MARKS & CHANNELS

How can I visually represent two numbers

e.g., 4 and 8

MARKS & CHANNELS

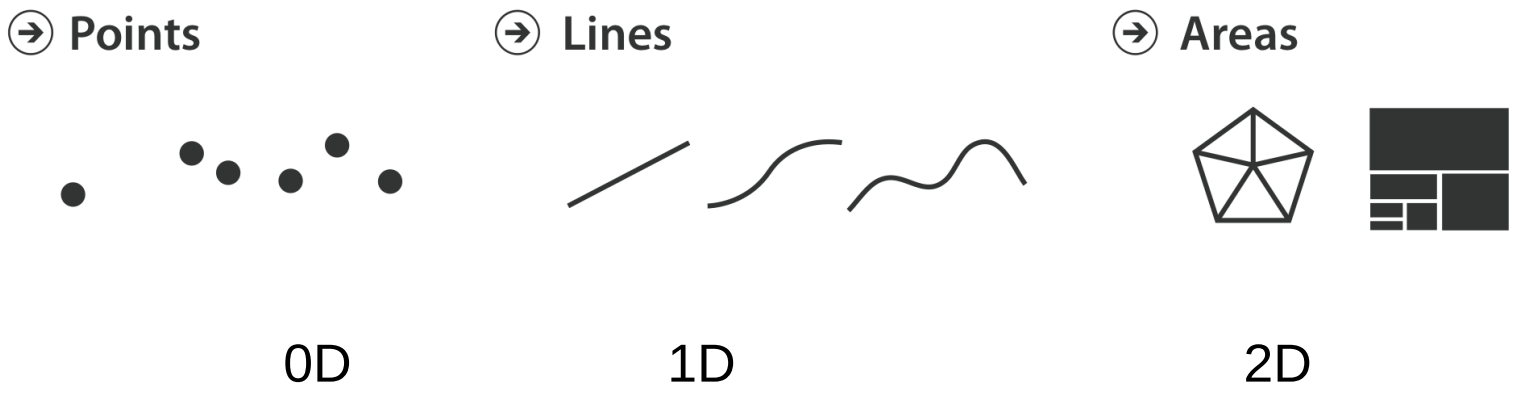
Marks: represent **items** or **links**

Channels: change **appearance** based on **attribute**

Channel = visual variable

MARKS FOR ITEMS

Basic geometric elements

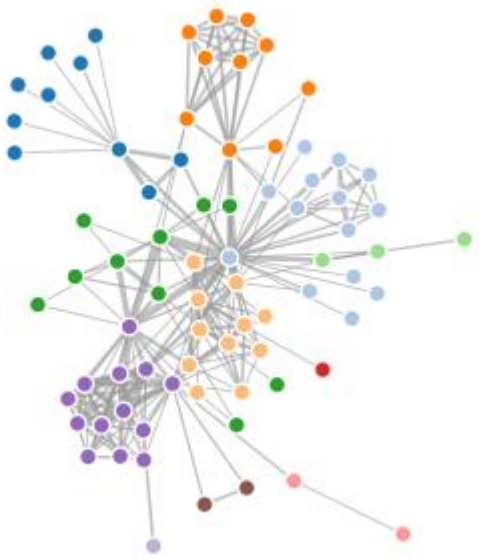


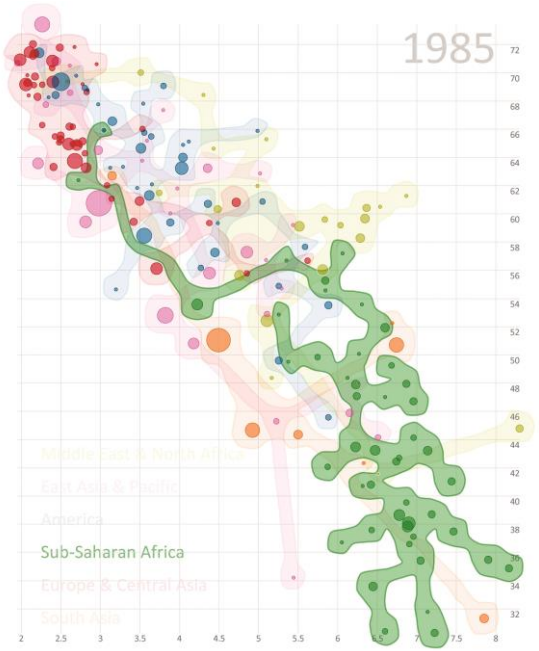
3D mark: Volume, but rarely used

MARKS FOR LINKS

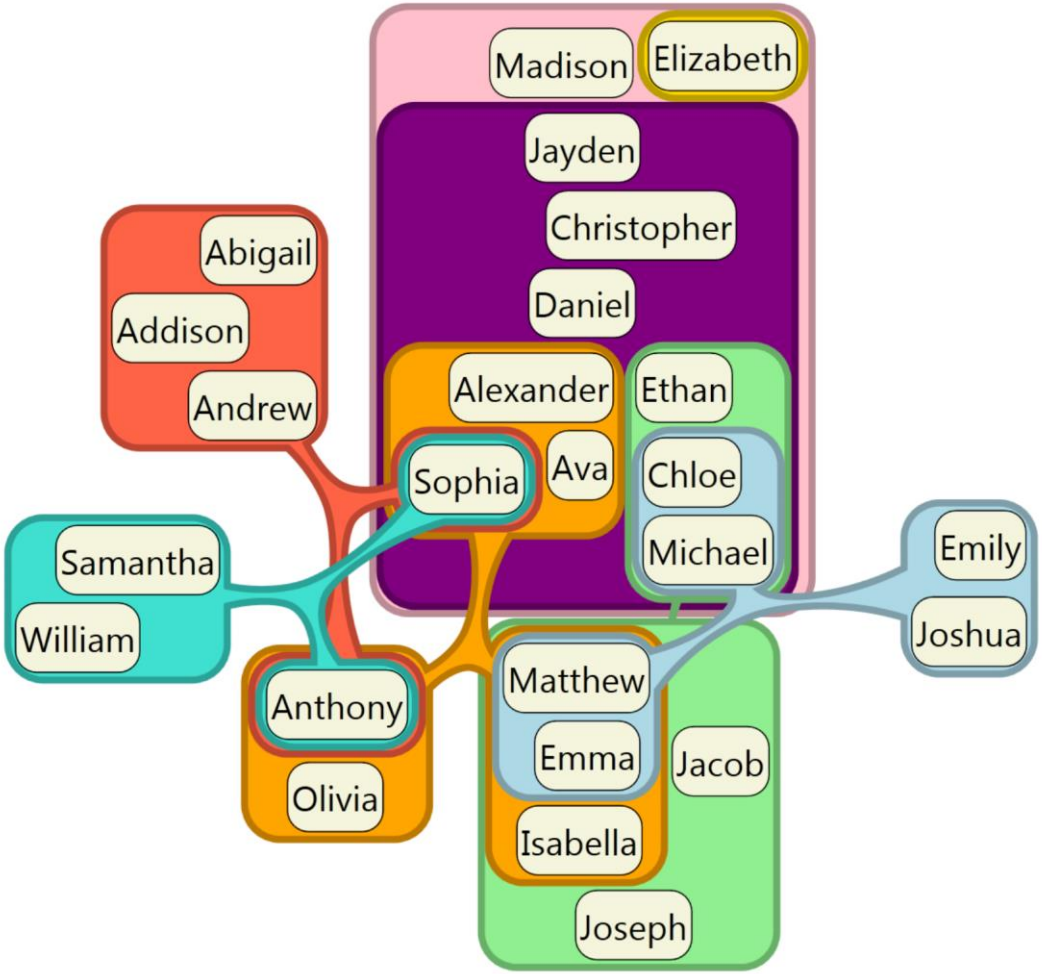
Containment

Connection





NESTED CONTAINMENT



CHANNELS

Change appearance proportional to or based on attributes

- **Position**
  - Horizontal
  - Vertical
  - Both

- **Color**

- **Shape**

- **Tilt**

- **Size**
  - Length
  - Area
  - Volume

JACQUES BERTIN

French cartographer

who makes or draws maps

Theoretical principles for visual encodings

BERTIN'S VISUAL VARIABLES

Marks: Points Lines Areas

Variables of image

Position

Size

(gray)Value

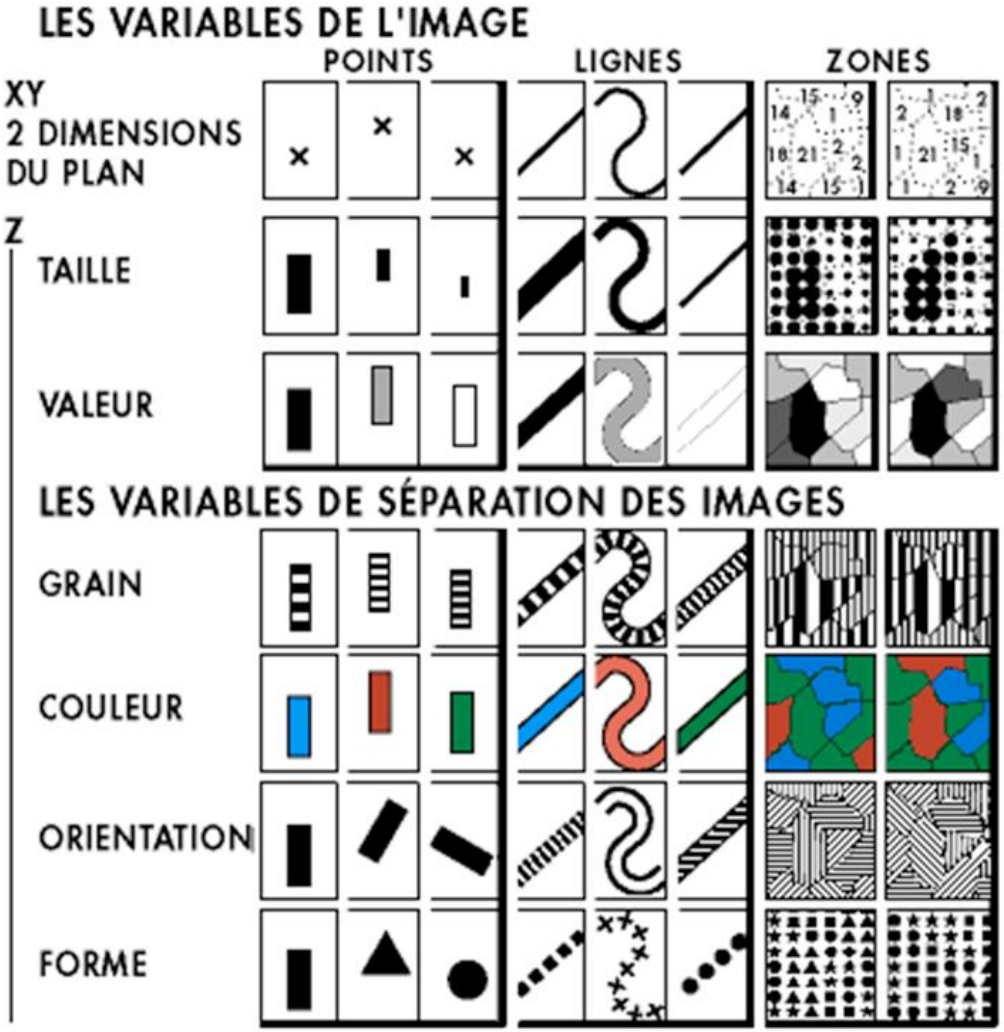
Variable to distinguish images

Texture

Color

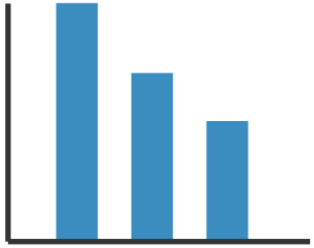
Orientation

Shape



Semiology of Graphics [J. Bertin, 67]

USING MARKS AND CHANNELS



Mark: Line

Channel:
Length, Position
1 quantitative attribute
1 categorical attribute

Mark: Point

Channel: Position

1 quantitative attr.

