PERCEPTION

CS 448B | Fall 2025

MANEESH AGRAWALA

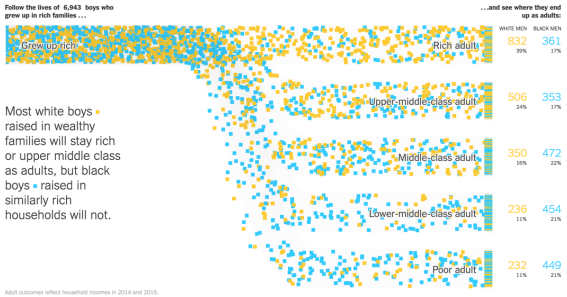
1

Extensive Data Shows Punishing Reach of Racism for Black Boys

By EMILY BADGER, CLAIRE CAIN MILLER, ADAM PEARCE and KEVIN QUEALY MARCH 19, 2018

Black boys raised in America, even in the wealthiest families and living in some of the most well-to-do neighborhoods, still earn less in adulthood than white boys with similar backgrounds, according to a sweeping new study that traced the lives of millions of children.

White boys who grow up rich are likely to remain that way. Black boys raised at the top, however, are more likely to become poor than to stay wealthy in their own adult households.



https://www.nytimes.com/interactive/2018/03/19/upshot/race-class-white-and-black-men.html

2

READING RESPONSE: QUESTIONS/THOUGHTS

I'm inclined to think that ***gen AI will push more users to packages with a higher level of complexity*** (D3 over VegaLite), as people can be more specific with verbalizing what they want a visualization to look like and iterating without technical skills. However, ***I'm worried this will come at the cost of quality/usability, as creators will have less knowledge of the specific steps being taken to create a visual, and said process will be harder to interpret and revise, especially if working collaboratively.***

3

GRAPHICAL PERCEPTION

7

DESIGN PRINCIPLES [Mackinlay 1986]

Expressiveness

A set of facts is *expressible* in a visual language if the sentences (i.e., the visualizations) in the language express ***all*** the facts in the set of data, and ***only*** the facts in the data.

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.

8

DESIGN PRINCIPLES *TRANSLATED* [Mackinlay 1986]

Expressiveness

Tell the truth and nothing but the truth.
(don't lie, and don't lie by omission)

Effectiveness

Use encodings that people decode better.
(where better = faster and/or more accurately)

9

EFFECTIVENESS RANKINGS [Mackinlay 1986]

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

10

Graphical Perception

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

11

TODAY

Learning Objectives

1. Understand basic features of human visual perception.
2. Understand why some visualizations more perceptually effective than others (i.e., understand graphical perception.).

12

SIGNAL DETECTION

14

DETECTING BRIGHTNESS

Which is brighter?

15

DETECTING BRIGHTNESS

(129, 129, 129) **(131, 131, 131)**

Which is brighter?

16

JUST NOTICEABLE DIFFERENCE

JND (Weber's Law)

Scale Factor
(Empirically Determined)

Perceived change
in Sensation

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

Change of
Intensity

Physical
Intensity

17

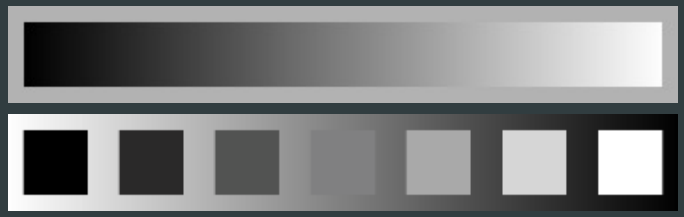
JUST NOTICEABLE DIFFERENCE

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



18

ENCODING DATA WITH COLOR

Value is perceived as ordered

∴ Encode ordinal variables (O)

