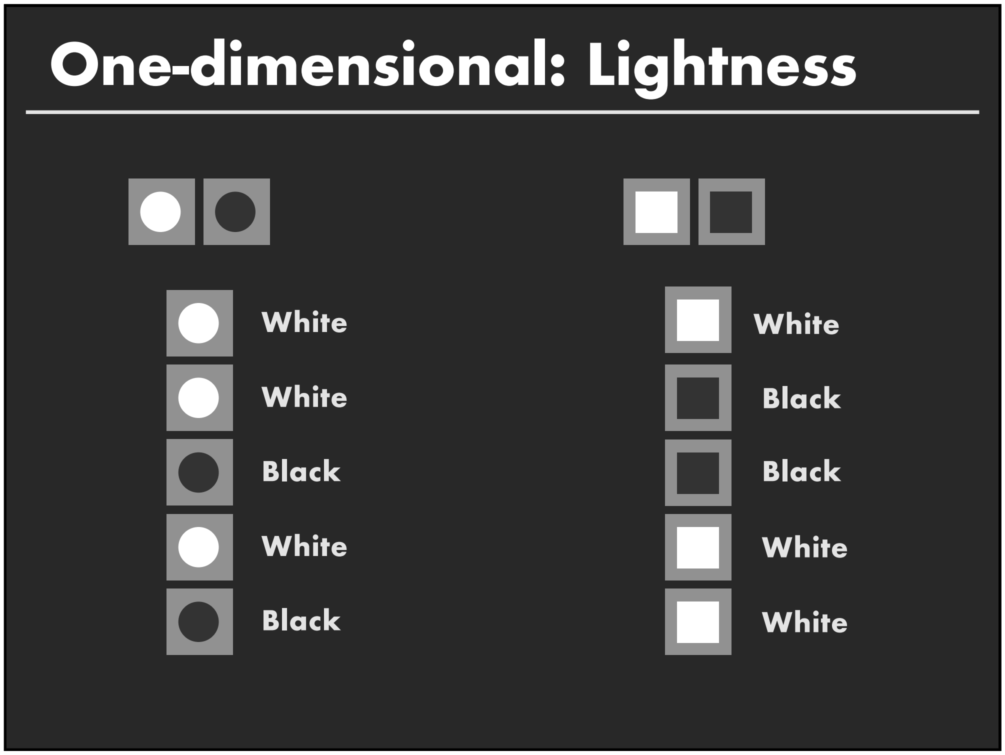
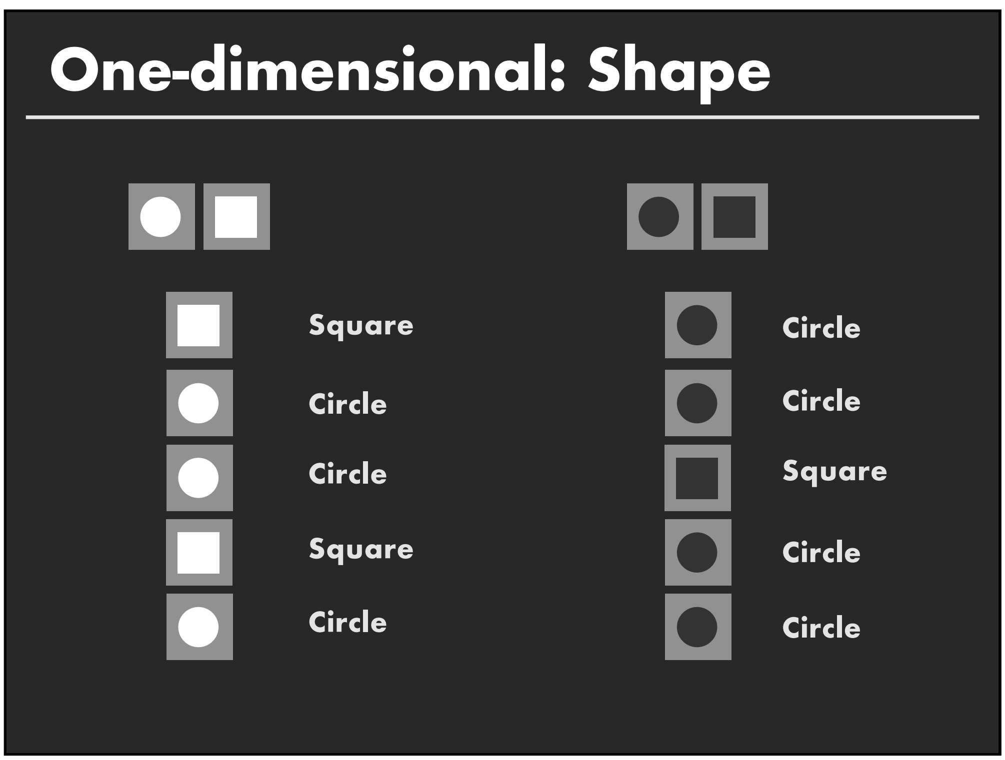