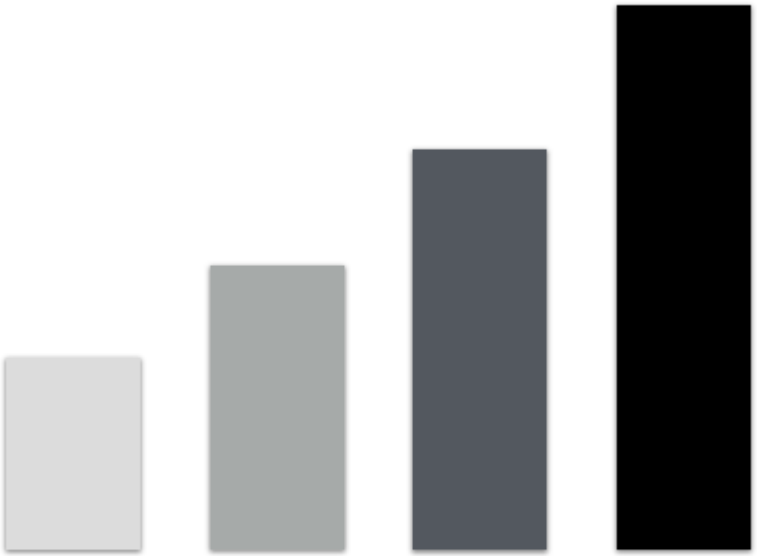
Adding Hue

+1 categorical attr.

Adding Size

+1 quantitative attr.

REDUNDANT ENCODING



Length, Position and Value

GOOD BAR CHART?

Rule: Use channel proportional to data!

https://twitter.com/ChaseThomason/status/1118478036507164672?s=19

TYPES OF CHANNELS

Magnitude channels

How much? Which rank?

Position

Length

Saturation …

Identity channels

What?

Shape

Color (hue)

Spatial region...

Ordinal & Quantitative data

Categorical Data

PRINCIPLES OF EXPRESSIVENESS AND EFFECTIVENESS

Expressiveness principle

The visual encoding should express **all of, and only**, the information in the dataset attributes

Effectiveness principle:

The importance of attribute should match the **salience** of the channel

Means:

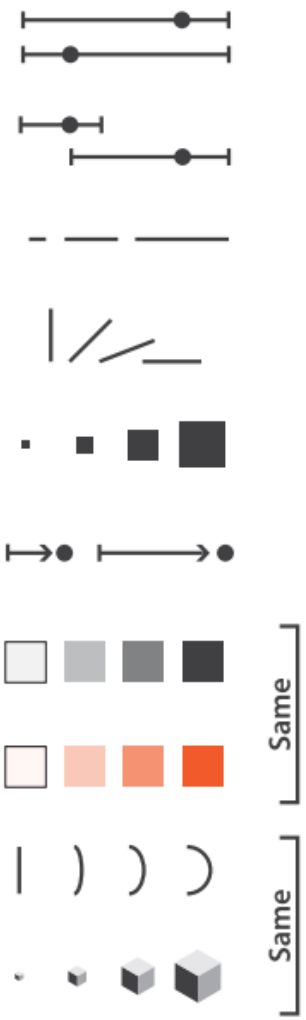
- The most important attributes should be encoded with the most effective channels in order to be most noticeable
- Then the following important attributes match with less effective channels

RANK OF CHANNELS

Channels: Expressiveness Types and Effectiveness Ranks

Magnitude Channels: Ordered Attributes

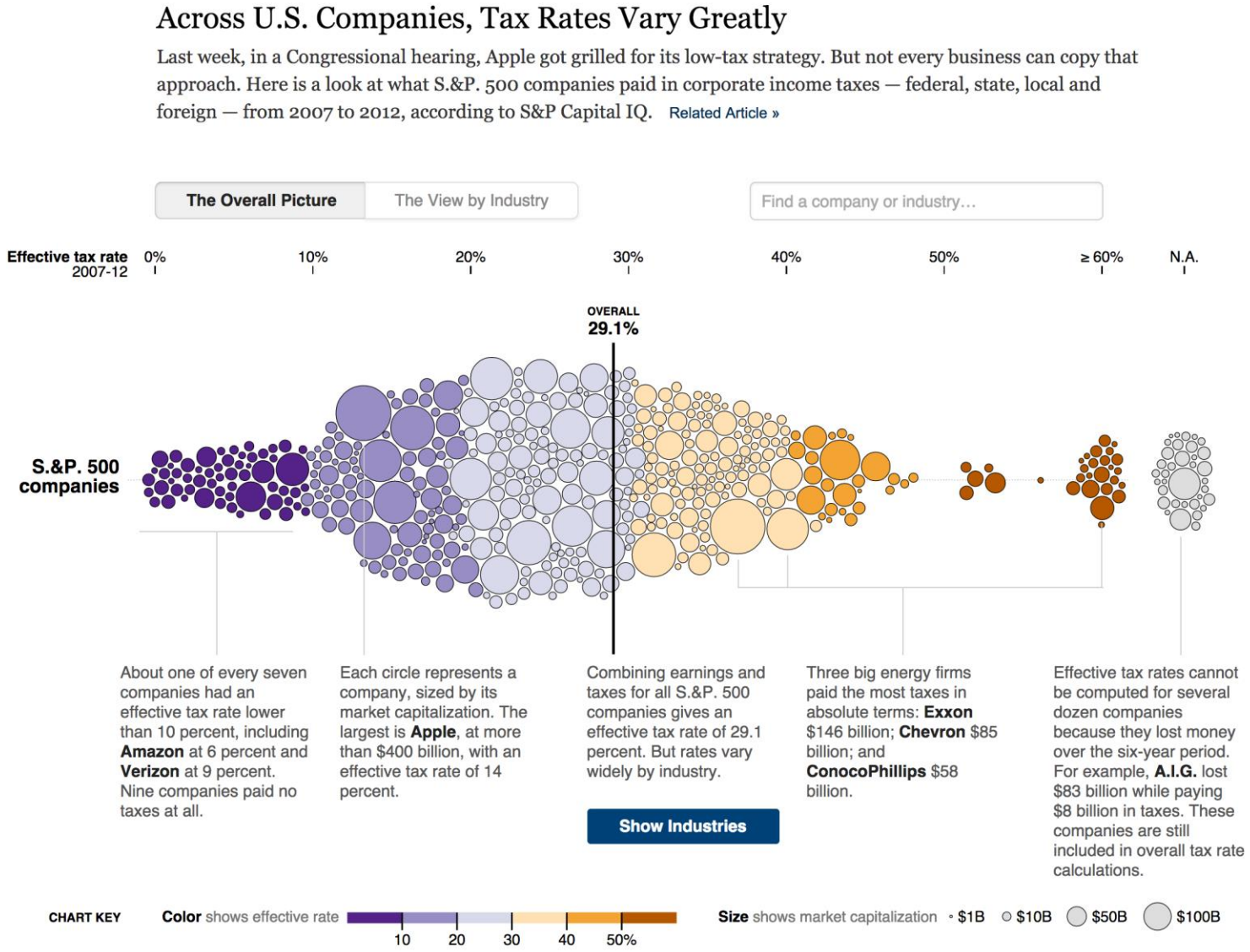
- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)



Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

WHAT VISUAL VARIABLES ARE USED?



http://www.nytimes.com/interactive/2013/05/25/sunday-review/corporate-taxes.html

CHARACTERISTICS OF CHANNELS

Selective

- Is a mark distinct from other marks?
- Can we make out the difference between two marks?

Associative

- Does it support grouping?

Quantitative (Magnitude vs identity channels)

- Can we quantify the difference between two marks?

CHARACTERISTICS OF CHANNELS

Order (Magnitude vs Identity)

Can we see a change in order?

Length

How many unique marks can we make?

POSITION

Strongest visual variables

Suitable for all data types

Problems:

- Sometimes not available (spatial data, map)
- Cluttering (many items overlapped)

