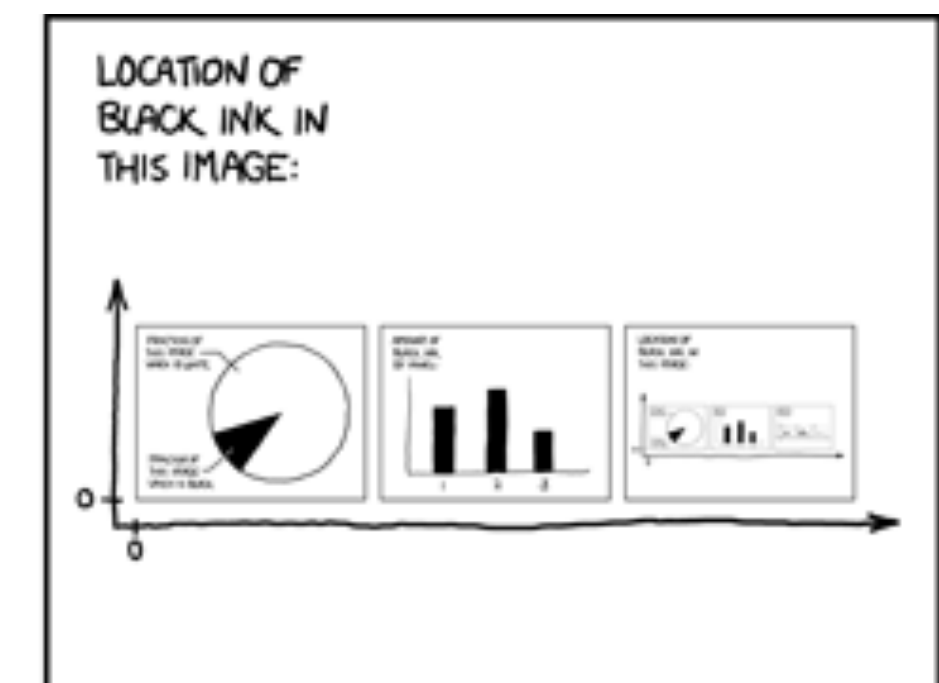
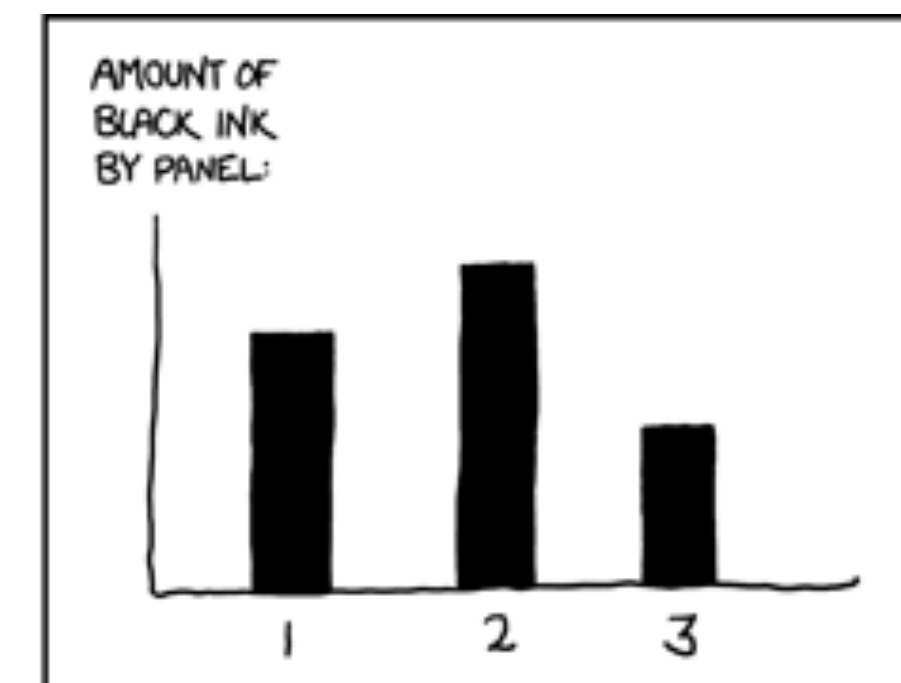
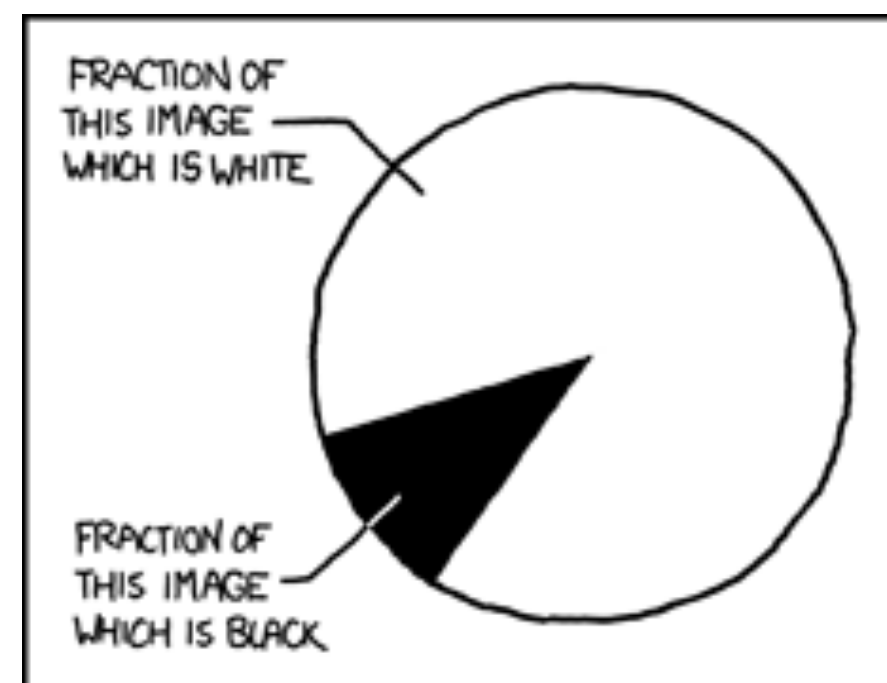


CS-5630 / CS-6630 Visualization for Data Science

The Visualization Alphabet: Marks and Channels

Alexander Lex
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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

➔ Points



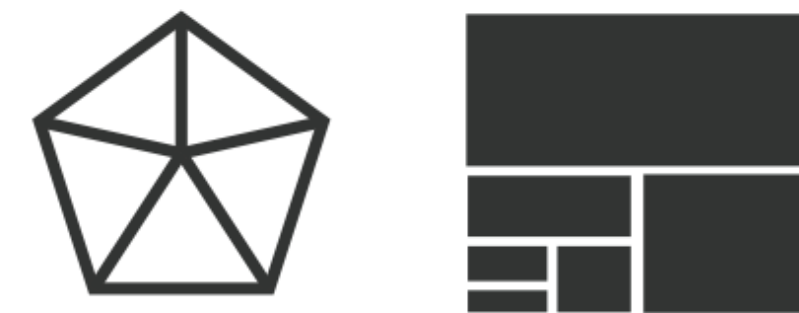
0D

➔ Lines



1D

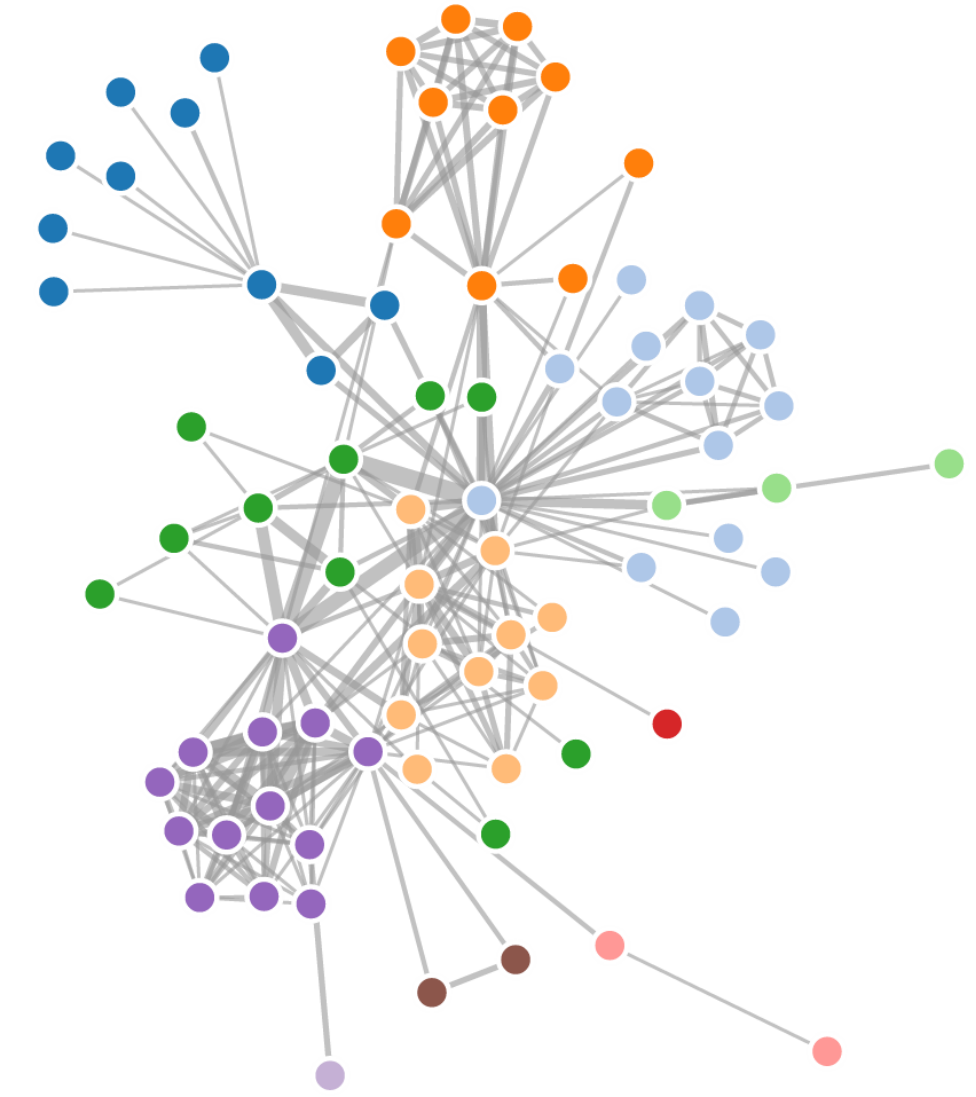
➔ Areas



2D

3D mark: Volume, but rarely used

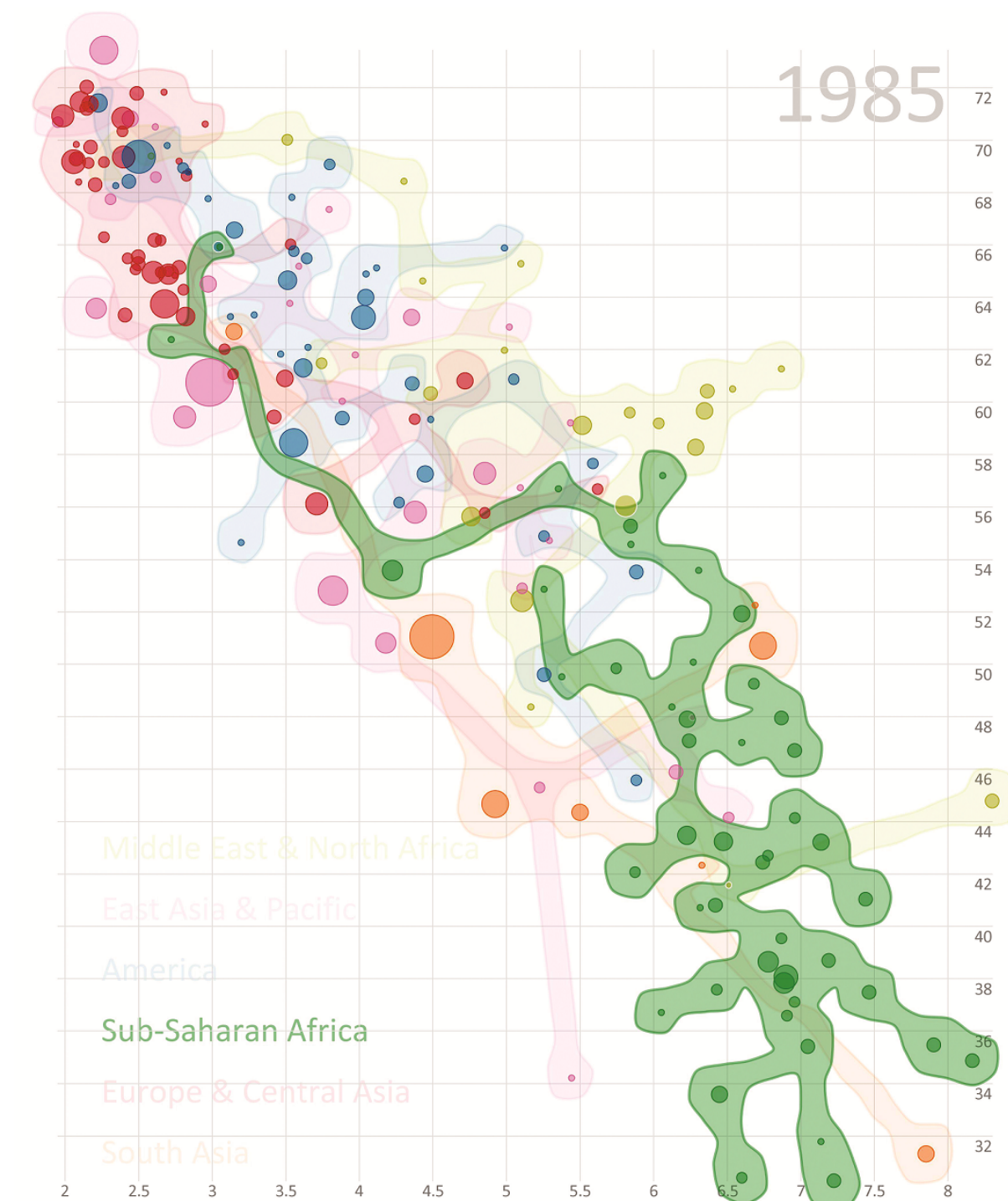
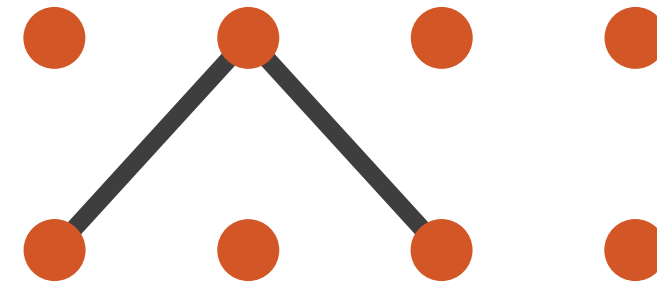
Marks for Links



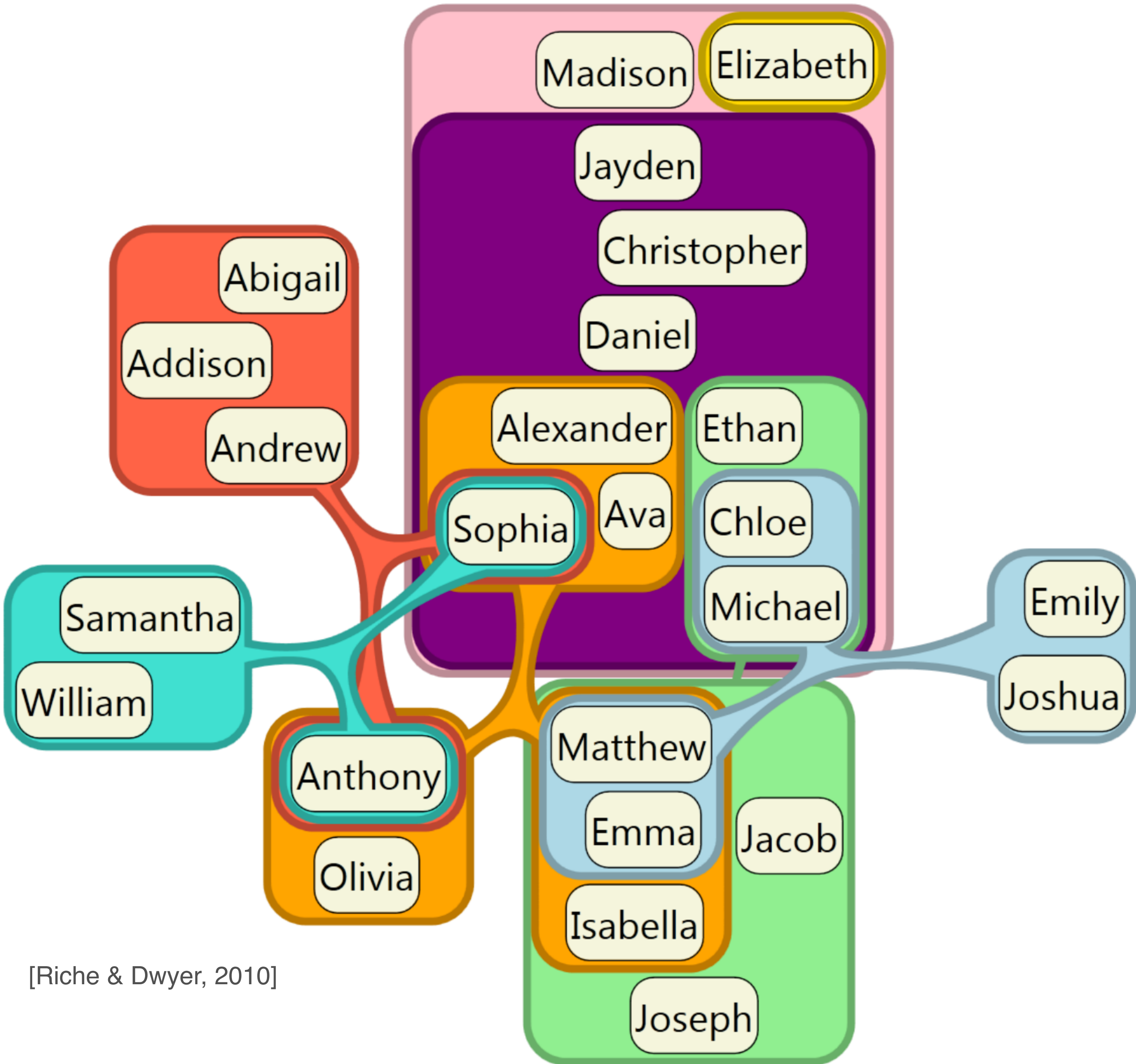
➔ Containment



➔ Connection



Containment can be nested



[Riche & Dwyer, 2010]