One-dimensional: Lightness
White
White
Black
White
Black
White
Black
Black
White
White

46


One-dimensional: Shape
Square
Circle
Circle
Square
Circle
Circle
Circle
Square
Circle
Circle

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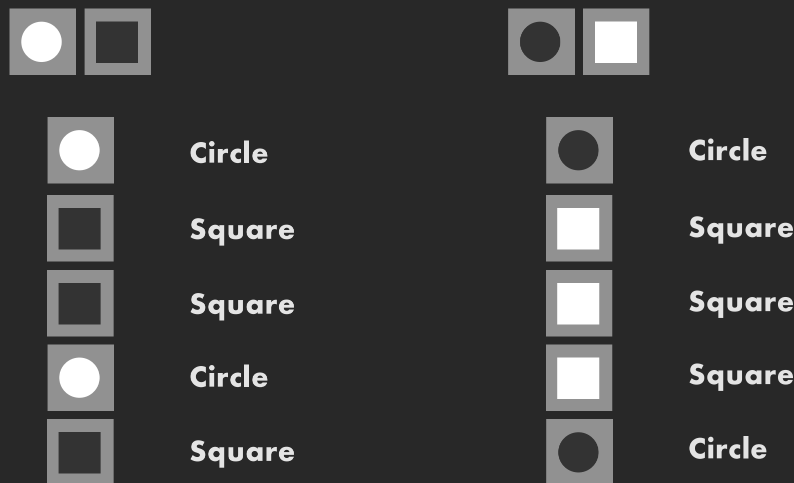
Correlated dims: Shape or lightness



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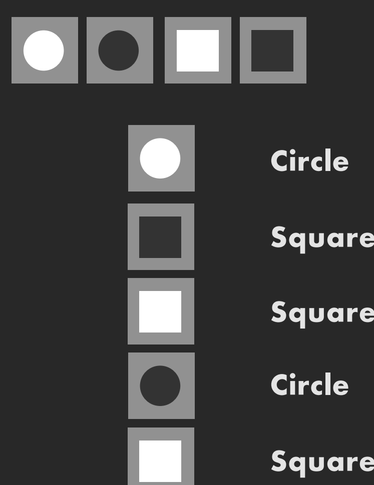
Orthogonal dims: Shape & lightness



