# CS-5630 / CS-6630 Visualization
# The Visualization Alphabet: Marks and Channels

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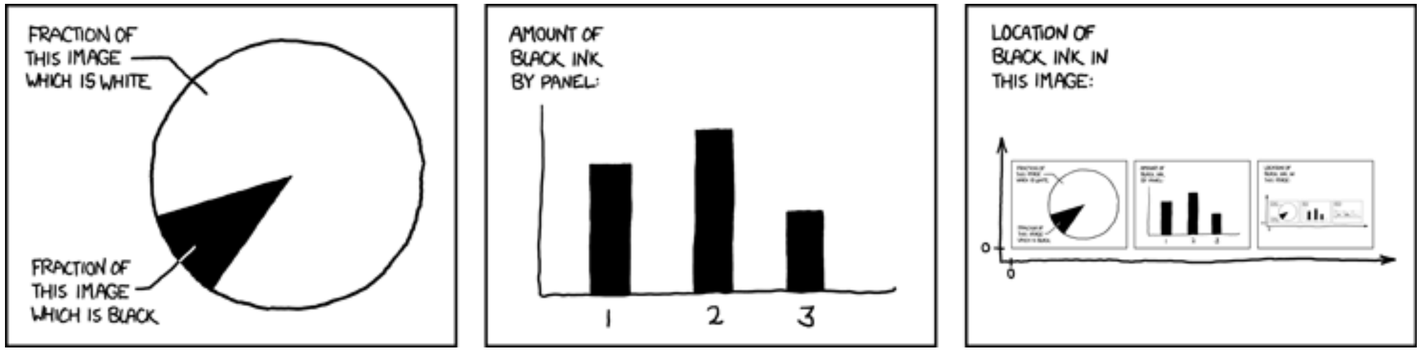
THE UNIVERSITY OF UTAH




[xkcd]

# This Week

Thursday: Design Guidelines, Tasks

Reading:

- Ch. 5 Marks and Channels
- Ch 6.3-6.6, and 6.9 Rules of Thumb
- Ch. 10.4 Mapping Other Channels
- Ch. 6.10 Function First, Form Next
- Ch. 3 Why: Task Abstraction

# Homework 4 is here!

Due Friday, Sept 30

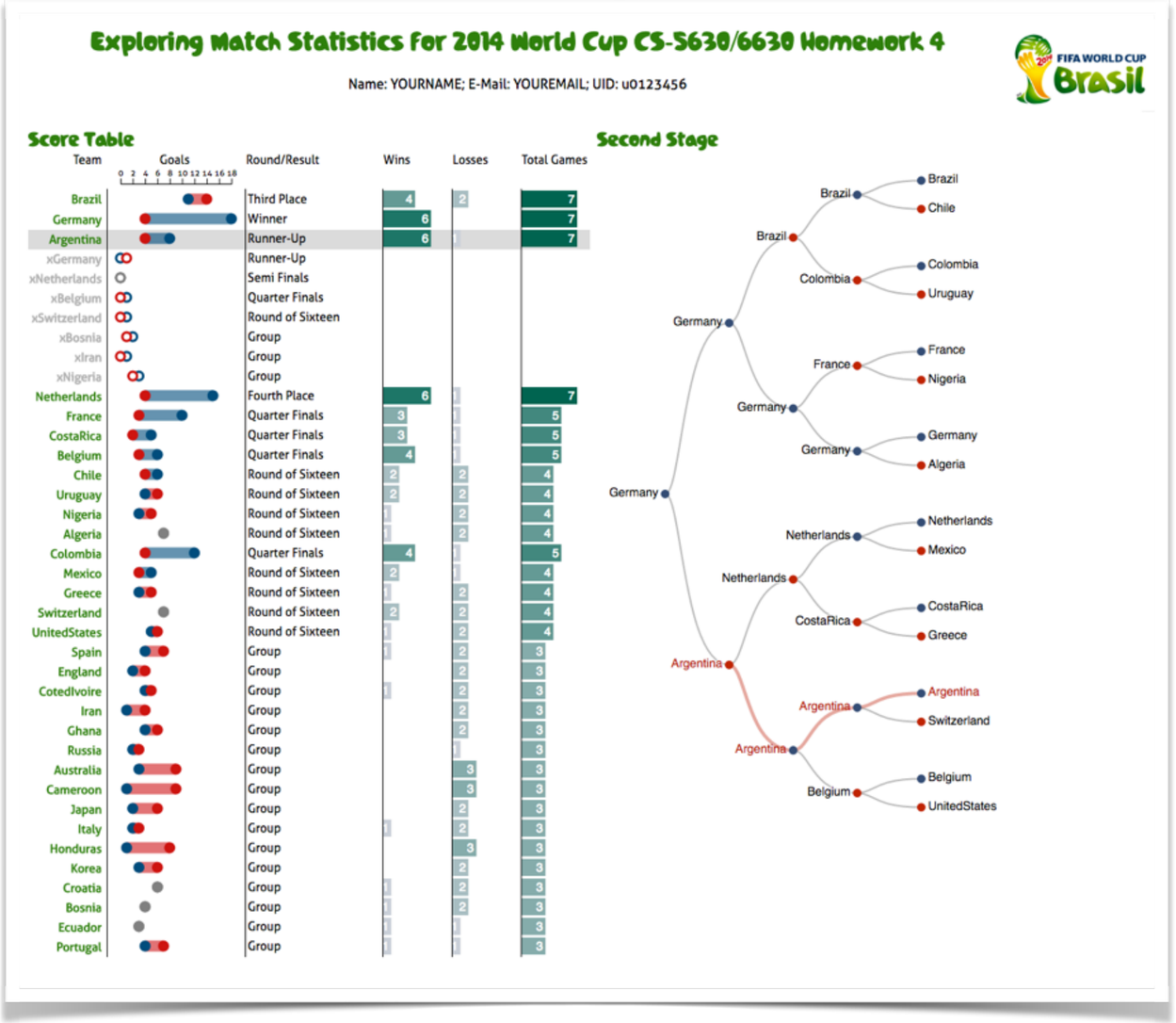
Intro Lab: Thursday 3:30 (Loc TBA)

Custom visual encoding

Intricate interaction

Implementation:

- Homework description describes one way of doing this.
- There are others, you can follow another path as long as it's good software engineering.



# The Visualization Alphabet: Marks and Channels

How can I visually represent two numbers, e.g.,

**4 and 8**

# Marks & Channels

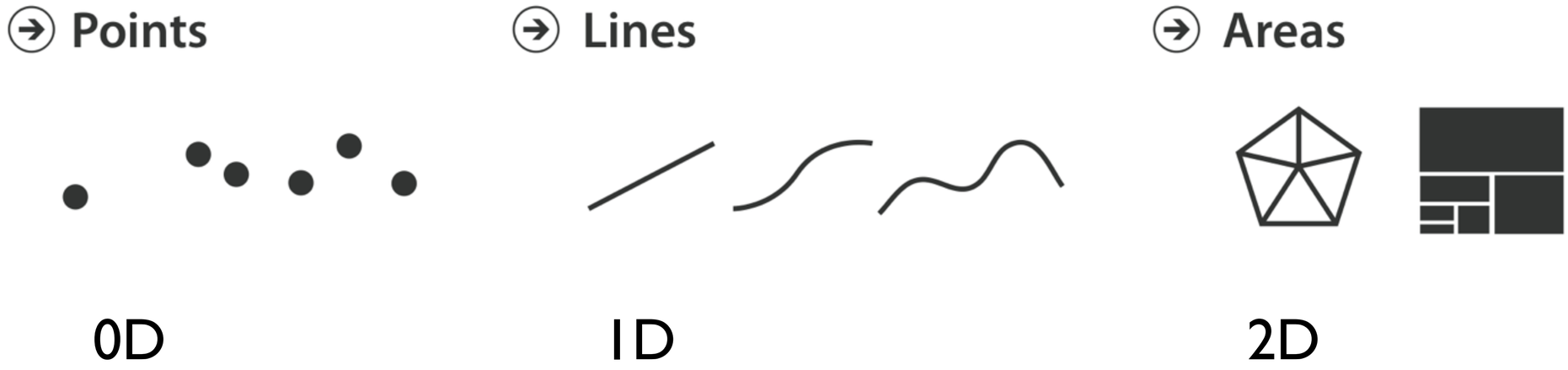
**Marks**: represent **items** or **links**