Channels (aka Visual Variables)

Control appearance
proportional to or
based on attributes

→ Position

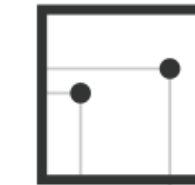
→ Horizontal



→ Vertical



→ Both



→ Color



→ Shape



→ Tilt



→ Size

→ Length



→ Area



→ Volume



Jacques Bertin

French cartographer
[1918-2010]

Semiology of Graphics [1967]

Theoretical principles for visual
encodings



Bertin's Visual Variables

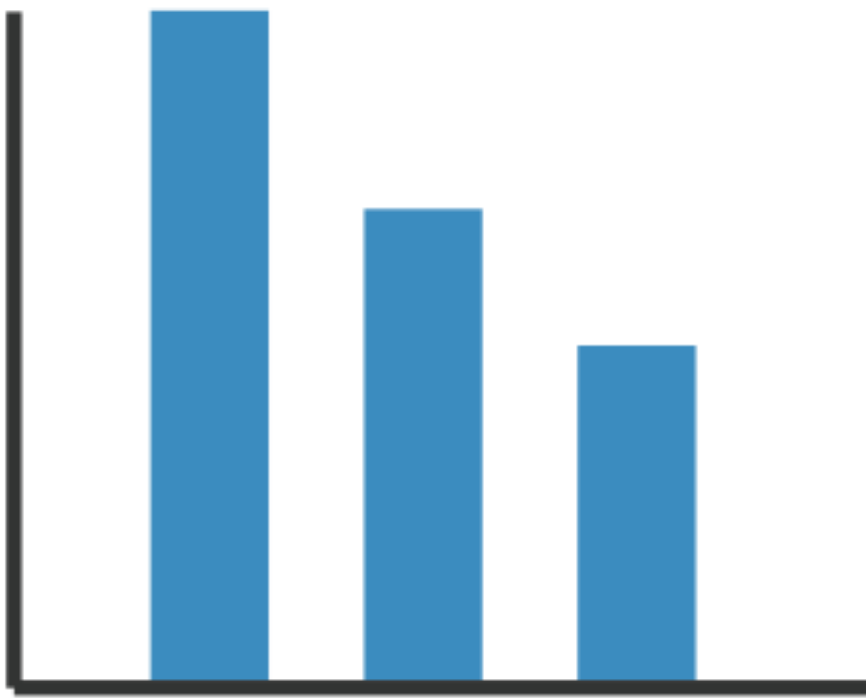
Marks: Points Lines Areas

Position
Size
(Grey) Value

Texture
Color
Orientation
Shape

		LES VARIABLES DE L'IMAGE							
		POINTS		LIGNES		ZONES			
XY	2 DIMENSIONS DU PLAN	x	x	x	/	~	/	14 15 9 18 21 2 14 15 1	2 1 18 2 1 21 15 1 1 2 9
Z	TAILLE	█	█	█	█	█	█	█	█
	VALEUR	█	█	█	█	█	█	█	█
		LES VARIABLES DE SÉPARATION DES IMAGES							
	GRAIN	█	█	█	█	█	█	█	█
	COULEUR	█	█	█	█	█	█	█	█
	ORIENTATION	█	█	█	█	█	█	█	█
	FORME	█	█	█	█	█	█	█	█

Using Marks and Channels



Mark: Line

Channel: Length, Position

1 quantitative attribute

1 categorical attribute



Mark: Point

Channel: Position

2 quantitative attr.



Adding Hue

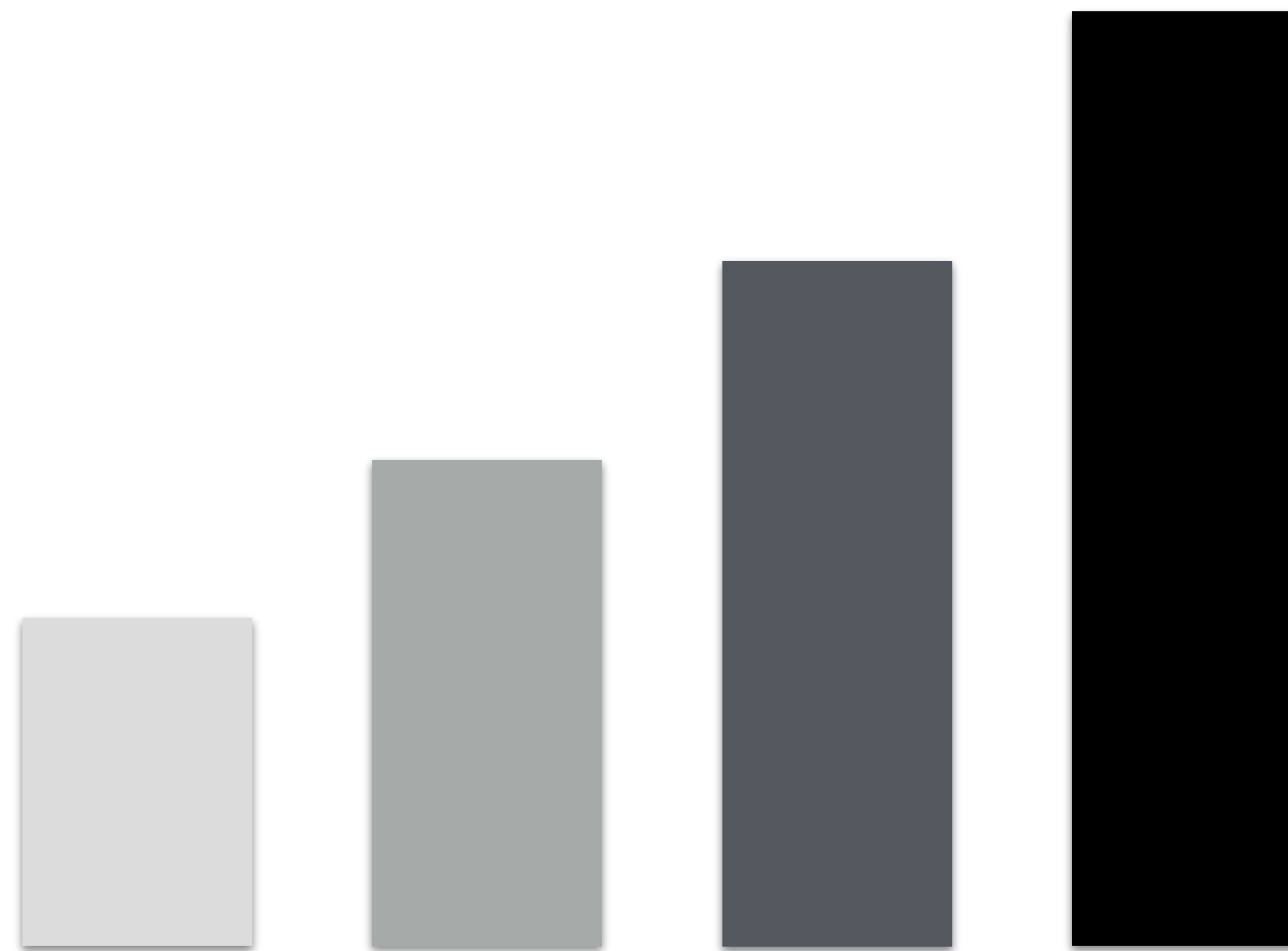
+1 categorical attr.



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? Which Rank?

Position

Length

Saturation ...

Ordinal & Quantitative Data

Identity Channels

What?

Shape

Color (hue)

Spatial region ...

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)



Same

Same

Same

Most Effectiveness Least

➔ Identity Channels: Categorical Attributes

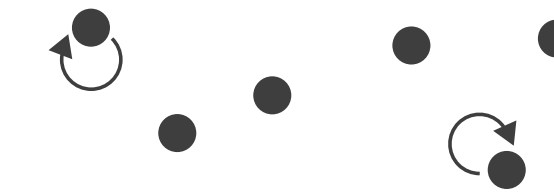
Spatial region



Color hue



Motion



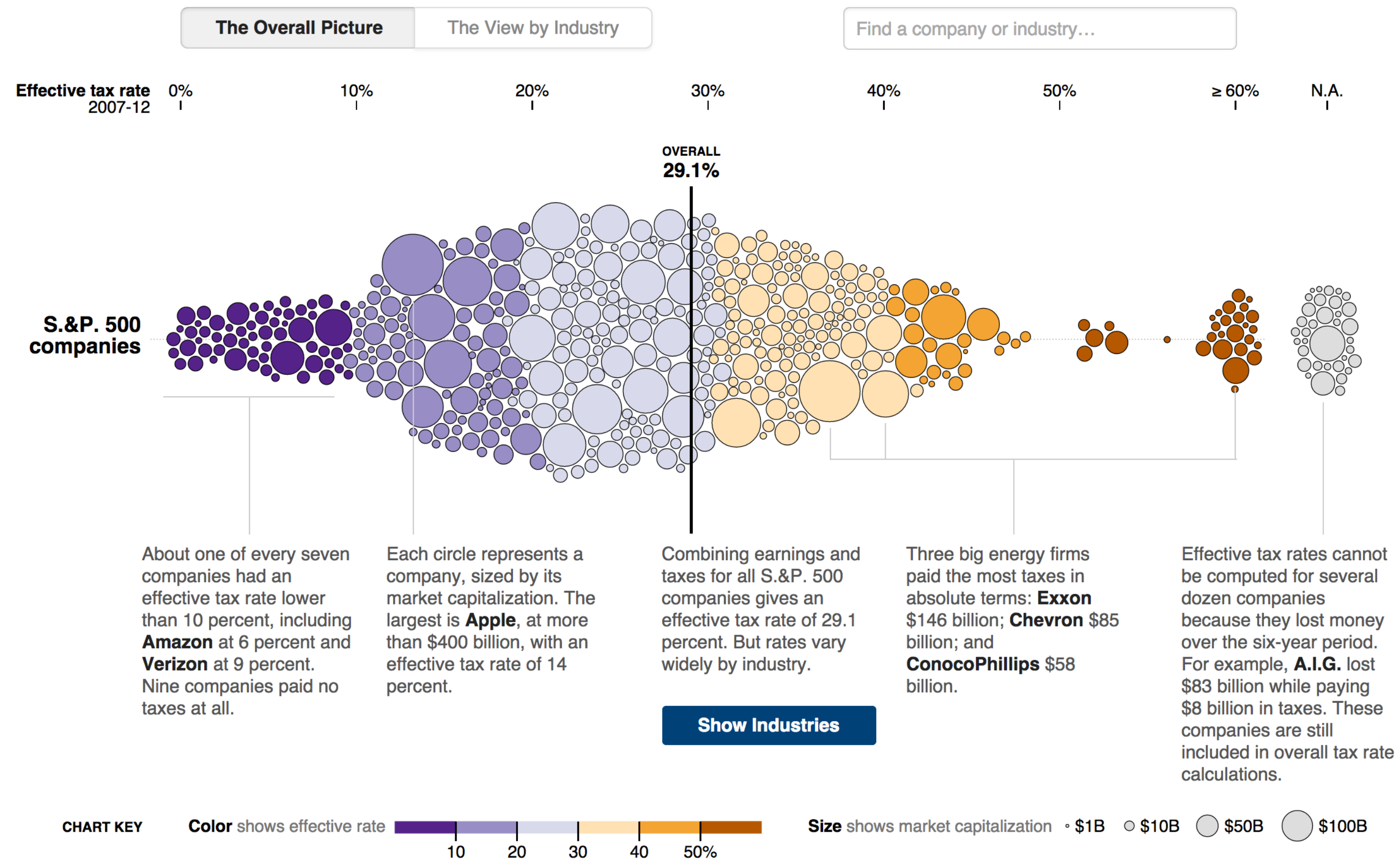
Shape



What visual variables are used?

Across U.S. Companies, Tax Rates Vary Greatly

Last week, in a Congressional hearing, Apple got grilled for its low-tax strategy. But not every business can copy that approach. Here is a look at what S.&P. 500 companies paid in corporate income taxes — federal, state, local and foreign — from 2007 to 2012, according to S&P Capital IQ. [Related Article »](#)



Characteristics of Channels

Selective

Is a mark distinct from other marks?

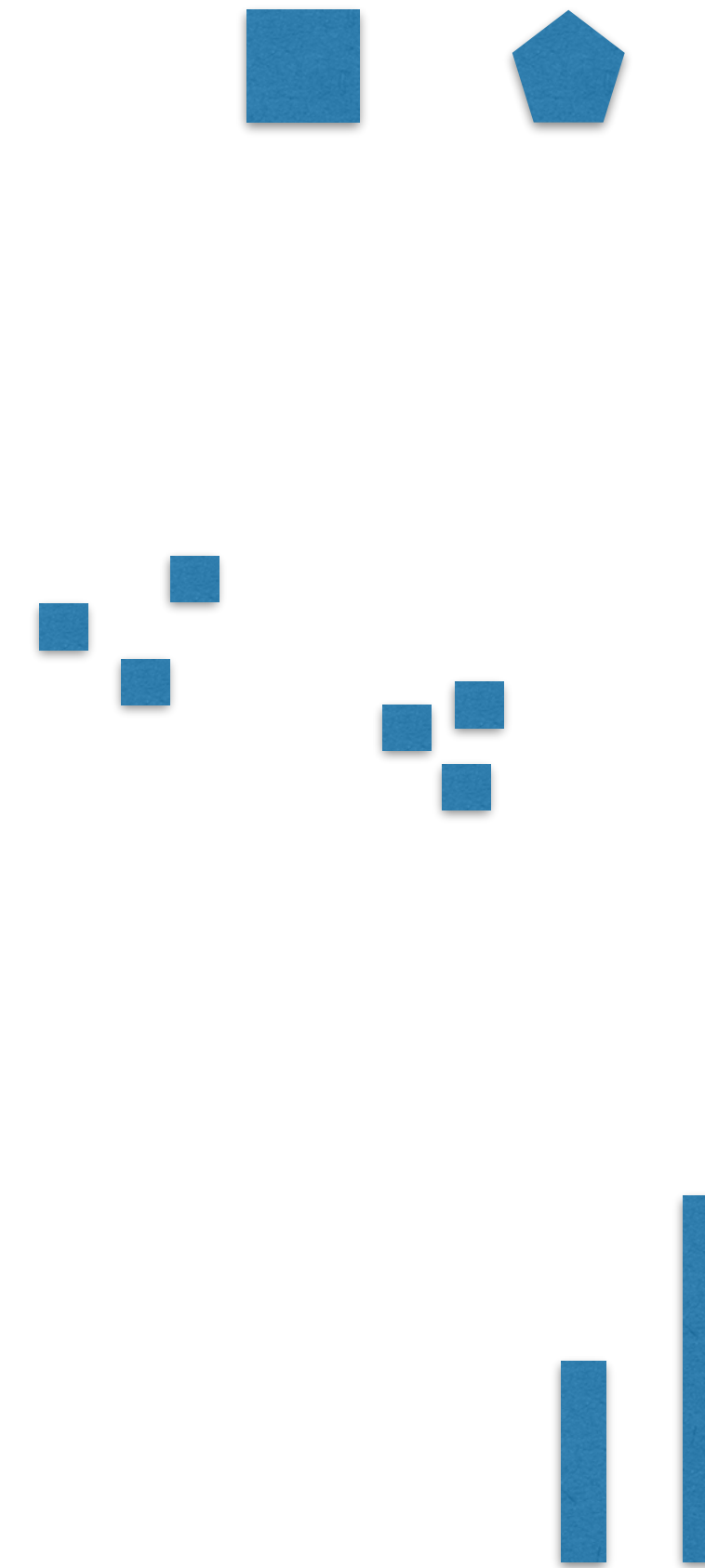
Can we make out the difference between two marks?

Associative

Does it support grouping?

Quantitative (Magnitude vs Identity Channels)

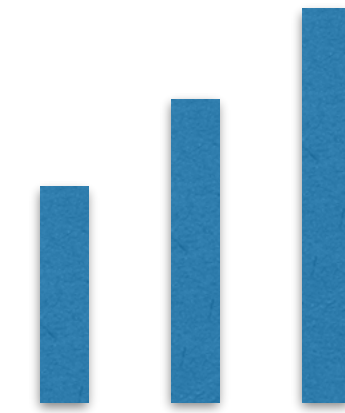
Can we quantify the difference between two marks?



Characteristics of Channels

Order (Magnitude vs Identity)

Can we see a change in order?



Length

How many unique marks can we make?

