Data Visualization (CSCI 627/490)

Marks and Channels

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D3 Examples

- Observable Notebook
- Three Bar Charts:
  - Similar Solution
  - With Axes and Scales
  - WIth Objects and Margin Convention
- More on Margin Convention:
  - https://observablehq.com/@d3/margin-convention

Toward Reusable Charts

- D3 does not provide "standard" charts
- E.g. there is no barchart method
- What is a standard chart?
  - "Should you expose the underlying scales and axes, or encapsulate them with chart-specific representations?"
  - "Should your chart support interaction and animation automatically?"
  - "Should the user be able to reach into your chart and tweak some aspect of its behavior?"

[Towards Reusable Charts, M. Bostock, 2012]

Assignment 3

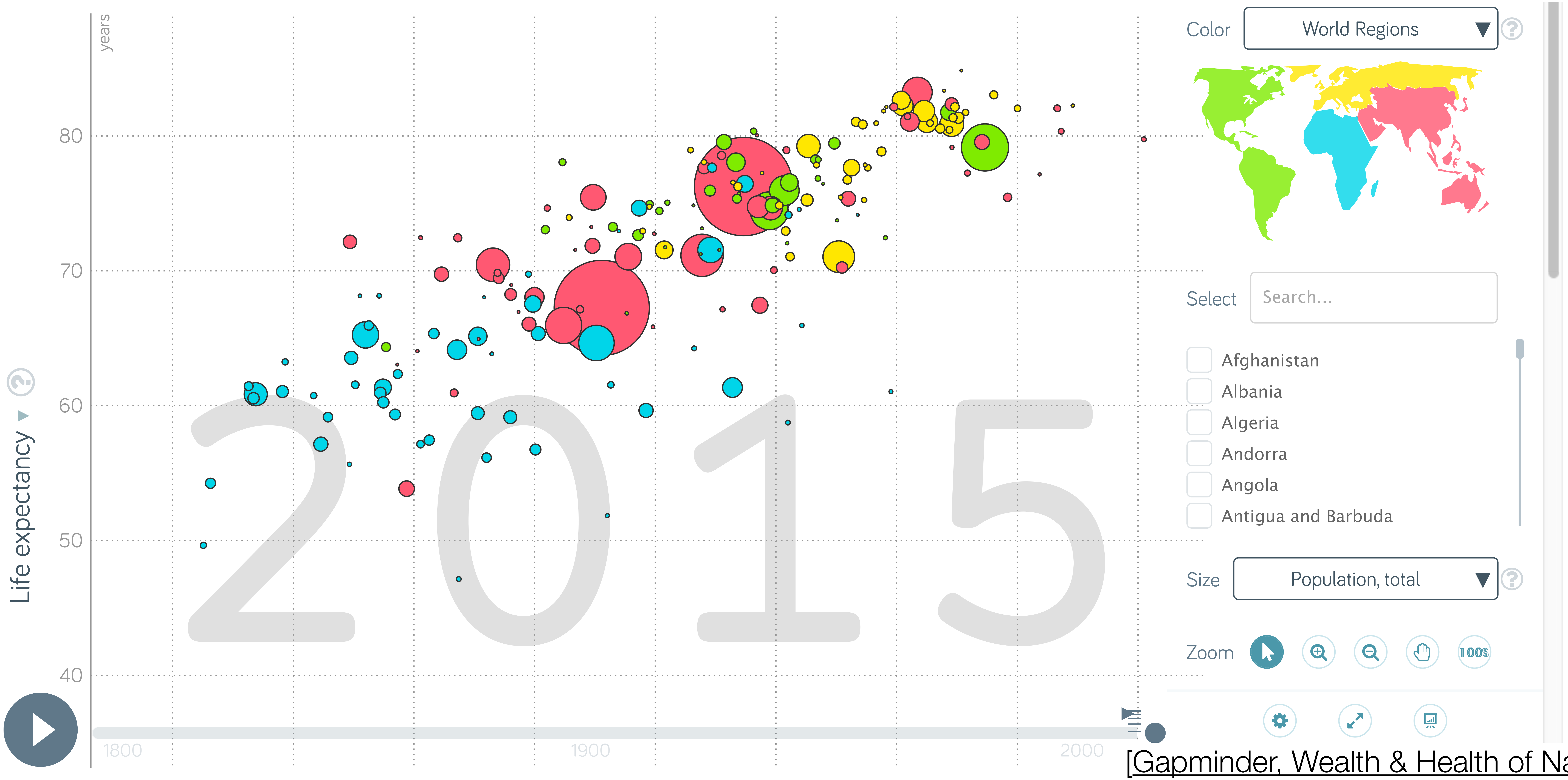
- Upcoming
- Same visualization
- Different tools

Visual Encoding

- How should we visualize this data?

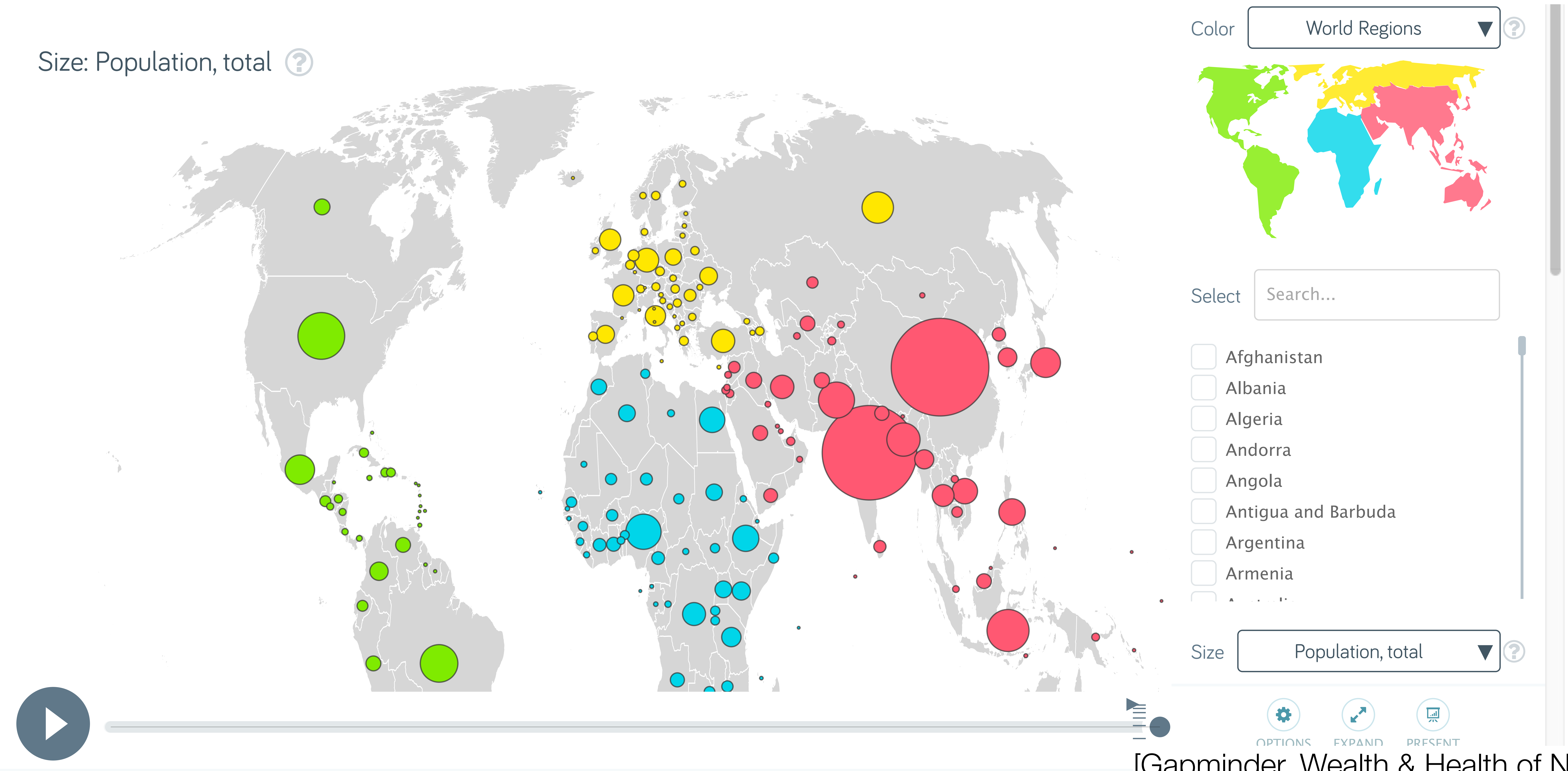
Name	Region	Population	Life Expectancy	Income
China	East Asia & Pacific	1335029250	73.28	7226.07
India	South Asia	1140340245	64.01	2731
United States	America	306509345	79.43	41256.08
Indonesia	East Asia & Pacific	228721000	71.17	3818.08
Brazil	America	193806549	72.68	9569.78
Pakistan	South Asia	176191165	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]

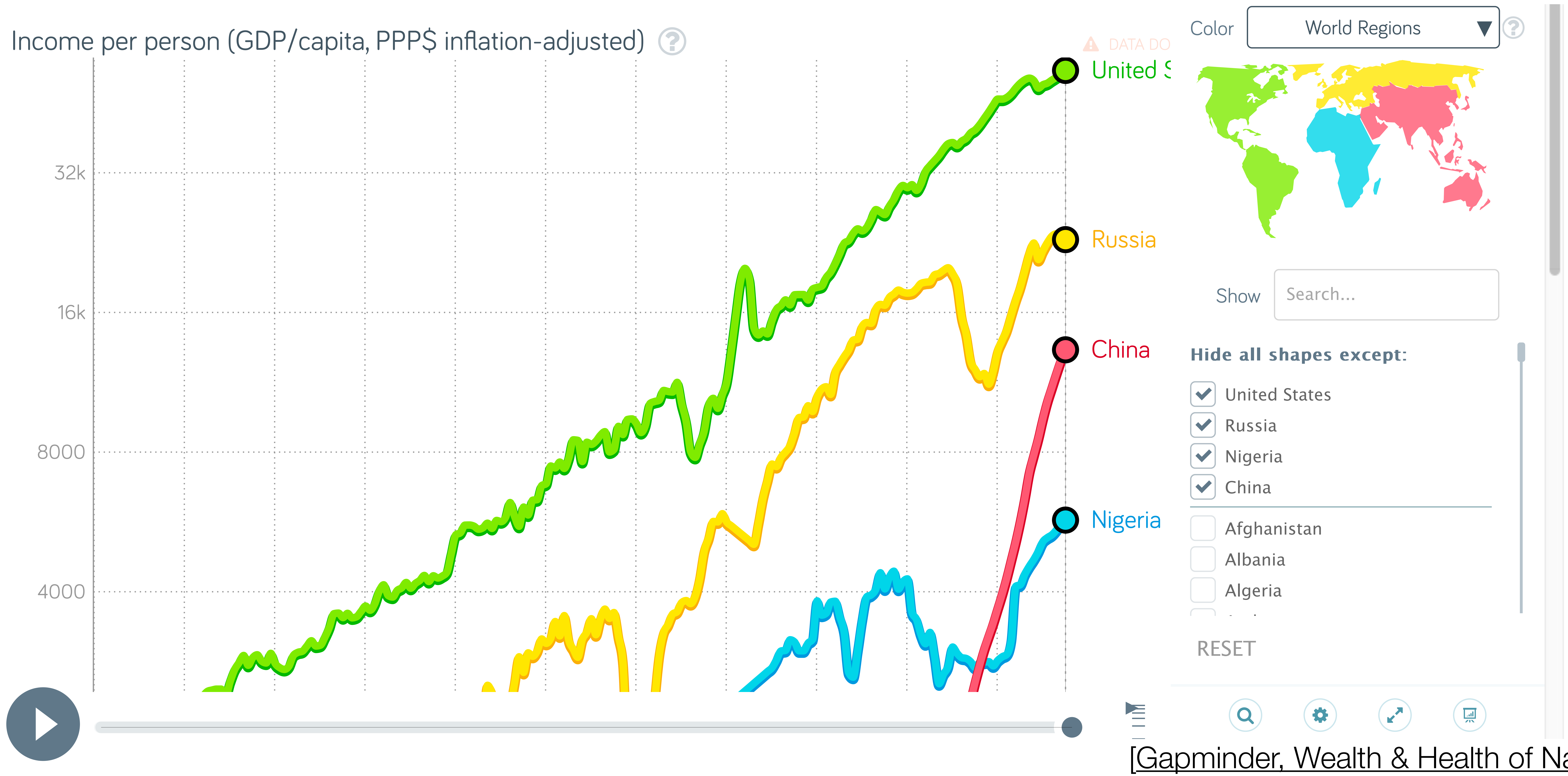
Another Solution



[Gapminder, Wealth & Health of Nations]

What about change over years?

Another Solution showing trends over time



[Gapminder, Wealth & Health of Nations]

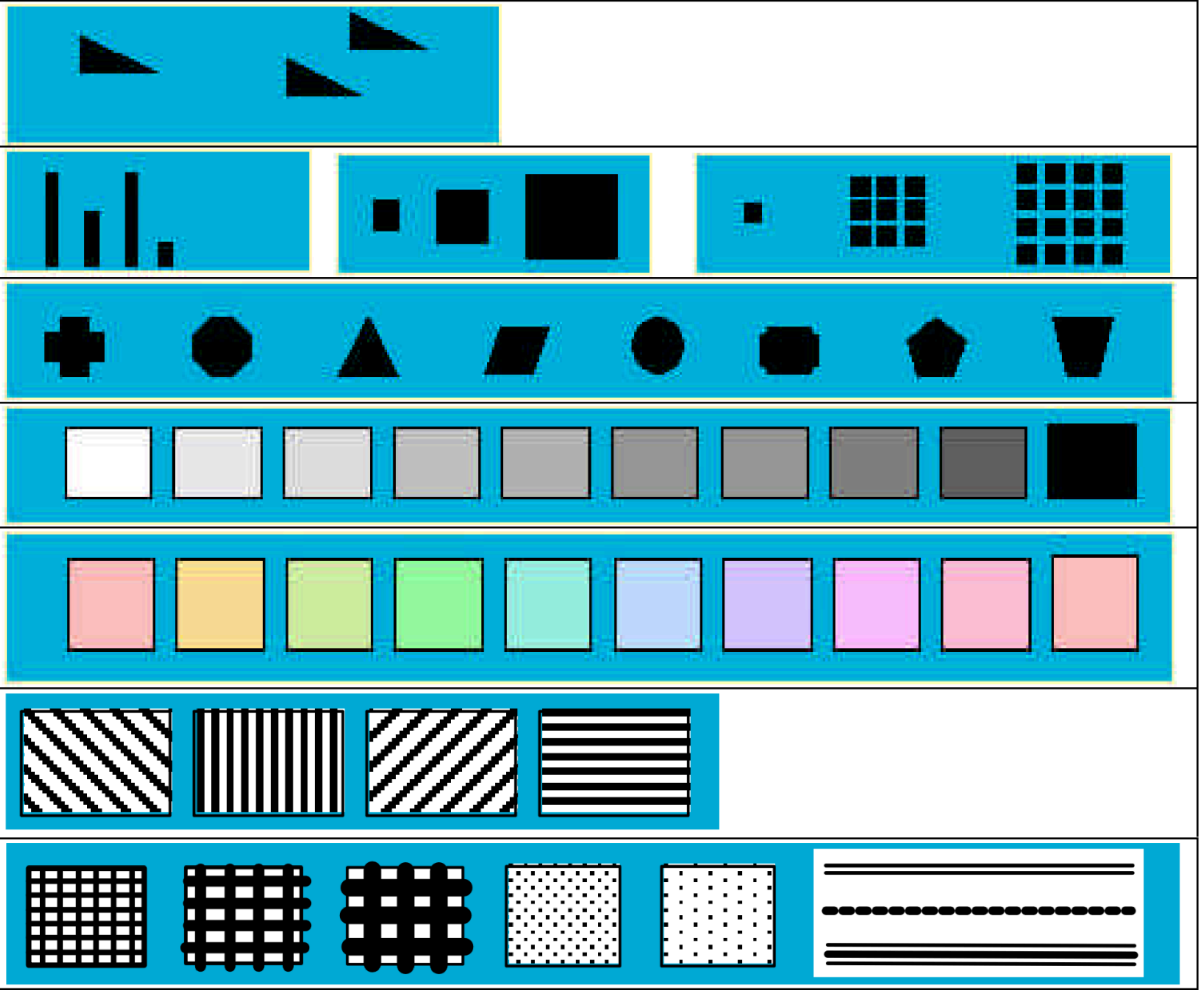
Visual Encoding

- 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:

