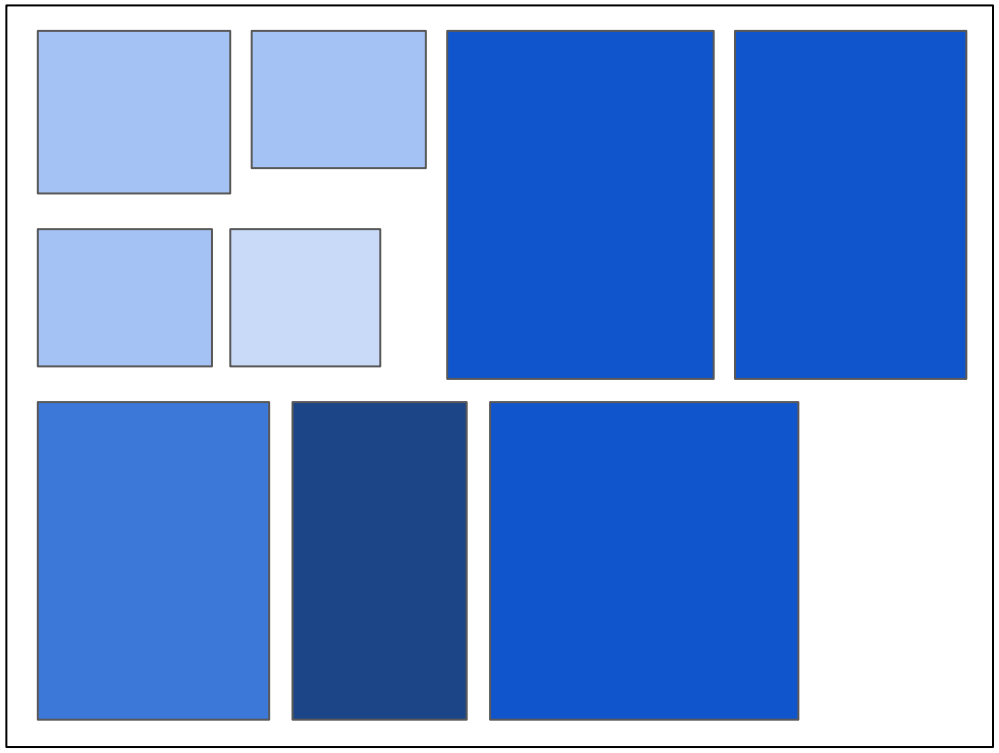
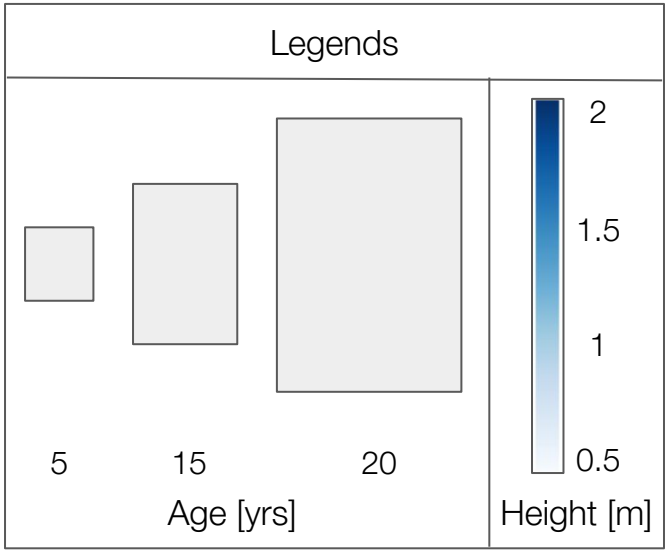
Arranging space - I