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

**Channel = Visual Variable**

# Marks for Items

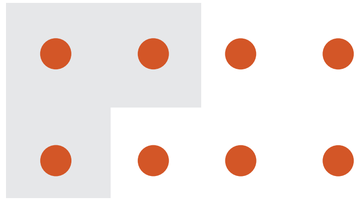
Basic geometric elements



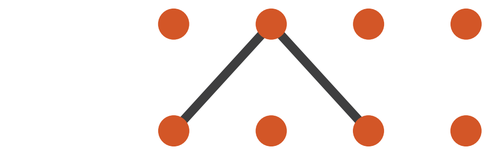

3D mark: Volume, but rarely used

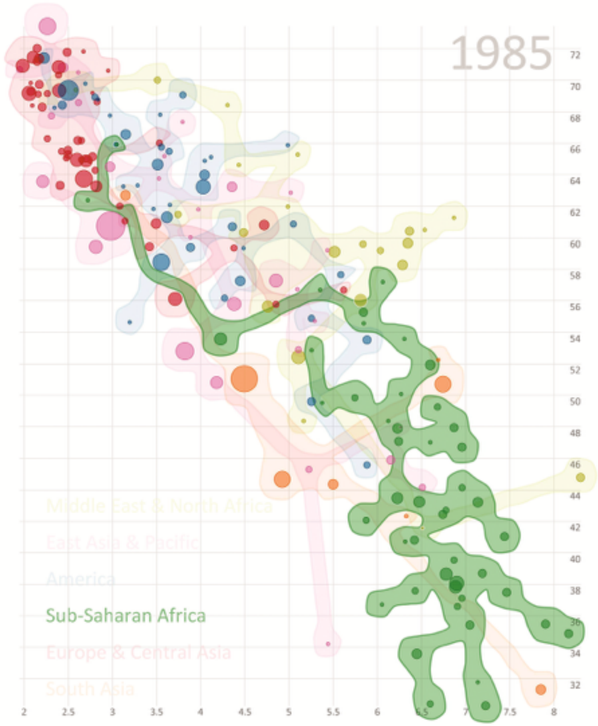
# Marks for Links

## Containment

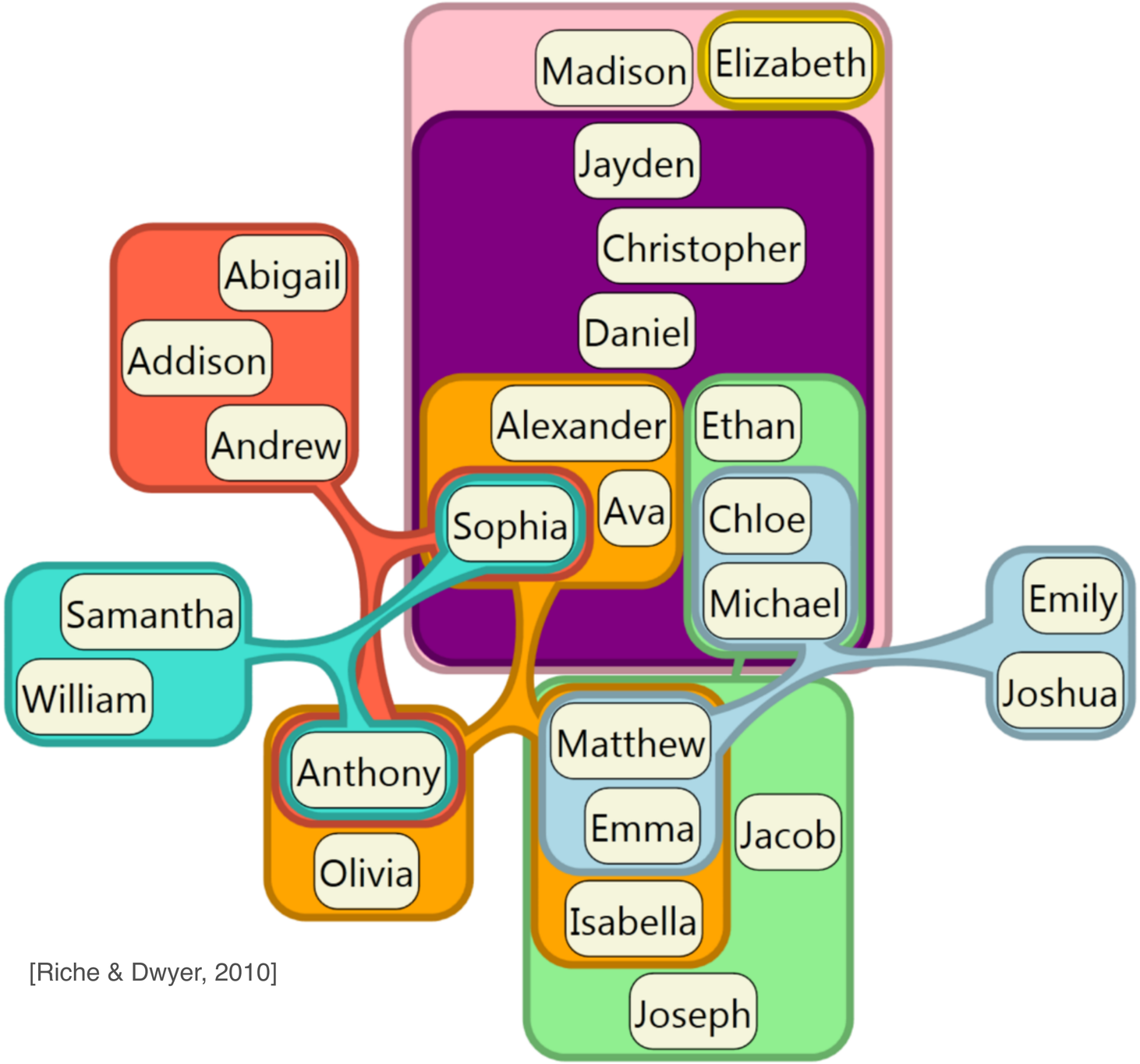


## Connection





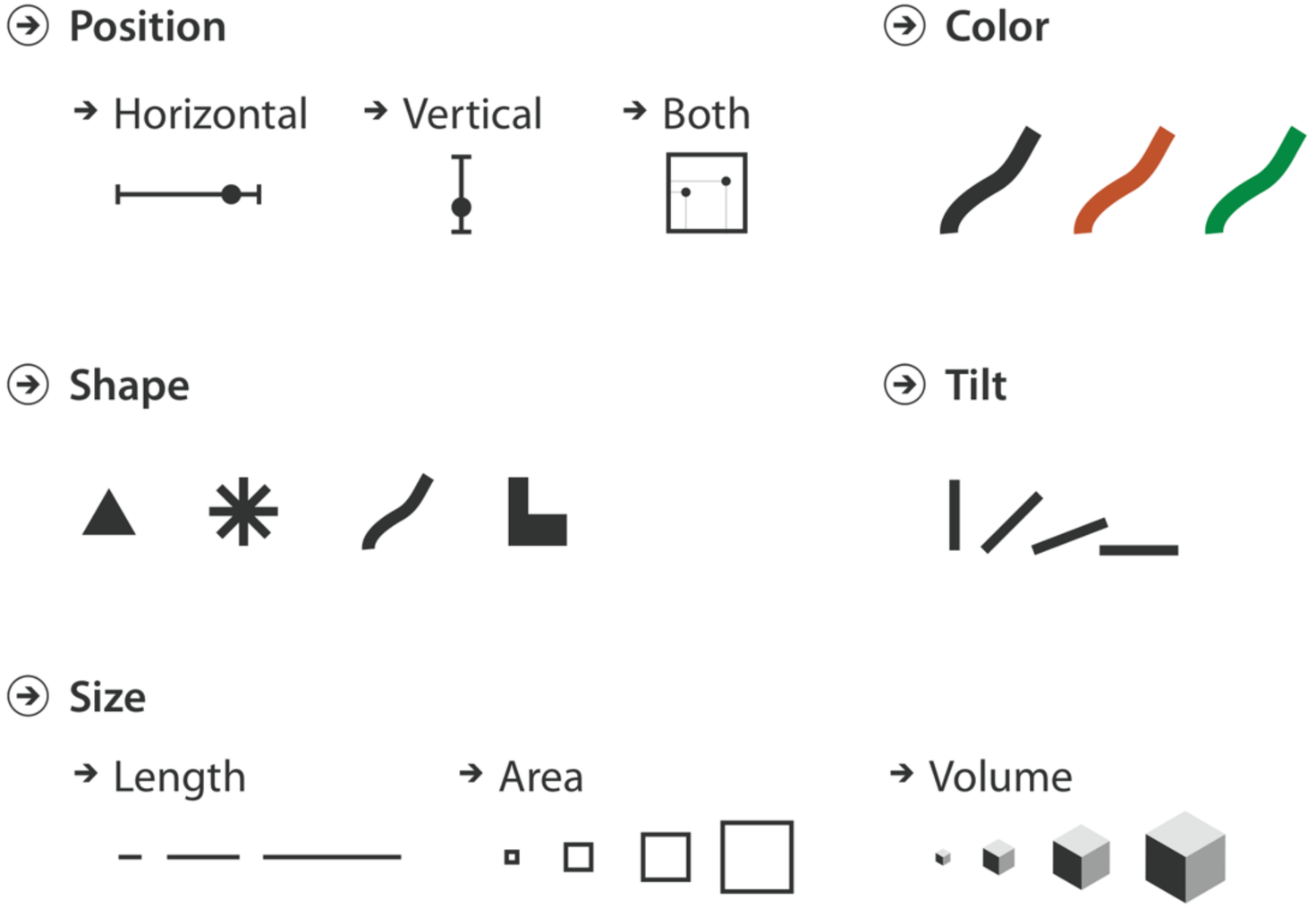
# Containment can be nested




[Riche & Dwyer, 2010]

# Channels (aka Visual Variables)

Control appearance proportional to or based on attributes



# Jacques Bertin

French cartographer
[1918-2010]

Semiology of Graphics [1967]

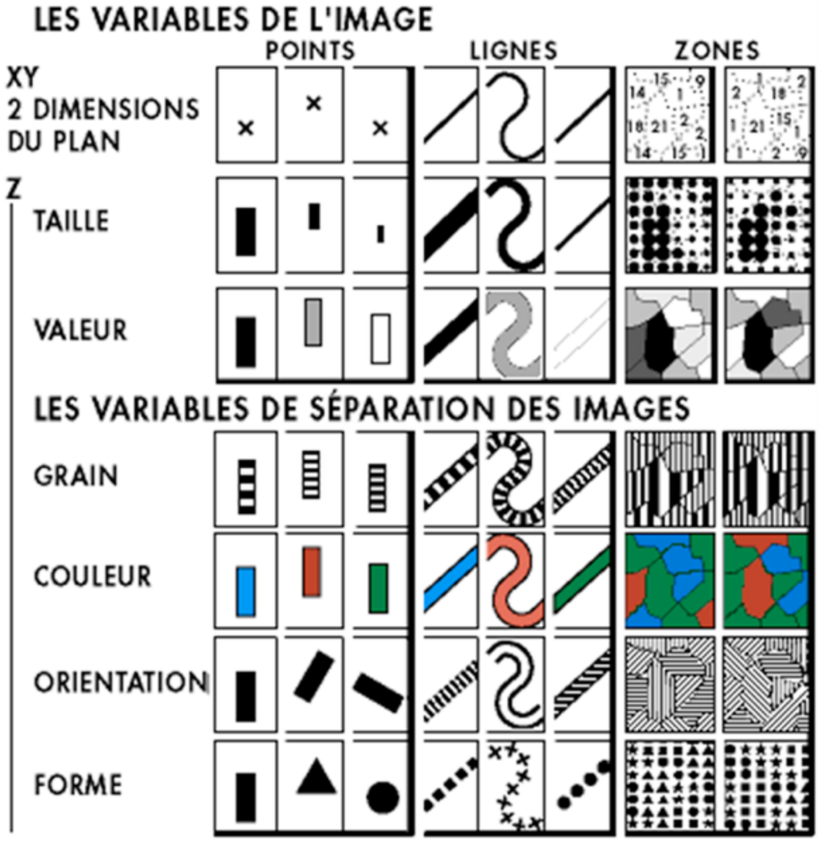
Theoretical principles for visual encodings

# Bertin's Visual Variables

Marks: Points Lines Areas

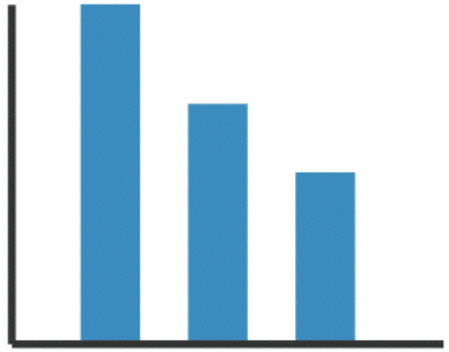
Position
Size
(Grey)Value

Texture
Color
Orientation
Shape




Semiology of Graphics [J. Bertin, 67]

# Using Marks and Channels

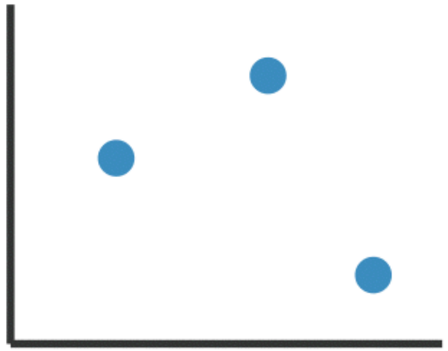


Mark: Line

Channel: Length/Position

1 quantitative attribute

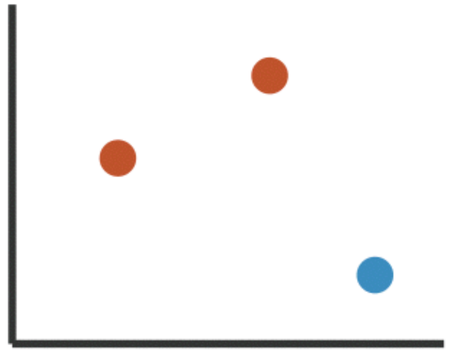
1 categorical attribute



Mark: Point

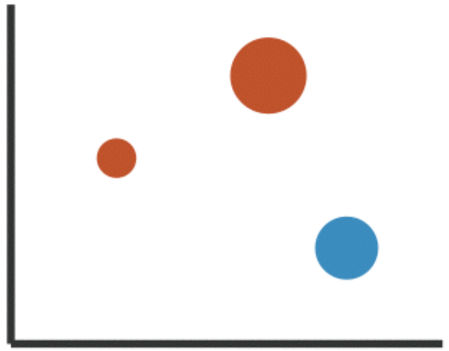
Channel: Position

2 quantitative attr.



Adding Hue

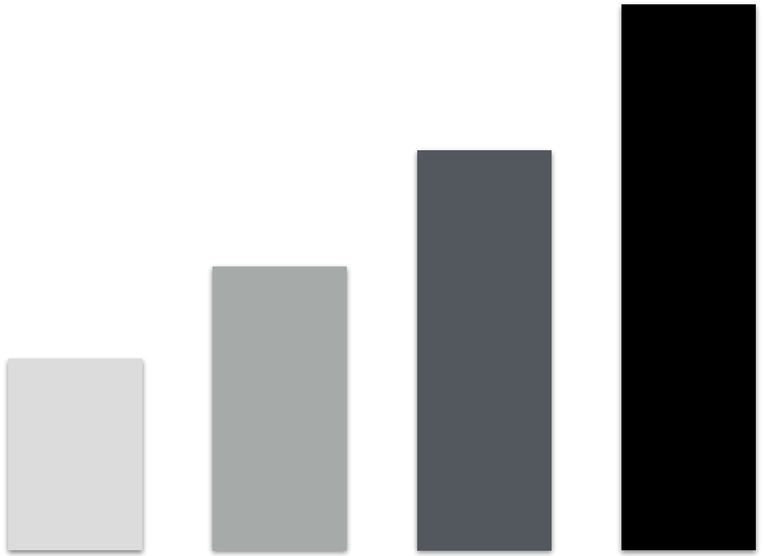
+1 categorical attr.



Adding Size

+1 quantitative attr.

# Redundant encoding



Length, Position and Value

# Good bar chart?


Rule: Use channel proportional to data!

# Types of Channels

**Magnitude Channels**

How much?

Position

Length

Saturation …

**Identity Channels**

What? Where?

Shape

Color (hue)

Spatial region …

**Ordinal & Quantitative Data**

**Categorical Data**

**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)

Most ▲ Effectiveness ▼ Least

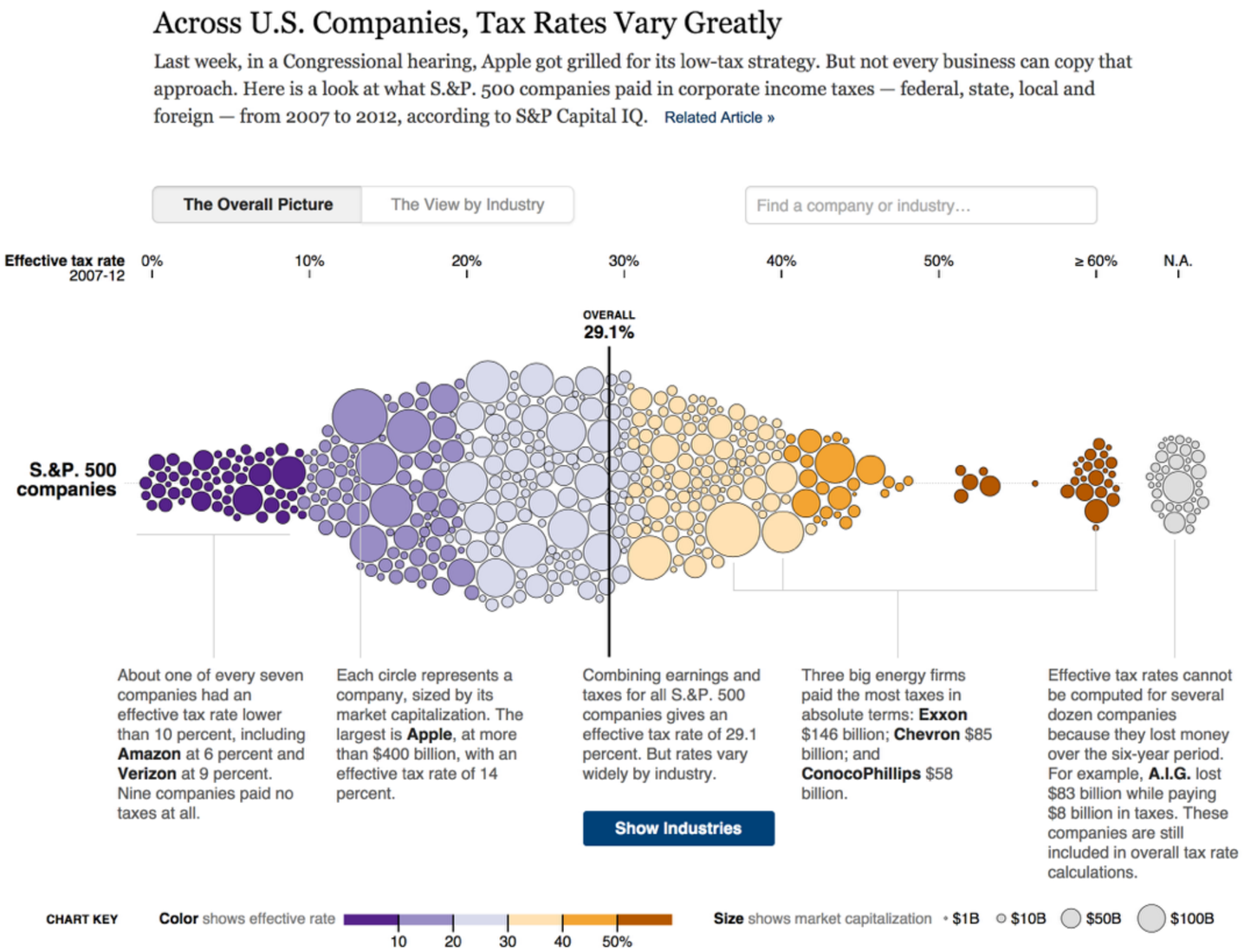
Same (Color luminance, Color saturation)

Same (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?

