# PERCEPTION

CS 448B | Fall 2024

MANEESH AGRAWALA

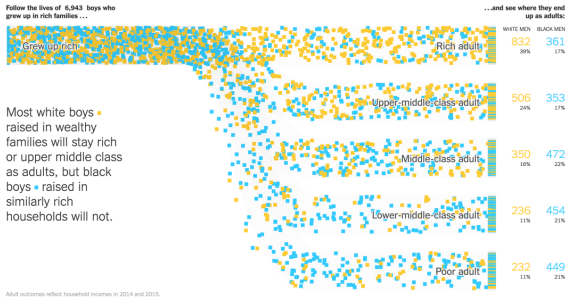
1

## *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.



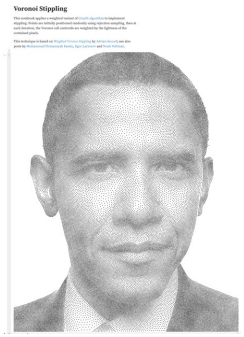

https://www.nytimes.com/interactive/2018/03/19/upshot/race-class-white-and-black-men.html

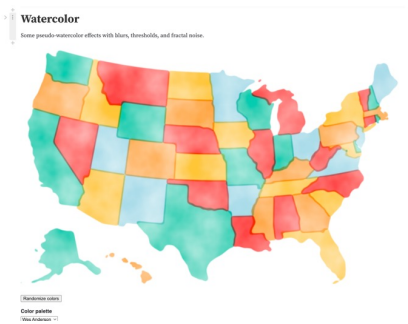
2

# READING RESPONSE: QUESTIONS/THOUGHTS

… I continued to ***peruse*** through the notebooks to the '***Just for Fun***' section… such as the ***Voronoi stippling of Obama*** … and the ***watercolor representation of the United States*** …, seemed to have little informational substance aside from demonstrating creation of artwork! … ***sometimes the designer's intent is for the audience to think that the visualization is cool!***

***Is the ability to draw formal conclusions always required for something to be considered data?***




3

# READING RESPONSE: QUESTIONS/THOUGHTS

… one con of **D3** is that it ***is very "low-level***." While D3's declarative model is incredibly powerful for creating custom, dynamic visualizations, the learning curve might be too high of a barrier for those who lack knowledge of JavaScript, HTML, and CSS. ***Could future iterations of D3 include higher-level abstractions or more user-friendly interfaces to lower the barrier to entry?***

4

# GRAPHICAL PERCEPTION

5

## 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.

6

# 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 accurate)

7

# 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 |

8

## Graphical Perception

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

9

## 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.).

10

# SIGNAL DETECTION

12

## DETECTING BRIGHTNESS

**Which is brighter?**

13

# DETECTING BRIGHTNESS

(129, 129, 129)

(131, 131, 131)

**Which is brighter?**

14

# 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

15

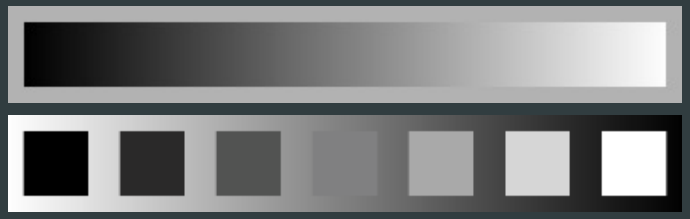
# JUST NOTICEABLE DIFFERENCE

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



16

# ENCODING DATA WITH COLOR

Value is perceived as ordered

∴ Encode ordinal variables (O)