Visualization
Sebastian Ratzenböck

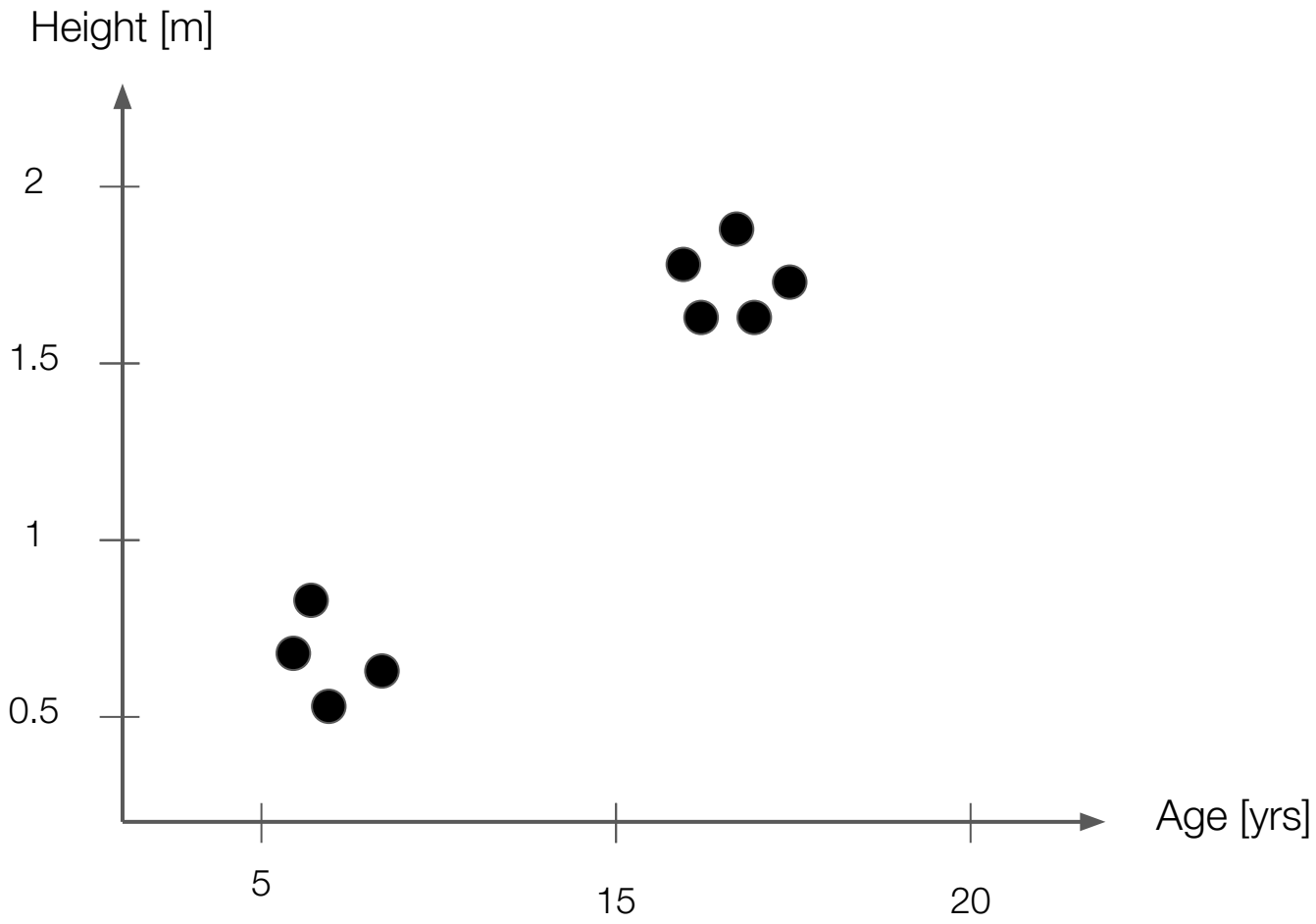
What is the “best” visualization for the following data?

