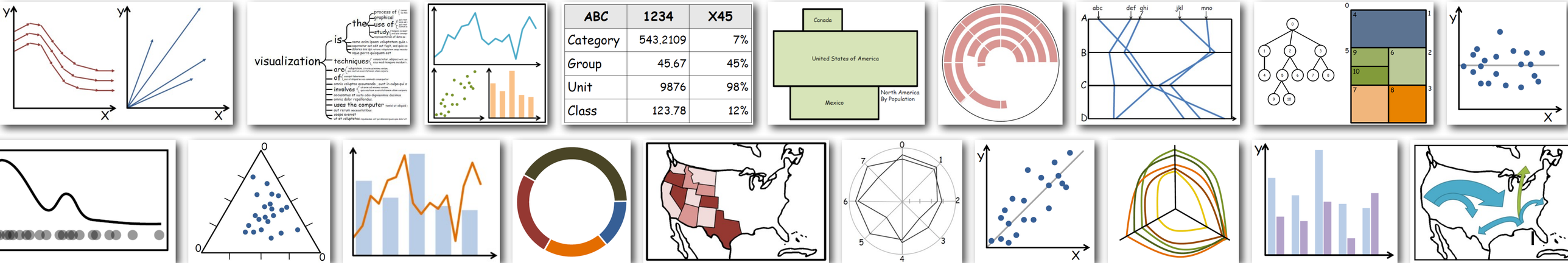


Lecture : Ranking of visualization channels

(Effectiveness and Expressiveness)

DATA ANALYSIS AND VISUALIZATION

FALL 2021

Dr. Muhammad Faisal Cheema

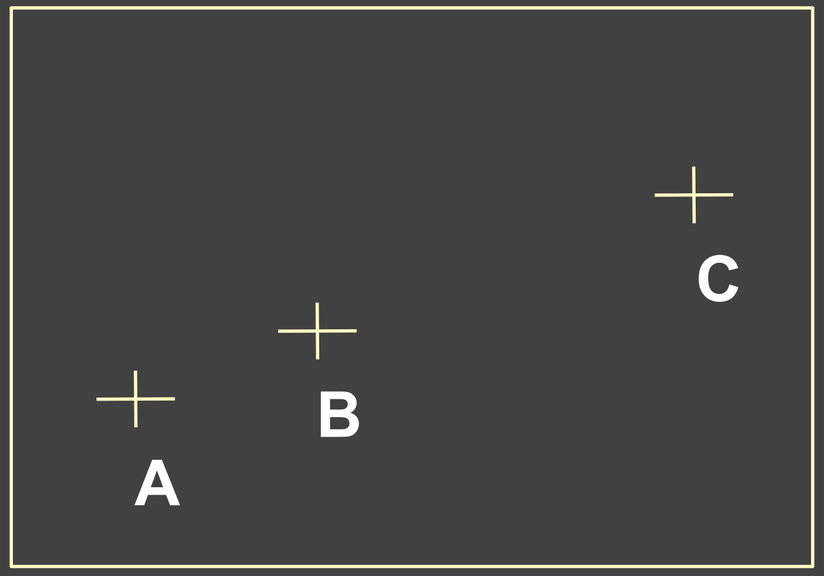
FAST NU

Goals for Today

- Learn which marks and channels are most effective for a given task ("perceptual ordering")

How do I pick *which* marks or channels to use?

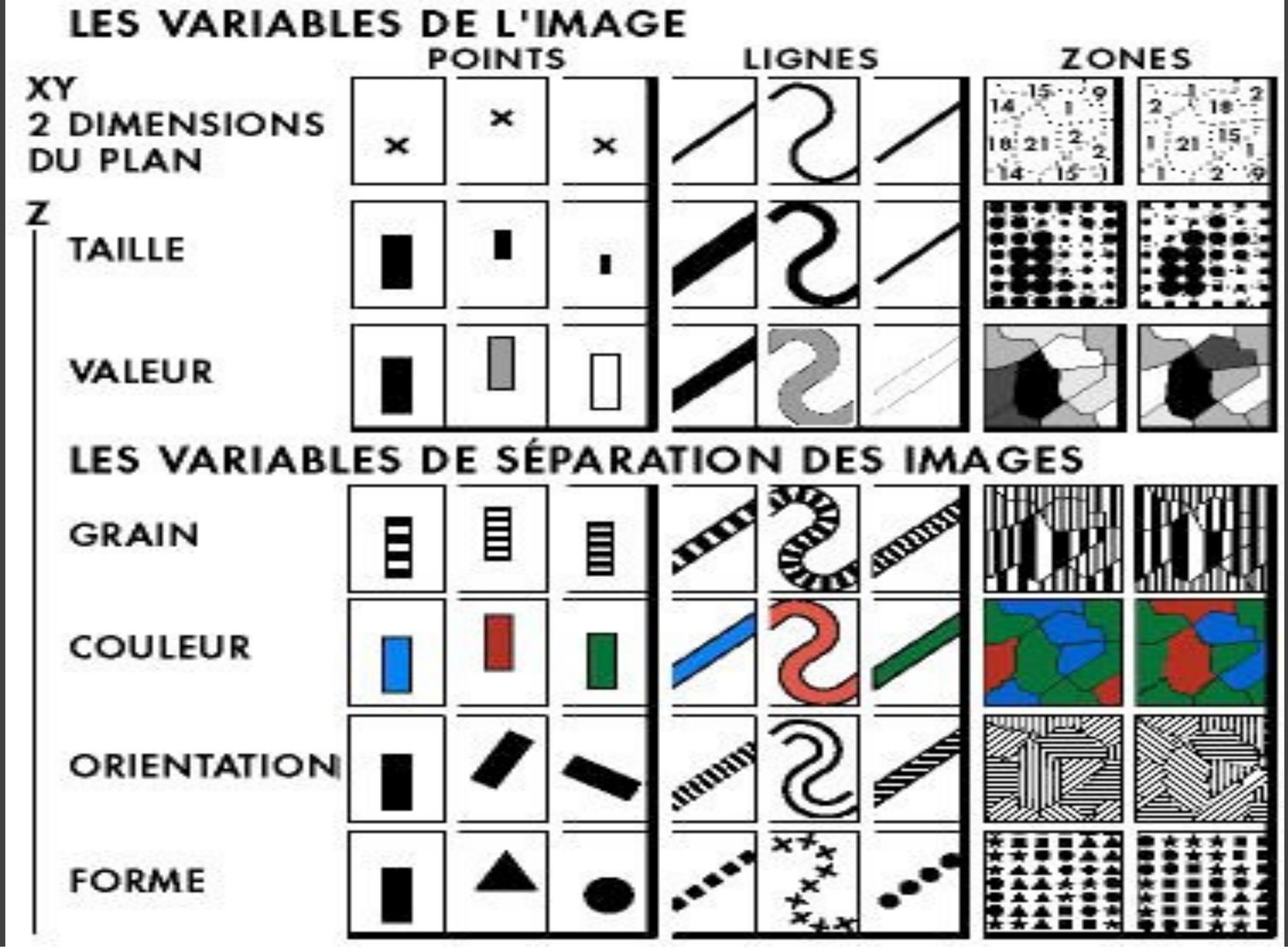
Bertin's Semiology of Graphics



1. A, B, C are distinguishable
2. B is between A and C.
3. BC is twice as long as AB.

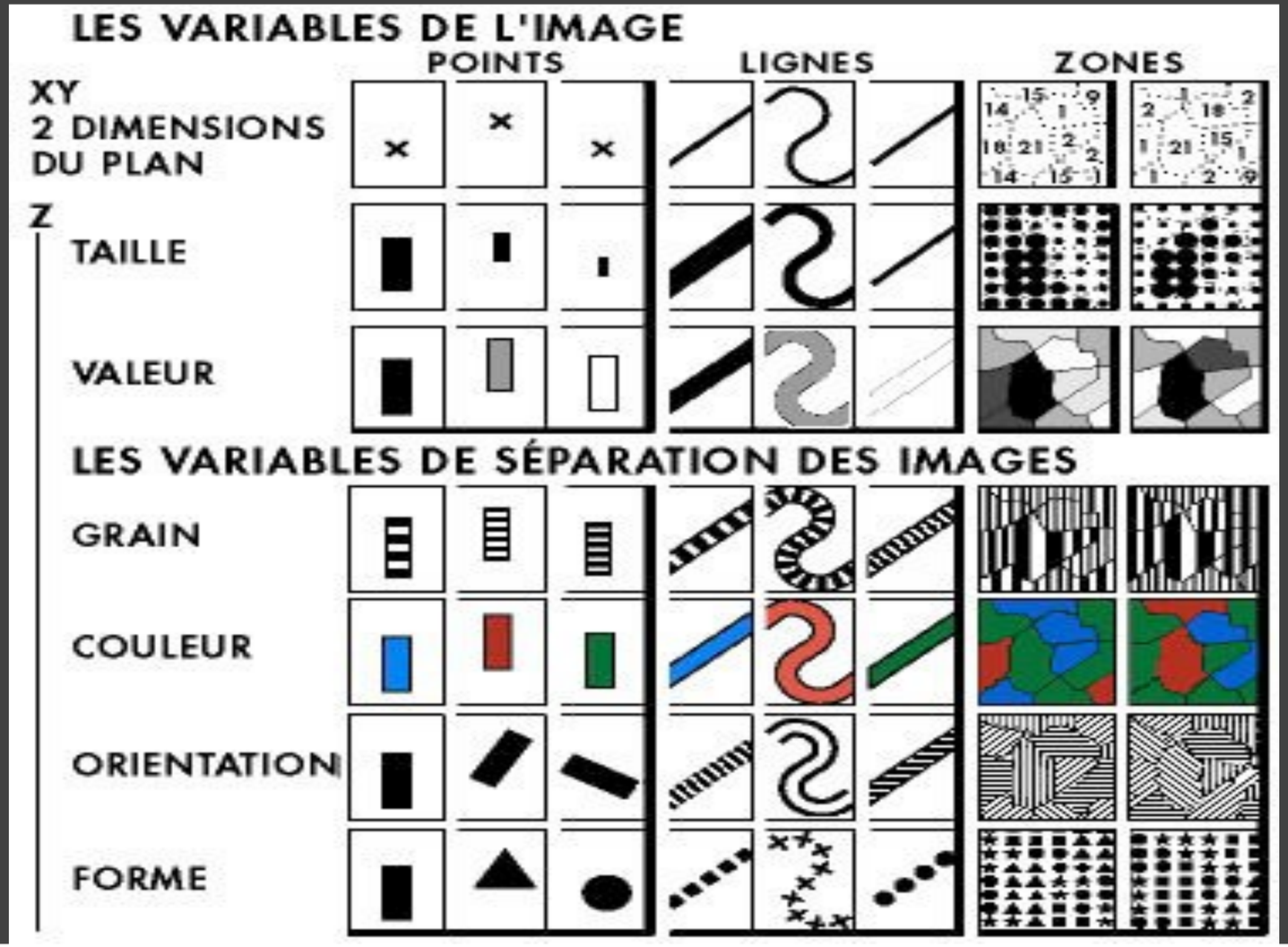
∴ Encode quantitative variables

"Resemblance, order and proportion are the three signifieds in graphics." - Bertin


LES VARIABLES DE L'IMAGE
POINTS
LIGNES
ZONES
XY
2 DIMENSIONS
DU PLAN
Z
TAILLE
VALEUR
LES VARIABLES DE SÉPARATION DES IMAGES
GRAIN
COULEUR
ORIENTATION
FORME

Visual encoding variables

Position (x 2)
Size
Value
Texture
Color
Orientation
Shape



Characteristics of Visual Variables

Selective

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

Associative

- Does it support grouping?

Quantitative

- Can we quantify the difference between two marks?

Characteristics of Visual Variables

Order

Can we see a change in order?

Length

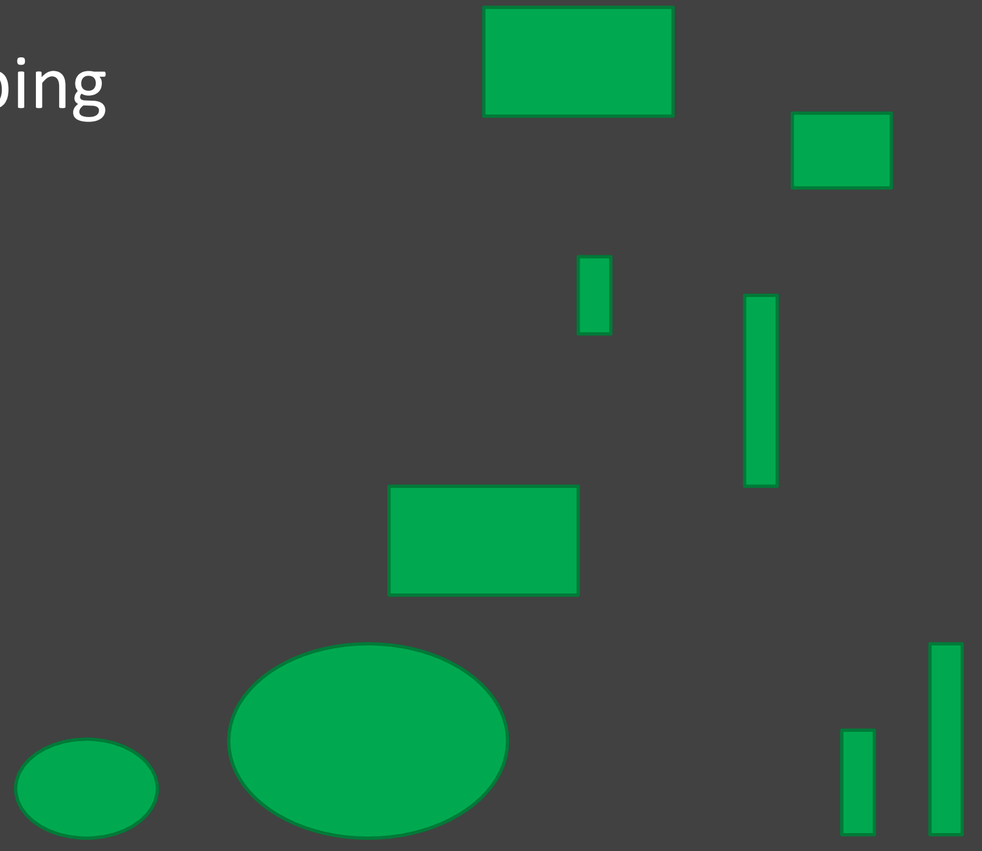
How many unique marks can we make?

Position

- Strongest visual variable Suitable for all data types
- Problems:
  - Sometimes not available
  - Cluttering

Size & Length

- Good visual variable
- Easy to see whether one is bigger Grouping works
- Judging differences
  - Good for aligned bars (position)
  - OK for changes in length
  - Bad for changes in area



Shape

Great to recognize many classes.

No ordering.

Value

Good for quantitative data when length & size are used.

Not very many shades recognizable

Supports grouping

Is preattentive (stands out) if sufficiently different

Color

Good for qualitative data Limited number of classes!

Not good for quantitative data!

Is preattentive if sufficiently different.

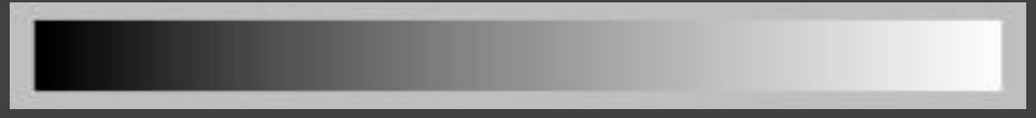
Lots of pitfalls! Be careful!

Information in color and value

Value is perceived as ordered

∴ Encode ordinal variables (O)

∴ Encode continuous variables (Q) [not as well]



Hue is normally perceived as unordered

∴ Encode nominal variables (N) using color

Bertin's "Levels of Organization"

Position	N	O	Q
Size	N	O	Q
Value	N	O	Q
Texture	N	O	
Color	N		
Orientation	N		
	N		

Nominal

Ordered

Quantitative

Note: **Q <O <N**

Q: How can levels of organization (of perceptual channels) be verified?

Q: How can levels of organization (of perceptual channels) be verified?

A: Different Data visualization scientists performed evaluation study to verify and obtain ordering/rankings of perceptual channels

Cleveland & McGill Experiments

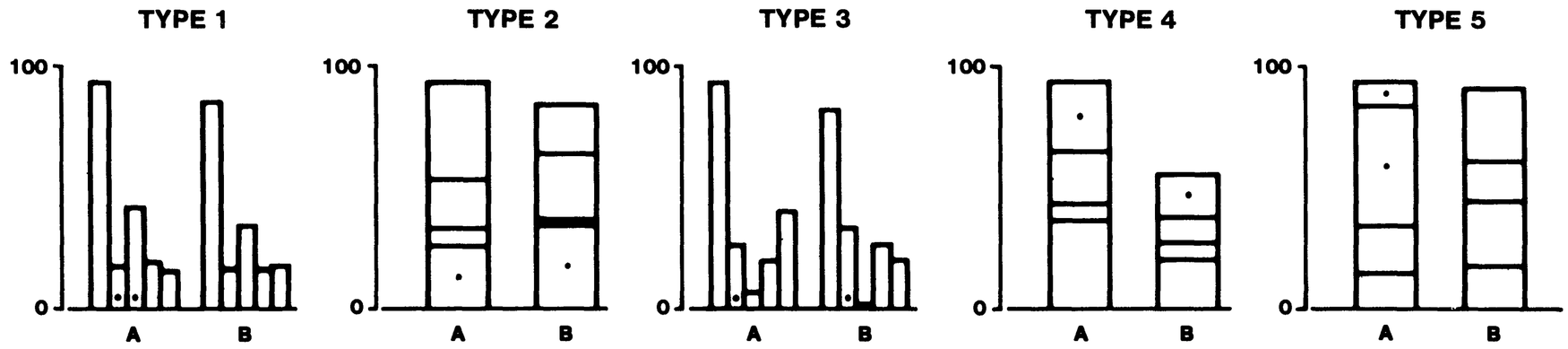


Figure 4. Graphs from position–length experiment.