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

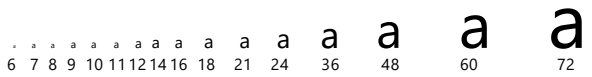
Hue is normally perceived as unordered

∴ Encode nominal variables (N) using color

17

# STEPS IN FONT SIZE

Sizes standardized in 16th century

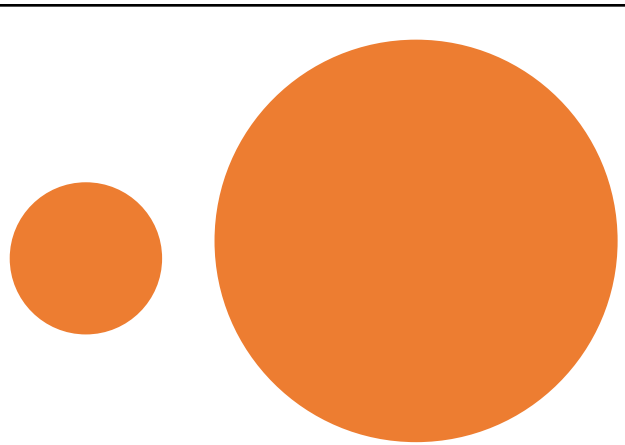



18

# ESTIMATING MAGNITUDE

19

20



**Compare areas of circles**

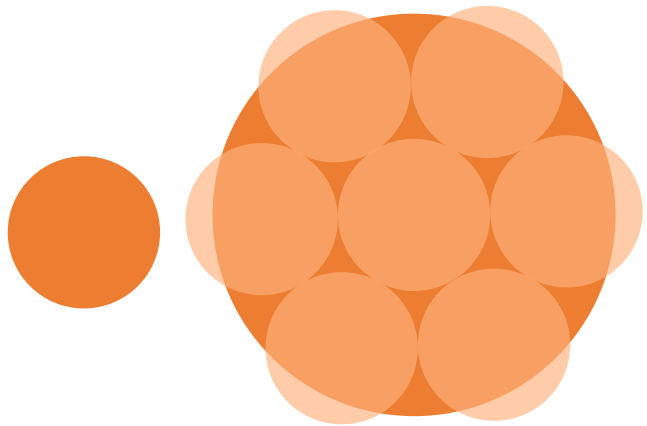
21

22

**Compare lengths of bars**

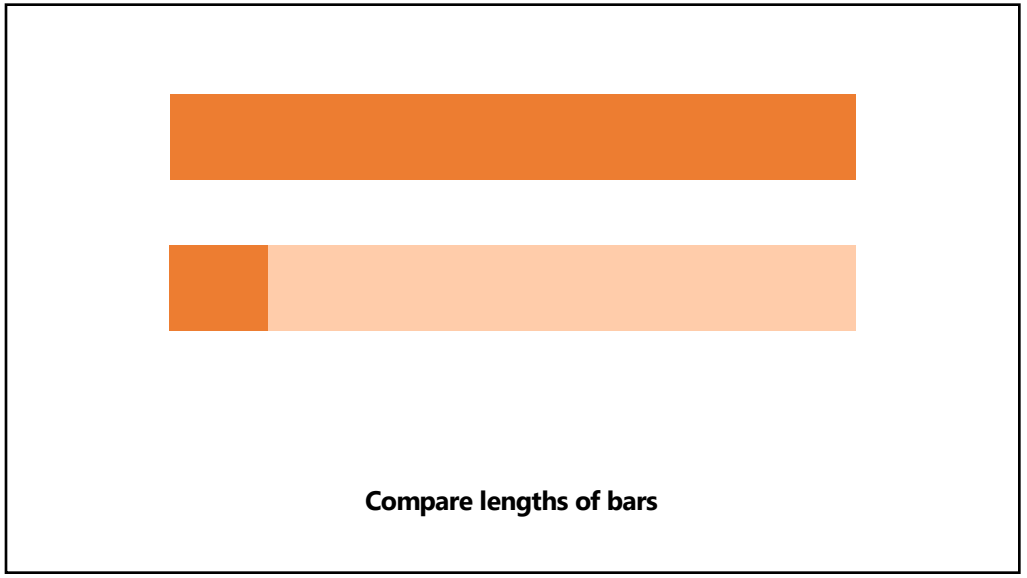
23

24



**Compare areas of circles**

25




26

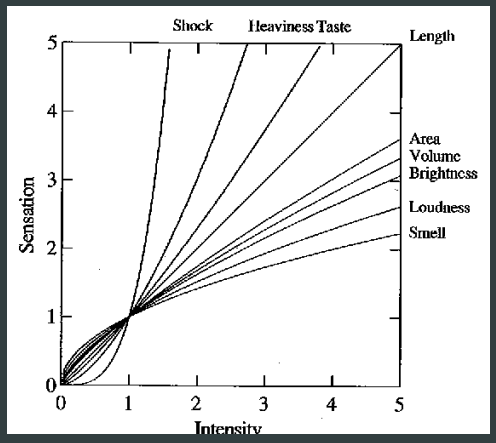
## STEPHEN'S POWER LAW

Exponent
(Empirically Determined)

$$S = I^p$$

Perceived Sensation — Physical Intensity

**p < 1 : underestimate**
**p > 1 : overestimate**




Graph from Wilkinson 1999, based on Stevens 1961

27

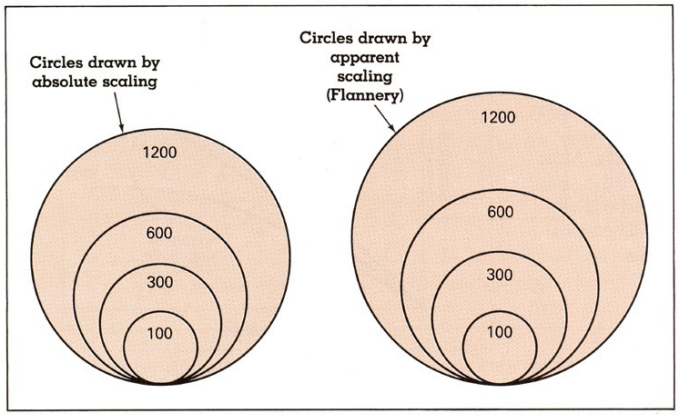
# EXPONENTS OF POWER LAW

| 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]

28

# APPARENT MAGNITUDE SCALING

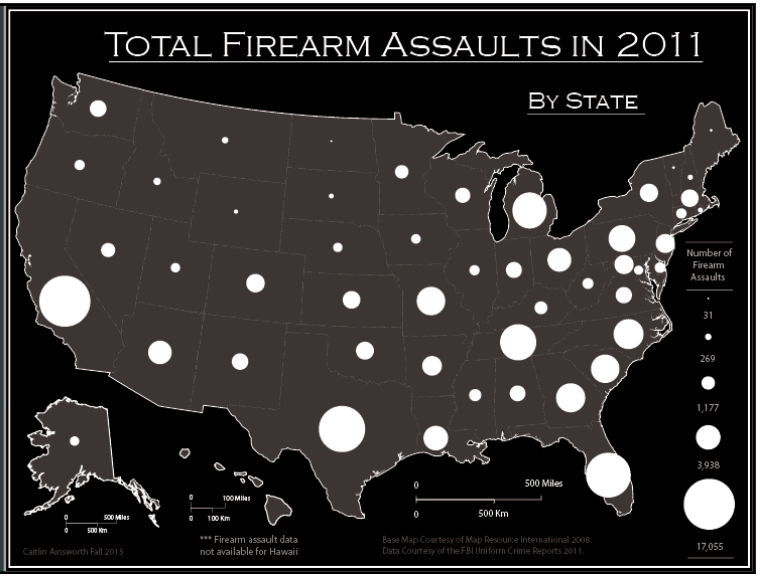



Cartography: Thematic Map Design, Figure 8.6, p. 170, [Dent 1996]