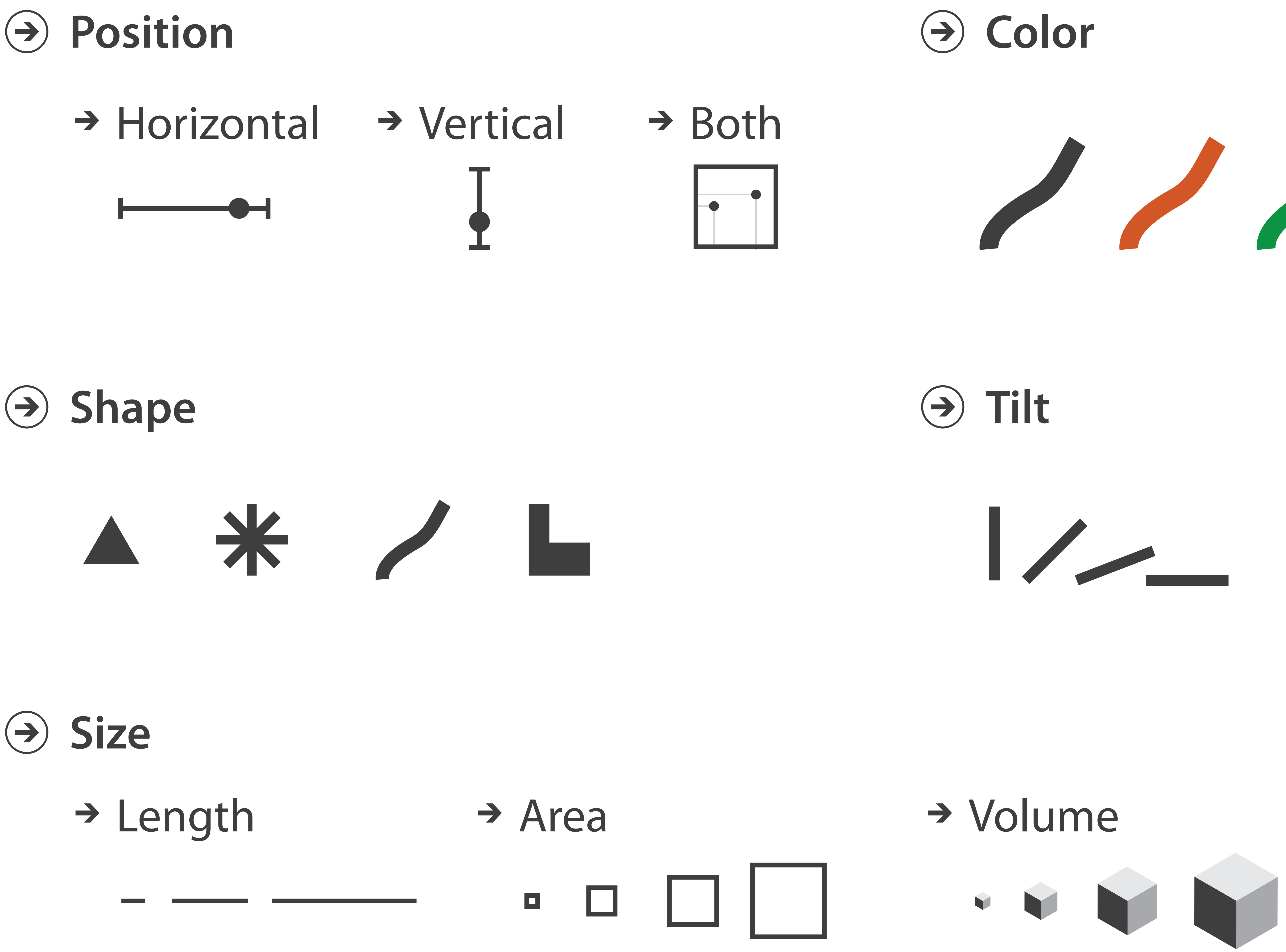
- Also can have surfaces, volumes
- Think of marks as a mathematical definition, or if familiar with tools like Adobe Illustrator or Inkscape, the path & point definitions

Bertin - Visual Variables

Bertin's Original Visual Variables
Position changes in the x, y location
Size change in length, area or repetition
Shape infinite number of shapes
Value changes from light to dark
Colour changes in hue at a given value
Orientation changes in alignment
Texture variation in 'grain'



Visual Channels



[Munzner (ill. Maguire), 2014]

Visual Attributes Survey

Table of Visual Attributes
Richard Brath
v. Sept 2013

		Information Visualization Researchers									Vision Rsch	Shape Rsch
		Bertin 1967	Cleveland 1985	MacKinlay 1986	MacEachren 1995	Wilkinson 1999	Ware 2000	Mazza 2009	Iliinsky 2012	Chen, Floridi 2013	Preattentive Perception	Brath 2009/2011
Trans-form	Position	X	X	X	X	X	X	X	X	X		
	Length		X	X			X	X	X	X	X	
	Size (Area)	X	X	X	X	X	X	X	X	X	X	
	Orientation	X		X	X	X	X	X	X	X	X	
	Volume		X	X			X					
Shape	Shape	X		X	X	X	X	X	X	X		X
	Angle		X	X						X		X
	Curvature										X	X
	Mark										X	X
	Line Ending							X	X	3	X	X
	Closure									X	X	X
	Local Warp											X
	Edge Type									1,2		X
	Corner Type									3		X
	Icon, glyph, etc									4		
Colour	Brightness	X		X	X	X	X	X	X	X	X	
	Hue	X	X	X	X	X	X	X	X	X	X	
	Saturation			X	X	X	X	X	X	X		

[R. Brath]

More Visual Attributes

Table of Visual Attributes
Richard Brath
v. Sept 2013

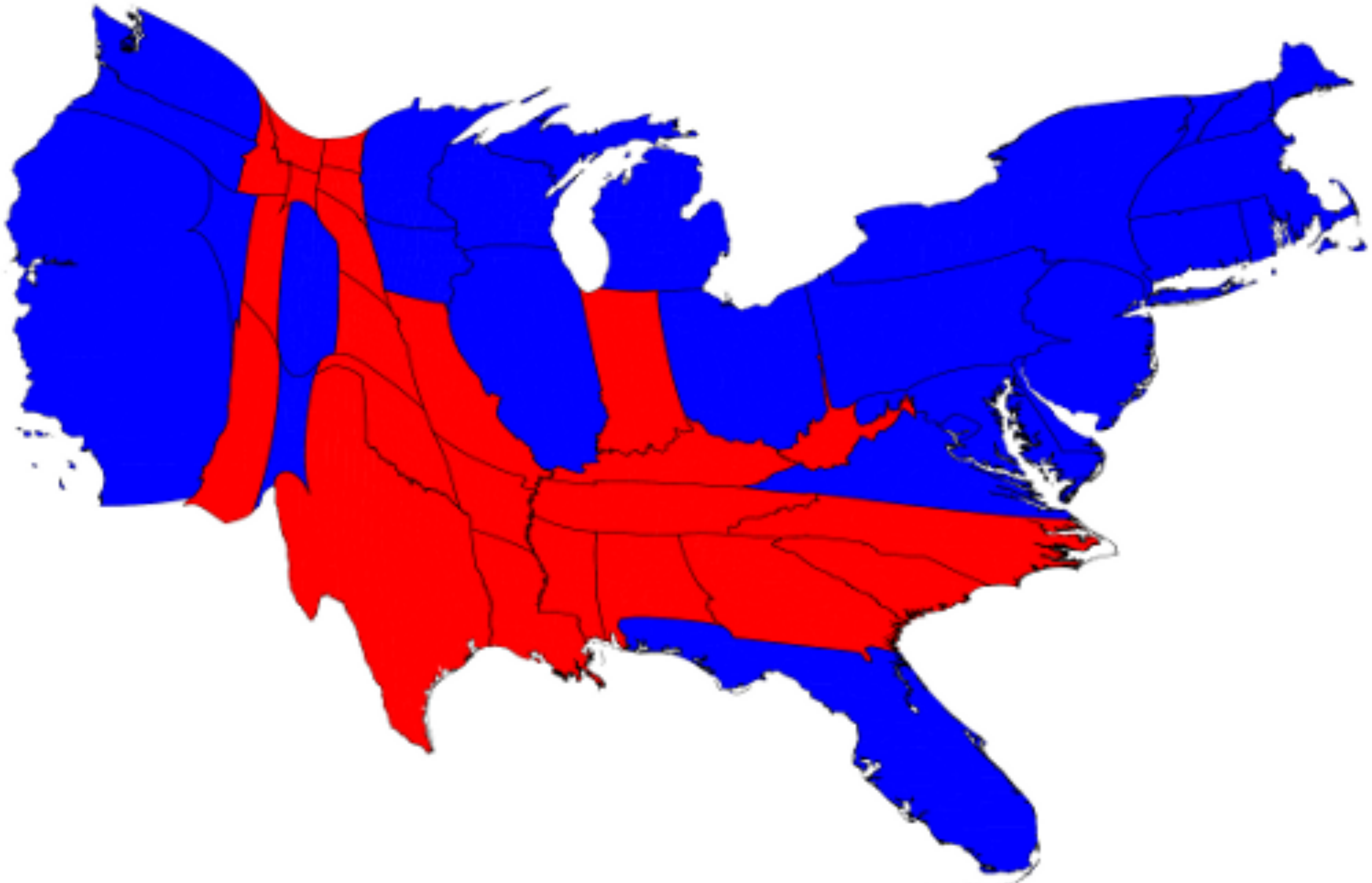
		Information Visualization Researchers									Vision Rsch	Shape Rsch
		Bertin 1967	Cleveland 1985	MacKinlay 1986	MacEachren 1995	Wilkinson 1999	Ware 2000	Mazza 2009	Iliinsky 2012	Chen, Floridi 2013	Preattentive Perception	Brath 2009/2011
Texture	Granularity	X		X	X	X	X	X	X	X		
	Pattern					X	X	X	X			
	Orientation					X	X					
Relation	Connection			X				X	X	X		
	Containment			X				X	X			
Optics	Blur				X	X				X		
	Transparency				X	X				X		
	Stereo Depth										X	
	Concavity									X	X	
	Light Direction									X	X	
	Shadow									X		
	Partial occlusion									X		
Move-ment	Flicker						X			X	X	
	Speed						X			X	X	
	Direction									X	X	
Misc	Numerosity									X	X	
	Spatial Grouping									X	X	
	Arrangement				X							
	Resolution				X							
	Artistic Effects										X	
	Text Labels							X	X	X		

[R. Brath]

Channels

- Usually map an attribute to a single channel
  - Could use multiple channels but…
  - **Limited** number of channels
- Restrictions on size and shape
  - Points are nothing but location so size and shape are ok
  - Lines have a length, cannot easily encode attribute as length
  - Maps with boundaries have area, changing size can be problematic

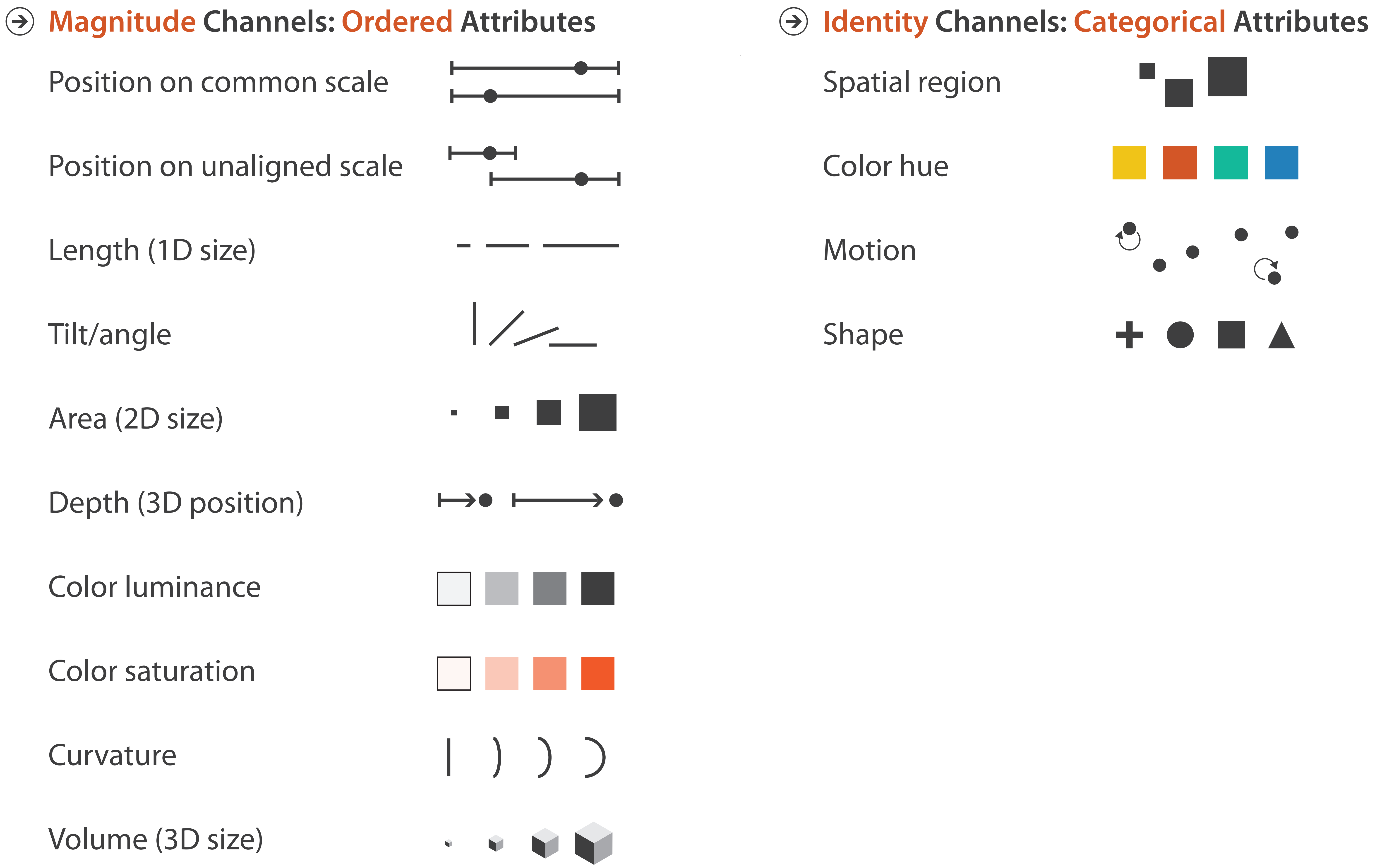
Cartograms



[Election Results by Population, M. Newman, 2012]