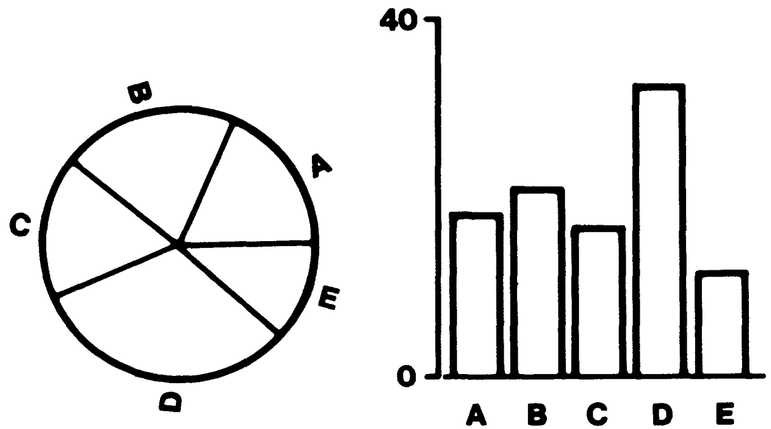
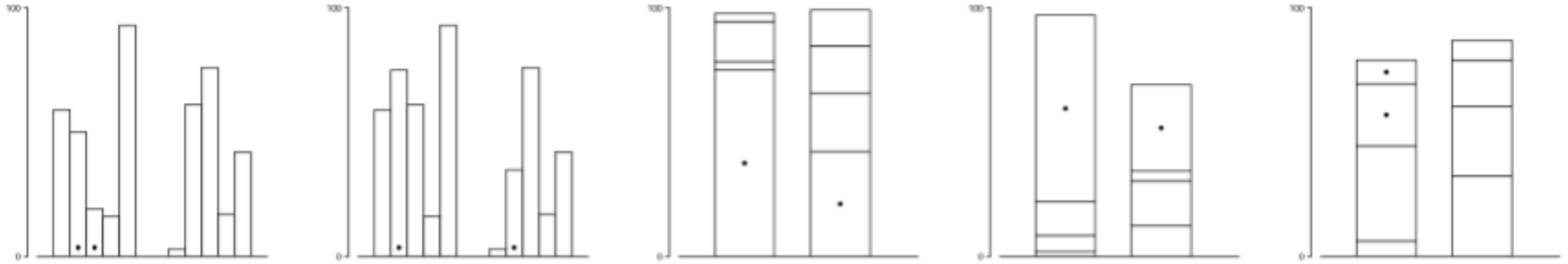


Figure 3. Graphs from position–angle experiment.

[Cleveland & McGill, 1984]



(a) Adjacent Bars (Type 1)

(b) Separated Bars (Type 3)

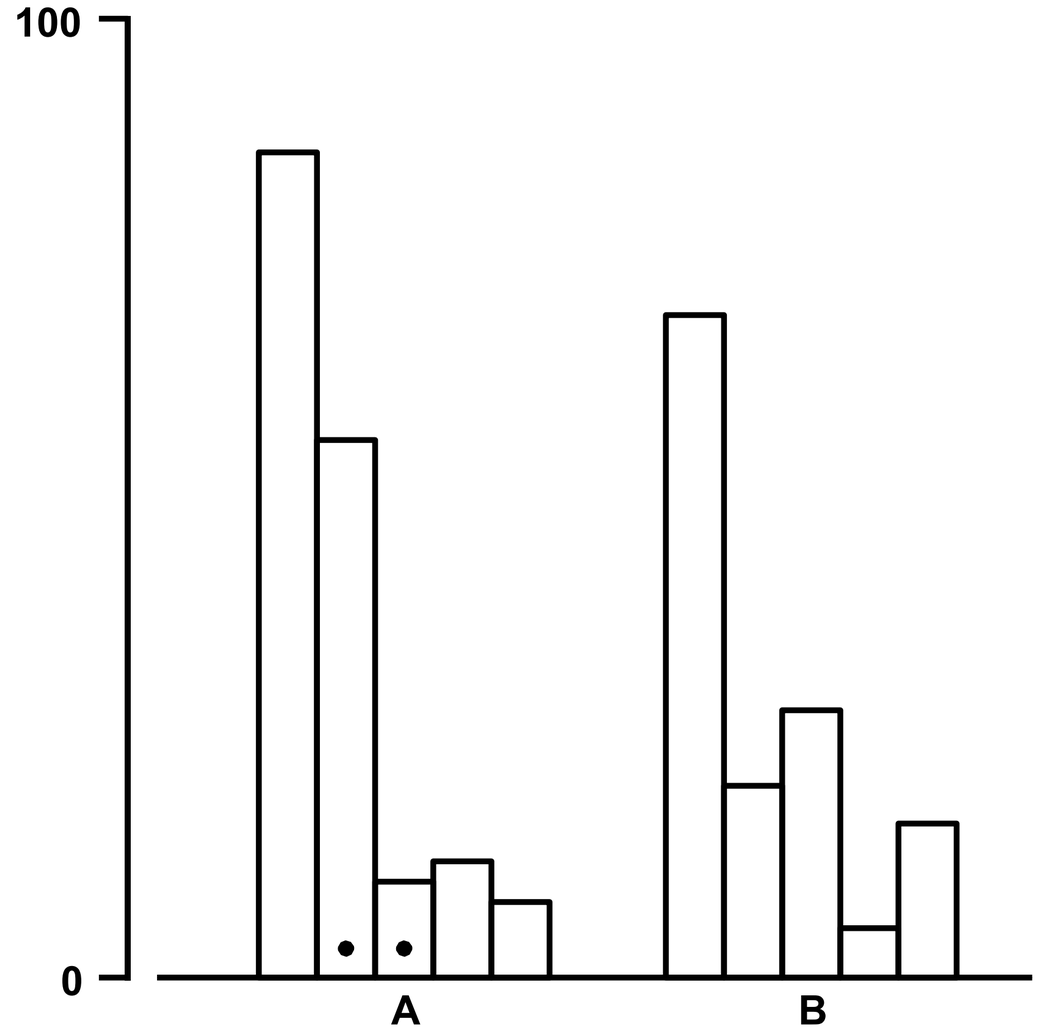
(c) Aligned Stacked Bars (Type 2)

(d) Unaligned Stacked Bars (Type 4)

(e) Divided Bar (Type 5)

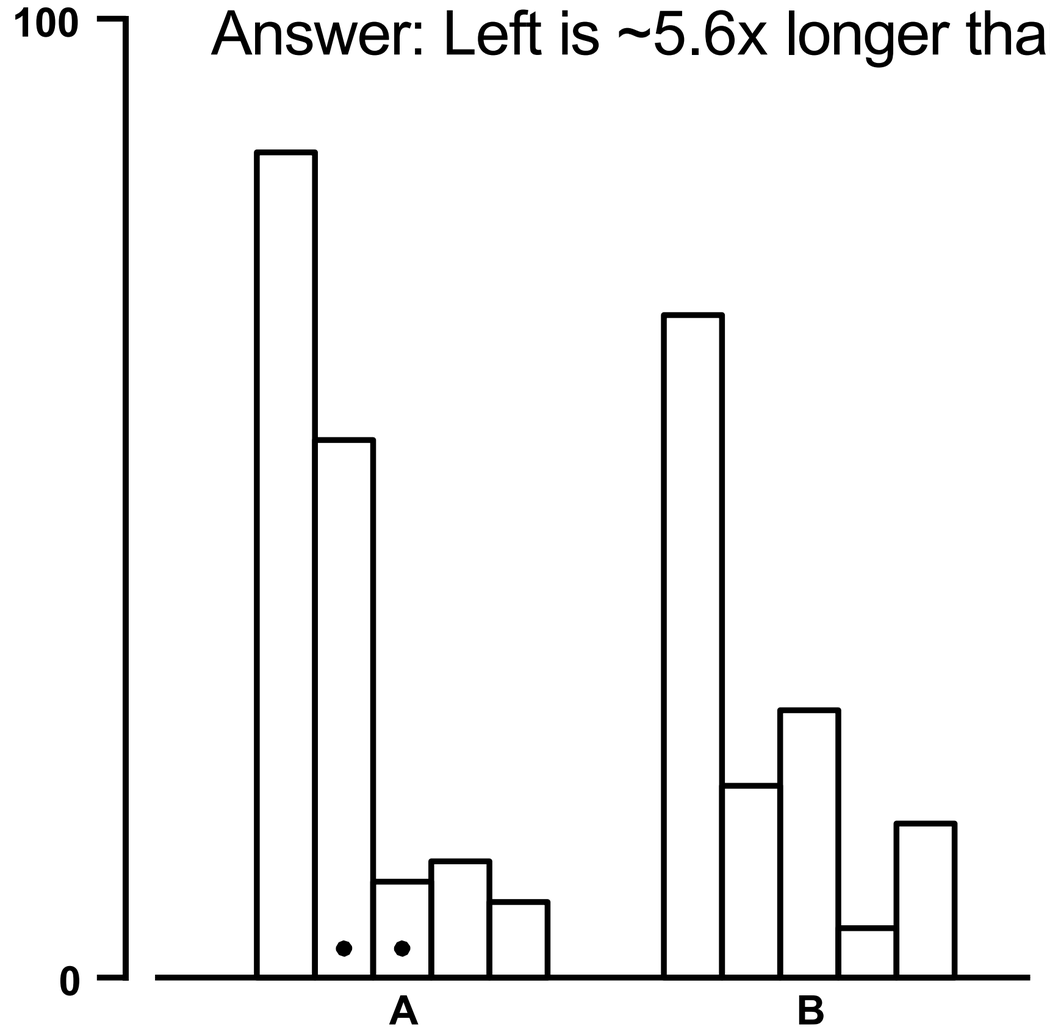
Fig. 1: The five bar chart tasks studied in Cleveland & McGill [1]. Study participants were asked to estimate the height of the shorter marked bar as a percent of the taller marked bar. Cleveland & McGill's ranked these tasks from lowest error (Type 1) to highest error (Type 5).

Test % difference in length between elements



[Heer & Bostock, 2010]

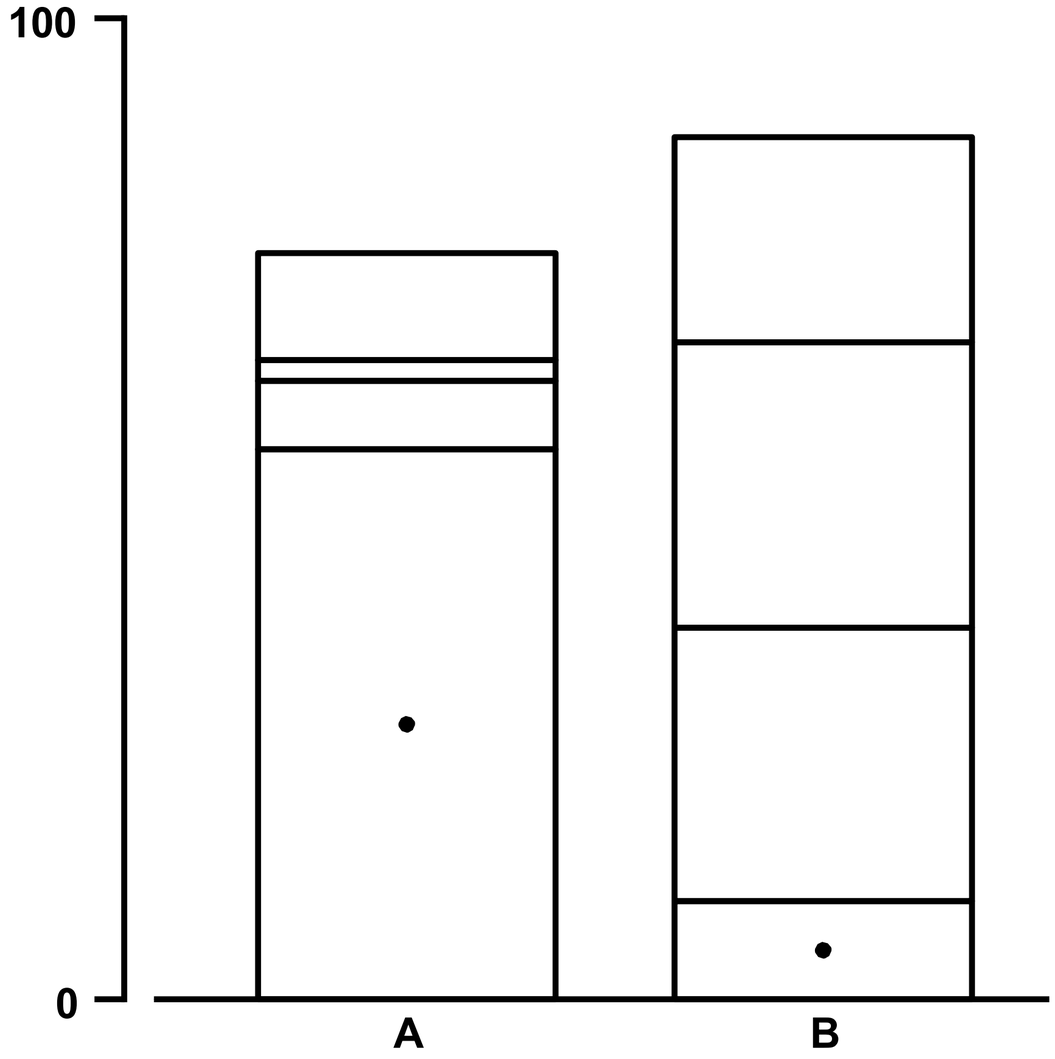
Test % difference in length between elements



Answer: Left is ~5.6x longer than Right

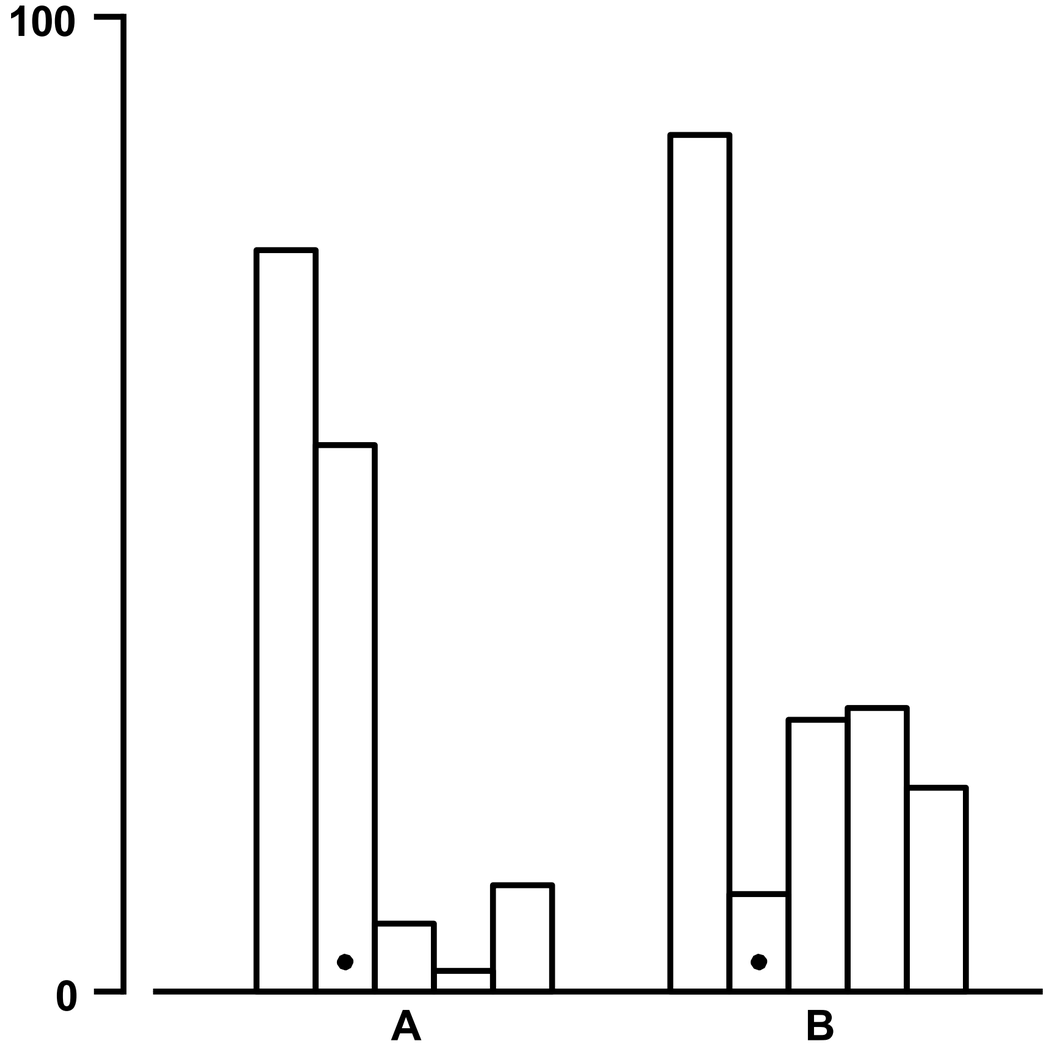
[Heer & Bostock, 2010]

