Data Visualization (CSCI 627/490)

Marks and Channels

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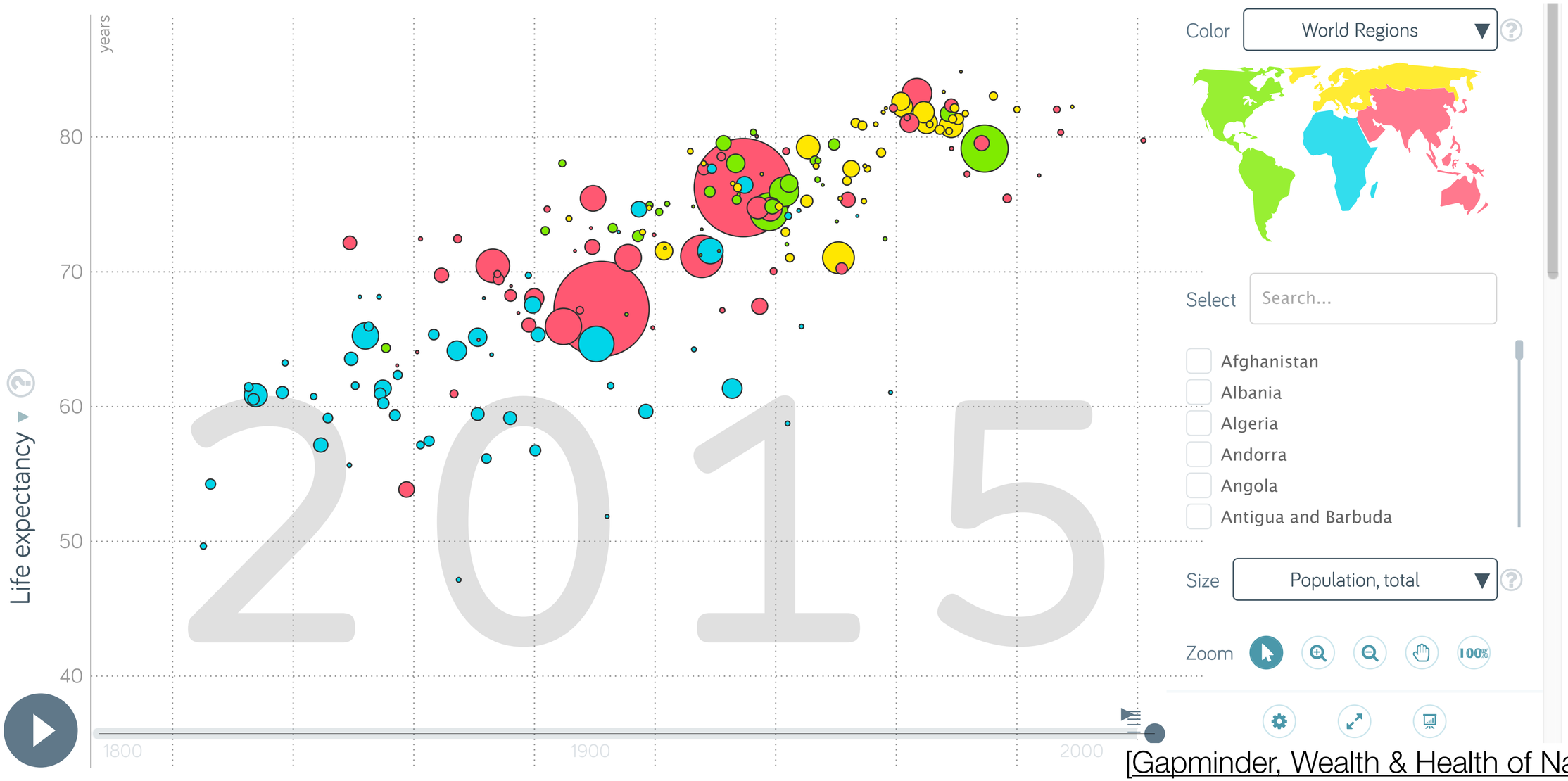
Visual Encoding

- How should we visualize this data?

Name	Region	Population	Life Expectancy	Income
China	East Asia & Pacific	1335029250	73.28	7226.07
India	South Asia	1140340245	64.01	2731
United States	America	306509345	79.43	41256.08
Indonesia	East Asia & Pacific	228721000	71.17	3818.08
Brazil	America	193806549	72.68	9569.78
Pakistan	South Asia	176191165	66.84	2603
Bangladesh	South Asia	156645463	66.56	1492
Nigeria	Sub-Saharan Africa	141535316	48.17	2158.98
Japan	East Asia & Pacific	127383472	82.98	29680.68
Mexico	America	111209909	76.47	11250.37
Philippines	East Asia & Pacific	94285619	72.1	3203.97
Vietnam	East Asia & Pacific	86970762	74.7	2679.34
Germany	Europe & Central Asia	82338100	80.08	31191.15
Ethiopia	Sub-Saharan Africa	79996293	55.69	812.16
Turkey	Europe & Central Asia	72626967	72.06	8040.78

Potential Solution



[Gapminder, Wealth & Health of Nations]

Visual Encoding

- How do we encode data visually?
  - **Marks** are the basic graphical elements in a visualization
  - **Channels** are ways to control the appearance of the marks
- Marks classified by dimensionality:

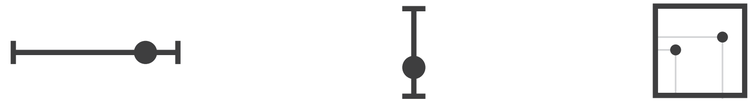
Points **Lines** **Areas**

- Also can have surfaces, volumes
- Think of marks as a mathematical definition, or if familiar with tools like Adobe Illustrator or Inkscape, the path & point definitions

Visual Channels

Position

- Horizontal
- Vertical
- Both



Color

Shape

Tilt

Size

- Length
- Area
- Volume

[Munzner (ill. Maguire), 2014]

Channel Types

- Identity => what or where, Magnitude => how much

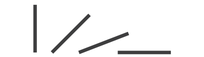
Magnitude Channels: Ordered Attributes

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

[Munzner (ill. Maguire), 2014]

Assignment 3

- Same stacked bar chart visualization
- Three tools
  - Tableau (free academic license)
  - Vega-Lite
  - D3
- For Vega-Lite, use the online editor
- For D3, use template files so the data is properly loaded
- [CS 490] Only need to do a standard bar chart in D3
- Three parts: set mini-deadlines

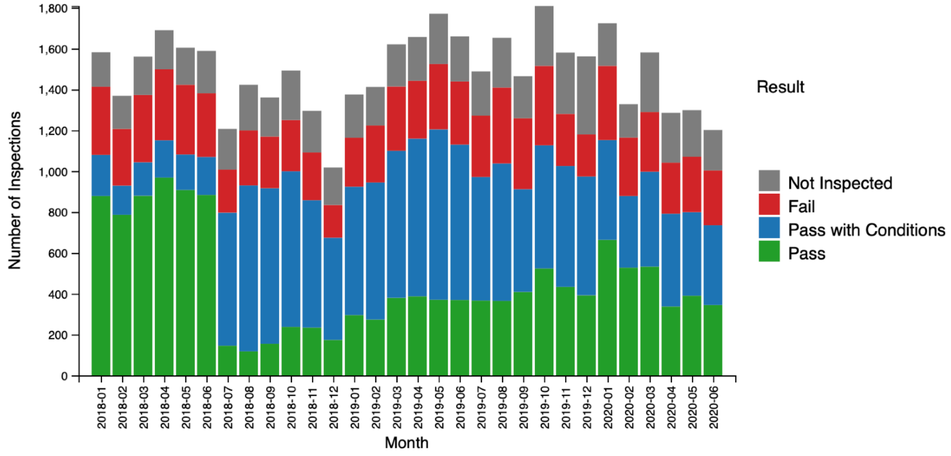
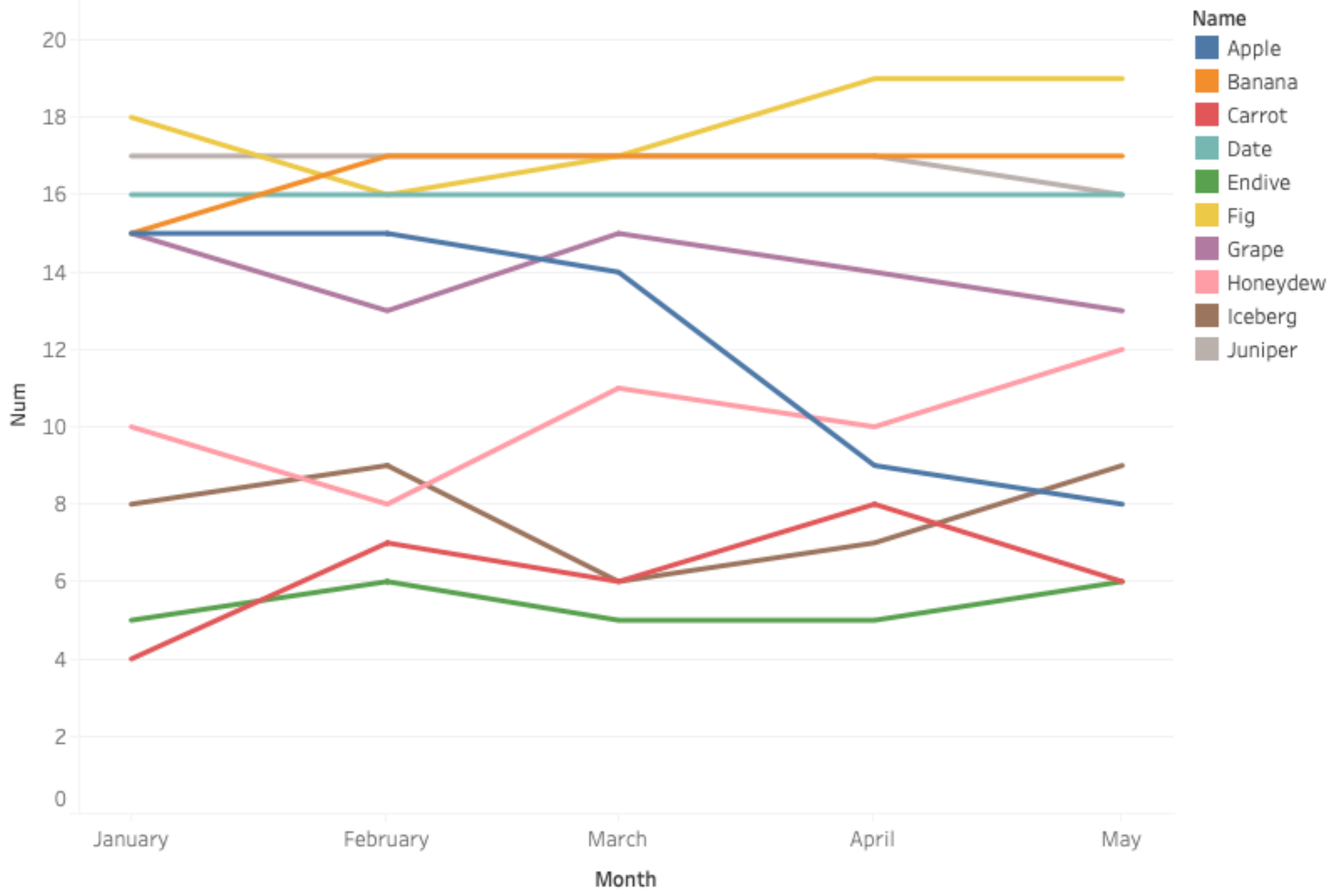