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

29

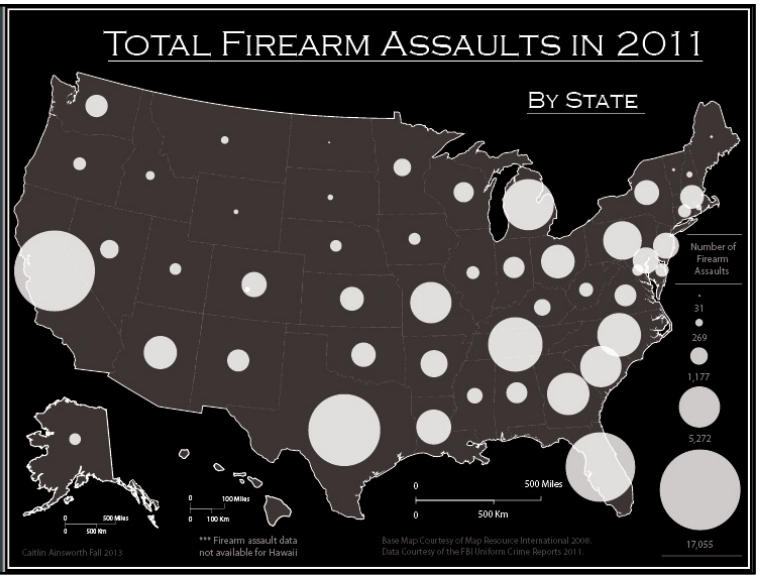
## ABSOLUTE SYMBOL SCALING




30

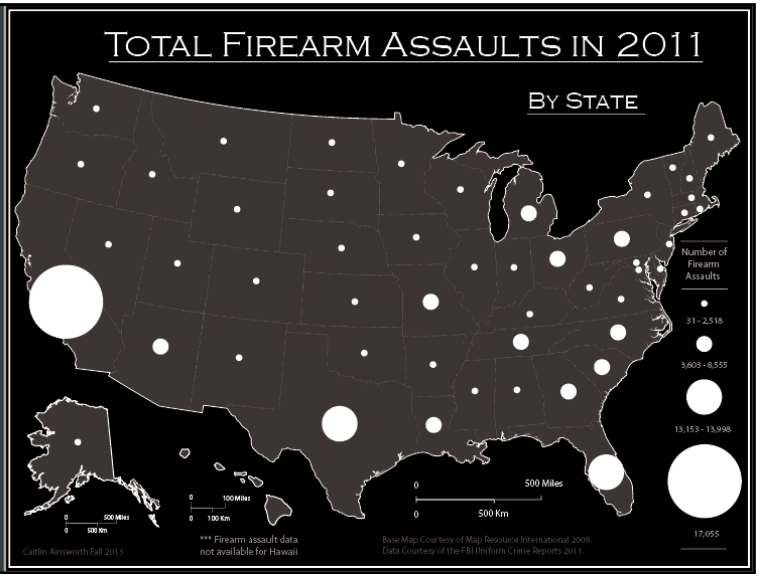
## FLANNERY SCALING

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

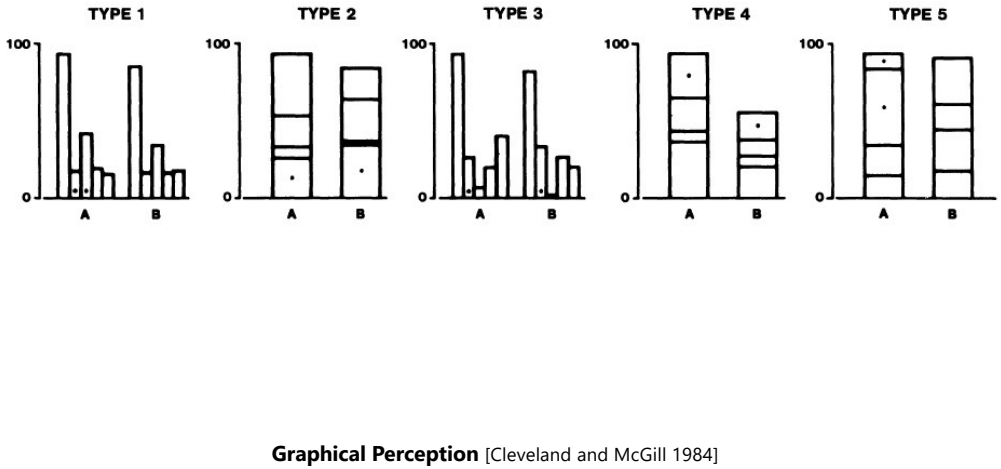



31

**RANGE GRADING**

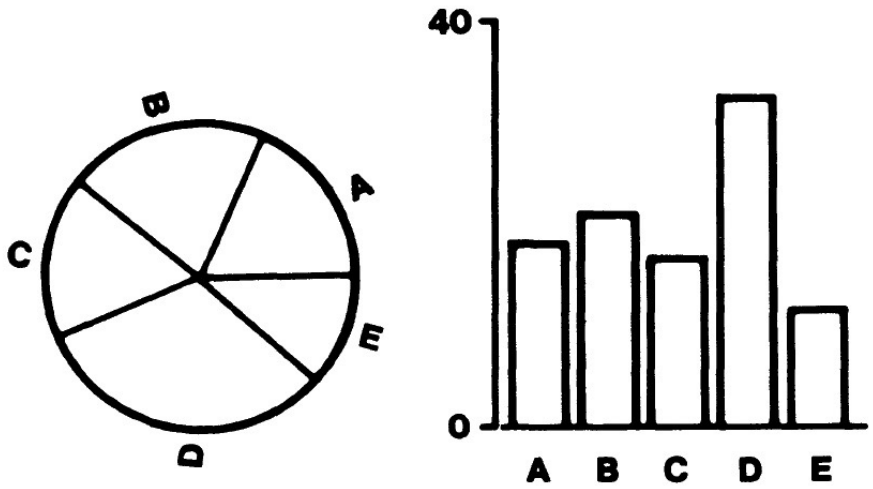



32




**Graphical Perception** [Cleveland and McGill 1984]

36




**Graphical Perception** [Cleveland and McGill 1984]

37

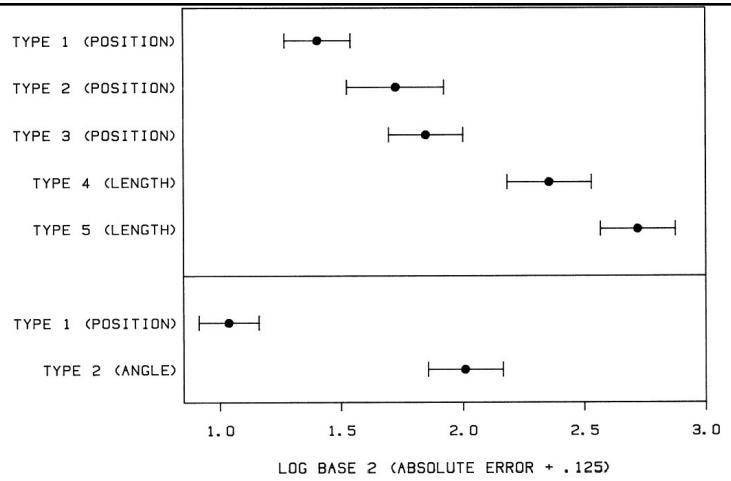



*Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).*

**Graphical Perception** [Cleveland and McGill 1984]

38

# RELATIVE MAGNITUDE ESTIMATION


39

# EFFECTIVENESS RANKINGS [Mackinlay 1986]

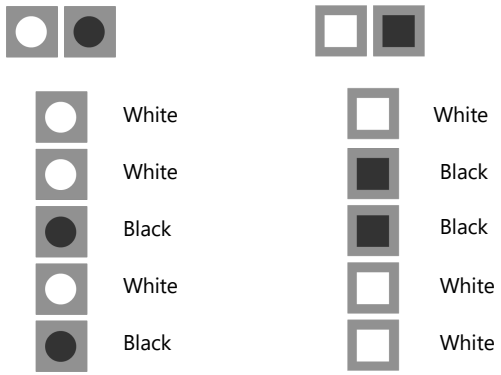
| QUANTITATIVE | ORDINAL | NOMINAL |
|---|---|---|
| Position | Position | Position |
| Length | Density (Value) | Color Hue |
| Angle | Color Sat | Texture |
| Slope | Color Hue | Connection |
| Area (Size) | Texture | Containment |