Test % difference in length between elements



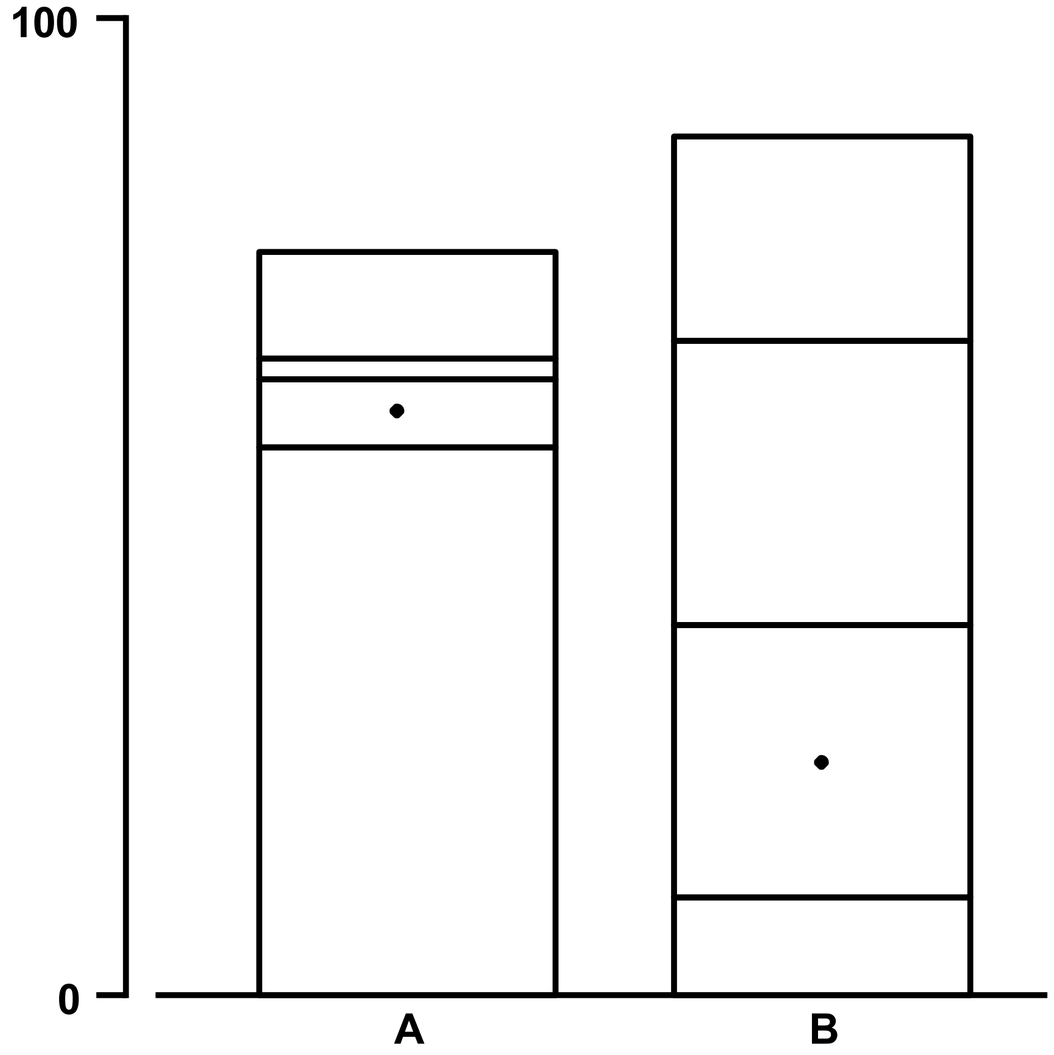
[Heer & Bostock, 2010]

Test % difference in length between elements



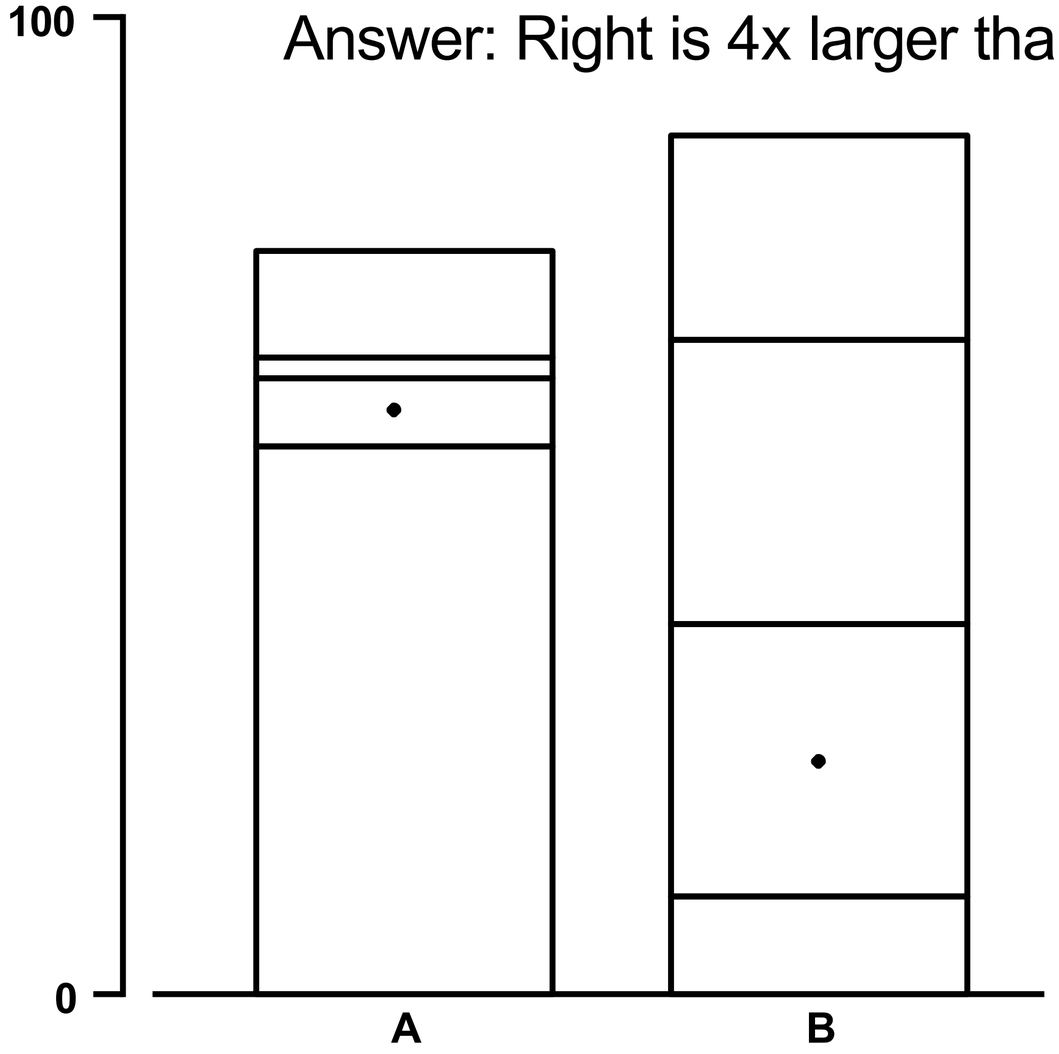
[Heer & Bostock, 2010]

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]

"Ordering of Elemental Perceptual Tasks"

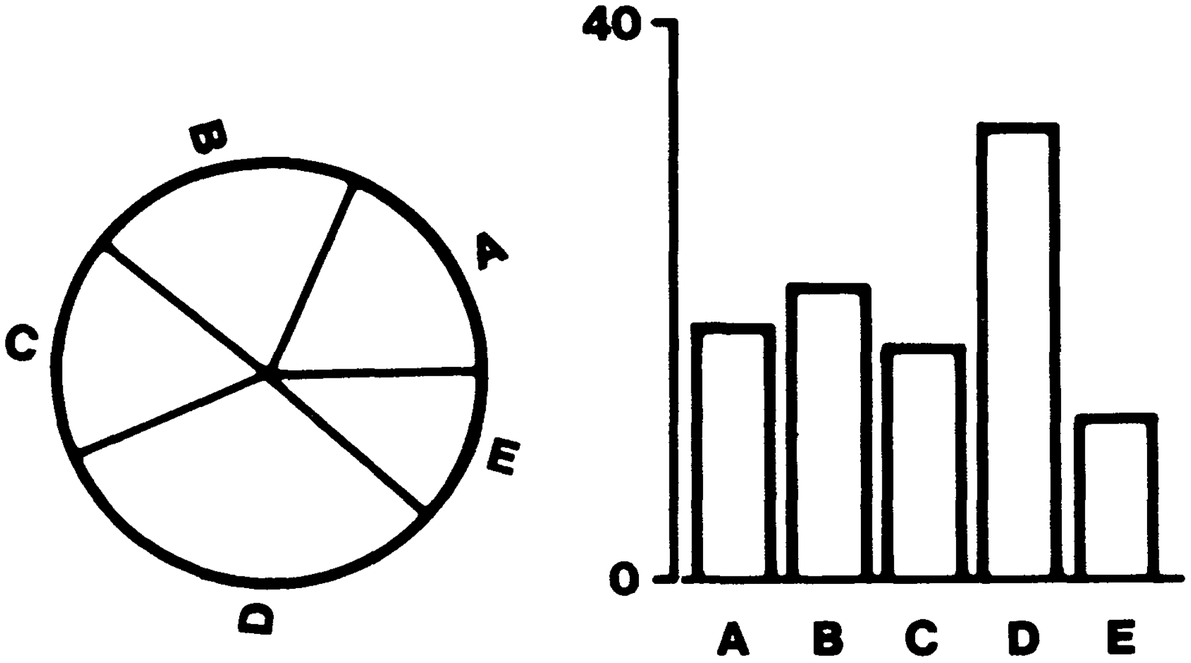


Figure 3. Graphs from position–angle experiment.

TASK: Which segment/bar is the maximum, and what is its percentage/value?

Cleveland & McGill (1984)

“Ordering of Elemental Perceptual Tasks”

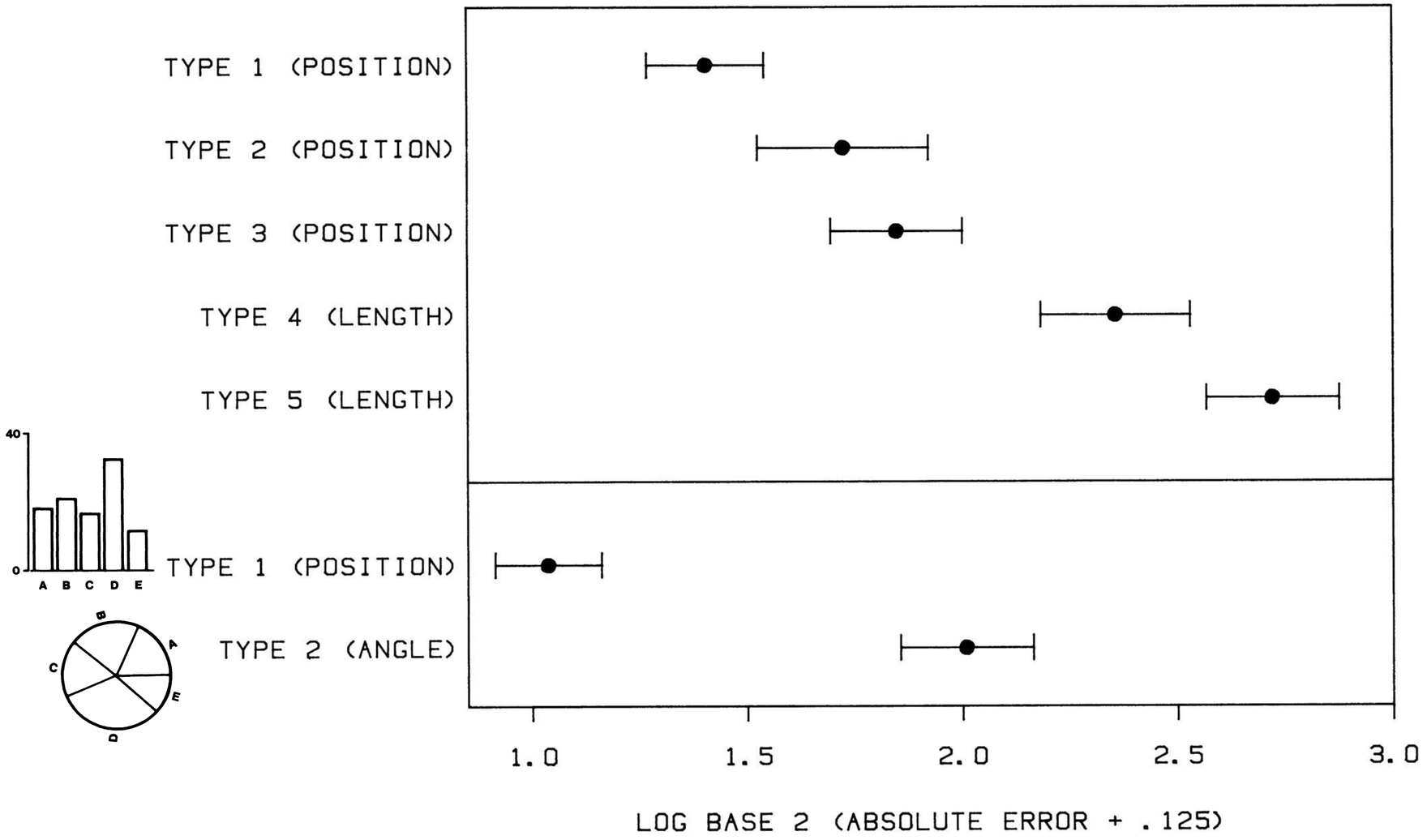


Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

Cleveland & McGill (1984)

“Ordering of Elemental Perceptual Tasks”

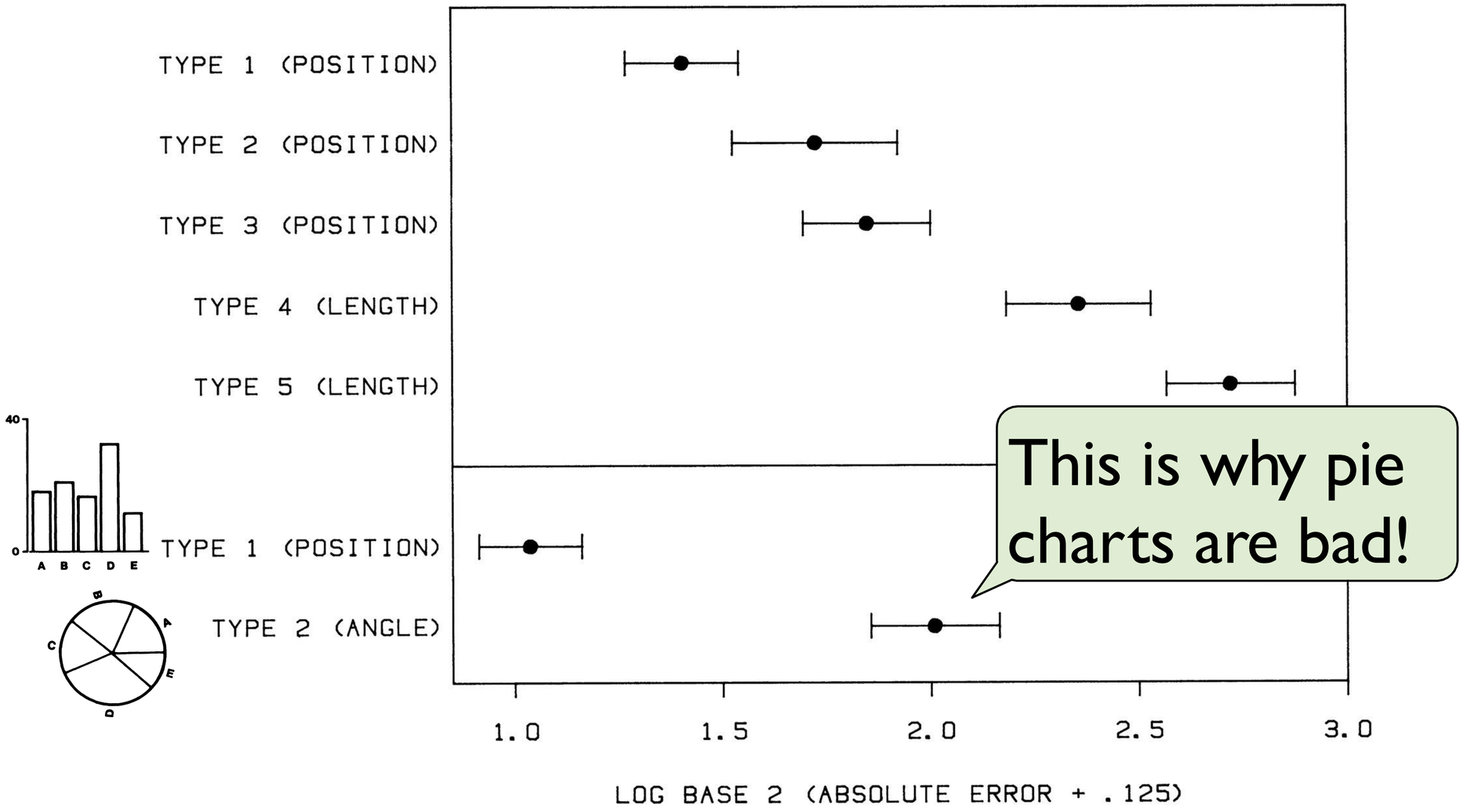
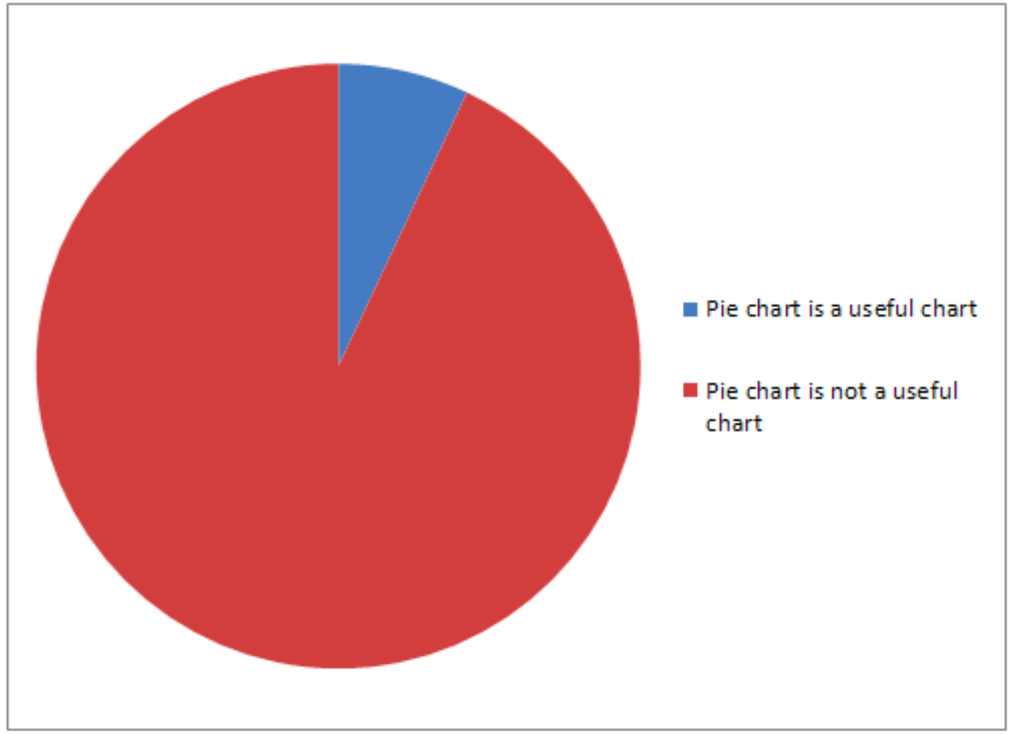
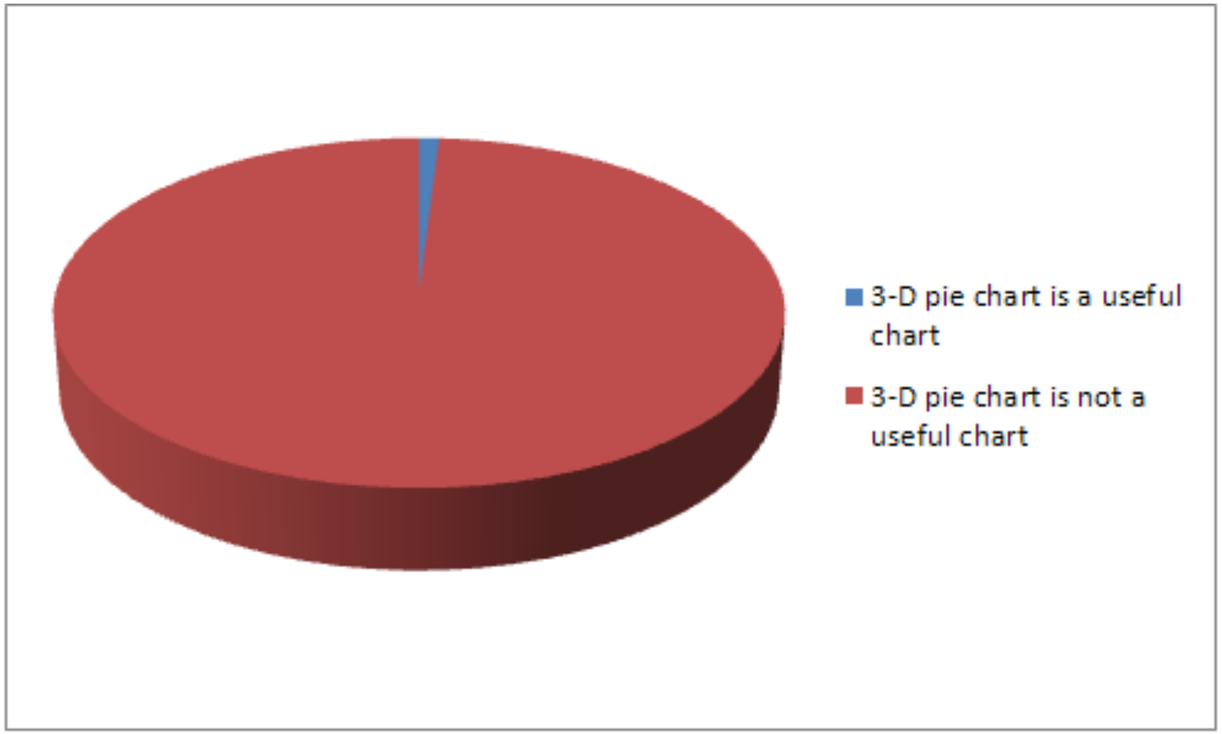