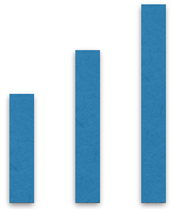
Associative

- 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?

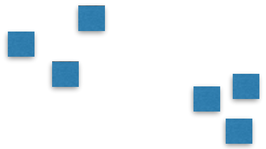
# Position

Strongest visual variable

Suitable for all data types

Problems:

- Sometimes not available (spatial data)
- Cluttering



Selective: yes

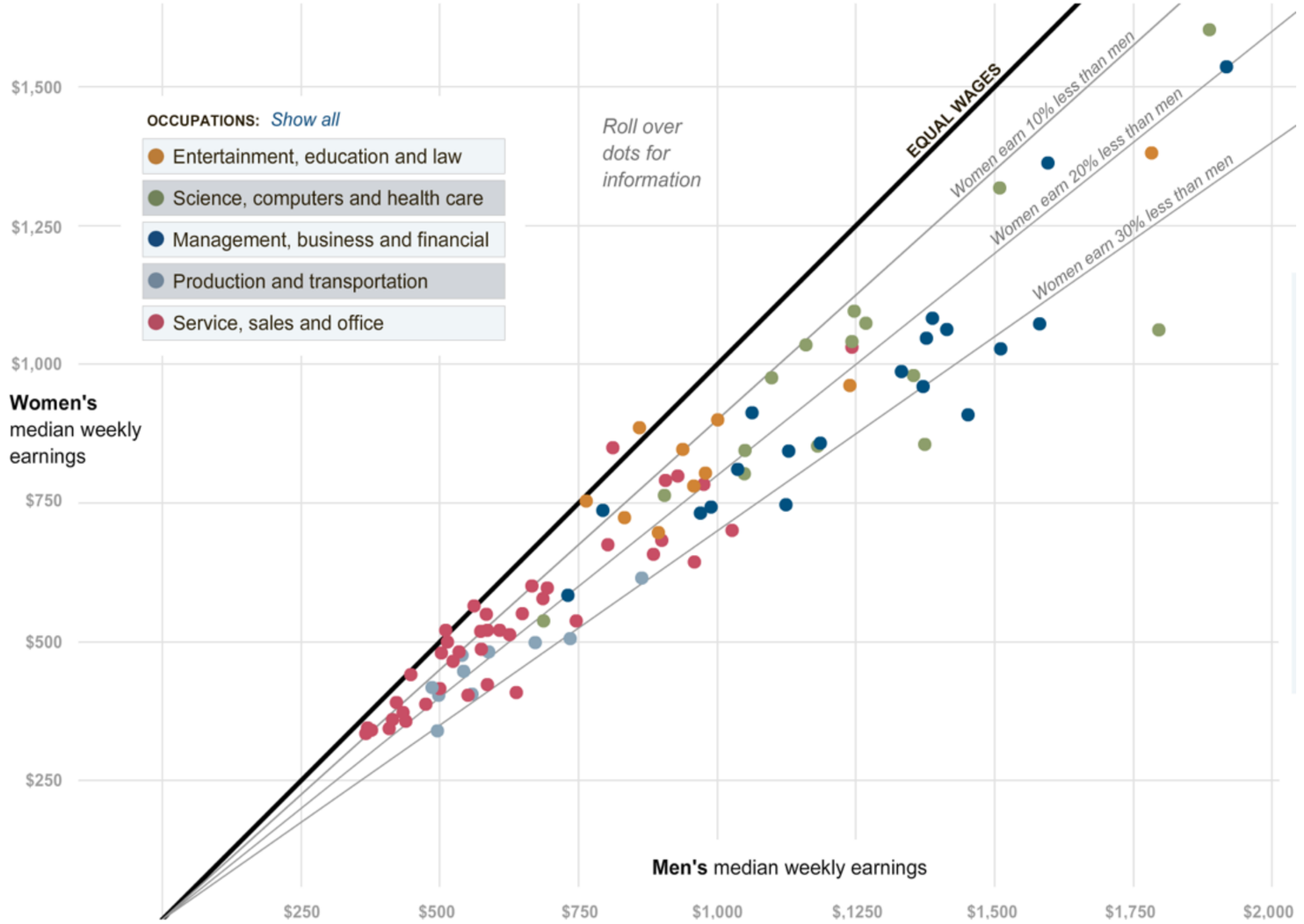
Associative: yes

Quantitative: yes

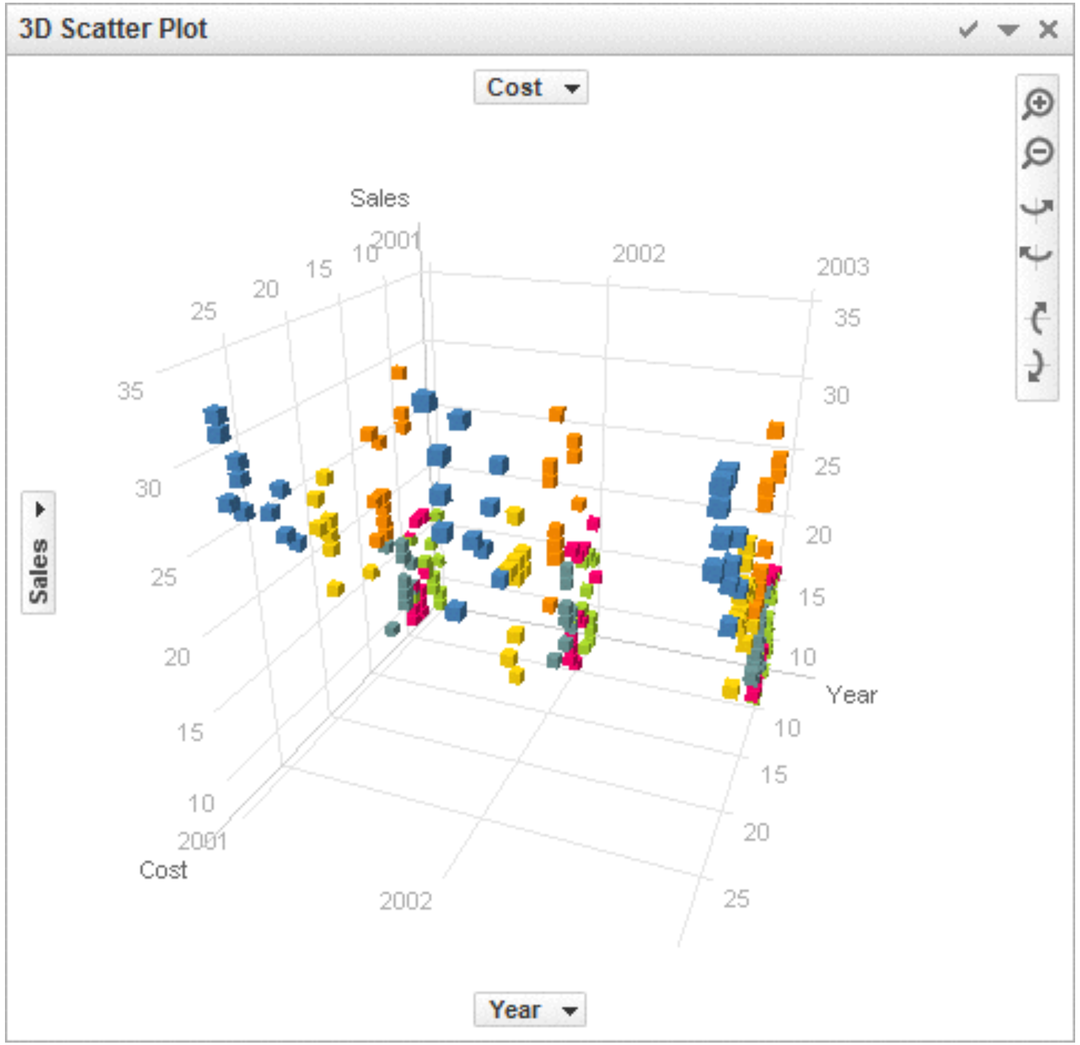
Order: yes

Length: fairly big

# Example: Scatterplot



# Position in 3D?




[Spotfire]

# Length & Size

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

Easy to see whether one is bigger

Aligned bars use position redundantly

For 1D length:

Selective: yes

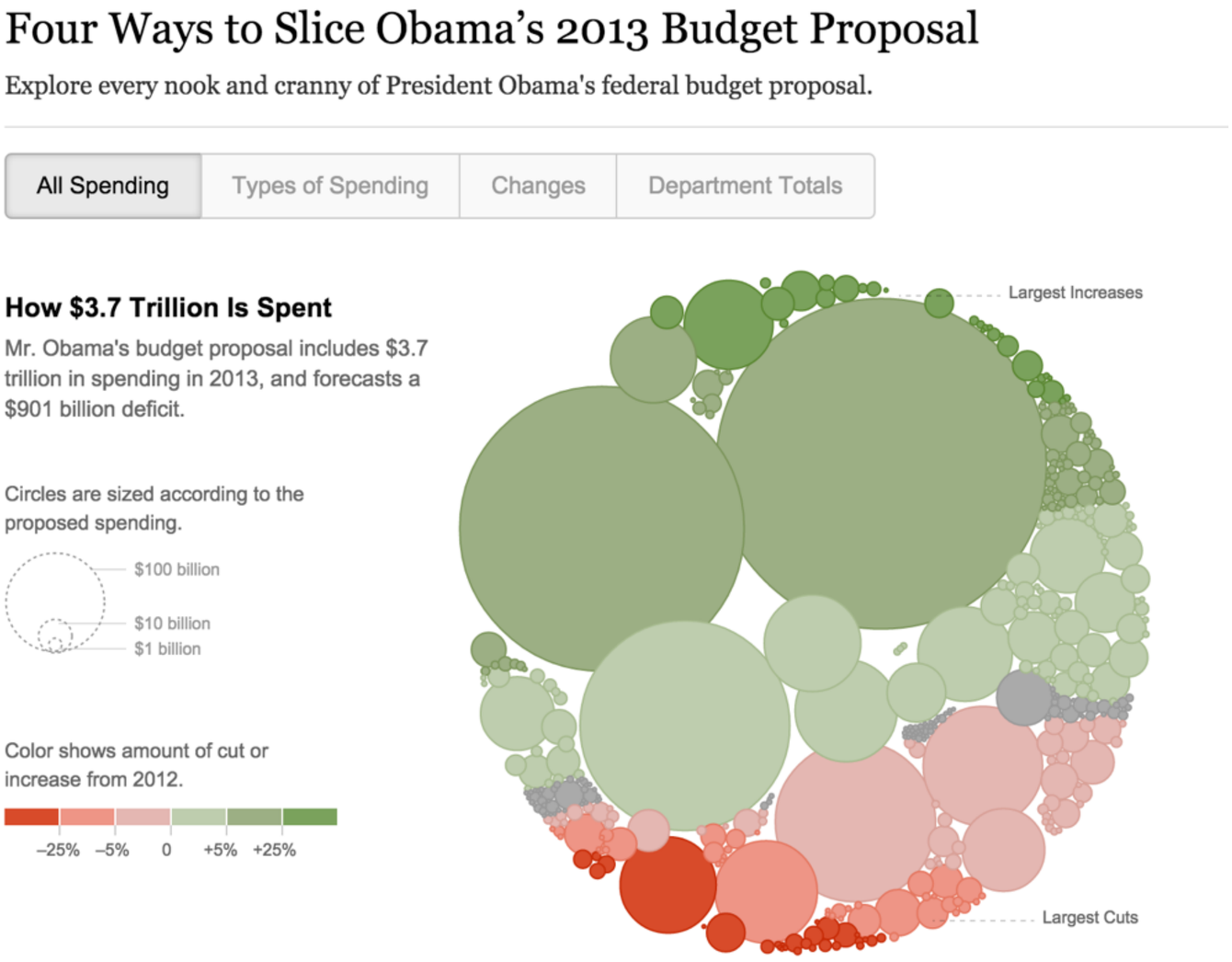
Associative: yes

Quantitative: yes

Order: yes

Length: high

# Example 2D Size: Bubbles



# Value/Luminance/Saturation

OK for quantitative data when length & size are used.