Position

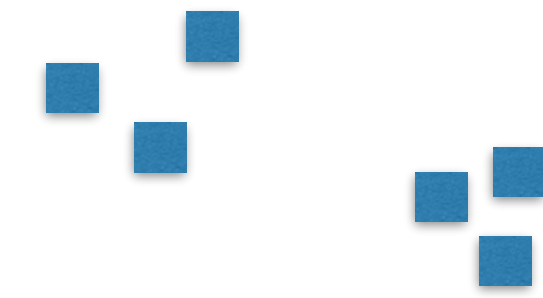
Strongest visual variable

Suitable for all data types

Problems:

Sometimes not available
(spatial data)

Cluttering



Selective: yes

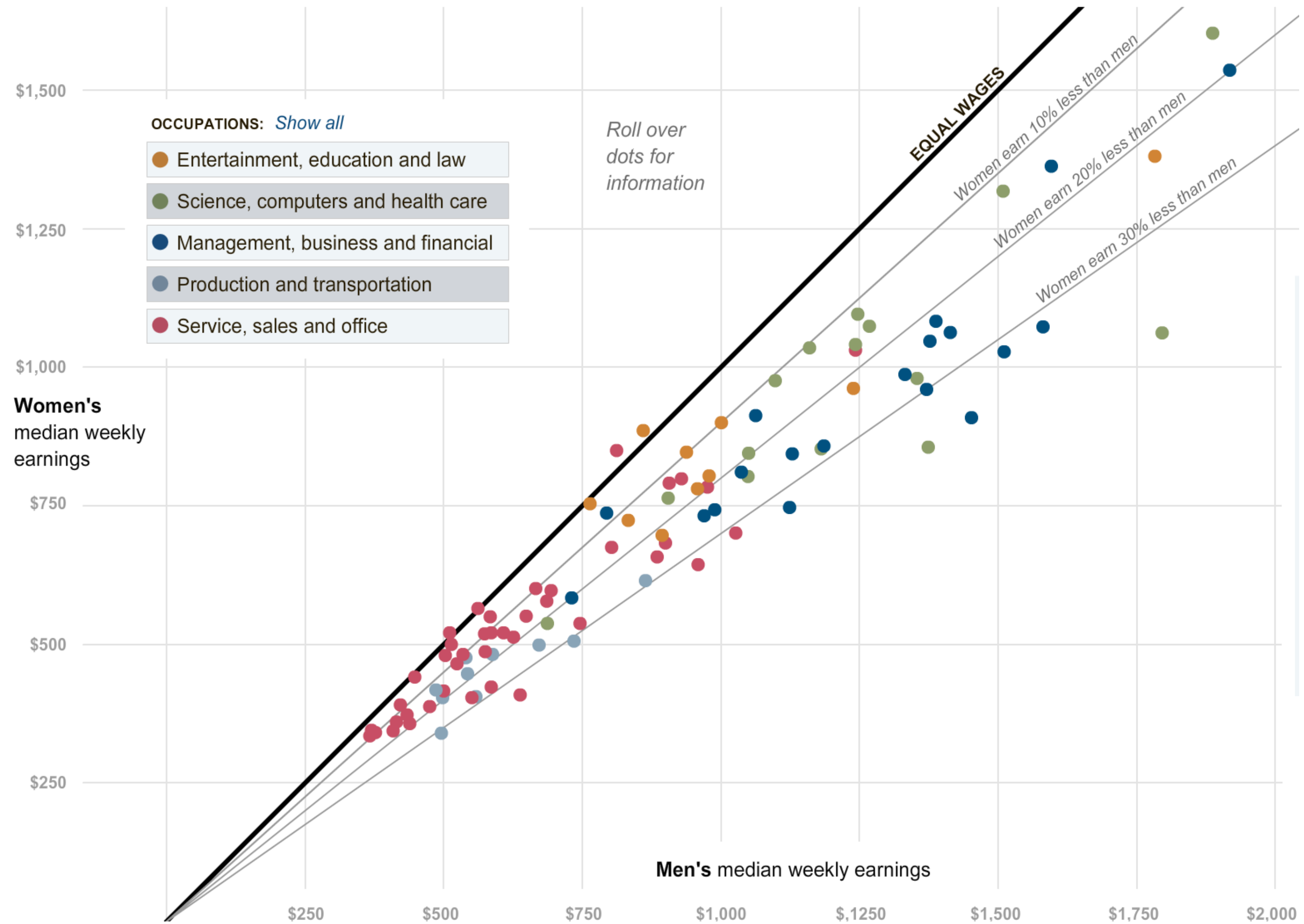
Associative: yes

Quantitative: yes

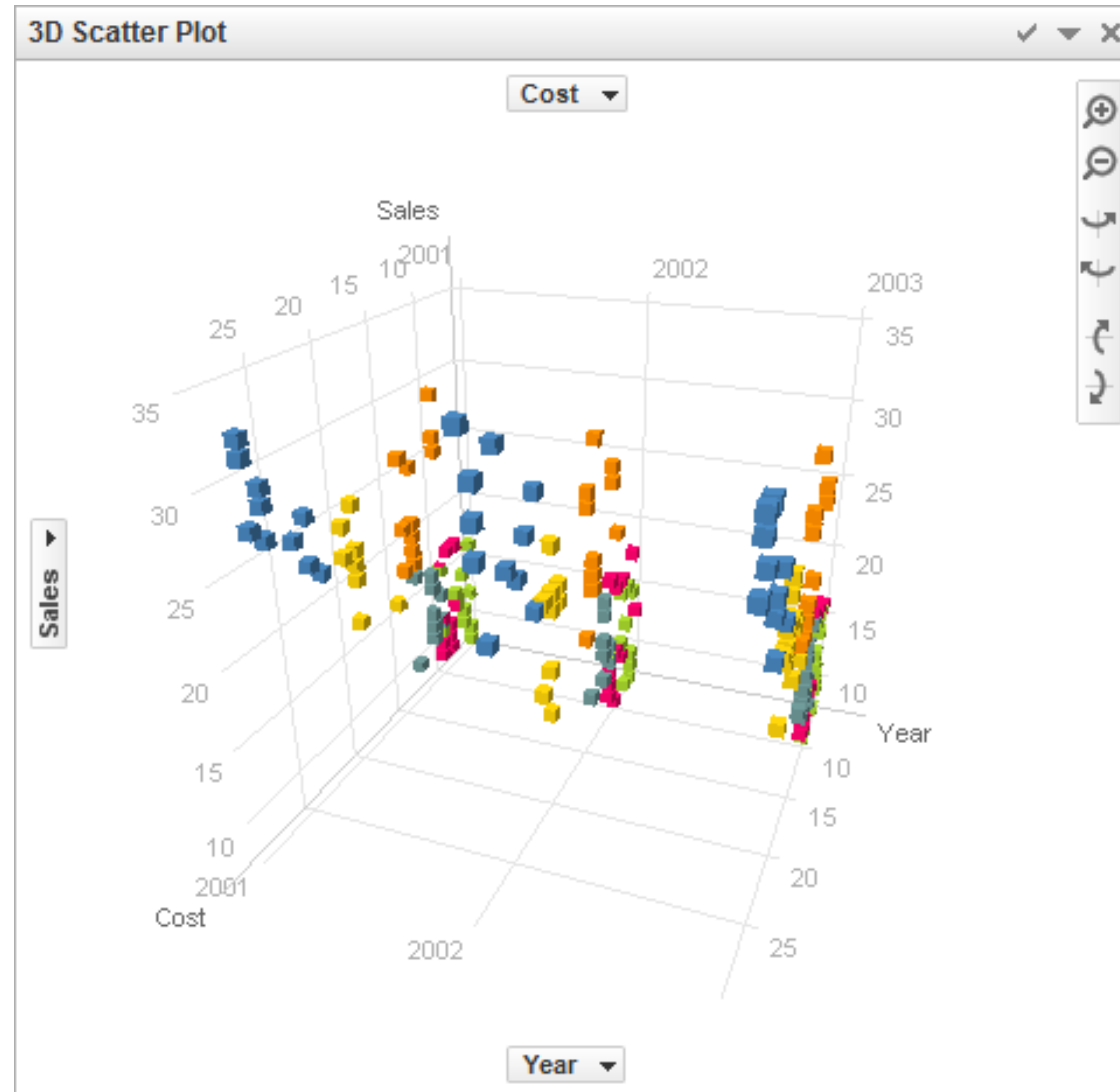
Order: yes

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

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

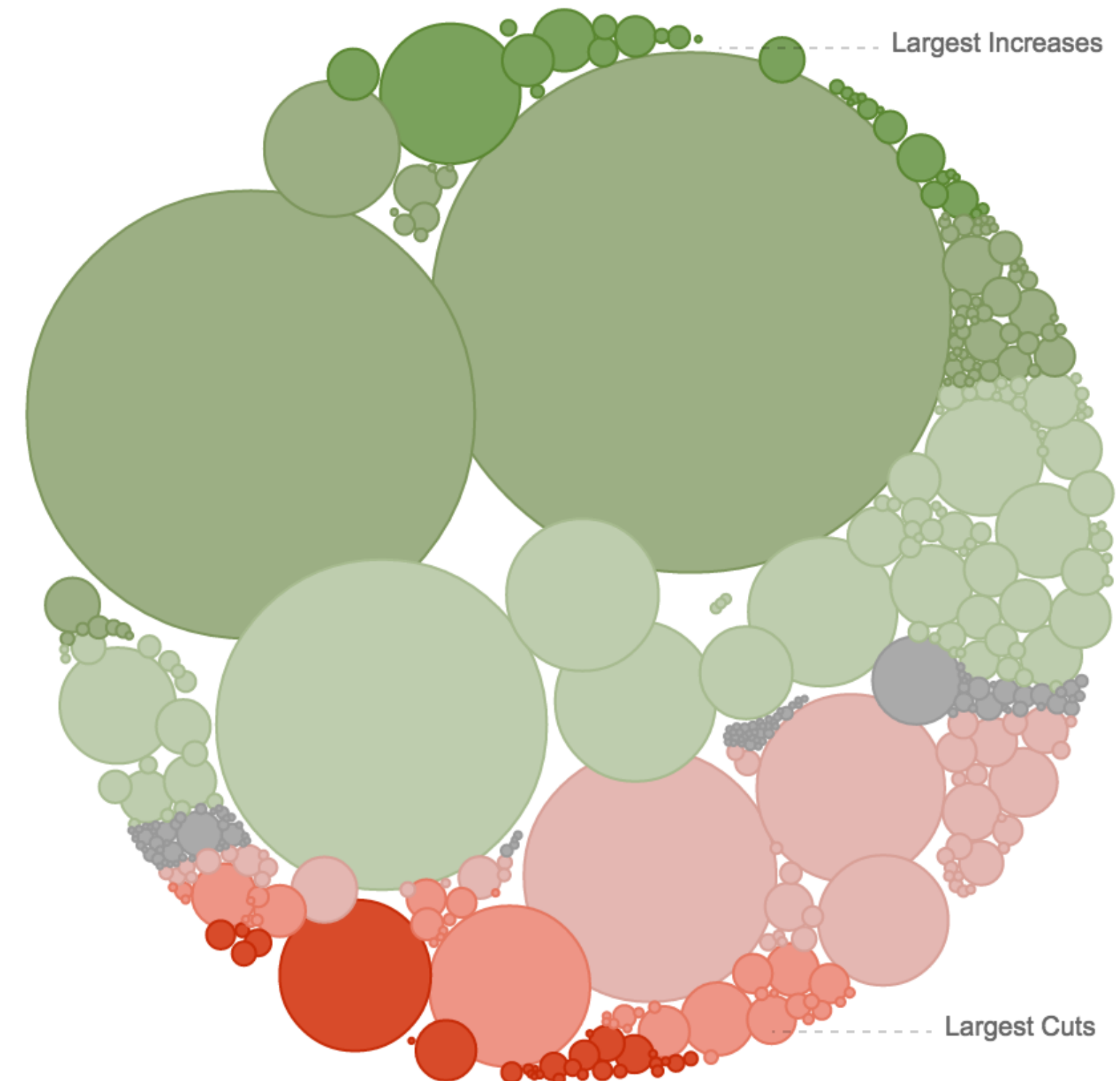
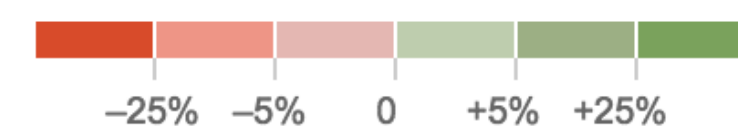
How \$3.7 Trillion Is Spent

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

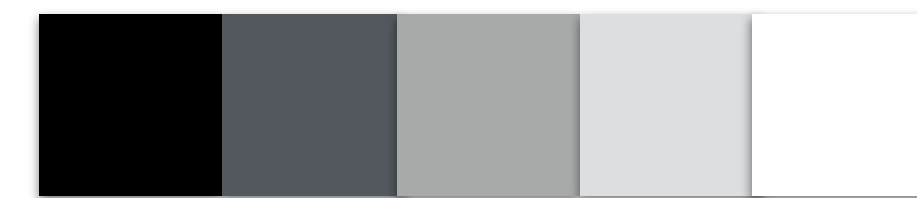
Selective: yes

Associative: yes

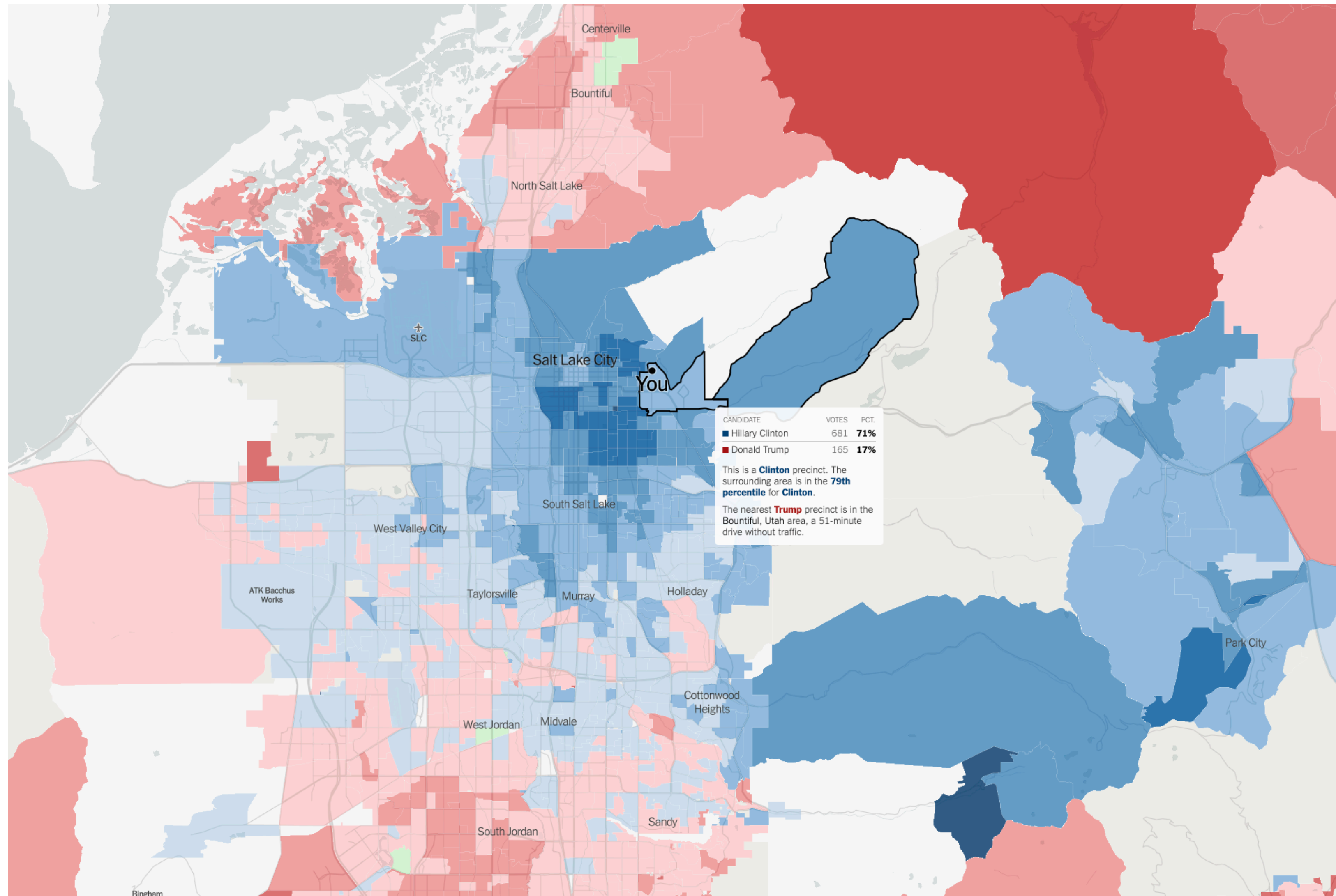
Quantitative: somewhat (with problems)