Figure 16. Log absolute error means and 95% confidence intervals for judgment types in position–length experiment (top) and position–angle experiment (bottom).

Cleveland & McGill (1984)

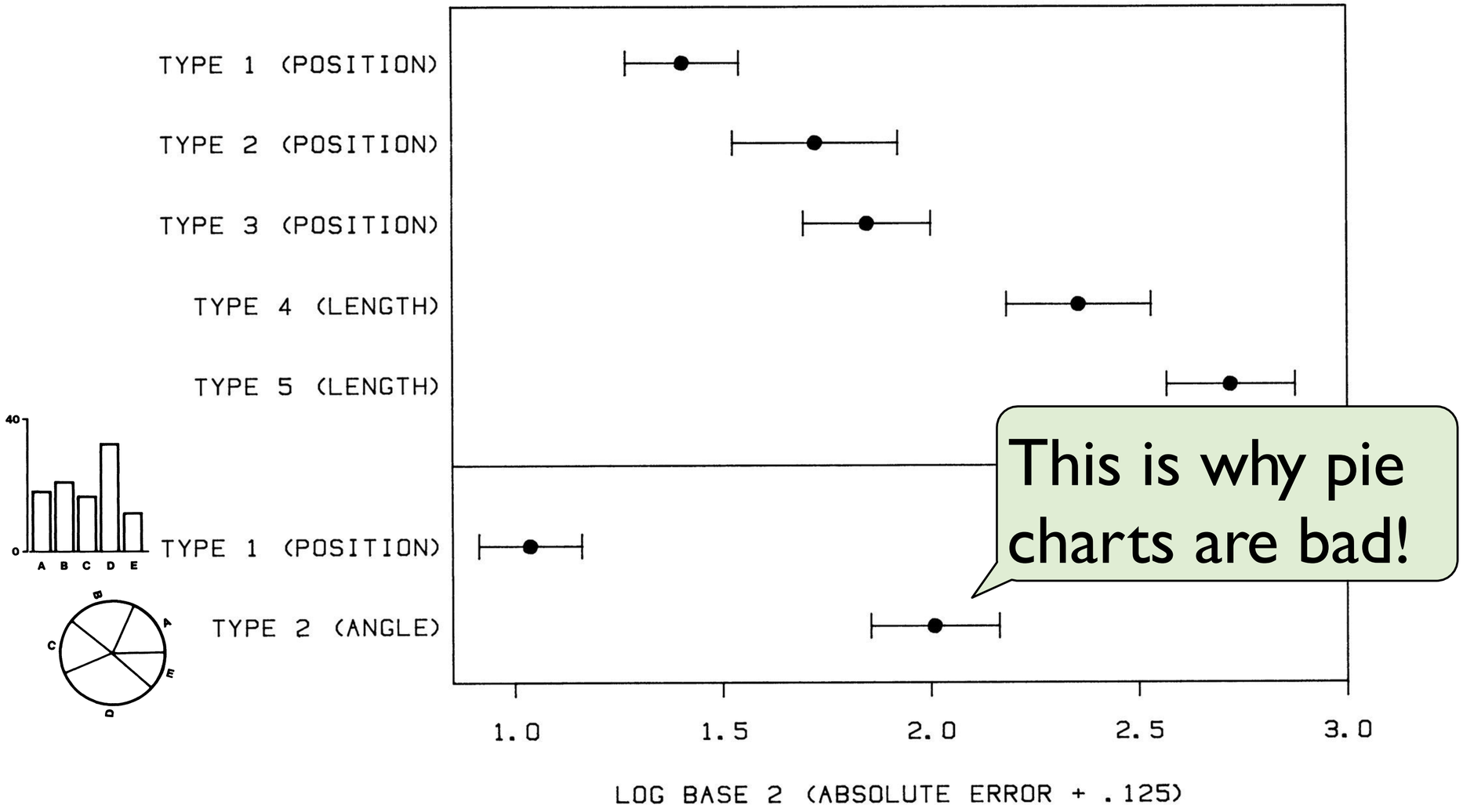
This is why pie charts are bad!





https://www.washingtonpost.com/news/wonk/wp/2013/06/17/the-usefulness-of-pie-charts-in-two-pie-charts/

“Ordering of Elemental Perceptual Tasks”



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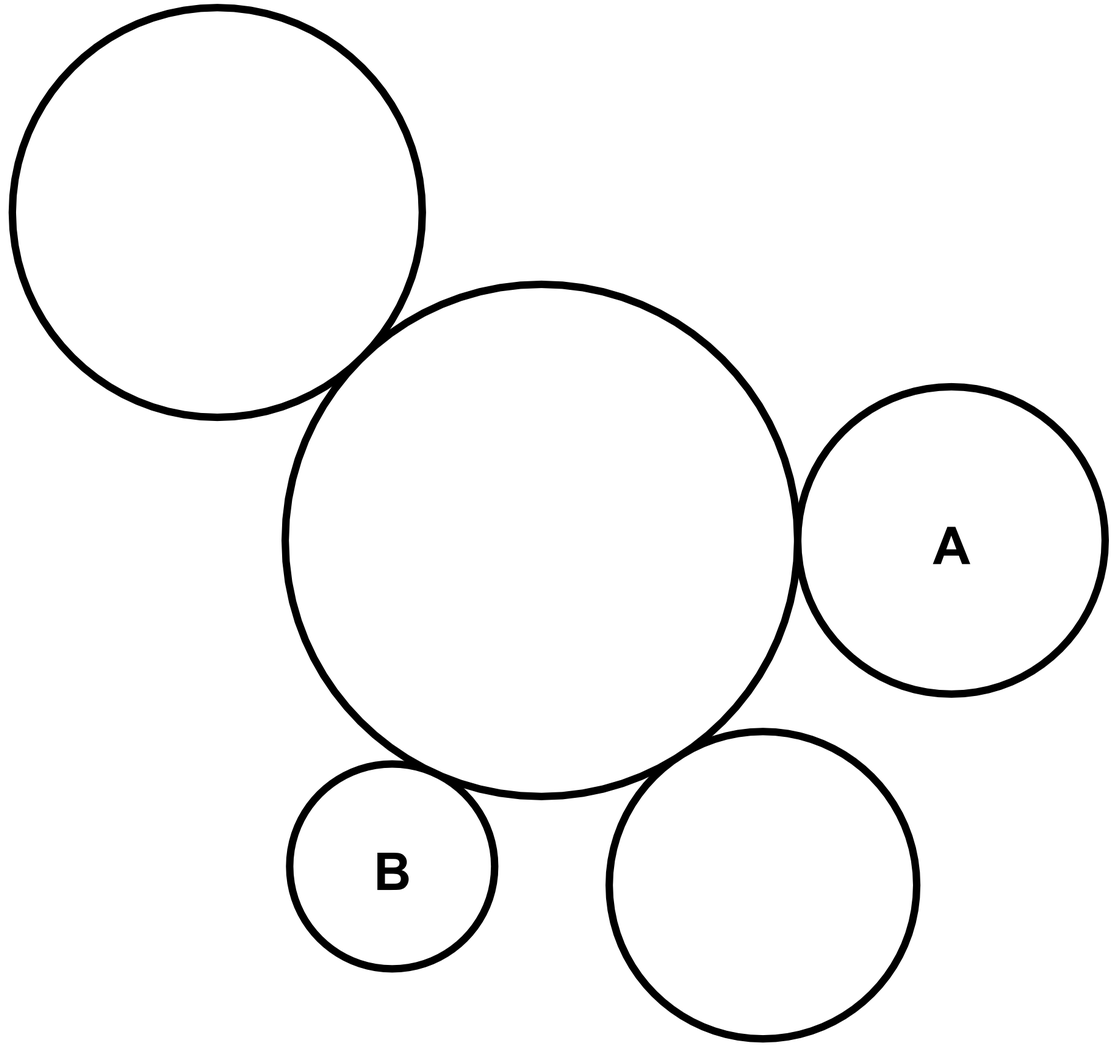
Cleveland & McGill (1984)

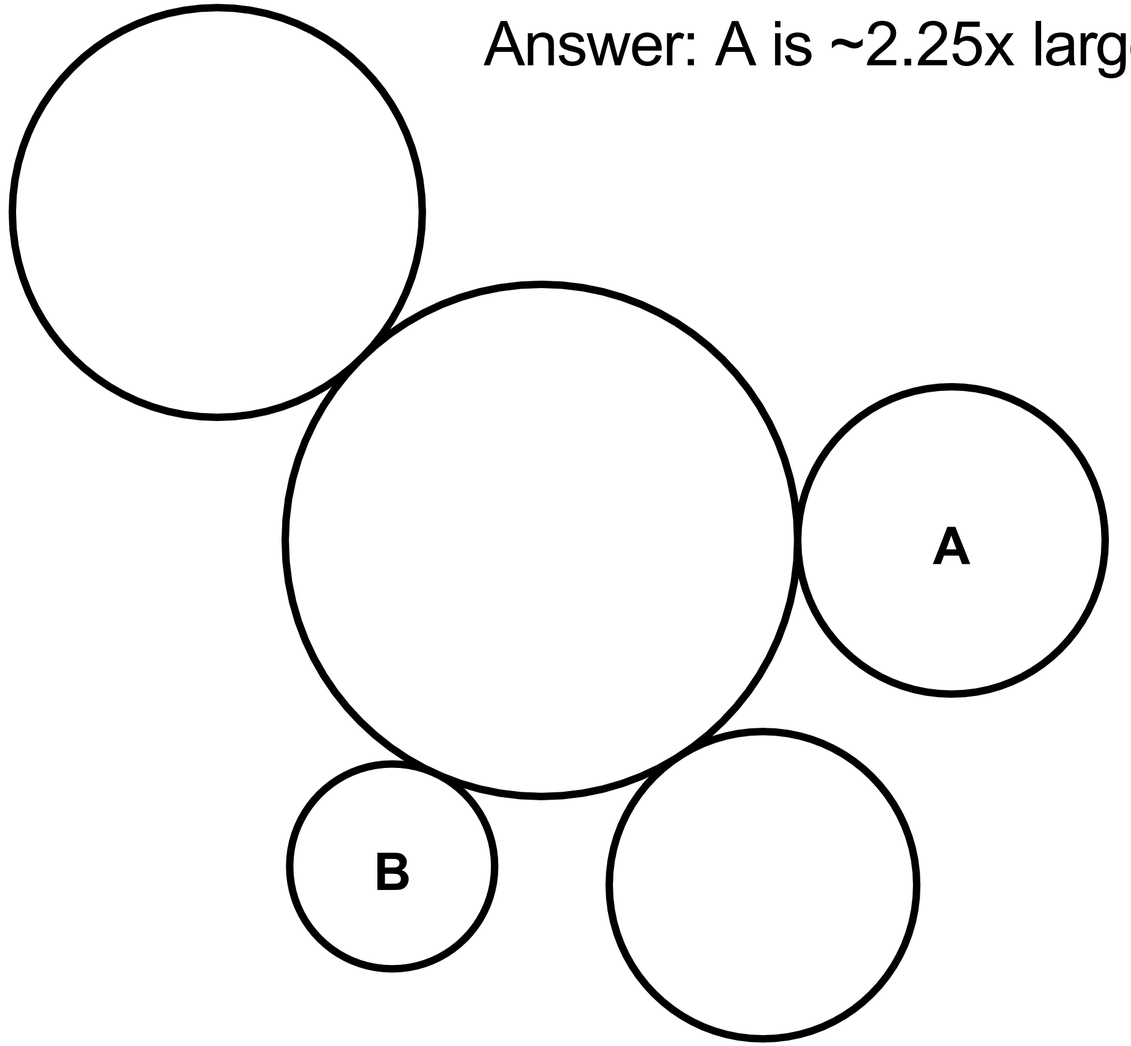
Test % difference in area between elements



[Heer & Bostock, 2010]

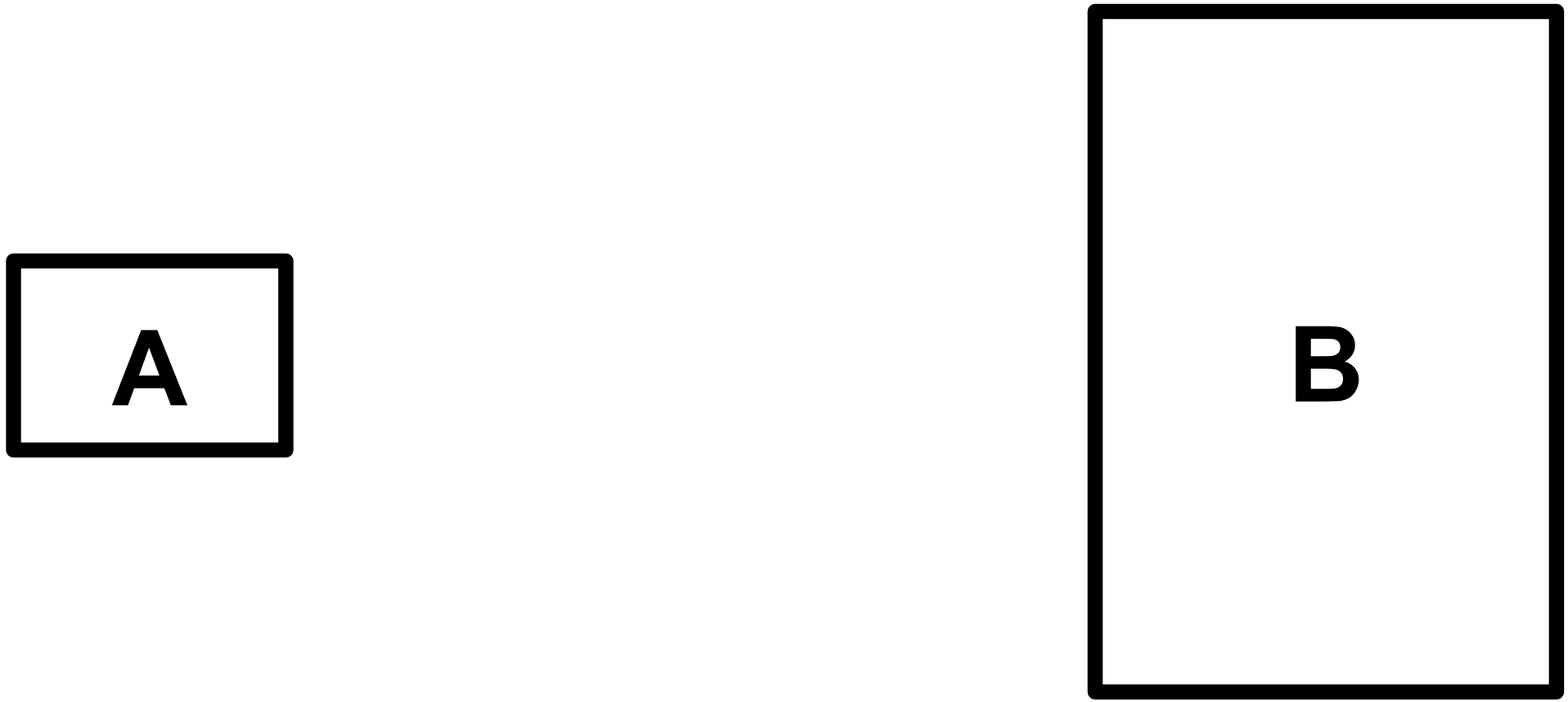
Test % difference in area between elements

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



[Heer & Bostock, 2010]

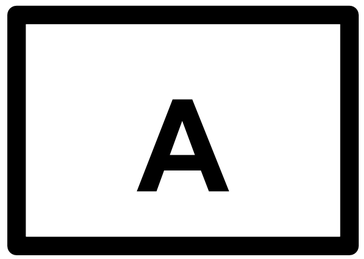
Test % difference in area between elements