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

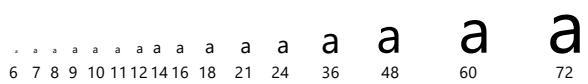
Hue is normally perceived as unordered

∴ Encode nominal variables (N) using color

19

STEPS IN FONT SIZE

Sizes standardized in 16th century

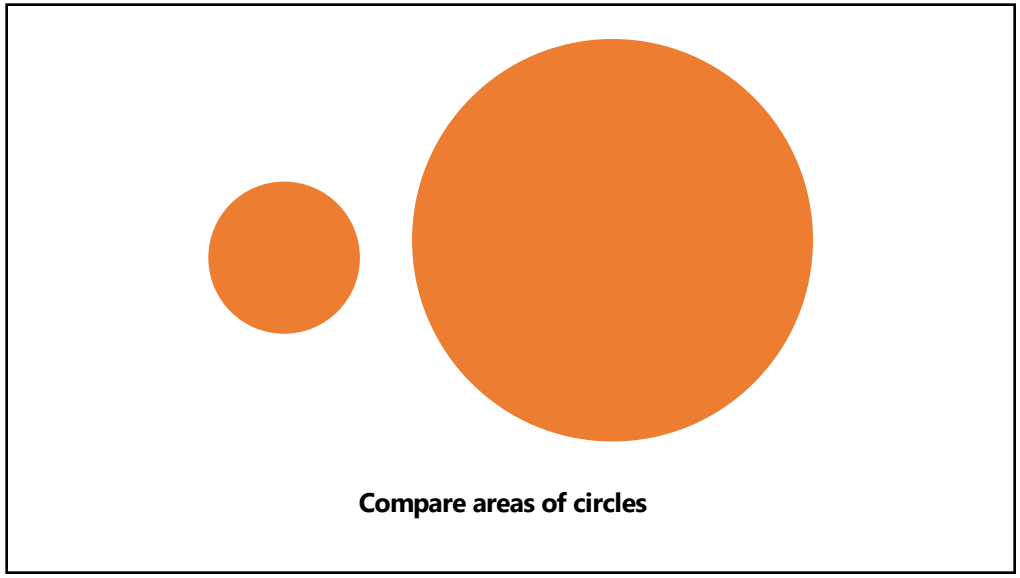


20

ESTIMATING MAGNITUDE

21

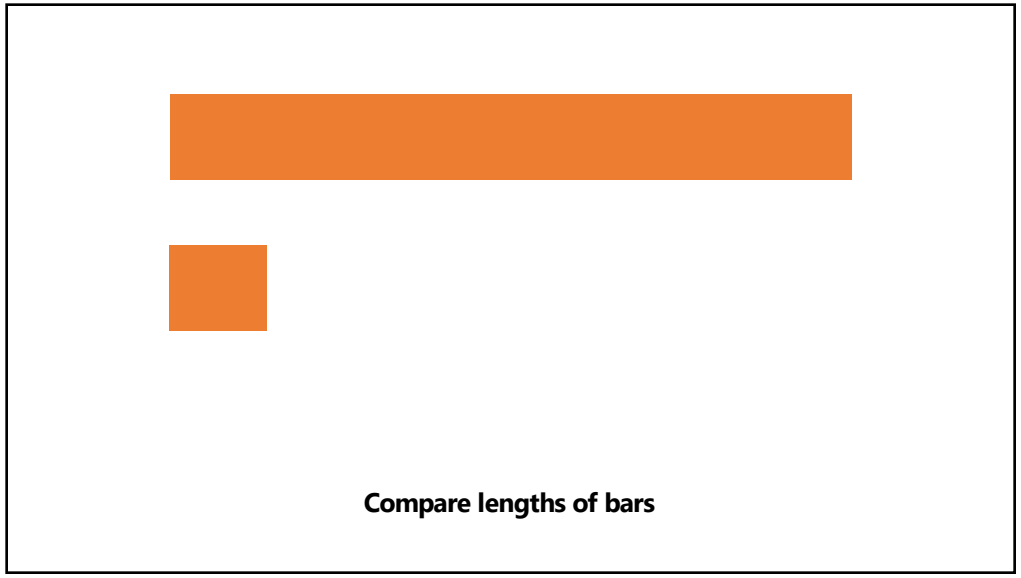
22



Compare areas of circles

23

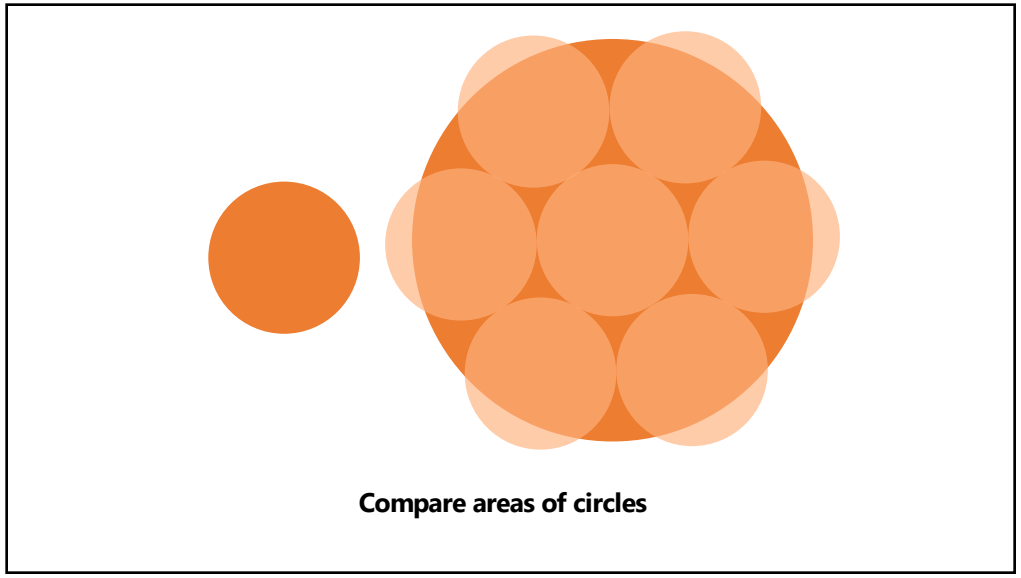
24



Compare lengths of bars

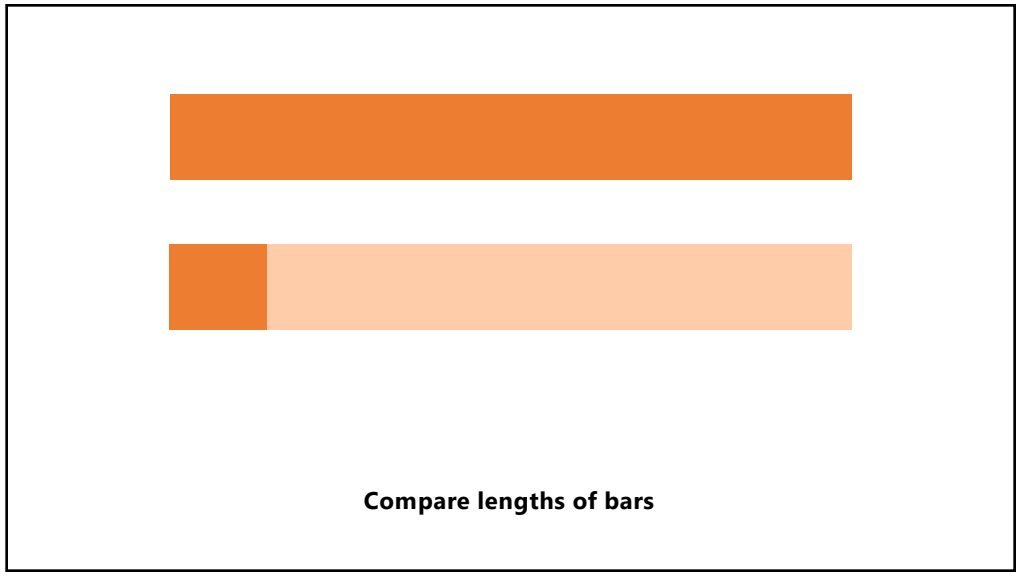
25

26



Compare areas of circles

27



Compare lengths of bars

28