Order: yes

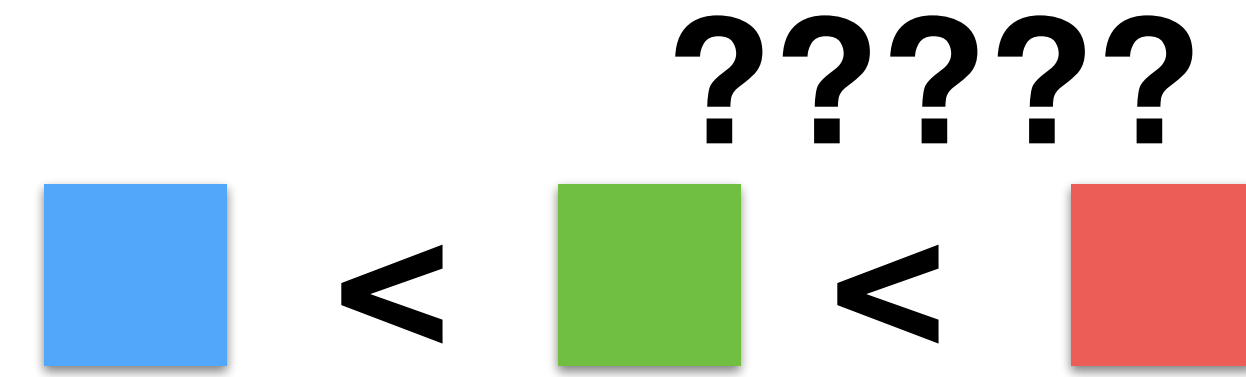
Length: limited



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

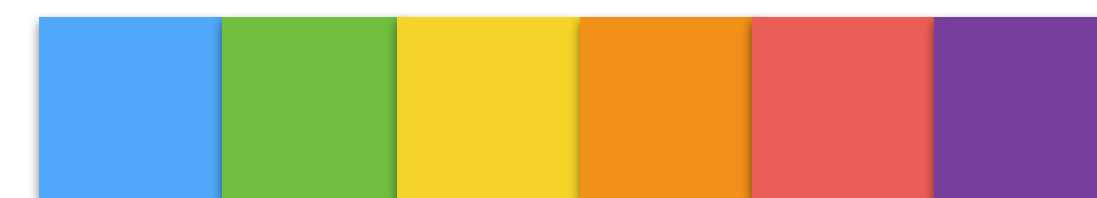
Selective: yes

Associative: yes

Quantitative: no

Order: no

Length: limited



Color: Bad Example

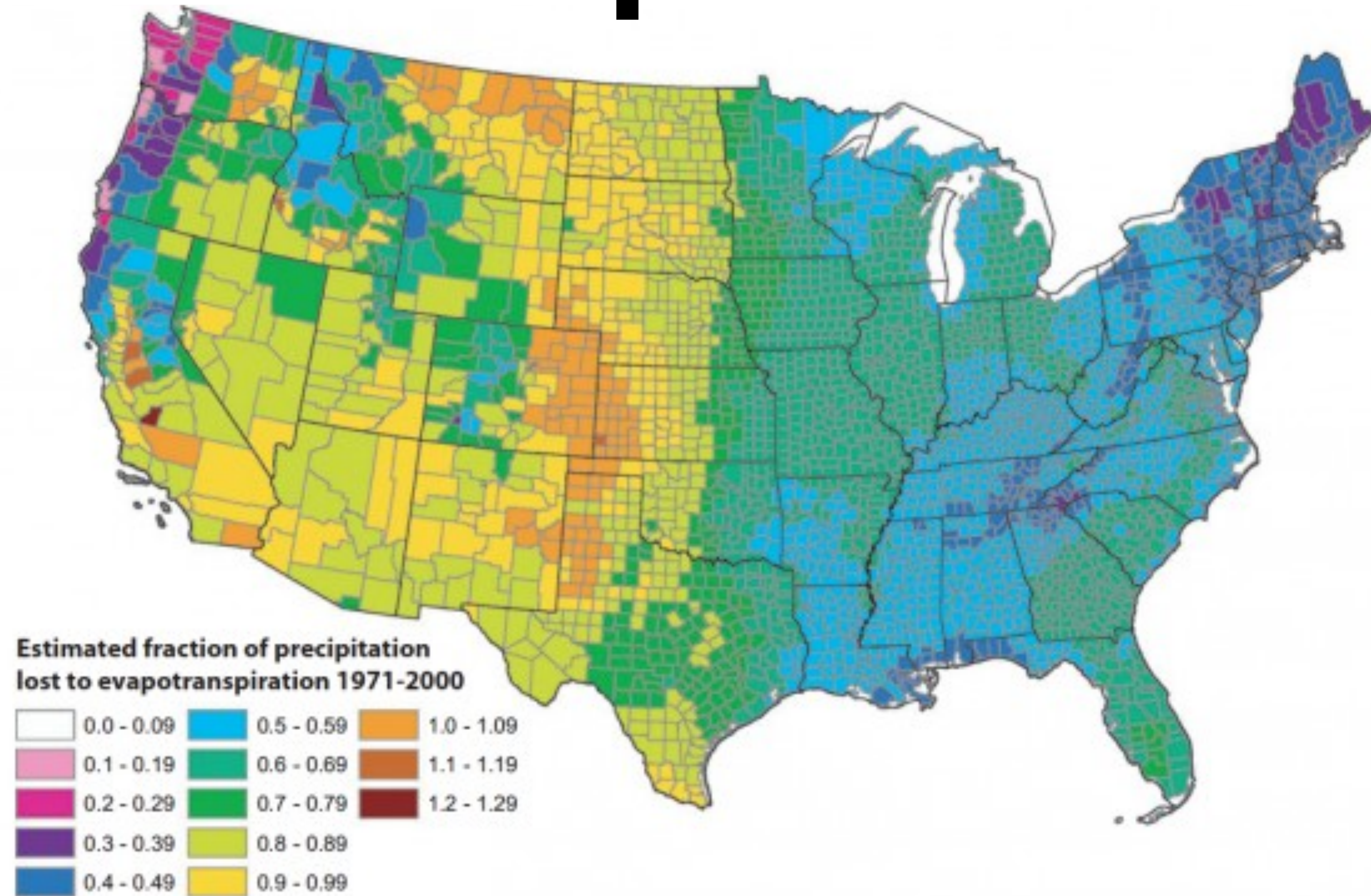


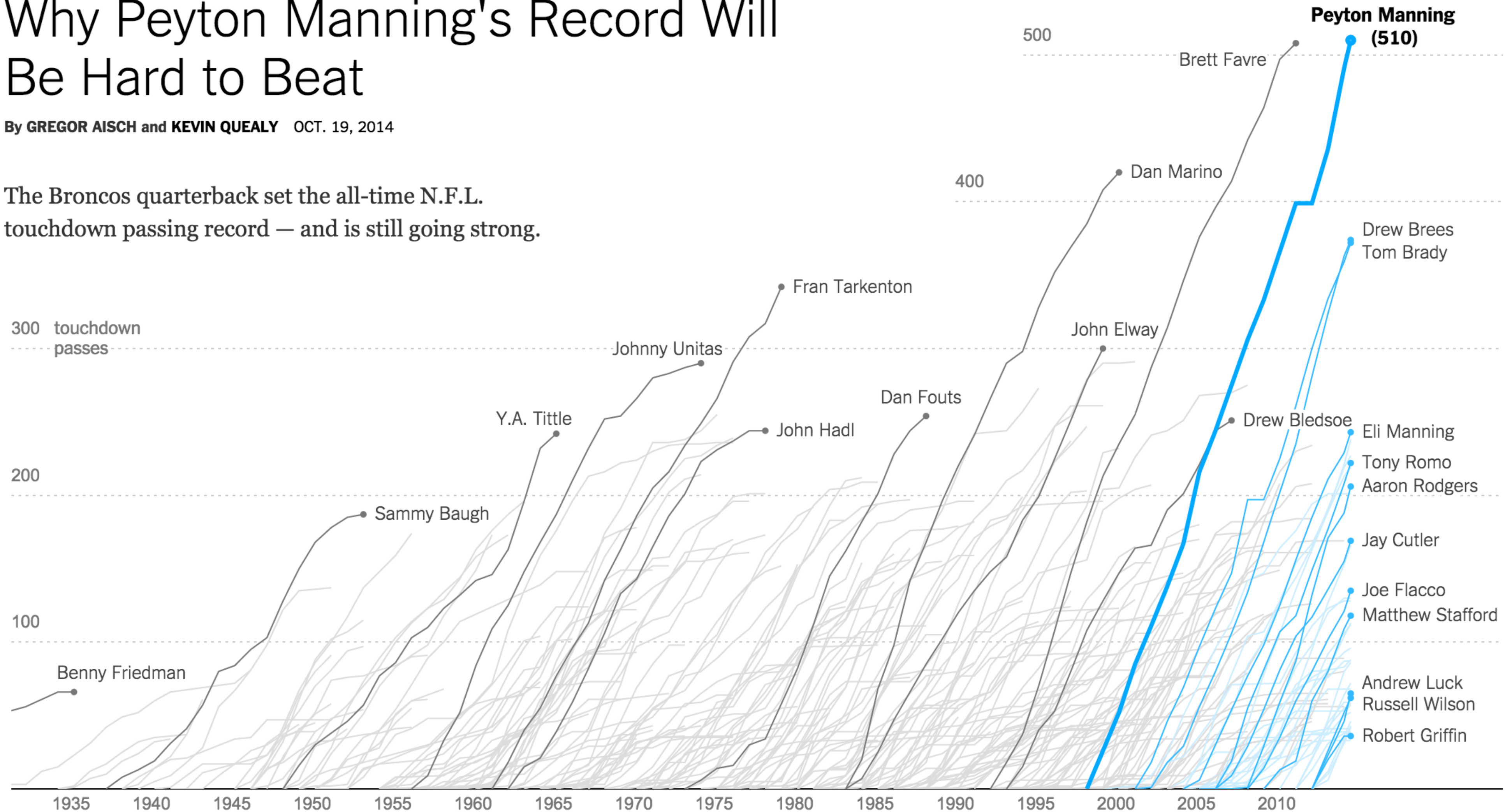
FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/ P were made first at the 800-m resolution of the PRISM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

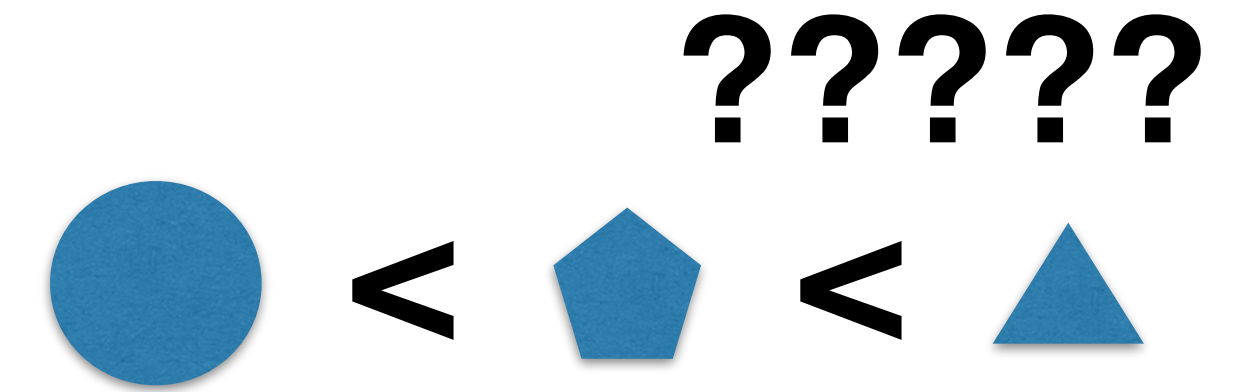
Why Peyton Manning's Record Will Be Hard to Beat

By GREGOR AISCH and KEVIN QUEALY OCT. 19, 2014

The Broncos quarterback set the all-time N.F.L. touchdown passing record — and is still going strong.



Shape



Great to recognize many classes.

No grouping, ordering.

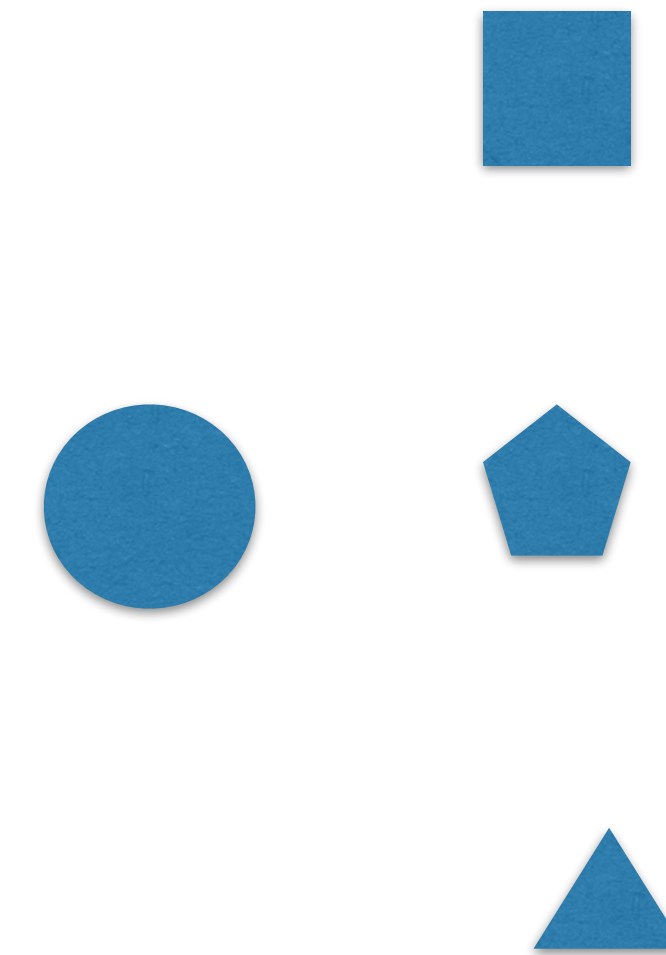
Selective: yes

Associative: limited

Quantitative: no

Order: no

Length: vast



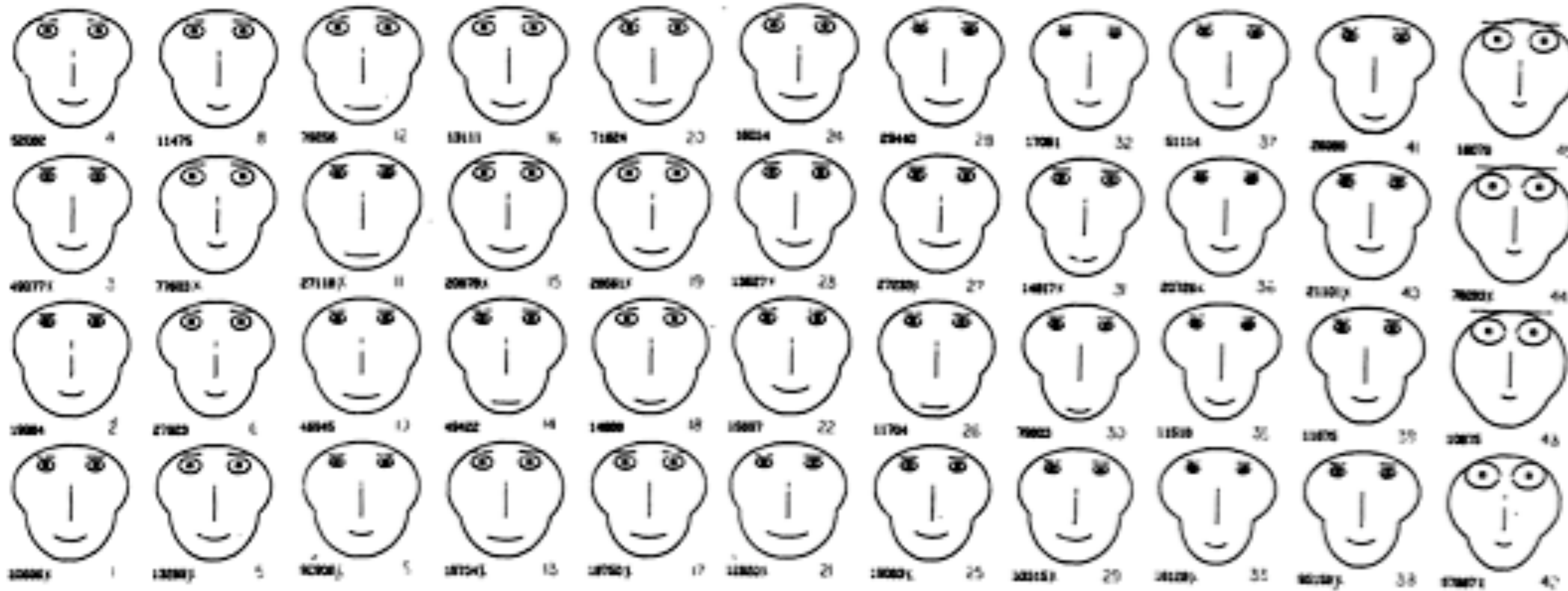


Autobahn	Autobahn ends	Motor vehicles only	End of motor vehicles only	Autobahn exit	Direction to autobahn	Distance to next change of traffic	Auto repairs	Gas station also with lead free fuel	Autobahn snack machines	Autobahn restaurant	Autobahn hotel	Danger	Crossroads	Oncoming traffic	Falling stones	Danger 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	<p>FOR SAFETY YOU MIGHT KNOW German traffic signs <small>(VARIE R POSTER 196-3412, Jan. 2011 Copyright VARIE R Poster 196-3412, No. 95)</small> http://www.hausarbeit.com/</p>				
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 (reversal) 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	Danger of unexpected ice	Orange traffic arrow	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	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

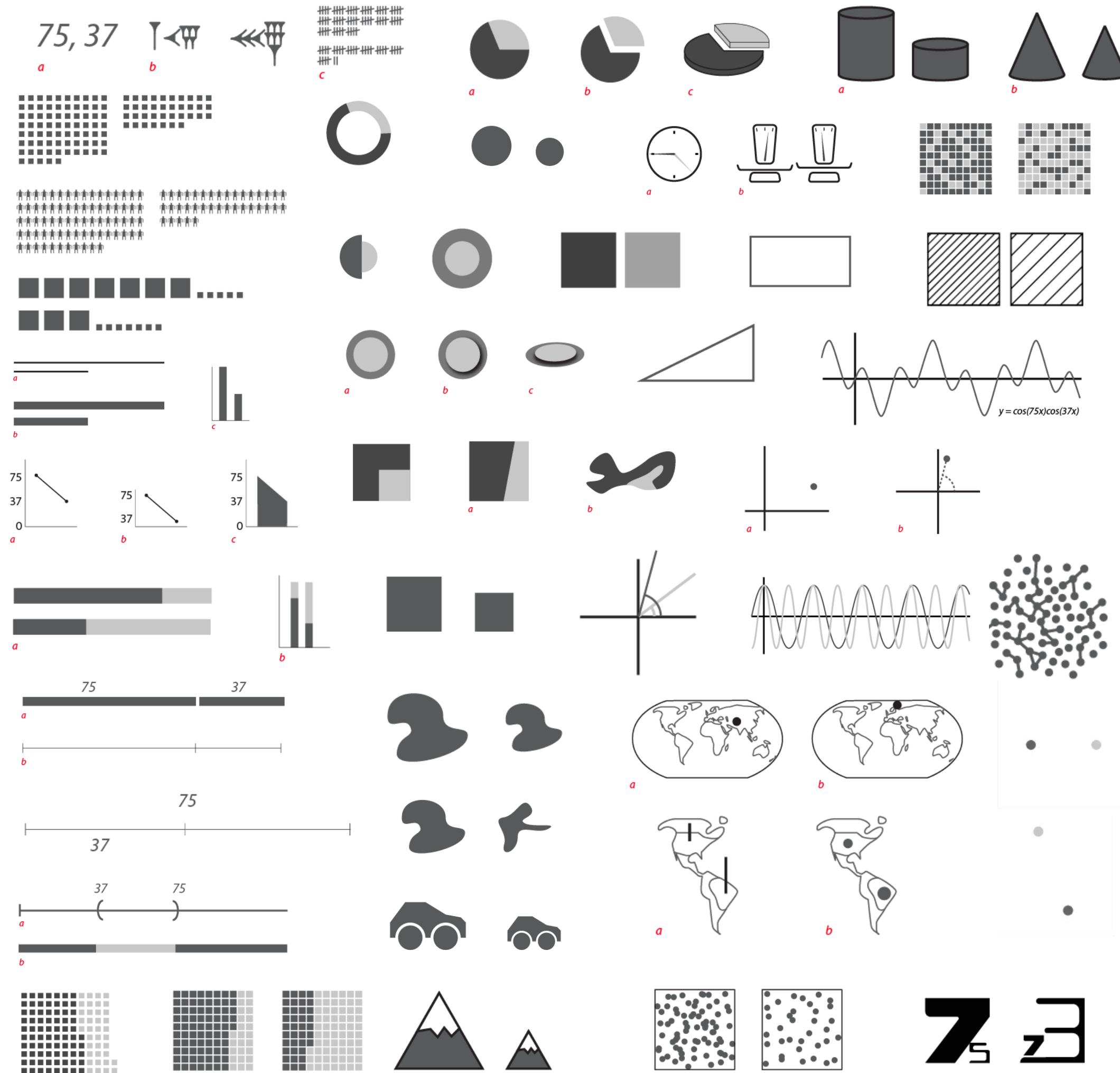
Idea: use facial parameters to map quantitative data



Does it work?
Not really!