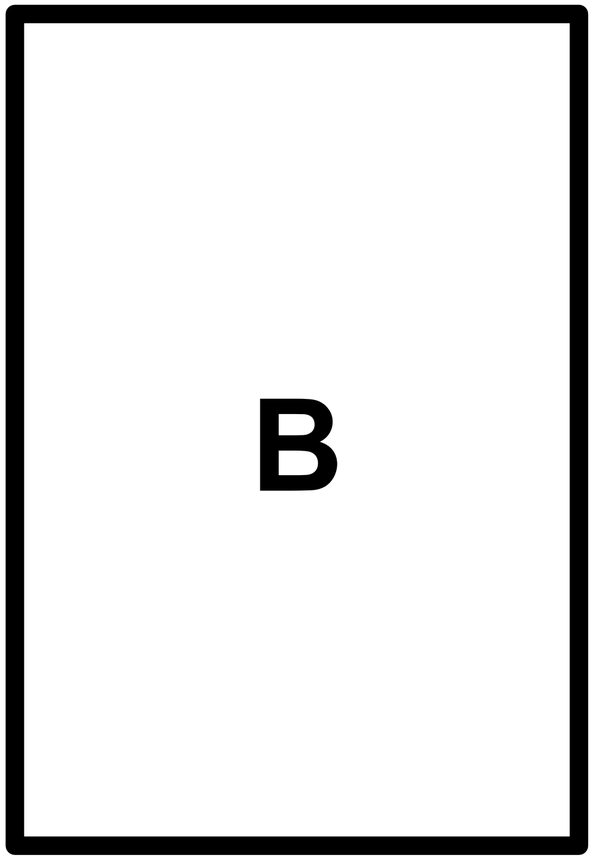


[Heer & Bostock, 2010]

Test % difference in area between elements

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





[Heer & Bostock, 2010]

Heer & Bostock Experiments

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

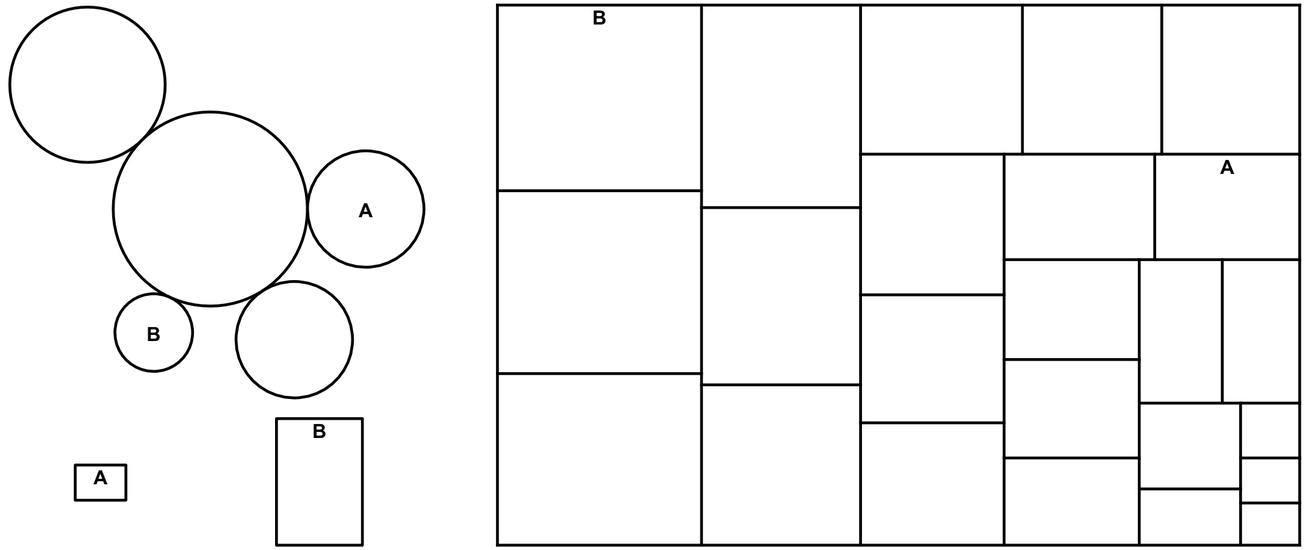
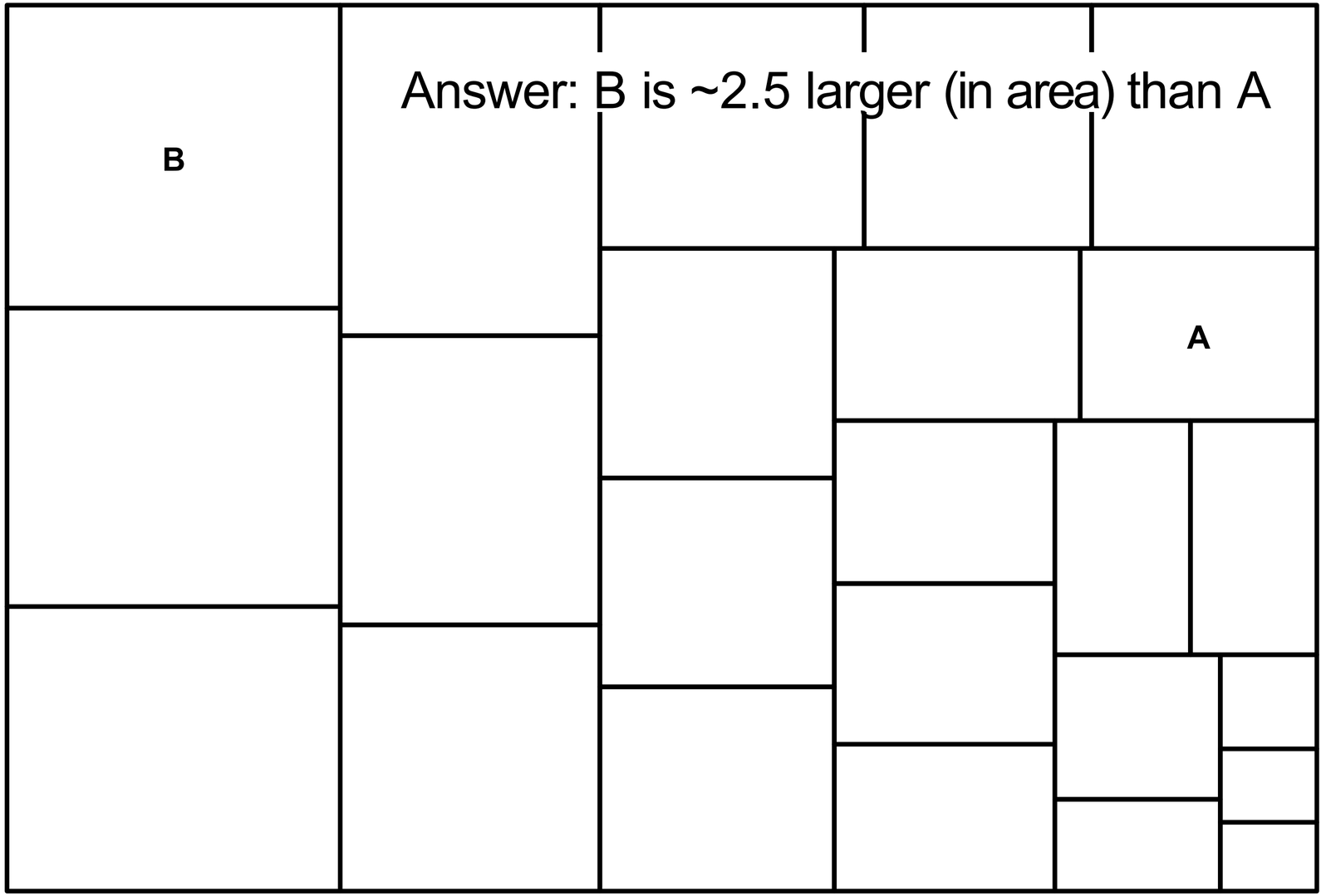


Figure 2: Area judgment stimuli. Top left: Bubble chart (T7), Bottom left: Center-aligned rectangles (T8), Right: Treemap (T9).

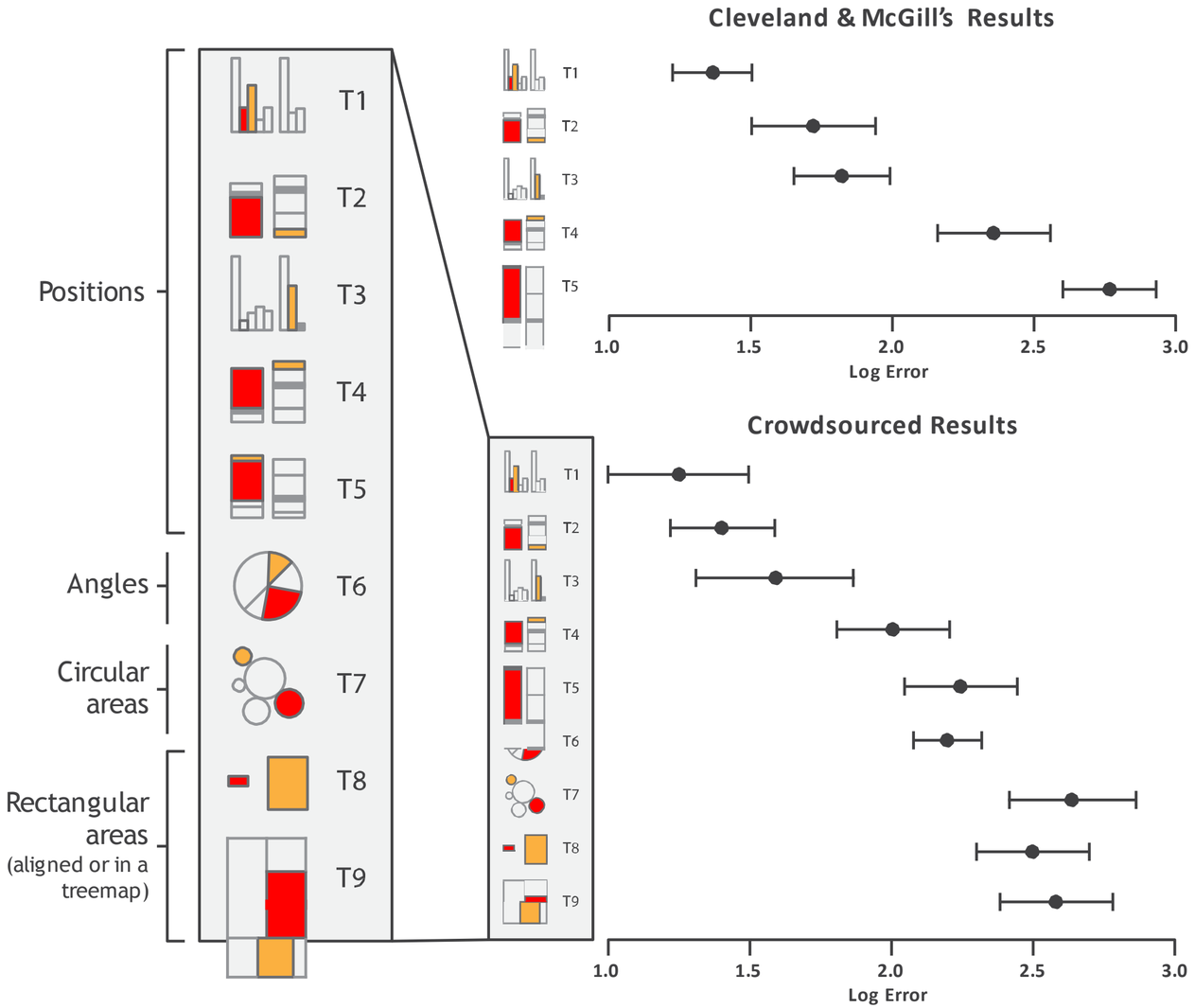
[Heer & Bostock, 2010]

Test % difference in area between elements



[Heer & Bostock, 2010]

Results Summary



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

Other scientists also came up with similar channel rankings (w.r.t data type)

Channel Ranking by Data Type

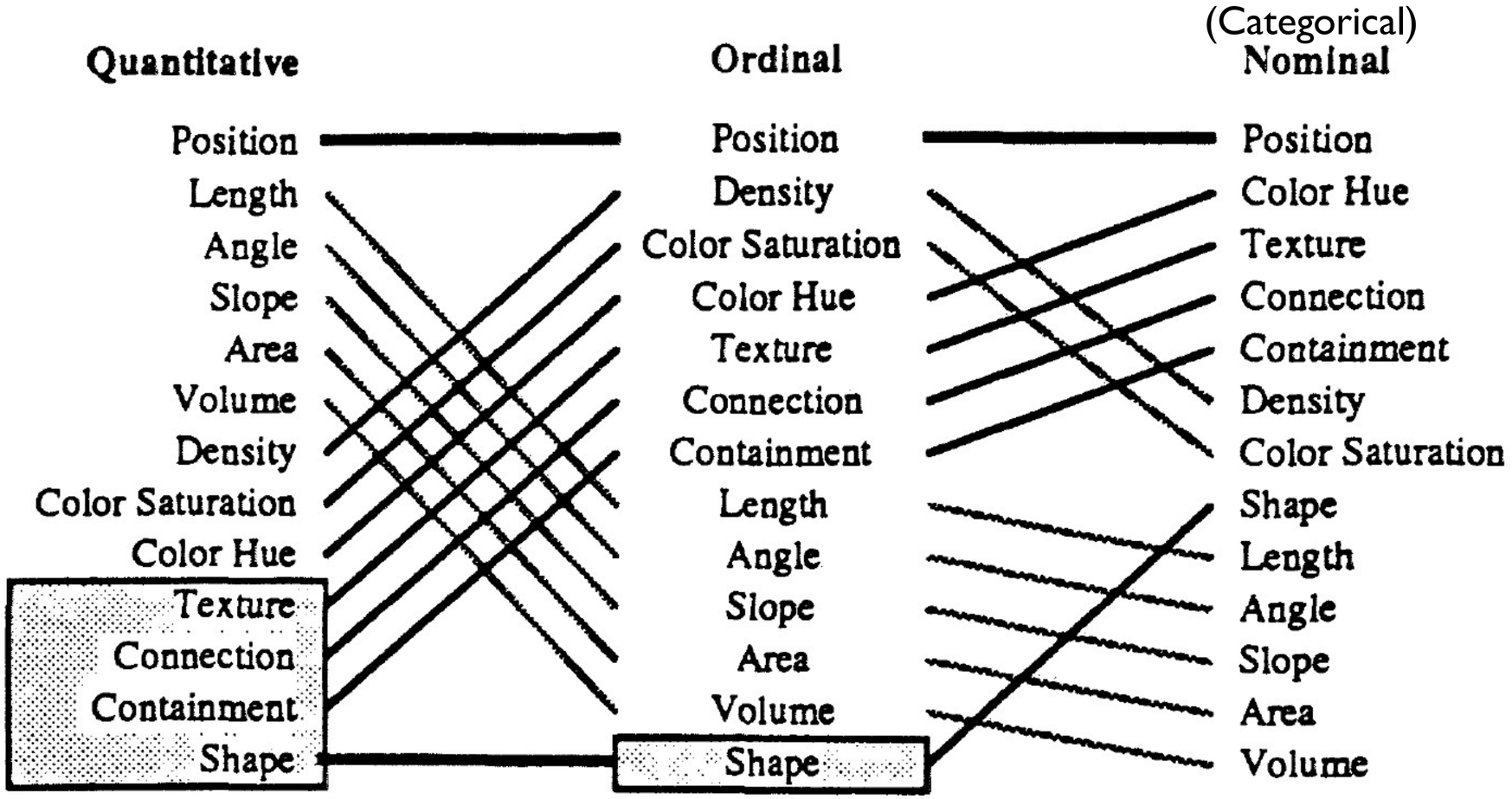
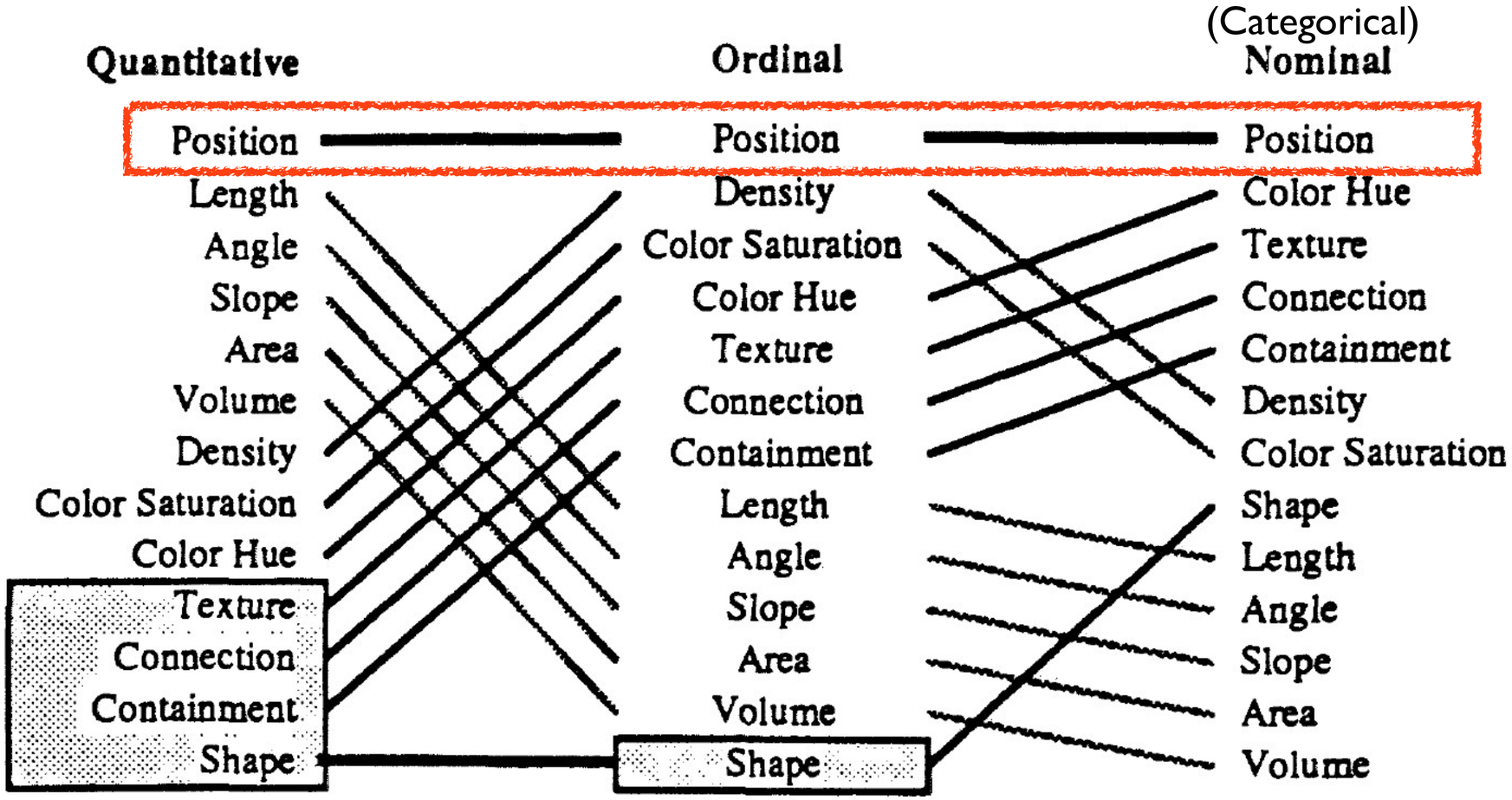