Selective: Yes

Associative: Yes

Quantitative: Yes

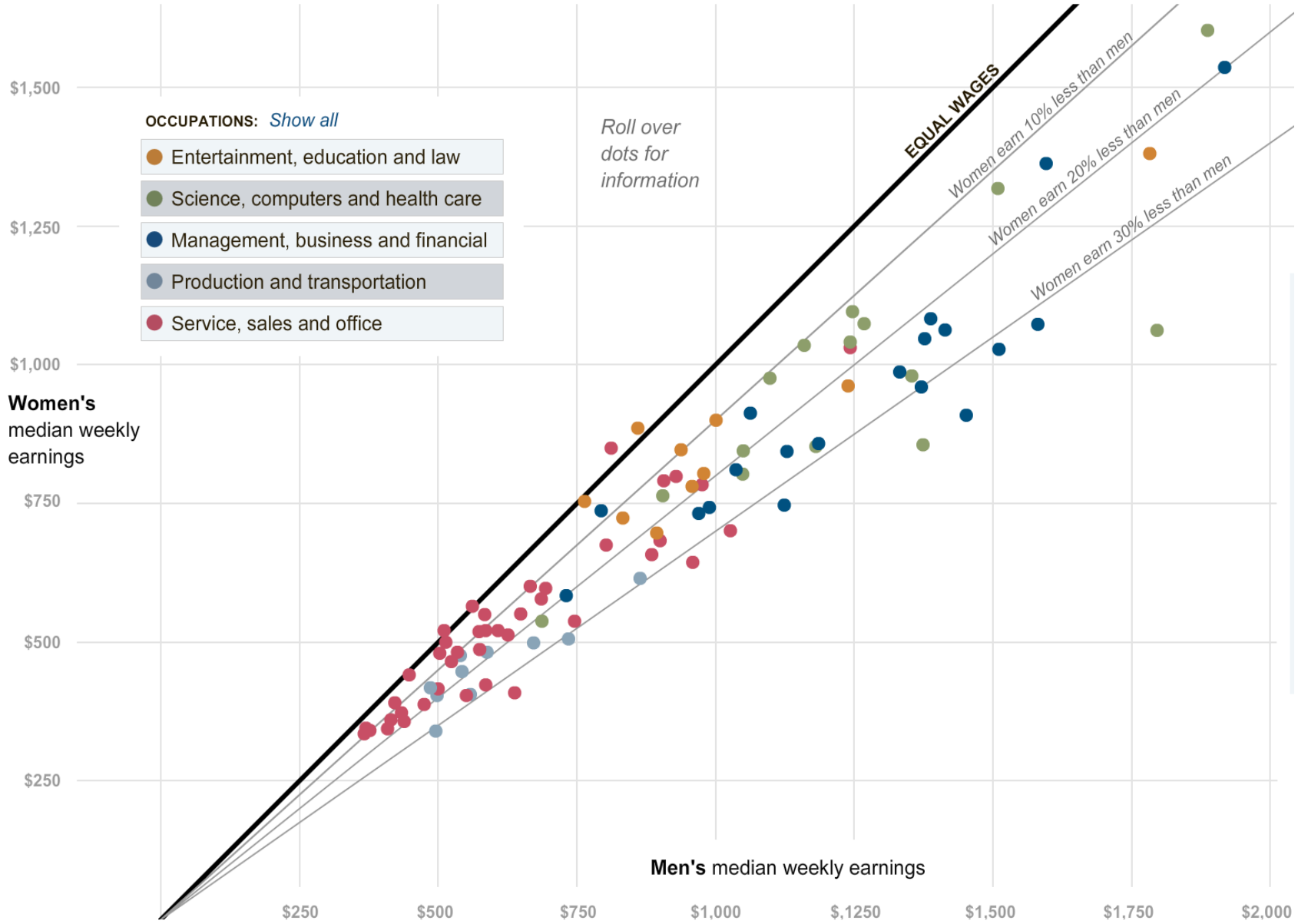
Order: Yes

Length: Fairly big

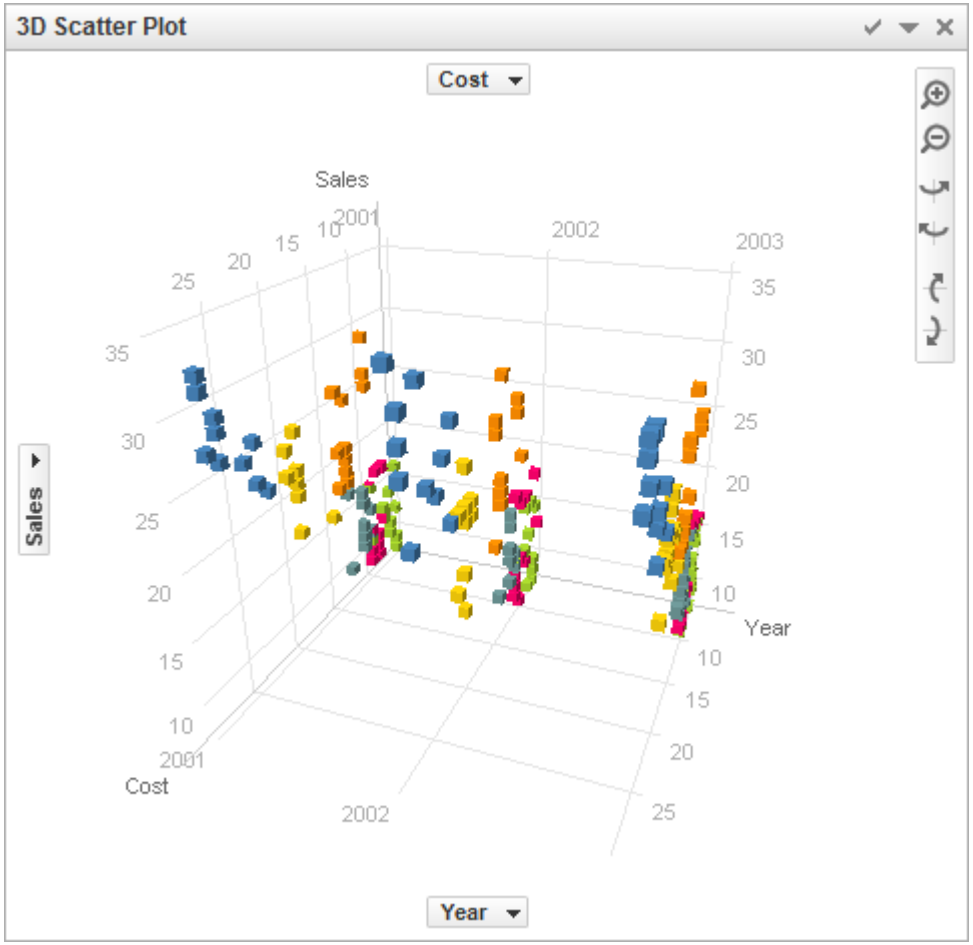
(options)

→ Good channel

EXAMPLE: SCATTERPLOT



POSITION IN 3D? NOT SO GOOD



LENGTH & SIZE

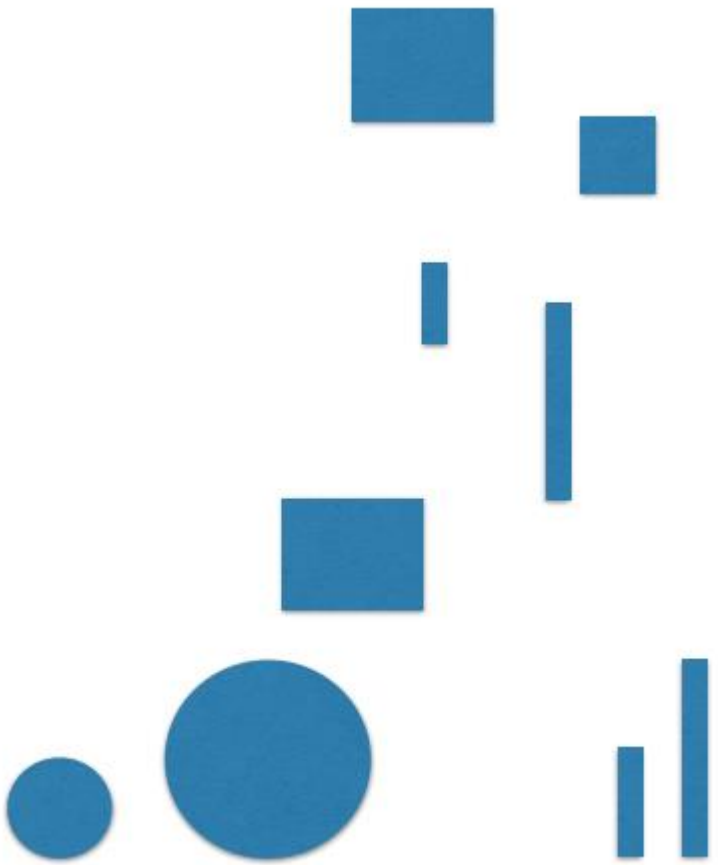
Good for 1D, OK for 2D, Bad for 3D

Easy to see which one is bigger

Aligned bars use position redundantly

1D length:

Selective:	yes
Associative:	yes
Quantitative:	yes
Order:	yes
Length:	yes



EXAMPLE 2D SIZE: BUBBLES

Four Ways to Slice Obama's 2013 Budget Proposal

Explore every nook and cranny of President Obama's federal budget proposal.

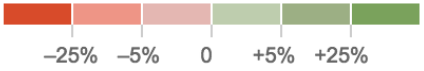
All Spending | Types of Spending | Changes | Department Totals

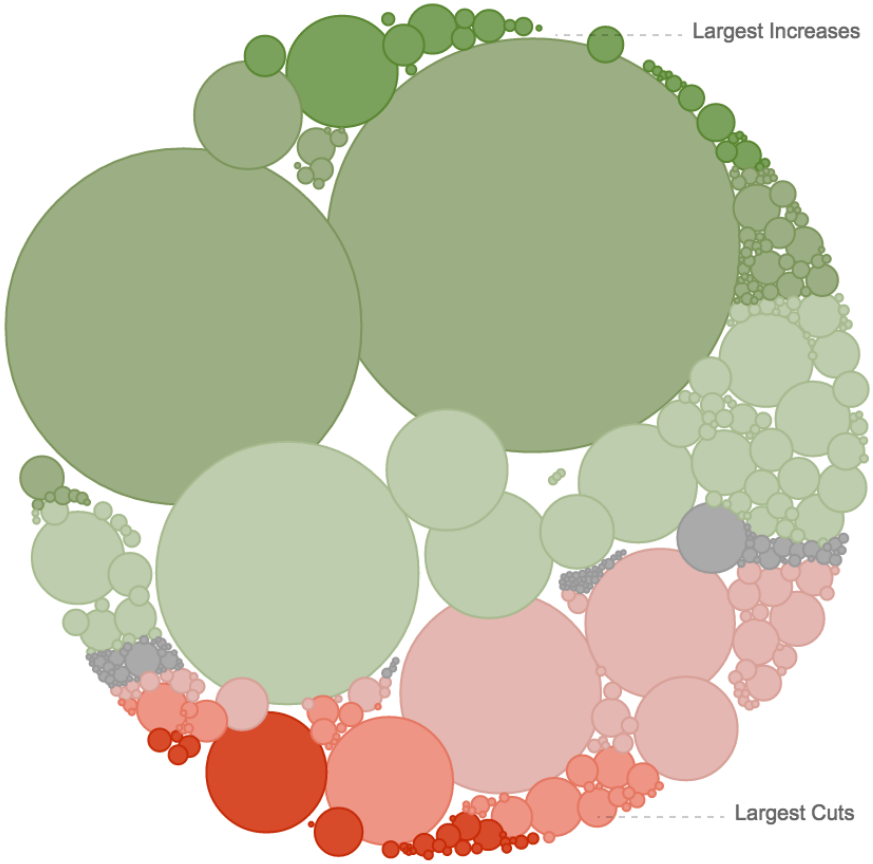
How $3.7 Trillion Is Spent

Mr. Obama's budget proposal includes $3.7 trillion in spending in 2013, and forecasts a $901 billion deficit.

Circles are sized according to the proposed spending.

Color shows amount of cut or increase from 2012.





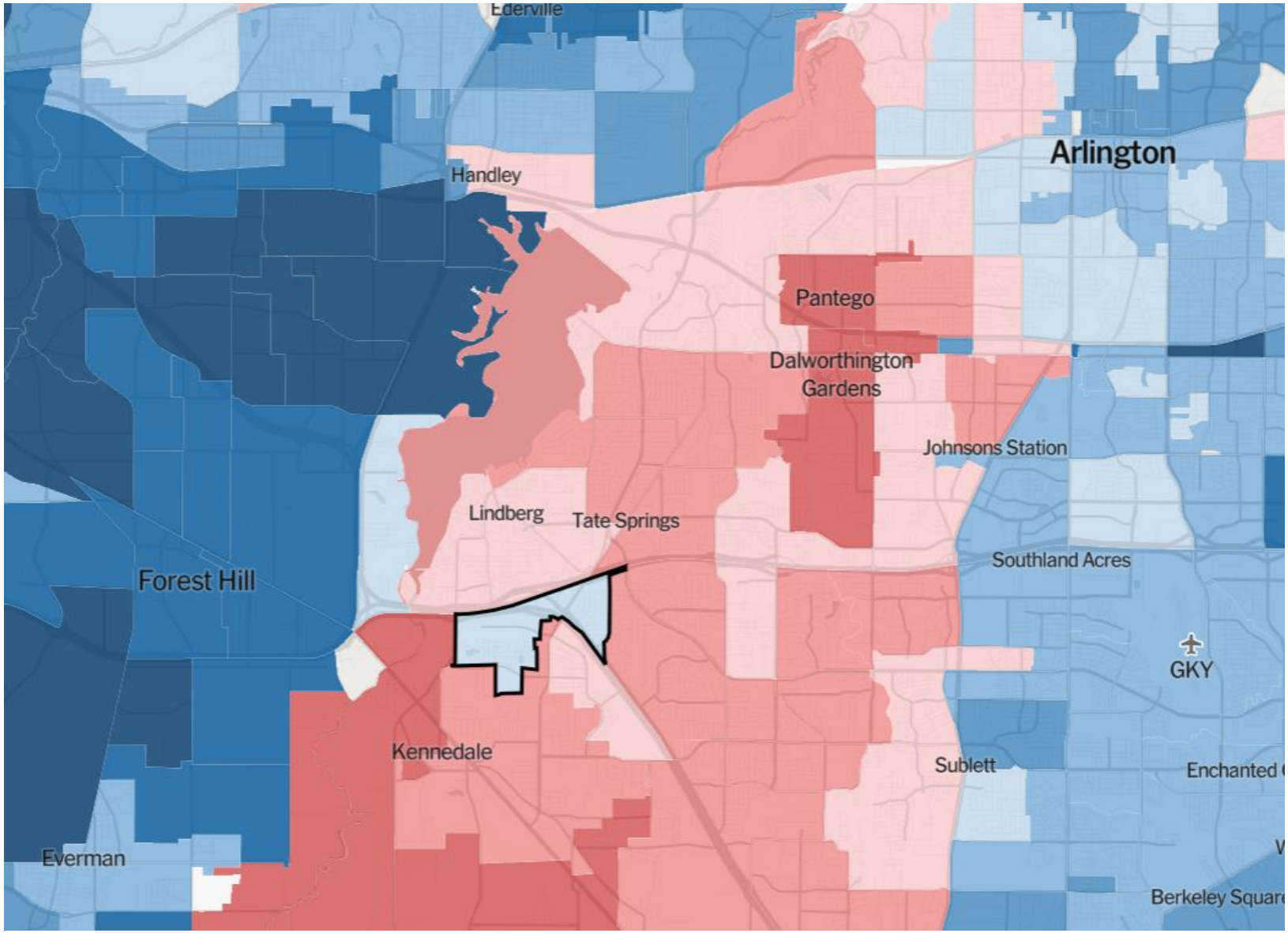
VALUE/LUMINANCE/SATURATION

OK for quantitative data when length & size are used

Not very many shades recognizable

Selective:	yes
Associative:	yes
Quantitative:	somewhat
Order:	yes
Length:	limited (around 7 – 8)