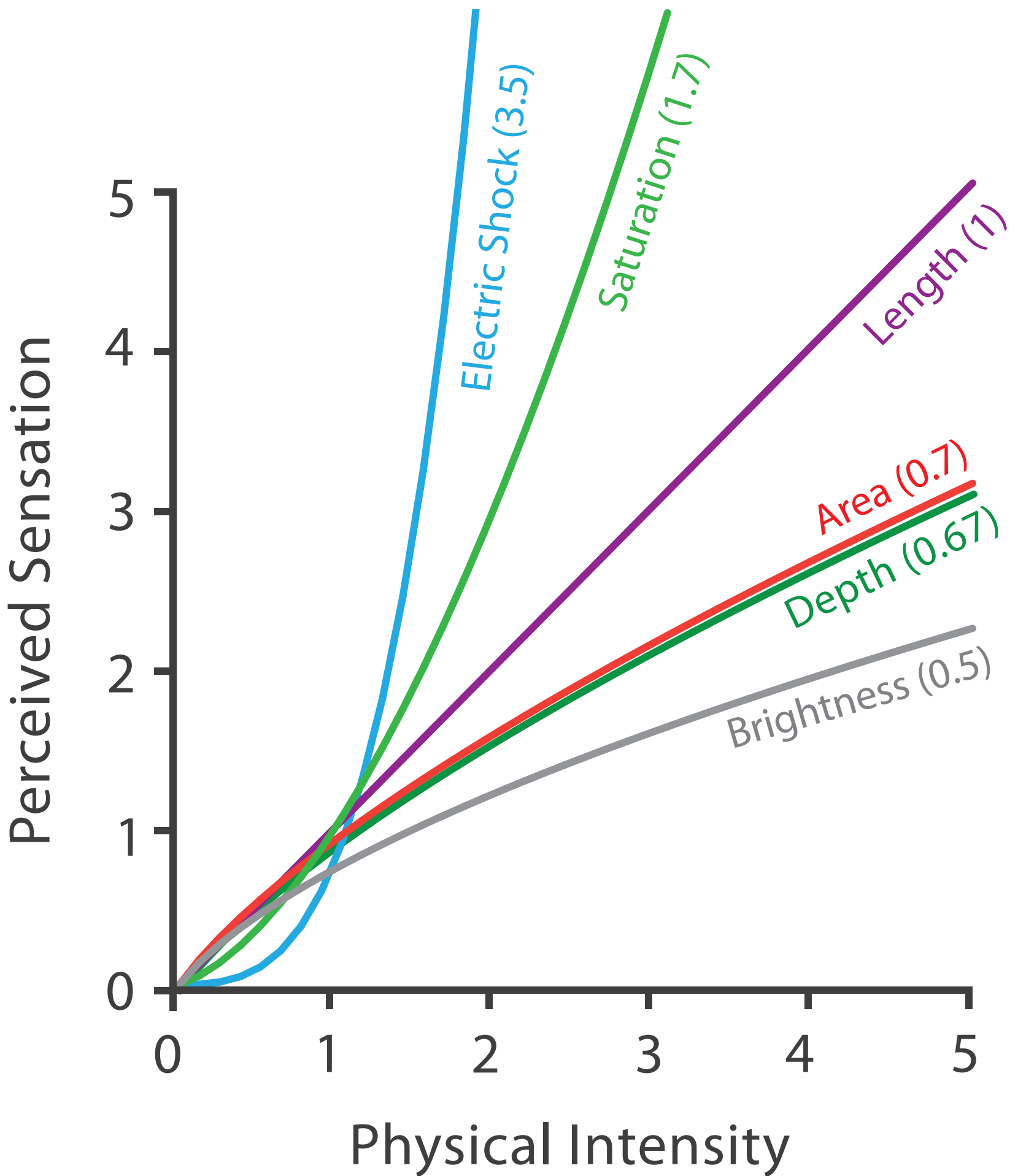
Critique: <https://eagereyes.org/criticism/chernoff-faces>

More Channels



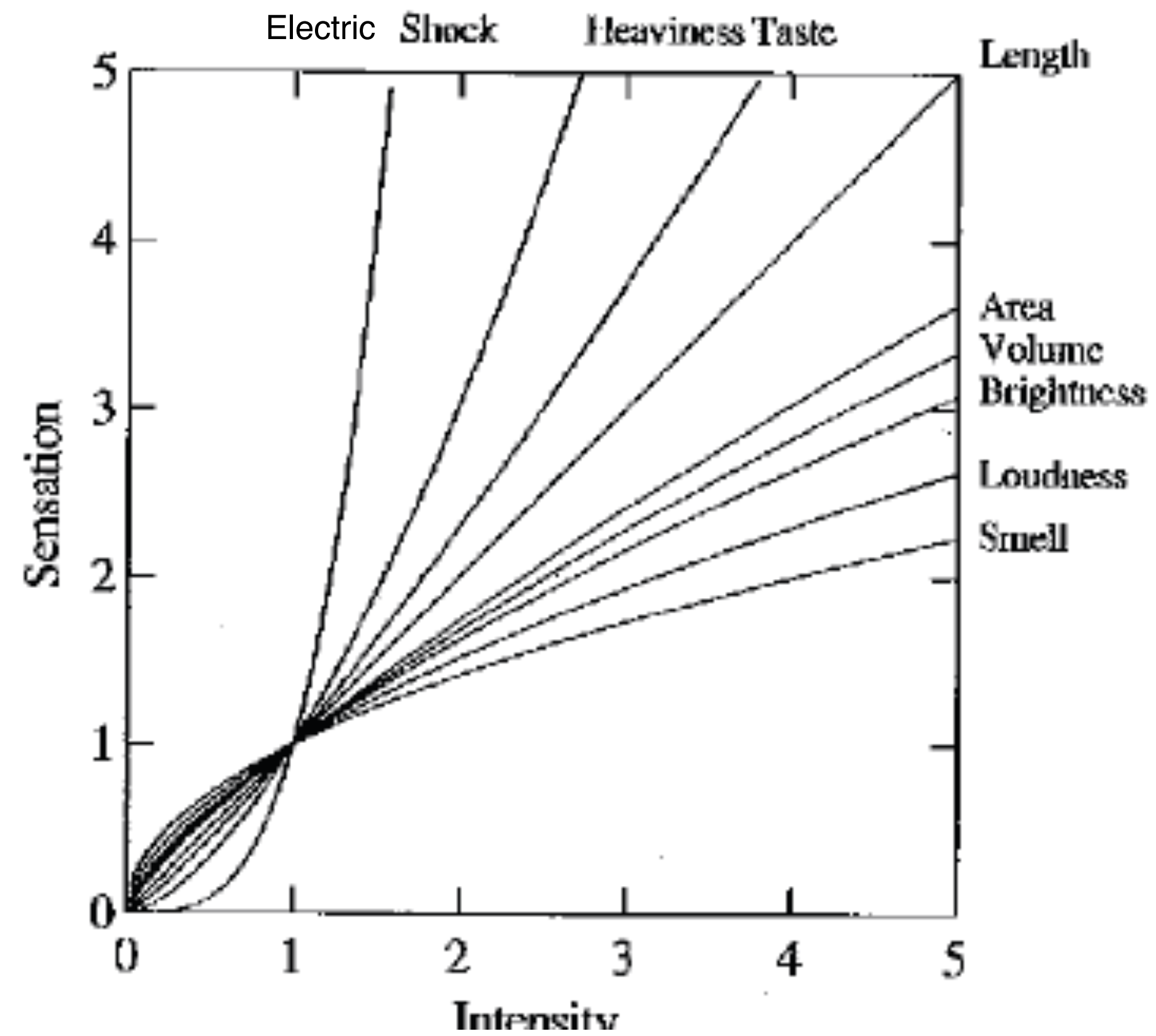
Why are quantitative channels different?

Steven's Psychophysical Power Law: $S = I^N$

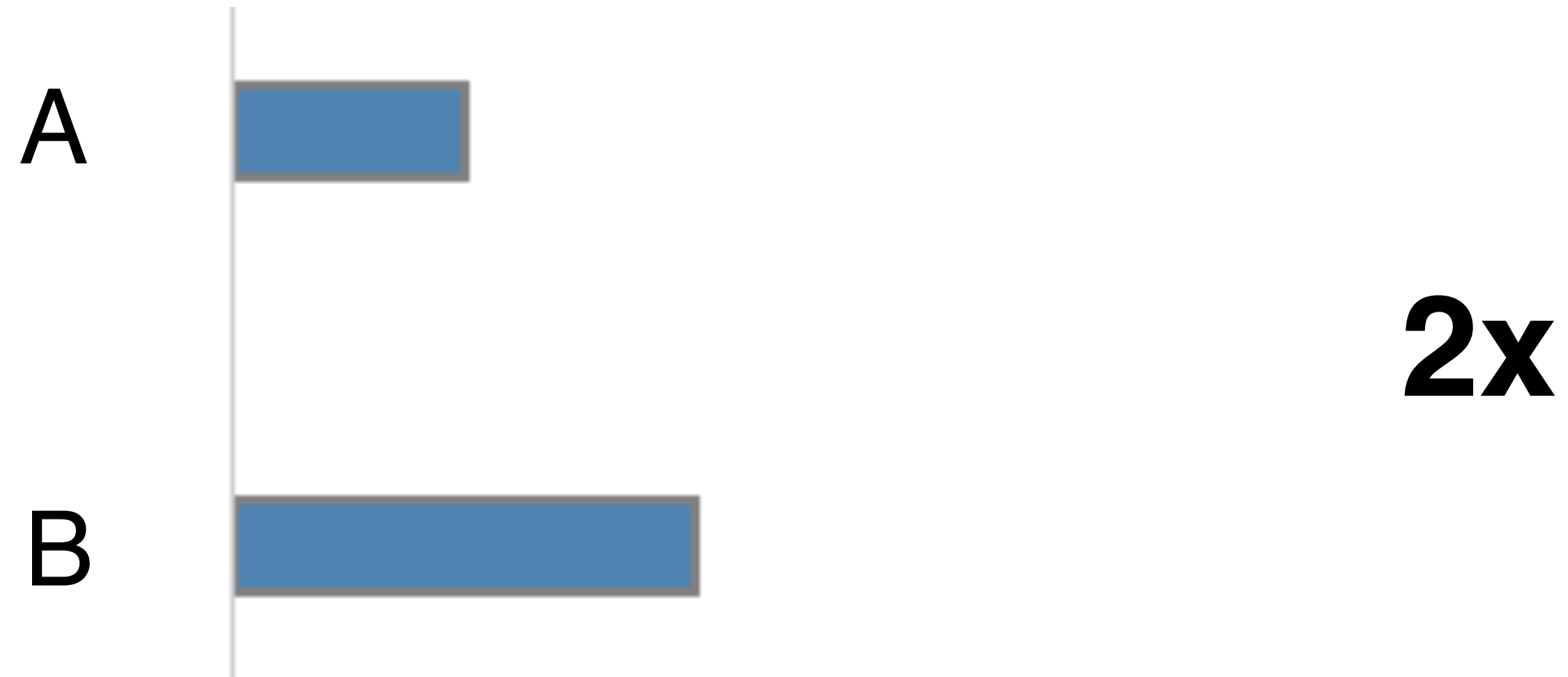


$S =$ sensation
 $I =$ intensity

Steven's Power Law, 1961



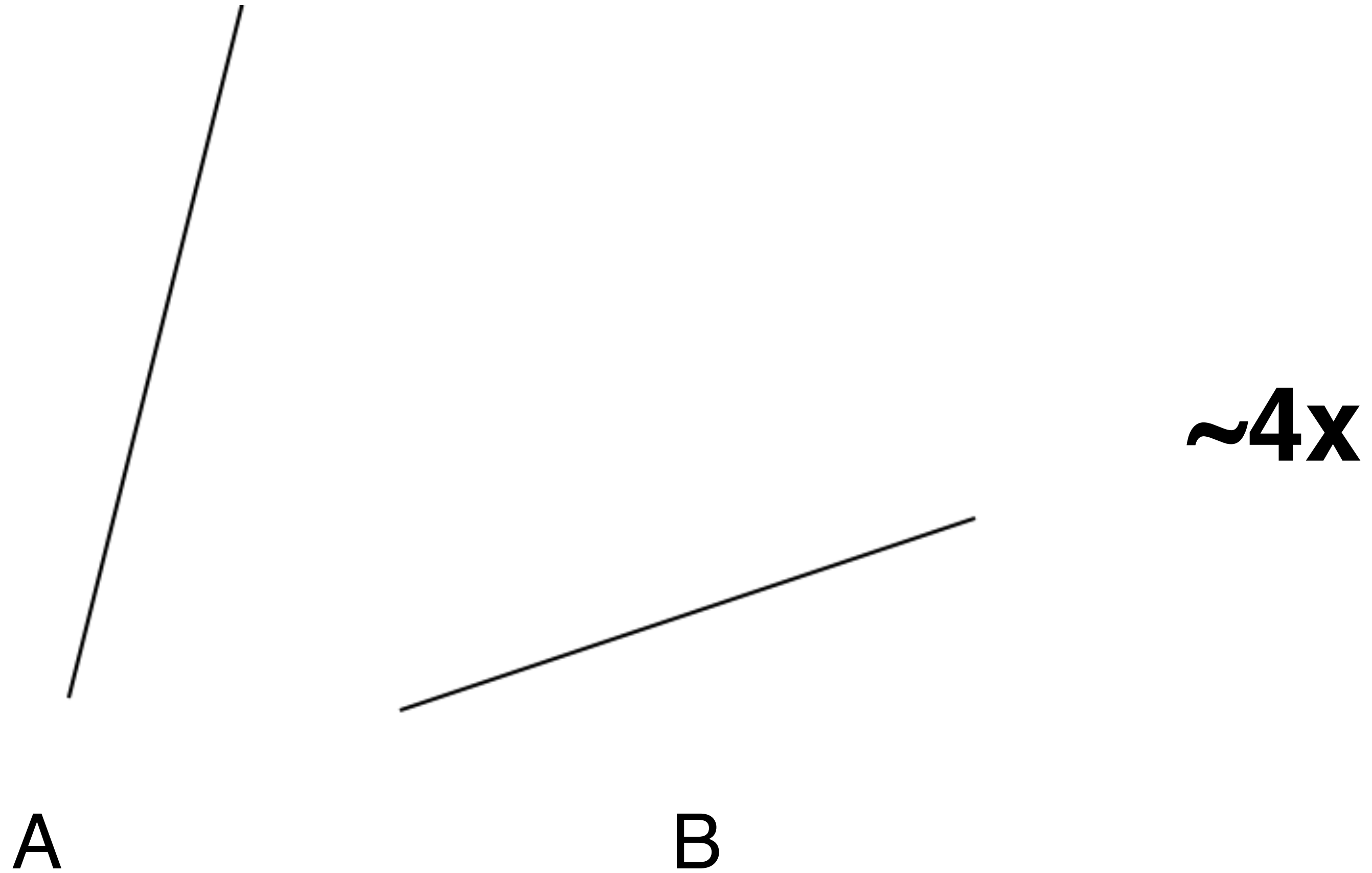
How much longer?



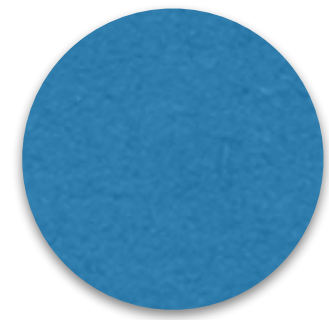
How much longer?