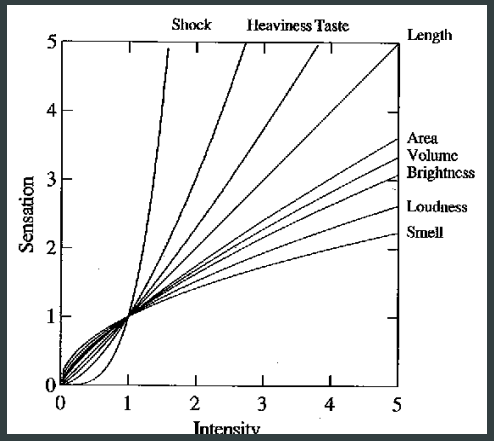
STEPHEN'S POWER LAW

Exponent
(Empirically Determined)

$$S = I^p$$

Perceived Sensation — Physical Intensity

p < 1 : underestimate
p > 1 : overestimate



Graph from Wilkinson 1999, based on Stevens 1961

29

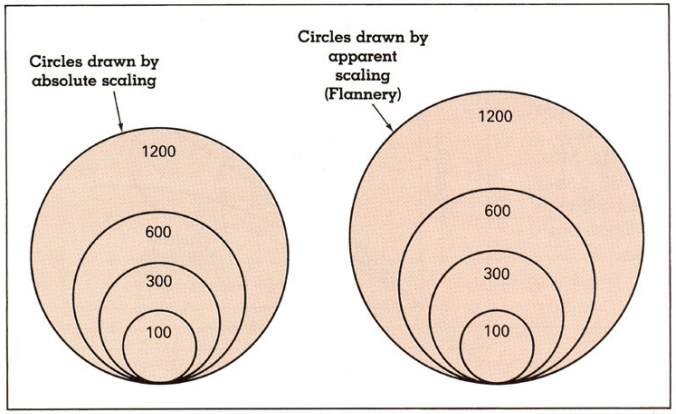
EXPONENTS OF POWER LAW

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 1961]

30

APPARENT MAGNITUDE SCALING

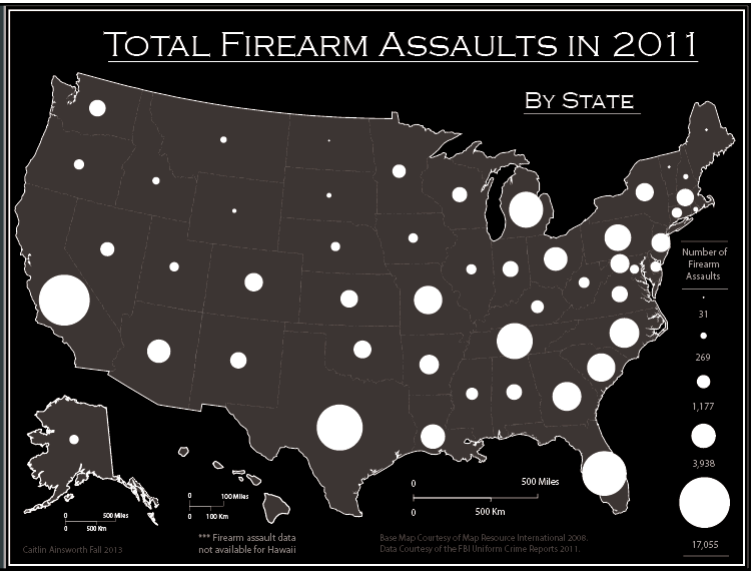


Cartography: Thematic Map Design, Figure 8.6, p. 170, [Dent 1996]

$$r = r_0(\frac{v}{v_0})^{0.5716}$$ [Flannery 1971]