Tableau Example



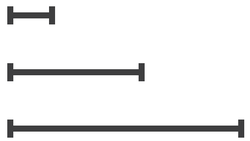
Data In Tableau

➔ Categorical

➔ Ordered

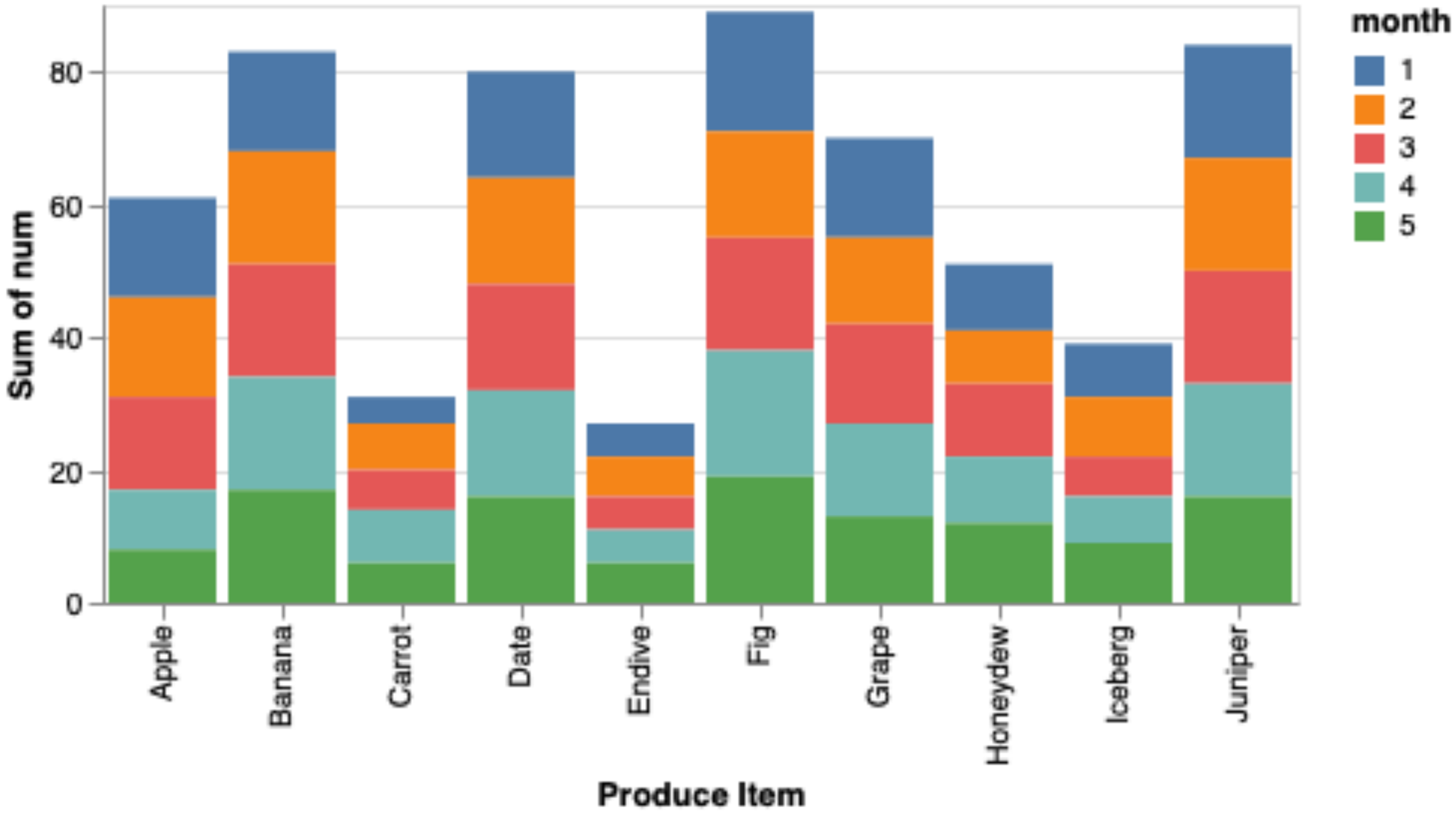
➔ *Ordinal*

➔ *Quantitative*



- Categorical data = Dimension
- Quantitative data = Measures

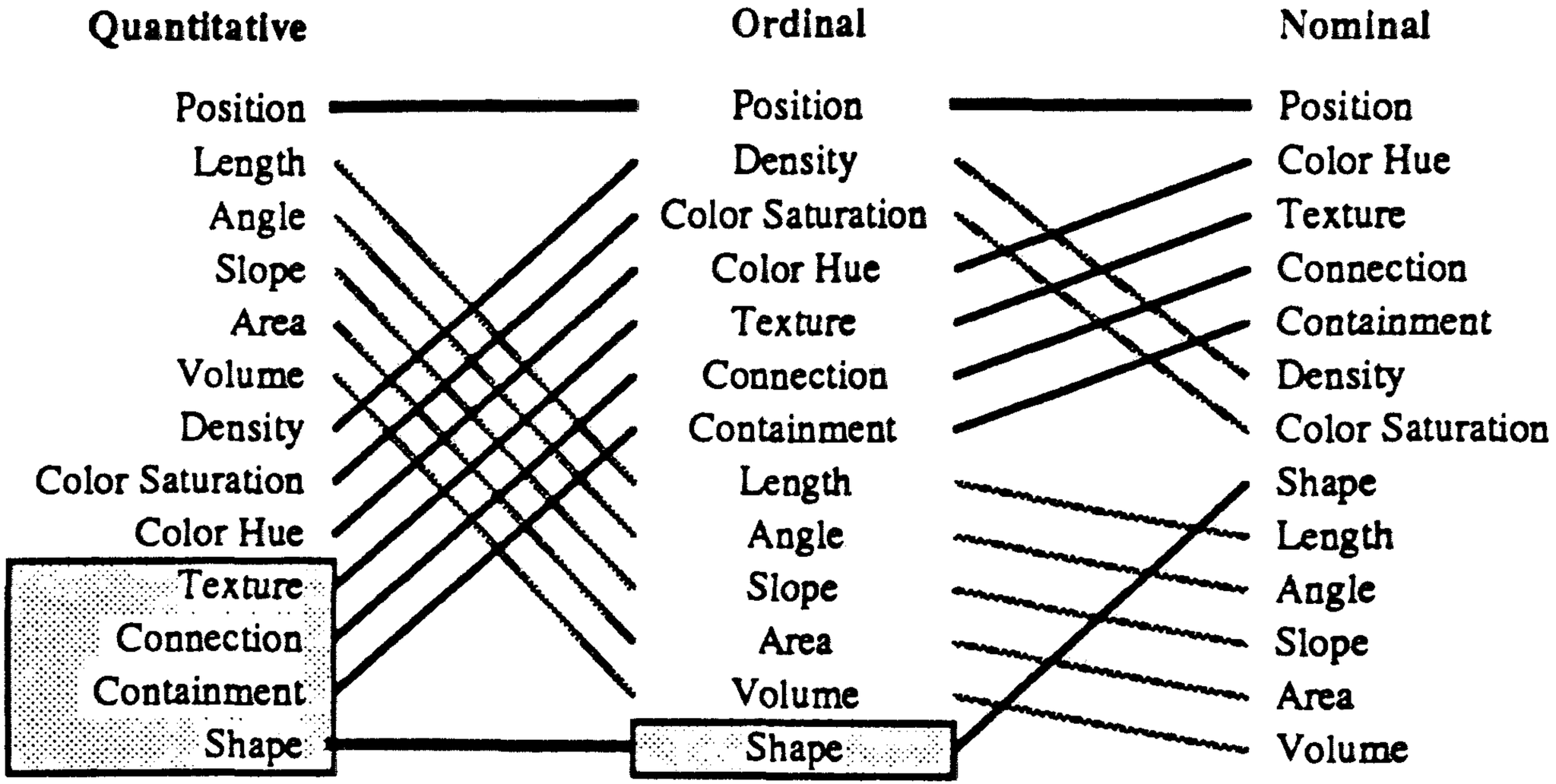
Vega-Lite Example



Expressiveness and Effectiveness

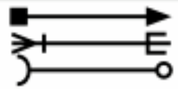
- Expressiveness Principle: all data from the dataset and nothing more should be shown
  - Do encode ordered data in an ordered fashion
  - Don’t encode categorical data in a way that implies an ordering
- Effectiveness Principle: the most important attributes should be the most **salient**
  - Saliency: how noticeable something is
  - How do the channels we have discussed measure up?

Mackinlay's Ranking of Perceptual Tasks



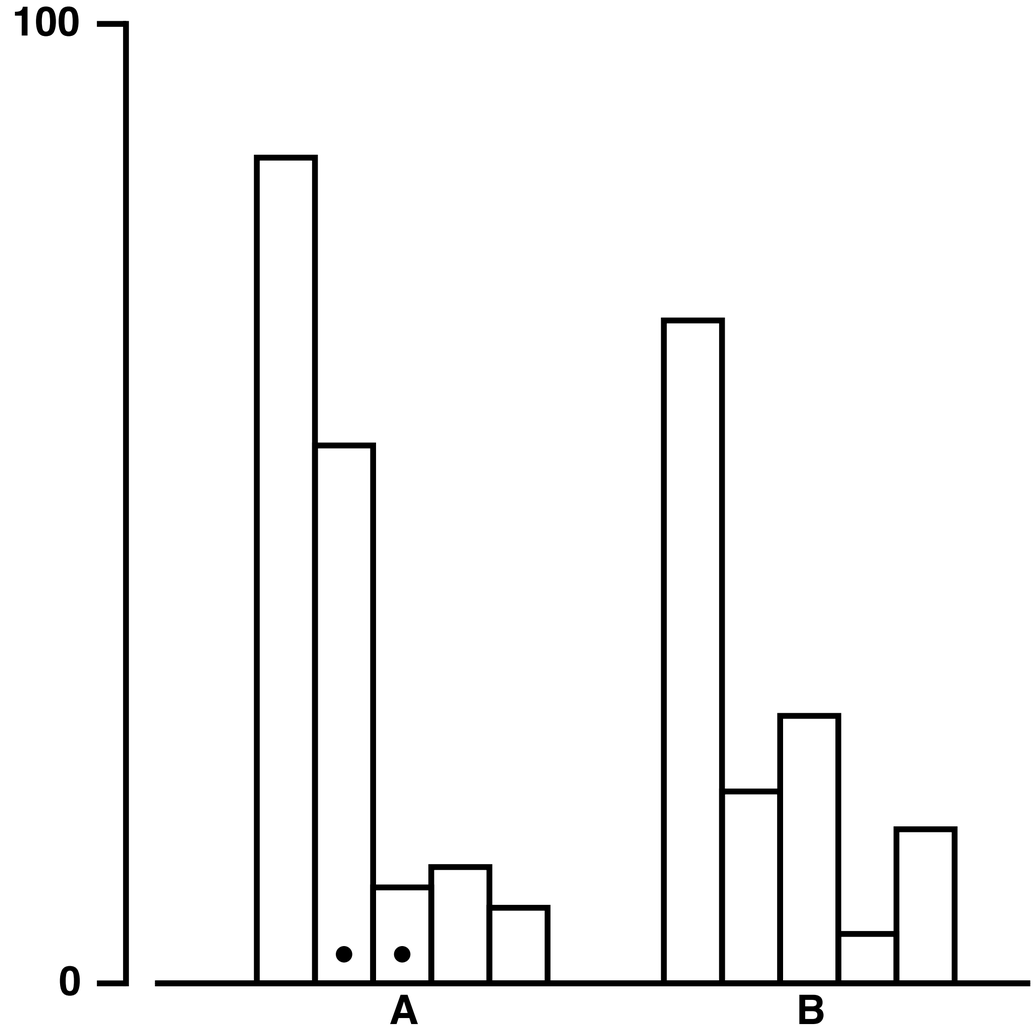
[Mackinlay,1986]

Iliinsky's Best Uses, +Ordering, +NumValues

Example	Encoding	Ordered	Useful values	Quantitative	Ordinal	Categorical	Relational
	position, placement	**yes**	**infinite**	Good	Good	Good	Good
1, 2, 3; A, B, C	text labels	**optional** (alphabetical or numbered)	**infinite**	Good	Good	Good	Good
	length	**yes**	**many**	Good	Good		
	size, area	**yes**	**many**	Good	Good		
	angle	**yes**	medium/few	Good	Good		
	pattern density	**yes**	few	Good	Good		
	weight, boldness	**yes**	few		Good		
	saturation, brightness	**yes**	few		Good		
	color	no	few (< 20)			Good	
	shape, icon	no	medium			Good	
	pattern texture	no	medium			Good	
	enclosure, connection	no	**infinite**			Good	Good
	line pattern	no	few				Good
	line endings	no	few				Good
	line weight	**yes**	few		Good		

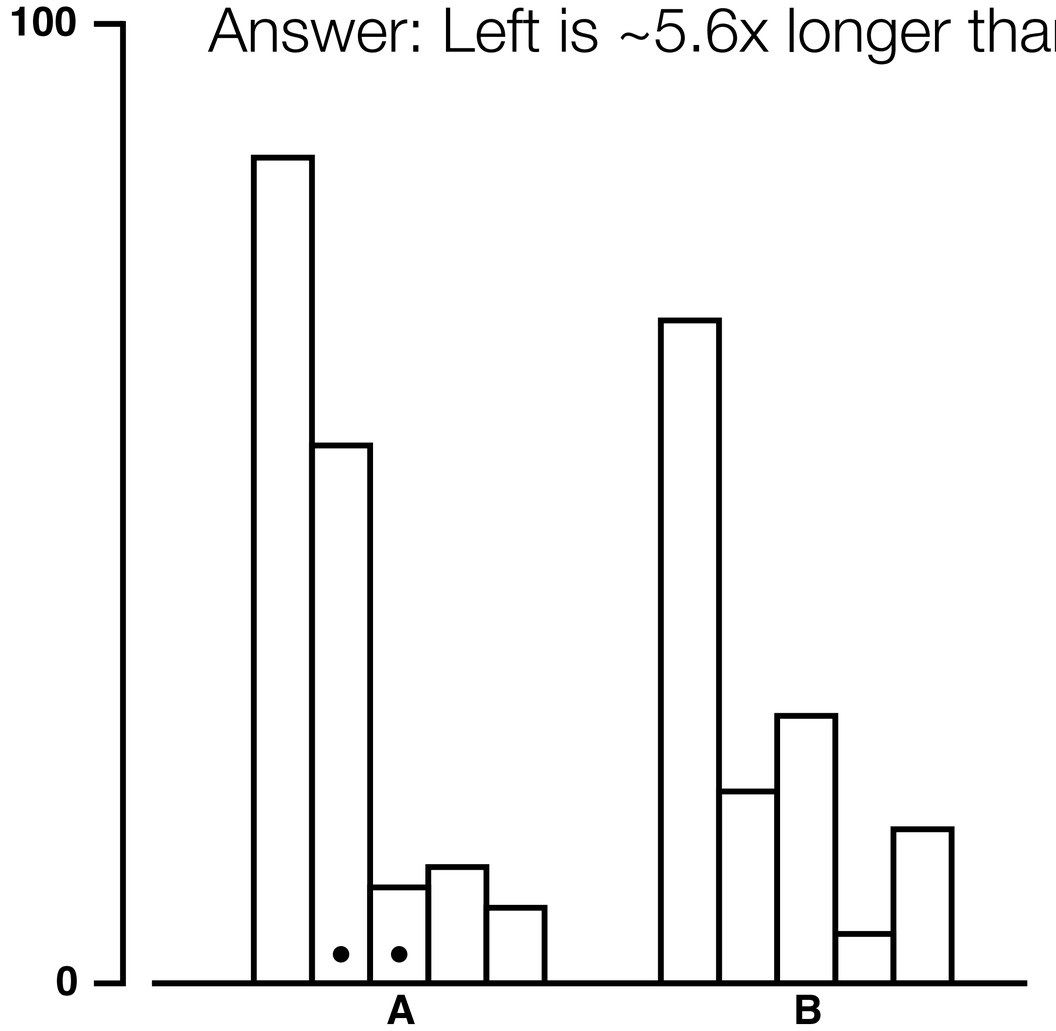
How do we get these rankings?