Not very many shades recognizable

Selective: yes

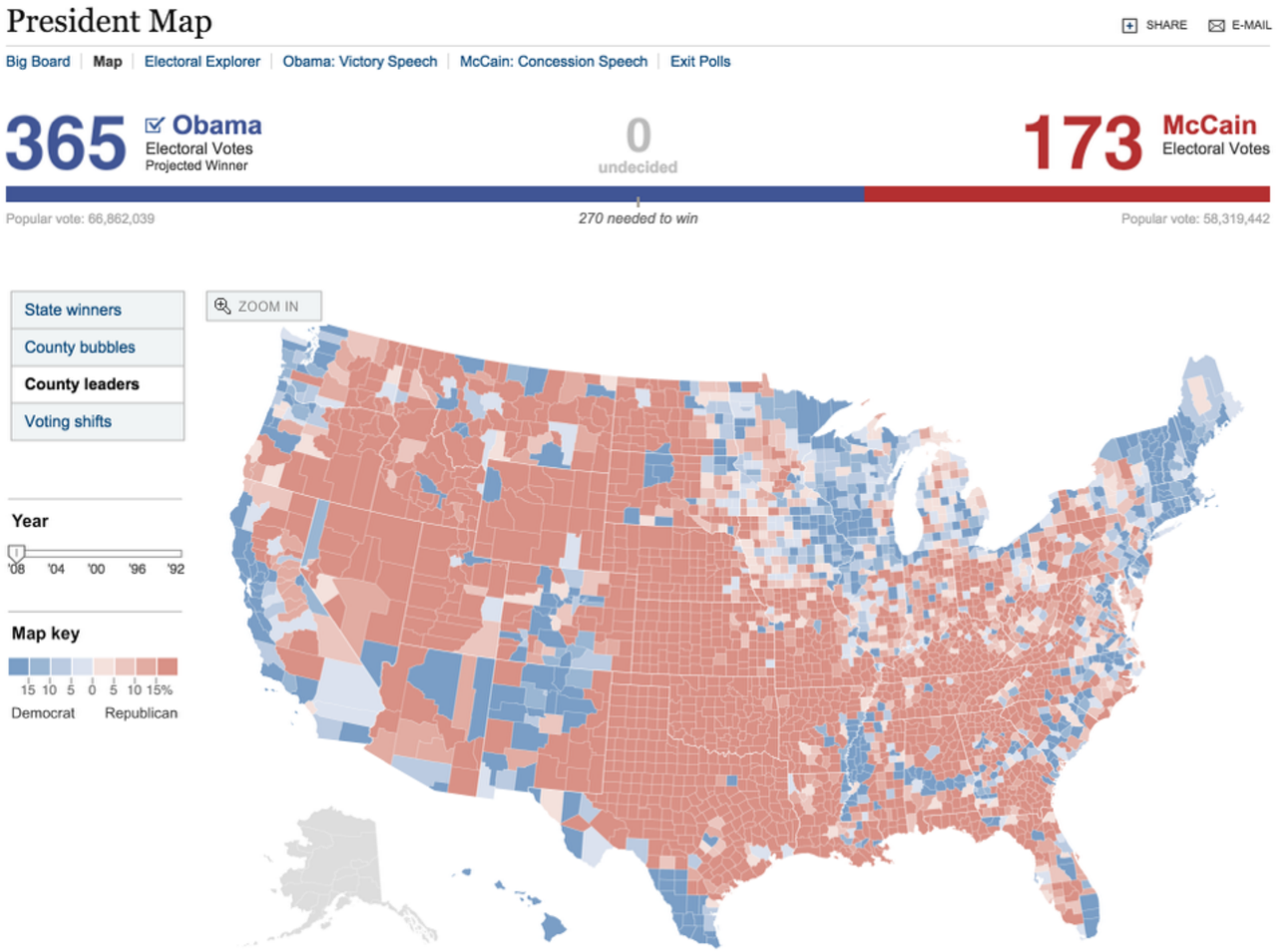
Associative: yes

Quantitative: somewhat (with problems)

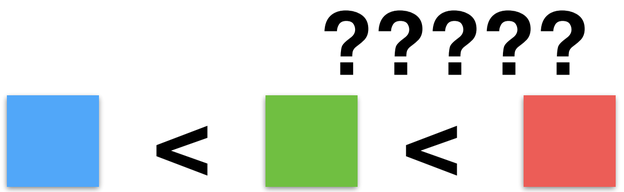
Order: yes

Length: limited

# Example: Diverging Value-Scale



# Color




Good for qualitative data (identity channel)

Limited number of classes/length (~7-10!)

Does not work for quantitative data!

Lots of pitfalls! Be careful!

My rule:

- minimize color use for encoding data
- use for brushing

Selective: yes

Associative: yes

Quantitative: no

Order: no

Length: limited

# Color: Bad Example

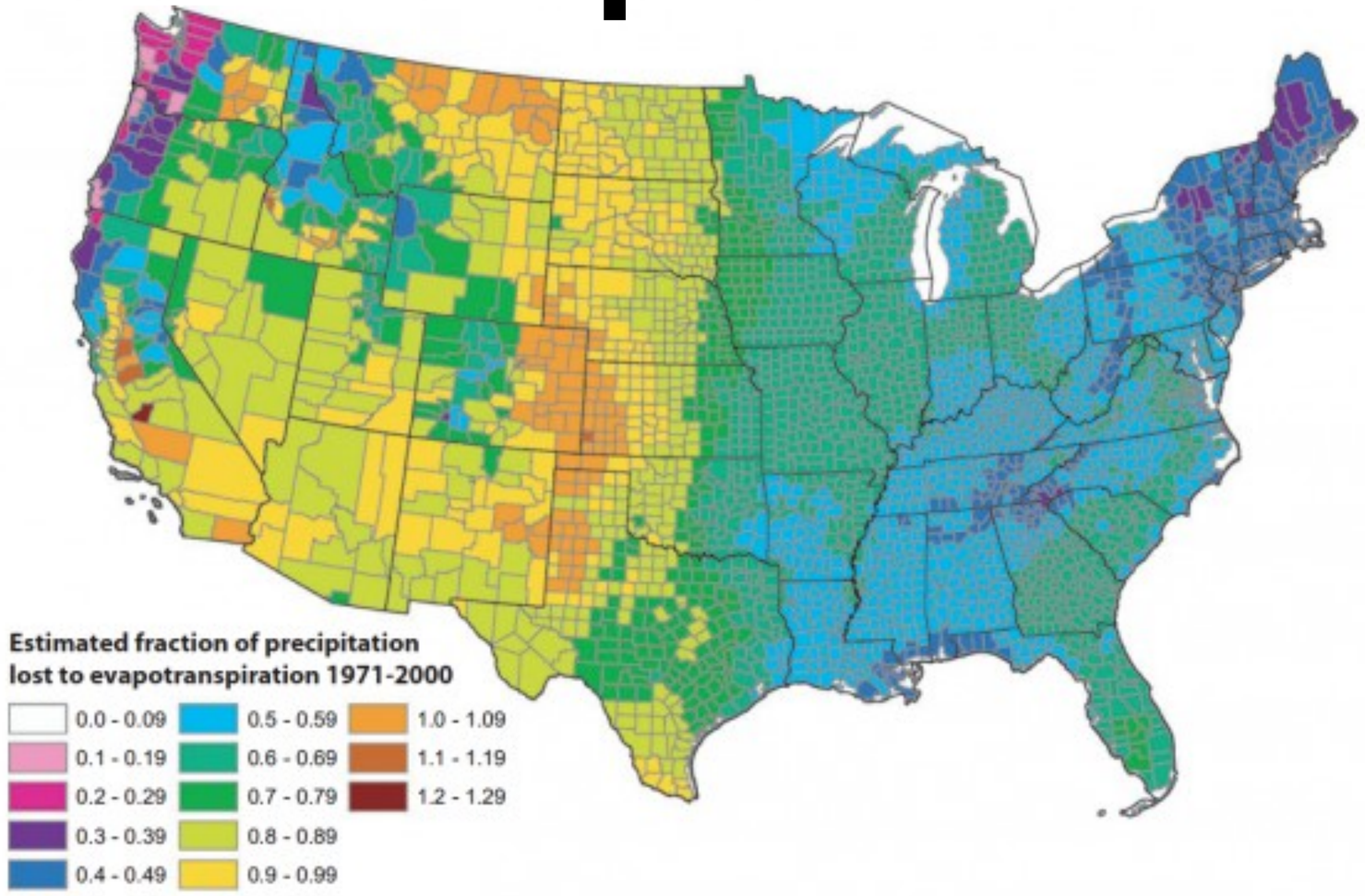
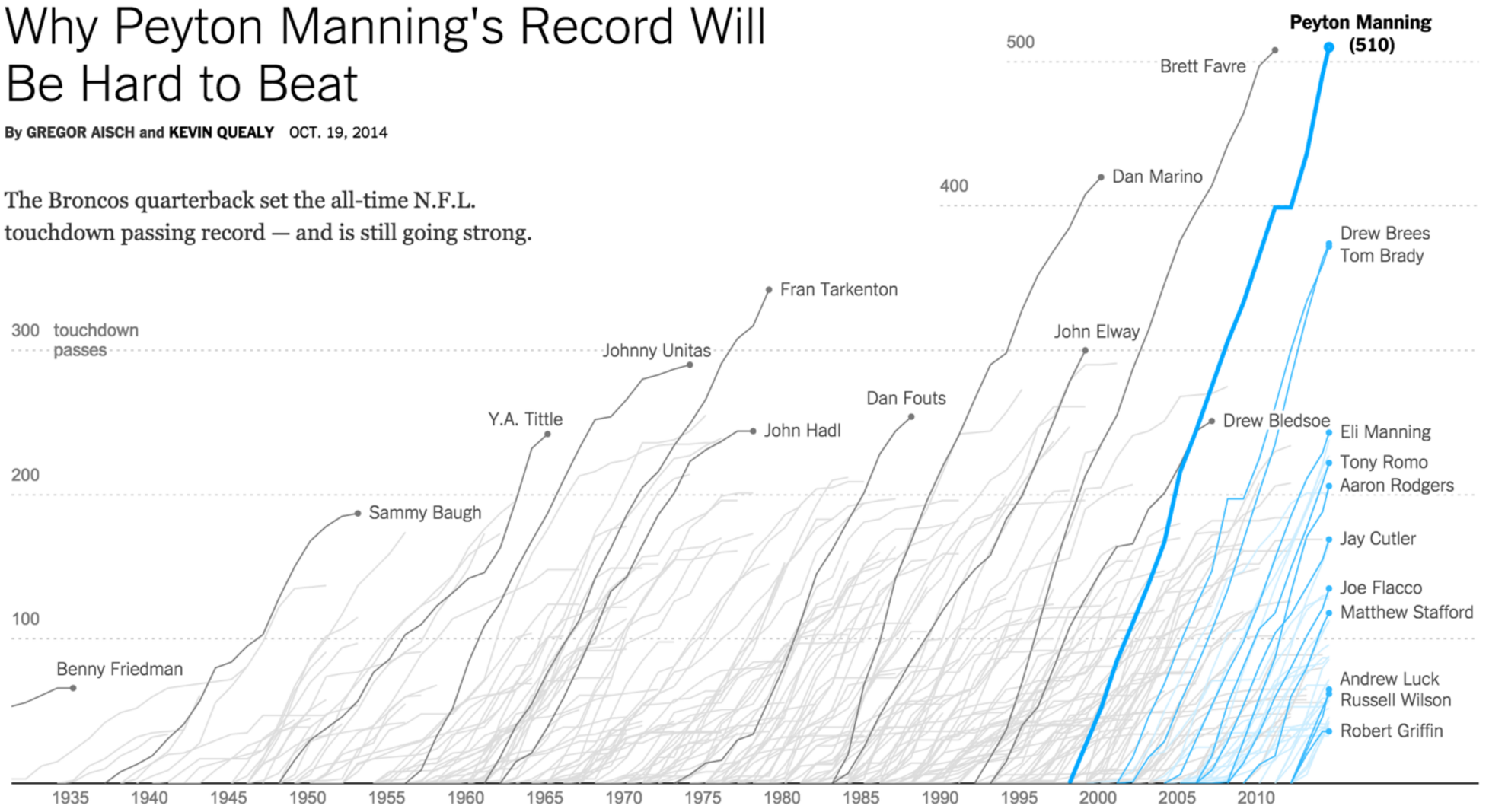
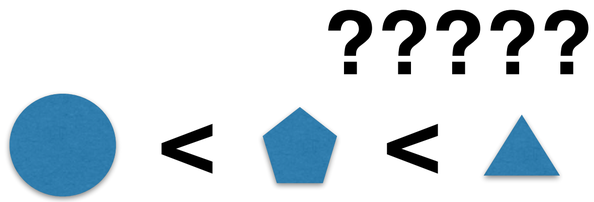



FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation ($P$) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of $ET/P$ were made first at the 800-m resolution of the 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

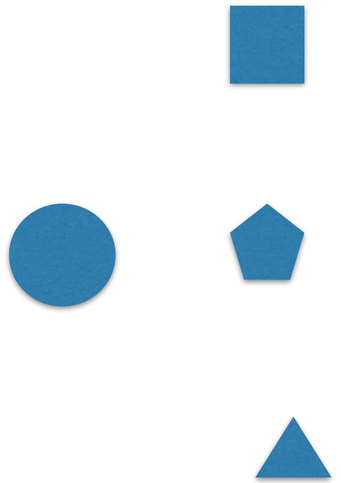


# Shape




Great to recognize many classes.

No grouping, ordering.