31

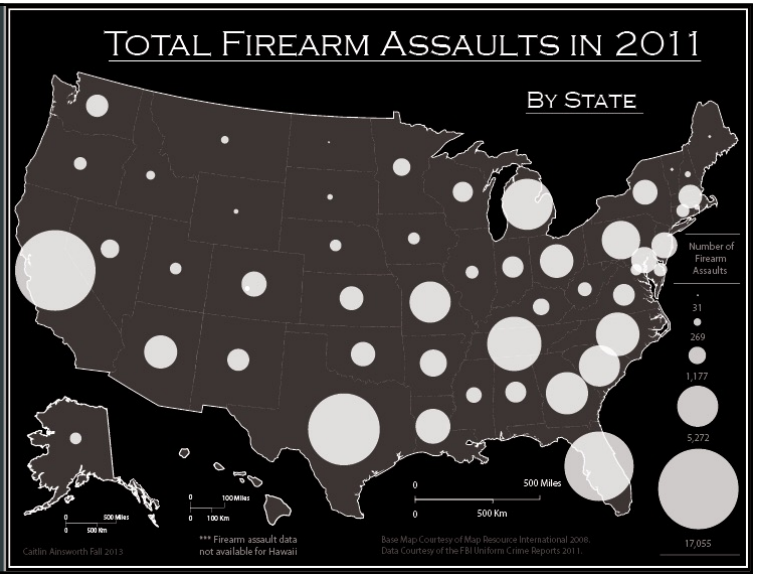
ABSOLUTE SYMBOL SCALING



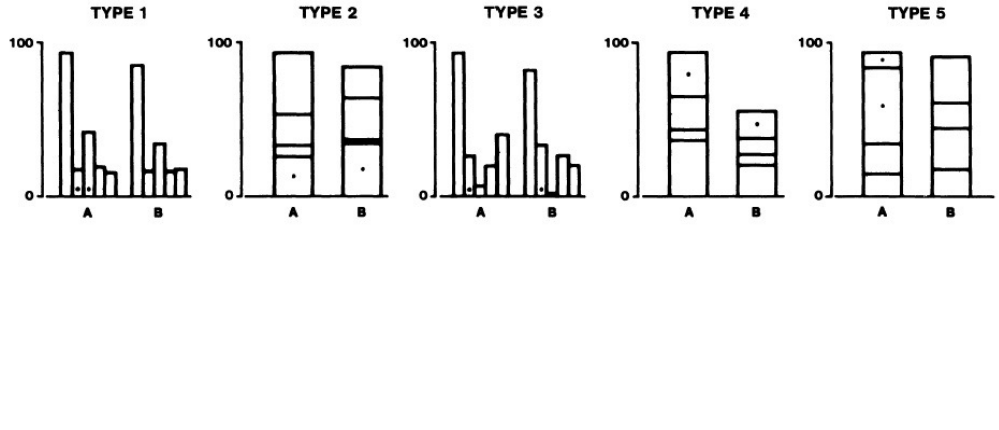
32

FLANNERY SCALING

$$r = r_0(\frac{v}{v_0})^{0.5716}$$

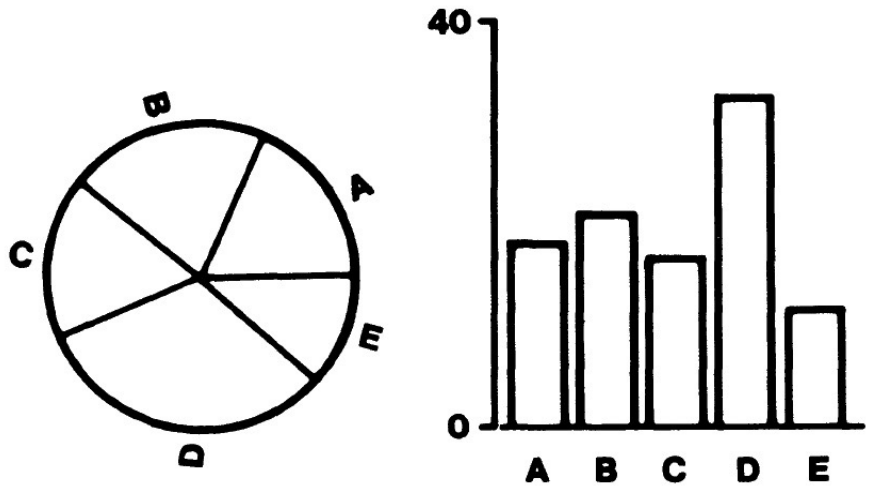


33



Graphical Perception [Cleveland and McGill 1984]

38



Graphical Perception [Cleveland and McGill 1984]

39

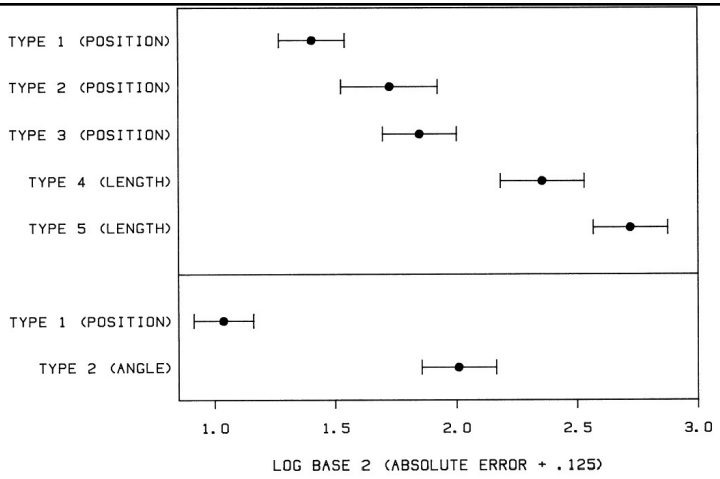


Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

Graphical Perception [Cleveland and McGill 1984]

40

RELATIVE MAGNITUDE ESTIMATION

41

EFFECTIVENESS RANKINGS [Mackinlay 1986]

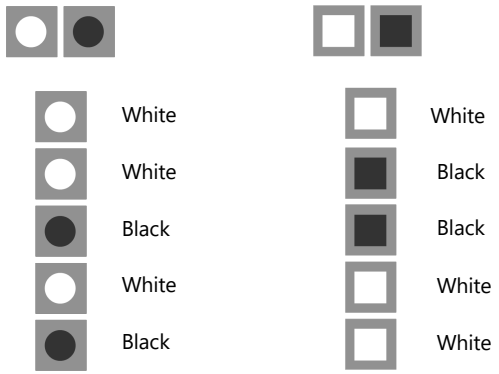
QUANTITATIVE	ORDINAL	NOMINAL
Position	Position	Position
Length	Density (Value)	Color Hue
Angle	Color Sat	Texture
Slope	Color Hue	Connection
Area (Size)	Texture	Containment
Volume	Connection	Density (Value)
Density (Value)	Containment	Color Sat
Color Sat	Length	Shape
Color Hue	Angle	Length
Texture	Slope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