Channel Types

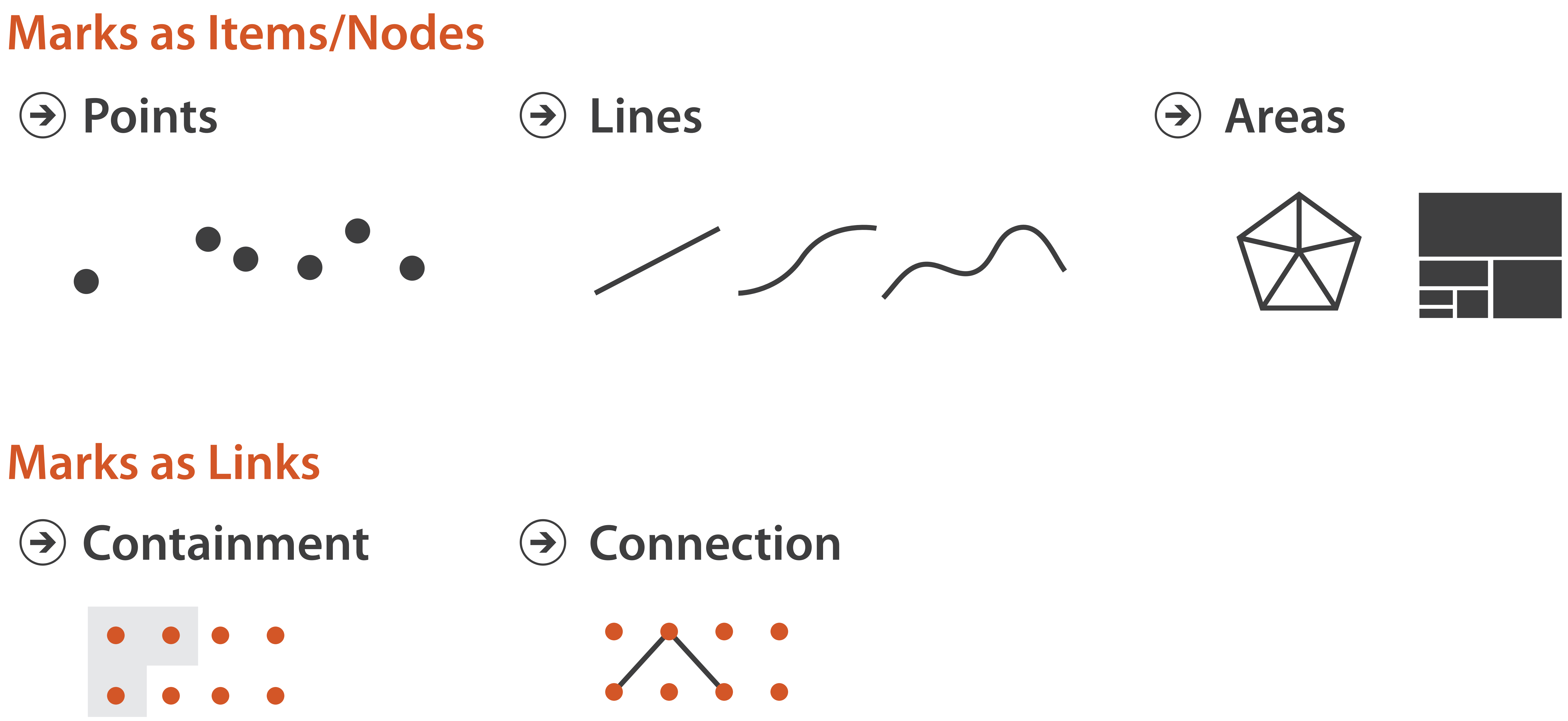
- Identity => what or where, Magnitude => how much



[Munzner (ill. Maguire), 2014]

Mark Types

- Can have marks for items and **links**
  - Connection => pairwise relationship
  - Containment => hierarchical relationship

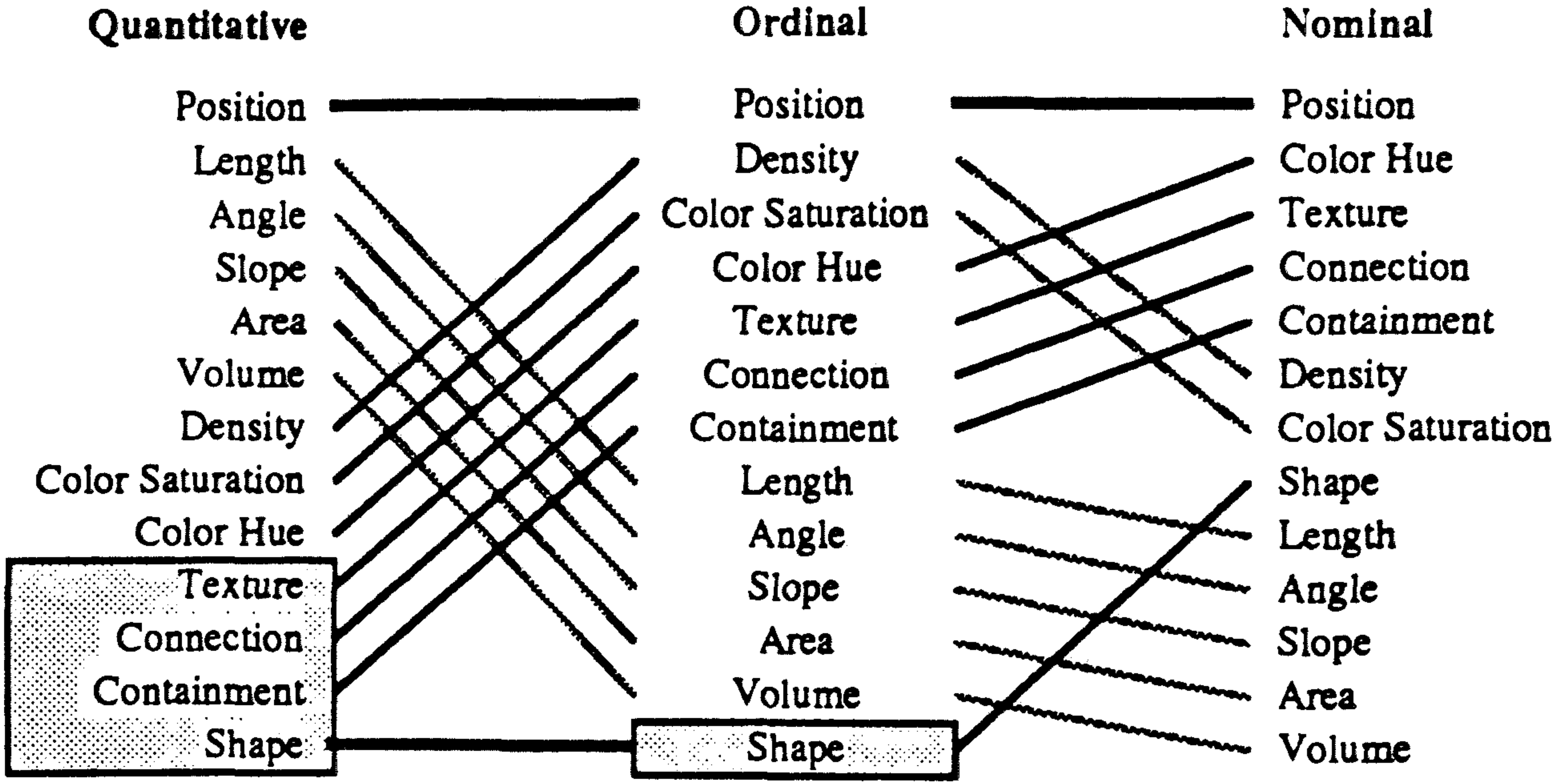


[Munzner (ill. Maguire), 2014]

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



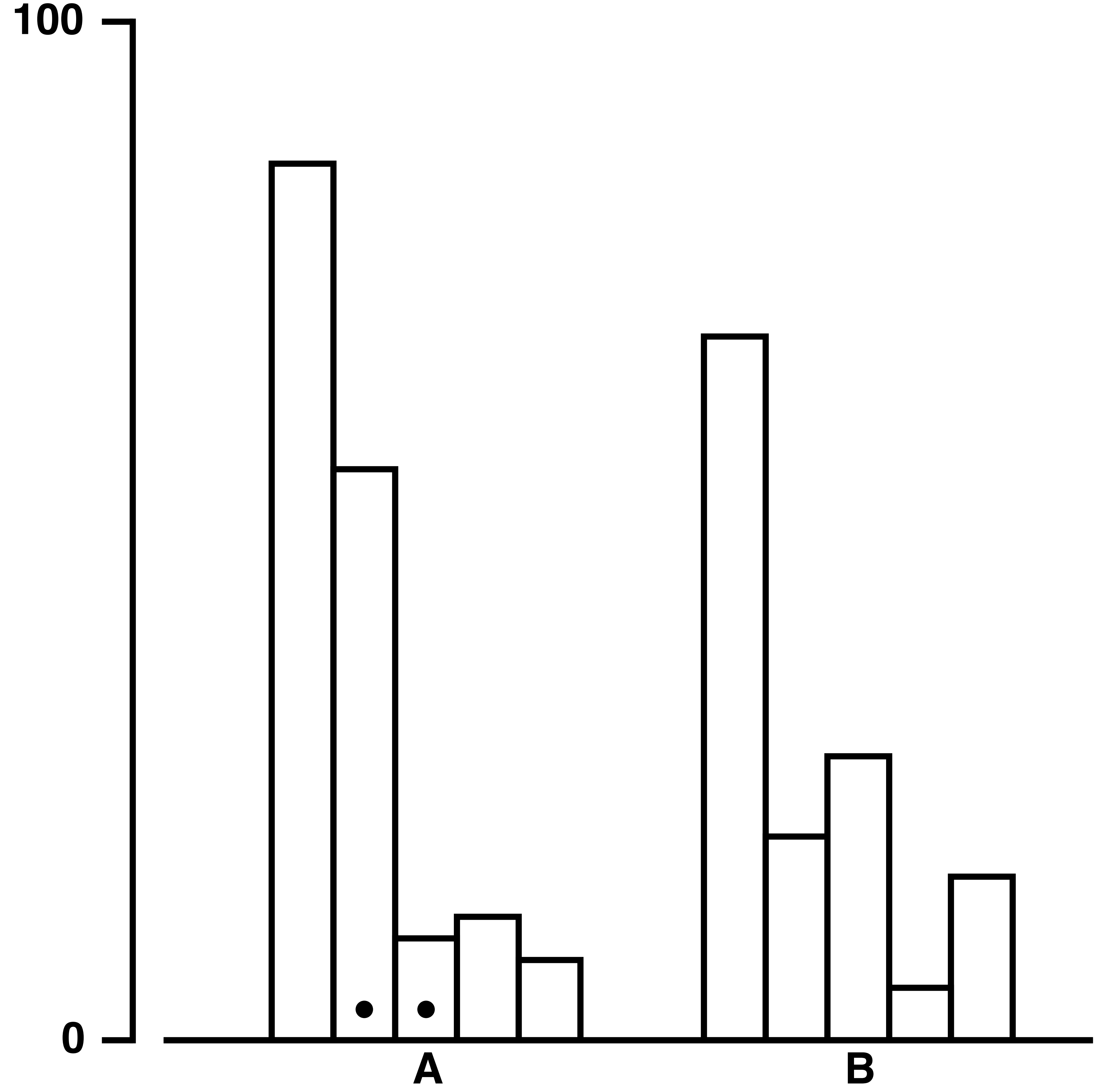
[Mackinlay,1986]

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		

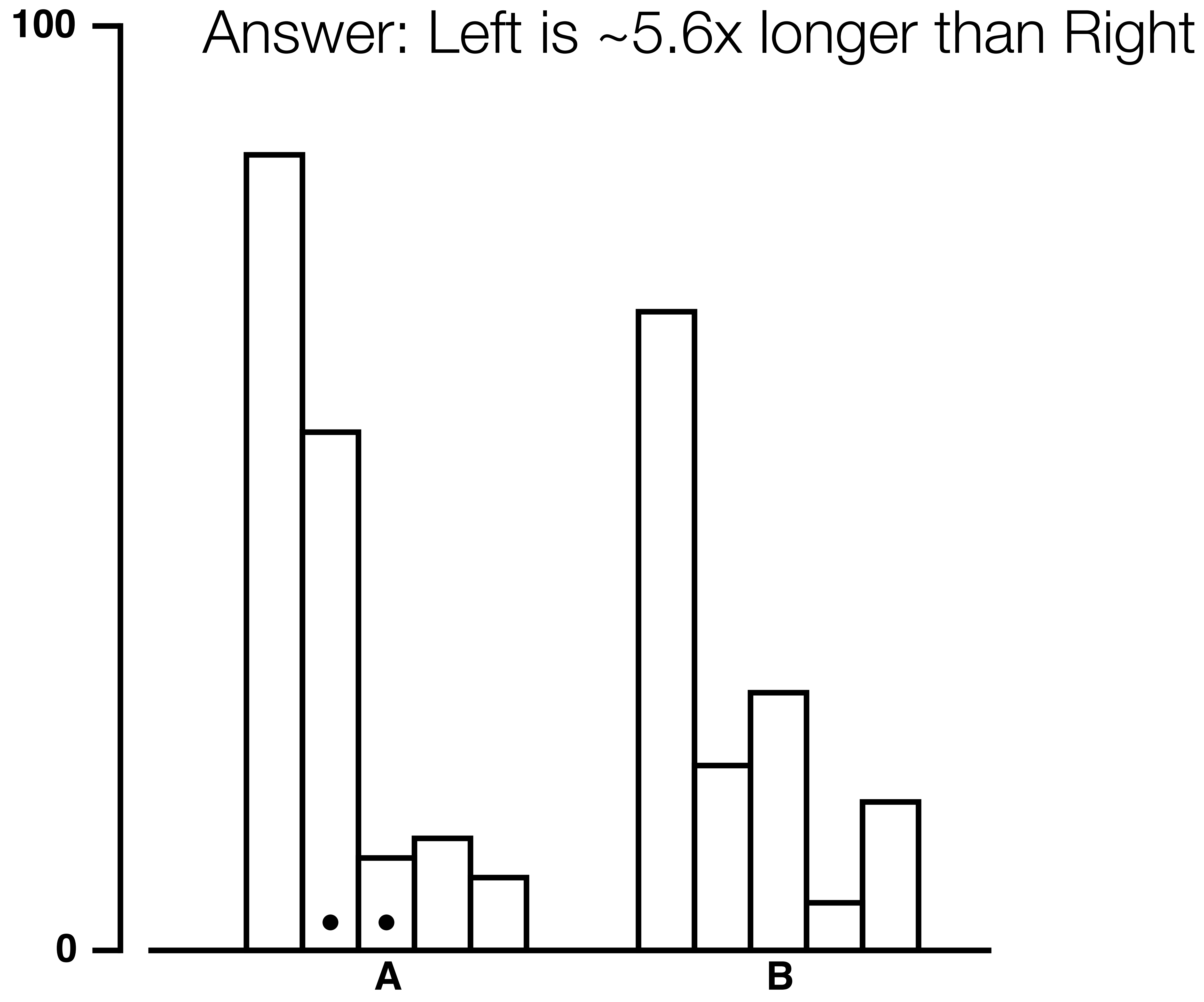
How do we get these rankings?