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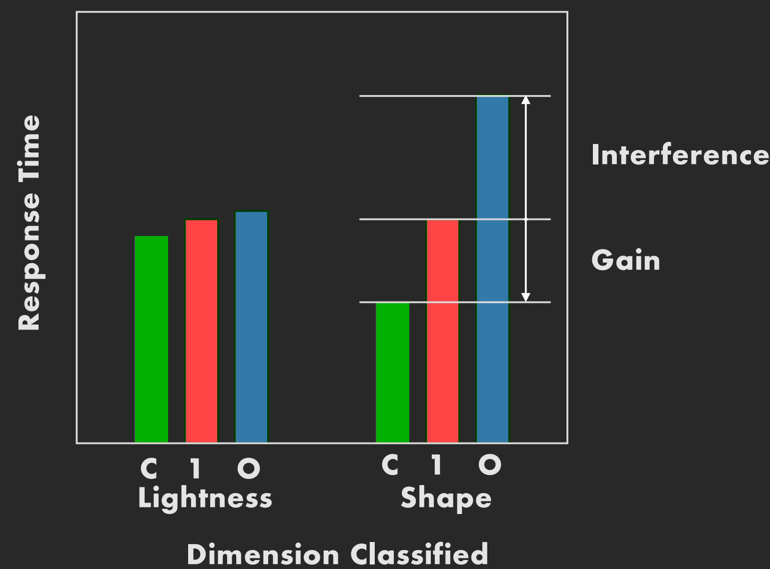
Speeded classification



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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

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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

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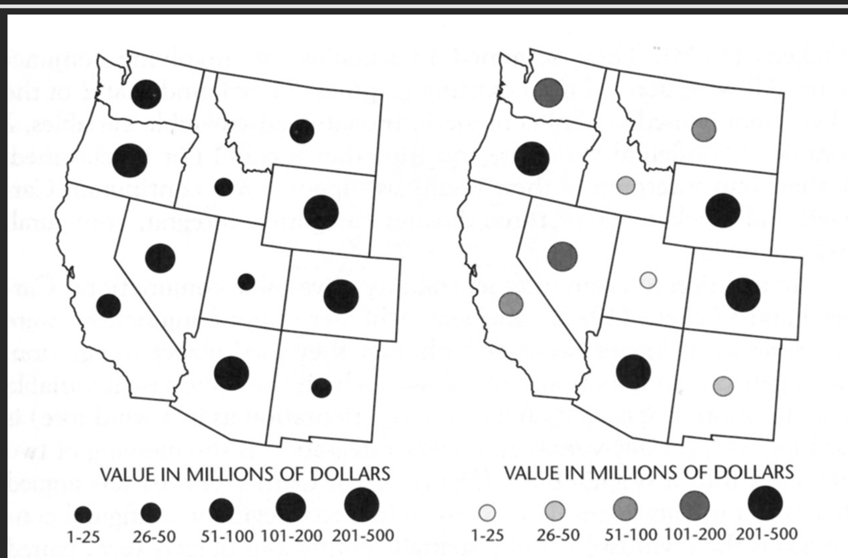
Correlated dims: Size and value



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

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Othogonal dims: Aspect ratio

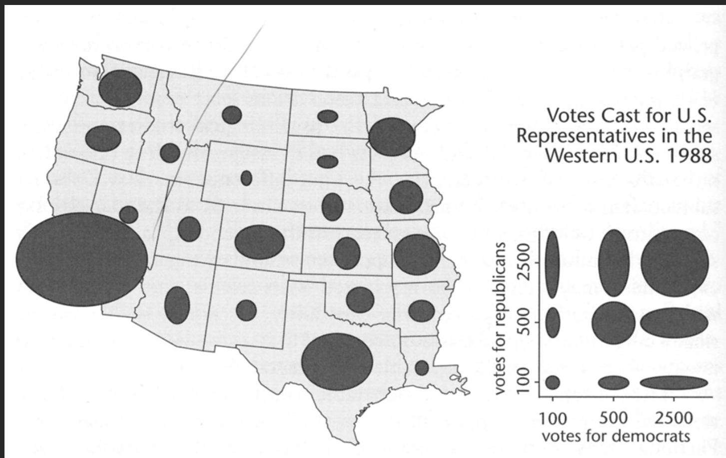

FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

[MacEachren 95]

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Orientation and Size (Single Mark)