Selective: yes

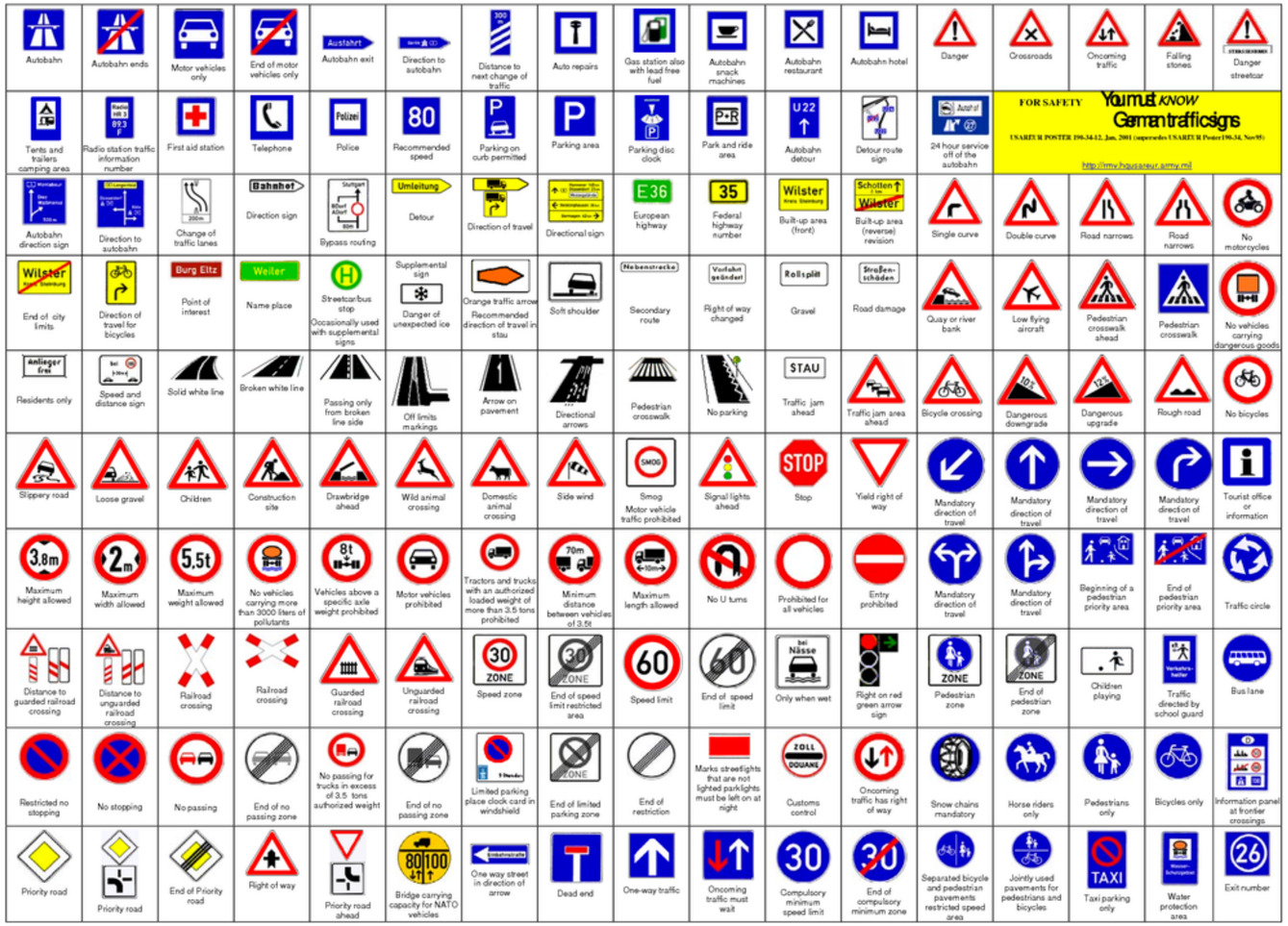
Associative: limited

Quantitative: no

Order: no

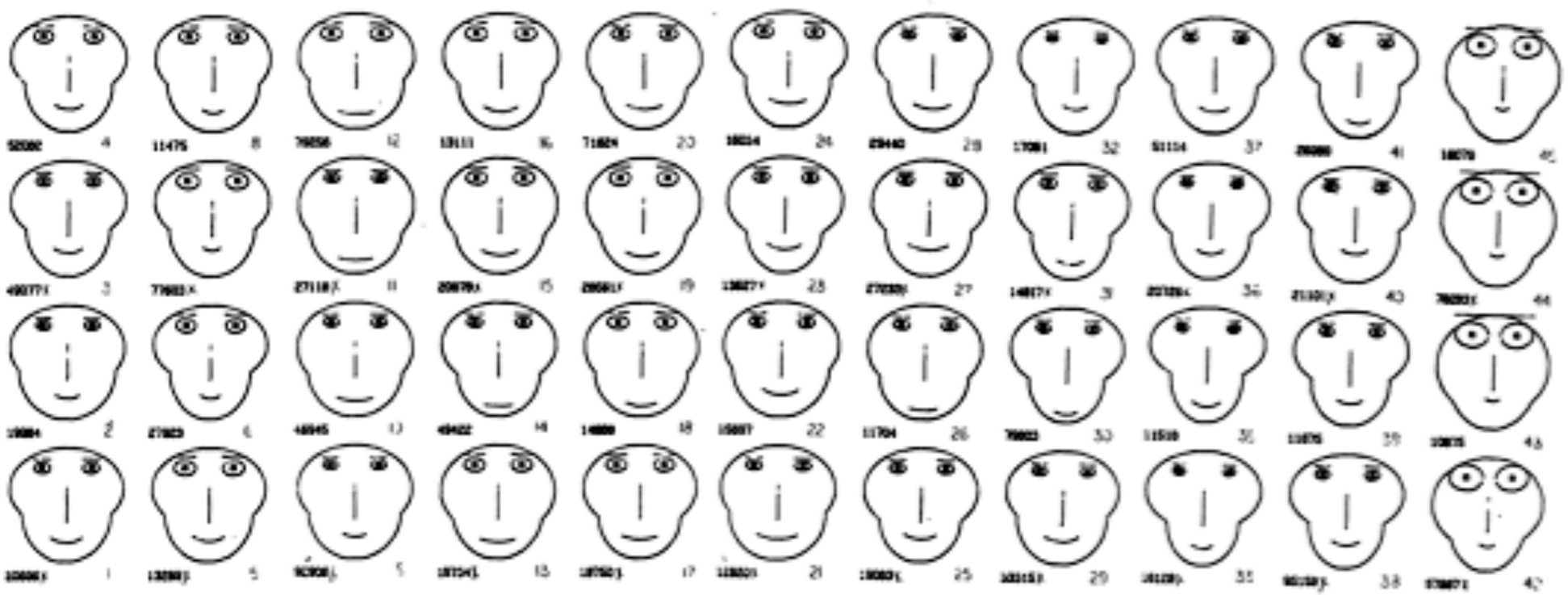
Length: vast


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


Autobahn
Autobahn ends
Motor vehicles only
End of motor vehicles only
Autobahn exit
Direction to autobahn
Distance to next change of traffic
Auto repairs
Gas station also with lead free fuel
Autobahn snack machines
Autobahn restaurant
Autobahn hotel
Danger
Crossroads
Oncoming traffic
Falling stones
Danger streetcar
Tents and trailers camping area
Radio station traffic information number
First aid station
Telephone
Police
Recommended speed
Parking on curb permitted
Parking area
Parking disc clock
Park and ride area
Autobahn detour
Detour route sign
24 hour service off of the autobahn
FOR SAFETY You must KNOW German trafficsigns
USAREUR POSTER 190-34-12, Jan. 2001 (supersedes USAREUR Poster190-34, Nov95)
http://mwr.hqusareur.army.mil
Autobahn direction sign
Direction to autobahn
Change of traffic lanes
Direction sign
Bypass routing
Detour
Direction of travel
Directional sign
European highway
Federal highway number
Built-up area (front)
Built-up area (reverse) revision
Single curve
Double curve
Road narrows
Road narrows
No motorcycles
End of city limits
Direction of travel for bicycles
Point of interest
Name place
Streetcar/bus stop
Occasionally used with supplemental signs
Supplemental sign
Danger of unexpected ice
Orange traffic arrow
Recommended direction of travel in stau
Soft shoulder
Secondary route
Right of way changed
Gravel
Road damage
Quay or river bank
Low flying aircraft
Pedestrian crosswalk ahead
Pedestrian crosswalk
No vehicles carrying dangerous goods
Residents only
Speed and distance sign
Solid white line
Broken white line
Passing only from broken line side
Off limits markings
Arrow on pavement
Directional arrows
Pedestrian crosswalk
No parking
Traffic jam ahead
Traffic jam area ahead
Bicycle crossing
Dangerous downgrade
Dangerous upgrade
Rough road
No bicycles
Slippery road
Loose gravel
Children
Construction site
Drawbridge ahead
Wild animal crossing
Domestic animal crossing
Side wind
Smog
Motor vehicle traffic prohibited
Signal lights ahead
Stop
Yield right of way
Mandatory direction of travel
Mandatory direction of travel
Mandatory direction of travel
Mandatory direction of travel
Tourist office or information
Maximum height allowed
Maximum width allowed
Maximum weight allowed
No vehicles carrying more than 3000 liters of pollutants
Vehicles above a specific axle weight prohibited
Motor vehicles prohibited
Tractors and trucks with an authorized loaded weight of more than 3.5 tons prohibited
Minimum distance between vehicles of 3.5t
Maximum length allowed
No U turns
Prohibited for all vehicles
Entry prohibited
Mandatory direction of travel
Mandatory direction of travel
Beginning of a pedestrian priority area
End of pedestrian priority area
Traffic circle
Distance to guarded railroad crossing
Distance to unguarded railroad crossing
Railroad crossing
Railroad crossing
Guarded railroad crossing
Unguarded railroad crossing
Speed zone
End of speed limit restricted area
Speed limit
End of speed limit
Only when wet
Right on red green arrow sign
Pedestrian zone
End of pedestrian zone
Children playing
Traffic directed by school guard
Bus lane
Restricted no stopping
No stopping
No passing
End of no passing zone
No passing for trucks in excess of 3.5 tons authorized weight
End of no passing zone
Limited parking place clock card in windshield
End of limited parking zone
End of restriction
Marks streetlights that are not lighted parklights must be left on at night
Customs control
Oncoming traffic has right of way
Snow chains mandatory
Horse riders only
Pedestrians only
Bicycles only
Information panel at frontier crossings
Priority road
Priority road
End of Priority road
Right of way
Priority road ahead
Bridge carrying capacity for NATO vehicles
One way street in direction of arrow
Dead end
One-way traffic
Oncoming traffic must wait
Compulsory minimum speed limit
End of compulsory minimum zone
Separated bicycle and pedestrian pavements restricted speed area
Jointly used pavements for pedestrians and bicycles
Taxi parking only
Water protection area
Exit number

# Chernoff Faces

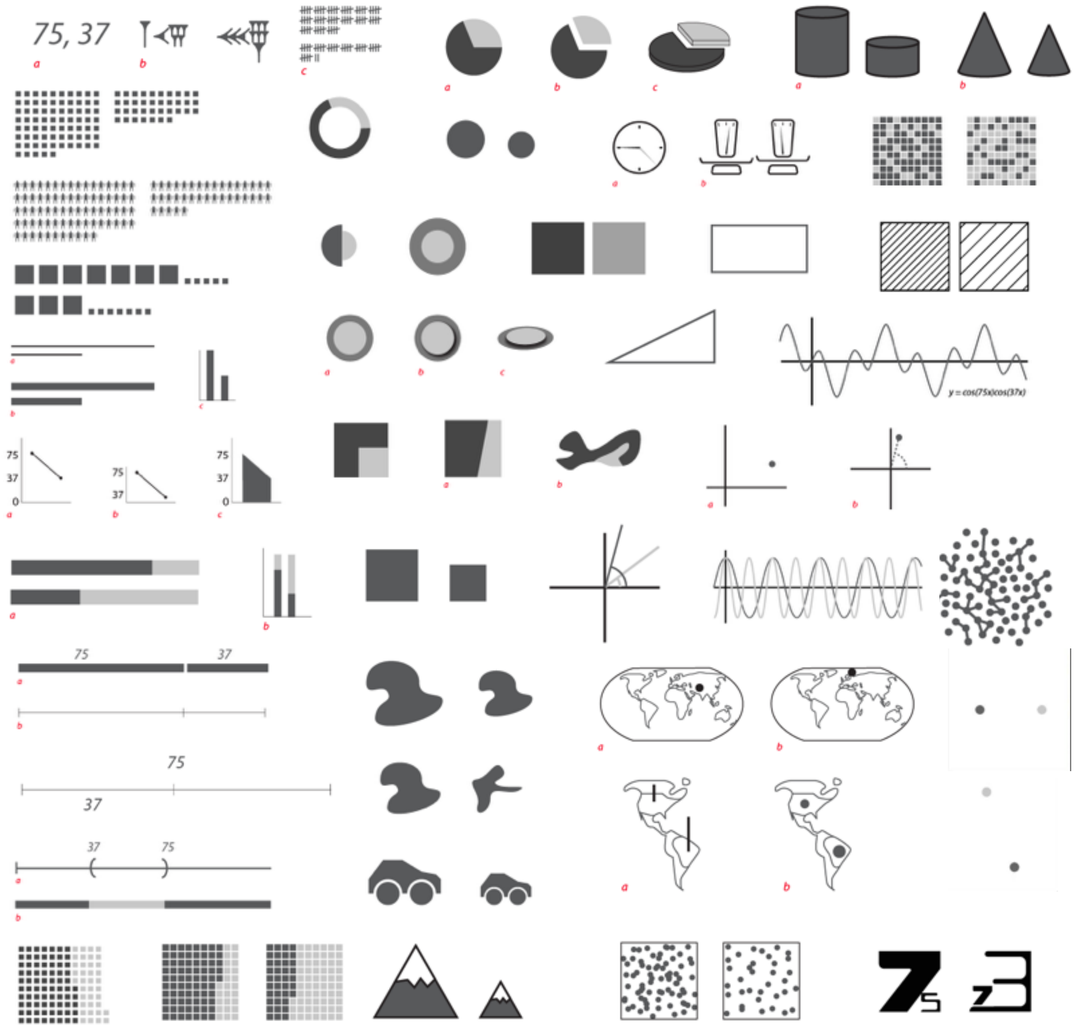
Idea: use facial parameters to map quantitative data



Does it work?
Not really!