42

MULTIPLE ATTRIBUTES

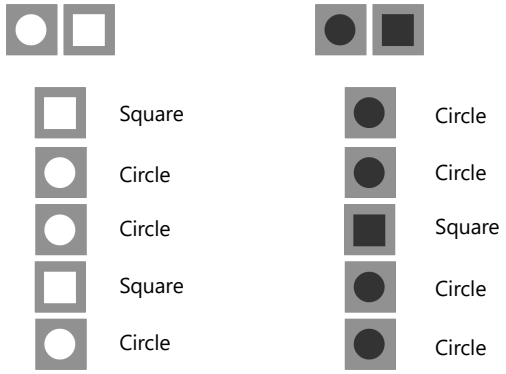
43

ONE-DIMENSIONAL: LIGHTNESS



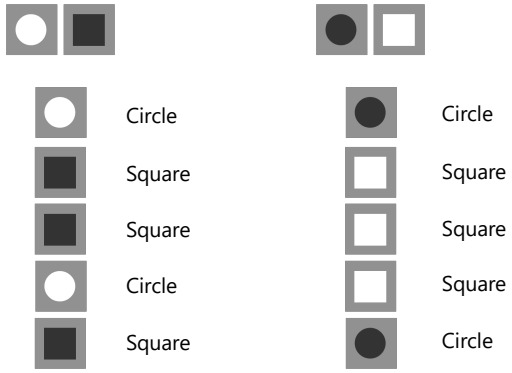
44

ONE-DIMENSIONAL: SHAPE



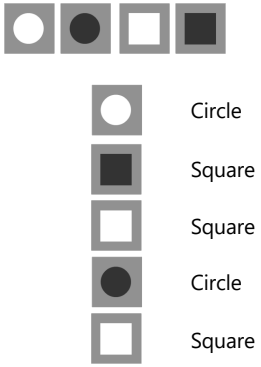
45

REDUNDANT: SHAPE & LIGHTNESS



46

ORTHOGONAL: SHAPE & LIGHTNESS



47

SPEEDED CLASSIFICATION

Redundancy gain

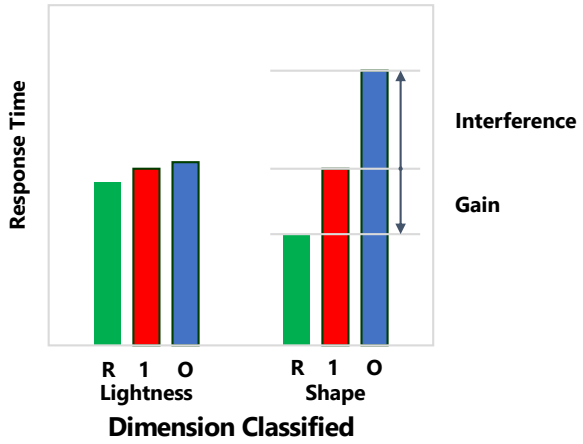
Facilitation in reading one dimension when the other provides redundant information

Filtering interference

Difficulty in ignoring one dimension while attending to the other

48

SPEEDED CLASSIFICATION



49

TYPES OF PERCEPTUAL DIMENSIONS

Integral
Filtering interference and redundancy gain

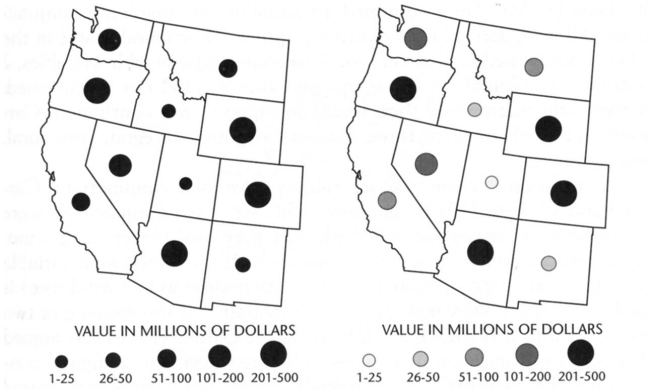
Separable
No interference or gain

Configural
Only interference, but no redundancy gain

Asymmetrical
One dimension separable from other, not vice versa

50

REDUNDANT: SIZE & VALUE



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

51

ORTHOGONAL: HEIGHT & WIDTH

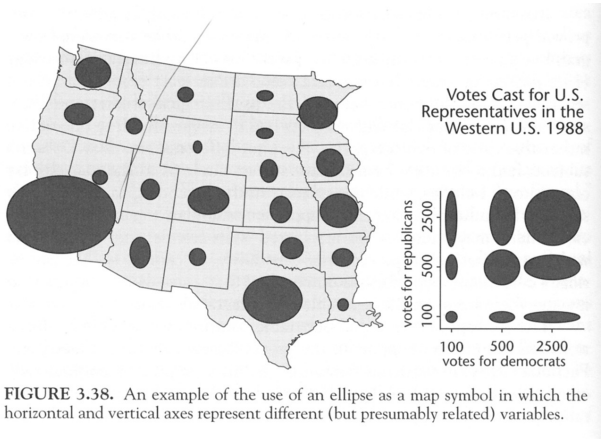


FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

[MacEachren 1995]

52

ORTHOGONAL: ORIENTATION & SIZE

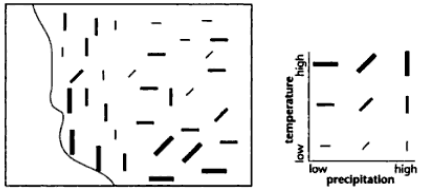


FIGURE 3.36. A map of temperature and precipitation using symbol size and orientation to represent data values on the two variables.

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

[MacEachren 1995]

53

ORTHOGONAL: SHAPE & SIZE

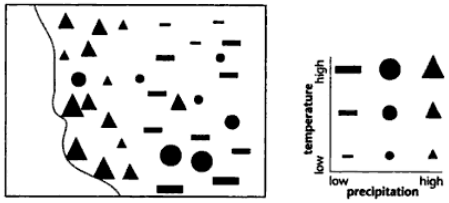


FIGURE 3.40. The bivariate temperature–precipitation map of Figure 3.36, this time using point symbols that vary in shape and size to represent the two quantities.