Test % difference in **length** between elements



[Heer & Bostock, 2010]

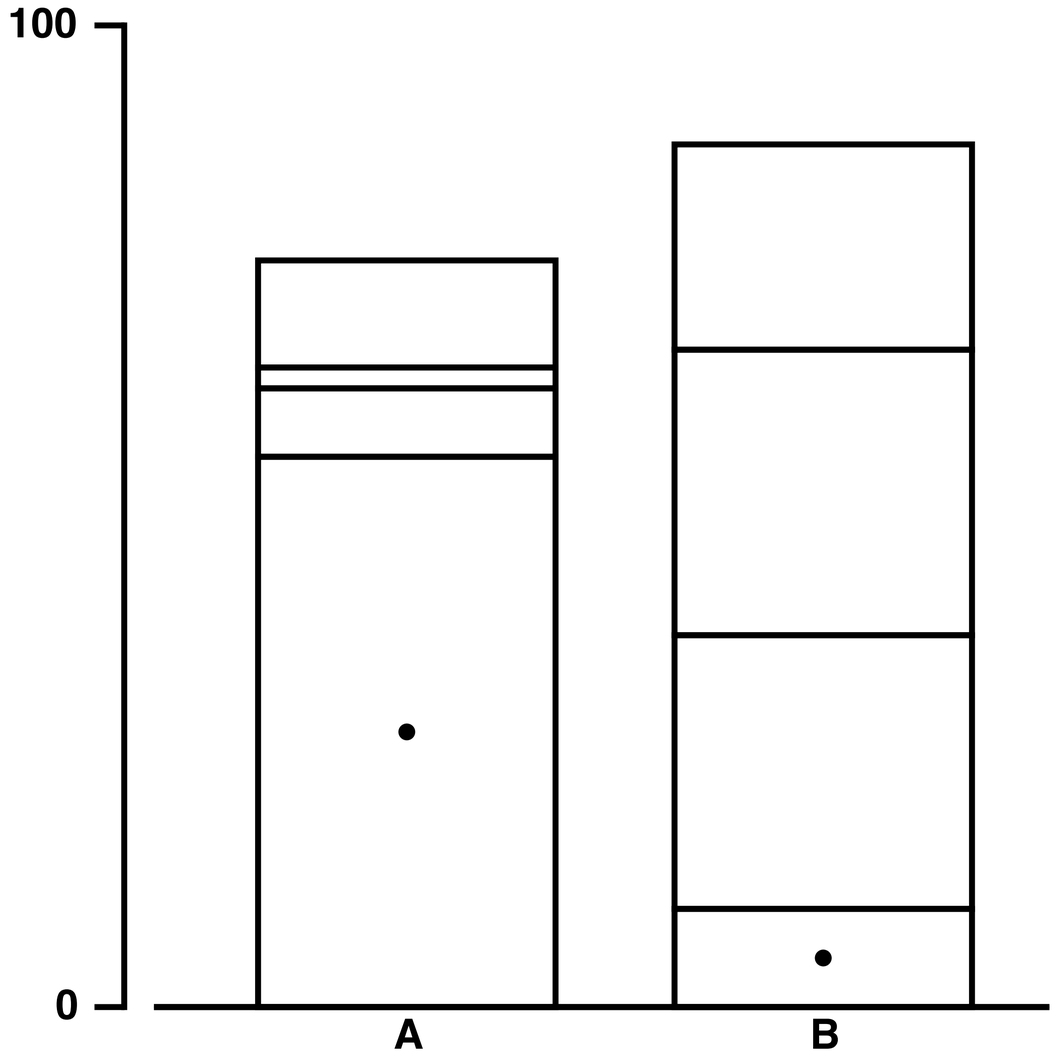
Test % difference in **length** between elements



Answer: Left is ~5.6x longer than Right

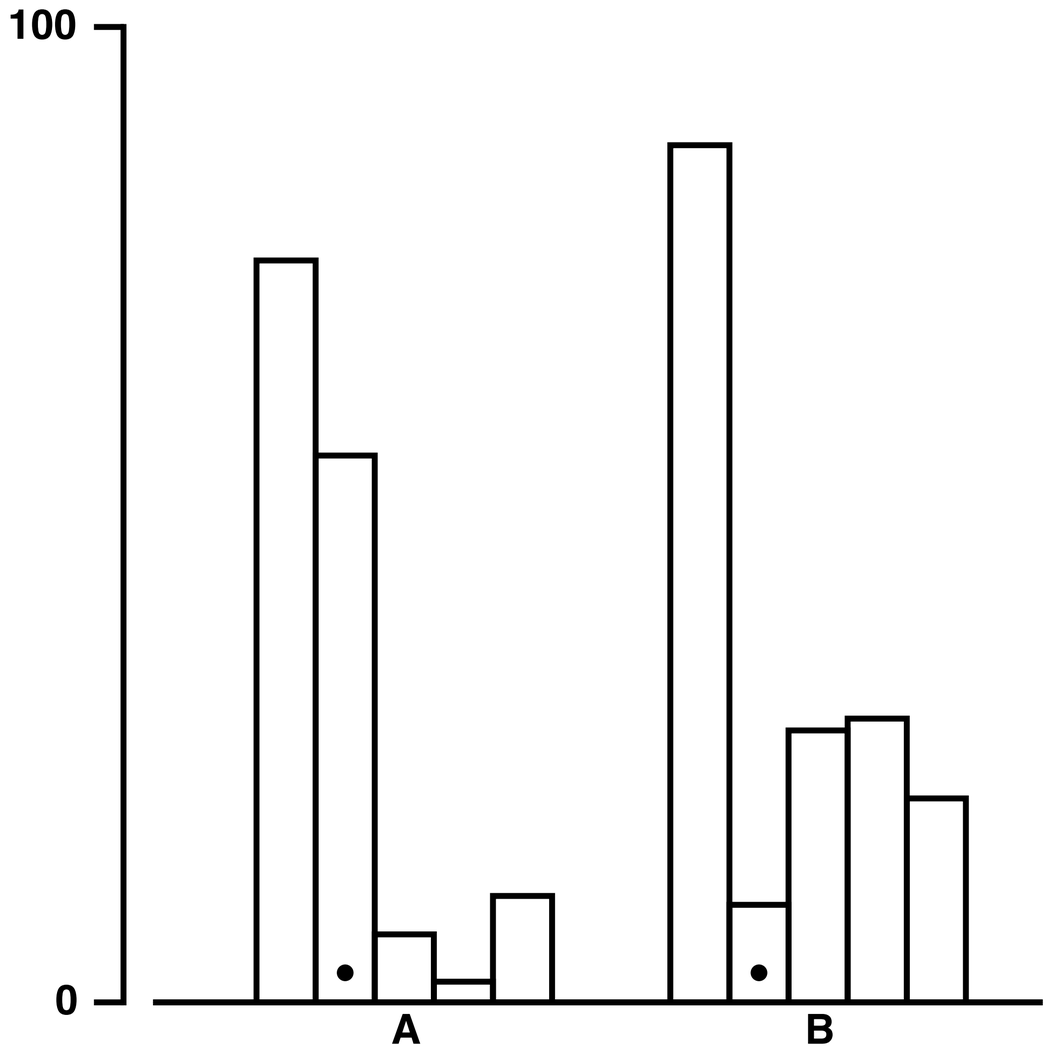
[Heer & Bostock, 2010]

Test % difference in **length** between elements



[Heer & Bostock, 2010]

Test % difference in **length** between elements



[Heer & Bostock, 2010]

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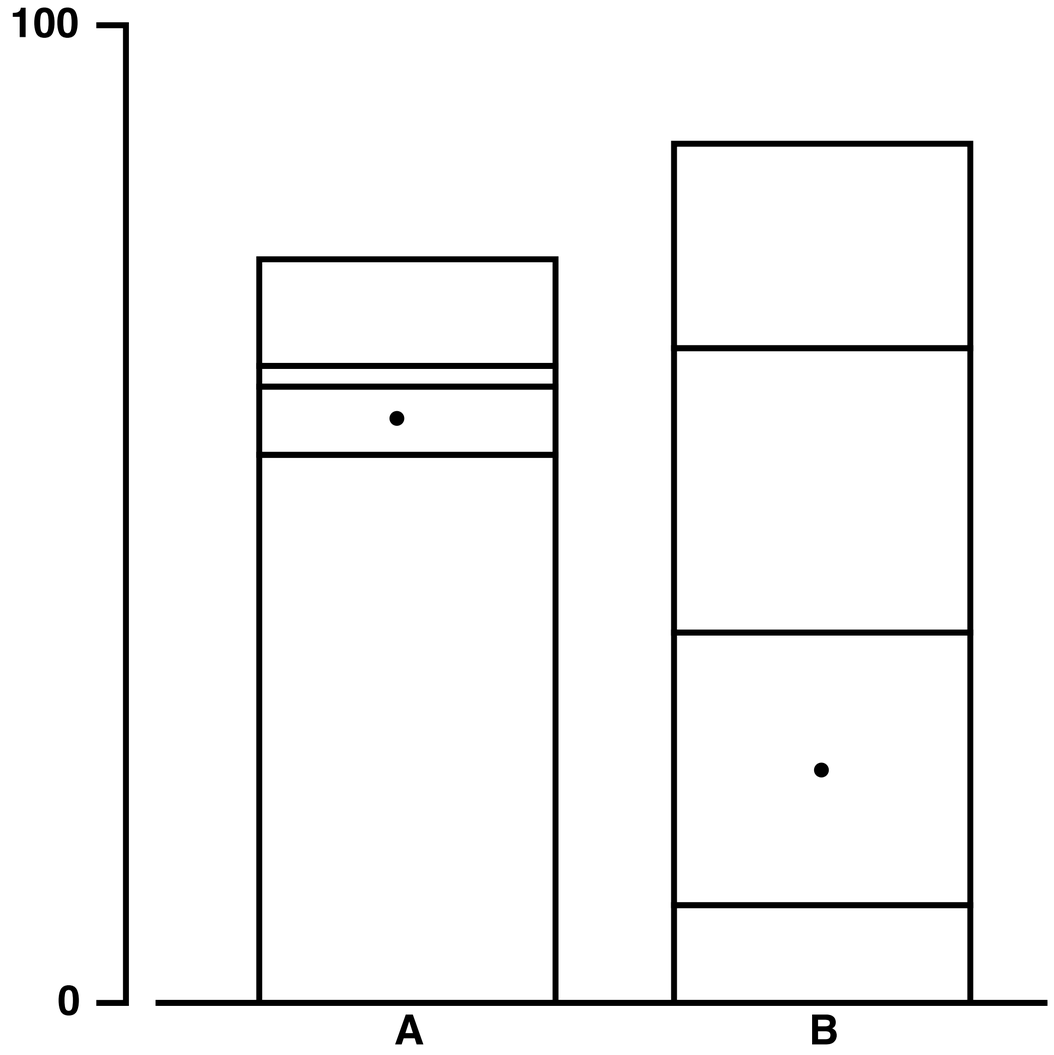
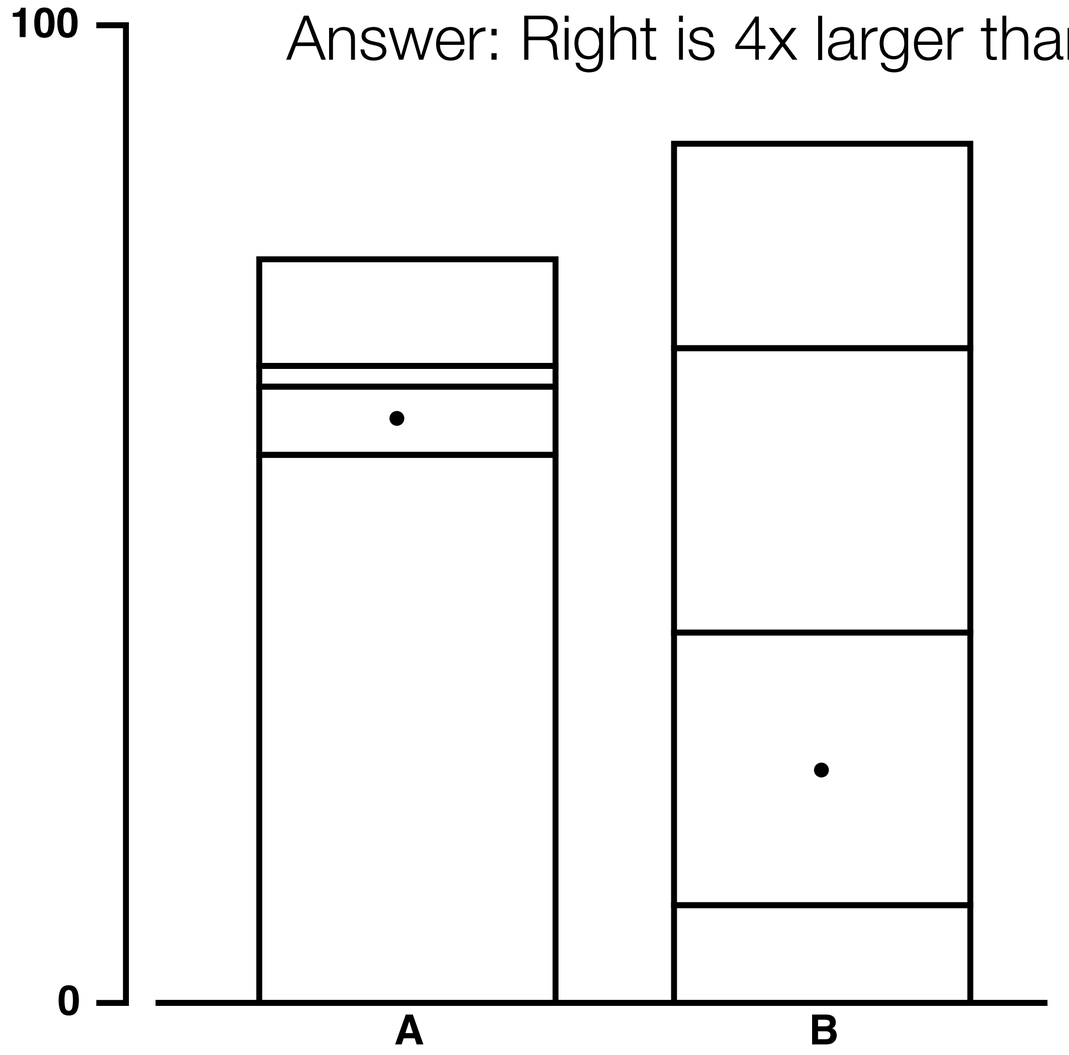