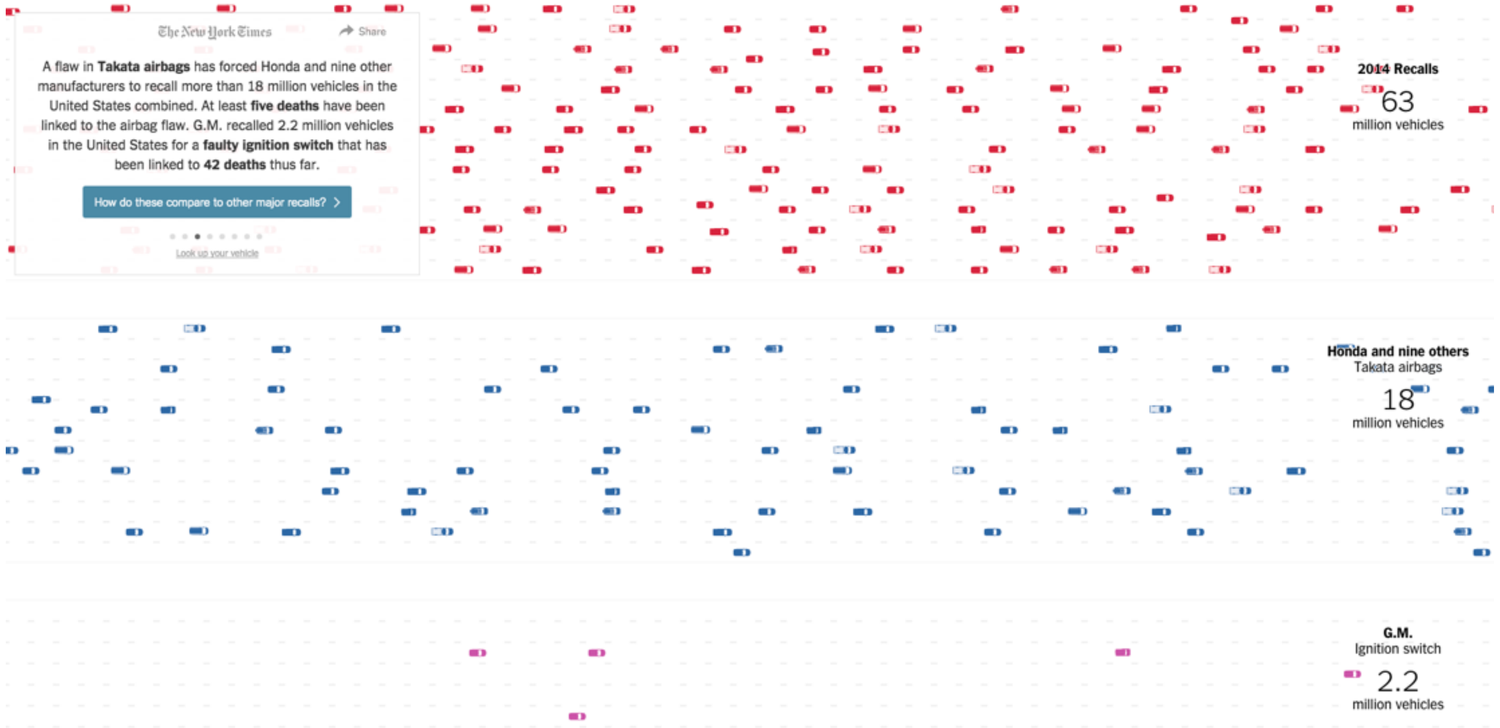
Critique: https://eagereyes.org/criticism/chernoff-faces