| Volume | Connection | Density (Value) |
| Density (Value) | Containment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

40

# MULTIPLE ATTRIBUTES

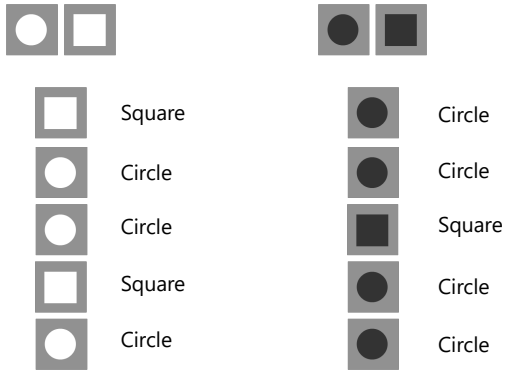
41

## ONE-DIMENSIONAL: LIGHTNESS



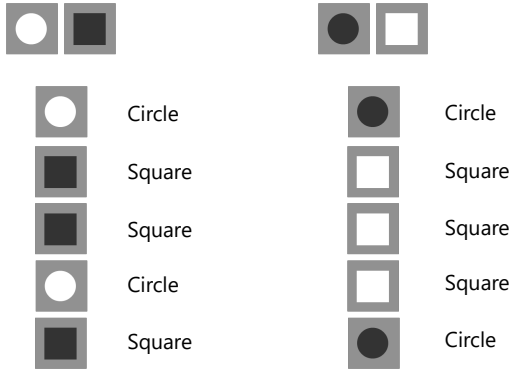

42

## ONE-DIMENSIONAL: SHAPE



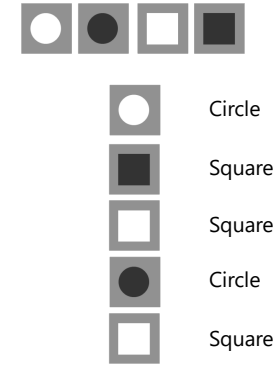

43

## REDUNDANT: SHAPE & LIGHTNESS




44

## ORTHOGONAL: SHAPE & LIGHTNESS




45

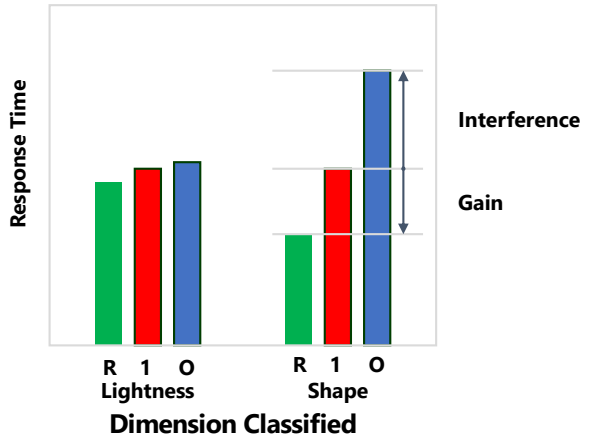
## SPEEDED CLASSIFICATION

**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

46

# SPEEDED CLASSIFICATION




47

# TYPES OF PERCEPTUAL DIMENSIONS

**Integral**
Filtering interference and redundancy gain

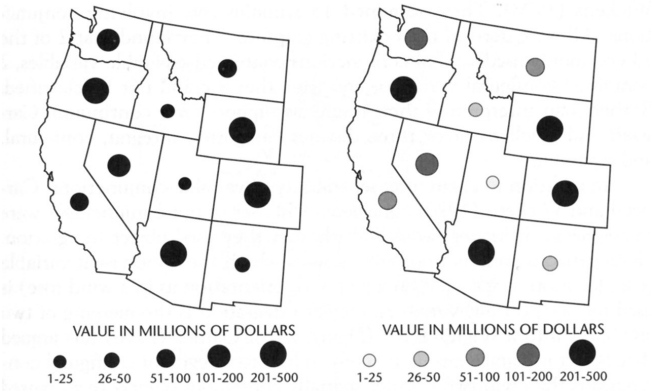
**Separable**
No interference or gain

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

**Asymmetrical**
One dimension separable from other, not vice versa
*Example:* The Stroop effect – color naming is influenced by word identity, but word naming is not influenced by color