[Modified from Heer & Bostock, 2010]

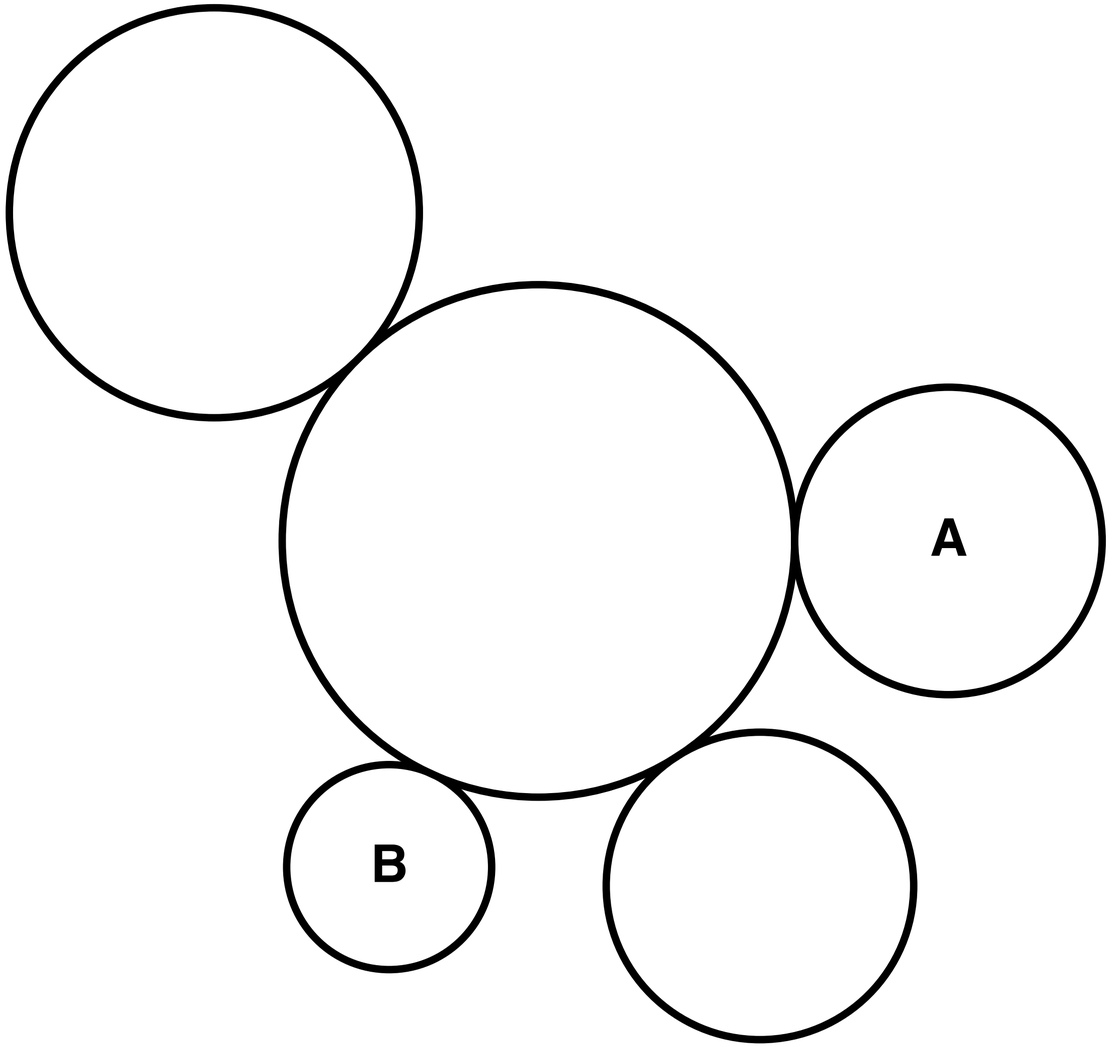
Test % difference in **length** between elements



Answer: Right is 4x larger than Left

[Modified from Heer & Bostock, 2010]

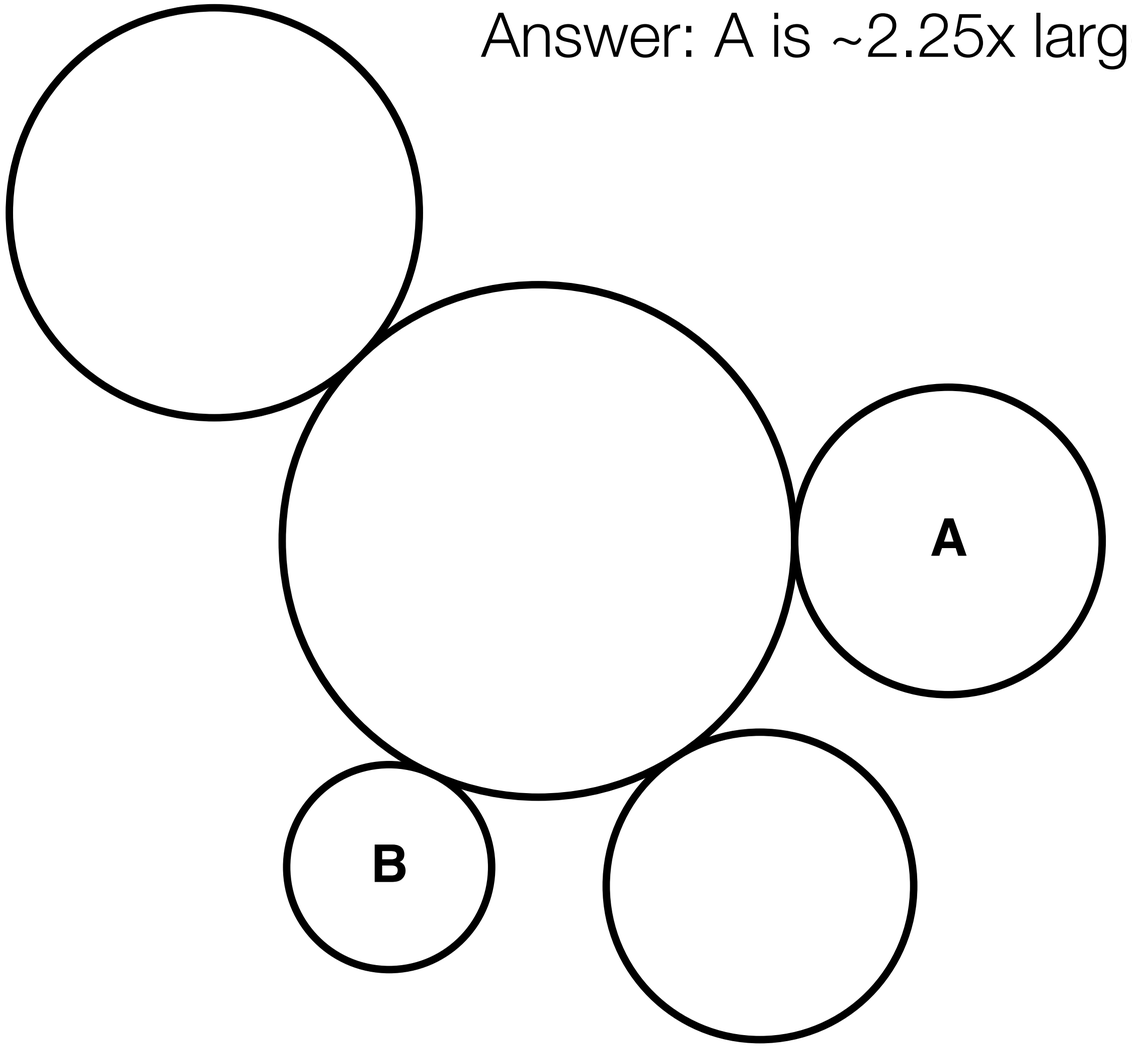
Test % difference in **area** between elements



[Heer & Bostock, 2010]

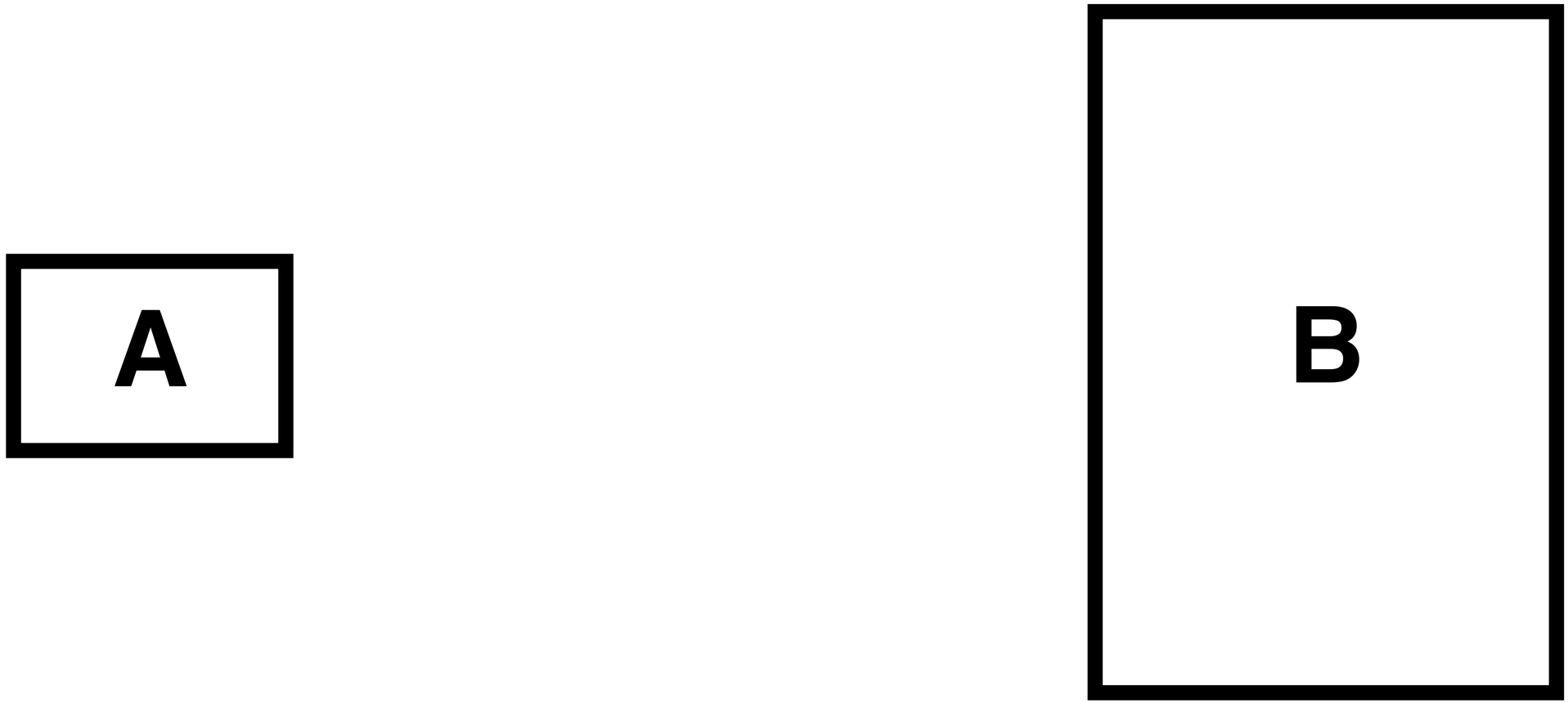
Test % difference in **area** between elements

Answer: A is ~2.25x larger (in area) than B



[Heer & Bostock, 2010]

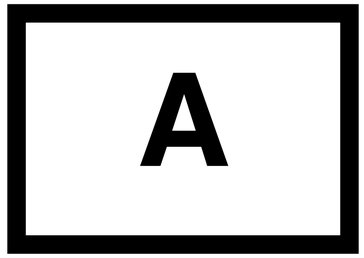
Test % difference in **area** between elements

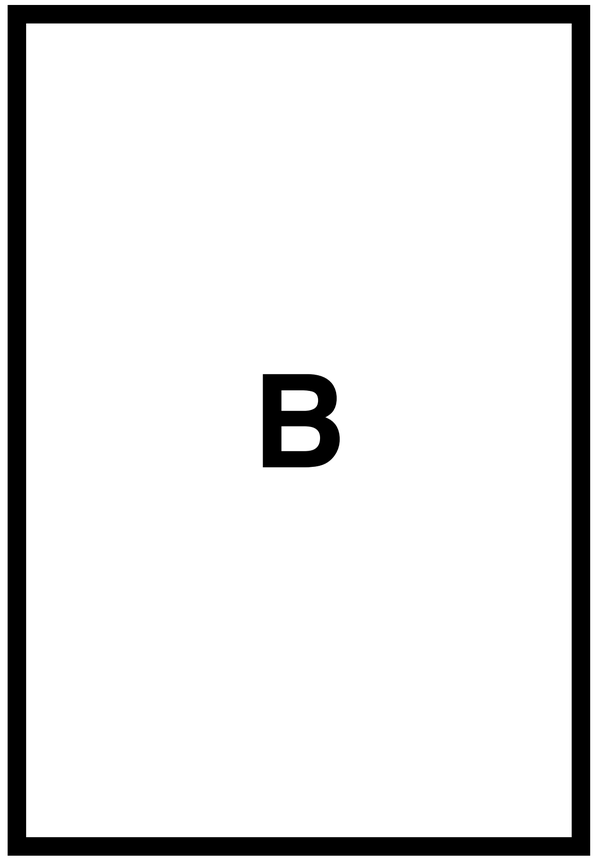


[Heer & Bostock, 2010]