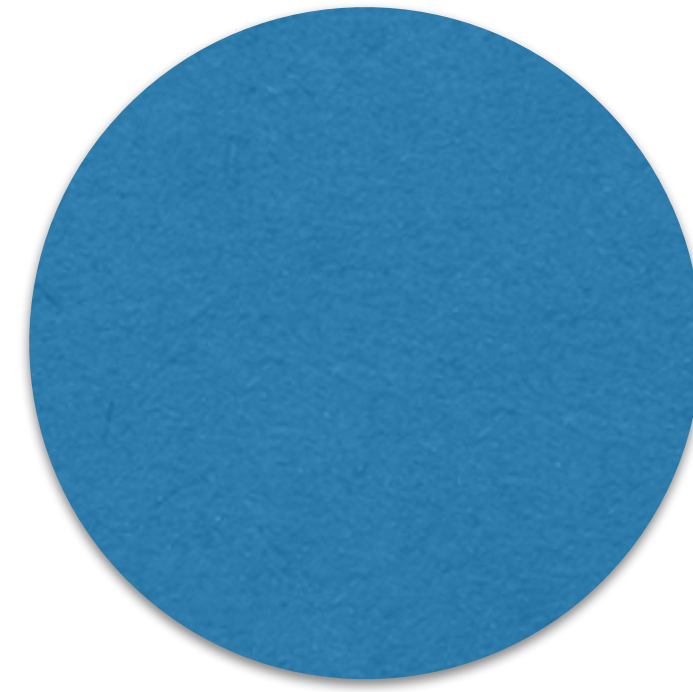
How much steeper?



How much larger?



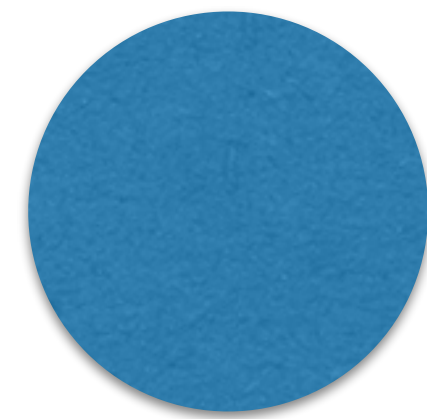
A



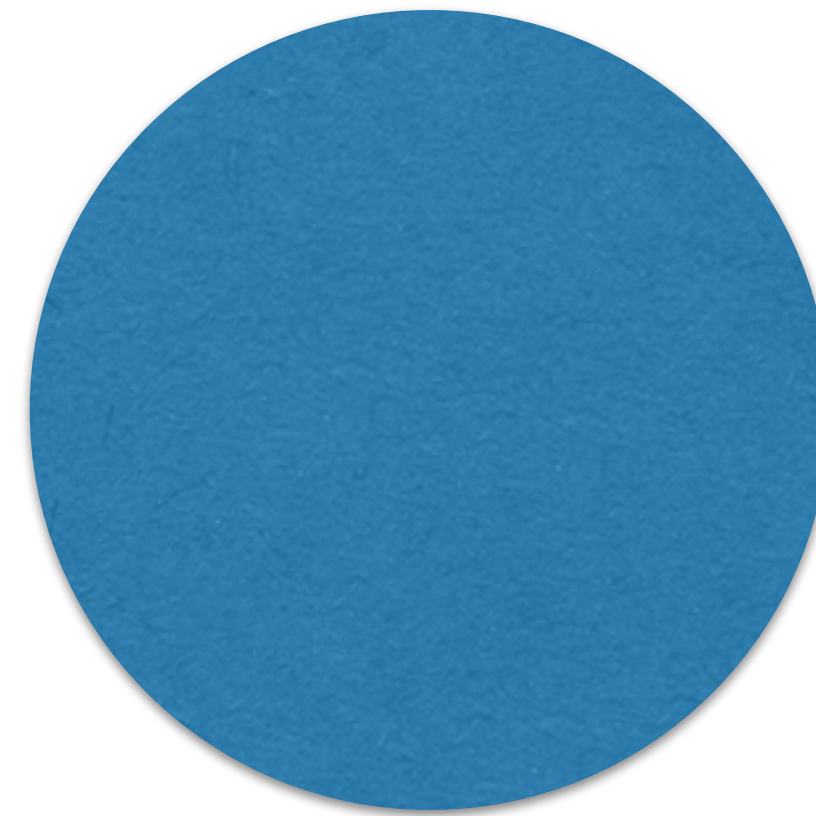
B

5x

How much larger?



A



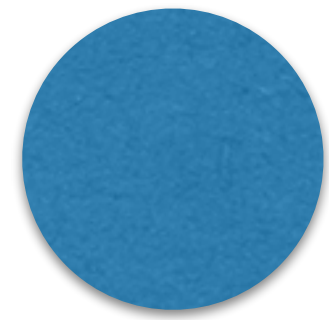
B

**2x
diameter**

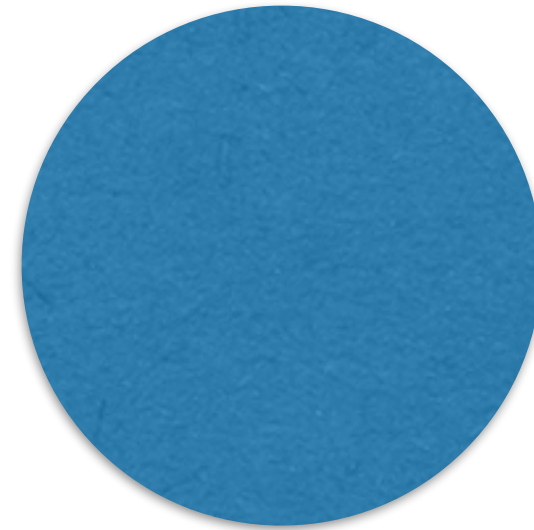
4x area

area is proportional to
diameter squared

How much larger (area)?



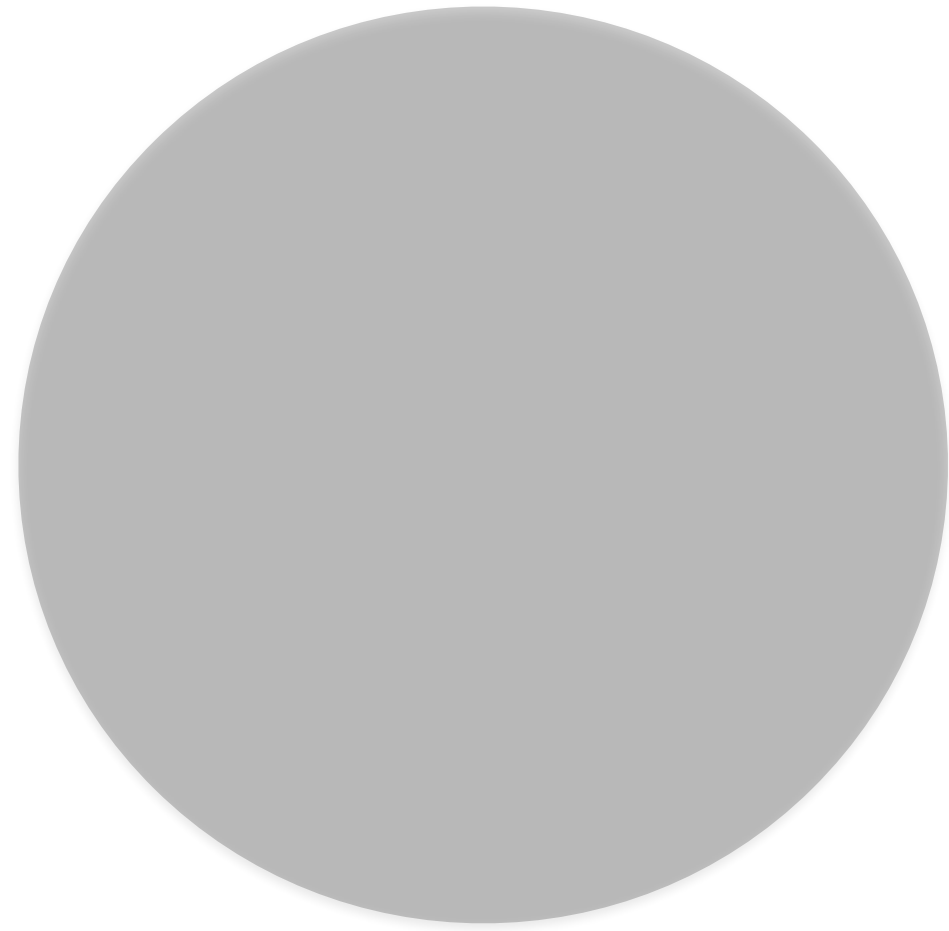
A



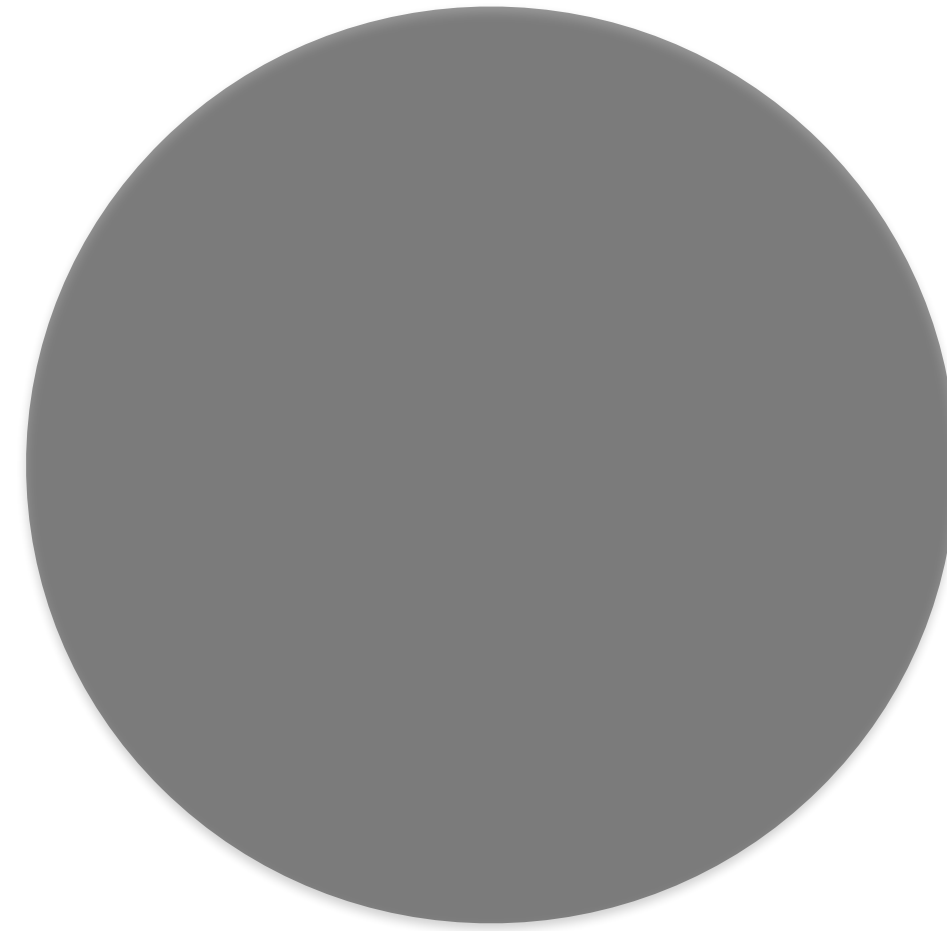
B

3x

How much darker?



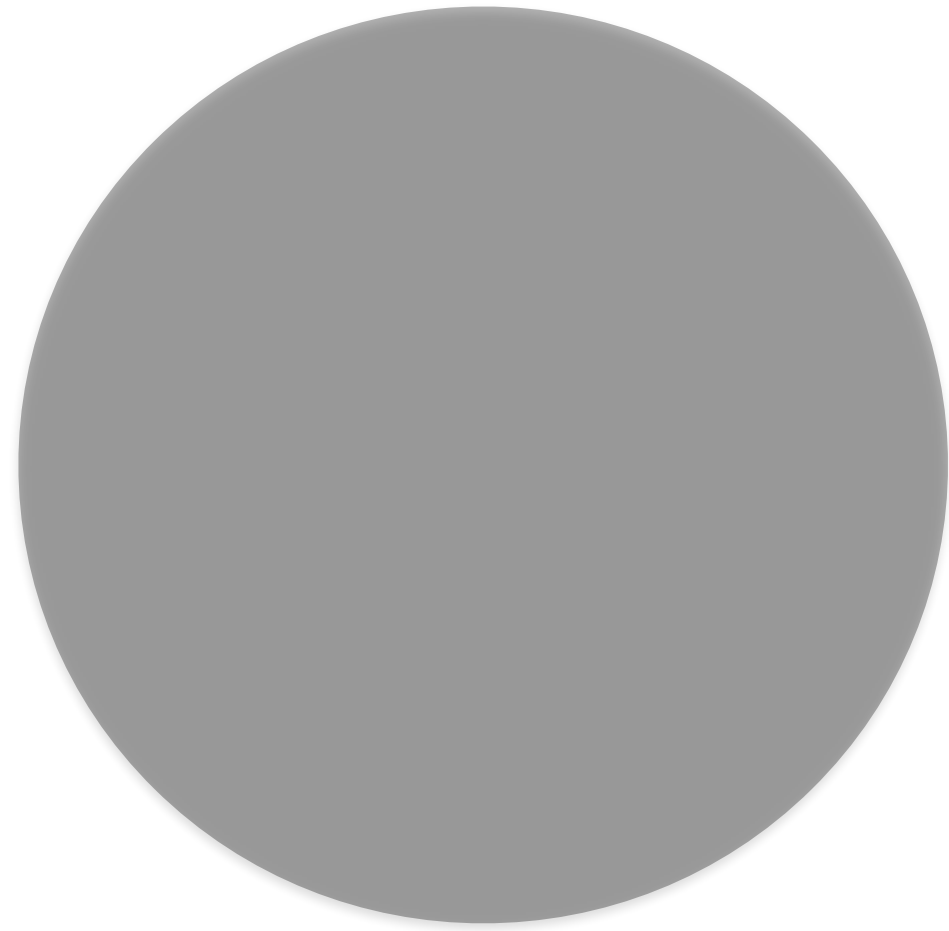
A



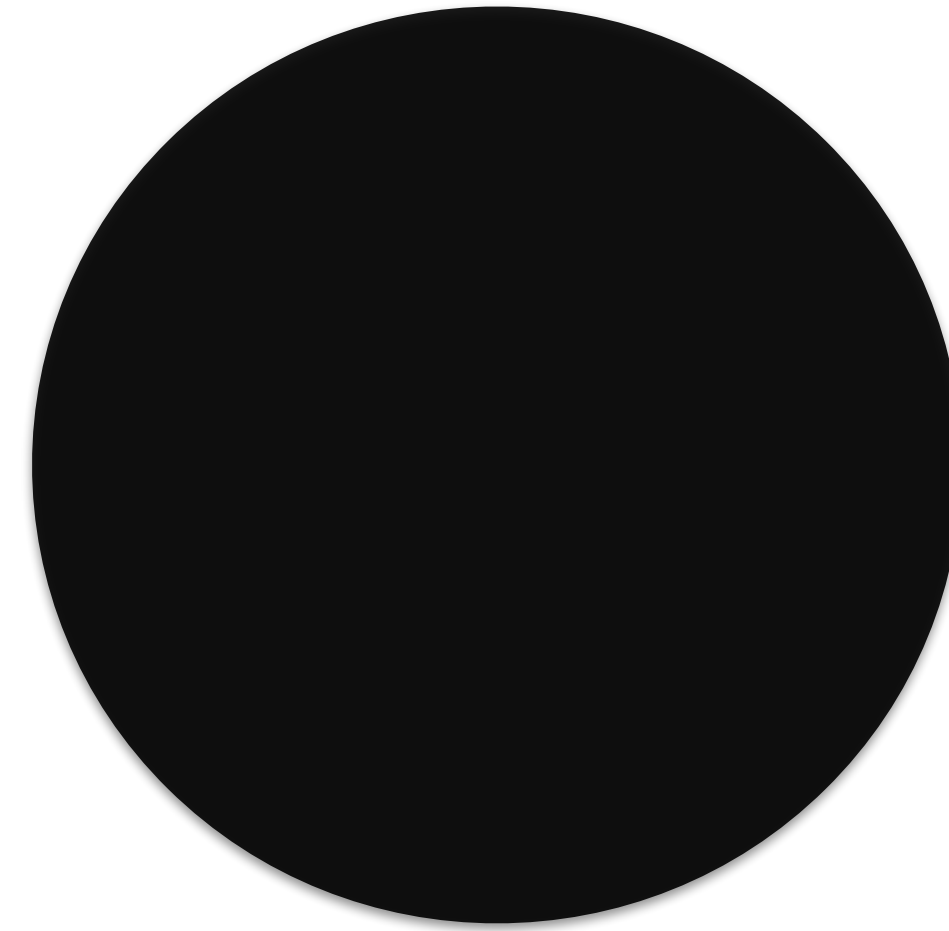
B

2x

How much darker?