Figure 15: Ranking of Perceptual Tasks. *The tasks shown in the gray boxes are not relevant to that type of data.*

Mackinlay (1986)

Channel Ranking by Data Type



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Mackinlay (1986)

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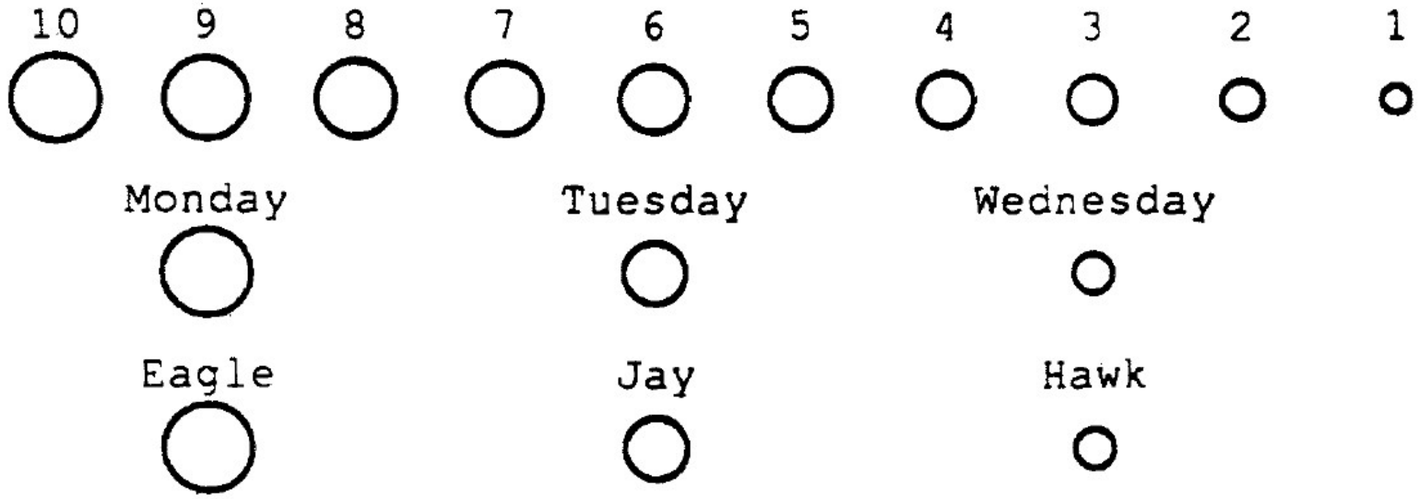
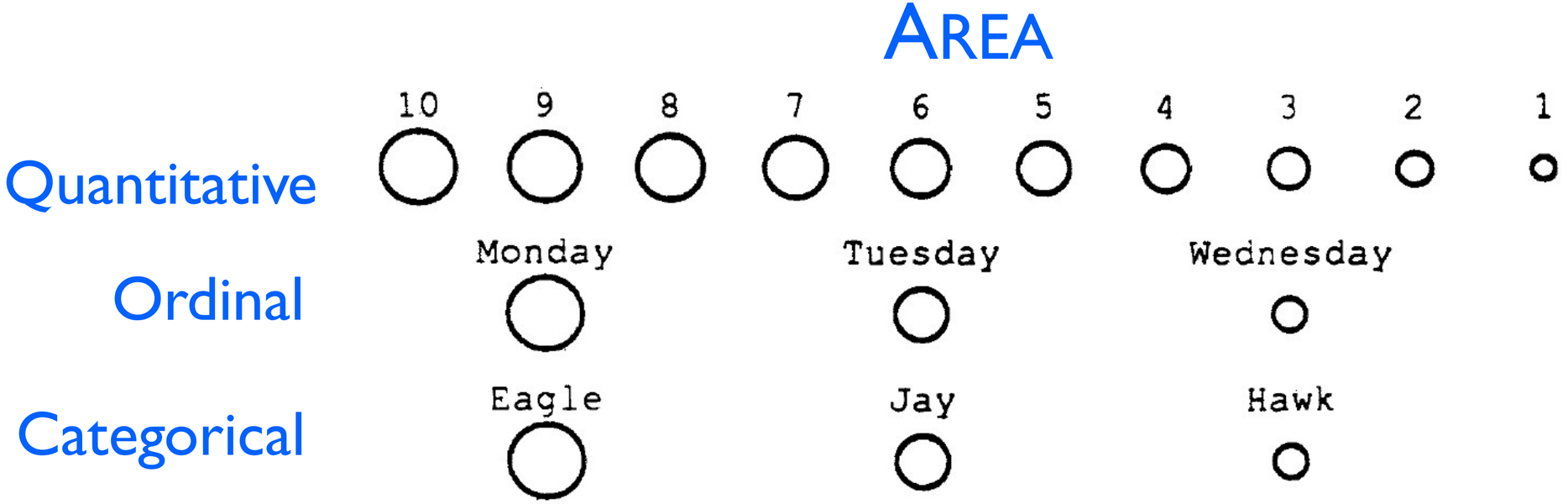


Figure 16: Analysis of the Area Task.

Mackinlay (1986)

Channel Ranking by Data Type



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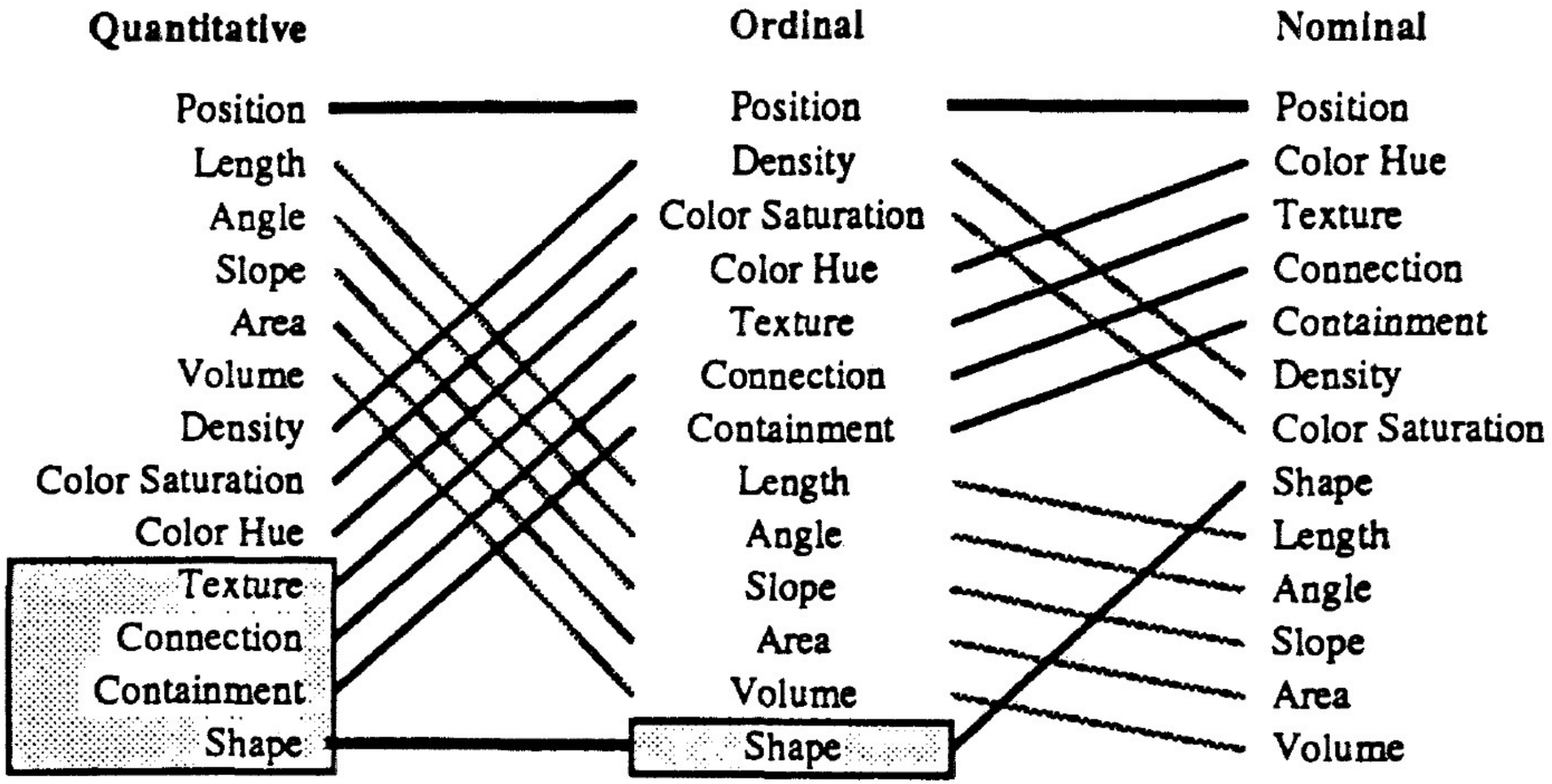

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Mackinlay (1986)

Channel Ranking by Data Type

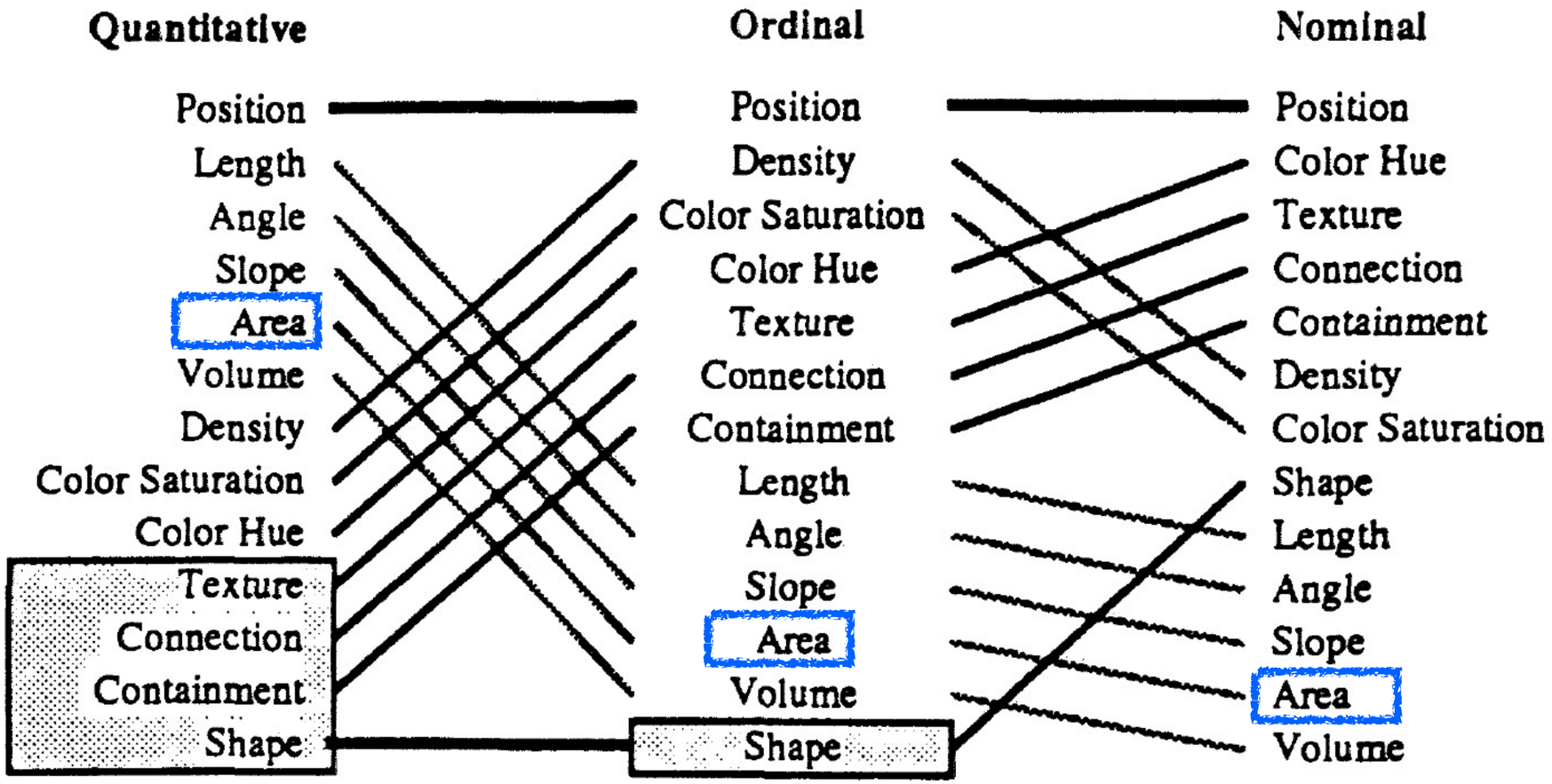


Figure 15: Ranking of Perceptual Tasks. *The tasks shown in the gray boxes are not relevant to that type of data.*

Mackinlay (1986)

Expressiveness and Effectiveness of a Visualization

Effectiveness

Effectiveness principle: the importance of the attribute should match the salience of the channel (i.e. the most important attributes should be the most salient).

Saliency: how noticeable something is

How-to-encode: most important attributes with highest ranked channels

- How do the channels we have discussed measure up?

Mackinlay (1986)

Expressiveness

Expressiveness principle: the visual encoding should express all of, and only, the information in the dataset attributes.
i.e. all data from the dataset and nothing more should be shown

How-to-encode: data characteristics should match the channel

- E.g. Do encode ordered data in an ordered fashion
- E.g. Don't encode categorical data in a way that implies an ordering

Mackinlay (1986)

Expressiveness

Expressiveness principle: the visual encoding should express all of, and only, the information in the dataset attributes.
(i.e., data characteristics should match the channel)

Mackinlay (1986)

Expressiveness and Effectiveness

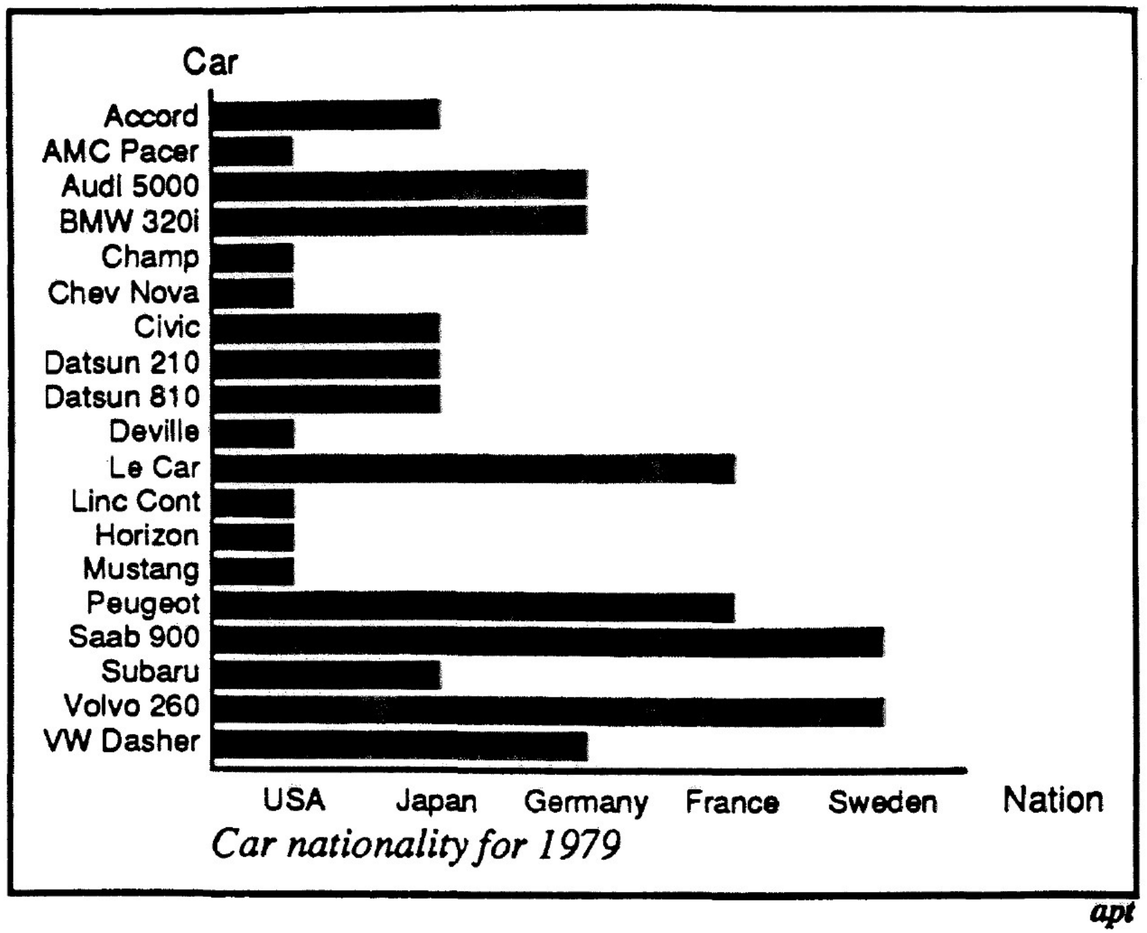


Figure 11: Incorrect Use of a Bar Chart for the Nation Relation. *The lengths of the bars suggest an ordering on the vertical axis, as if the* USA *cars were longer or better than the other cars, which is not true for the Nation relation.*