Test % difference in **area** between elements

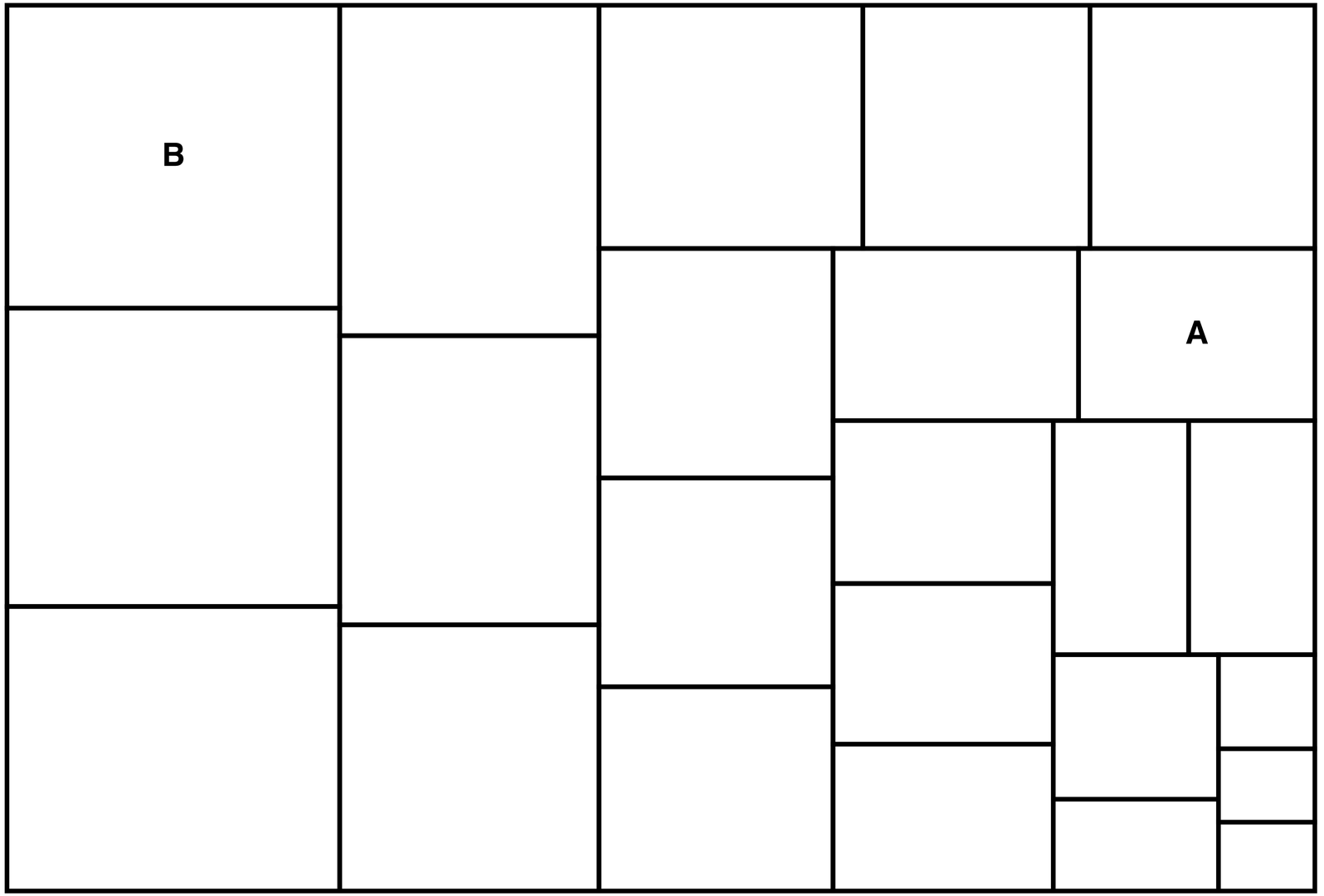
Answer: B is ~6.1x larger (in area) than A





[Heer & Bostock, 2010]

Test % difference in **area** between elements



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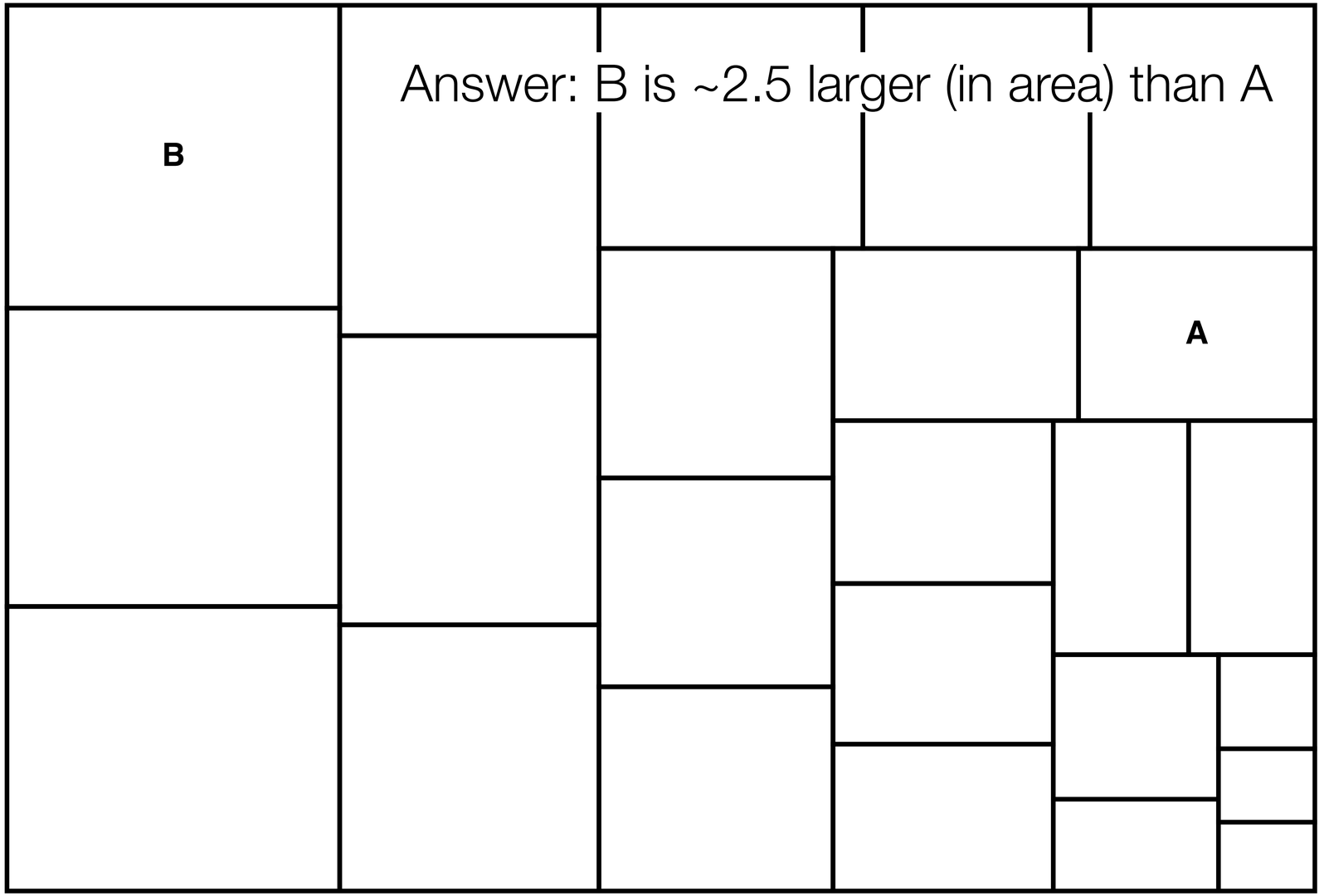
Test % difference in **area** between elements



[Heer & Bostock, 2010]

Cleveland & McGill Experiments

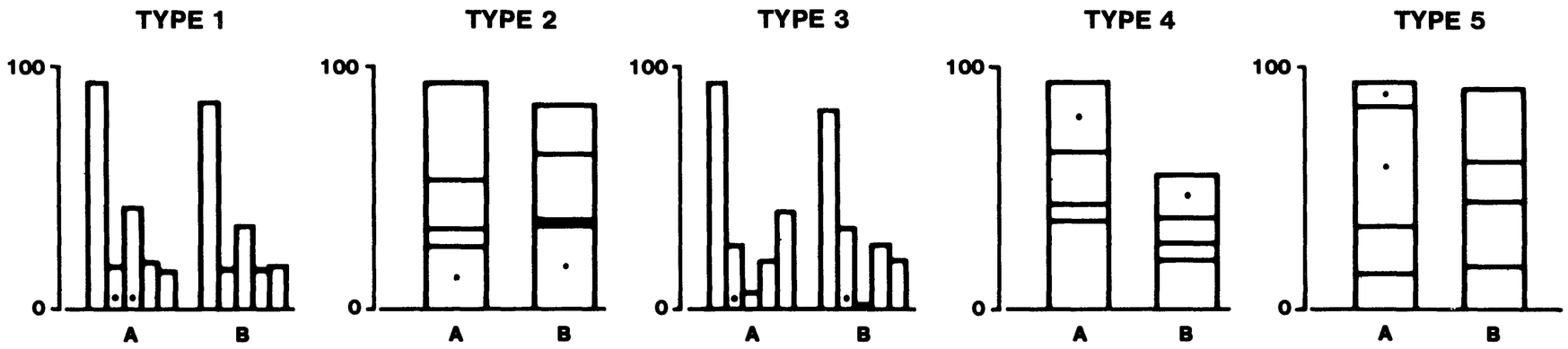


Figure 4. Graphs from position–length experiment.

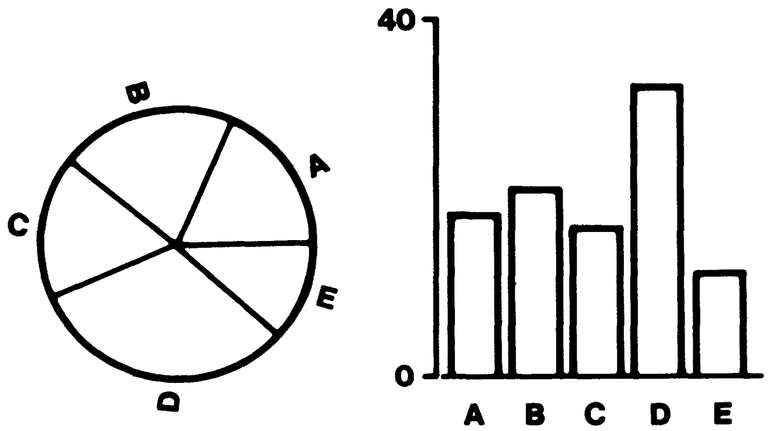


Figure 3. Graphs from position–angle experiment.

[Cleveland & McGill, 1984]

Heer & Bostock Experiments

- Rerun Cleveland & McGill's experiment using Mechanical Turk
- … with more tests

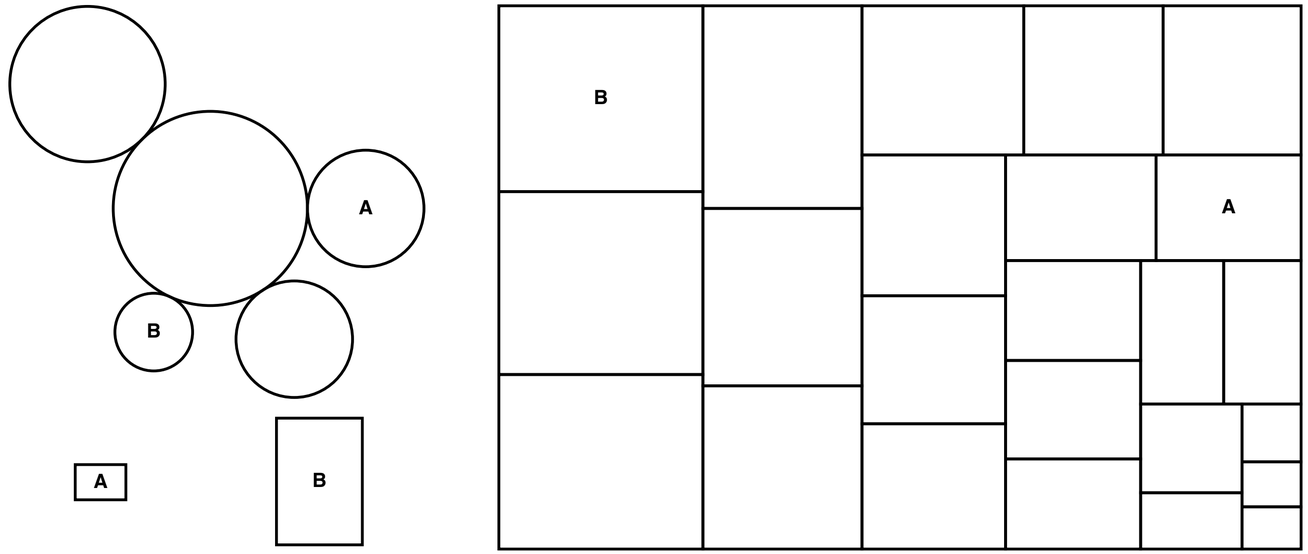
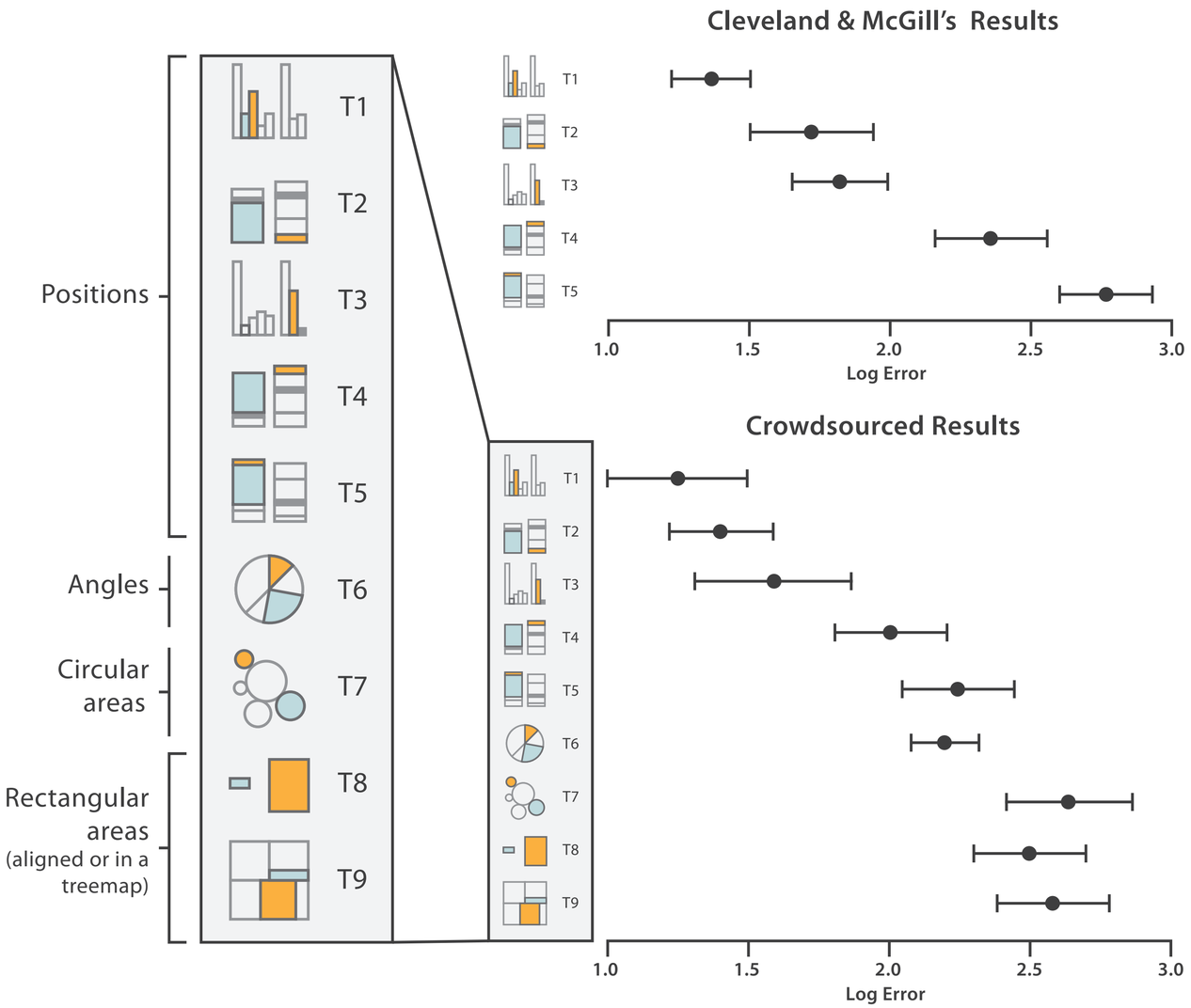