# More Channels



# Design Critique

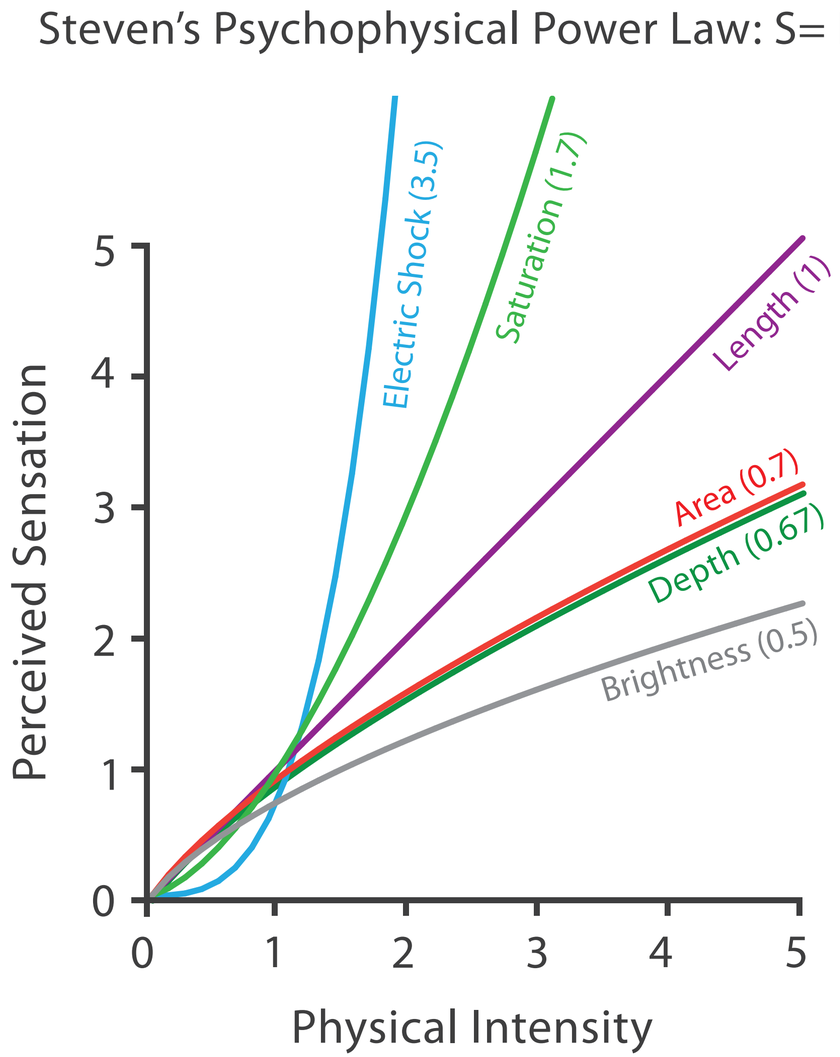
# A Record Year for Auto Recalls




https://goo.gl/DYpvvr

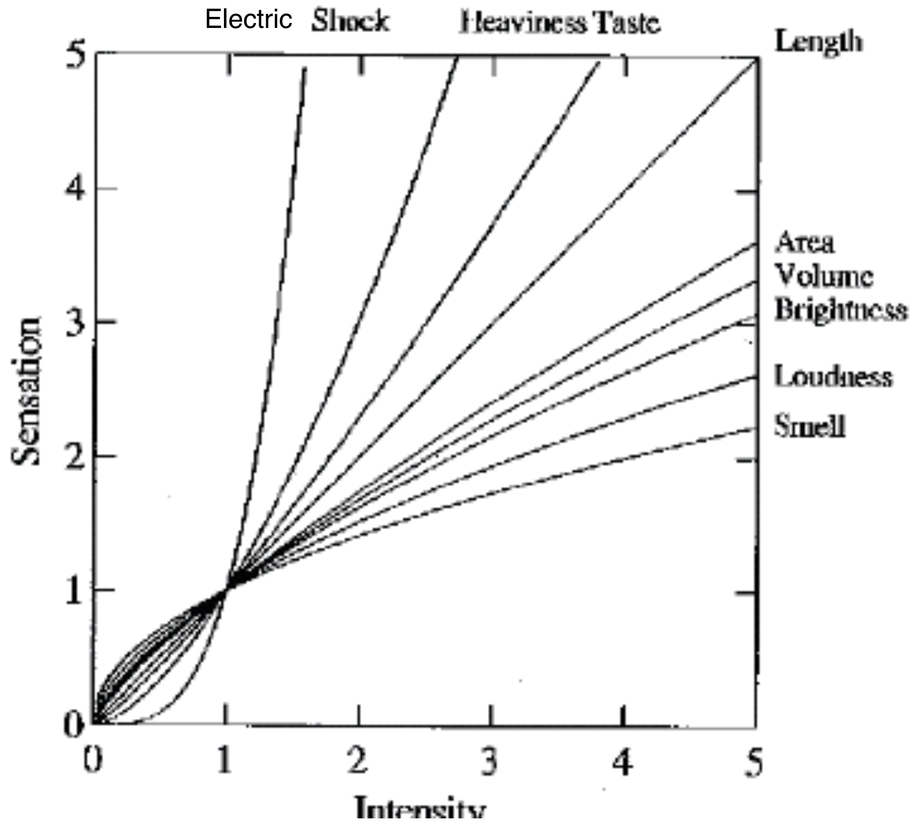
NY Times: http://goo.gl/tDVISB

# Why are quantitative channels different?



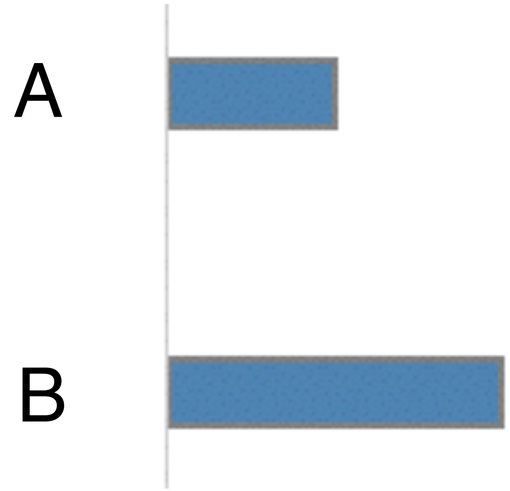

S = sensation
I = intensity

# Steven's Power Law, 1961



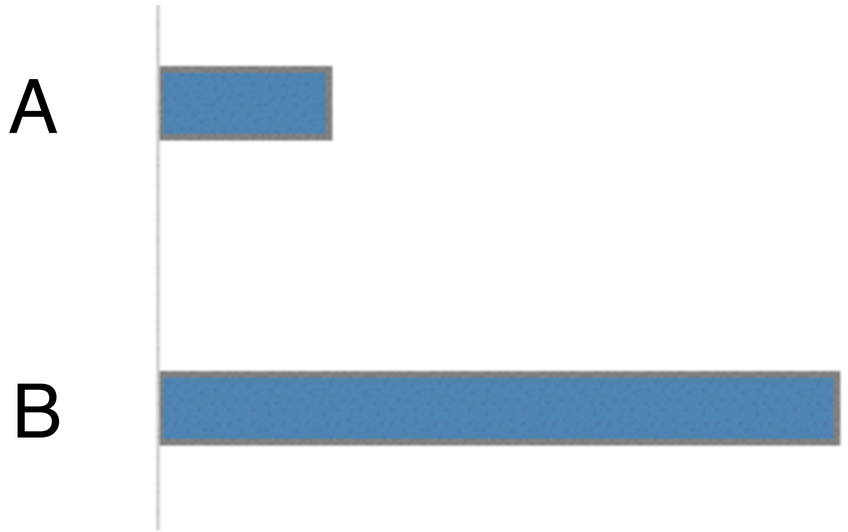

From Wilkinson 99, based on Stevens 61

# How much longer?



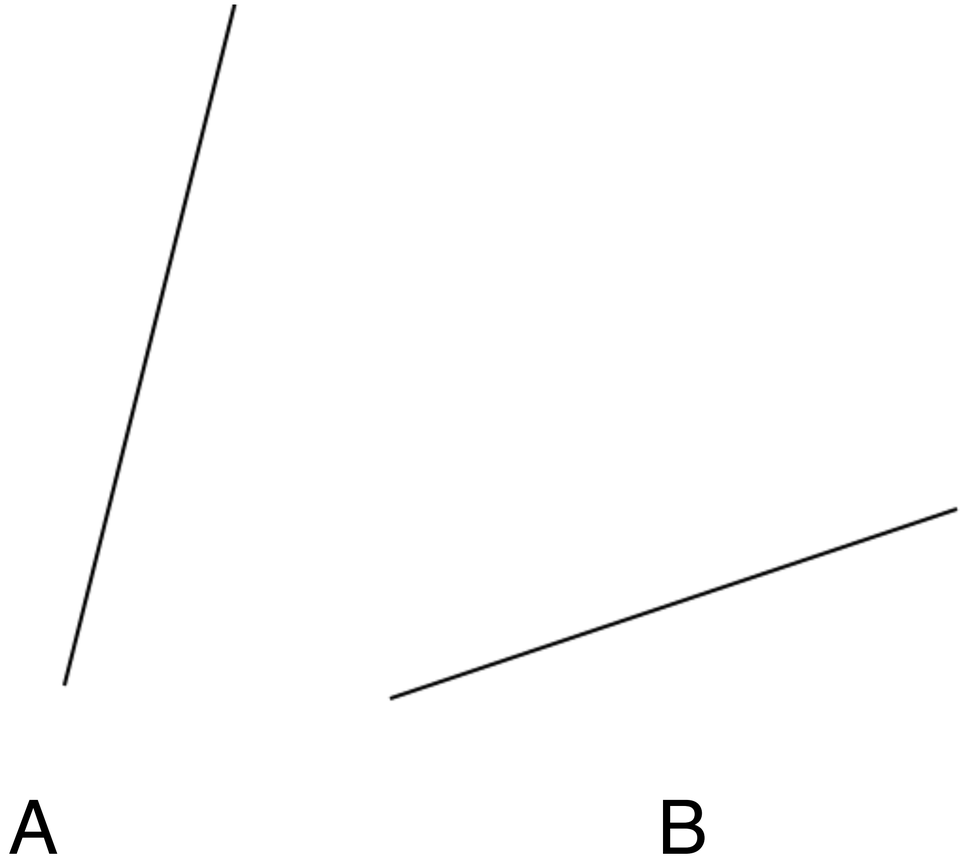

**2x**

# How much longer?



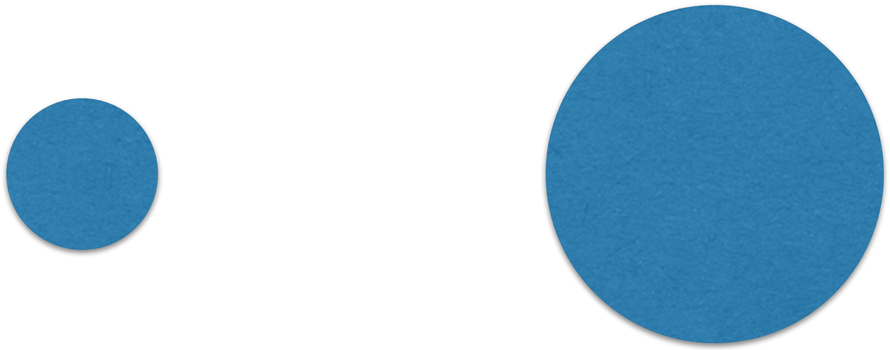

**4x**

# How much steeper?




**~4x**

# How much larger?

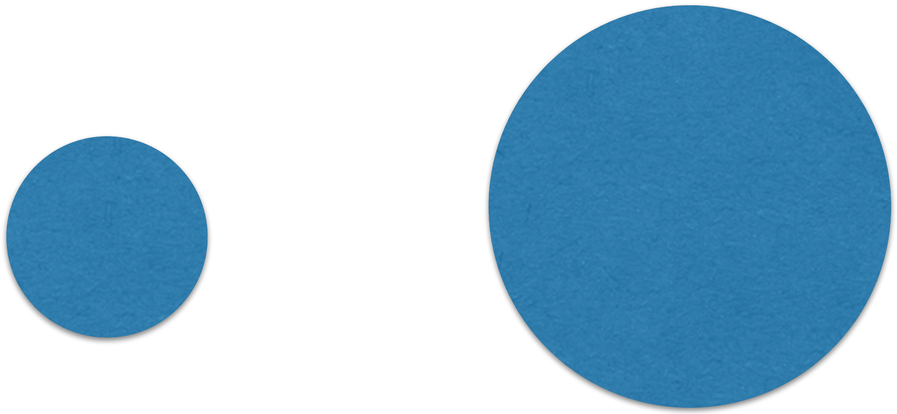


A

B

**5x**

# How much larger?



A B

**2x diameter**

**4x area**

**area is proportional to diameter squared**

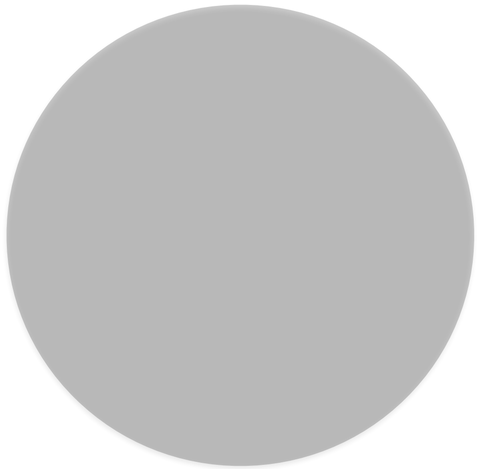
# How much larger (area)?

A

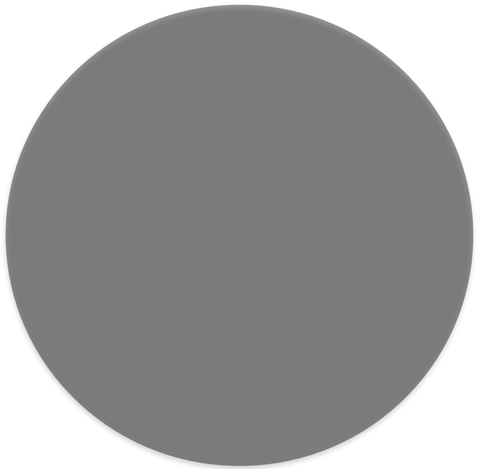
B

**3x**

# How much darker?



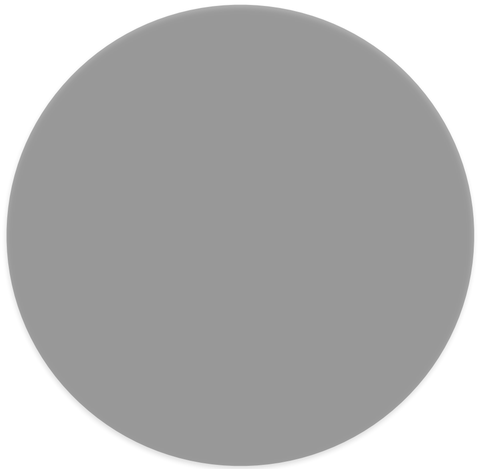
A



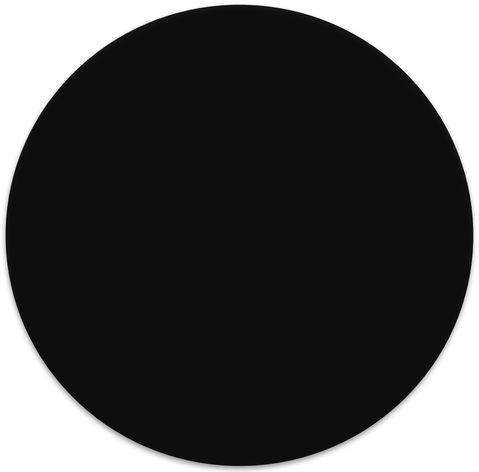
B

**2x**

# How much darker?



A



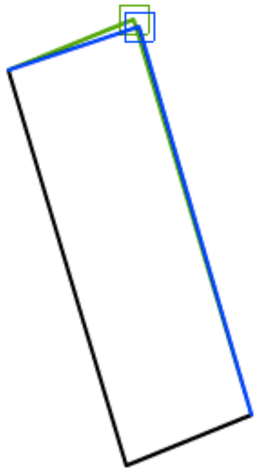
B

**3x**

# Position, Length & Angle

## The eyeballing game

**Adjust to make a parallelogram**



**Accurate to 5.0 units**

Next

**Your inaccuracy by category:**

| | | | |
|---|---|---|---|
| Parallelogram | 5.0 | ---- | ---- |
| Midpoint | ---- | ---- | ---- |
| Bisect angle | ---- | ---- | ---- |
| Triangle center | ---- | ---- | ---- |
| Circle center | ---- | ---- | ---- |
| Right angle | ---- | ---- | ---- |
| Convergence | ---- | ---- | ---- |

**Average error:** 5.00 (lower is better)
**Time taken:** 3.3

---

**Best of last 500 score and time:** (more)

| | | |
|---|---|---|
| 1.32 | 250 s | Harabubakken sparkakar kl |
| 1.36 | 81 s | ± rides saddle horn |
| 1.39 | 110 s | have both-can f myself± |
| 1.46 | 93 s | ± is one kinky dude |
| 1.50 | 95 s | no NT...sample my taco? ± |
| 1.55 | 114 s | |
| 1.57 | 113 s | |
| 1.65 | 85 s | ± "come on funny feeling" |
| 1.70 | 71 s | JSA |
| 1.75 | 89 s | JSA |