Test % difference in **length** between elements



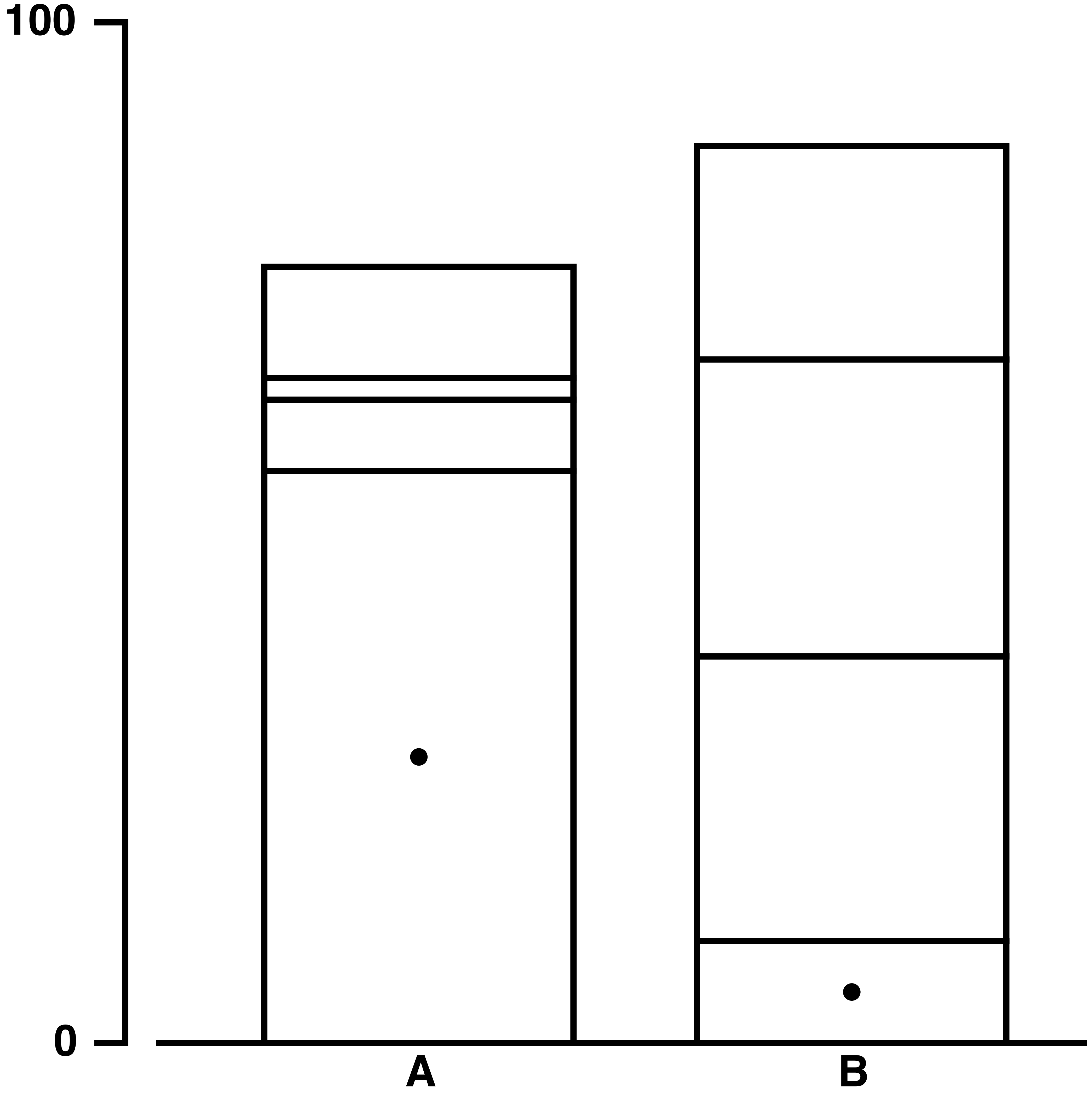
[Heer & Bostock, 2010]

Test % difference in **length** between elements



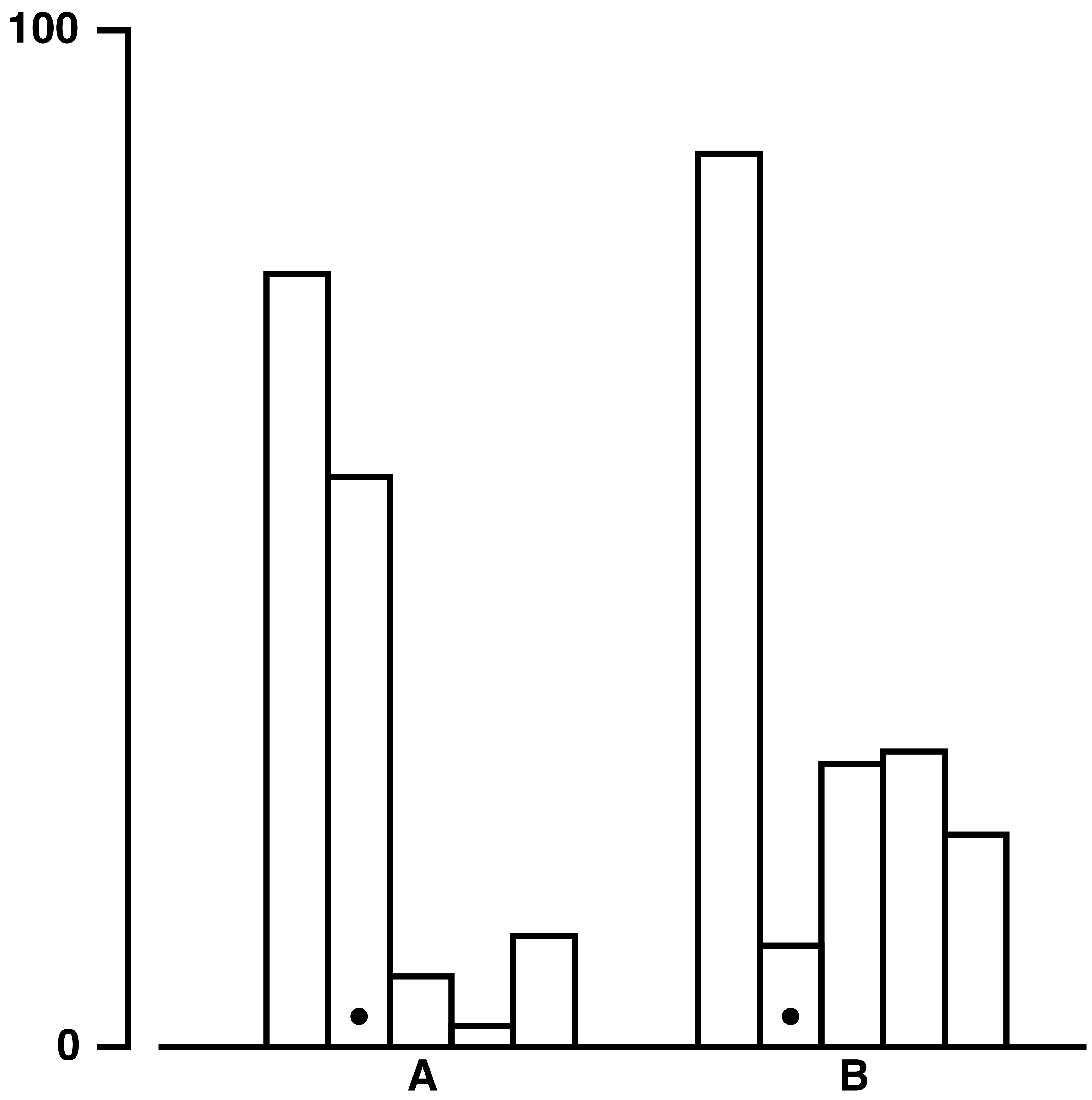
[Heer & Bostock, 2010]

Test % difference in **length** between elements



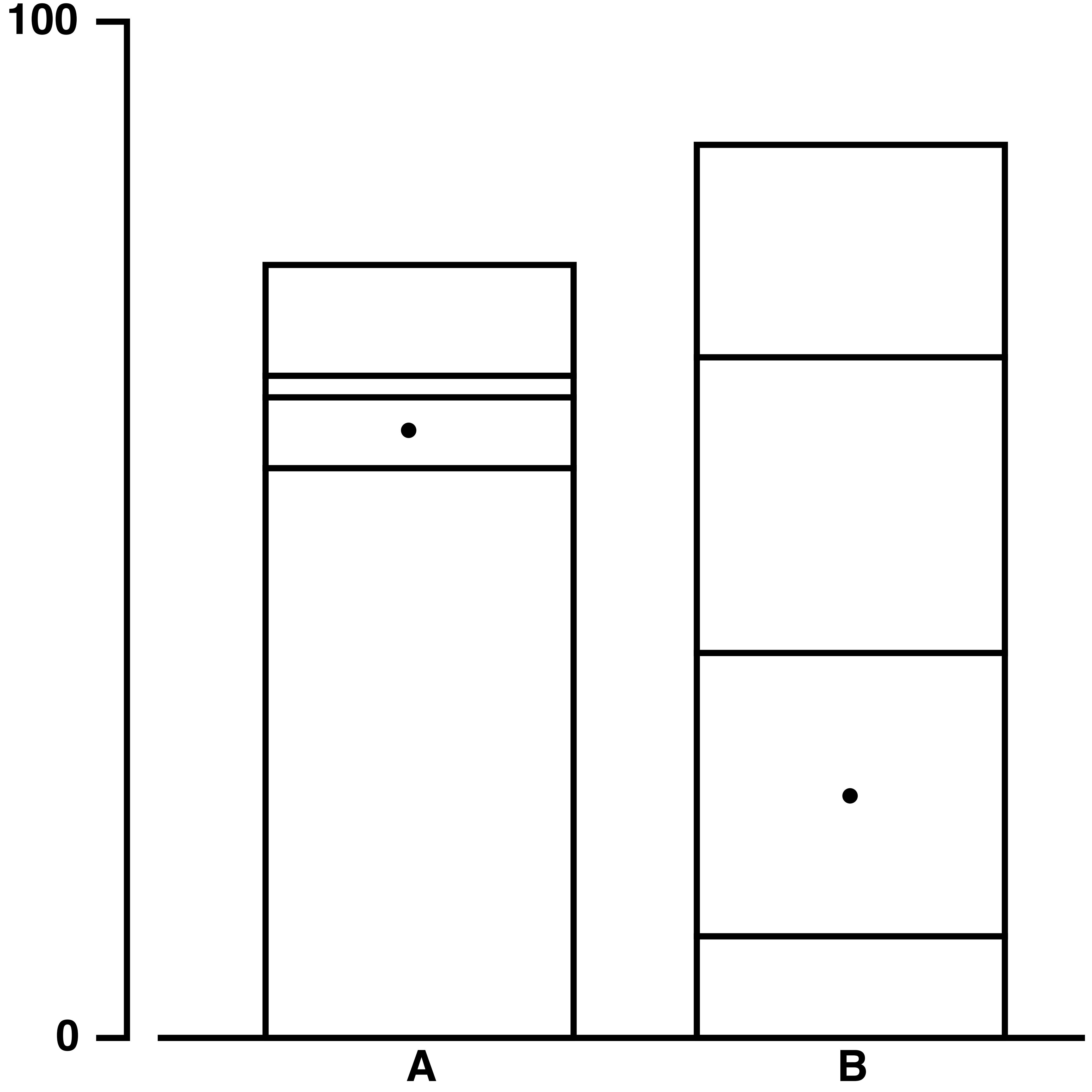
[Heer & Bostock, 2010]

Test % difference in **length** between elements



[Heer & Bostock, 2010]

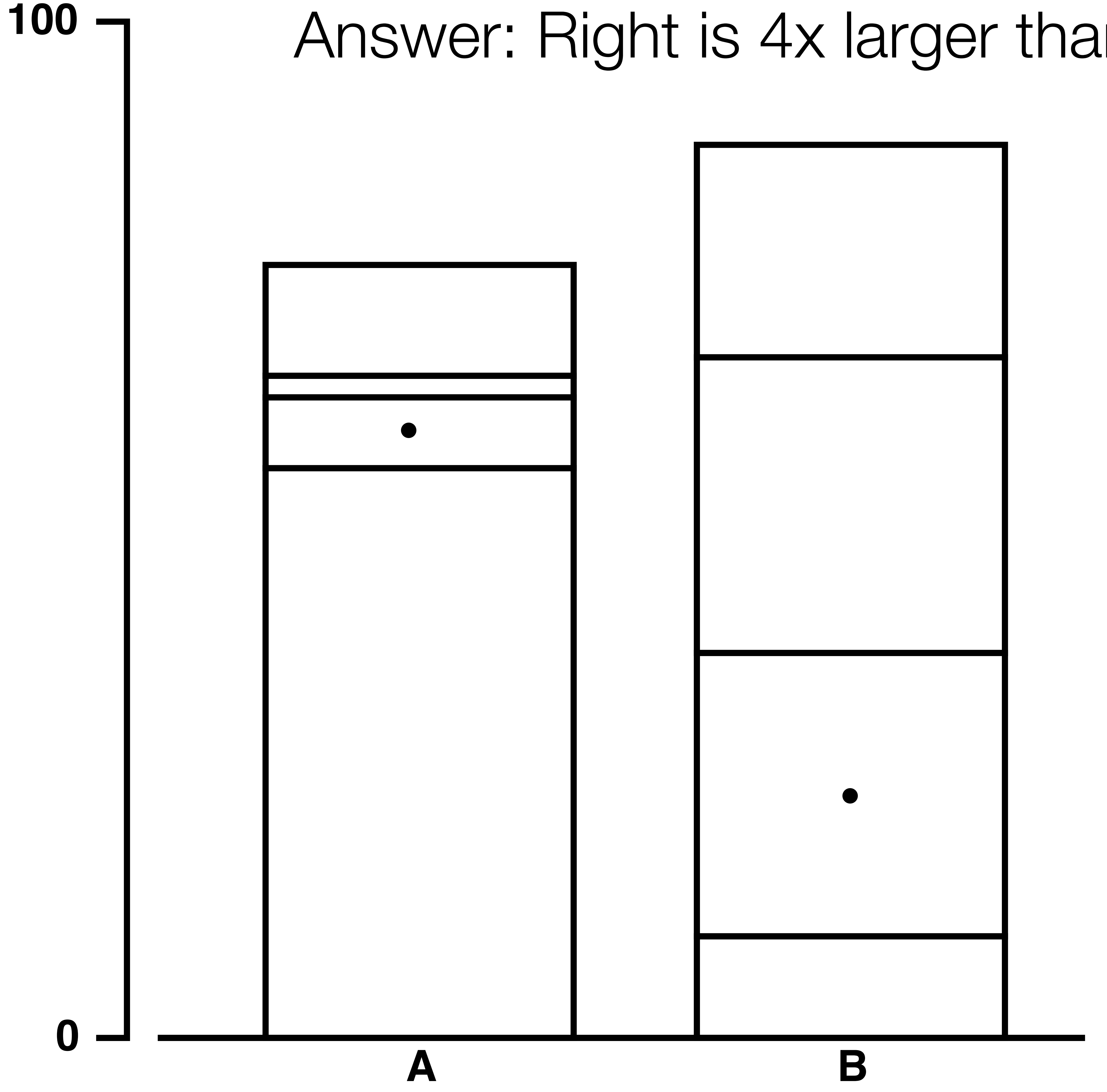
Test % difference in **length** between elements



[Modified from Heer & Bostock, 2010]

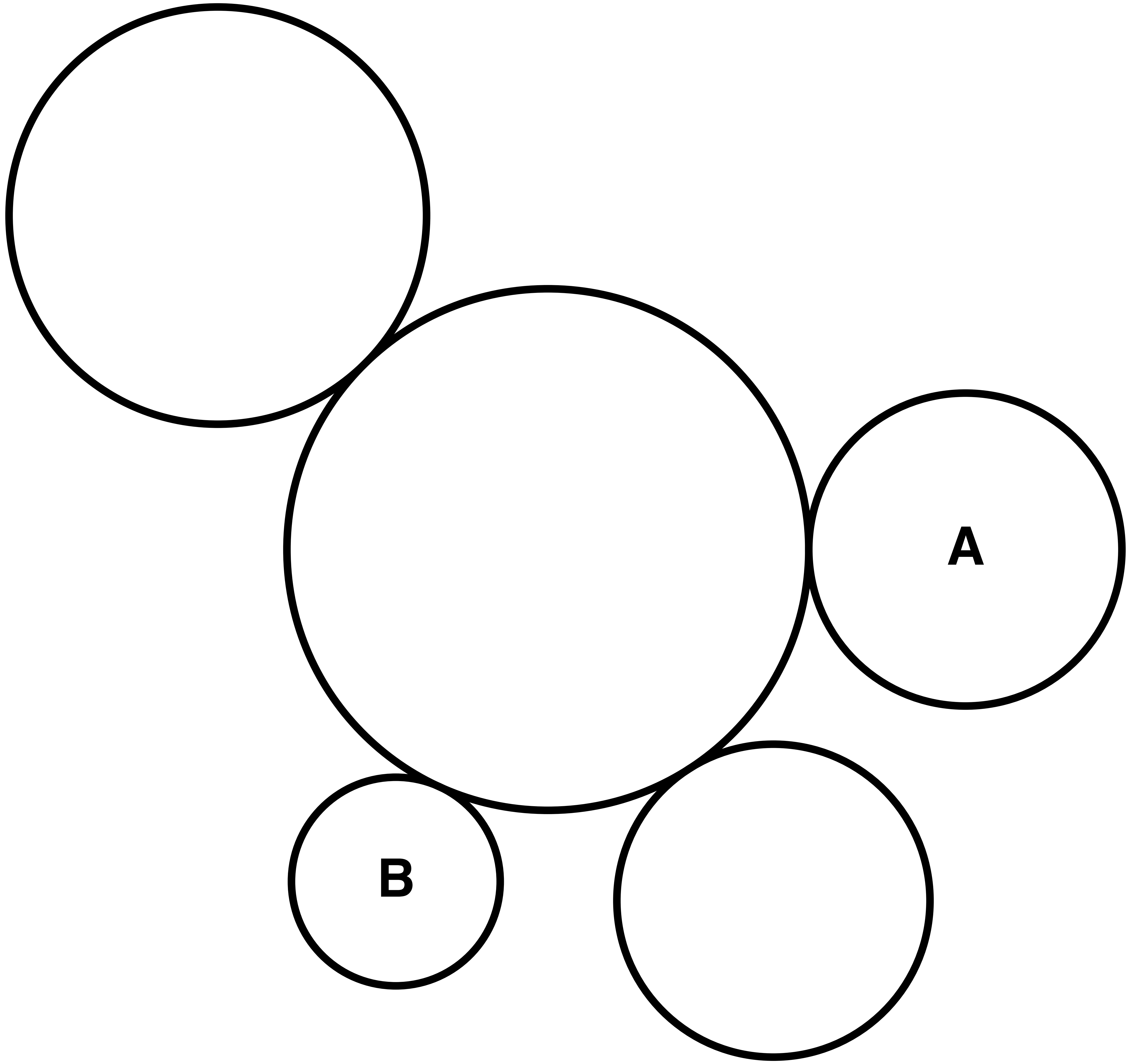
Test % difference in **length** between elements