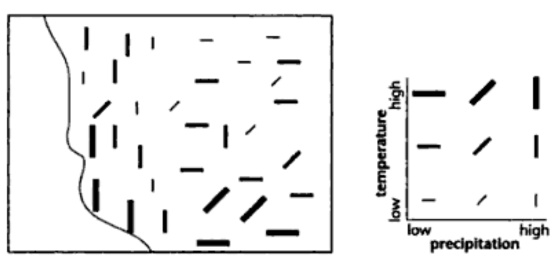

FIGURE 3.36. A map of temperature and precipitation using symbol size and orientation to represent data values on the two variables.

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

[MacEachren 95]

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Shape and Size

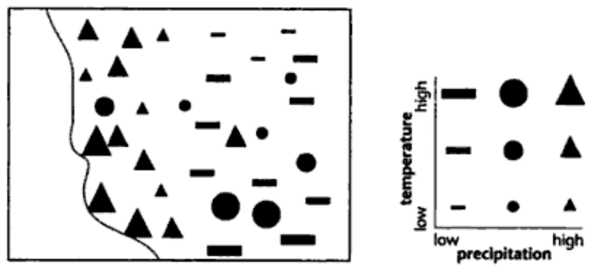

FIGURE 3.40. The bivariate temperature–precipitation map of Figure 3.36, this time using point symbols that vary in shape and size to represent the two quantities.

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

[MacEachren 95]

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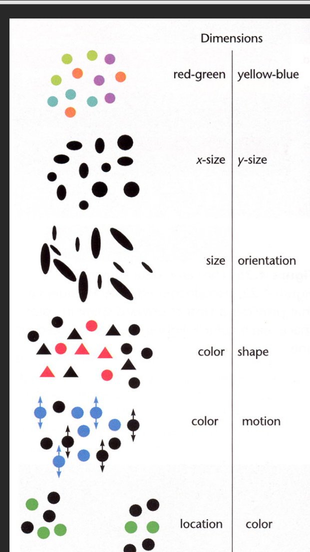
Summary of Integral-Separable



Integral

Separable

[Figure 5.25, Color Plate 10, Ware 00]

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Gestalt

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Principles

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

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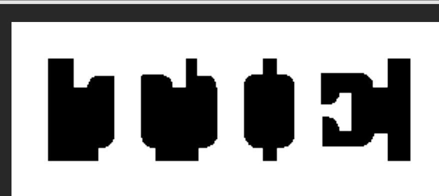
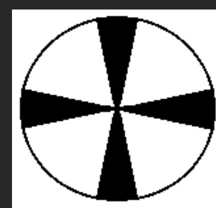
Figure/Ground

Ambiguous



Principle of surroundedness



Principle of relative size

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

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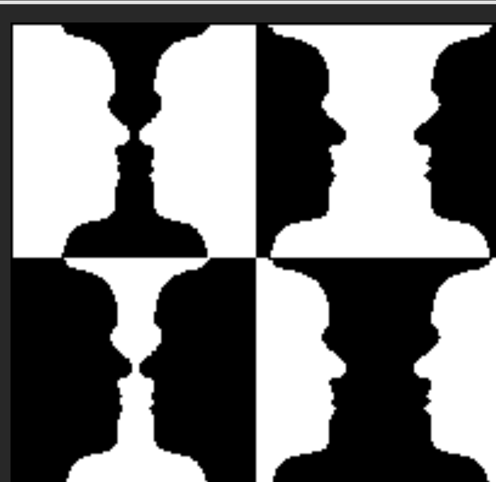
Figure/Ground