Figure 2: Area judgment stimuli. Top left: Bubble chart (T7), Bottom left: Center-aligned rectangles (T8), Right: Treemap (T9).

[Heer & Bostock, 2010]

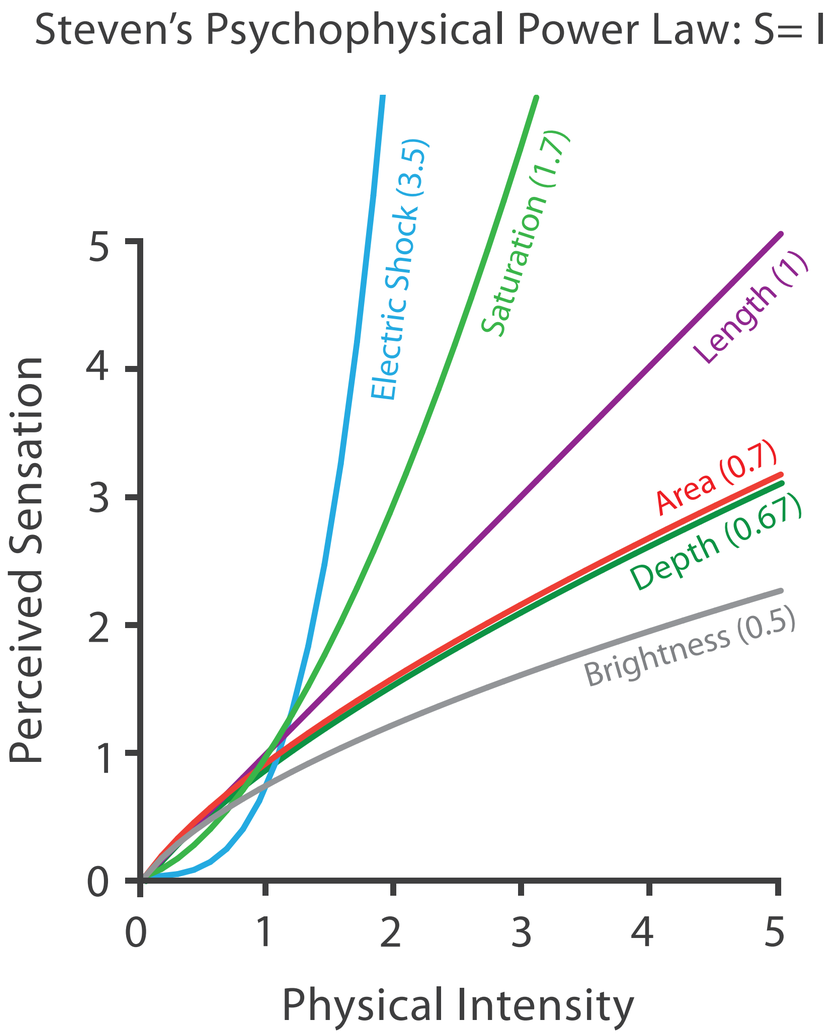
Results Summary



[Munzner (ill. Maguire) based on Heer & Bostock, 2014]

Psychophysics

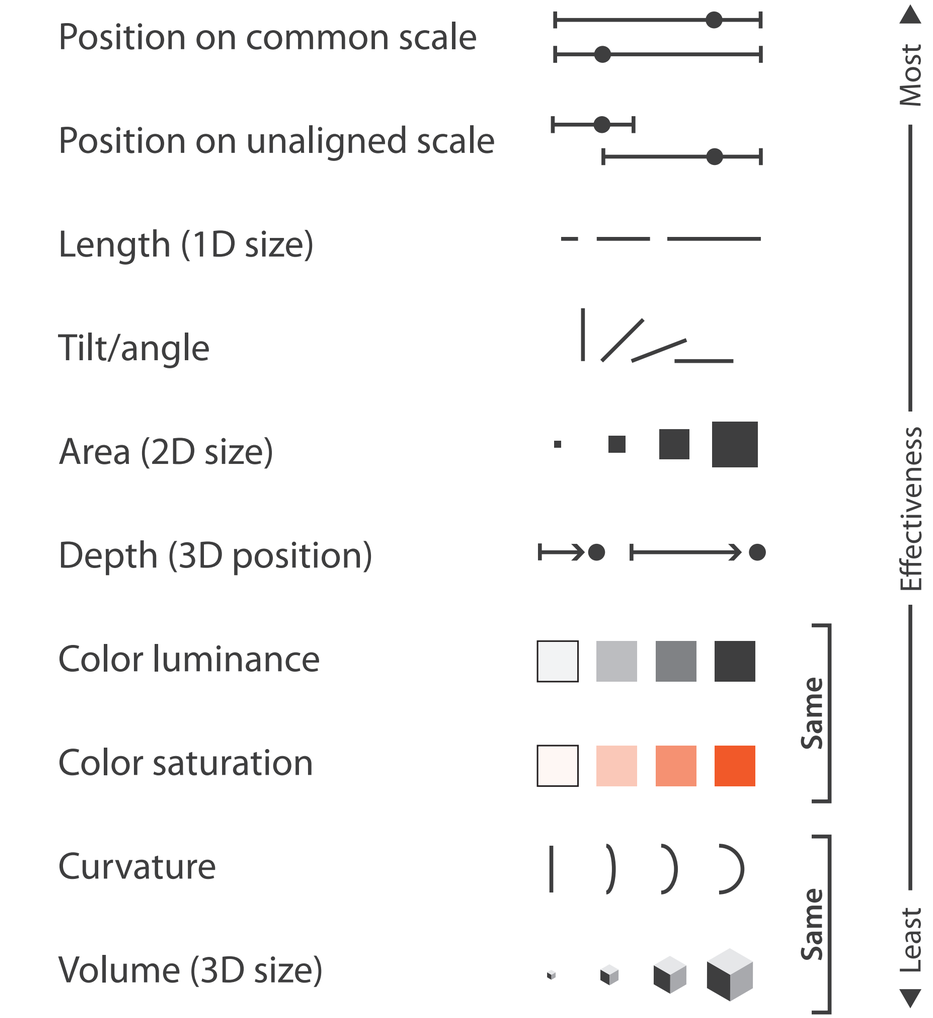
- How do we perceive changes in stimuli
- The Psychophysical Power Law [Stevens, 1975]: All sensory channels follow a power function based on stimulus intensity ($S = I^n$)
- Length is fairly accurate
- Magnified vs. compressed sensations



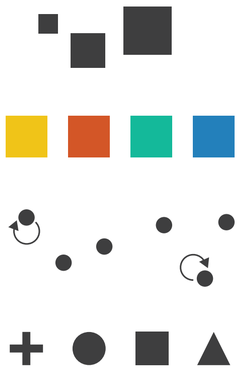
[Munzner (ill. Maguire), 2014]

Ranking Channels by Effectiveness

Magnitude Channels: Ordered Attributes



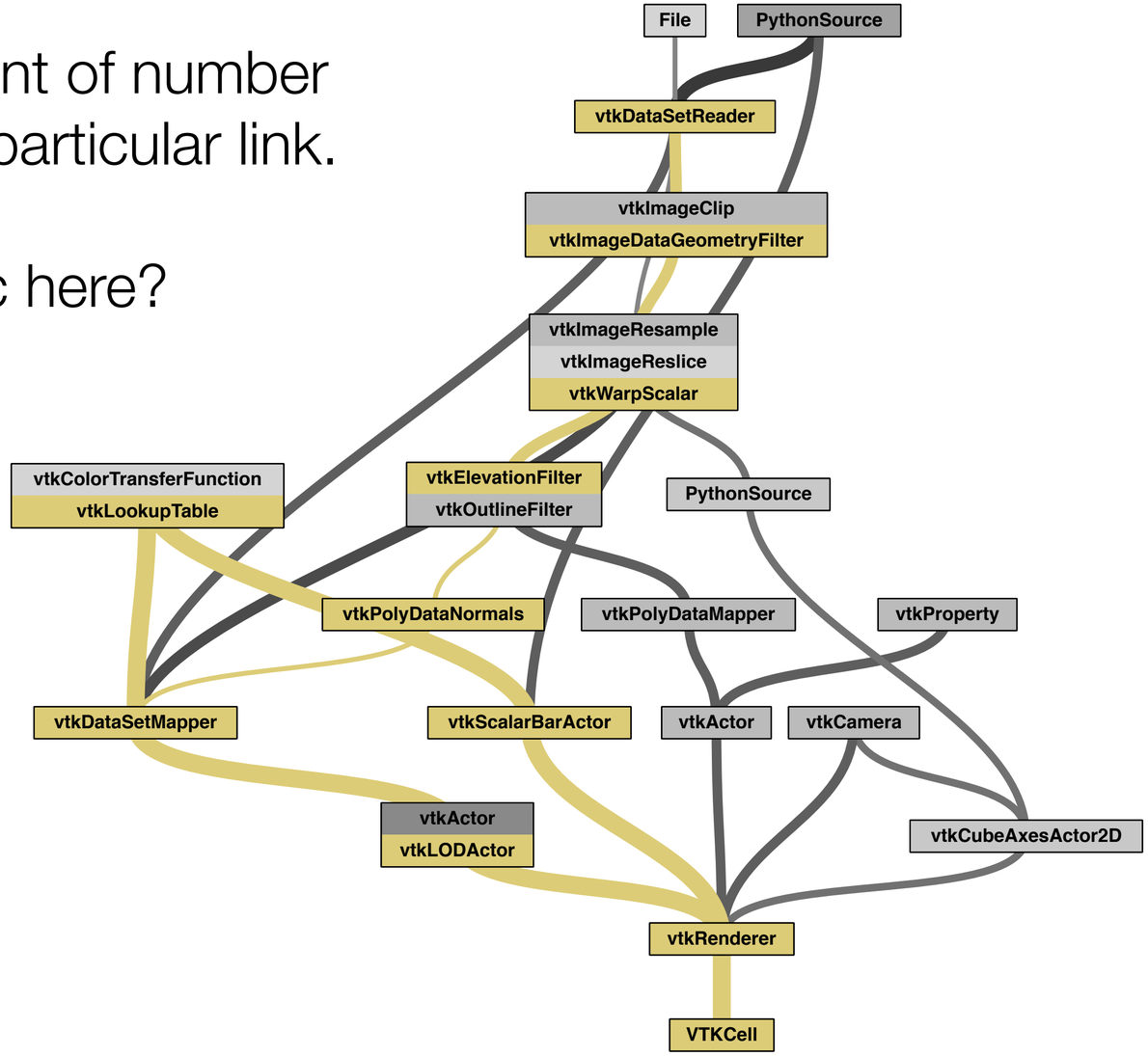
Identity Channels: Categorical Attributes



[Munzner (ill. Maguire), 2014]

Discriminability

- Width encodes count of number of networks with a particular link.
- What is problematic here?