48

# REDUNDANT: SIZE & VALUE




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

49

# ORTHOGONAL: HEIGHT & WIDTH

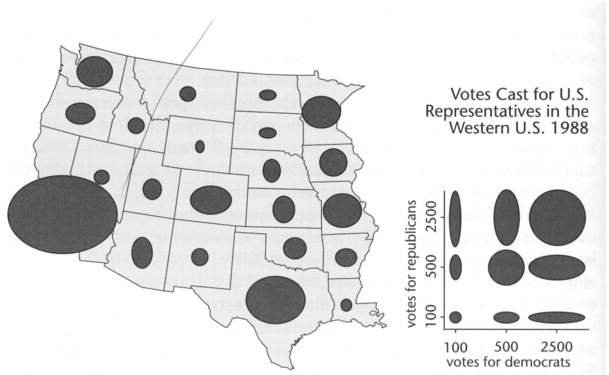



FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

[MacEachren 1995]

50

# ORTHOGONAL: ORIENTATION & SIZE

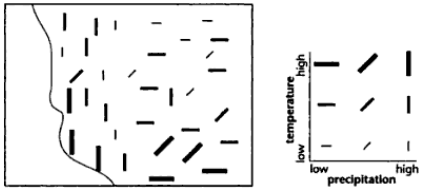



**FIGURE 3.36.** A map of temperature and precipitation using symbol size and orientation to represent data values on the two variables.

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

[MacEachren 1995]

51

# ORTHOGONAL: SHAPE & SIZE

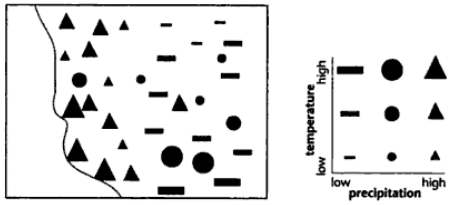



**FIGURE 3.40.** The bivariate temperature–precipitation map of Figure 3.36, this time using point symbols that vary in shape and size to represent the two quantities.

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

[MacEachren 1995]

52

## STROOP EFFECT: WHAT WORD?

blue
yellow
red
orange
green
purple

53

## STROOP EFFECT: WHAT COLOR?

blue
yellow
red
orange
green
purple

54

# SUMMARY OF INTEGRAL-SEPARABLE

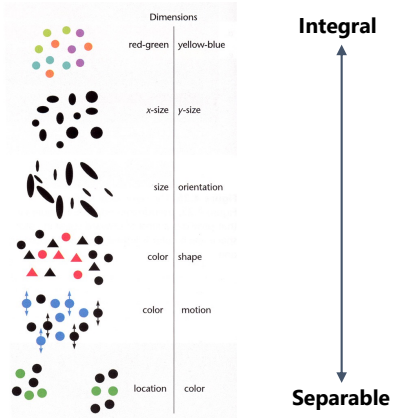



Figure 5.25, Color Plate 10, [Ware 2000]