Ambiguous



Unambiguous

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

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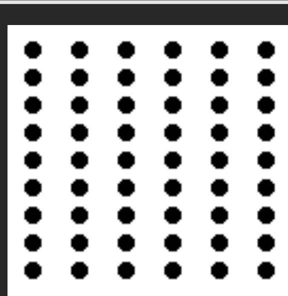
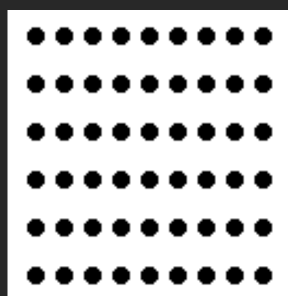
Proximity





[Ware 00]

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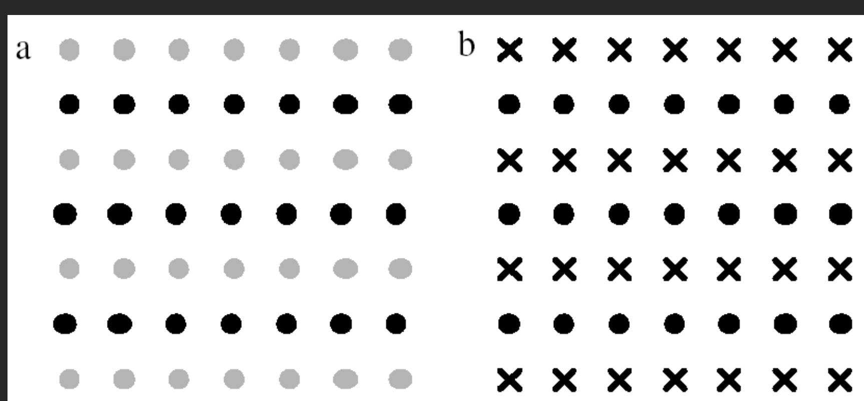
Similarity



Rows dominate due to similarity [from Ware 04]

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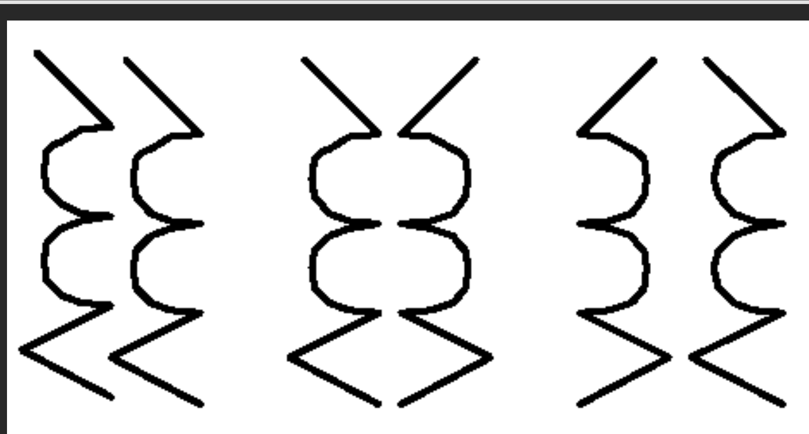
Symmetry



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

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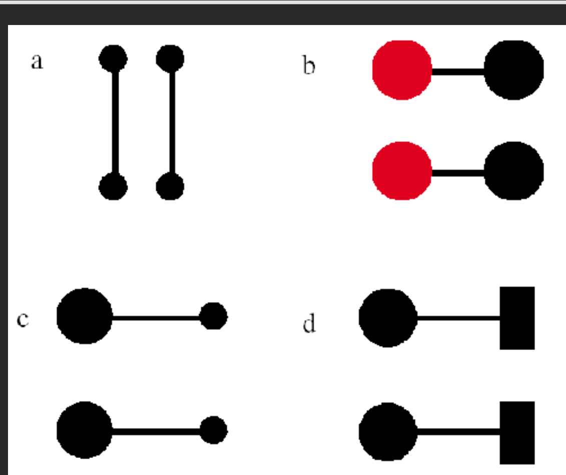
Connectedness