Answer: Right is 4x larger than Left



[Modified from Heer & Bostock, 2010]

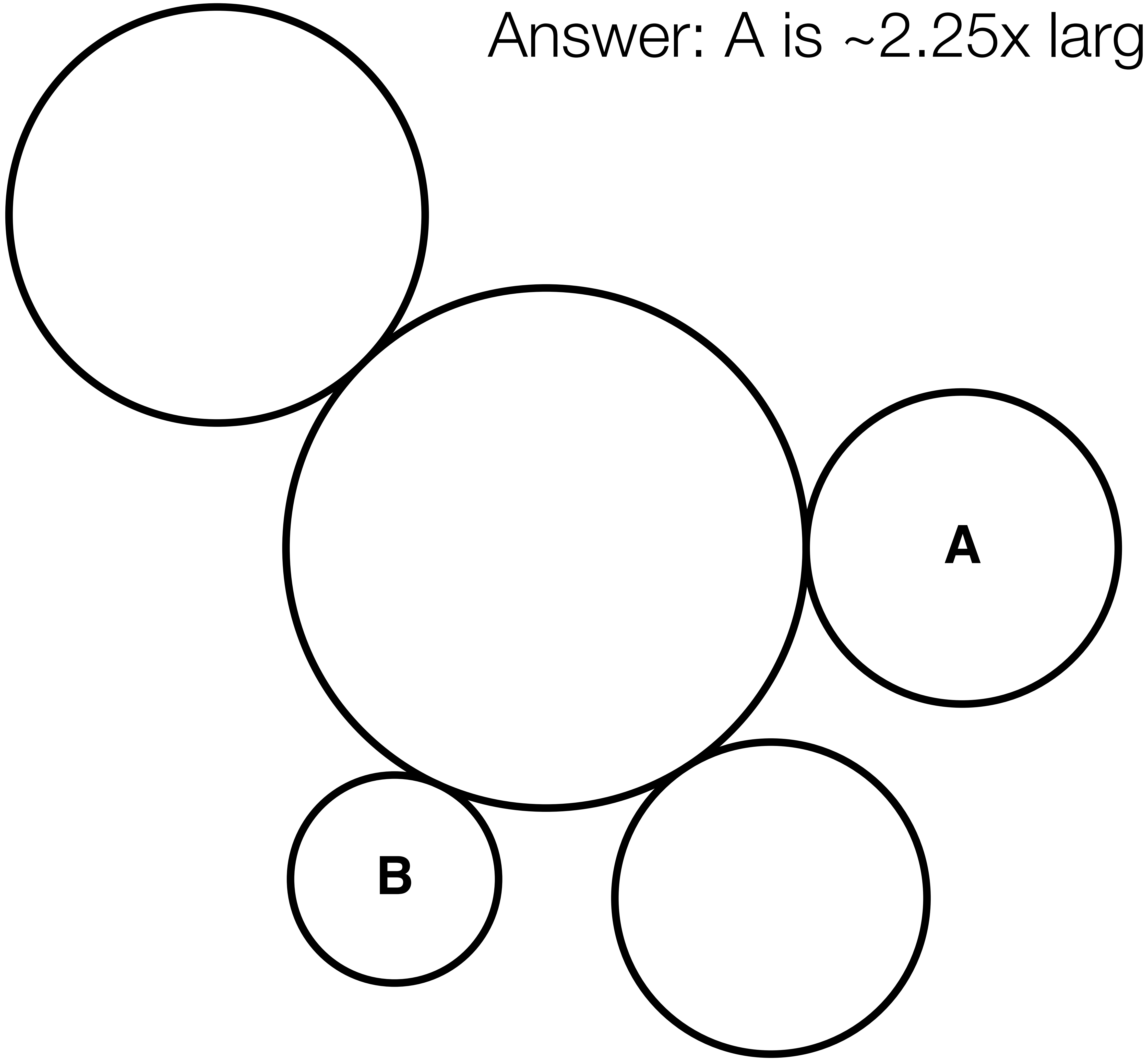
Test % difference in **area** between elements



[Heer & Bostock, 2010]

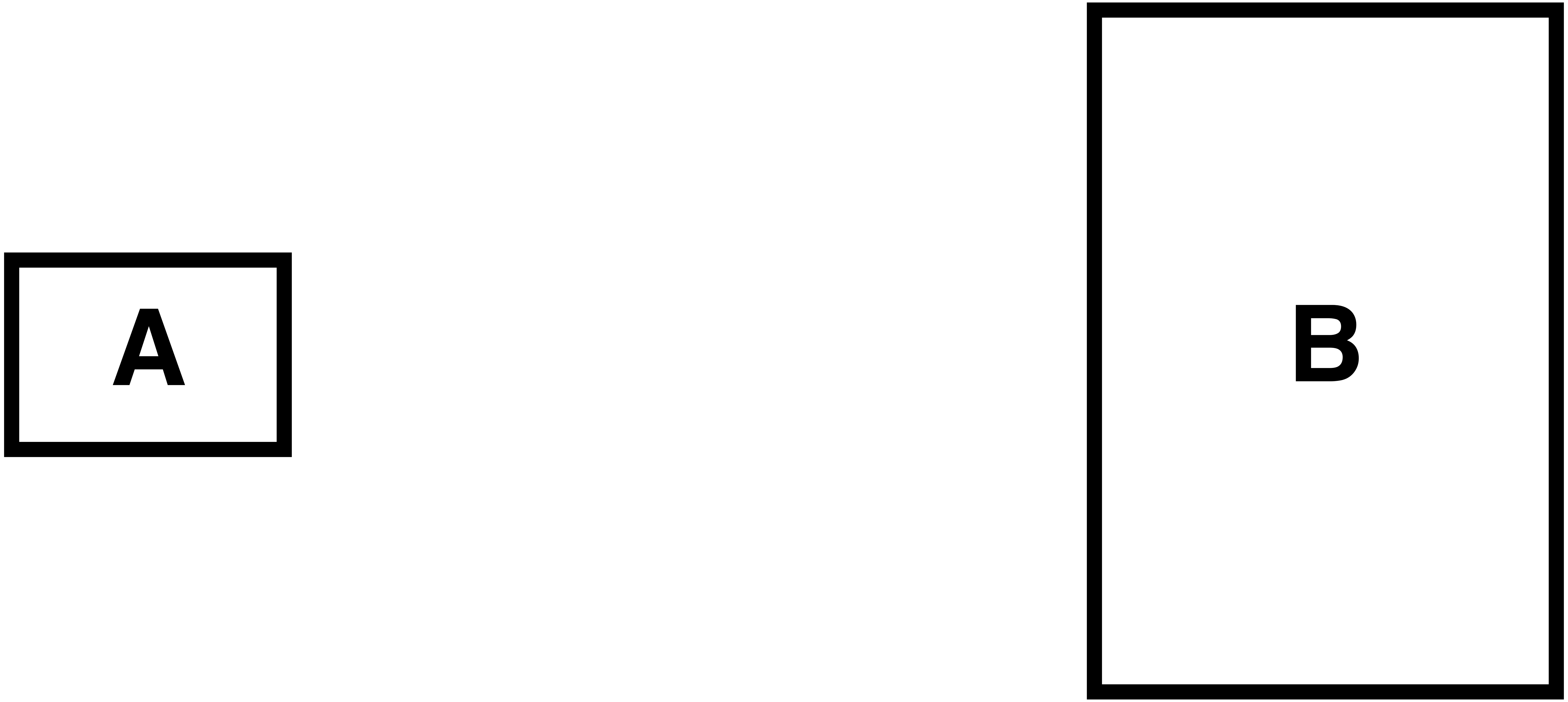
Test % difference in **area** between elements

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



[Heer & Bostock, 2010]

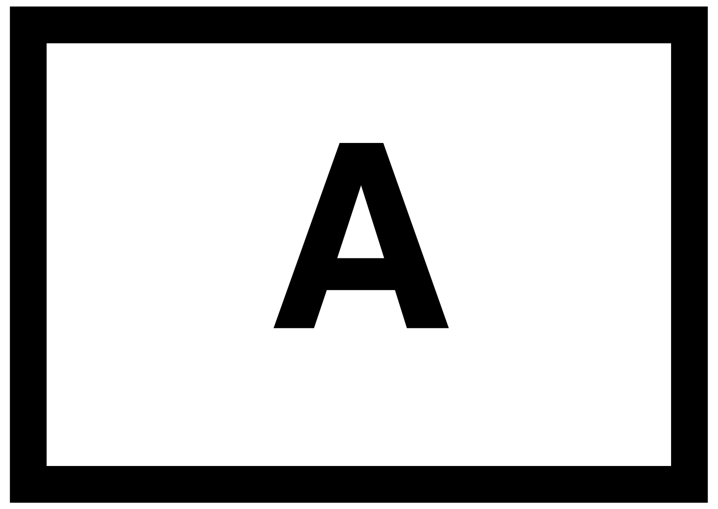
Test % difference in **area** between elements

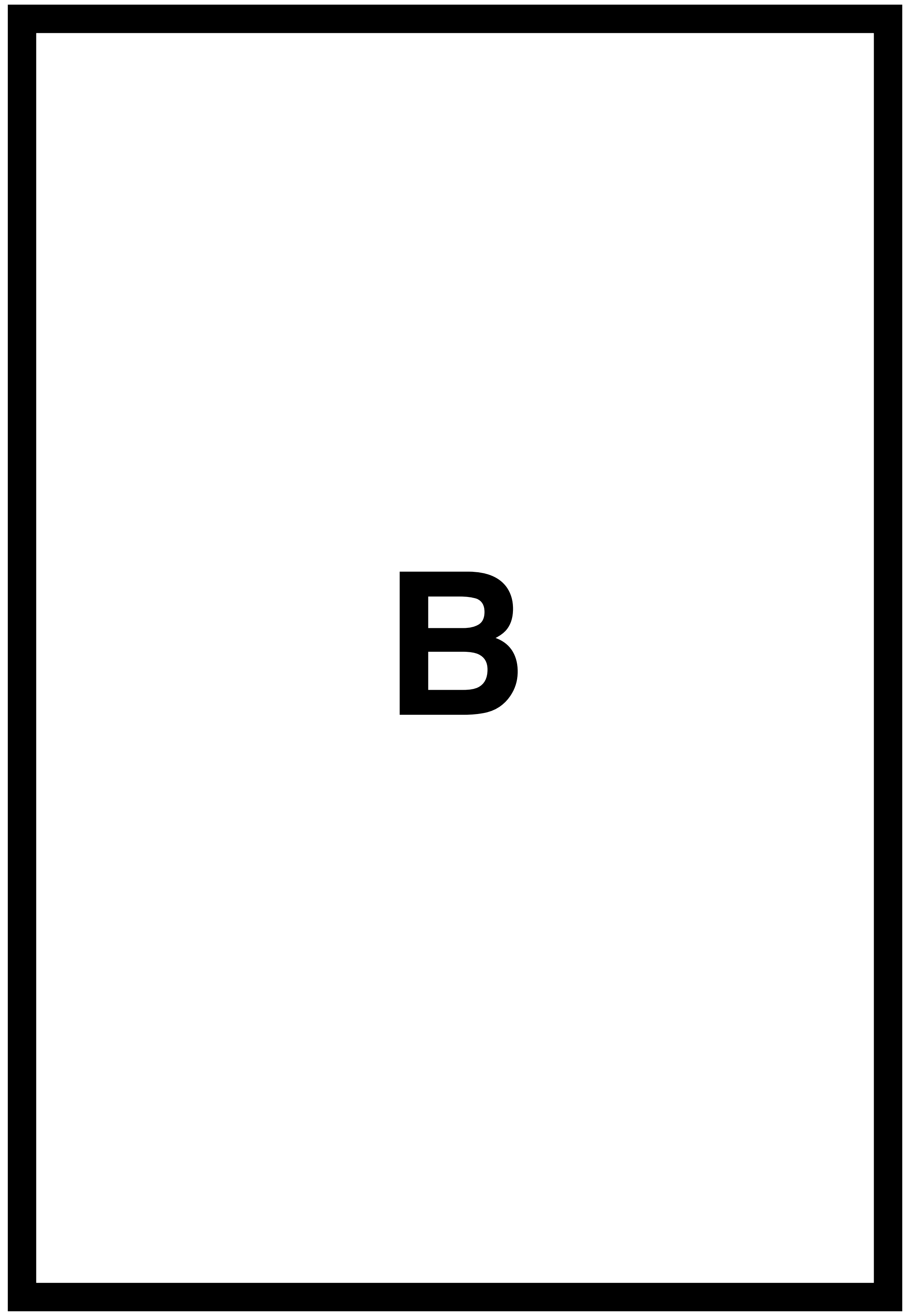


[Heer & Bostock, 2010]

Test % difference in **area** between elements

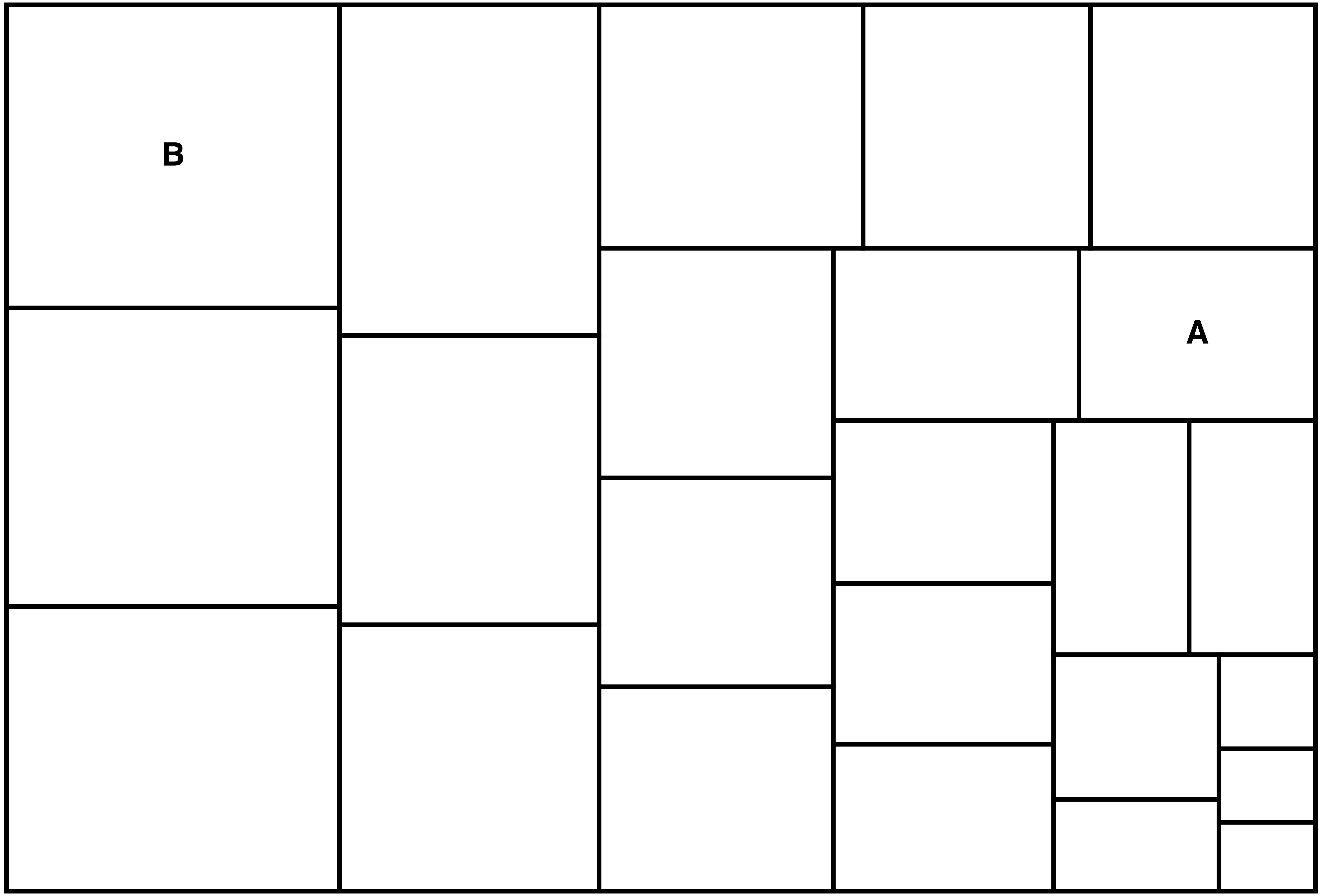
Answer: B is ~6.1x larger (in area) than A