Mackinlay (1986)

Expressiveness and Effectiveness

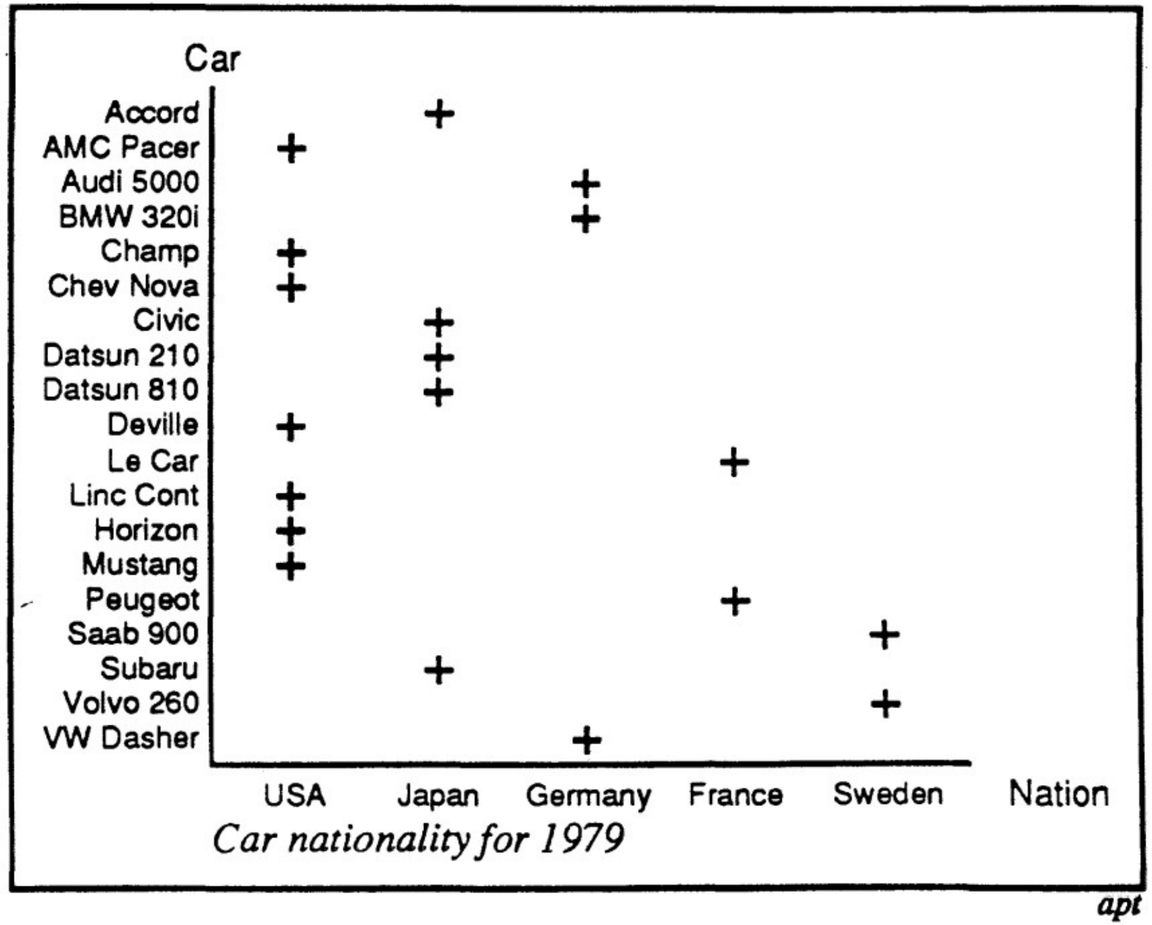
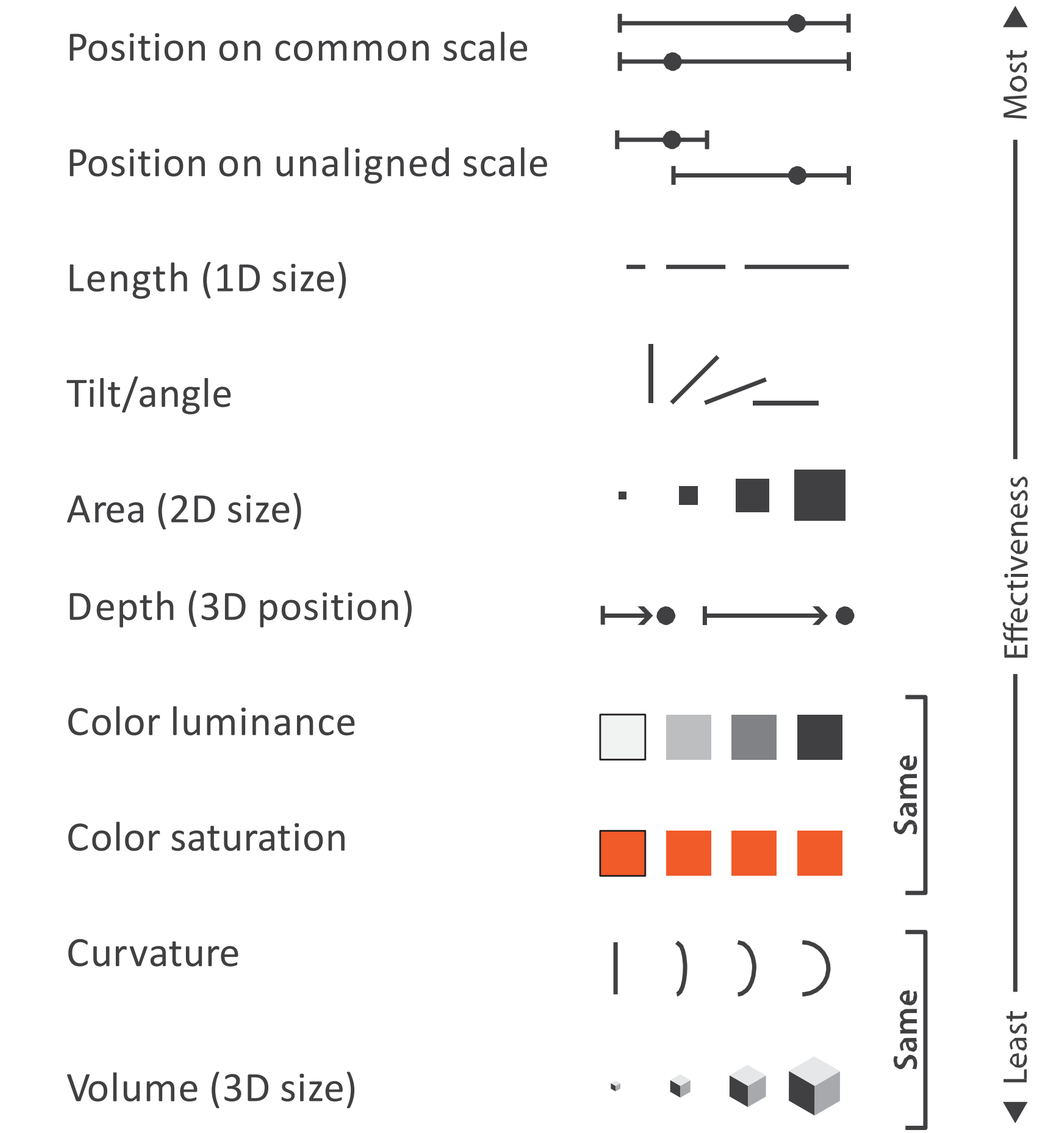


Figure 12: Correct Use of a Plot Chart for the Nation Relation. *Since bar charts encode ordered domain sets, plot charts are conventionally used to encode nominal domain sets. The ordering of the labels on the axes is ignored.*

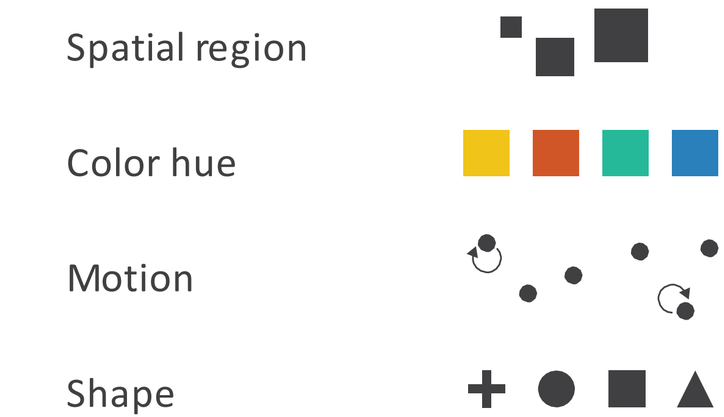
Mackinlay (1986)

Channels: Expressiveness Types and Effectiveness Ranks

Magnitude Channels: Ordered Attributes



Identity Channels: Categorical Attributes

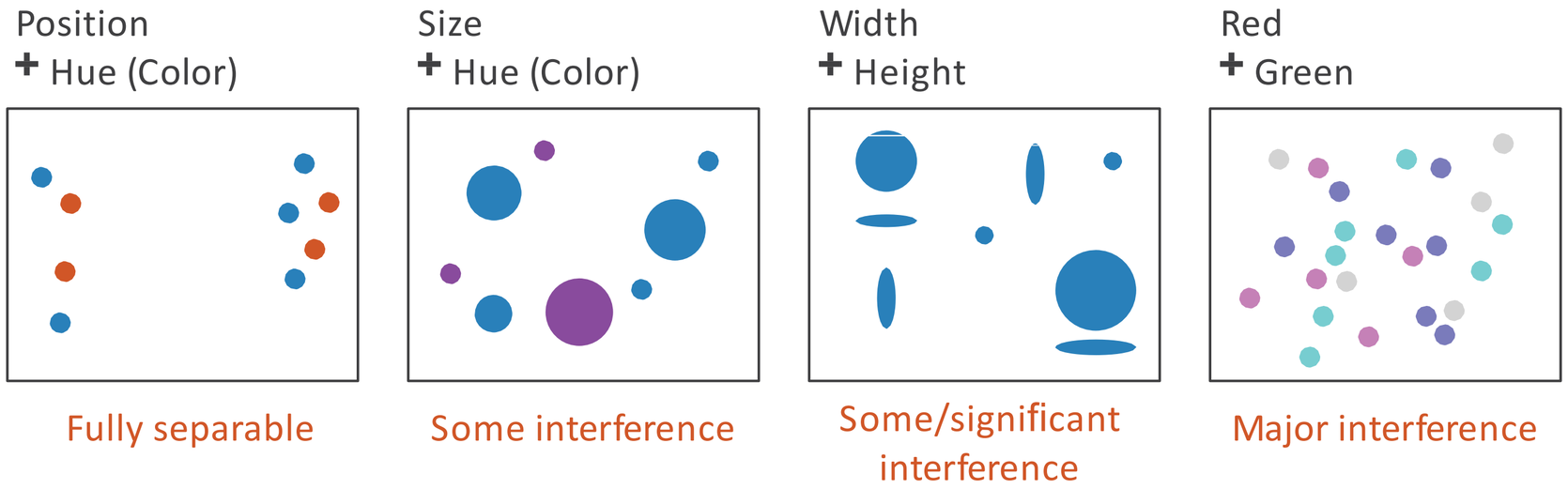


Visual Channel considerations

Some other factors important too

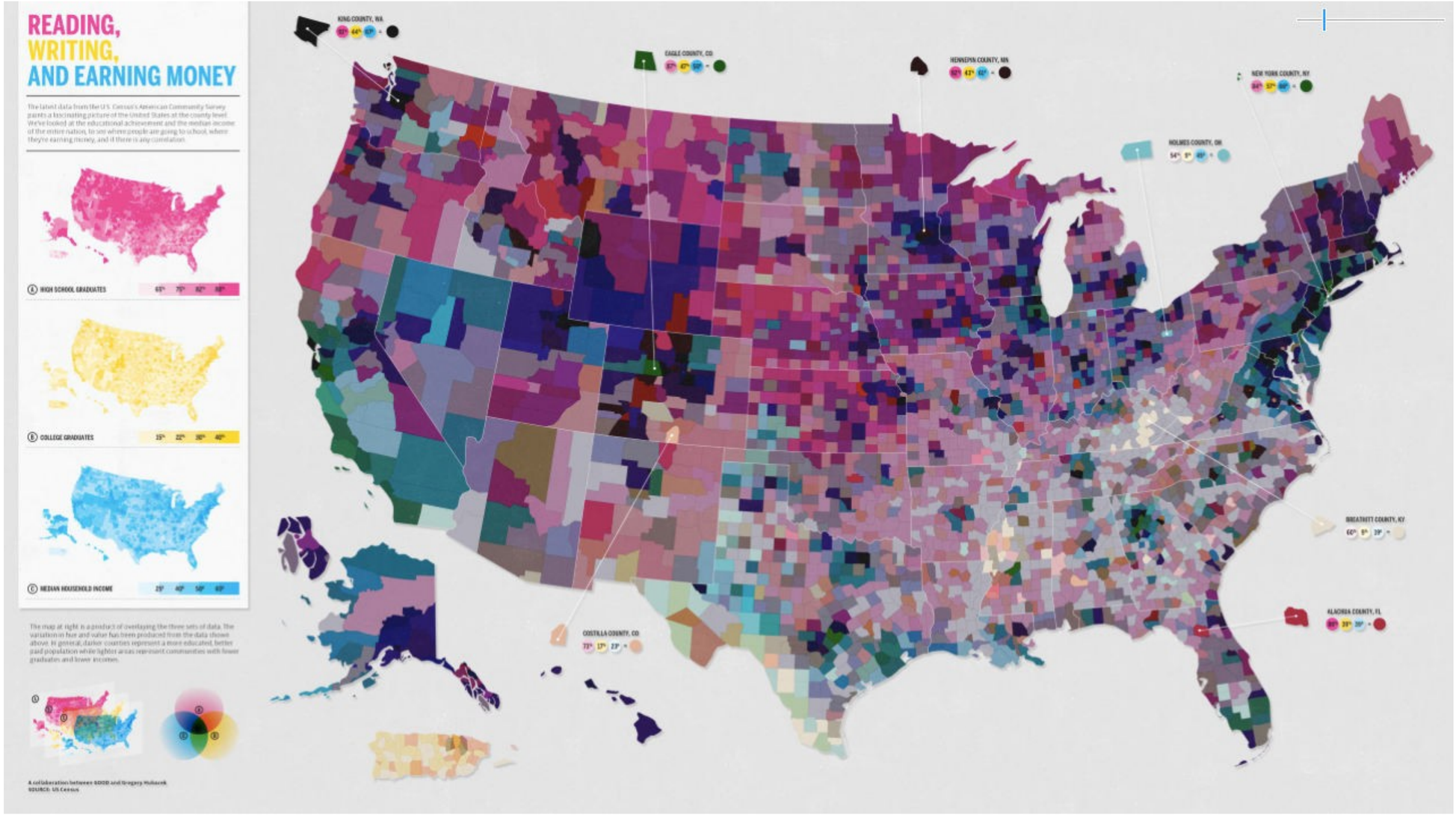
Separability

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

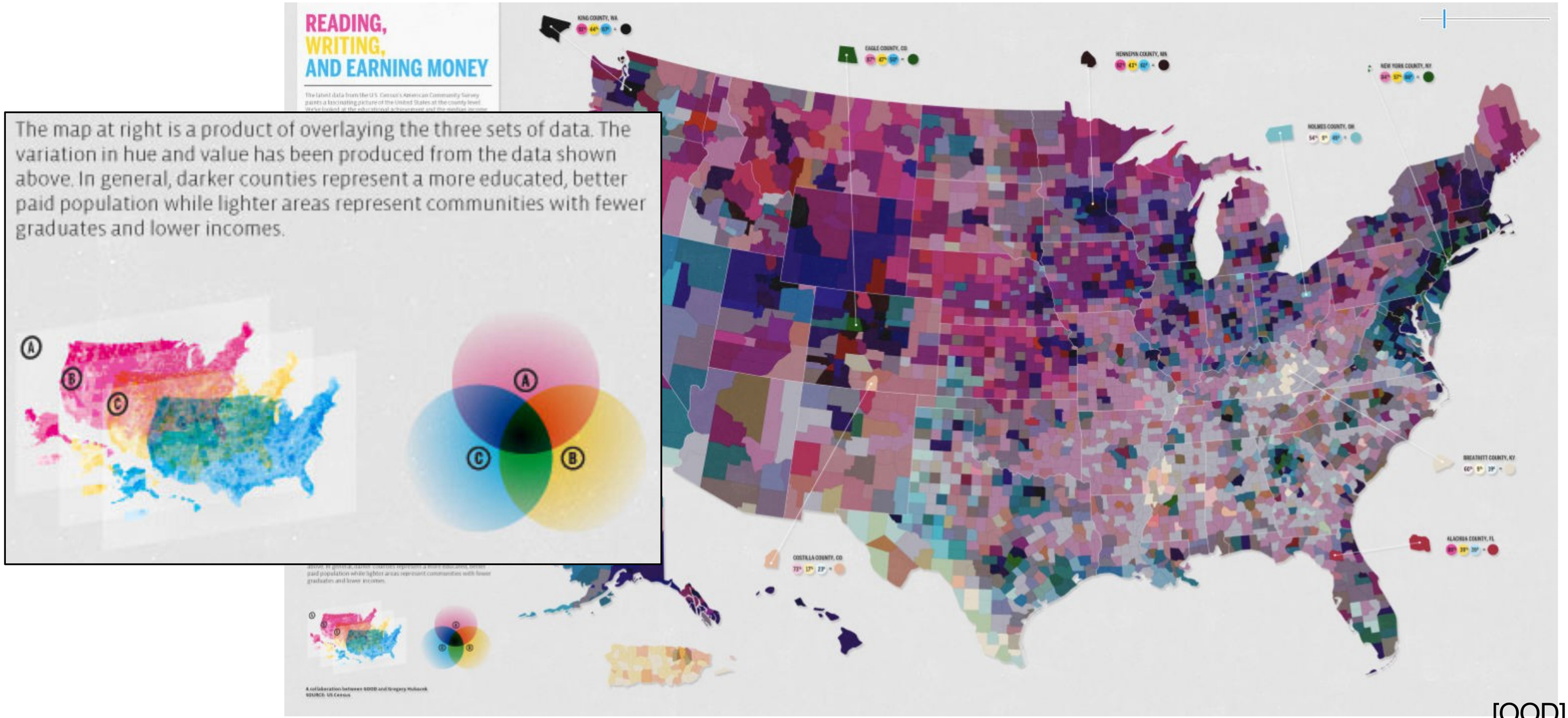


[Munzner (ill. Maguire) based on Ware, 2014]

Separable or Integral?