EXAMPLE: DIVERGING VALUE-SCALE



https://www.nytimes.com/interactive/2018/upshot/election-2016-voting-precinct-maps.html#11.08/32.700/-97.197/115304

COLOR

Good for qualitative data (identity channel)

Limited number of classes/length (7-10)

Do not work for quantitative data

Lots of pitfalls !

Good practice: minimize use of color for encoding data

Selective:	yes
Associative:	yes
Quantitative:	no
Order:	no
Length:	limited

COLOR: BAD EXAMPLE

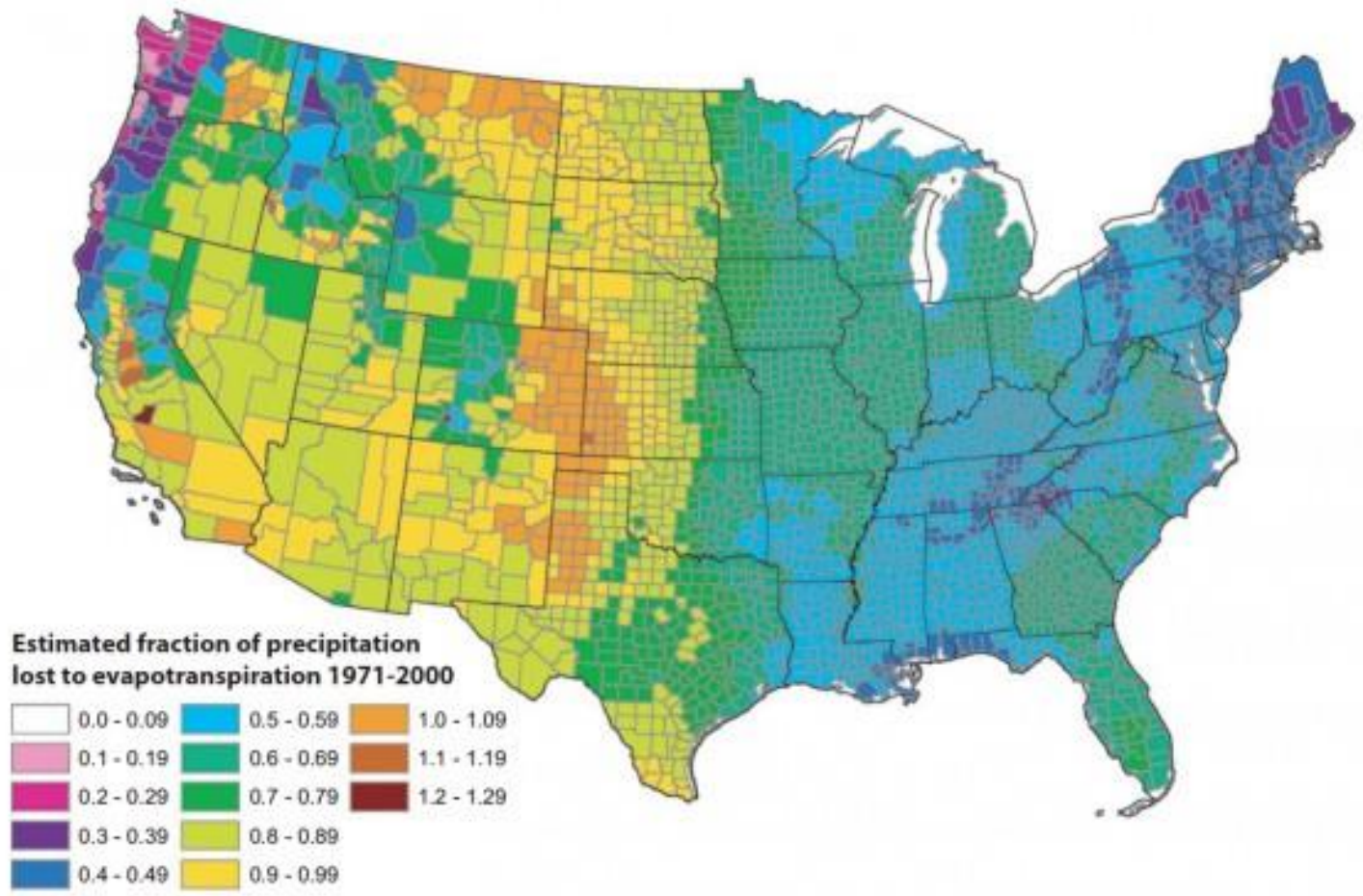
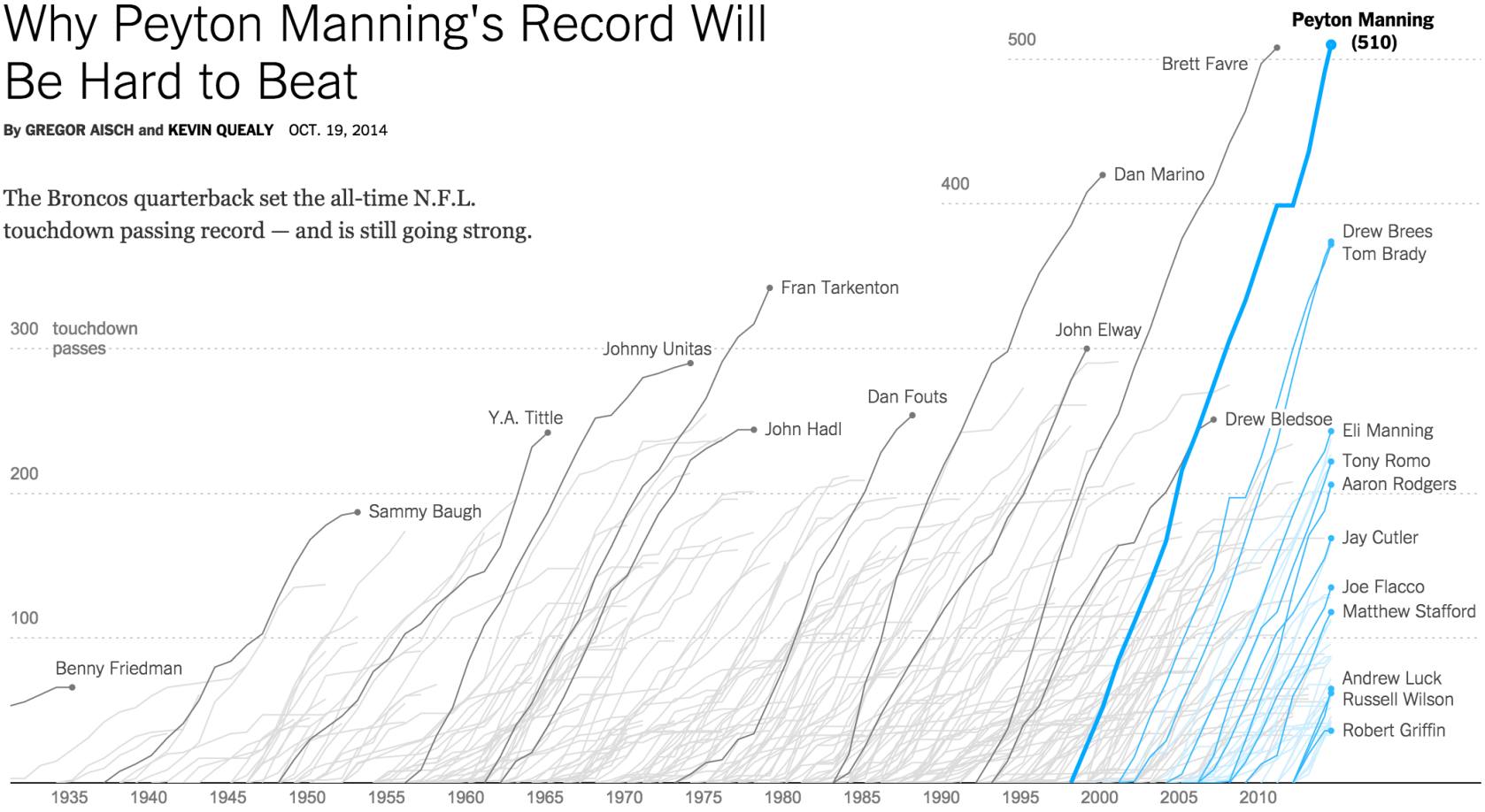


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.