VIS 1

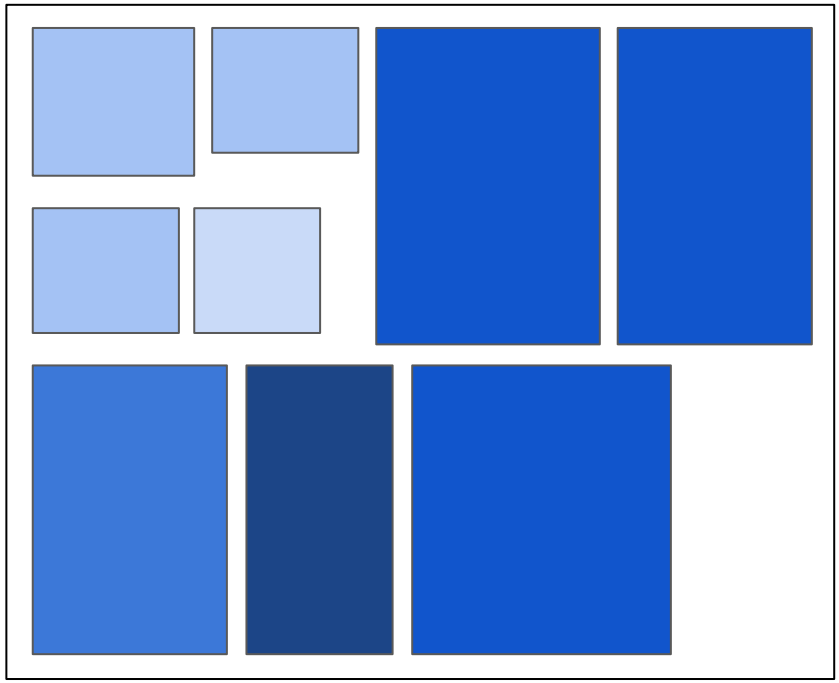


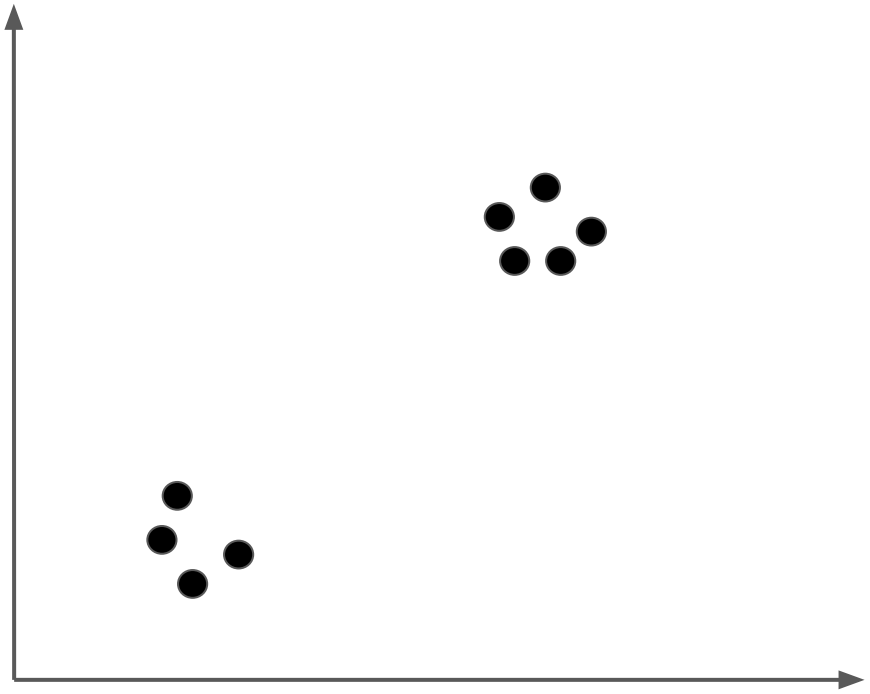


VIS 2