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

[MacEachren 1995]

54

STROOP EFFECT: WHAT WORD?

blue
yellow
red
orange
green
purple

55

STROOP EFFECT: WHAT COLOR?

blue
yellow
red
orange
green
purple

56

SUMMARY OF INTEGRAL-SEPARABLE

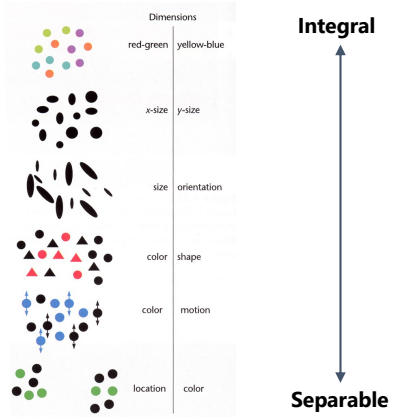


Figure 5.25, Color Plate 10, [Ware 2000]

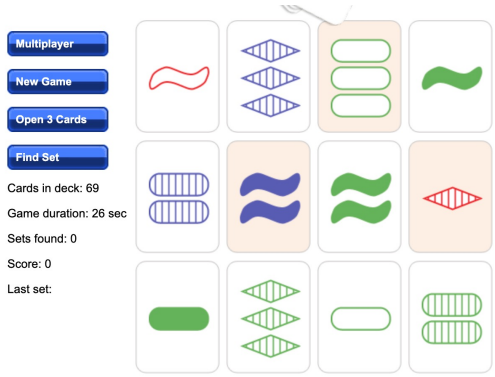
58

SET

Each card has 4 features:

- Color
- Symbol
- Number
- Texture

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



https://smart-games.org/en/set/find_set

59

PRE-ATTENTIVE VS. ATTENTIVE

60

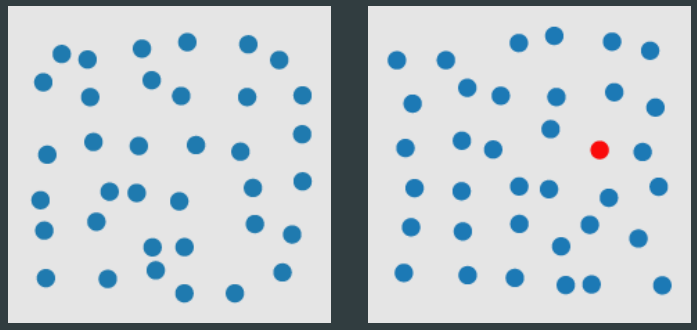
128176875613897654698450698560498282676 2
980985845822450985645894509845098094358 5
909103020990595959577256467505067890456 7
884578980982167765487636490856091294968 6

61

12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496862

62

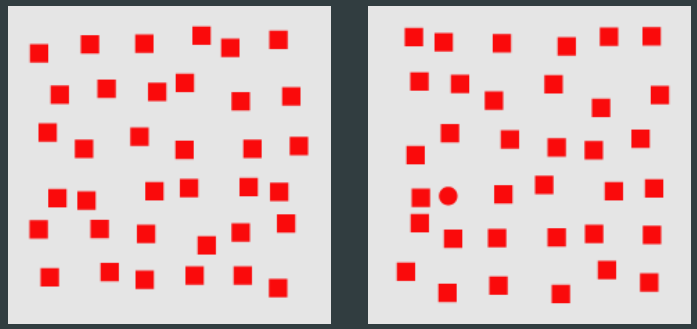
VISUAL POP-OUT: COLOR



https://www.csc2.ncsu.edu/faculty/healey/PP/

63

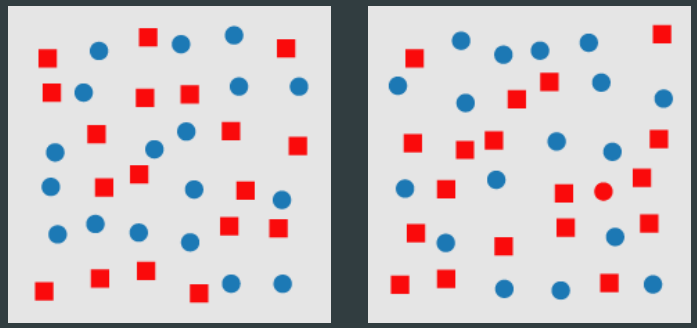
VISUAL POP-OUT: SHAPE



https://www.csc2.ncsu.edu/faculty/healey/PP/

64

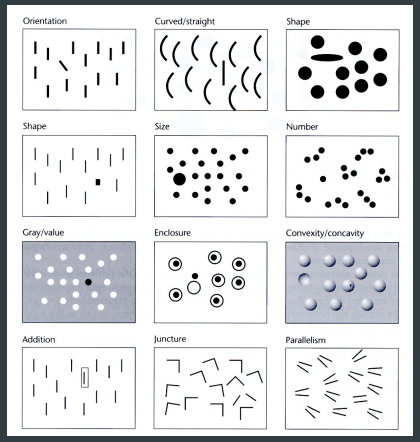
FEATURE CONJUNCTIONS



https://www.csc2.ncsu.edu/faculty/healey/PP/

65

PRE-ATTENTIVE FEATURES



Information Visualization. Figure 5. 5 [Ware 2004]