**Best on this computer score and time:**

# Other Factors Affecting Accuracy

Alignment

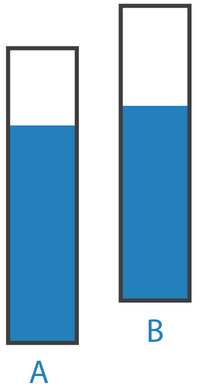
Distractors

Distance

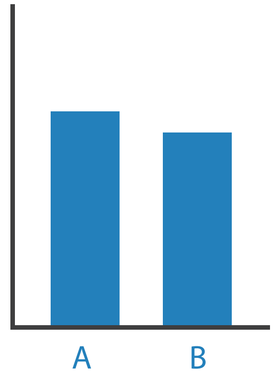
Common scale

…

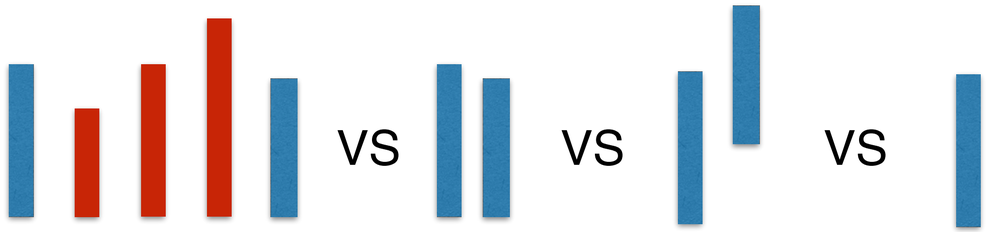

Unframed
Unaligned




Framed
Unaligned




Unframed
Aligned



# Cleveland / McGill, 1984

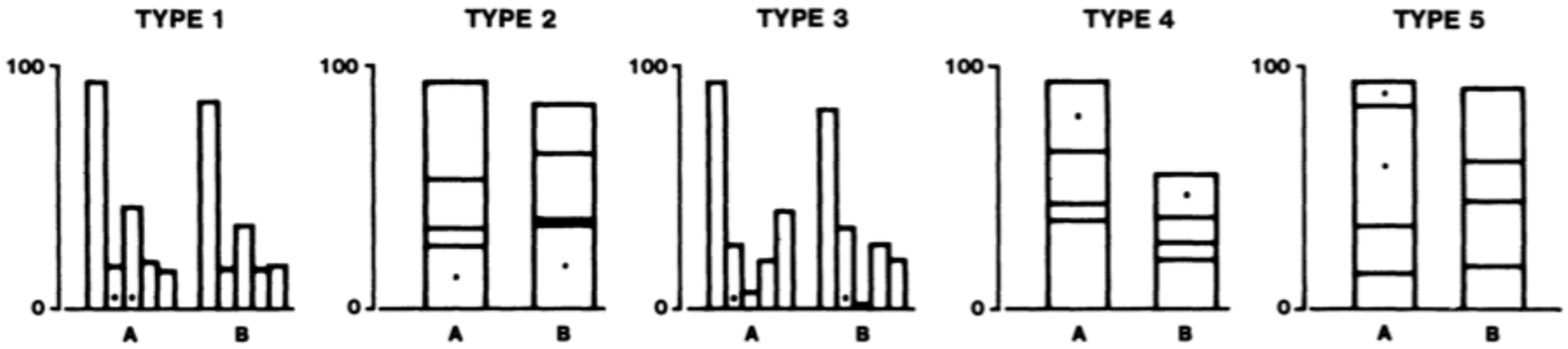



*Figure 4. Graphs from position–length experiment.*

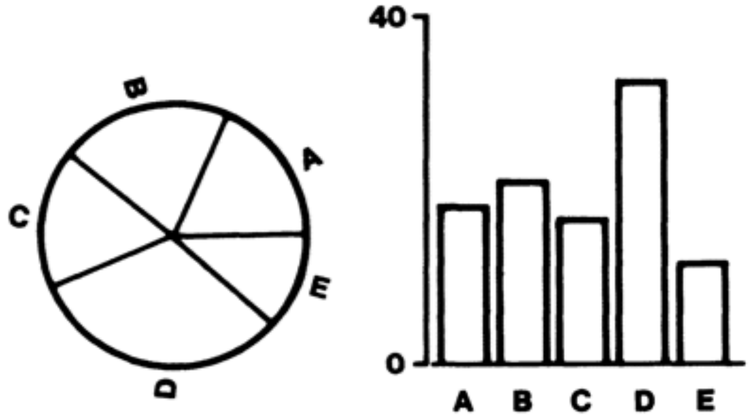
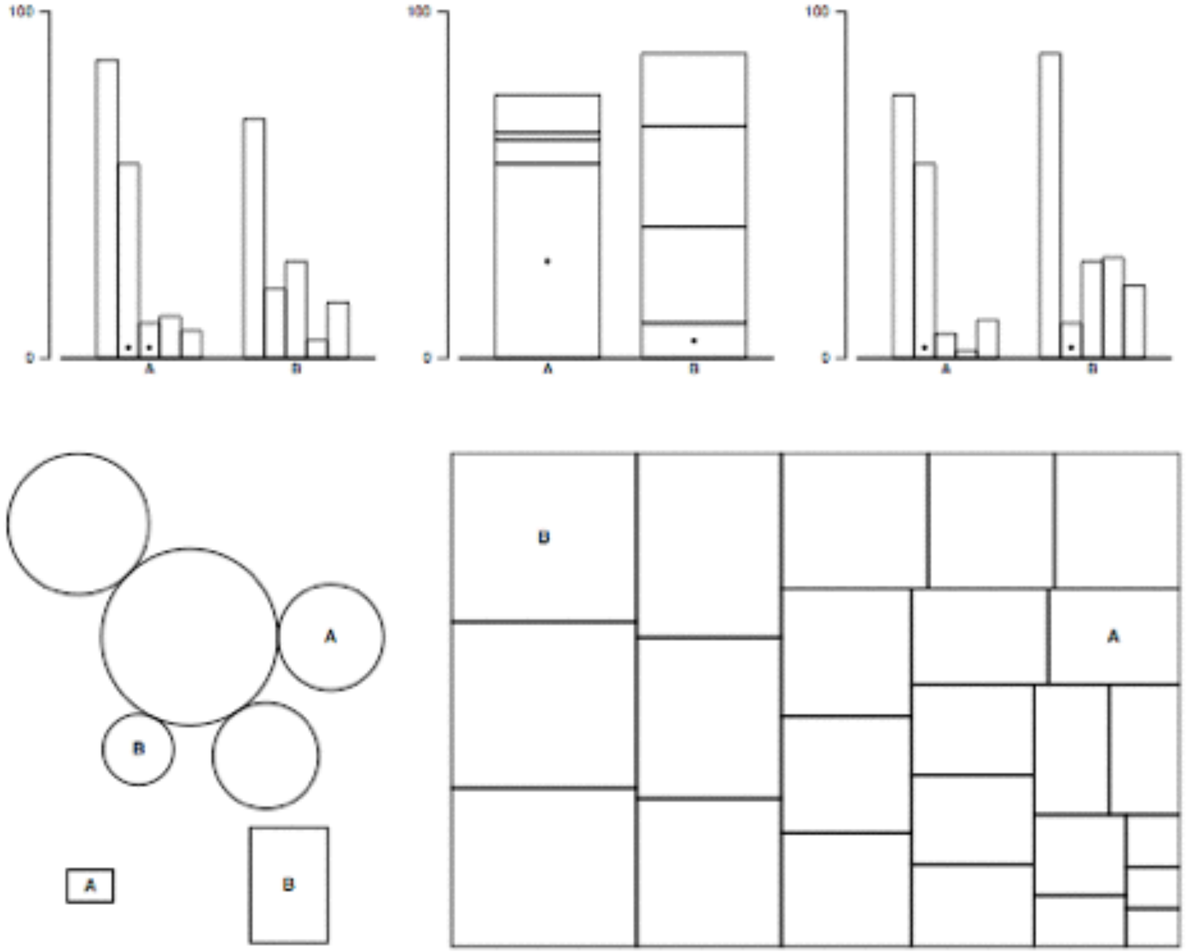
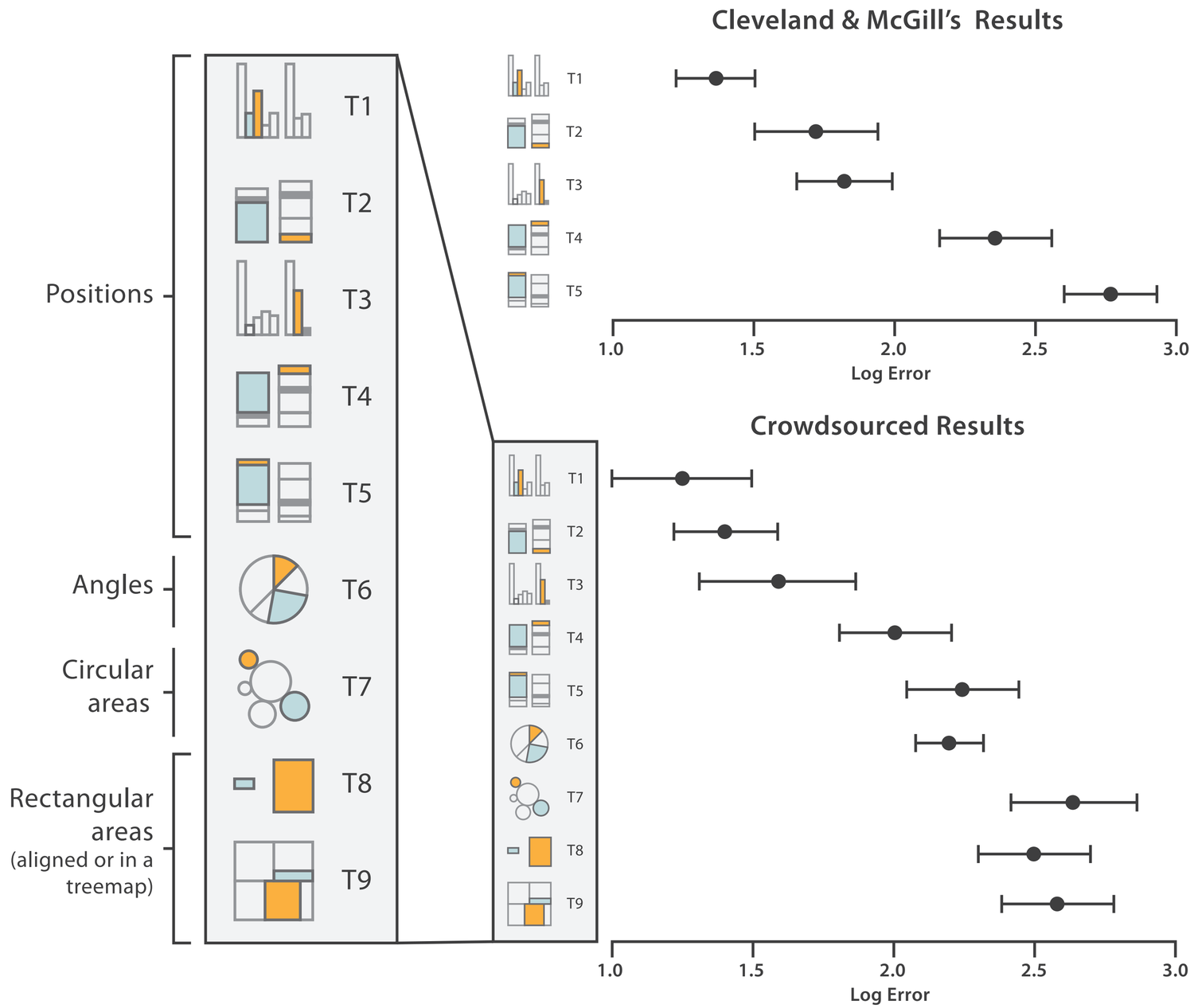



*Figure 3. Graphs from position–angle experiment.*

William S. Cleveland; Robert McGill , “Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods.” 1984

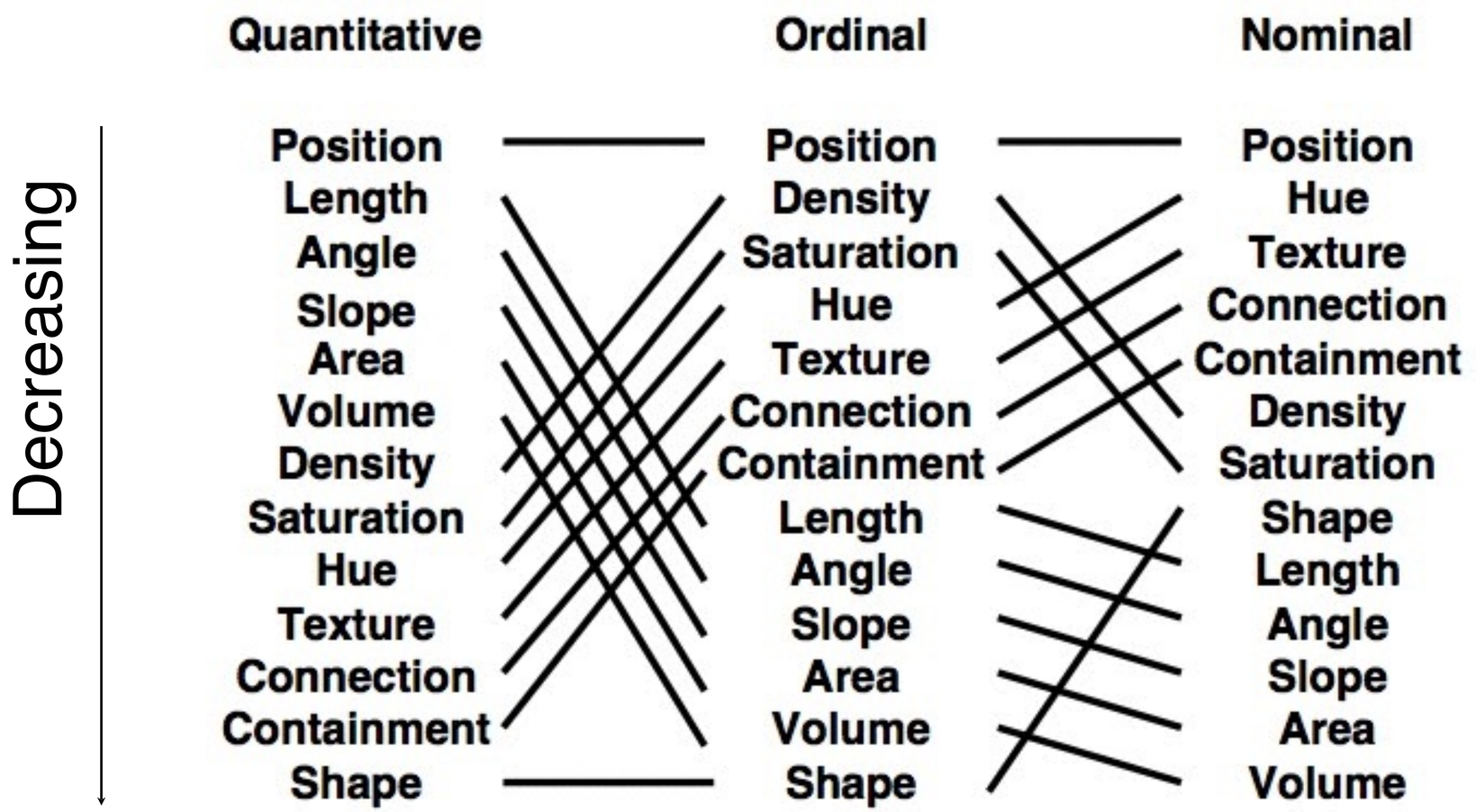
# Heer & Bostock, 2010






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

# Jock Mackinlay, 1986




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

**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)

Most ▲ Effectiveness ▼ Least

Same (Color luminance, Color saturation)

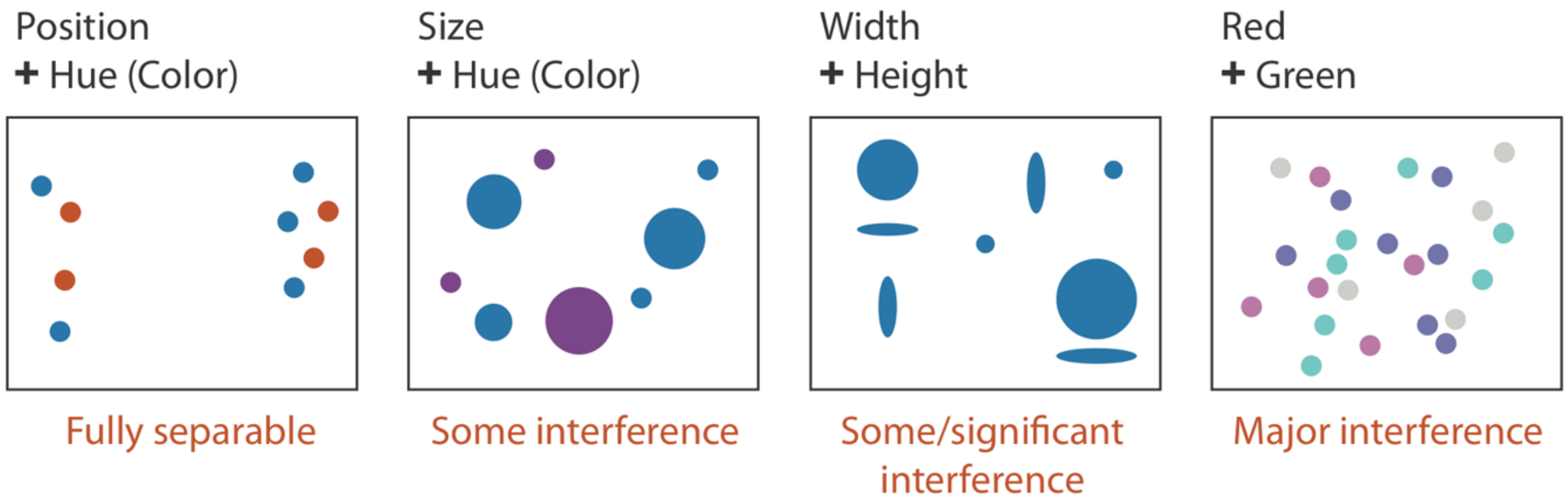
Same (Curvature, Volume (3D size))

## Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

# Separability of Attributes

Can we combine multiple visual variables?




T. Munzner, Visualization Analysis and Design, 2014