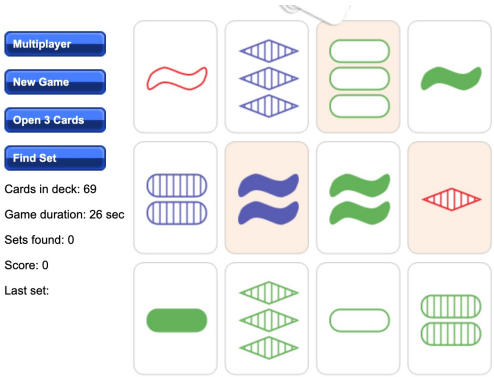
56

# 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

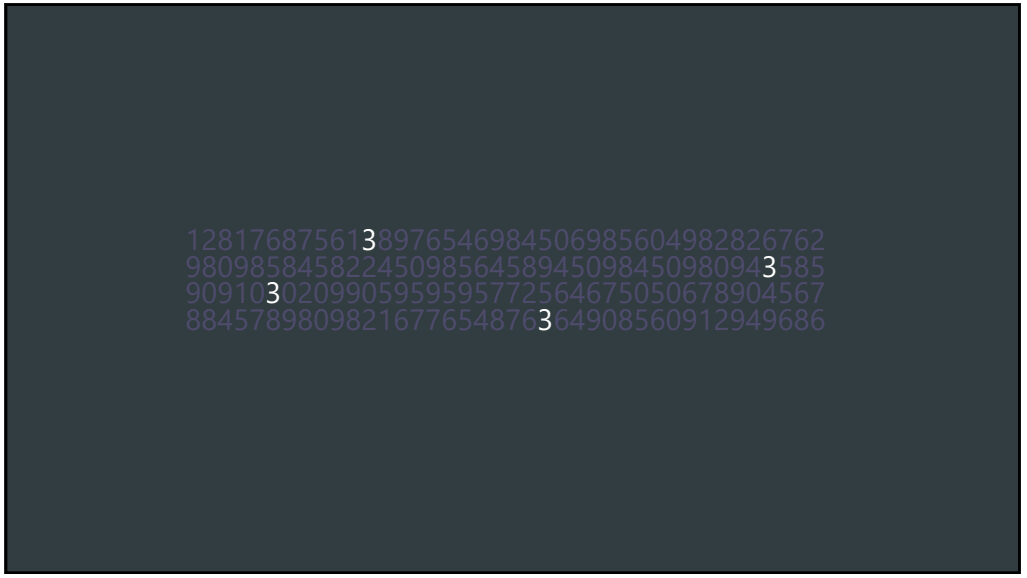
57

# PRE-ATTENTIVE VS. ATTENTIVE

59

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

60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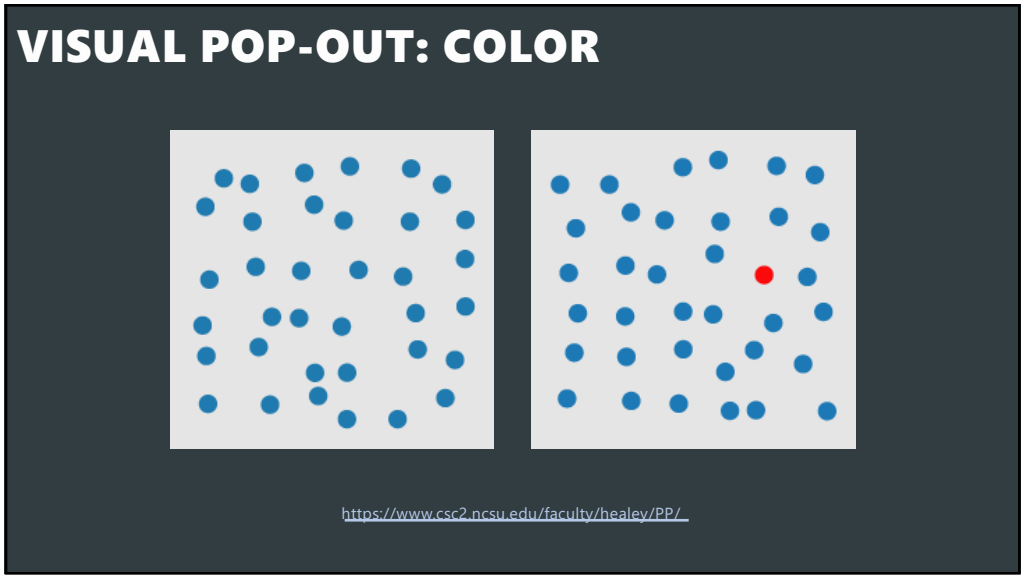
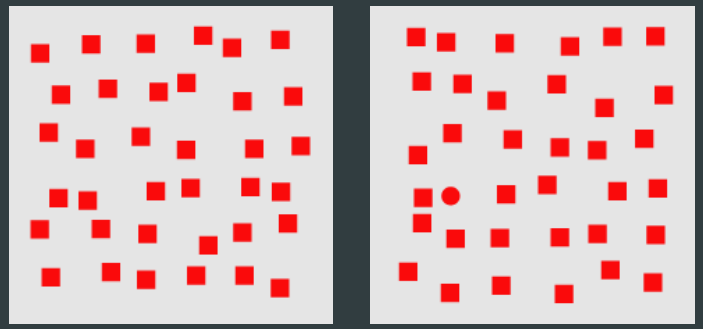
61


VISUAL POP-OUT: COLOR
https://www.csc2.ncsu.edu/faculty/healey/PP/

62

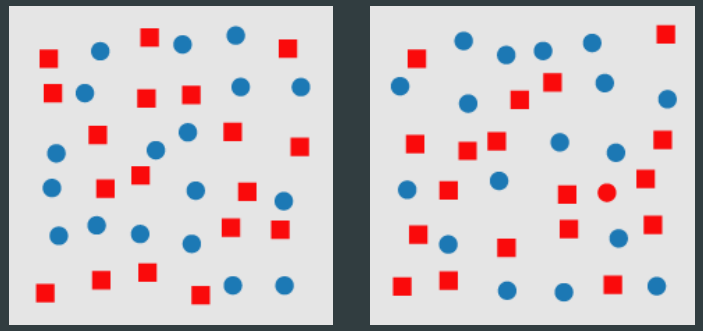
## VISUAL POP-OUT: SHAPE



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

63

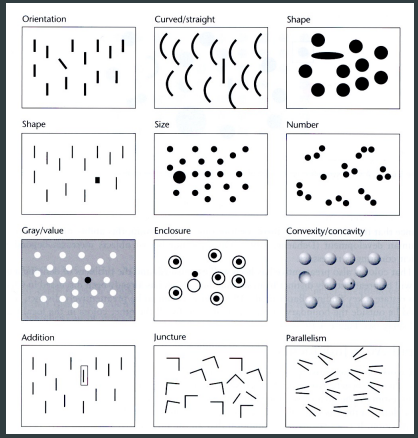
## FEATURE CONJUNCTIONS



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

64

# PRE-ATTENTIVE FEATURES




Information Visualization. Figure 5. 5 [Ware 2004]

65

# 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

66

# PRE-ATTENTIVE CONJUNCTIONS

**Spatial conjunctions** are often pre-attentive

Motion and 3D disparity

Motion and color

Motion and shape

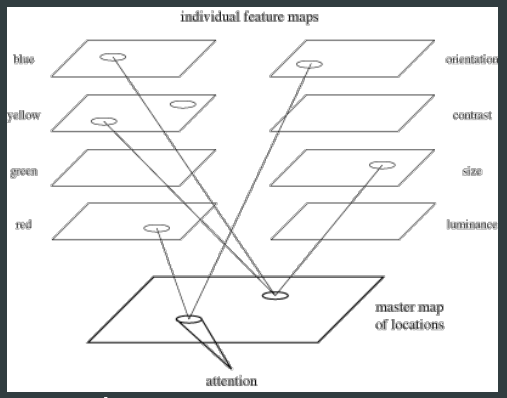
3D disparity and color

3D disparity and shape

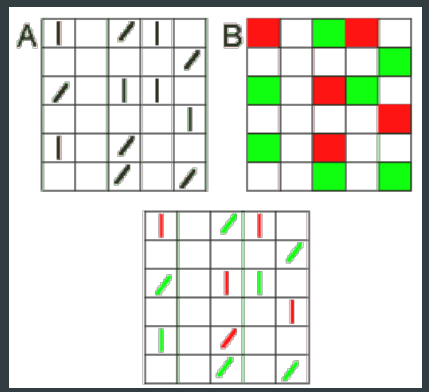
Most conjunctions are **NOT** preattentive