66

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

67

PRE-ATTENTIVE CONJUNCTIONS

Spatial conjunctions are often pre-attentive

Motion and 3D disparity

Motion and color

Motion and shape

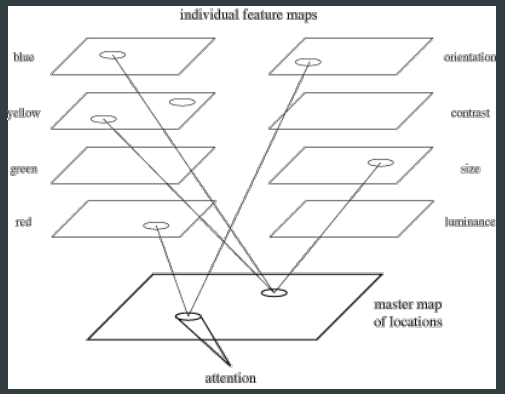
3D disparity and color

3D disparity and shape

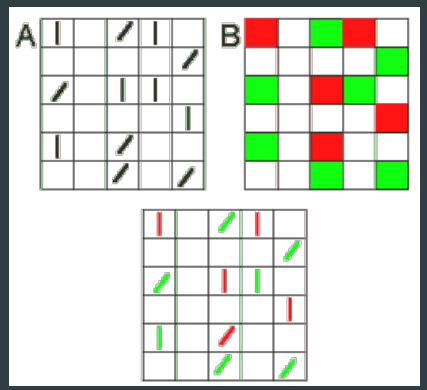
Most conjunctions are **NOT** preattentive

68

FEATURE INTEGRATION THEORY



Treisman's feature integration model [Healey 2004]



Feature maps for orientation & color

69

ANNOUNCEMENTS

70

ASSIGNMENT 3: INTERACTION

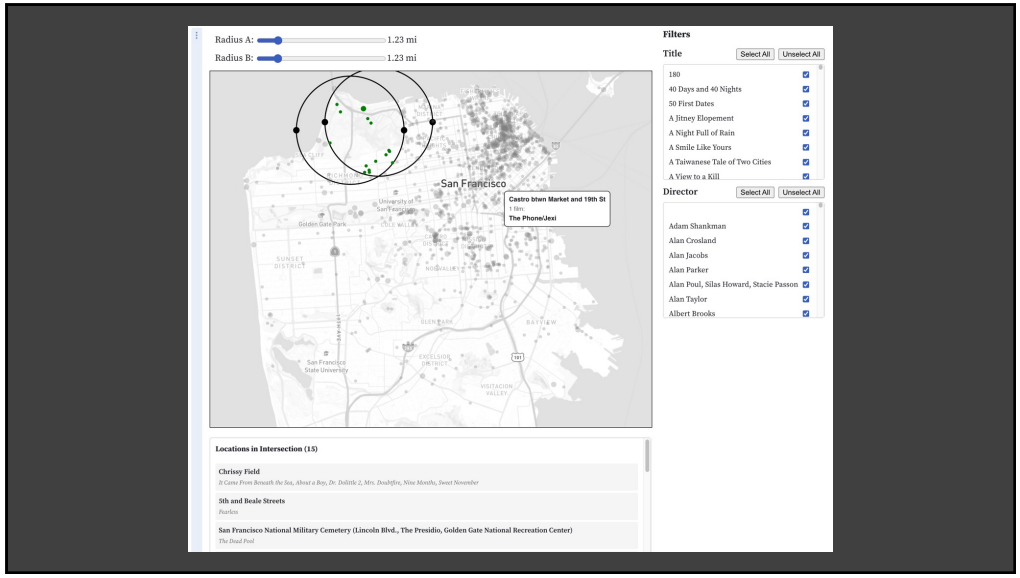
Due 10/27 10:30am

Create a small interactive dynamic query application similar to HomeFinder, but for San Francisco film locations.

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

Can work alone or in pairs

71



72

GESTALT

73

GESTALT PRINCIPLES

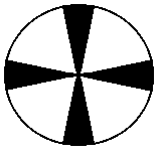
figure/ground
proximity
similarity
symmetry
connectedness
continuity
closure
common fate
transparency

74

FIGURE/GROUND

Ambiguous

Principle of surroundedness

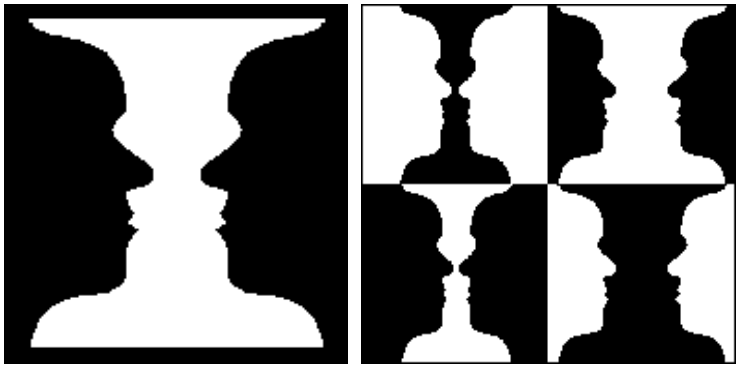


Principle of relative size

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

75

FIGURE/GROUND

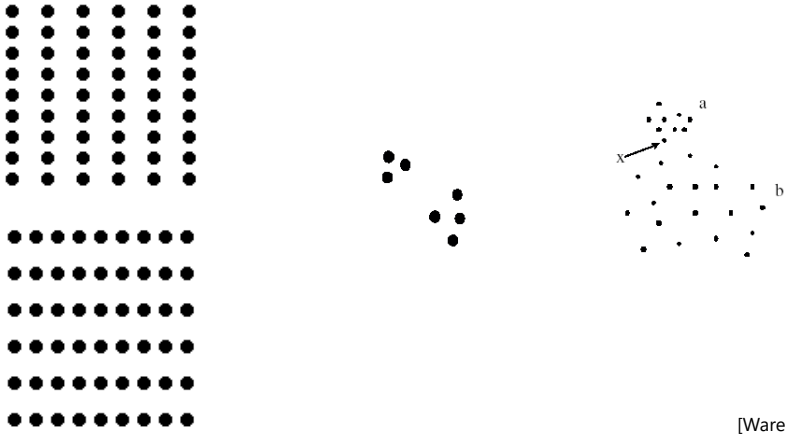


Ambiguous Unambiguous

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

76

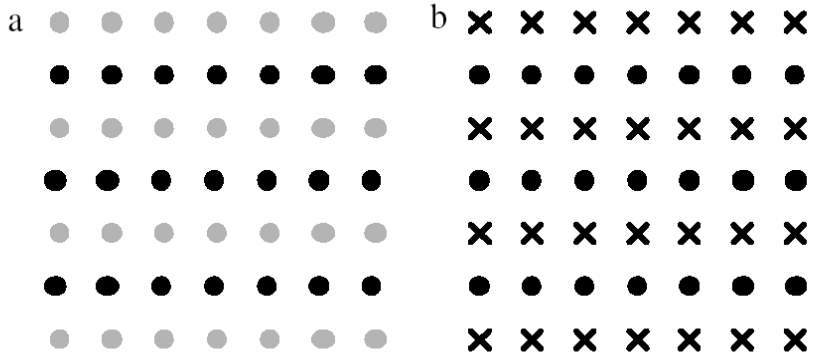
PROXIMITY



[Ware 2000]