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

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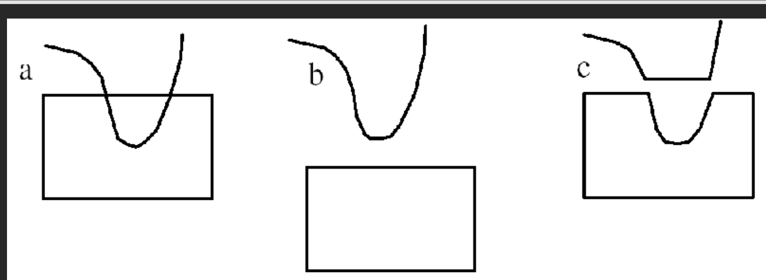
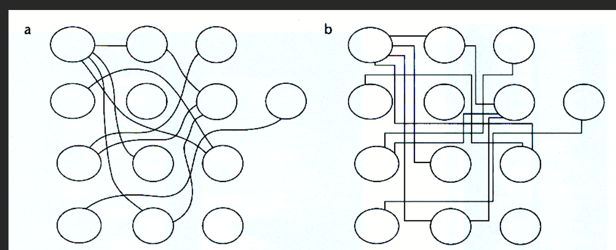
Continuity



We prefer smooth not abrupt changes [from Ware 04]



Connections are clearer with smooth contours [from Ware 04]

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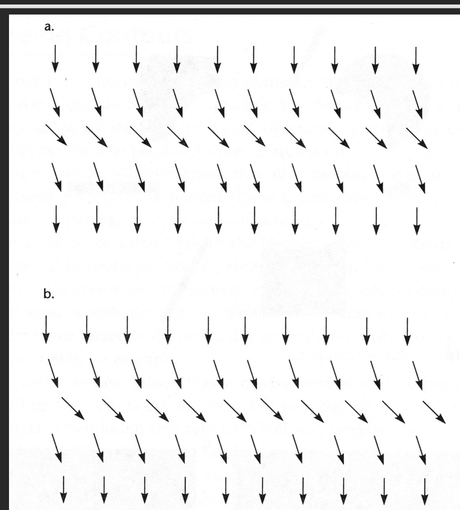
Continuity: Vector fields



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

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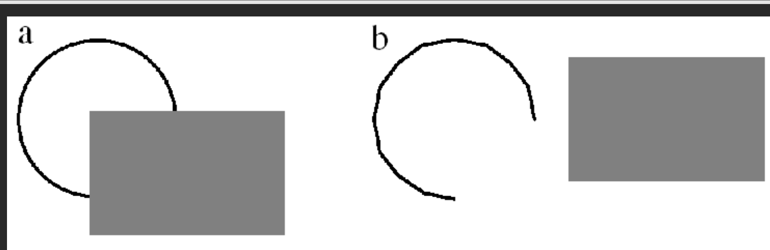
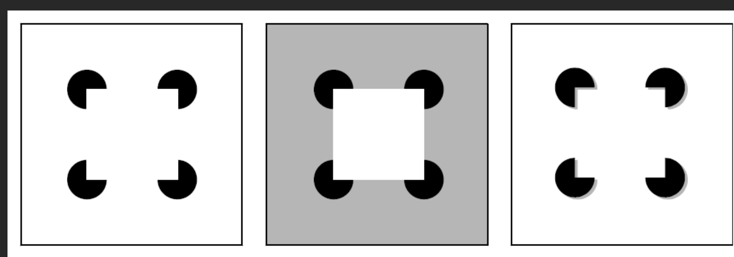
Closure



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



Illusory contours [from Durand 02]

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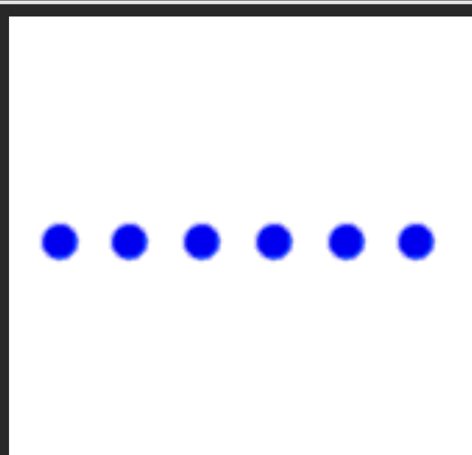
Common fate