A



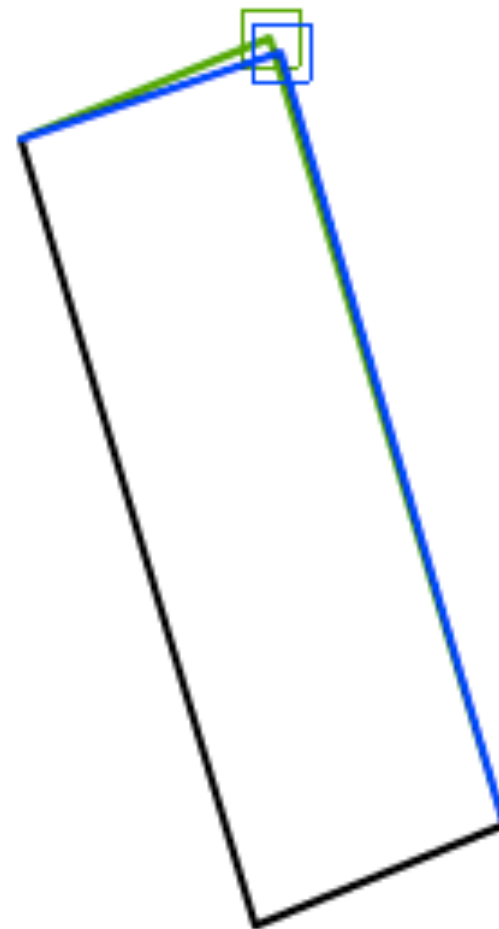
B

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

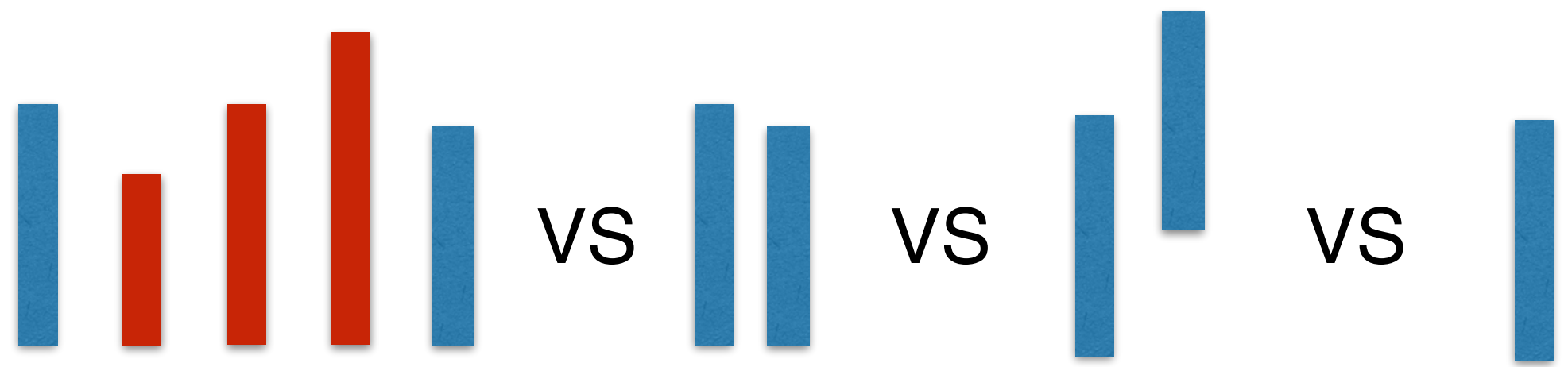
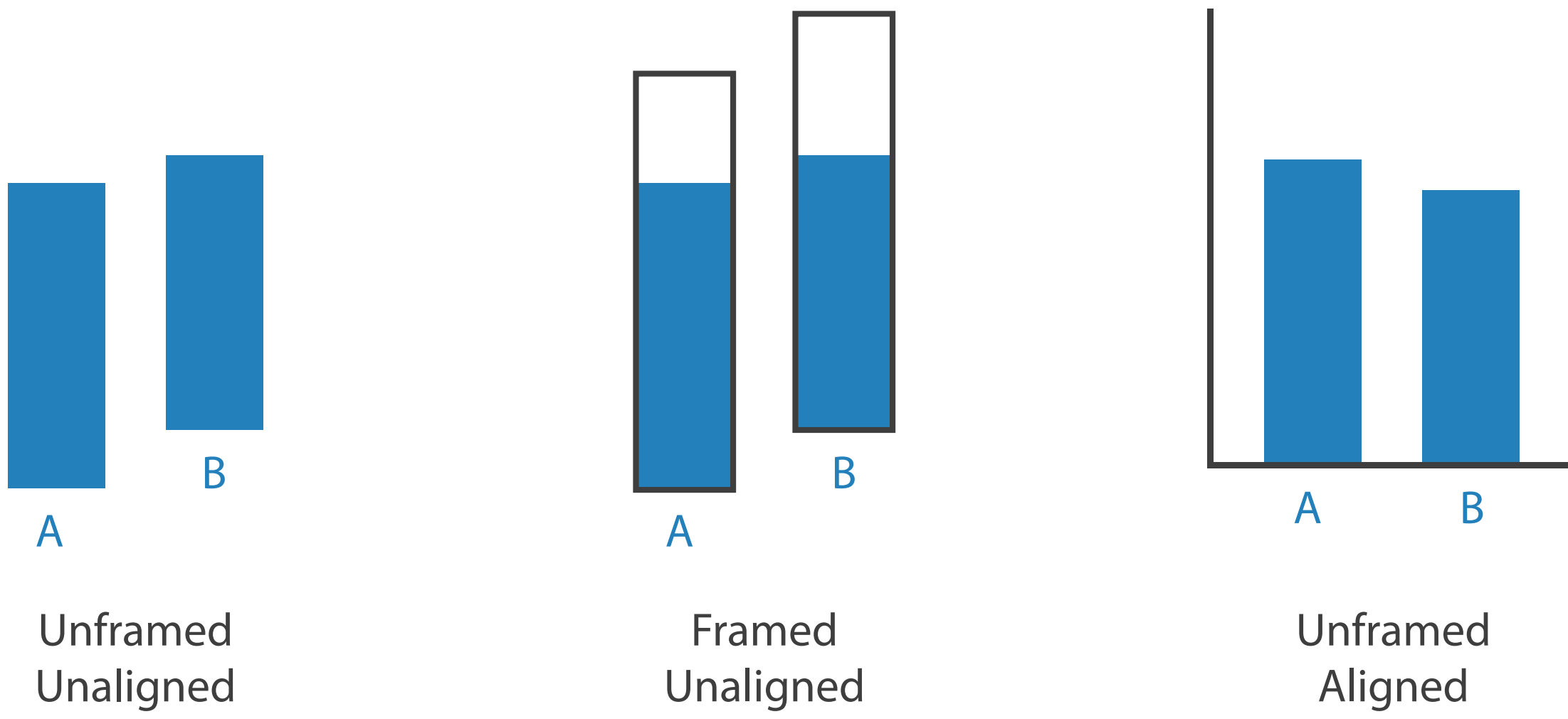
Alignment

Distractors

Distance

Common scale

...



Cleveland / McGill, 1984

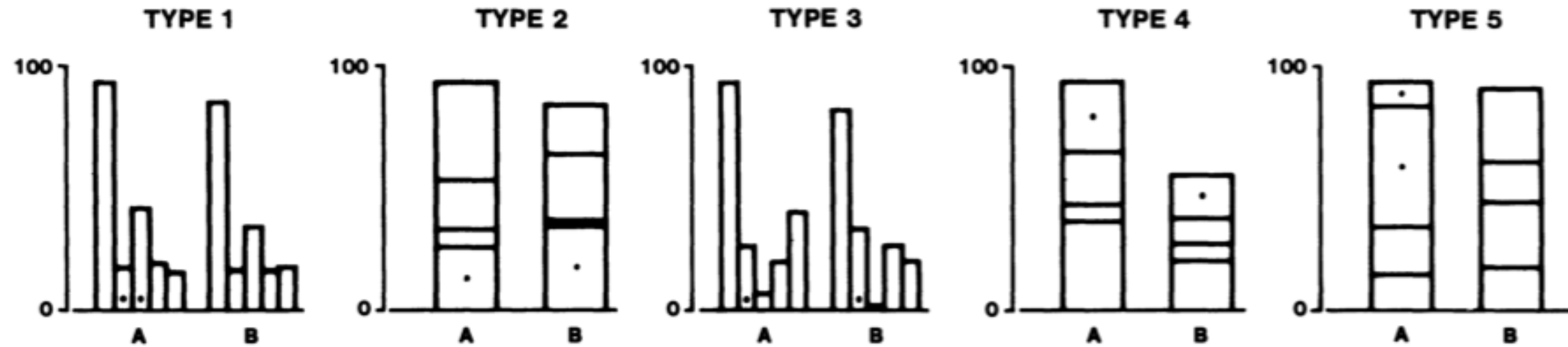


Figure 4. Graphs from position-length experiment.

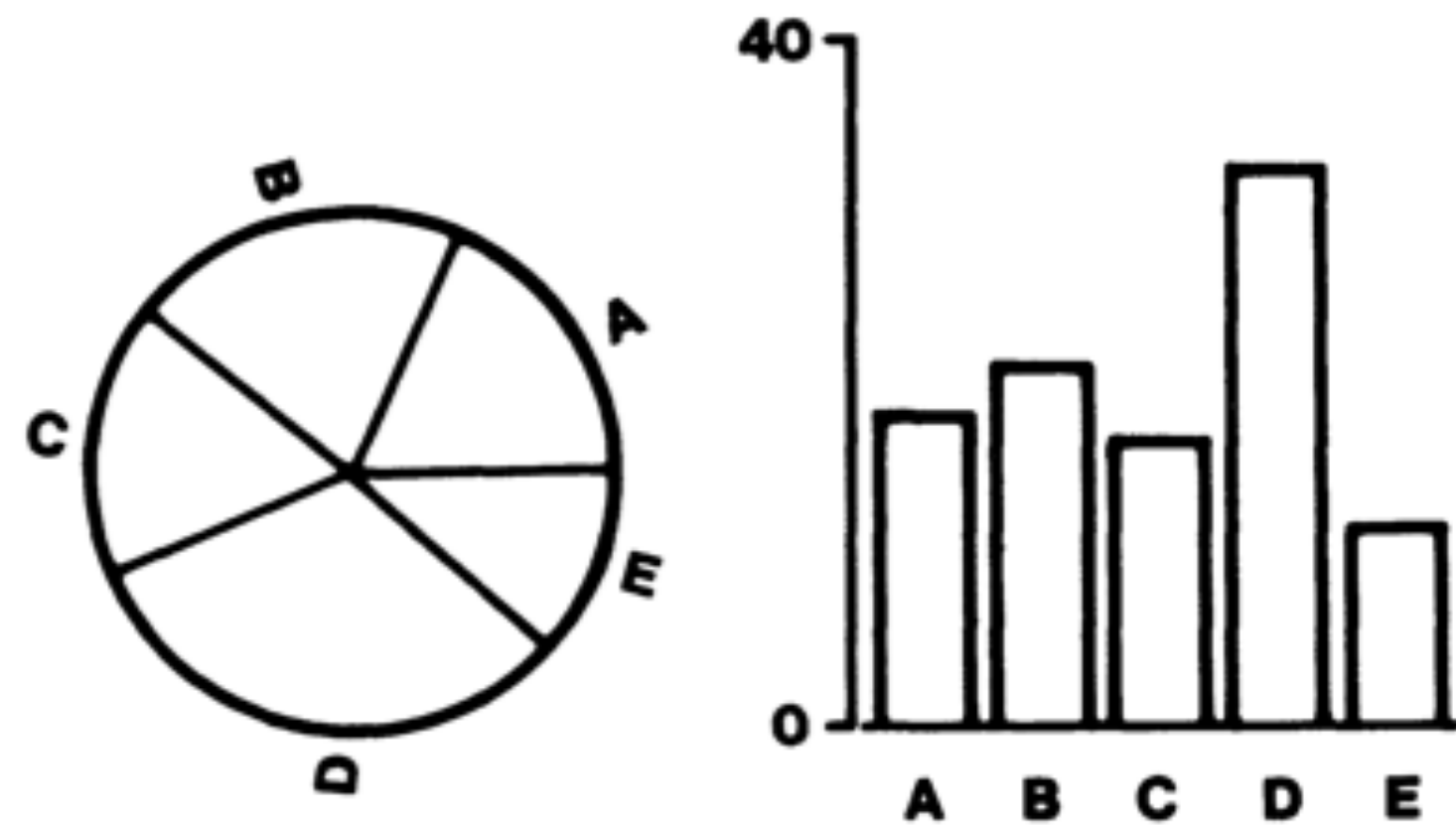
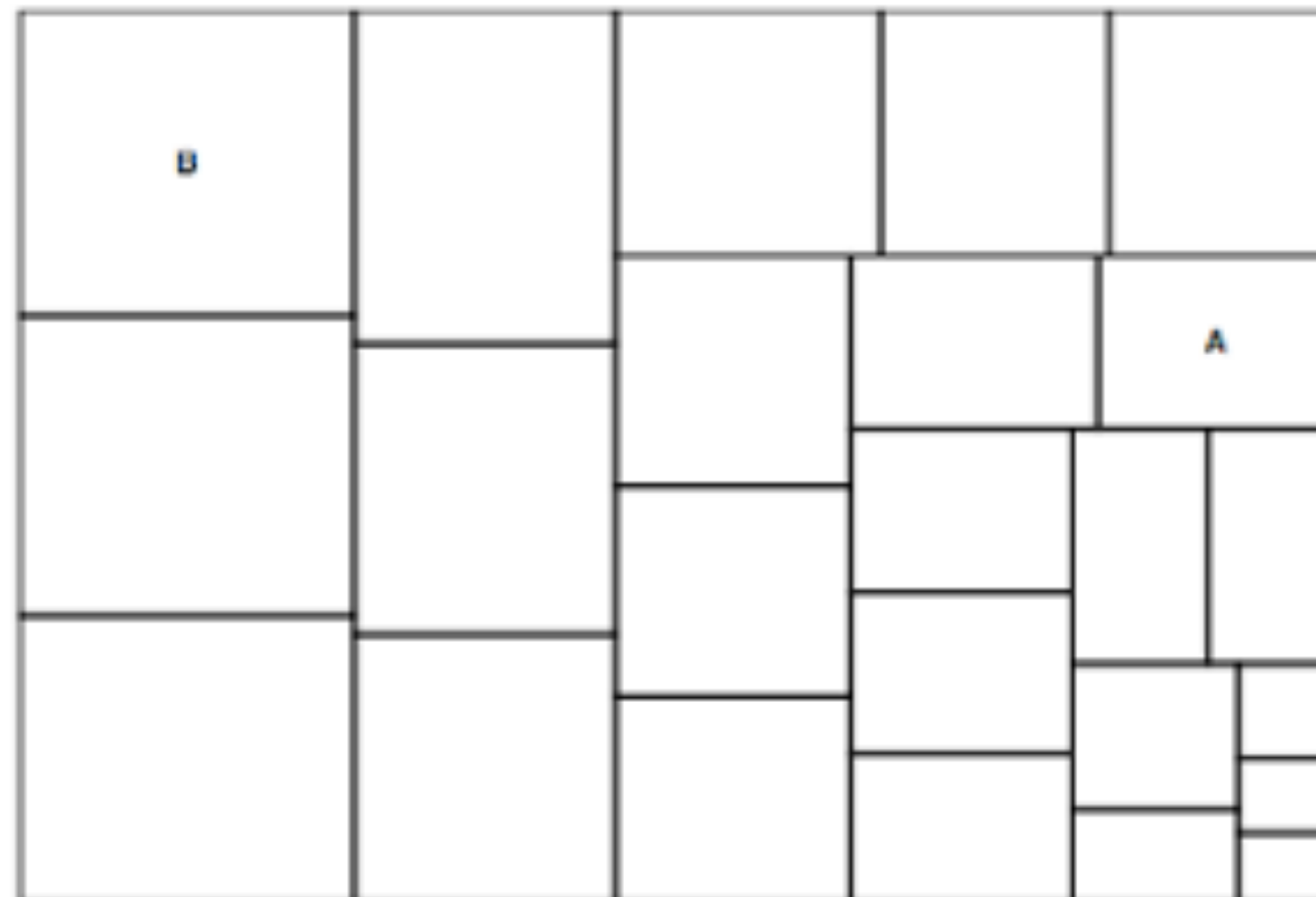
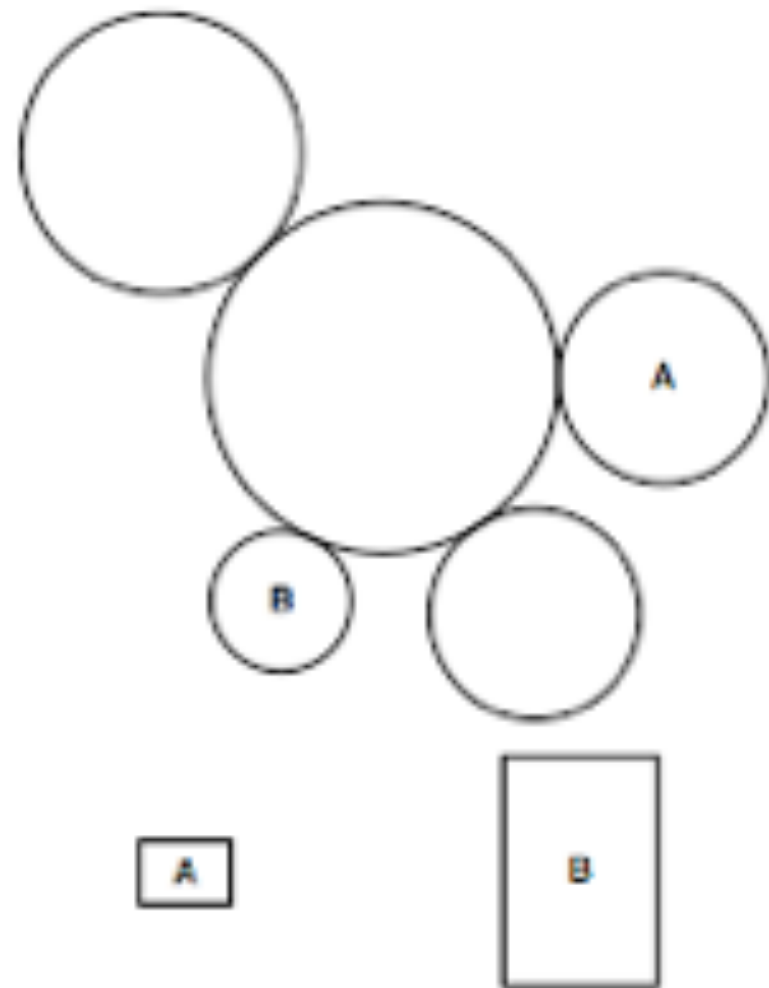
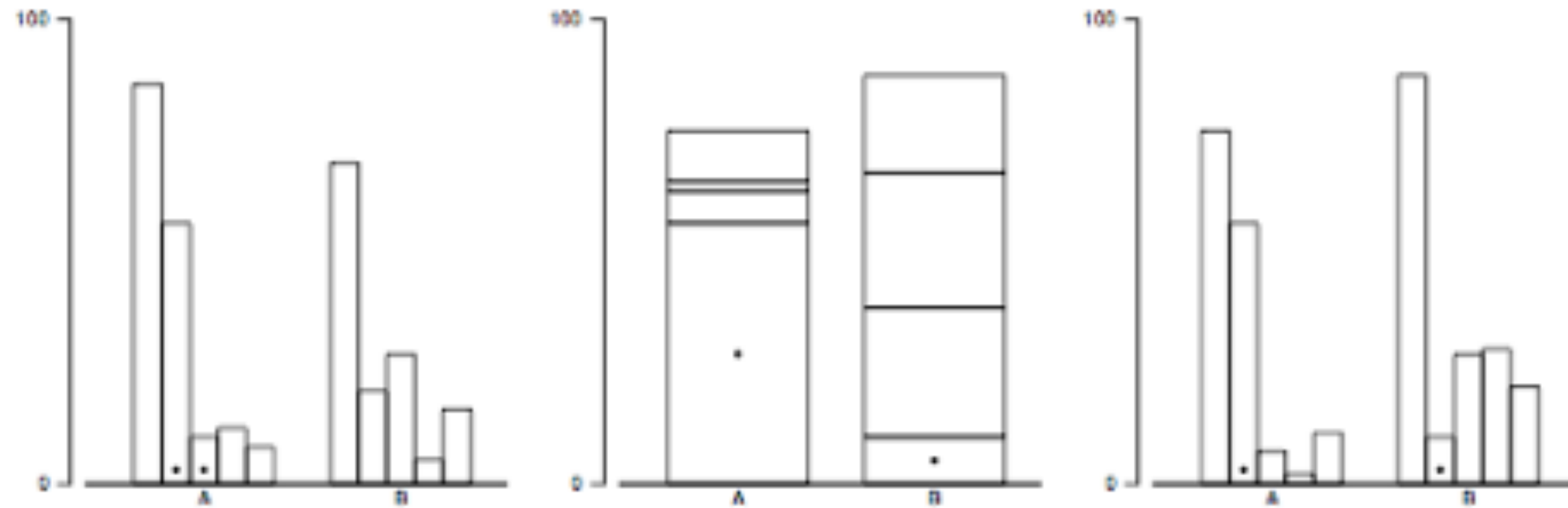


Figure 3. Graphs from position-angle experiment.