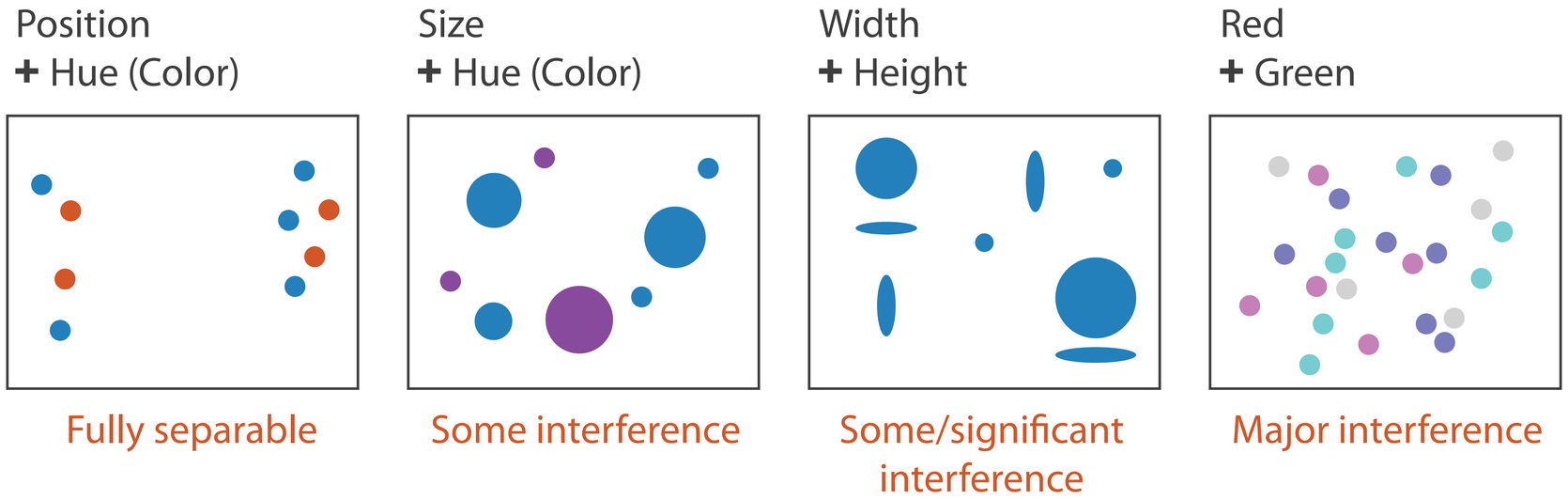
[Koop et al., 2013]

Discriminability

- Can someone tell the difference?
- How many values (bins) can be used so that a person can tell the difference?
- Example: Line width
  - Matching a particular width with a legend
  - Comparing two widths

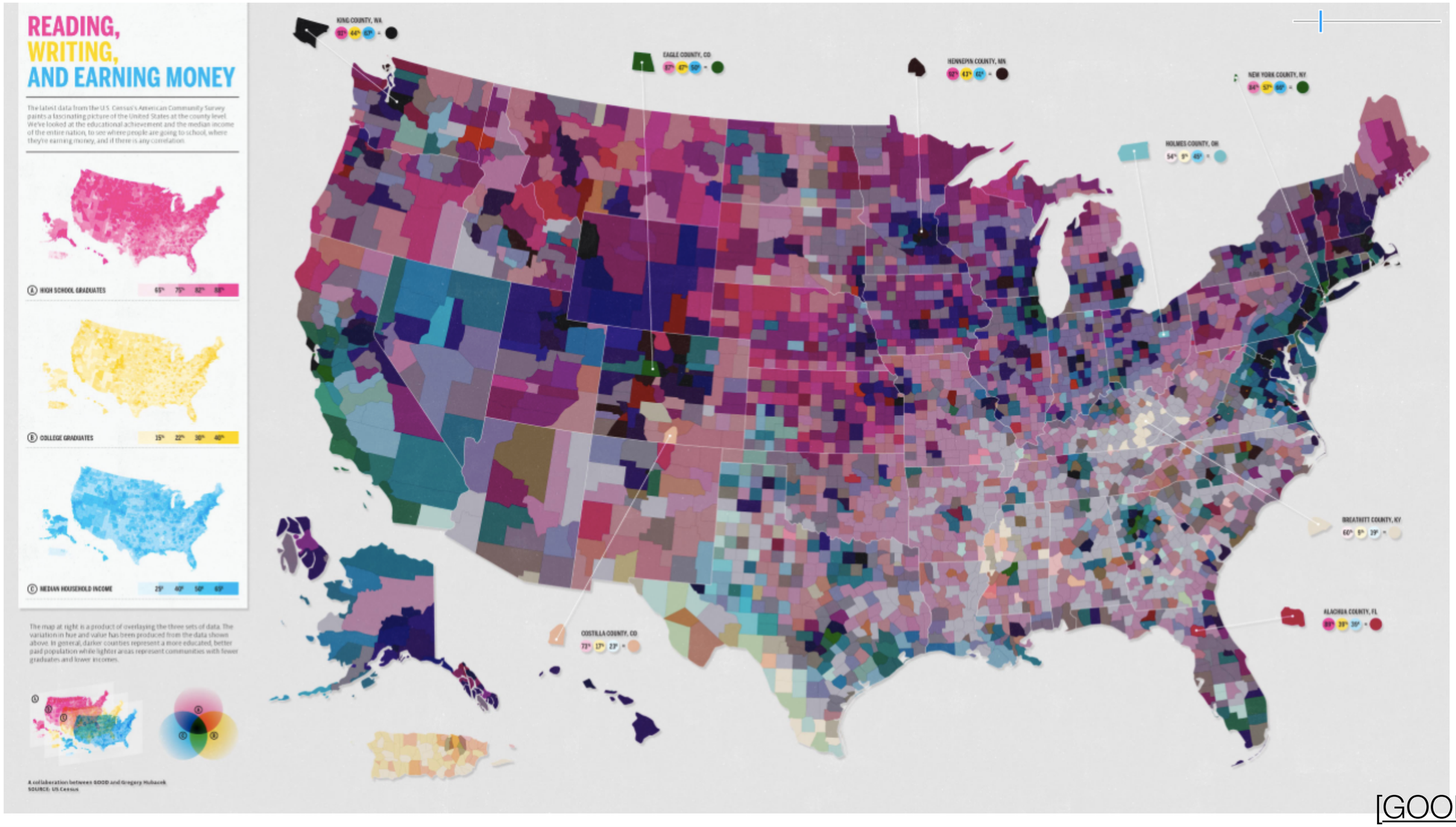
Separability

- Cannot treat all channels as independent!
- **Separable** means each individual channel can be distinguished
- **Integral** means the channels are perceived together



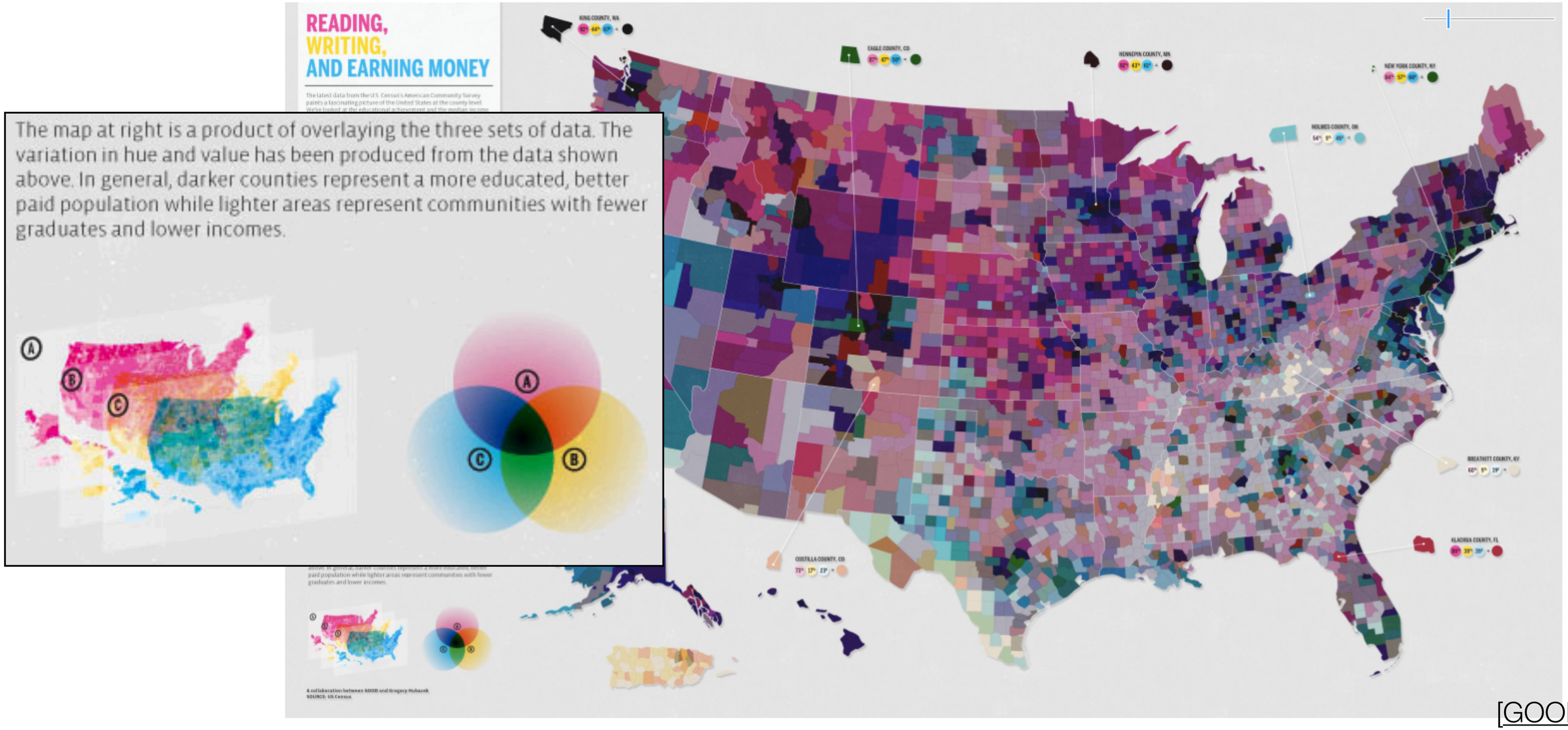
[Munzner (ill. Maguire) based on Ware, 2014]

Separable or Integral?



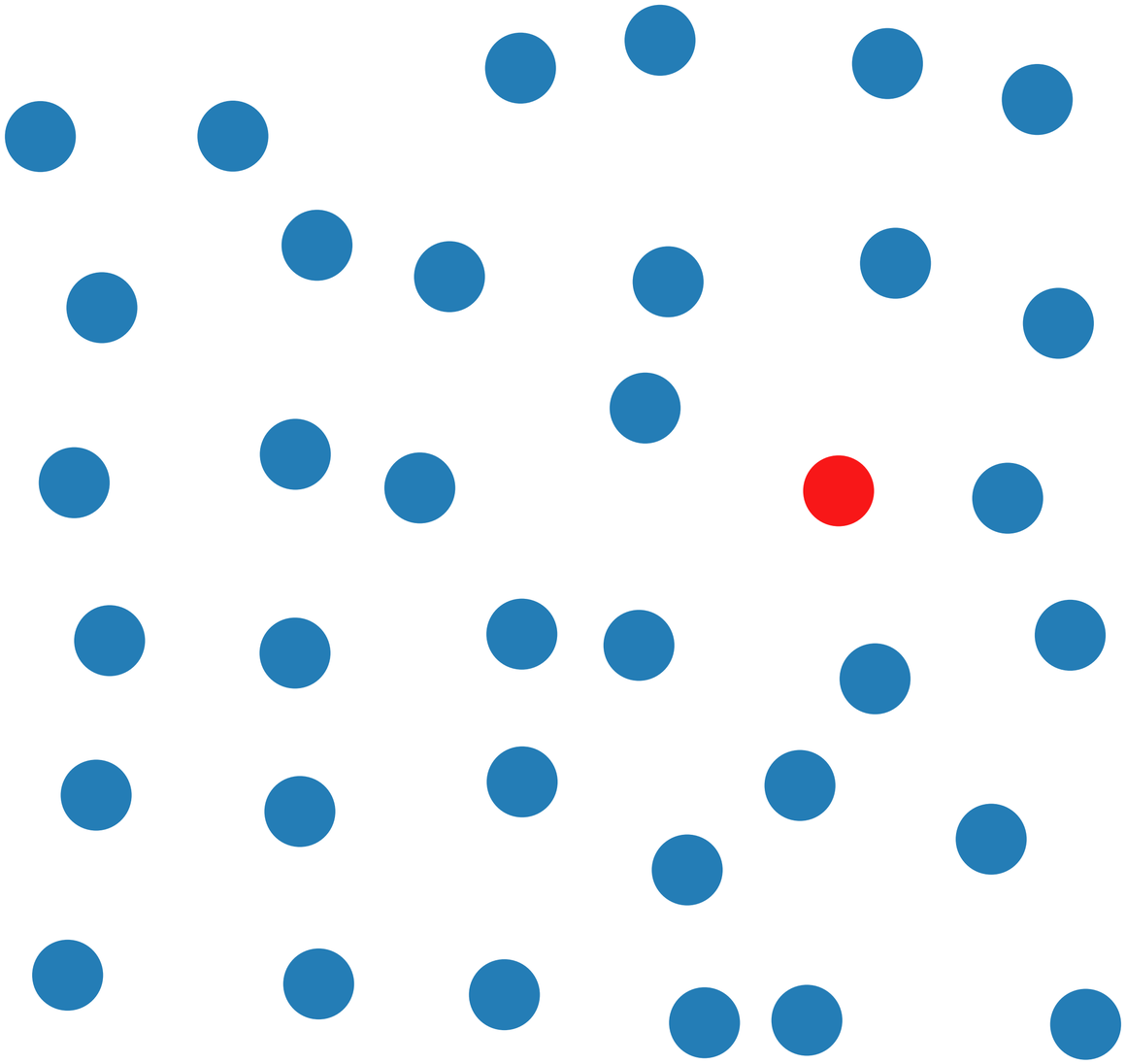
[GOOD]

Separable or Integral?