COLOR: GOOD EXAMPLE

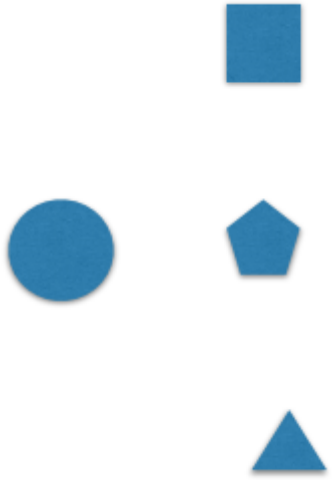


SHAPE

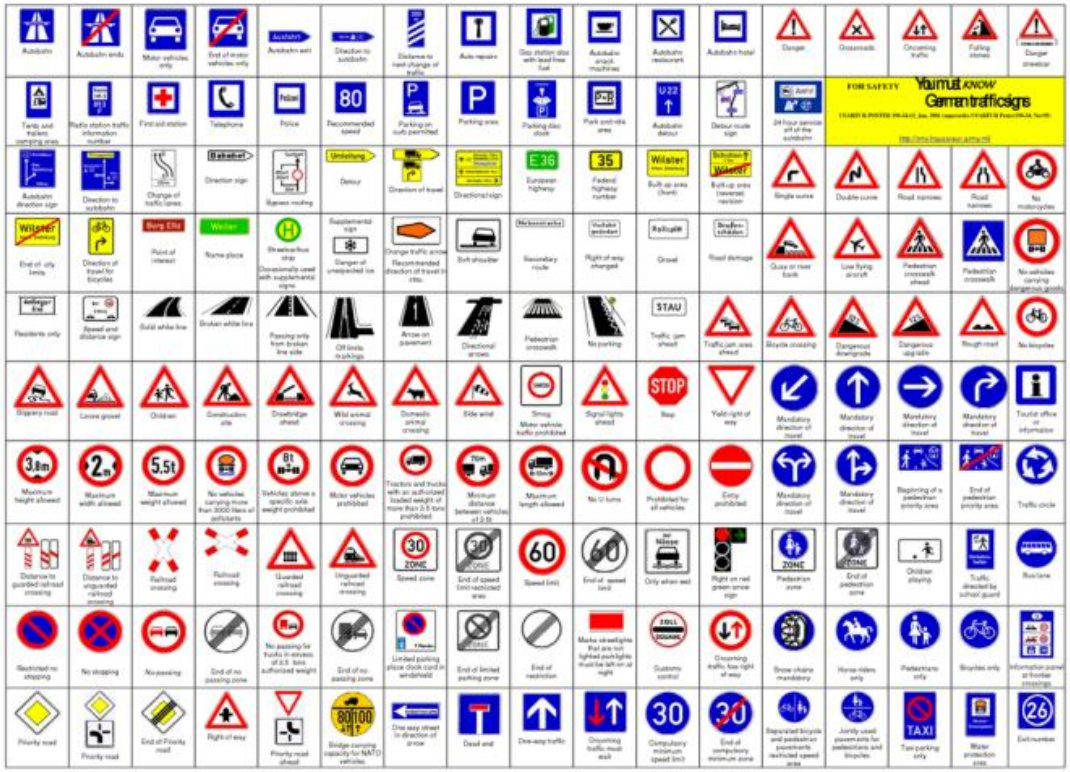
Great to recognize many classes

No grouping, ordering

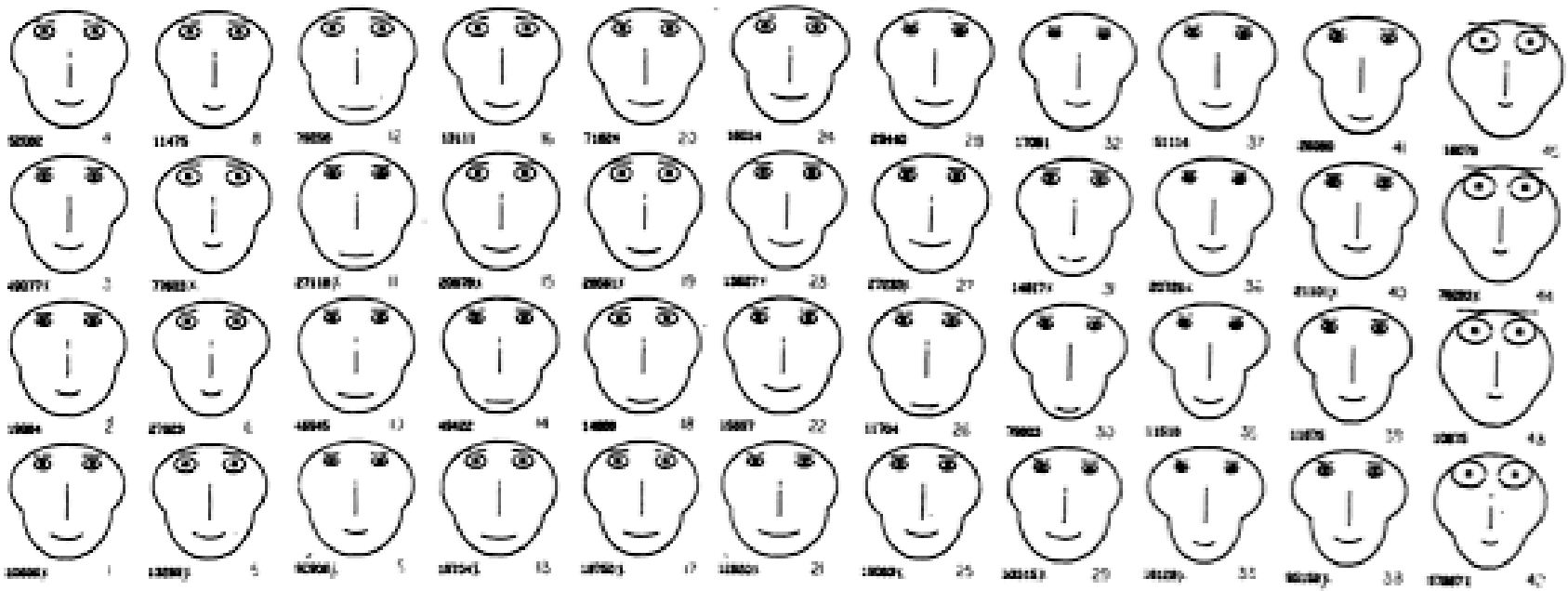
Selective:	yes
Associative:	limited
Quantitative:	no
Order:	no
Length:	vast



ALFA ROMEO
ACURA
ASTON MARTIN
ASTON MARTIN
Audi
BENTLEY
BMW
MITSUBISHI MOTORS
Ferrari
Photoshop plugins


FOR SAFETY
You must KNOW
German trafficsigns

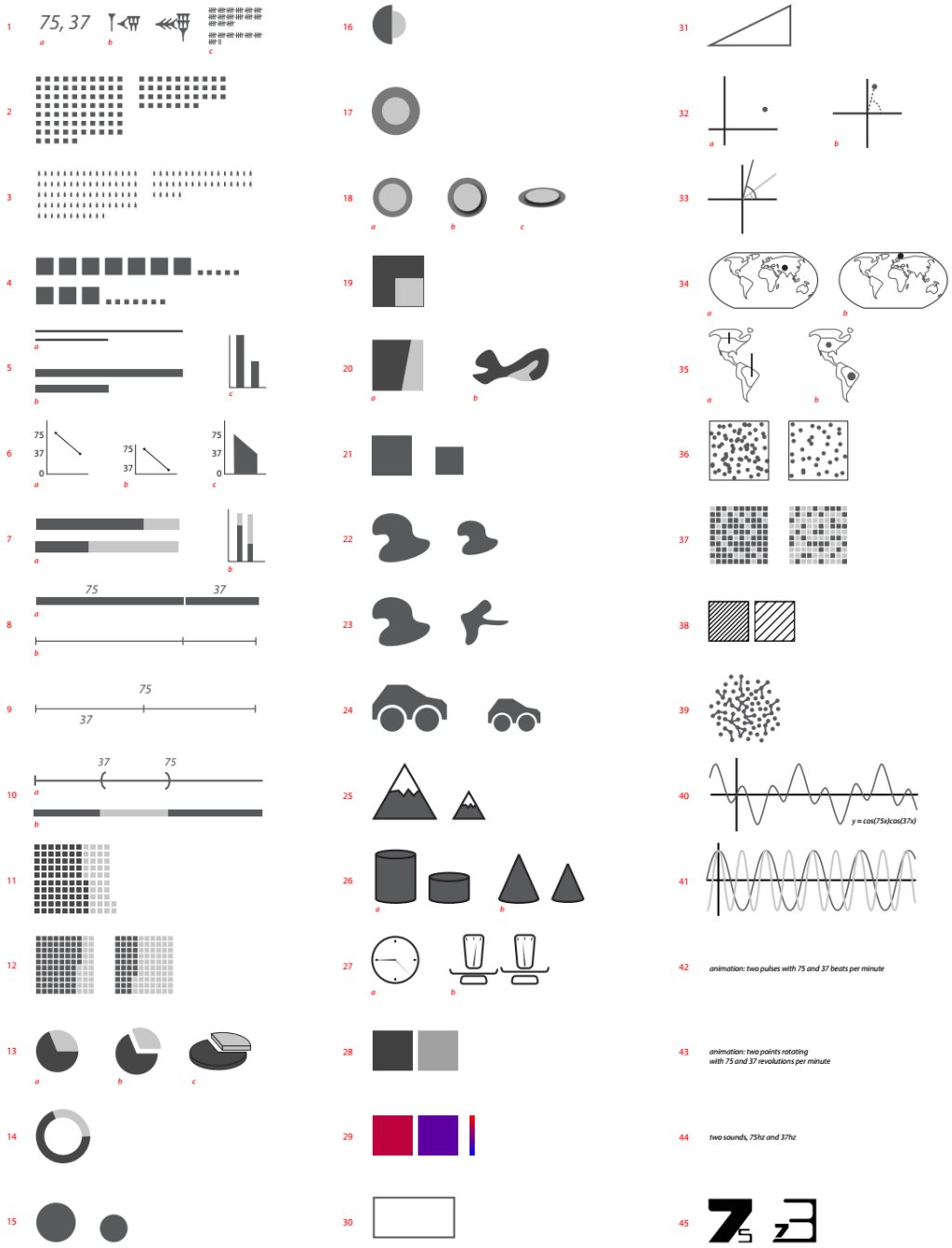
Idea: use facial parameters to map quantitative data



Does it work? Not really

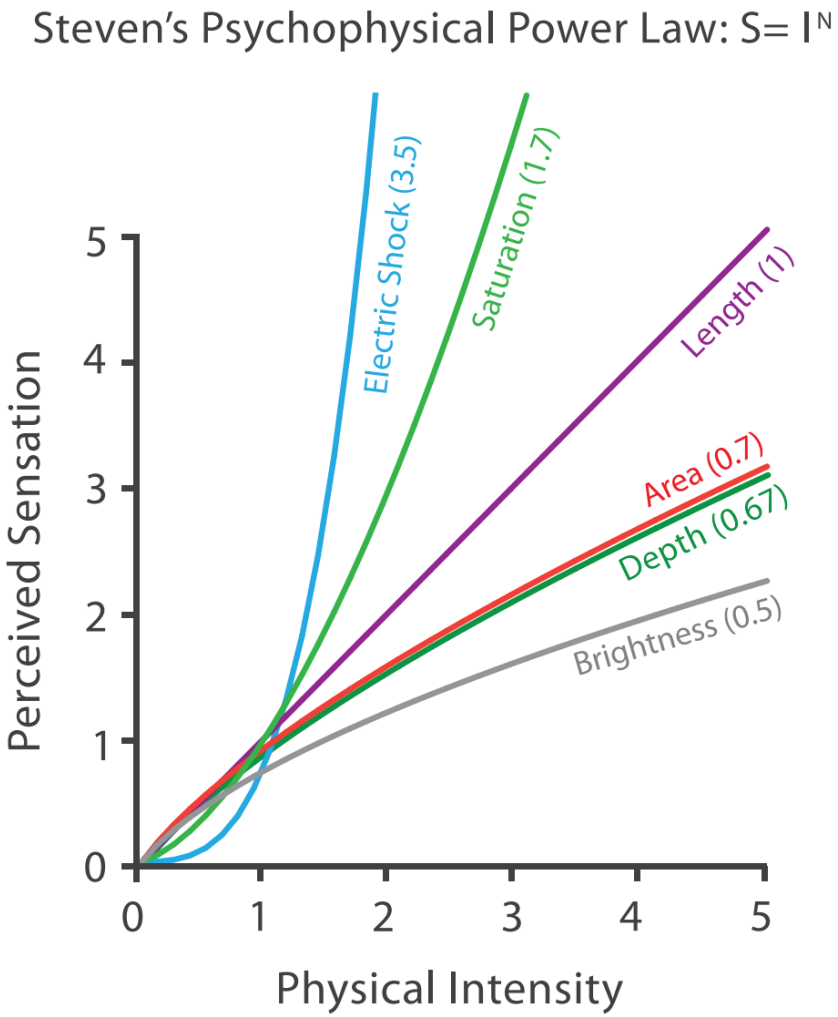
Critique: https://eagereyes.org/criticism/chernoff-faces