Dots moving together are grouped

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

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Transparency

Requires continuity and proper color correspondence [from Ware 04]

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Layering and Small Multiples

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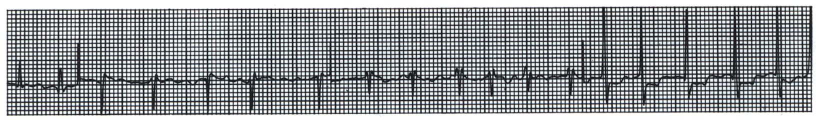
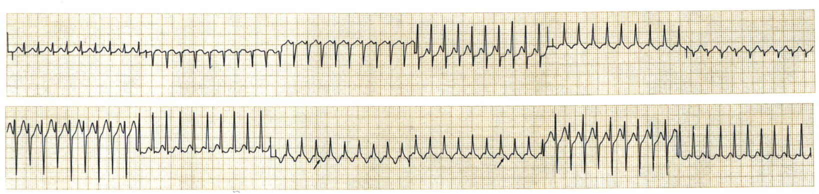
Layering: Gridlines



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]

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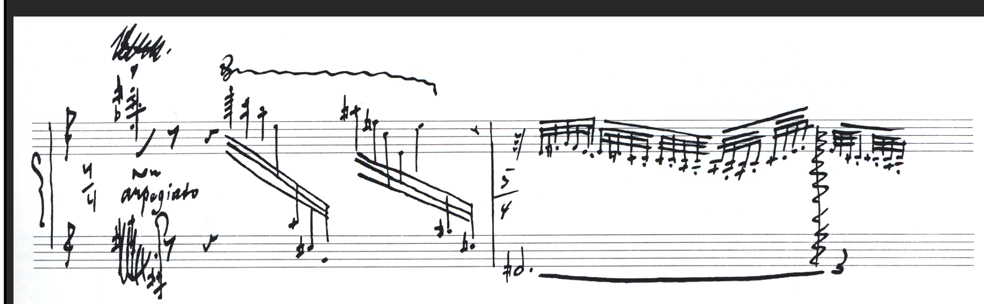
Layering: Gridlines



Stravinsky score [from Tufte 90]

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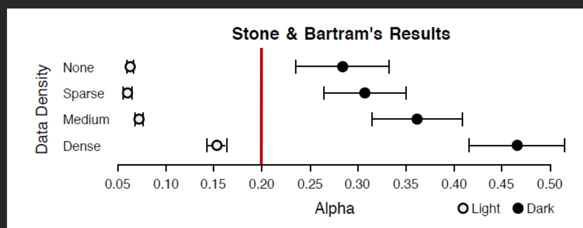
Setting Gridline Contrast

How light can gridlines be and remain visible?
How dark can gridlines be and not distract?



Safe setting: 20% Alpha

[Stone & Bartram 2009]