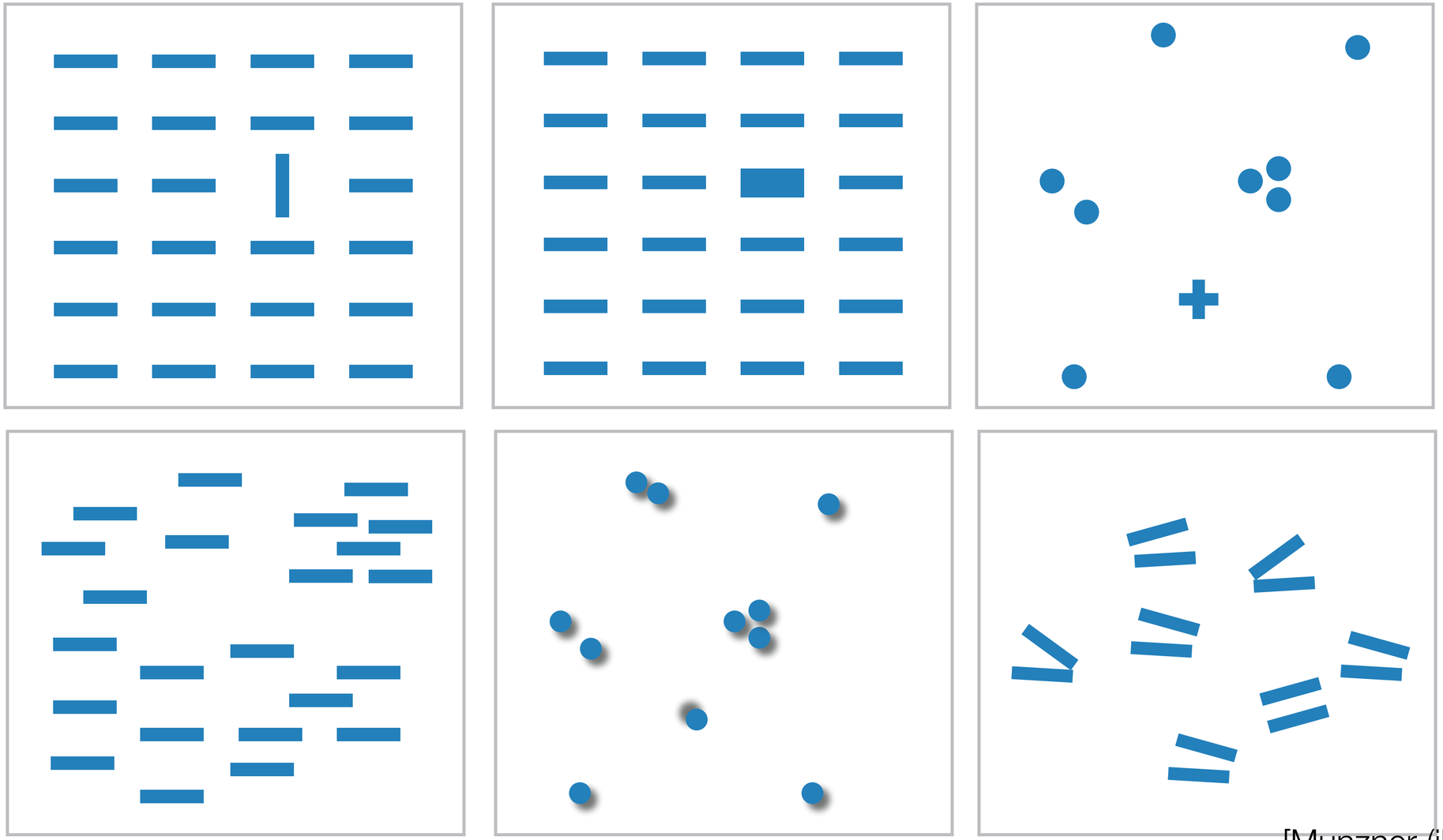
[GOOD]

Visual Popout



[C. G. Healey]

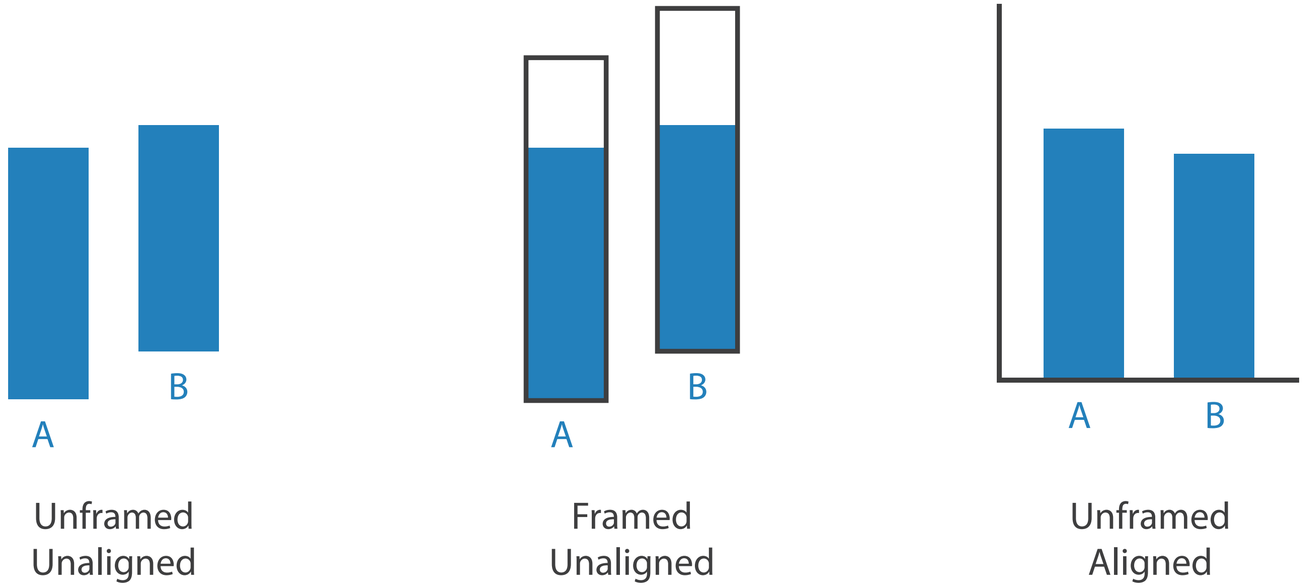
Visual Popout: Parallel Lines Require Search…



[Munzner (ill. Maguire), 2014]

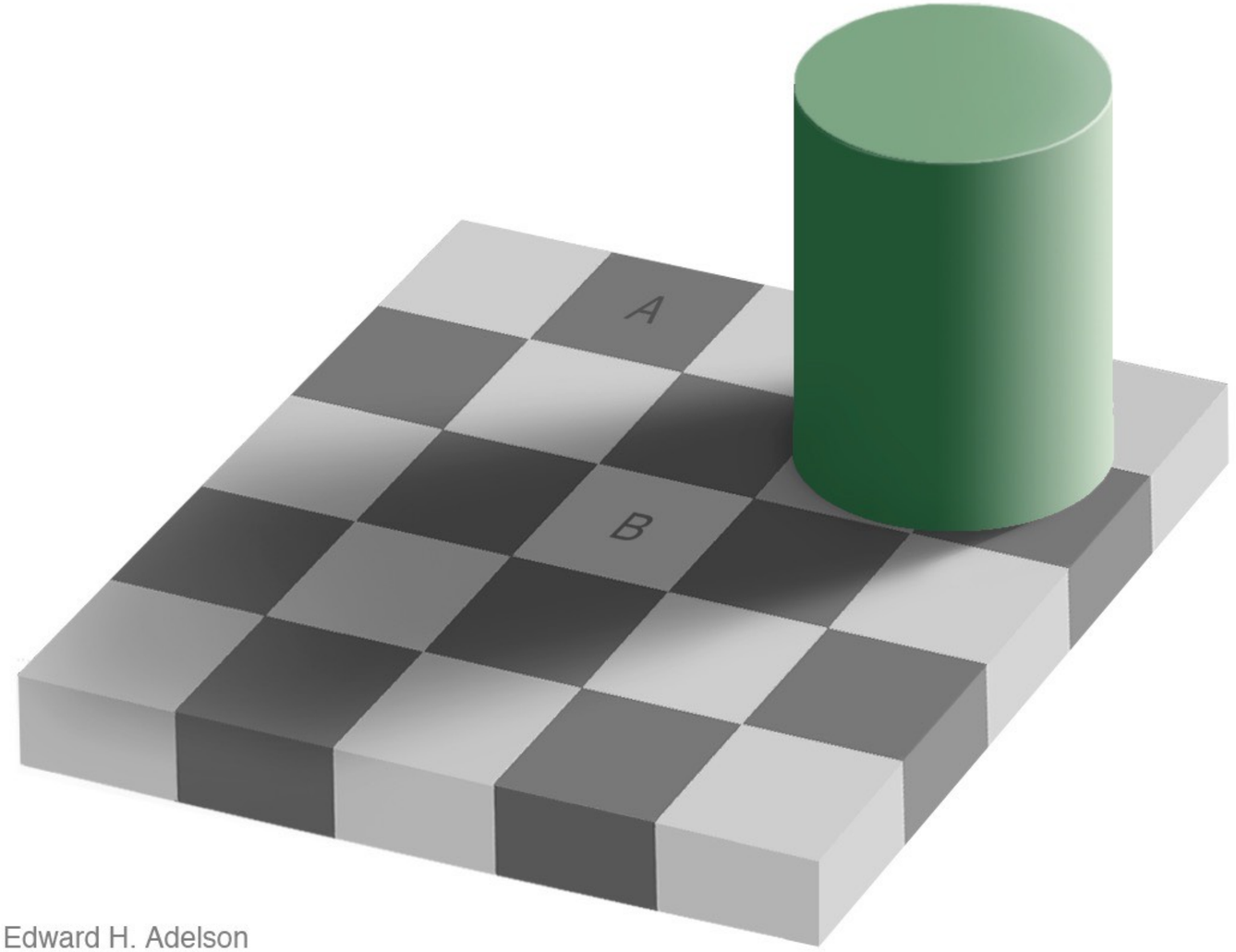
Relative vs. Absolute Judgments

- Weber's Law:
  - We judge based on relative not absolute differences
  - The amount of perceived difference is relative to the object's magnitude!



[Munzner (ill. Maguire), 2014]

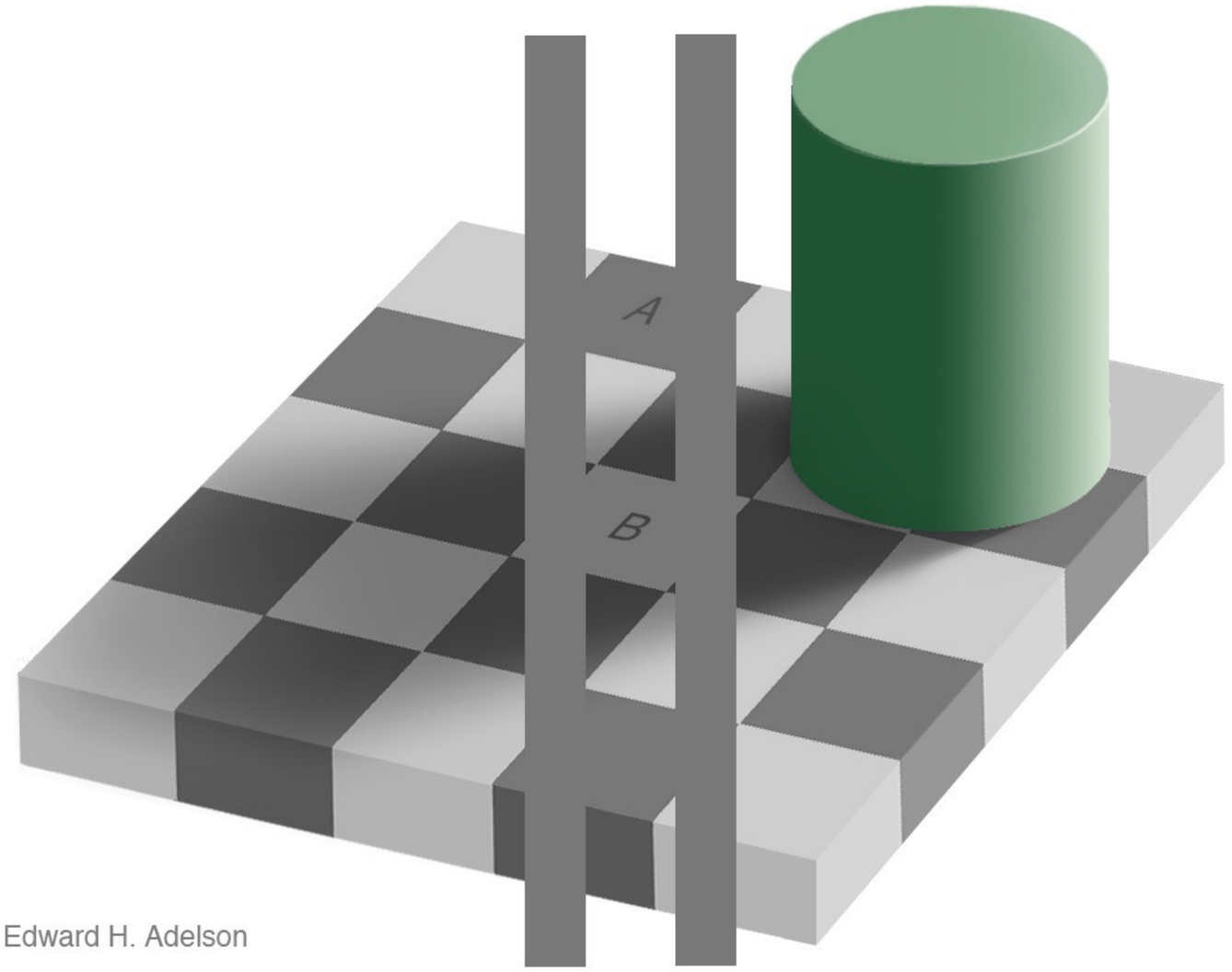
Luminance Perception



Edward H. Adelson

[E. H. Adelson, 1995]

Luminance Perception



[E. H. Adelson, 1995]