MORE CHANNELS



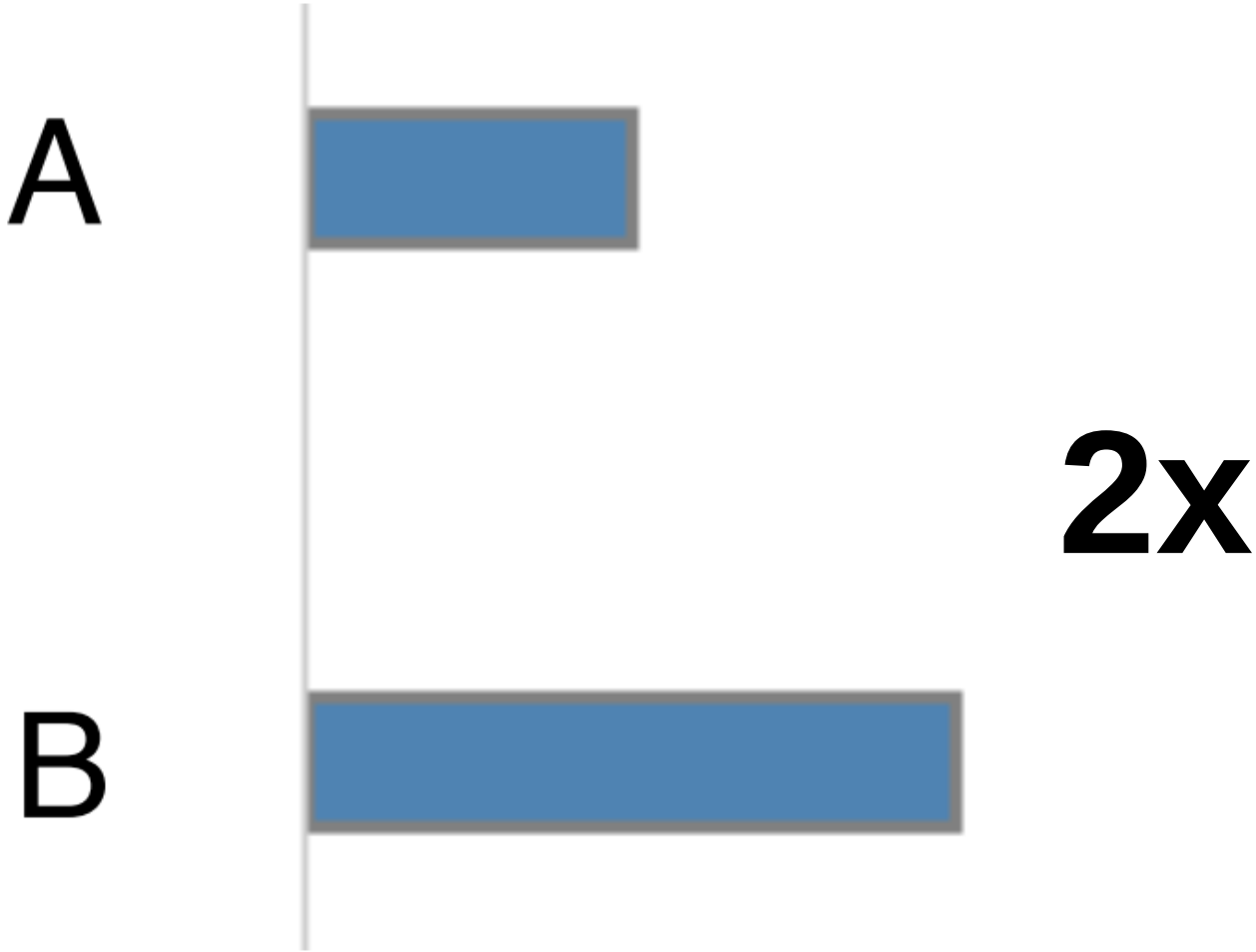
https://en.rockcontent.com/blog/2012/07/27/45-ways-to-communicate-two-quantities/

ACCURACY OF CHANNELS

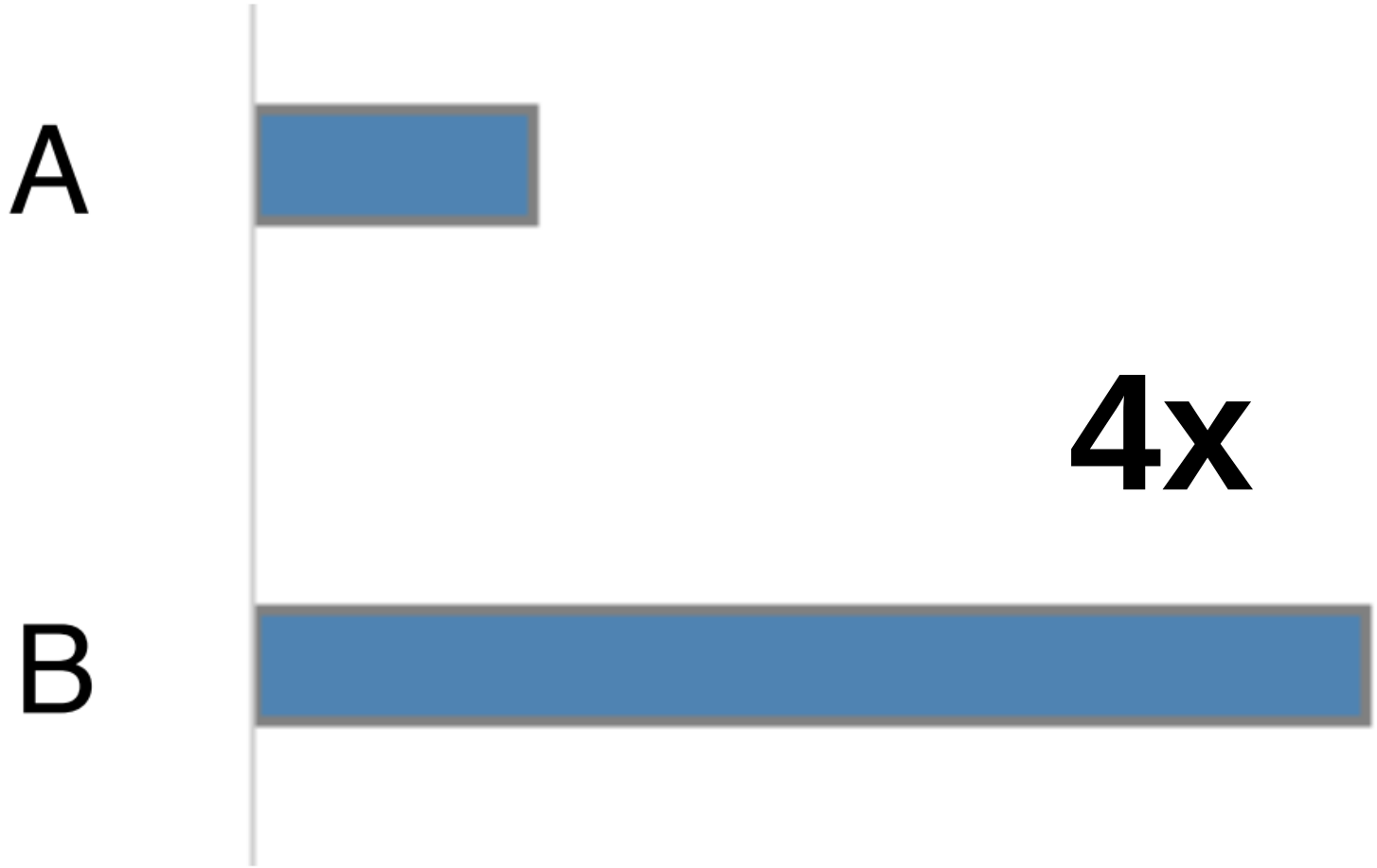


S = sensation
I = intensity

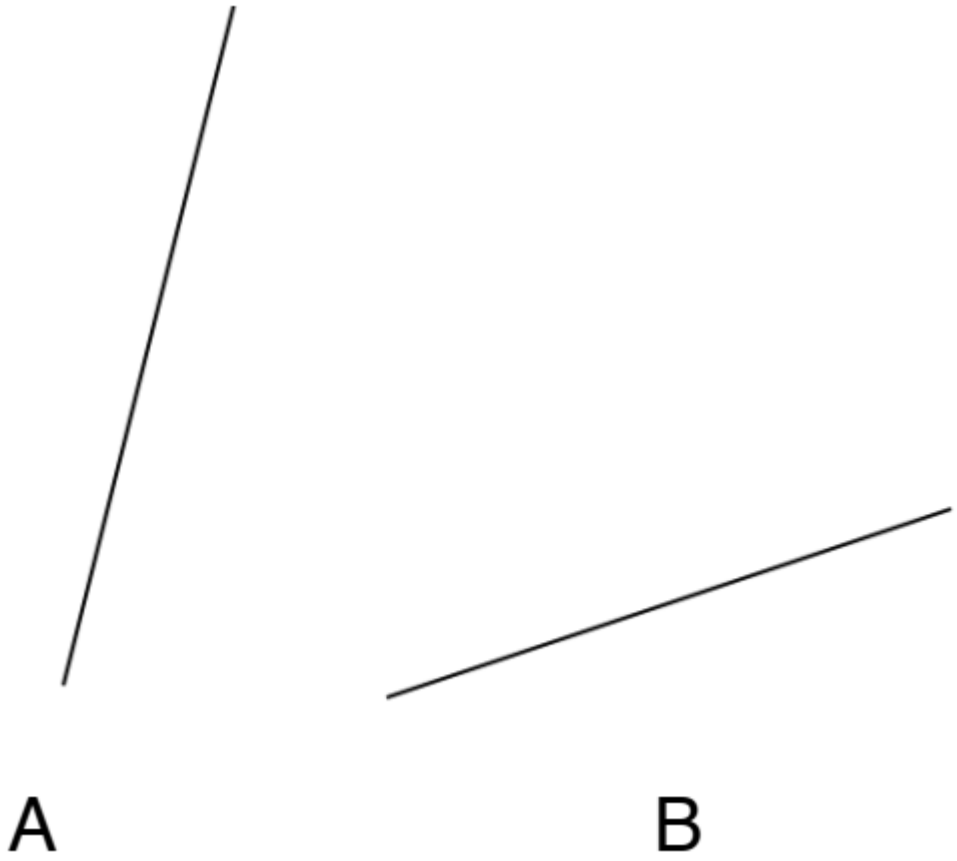
HOW MUCH LONGER?



HOW MUCH LONGER

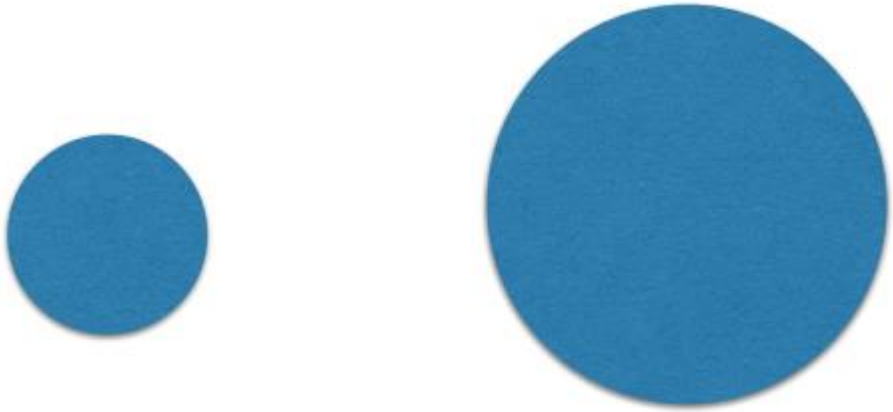


HOW MUCH STEEPER?