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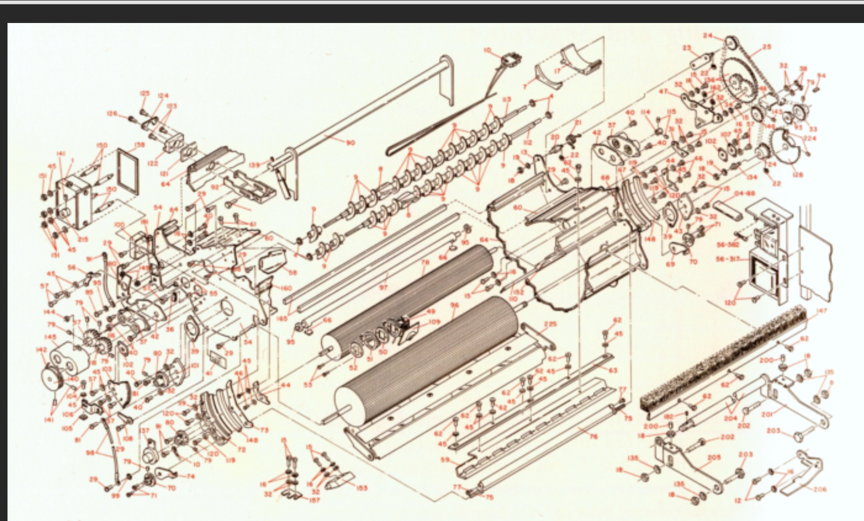
Layering: Color and line width



IBM Series III Copier [from Tufte 90]

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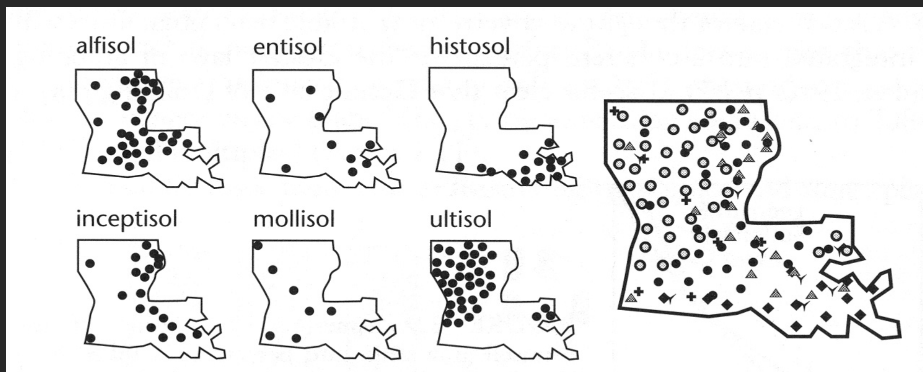
Small multiples



[Figure 2.11, p. 38, MacEachren 95]

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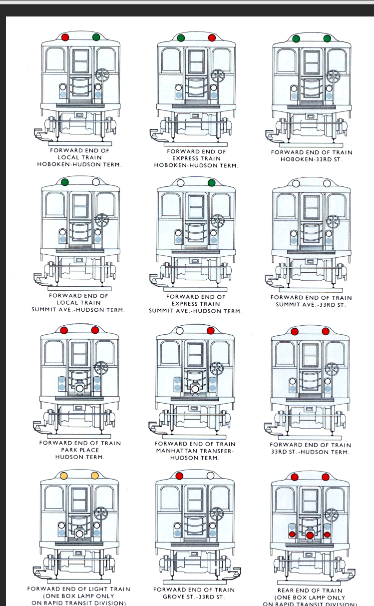
Small multiples



Operating trains. Redrawn by Tufte to emphasize colored lights. [fromTufte 90]

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Change blindness

[Example from Palmer 99, originally due to Rock]

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Change detection

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Change detection

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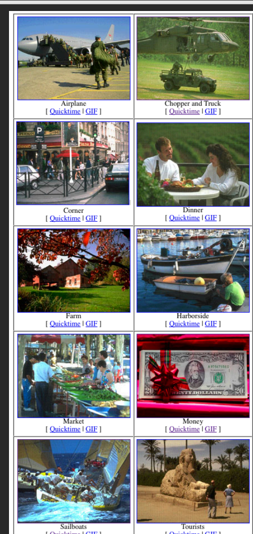
Rensink's demonstration



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

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Summary

Choosing effective visual encodings requires knowledge of visual perception

Visual features/attributes

- Individual attributes often preattentive
- Multiple attributes may be separable, often integral

Gestalt principles provide higher level design guidelines

We don't always see everything that is there

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