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
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Stanford University
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ABSTRACT

Understanding perception is critical to effective visualization design. With its low cost and scalability, crowdsourcing presents an attractive option for evaluating the large design space of visualizations; however, it first requires validation. In this paper, we assess the viability of Amazon’s Mechanical Turk as a platform for graphical perception experiments. We replicate previous studies of spatial encoding and luminance contrast and compare our results. We also conduct new experiments on rectangular area perception (as in treemaps or cartograms) and on chart size and gridline spacing. Our results demonstrate that crowdsourced perception experiments are viable and contribute new insights for visualization design. Lastly, we report cost and performance data from our experiments and distill recommendations for the design of crowdsourced studies.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces—Evaluation/Methodology

General Terms: Experimentation, Human Factors.

Keywords: Information visualization, graphical perception, user study, evaluation, Mechanical Turk, crowdsourcing.

INTRODUCTION

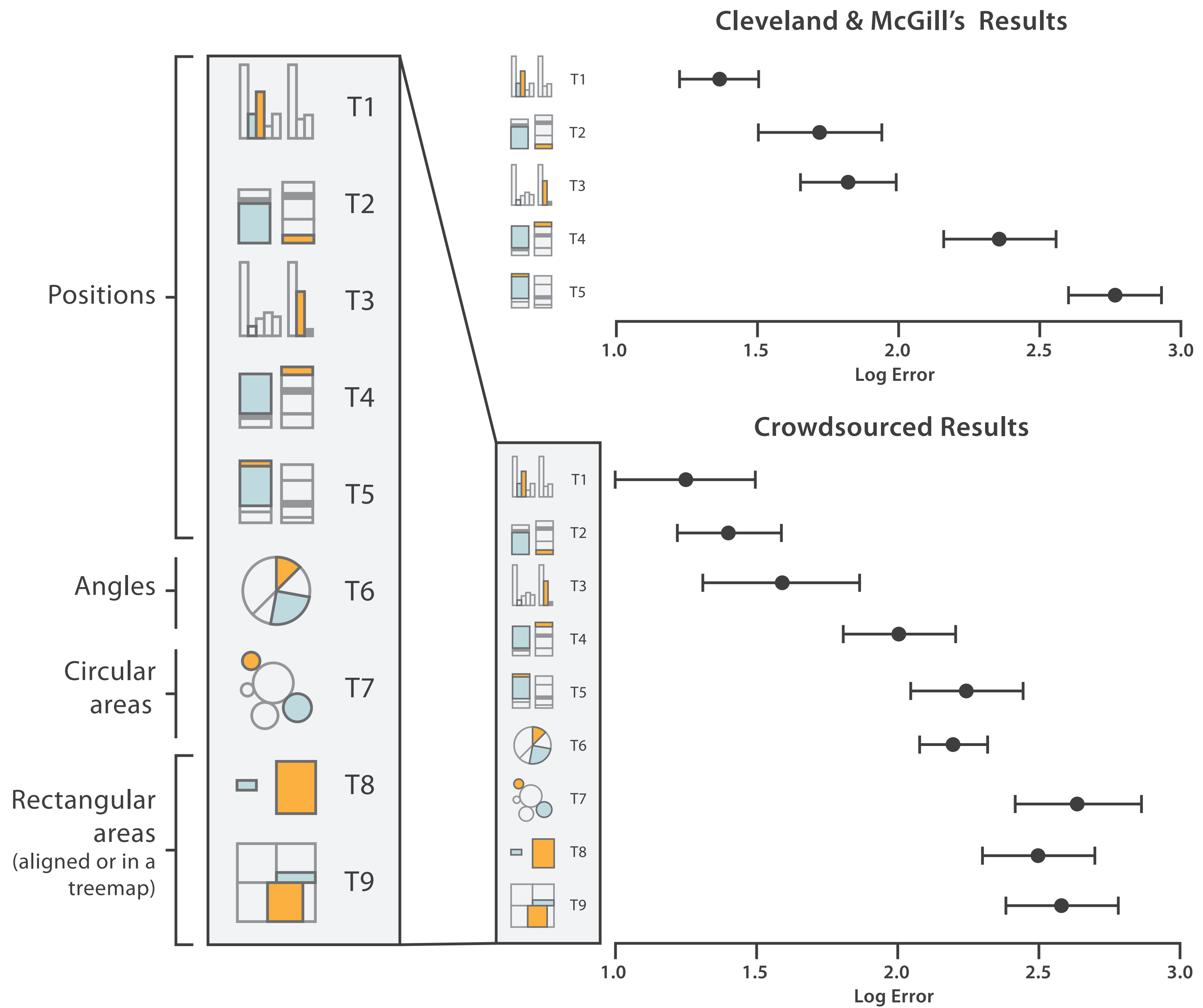
“Crowdsourcing” is a relatively new phenomenon in which web workers complete one or more small tasks, often for micro-payments on the order of \$0.01 to \$0.10 per task

for ecological validity. Crowdsourced experiments may also substantially reduce both the cost and time to result.

Unfortunately, crowdsourcing introduces new concerns to be addressed before it is credible. Some concerns, such as ecological validity, subject motivation and expertise, apply to any study and have been previously investigated [13, 14, 23]; others, such as display configuration and viewing environment, are specific to visual perception. Crowdsourced perception experiments lack control over many experimental conditions, including display type and size, lighting, and subjects’ viewing distance and angle. This loss of control inevitably limits the scope of experiments that reliably can be run. However, there likely remains a substantial subclass of perception experiments for which crowdsourcing can provide reliable empirical data to inform visualization design.

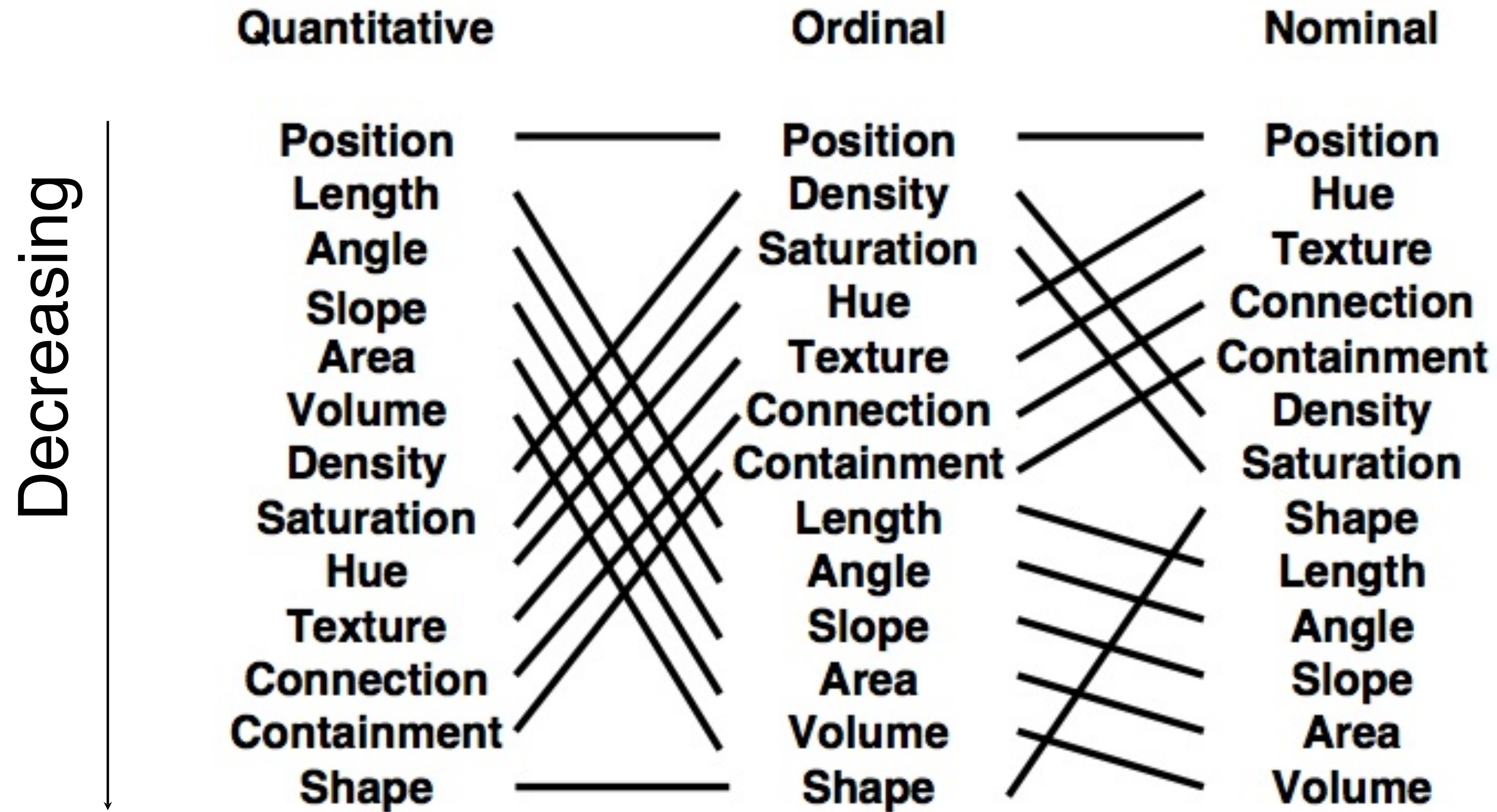
In this work, we investigate if crowdsourced experiments insensitive to environmental context are an adequate tool for graphical perception research. We assess the feasibility of using Amazon’s Mechanical Turk to evaluate visualizations and then use these methods to gain new insights into visualization design. We make three primary contributions:

- We replicate prior laboratory studies on spatial data encodings and luminance contrast using crowdsourcing techniques. Our new results match previous work, are consistent with theoretical predictions [21], and suggest that



Log Error = $\log_2(\text{judged percent} - \text{true percent} + 1/8)$

Jock Mackinlay, 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)



Same

Most
Effectiveness
Least

➔ Identity Channels: Categorical Attributes

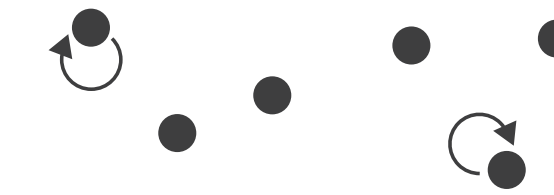
Spatial region



Color hue



Motion



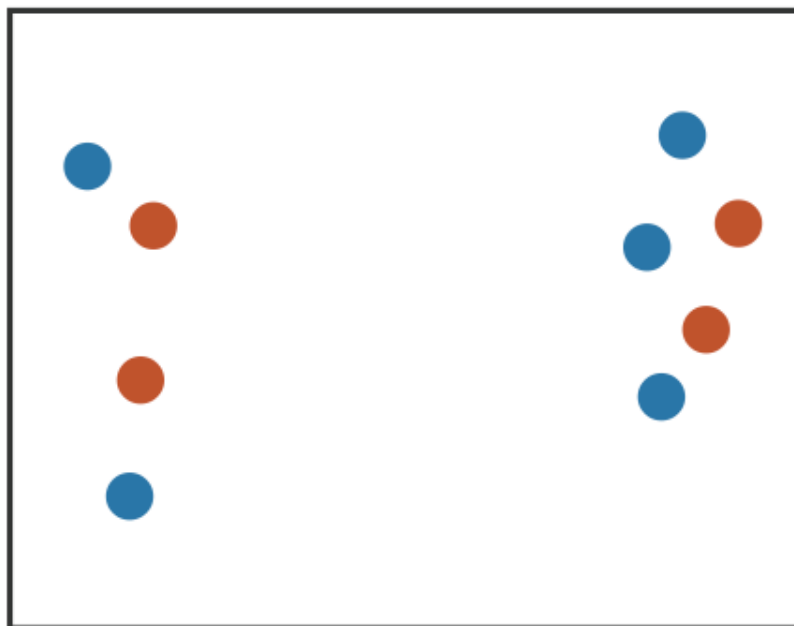
Shape



Separability of Attributes

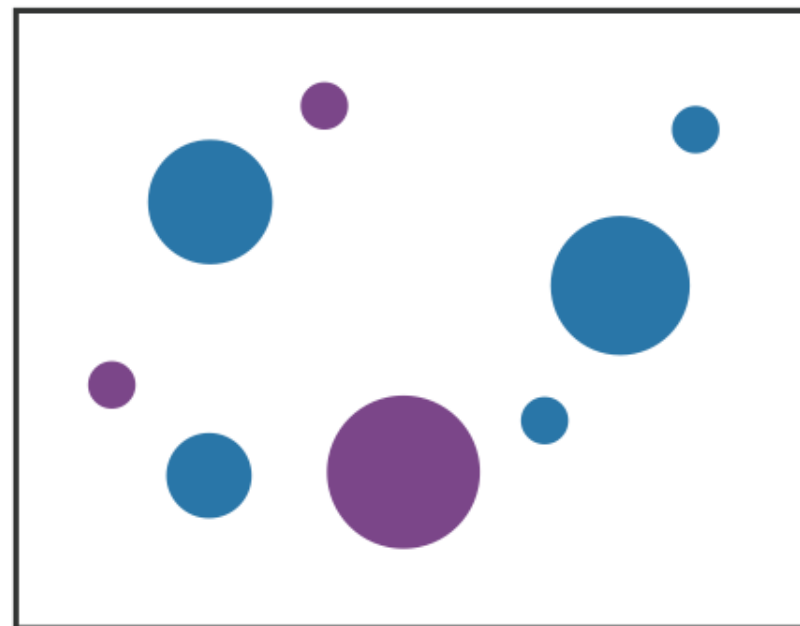
Can we combine multiple visual variables?

Position
+ Hue (Color)



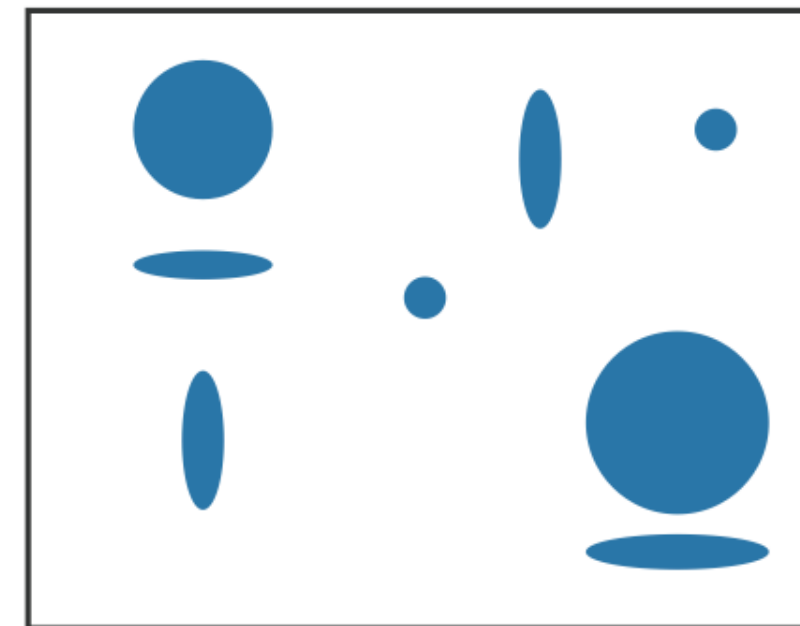
Fully separable

Size
+ Hue (Color)



Some interference

Width
+ Height



Some/significant
interference

Red
+ Green



Major interference