~4x

HOW MUCH LARGER?



A B

2x diameter
4x area

HOW MUCH LARGER?

A

B

5x

HOW MUCH LARGER (AREA)?

A

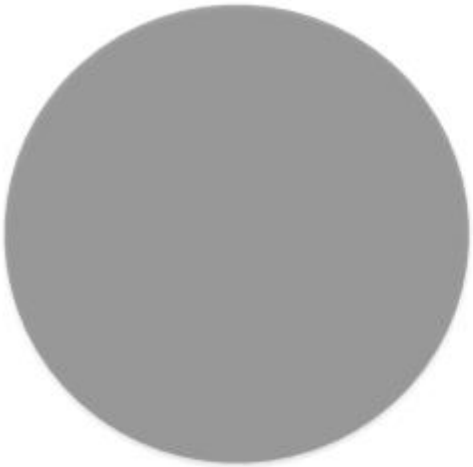
B

3x

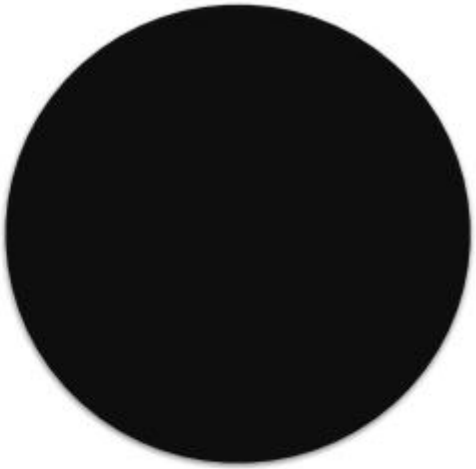
HOW MUCH DARKER?

2x

HOW MUCH DARKER?