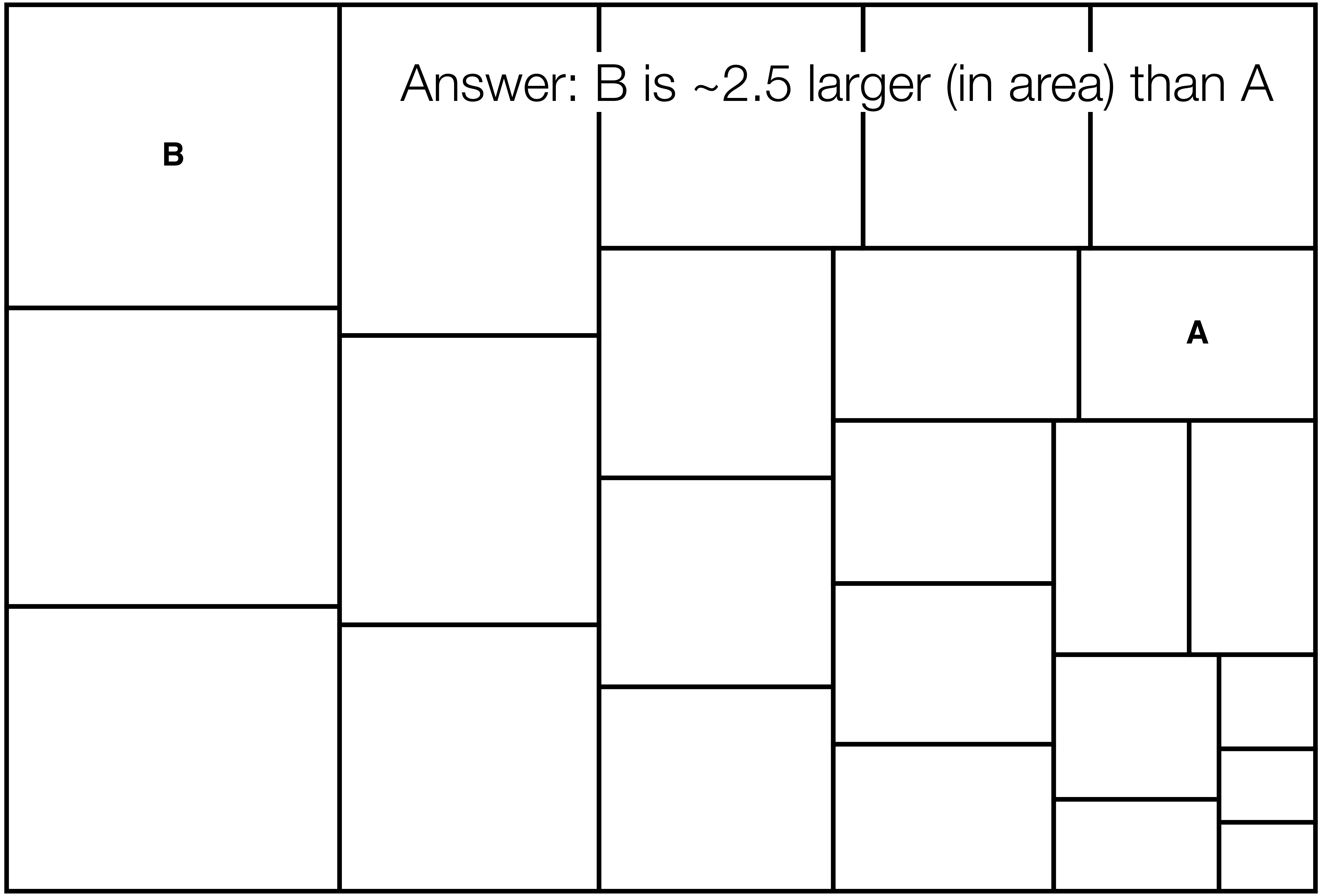
[Heer & Bostock, 2010]

Test % difference in **area** between elements



[Heer & Bostock, 2010]

Test % difference in **area** between elements



[Heer & Bostock, 2010]

Cleveland & McGill Experiments

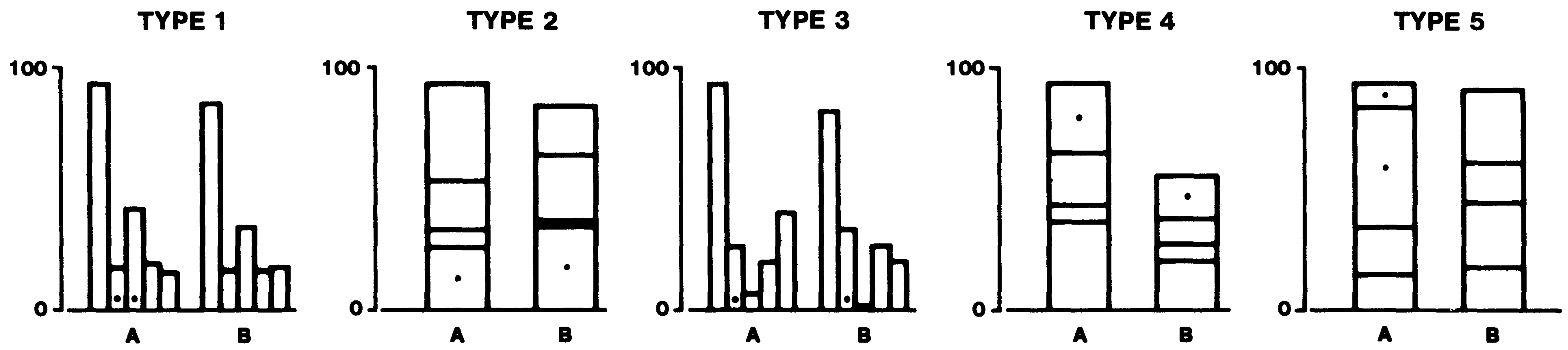


Figure 4. Graphs from position–length experiment.

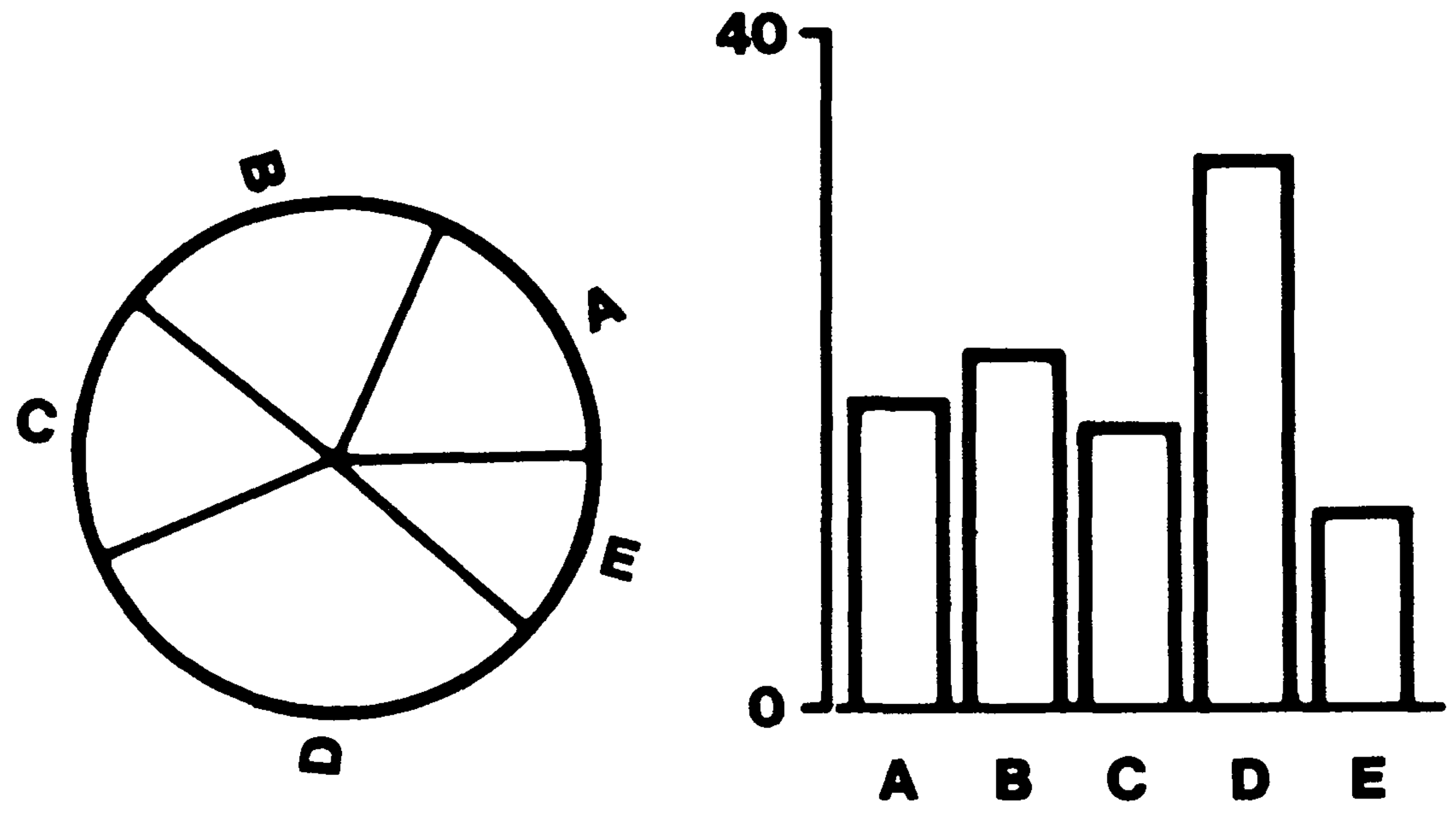


Figure 3. Graphs from position–angle experiment.

[Cleveland & McGill, 1984]

Heer & Bostock Experiments

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

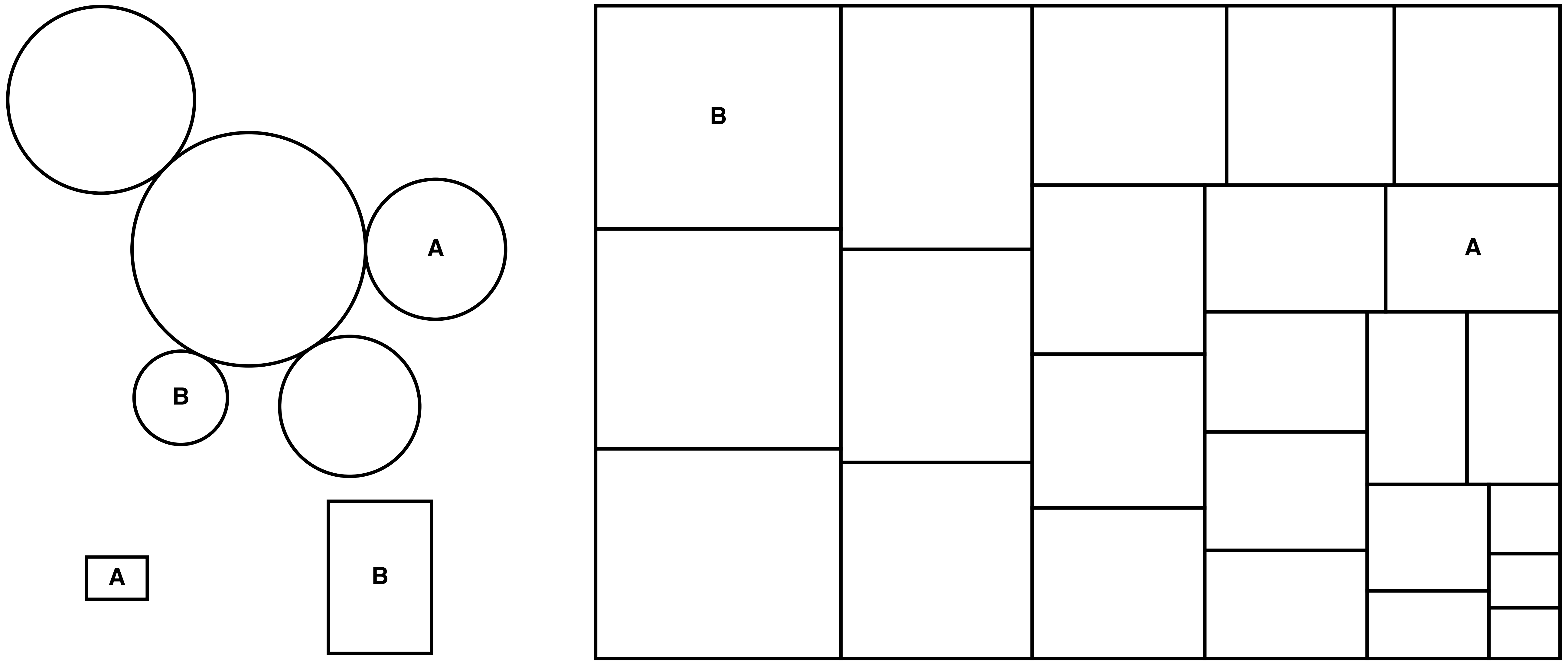
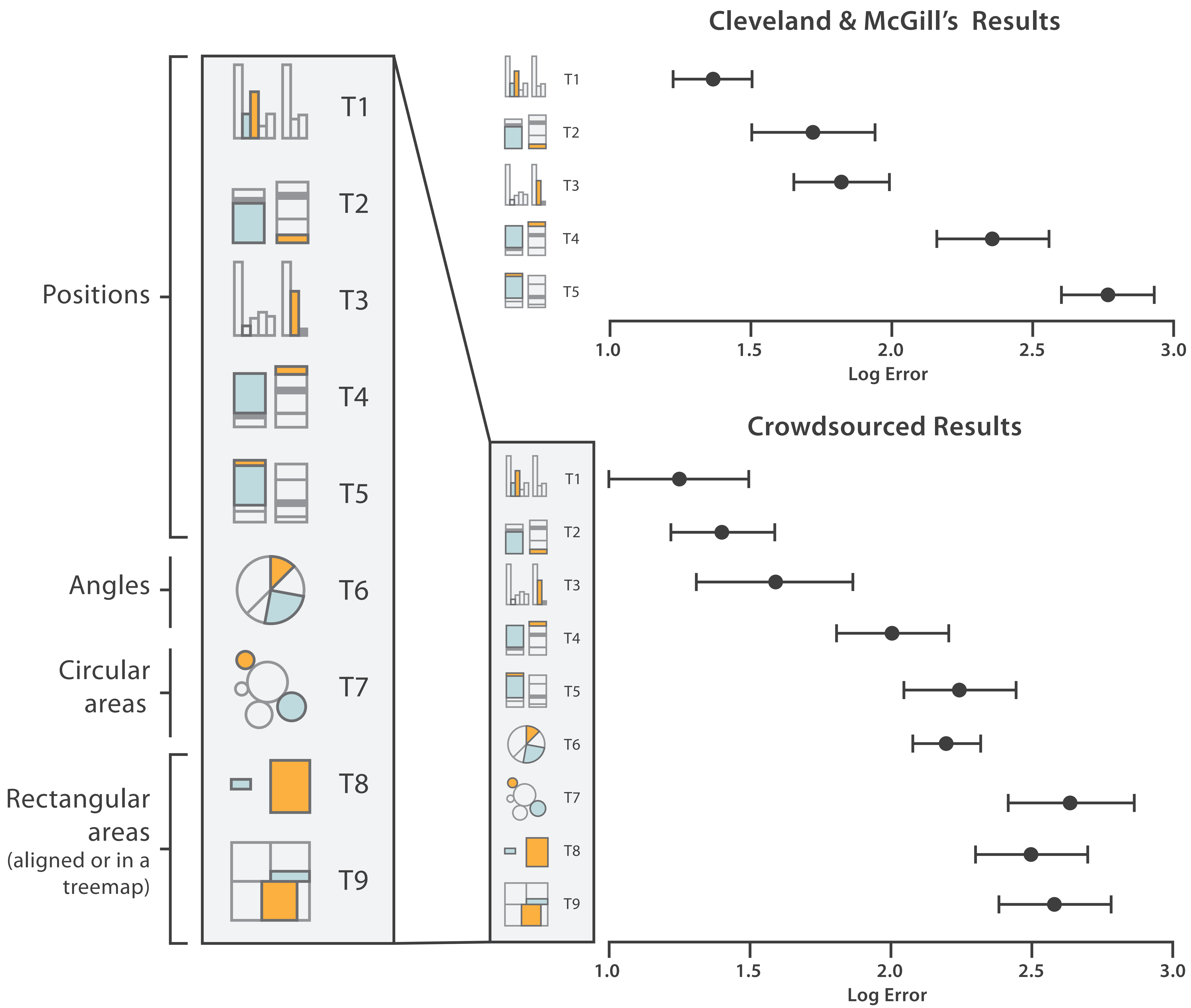