67

# FEATURE INTEGRATION THEORY




**Treisman's feature integration model** [Healey 2004]




**Feature maps for orientation & color**

68

# ANNOUNCEMENTS

69

# ASSIGNMENT 3: INTERACTION

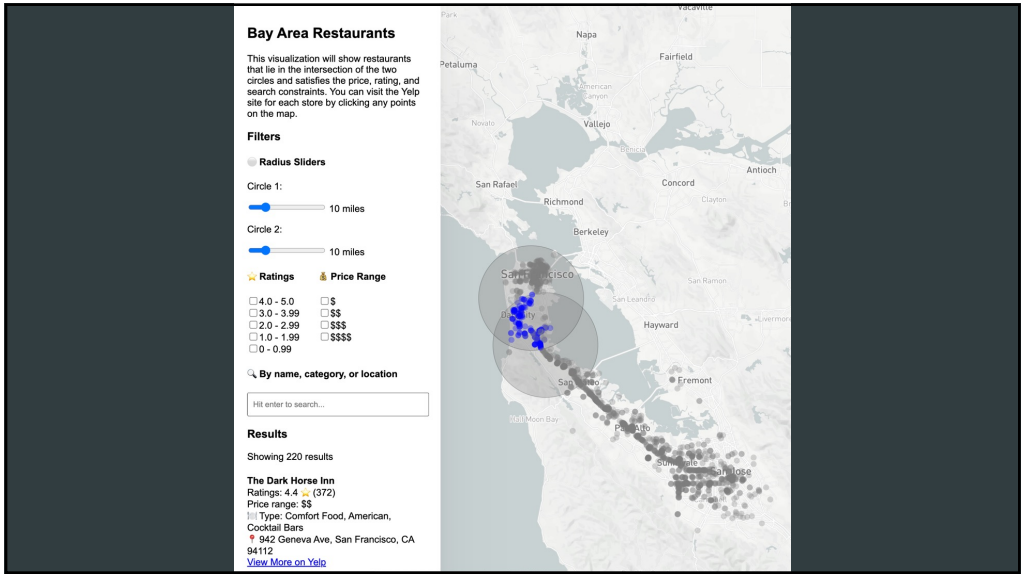
**Due 10/28 10:30am**

Create a small interactive dynamic query application similar to HomeFinder, but for Bay Area restaurants.

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

Can work alone or in pairs


70




71

# GESTALT

72

# GESTALT PRINCIPLES

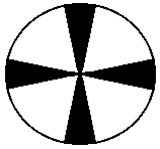
figure/ground
proximity
similarity
symmetry
connectedness
continuity
closure
common fate
transparency

73

# FIGURE/GROUND

**Ambiguous**

**Principle of surroundedness**

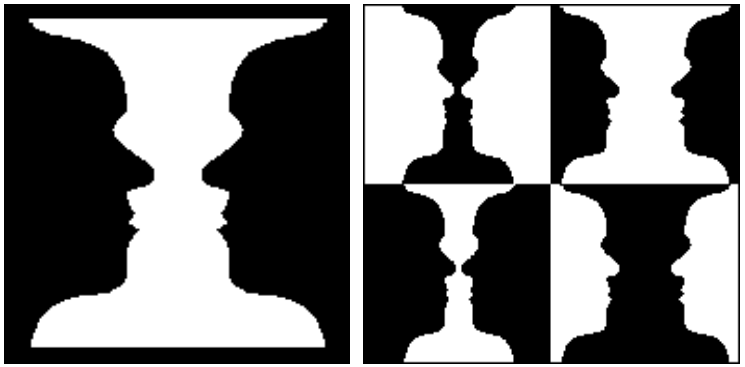


**Principle of relative size**

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

74

# FIGURE/GROUND

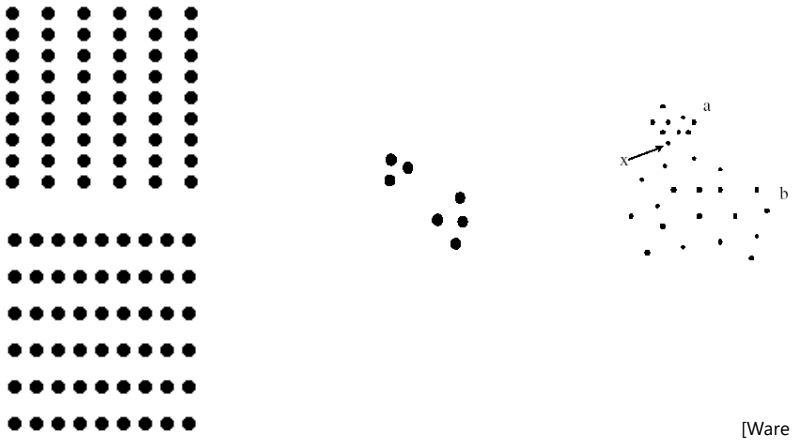


Ambiguous Unambiguous

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

75

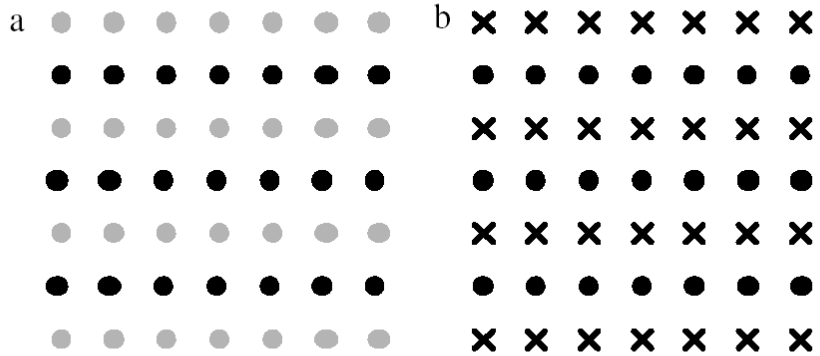
# PROXIMITY




[Ware 2000]