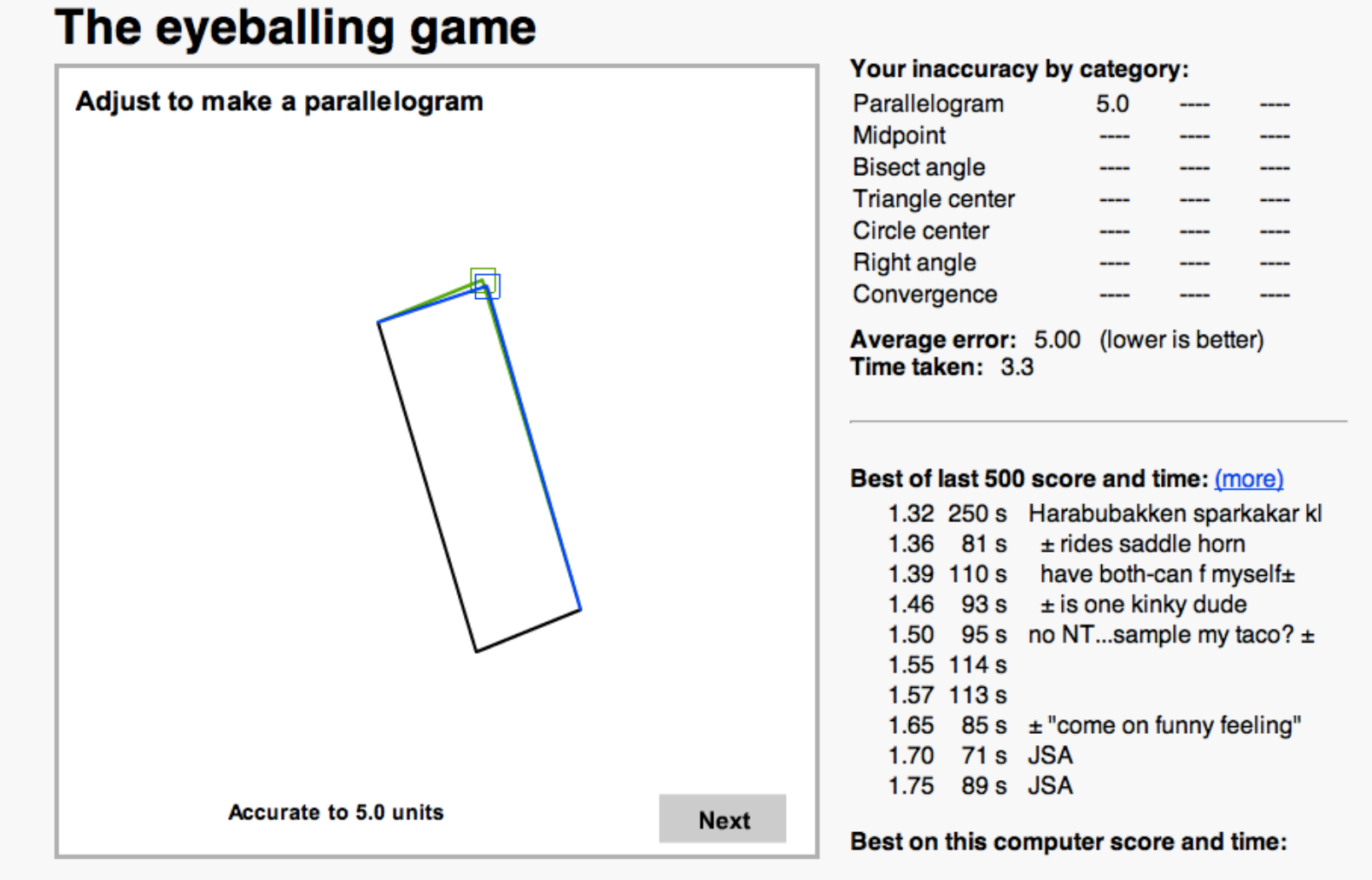
A



B

3x

POSITION, LENGTH & ANGLE



https://woodgears.ca/eyeball/index.html

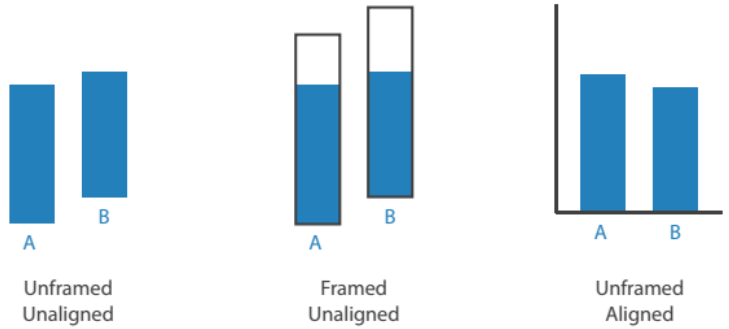
OTHER FACTORS AFFECTING ACCURACY

Alignment

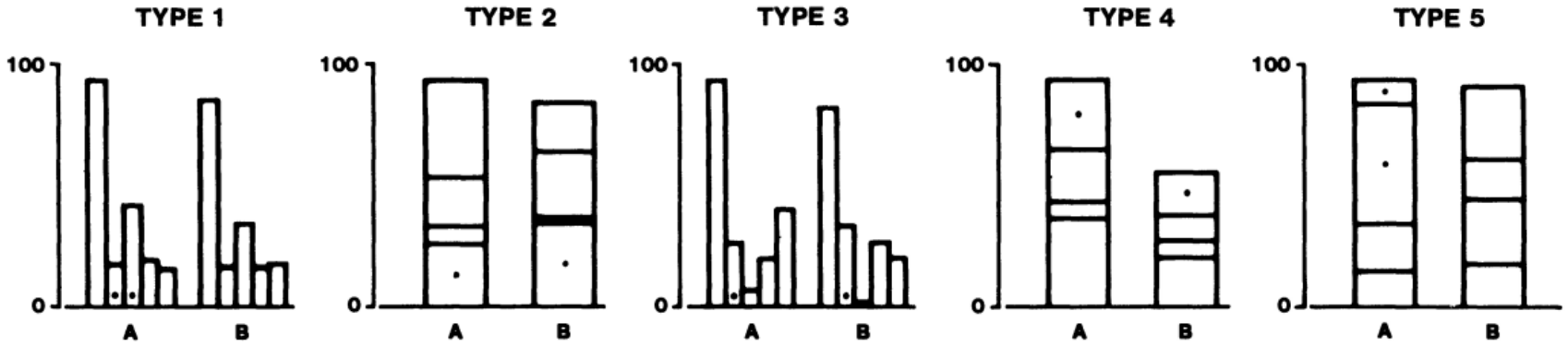
Distractors

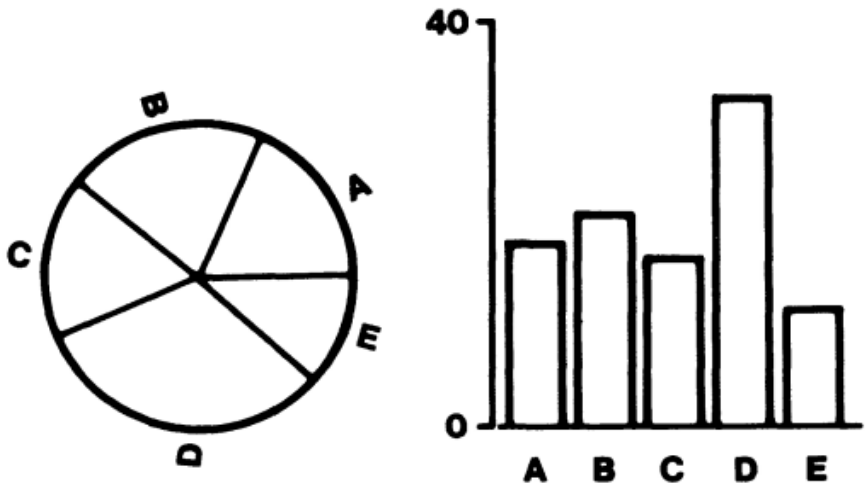
Distance

Common scale

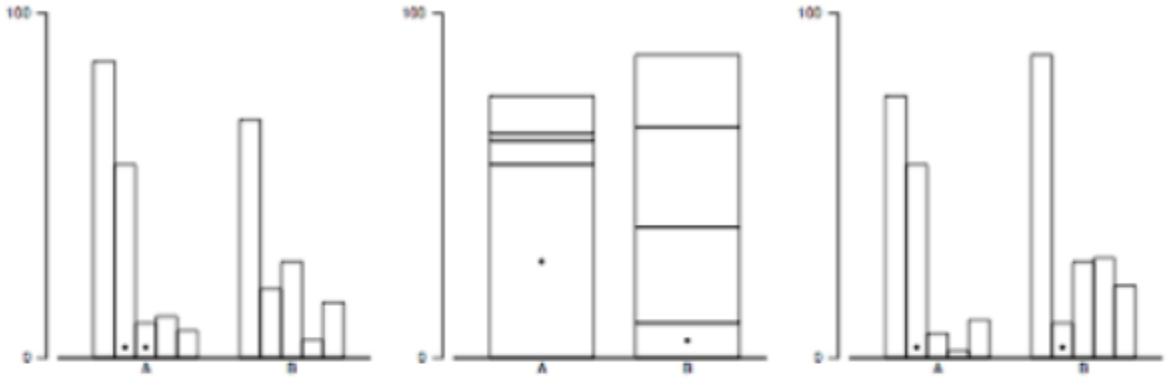


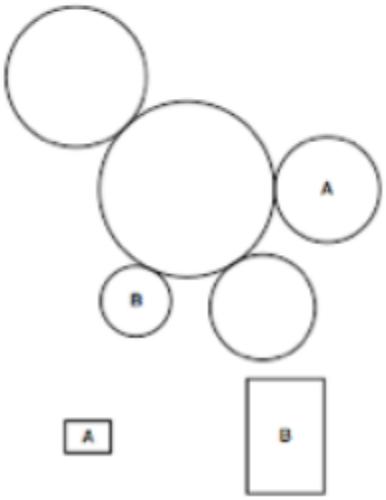
RESEARCH BY CLEVELAND 1984

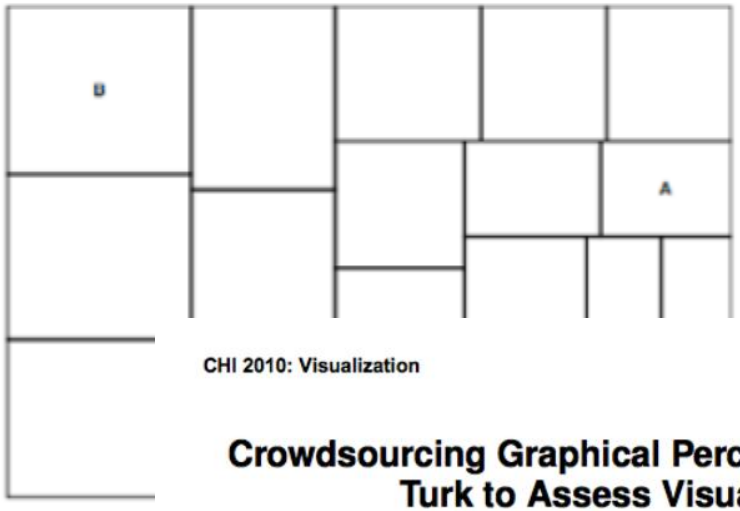




HEER & BOSTOCK, 2010







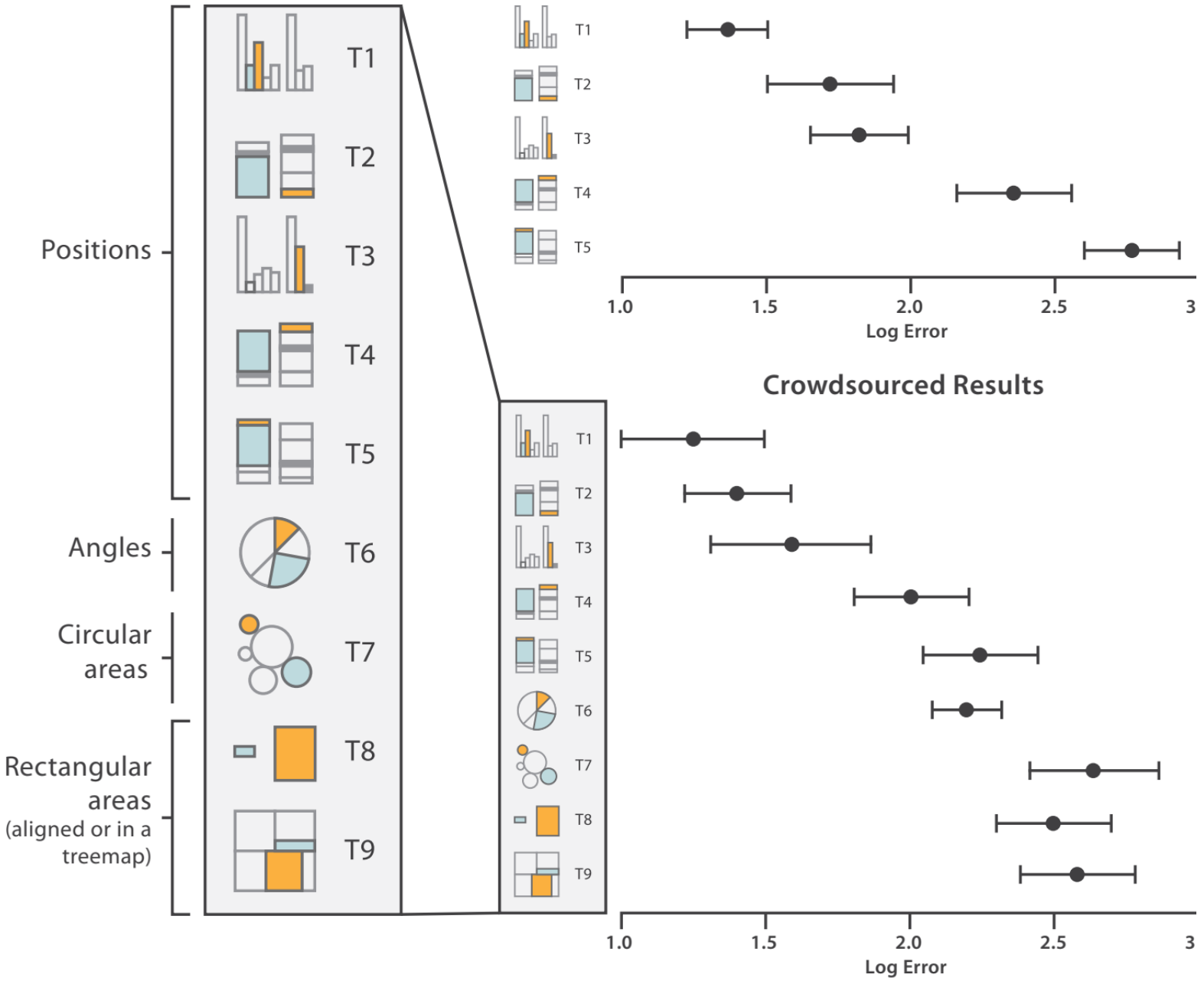
CHI 2010: Visualization

April 10–15, 2010, Atlanta, GA, USA

Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design

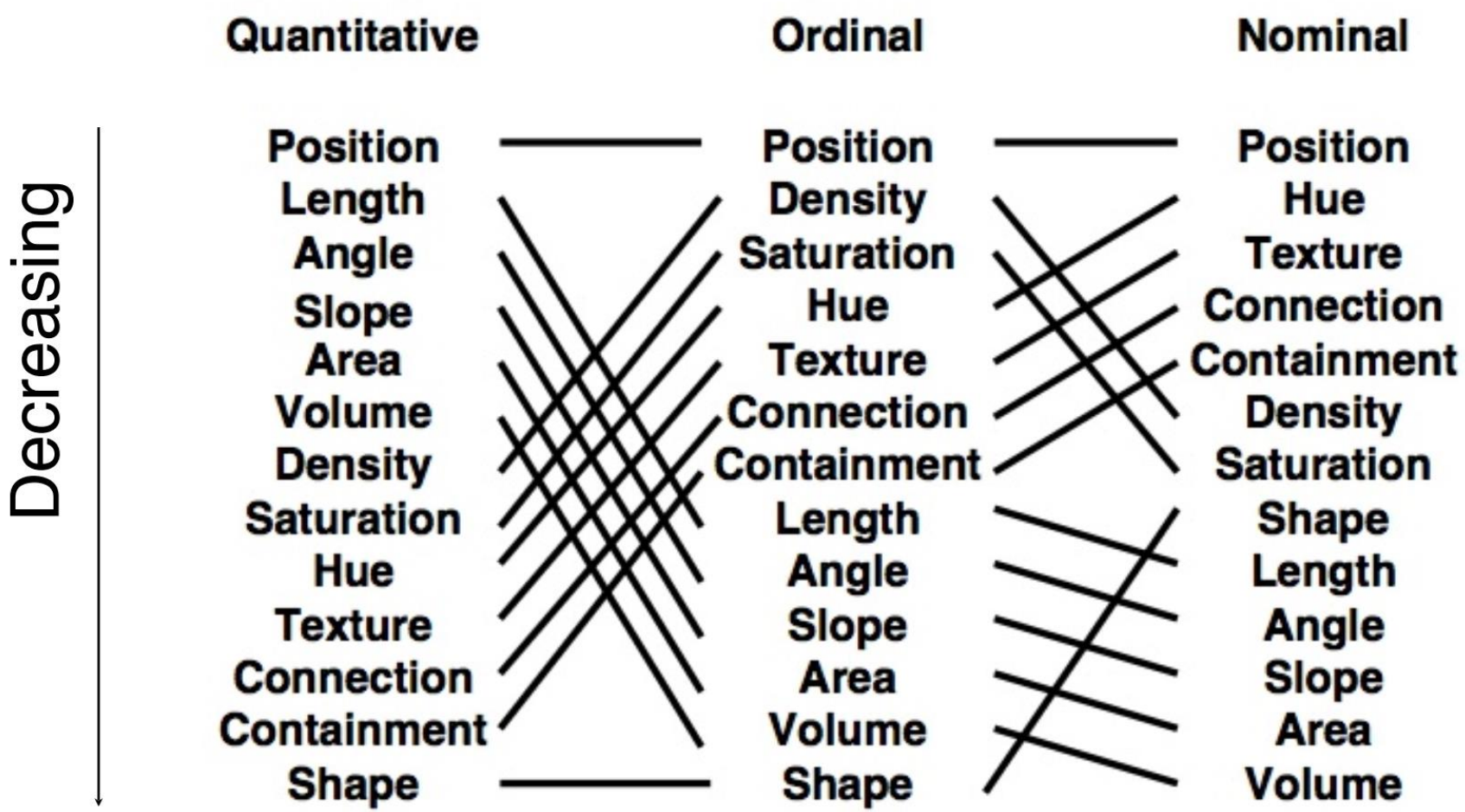
Jeffrey Heer and Michael Bostock
Computer Science Department
Stanford University
{jheer, mbostock}@cs.stanford.edu

https://www.mturk.com/worker



Error = log2(judged percent - true percent + 1/8)

JOCK MACKINLAY, 1986

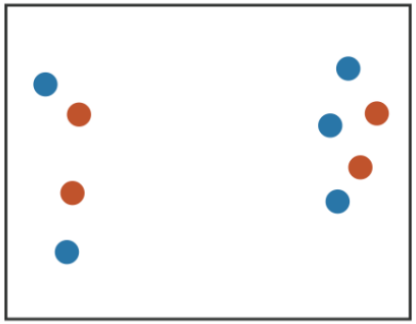


[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, 1986]

SEPARABILITY OF ATTRIBUTES

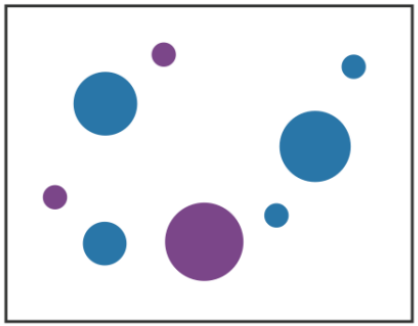
Can we combine multiple visual variables?

Position
+ Hue (Color)



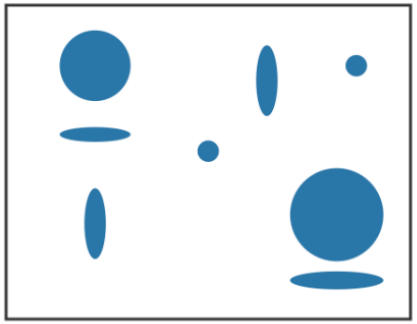
Fully separable

Size
+ Hue (Color)



Some interference

Width
+ Height



Some/significant interference

Red
+ Green

Major interference

T. Munzner, Visualization Analysis and Design, 2014