77

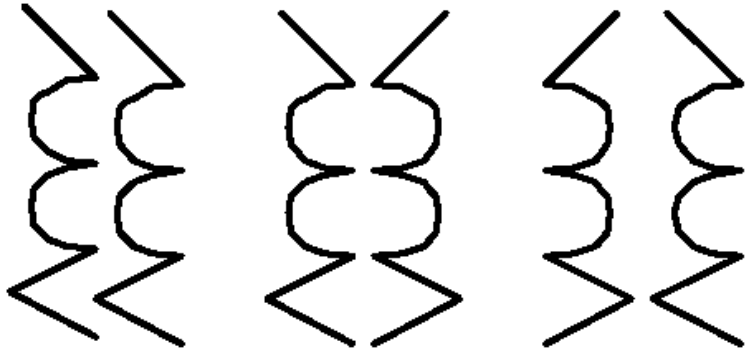
SIMILARITY



Rows dominate due to similarity [Ware 2004]

78

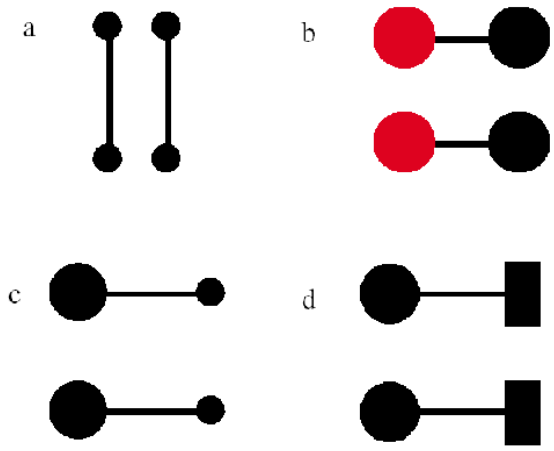
SYMMETRY



Bilateral symmetry gives strong sense of figure [Ware 2004]

79

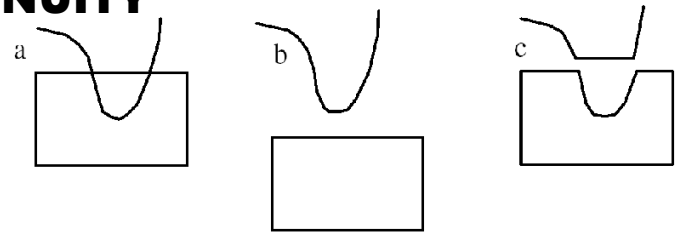
CONNECTEDNESS



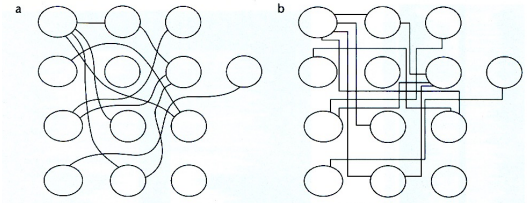
Connectedness overrules proximity, size, color shape [Ware 2004]

80

CONTINUITY



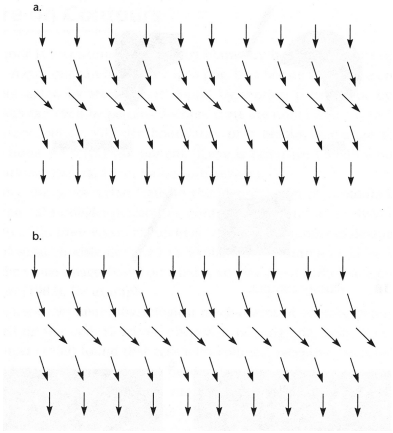
We prefer smooth not abrupt changes [Ware 2004]



Connections are clearer with smooth contours [Ware 2004]

81

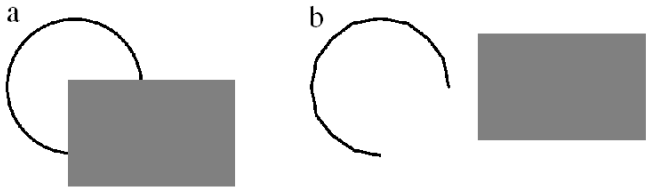
CONTINUITY: VECTOR FIELDS



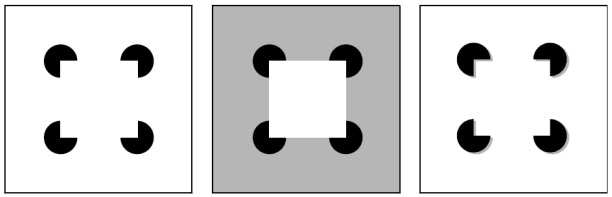
Prefer field that shows smooth continuous contours [Ware 2004]

82

CLOSURE



We see a circle behind a rectangle, not a broken circle [Ware 2004]



Illusory contours [from Durand 2002]

83

COMMON FATE

Dots moving together are grouped

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

84

TRANSPARENCY

Requires continuity and proper color correspondence [Ware 2004]

a

85