76

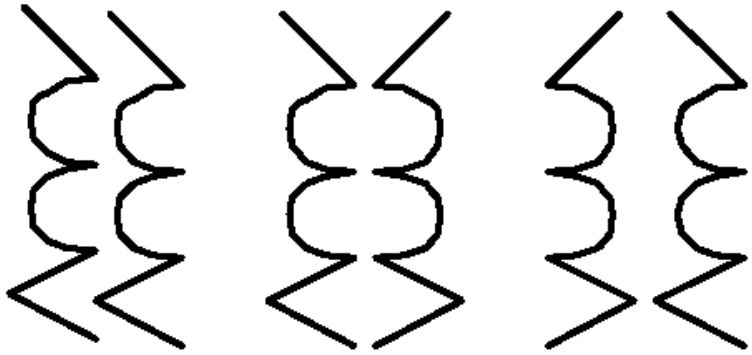
## SIMILARITY




**Rows dominate due to similarity** [Ware 2004]

77

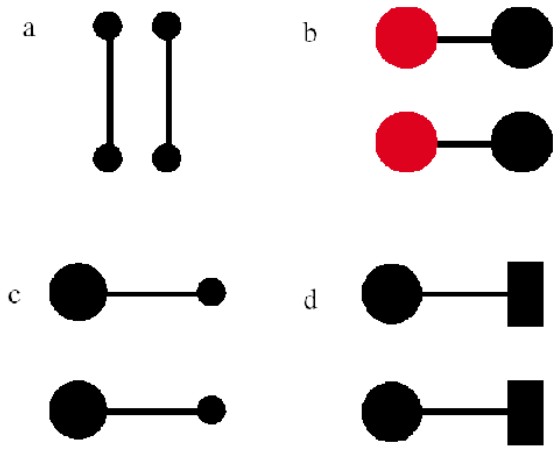
## SYMMETRY



**Bilateral symmetry gives strong sense of figure** [Ware 2004]

78

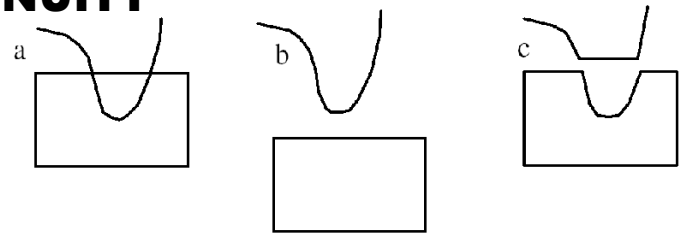
## CONNECTEDNESS



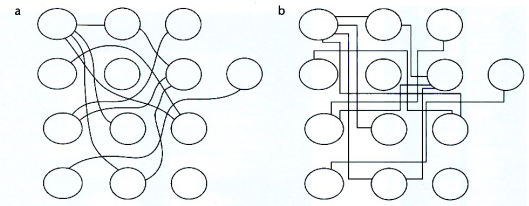

**Connectedness overrules proximity, size, color shape** [Ware 2004]

79

## CONTINUITY



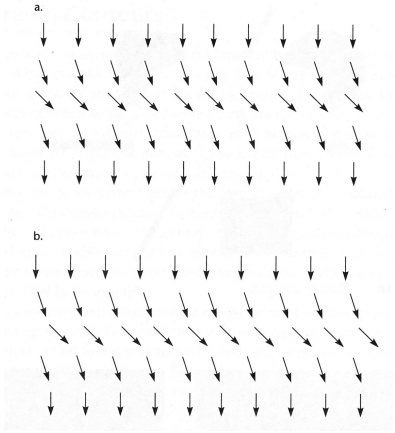

**We prefer smooth not abrupt changes** [Ware 2004]




**Connections are clearer with smooth contours** [Ware 2004]

80

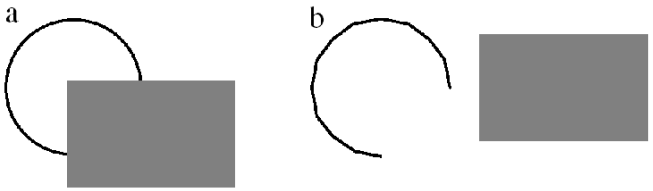
# CONTINUITY: VECTOR FIELDS



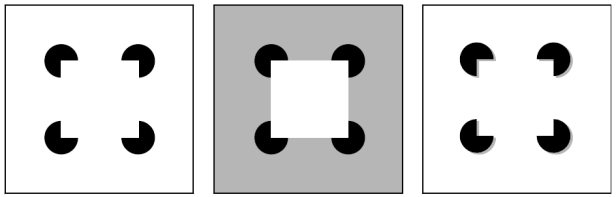

**Prefer field that shows smooth continuous contours** [Ware 2004]

81

# CLOSURE




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



**Illusory contours** [from Durand 2002]

82

# COMMON FATE

**Dots moving together are grouped**

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

83

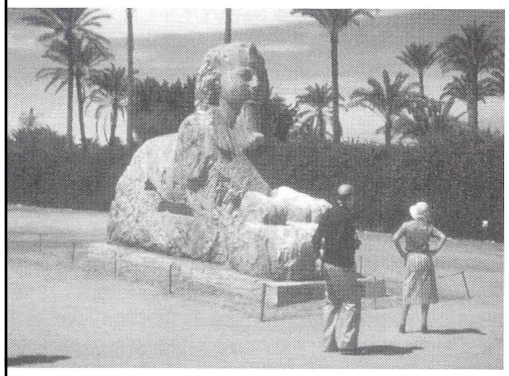
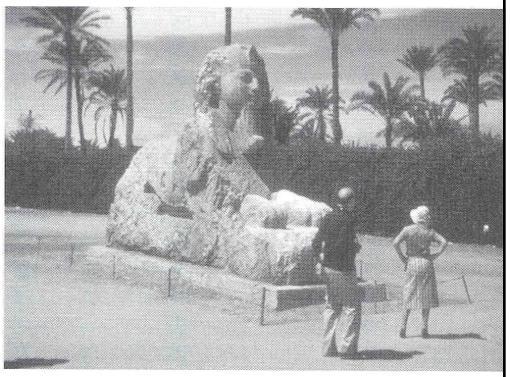
# TRANSPARENCY


**Requires continuity and proper color correspondence** [Ware 2004]

84

# CHANGE BLINDNESS

92

Example from Palmer 1999, originally due to Rock

93

94

95

# RENSINK'S DEMONSTRATIONS

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


96

# 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

97