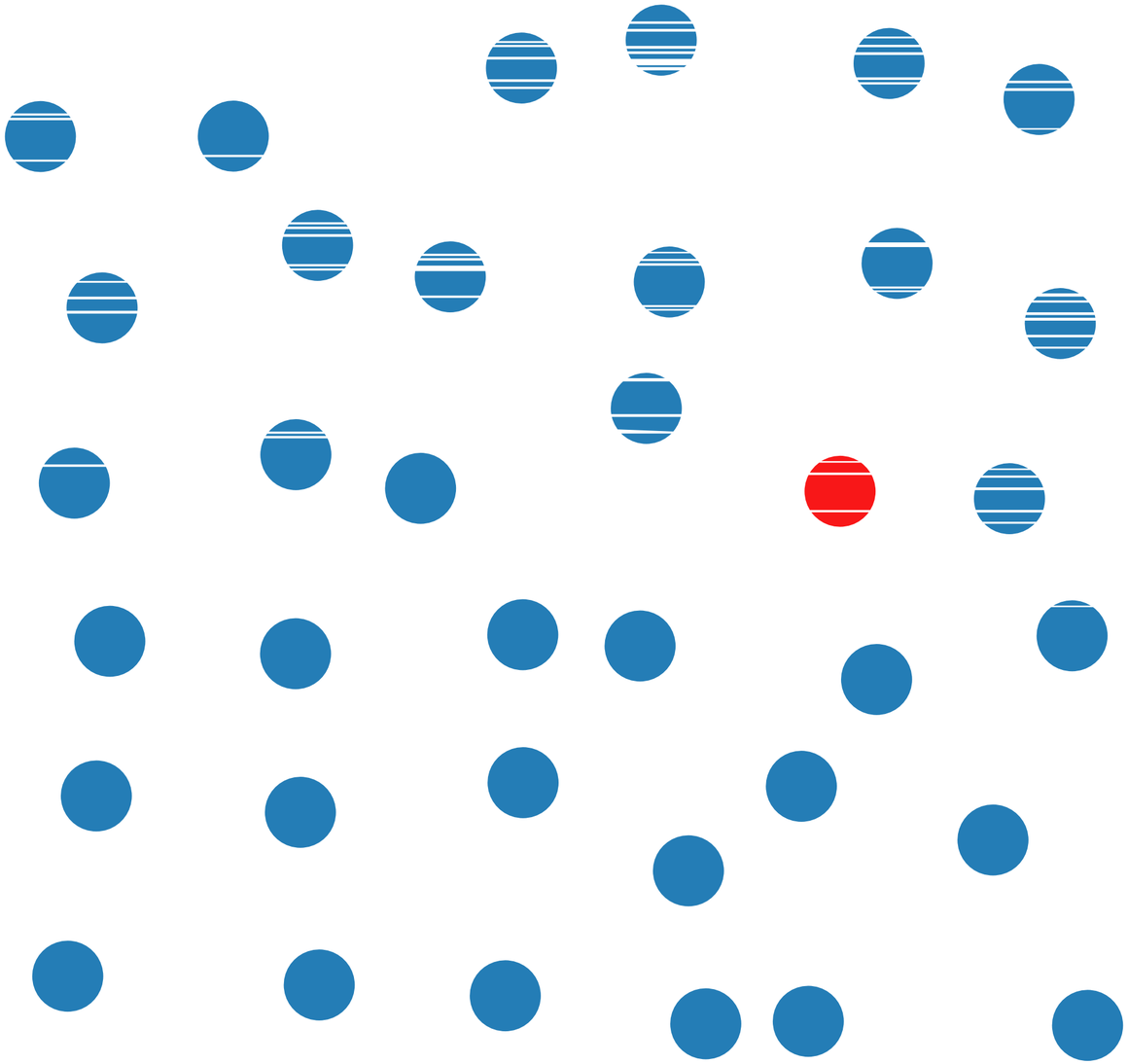


Separable or Integral?



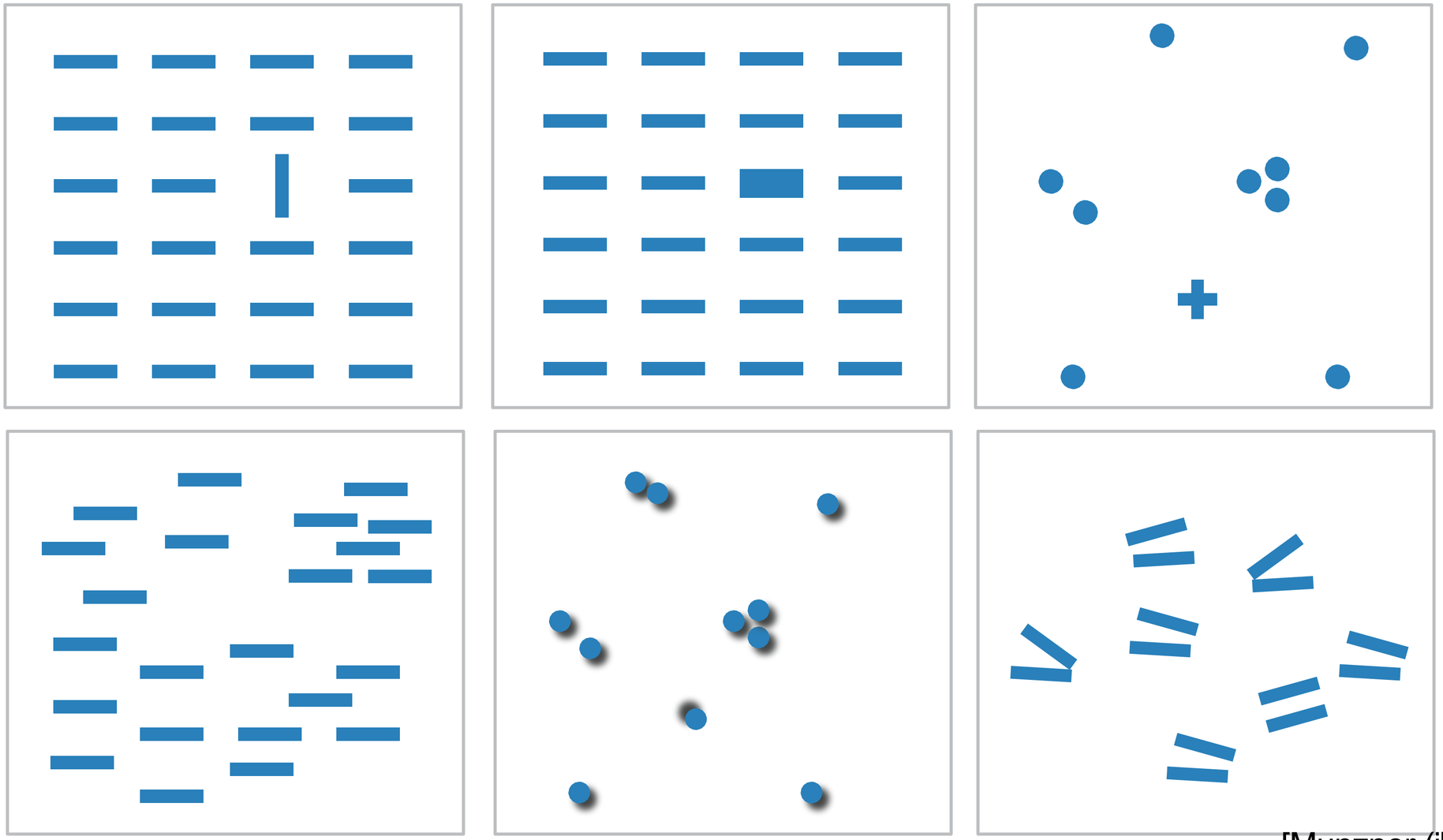
[OOD]

Visual Popout



[C. G. Healey]

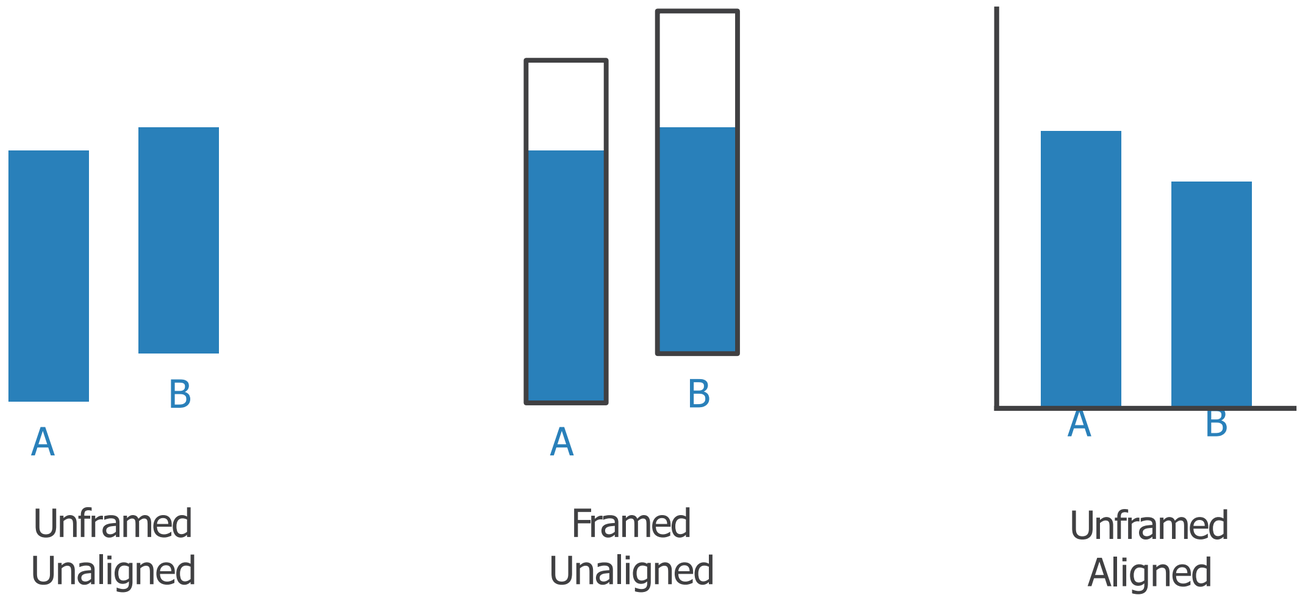
Visual Popout: Parallel Lines Require Search…



[Munzner (ill. Maguire), 2014]

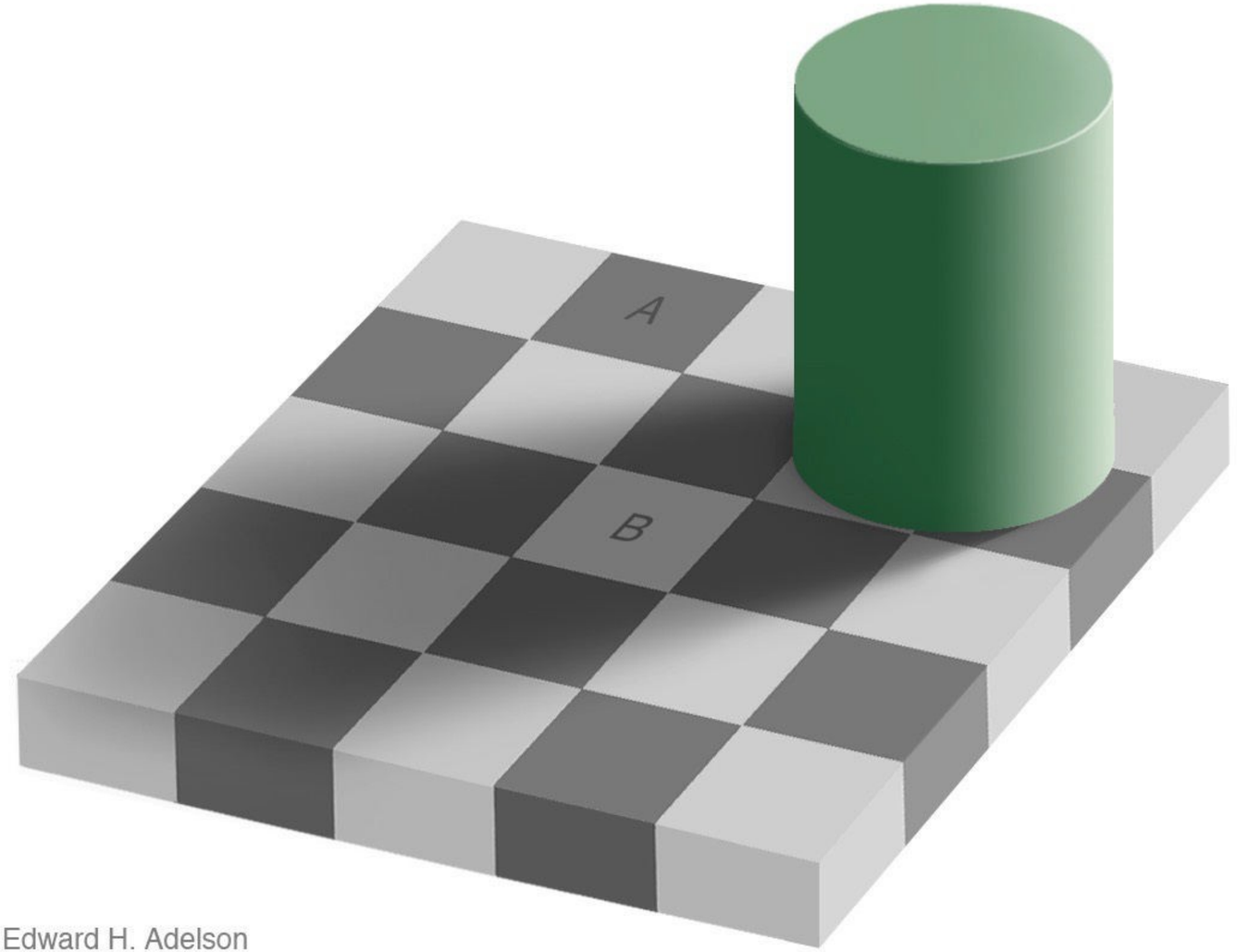
Relative vs. Absolute Judgments

- 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]

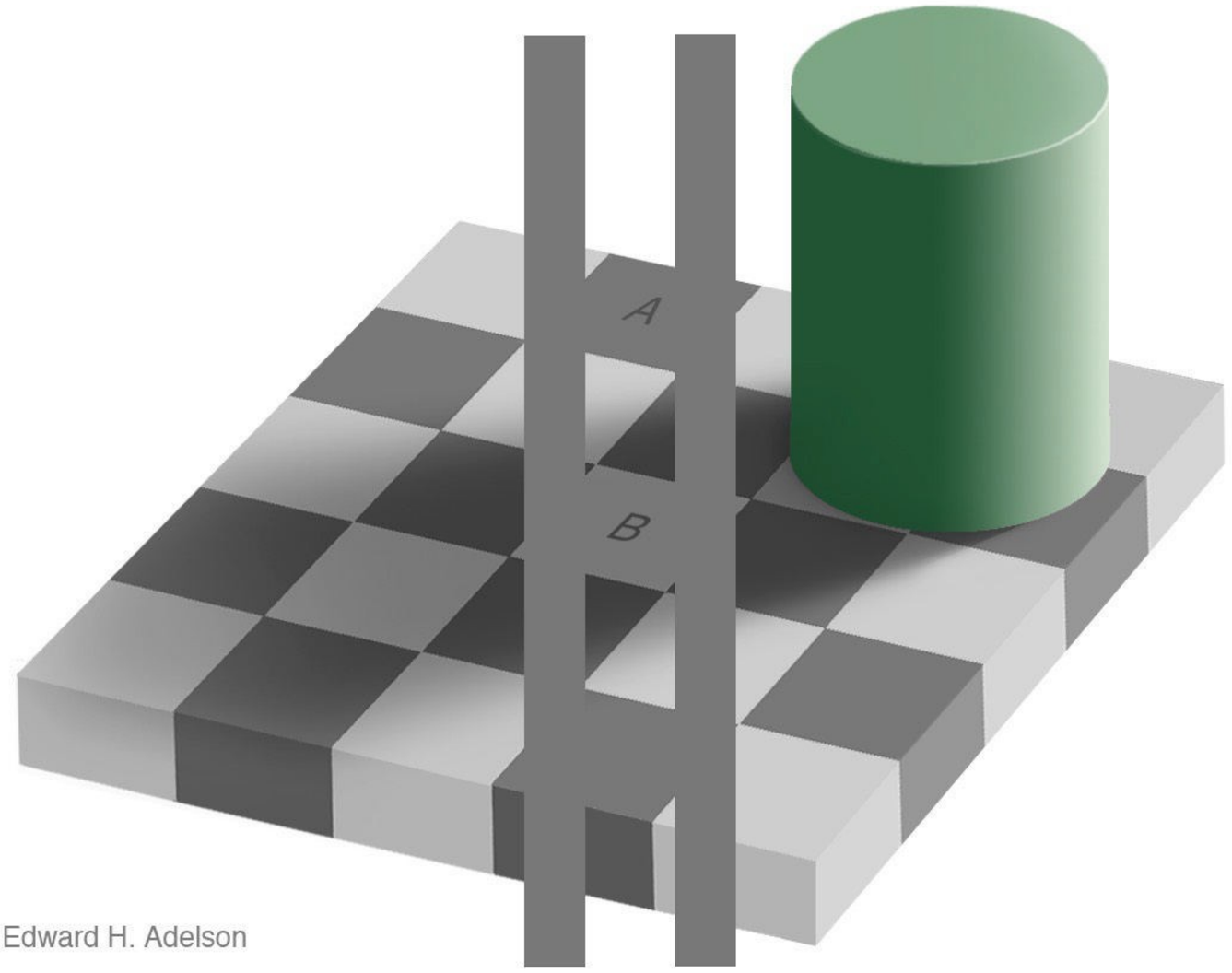
Luminance Perception



Edward H. Adelson

[E. H. Adelson, 1995]

Luminance Perception



[E. H. Adelson, 1995]