Figure 2: Area judgment stimuli. Top left: Bubble chart (T7), Bottom left: Center-aligned rectangles (T8), Right: Treemap (T9).

[Heer & Bostock, 2010]

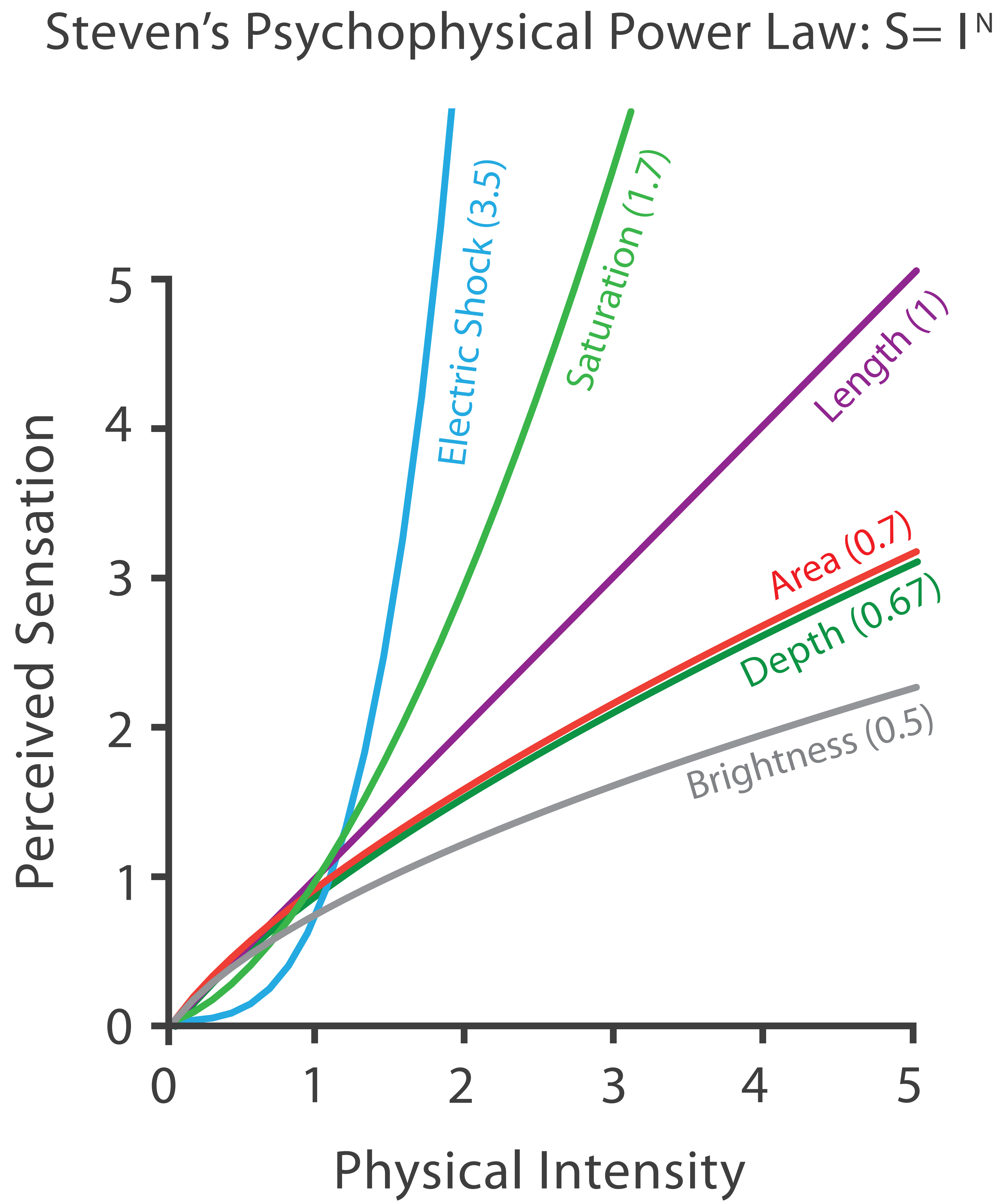
Results Summary



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

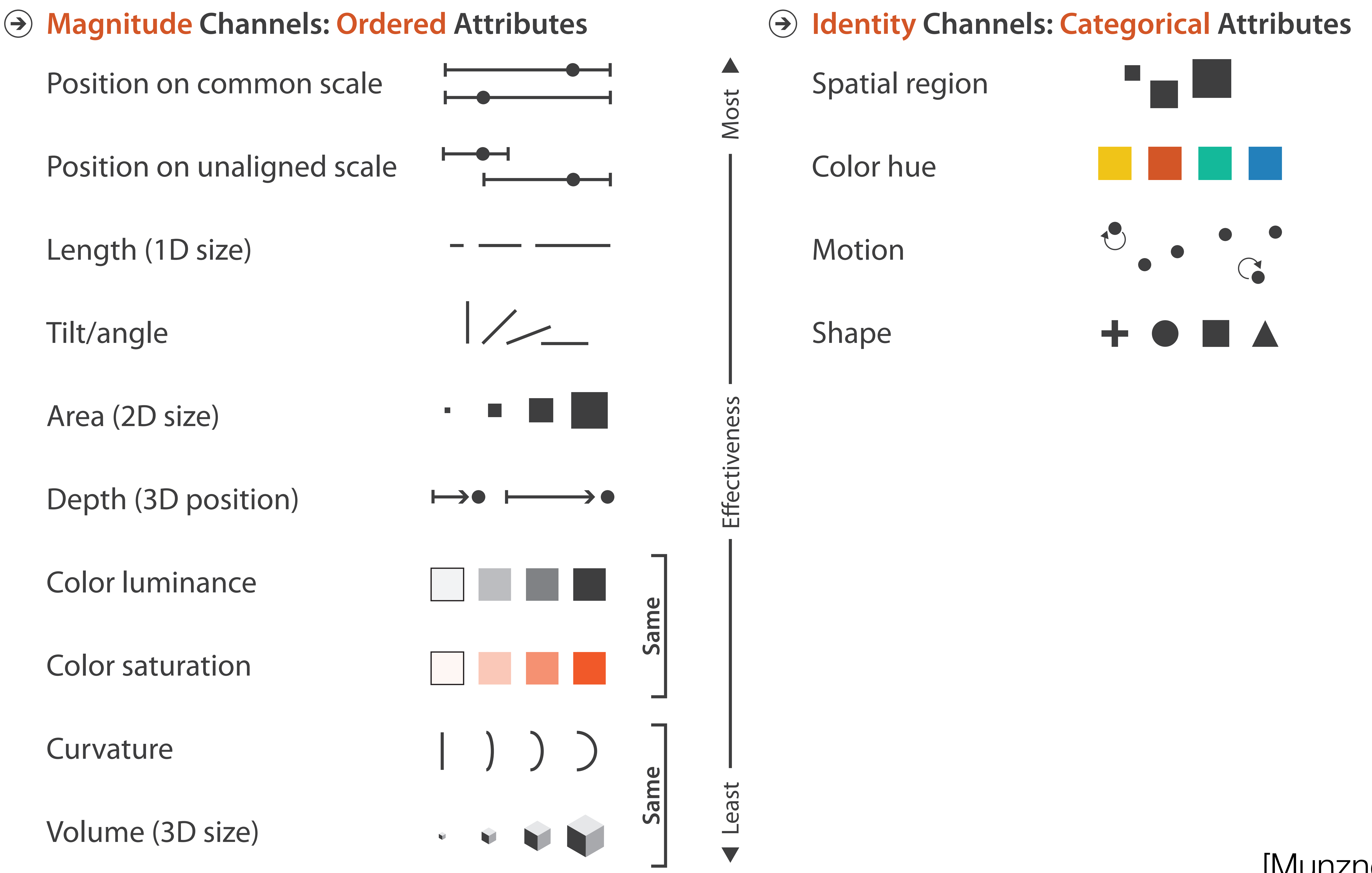
Psychophysics

- 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]

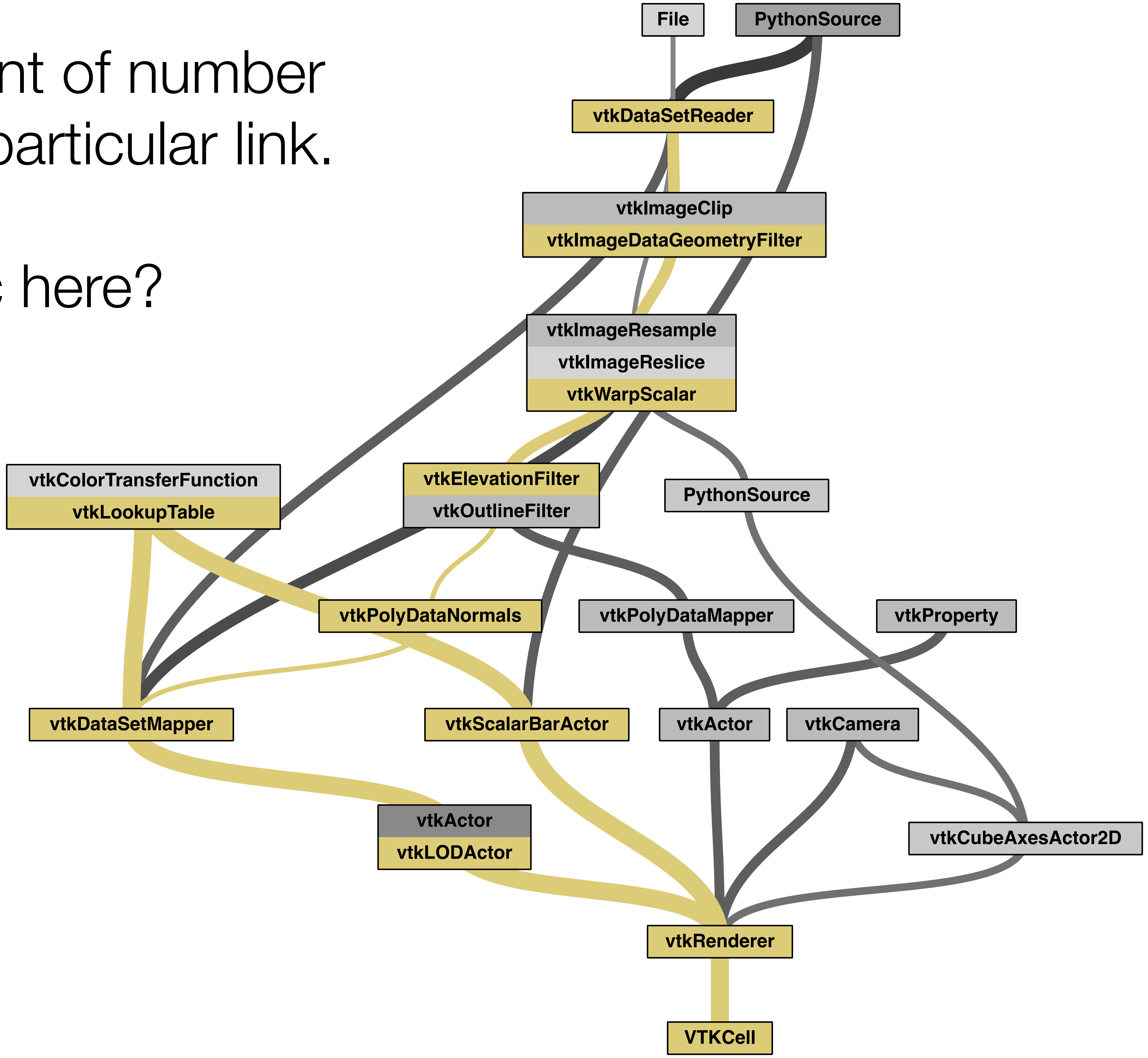
Ranking Channels by Effectiveness



[Munzner (ill. Maguire), 2014]

Discriminability

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



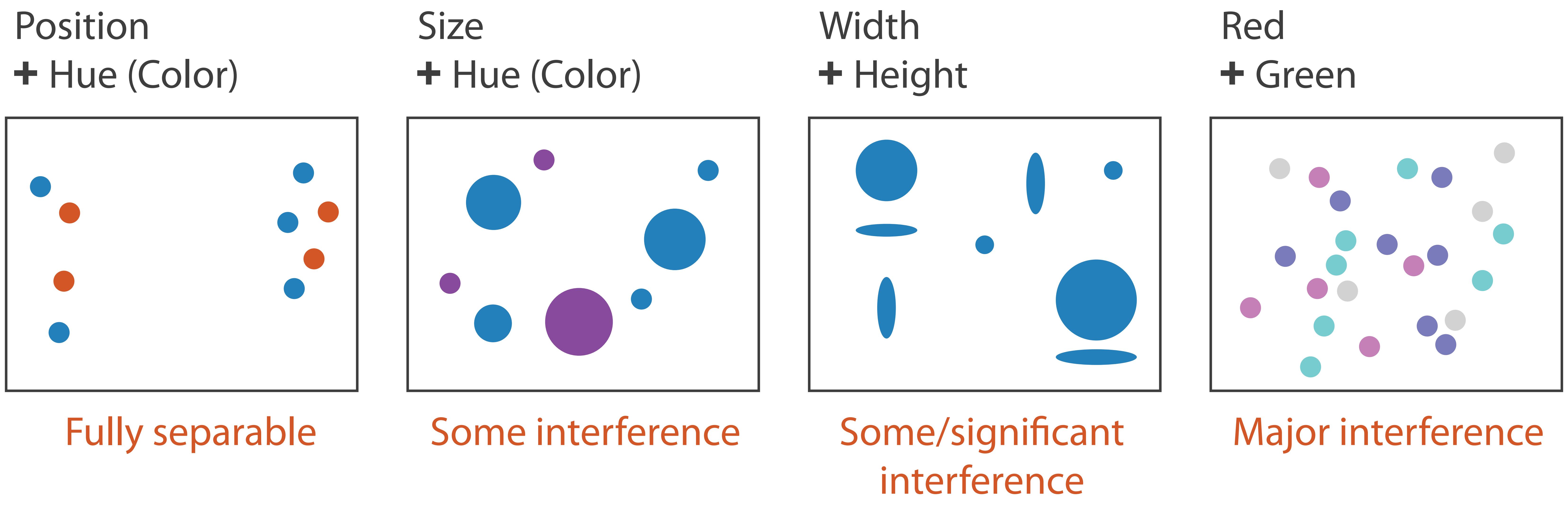
[Koop et al., 2013]

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

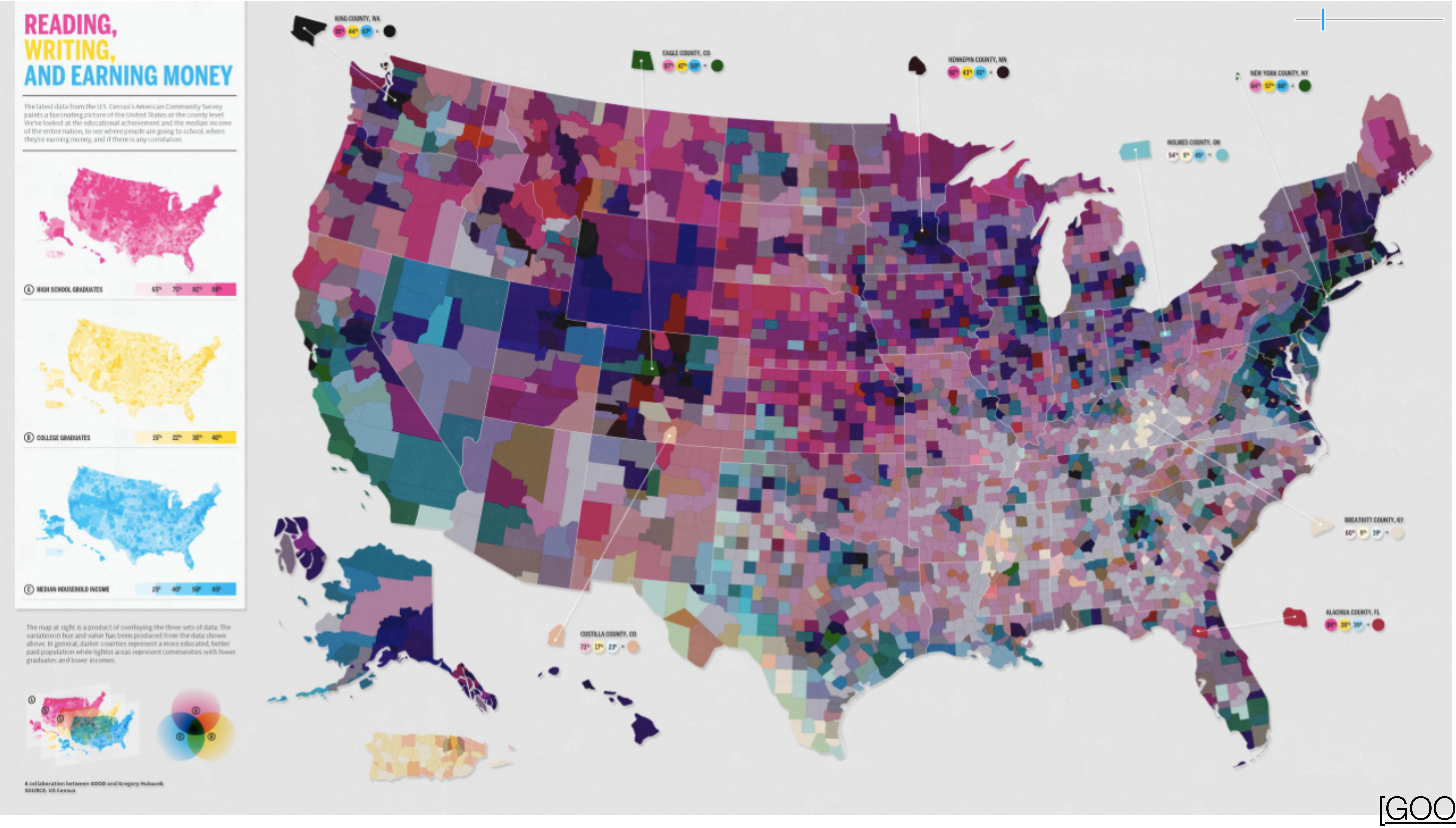
Separability

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



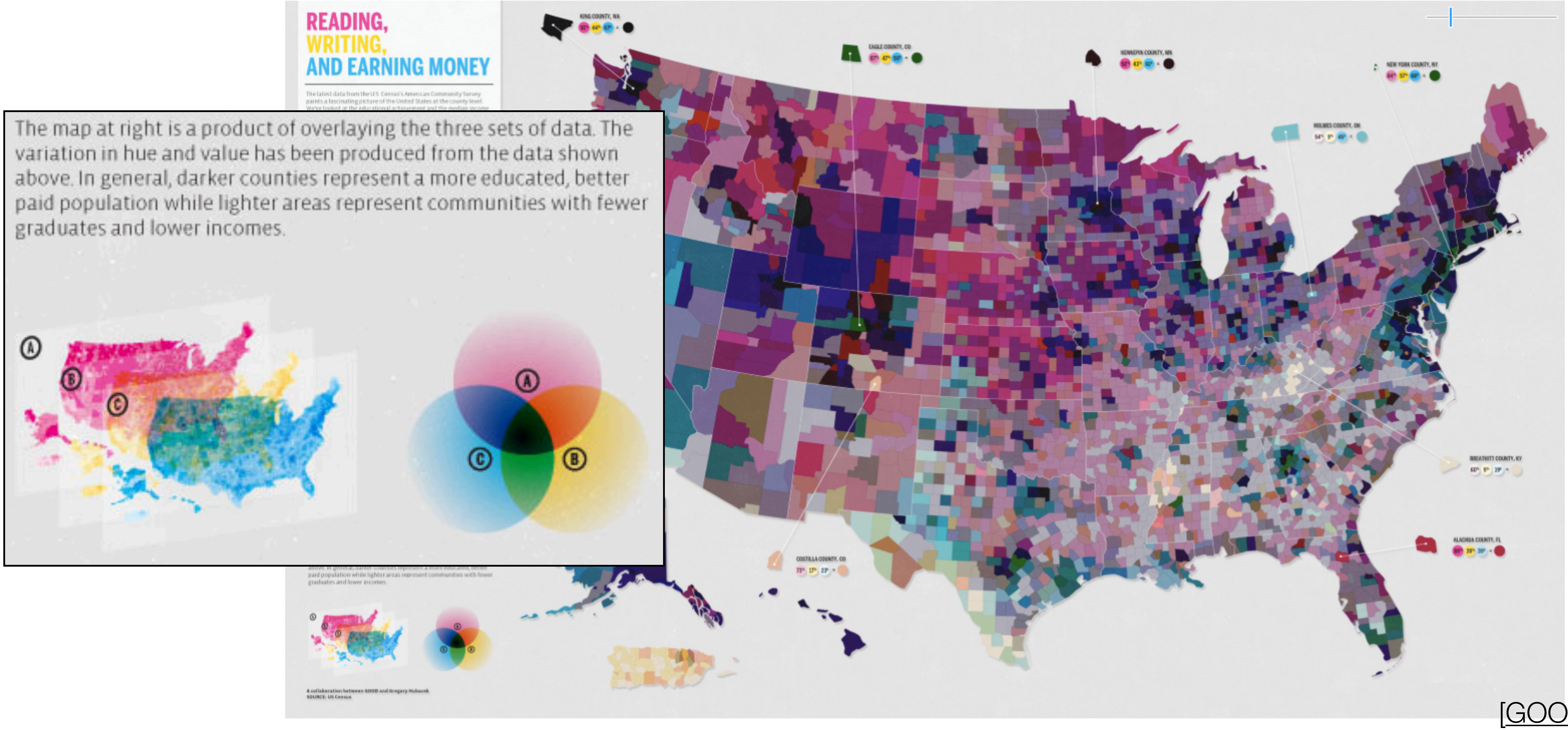
[Munzner (ill. Maguire) based on Ware, 2014]

Separable or Integral?



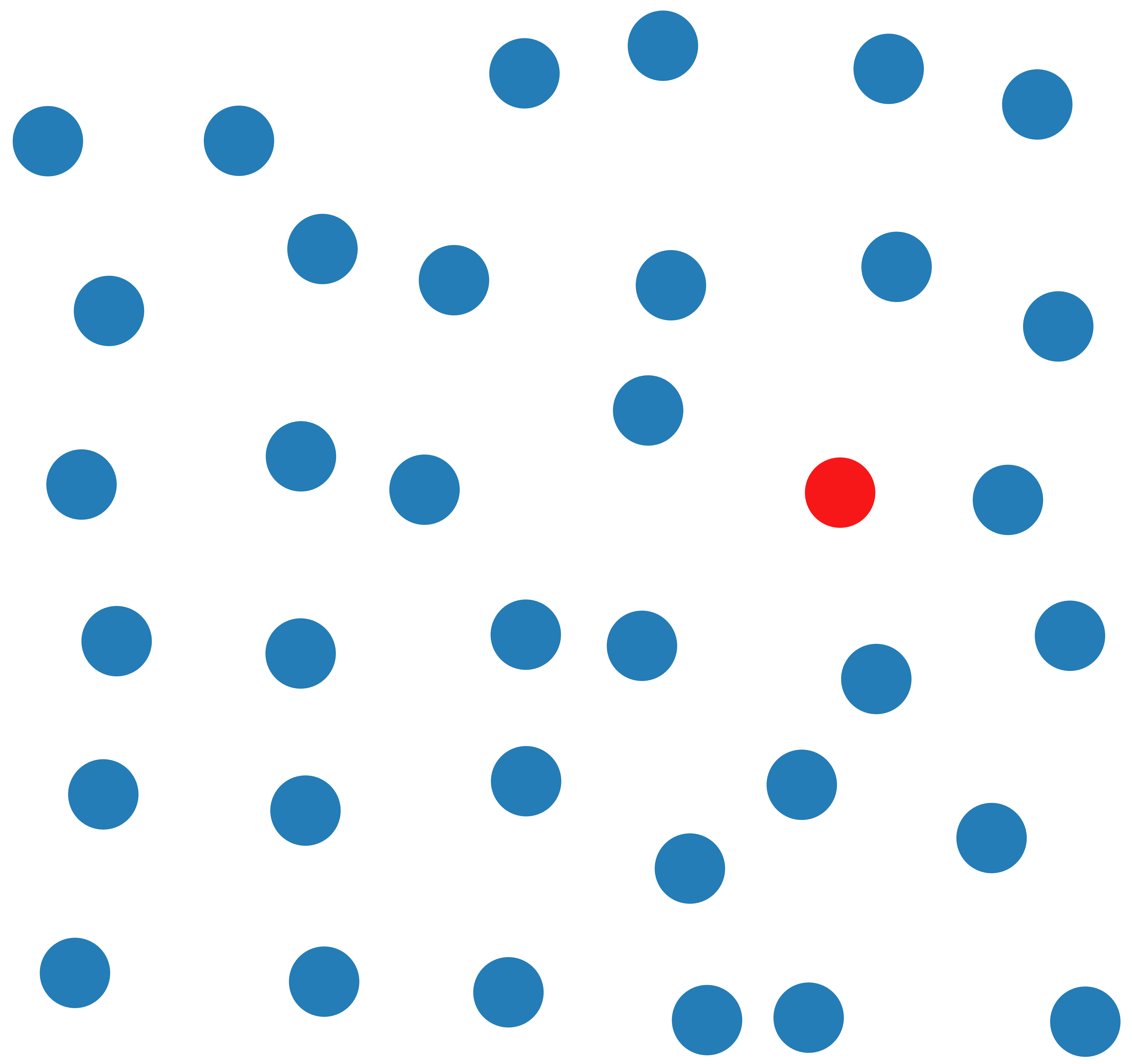
[GOOD]

Separable or Integral?



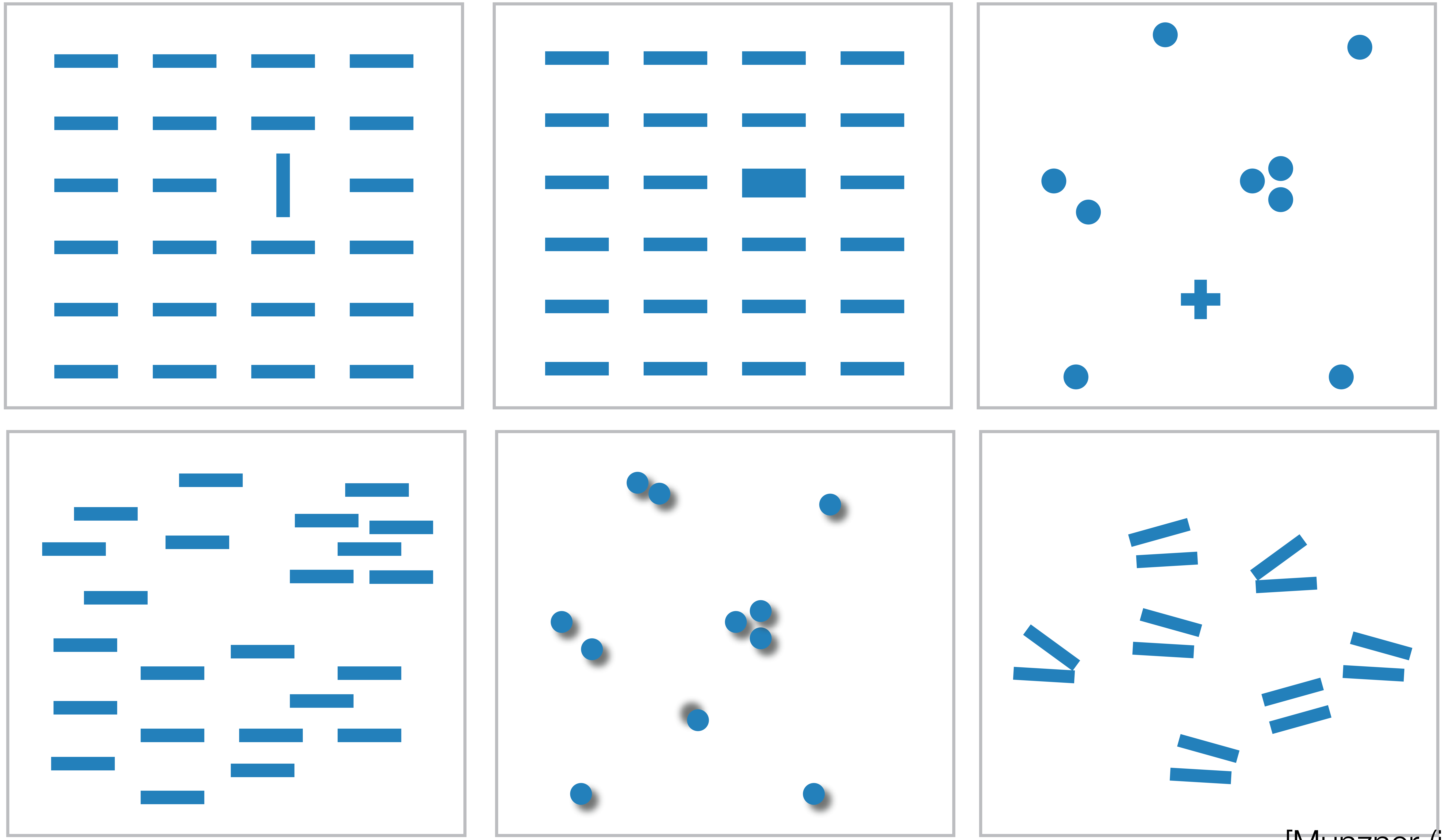
[GOOD]

Visual Popout



[C. G. Healey]

Visual Popout: Parallel Lines Require Search…



[Munzner (ill. Maguire), 2014]