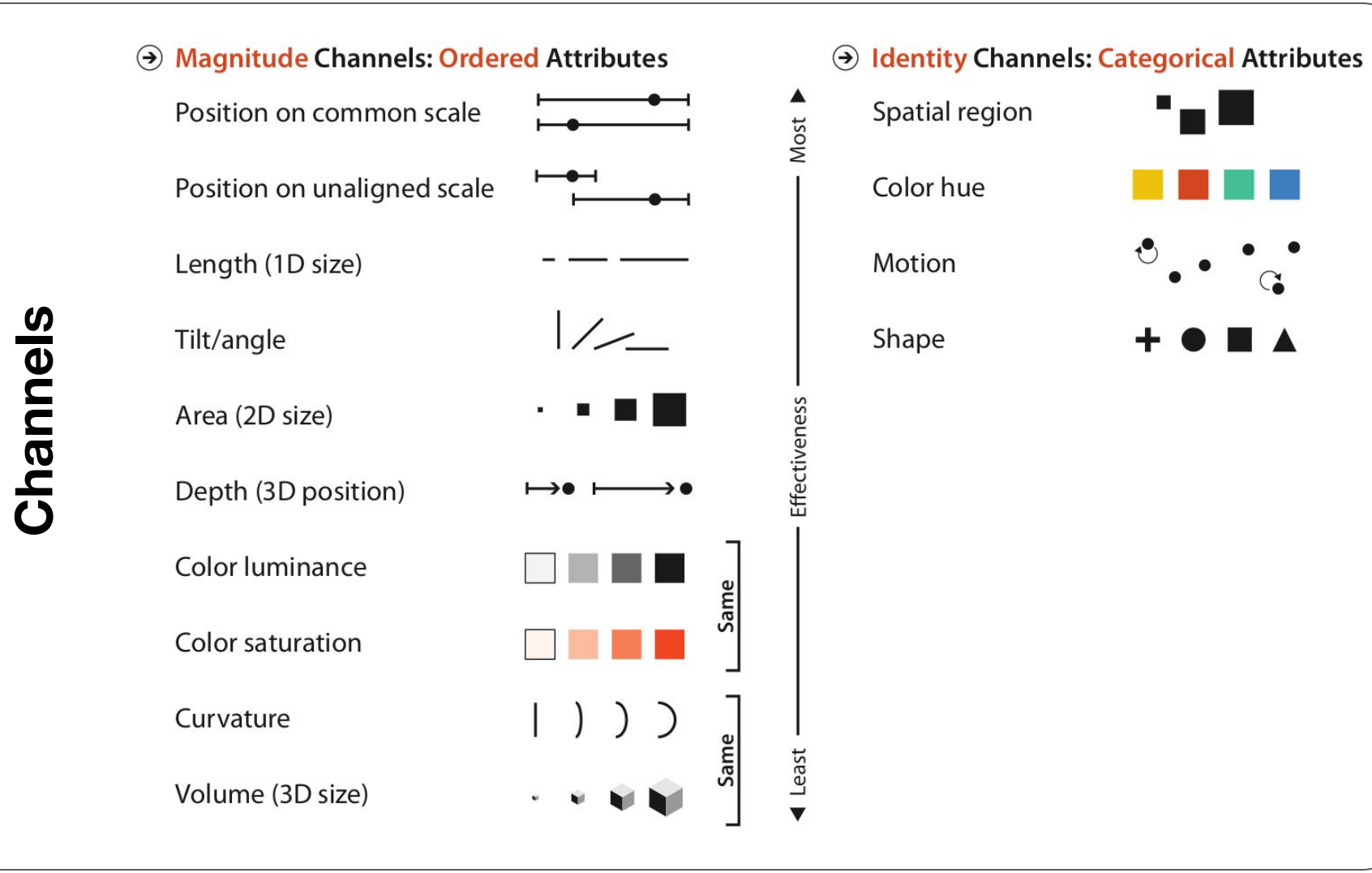
VIS 1 or 2?





Why?

Recap: effectiveness ranking

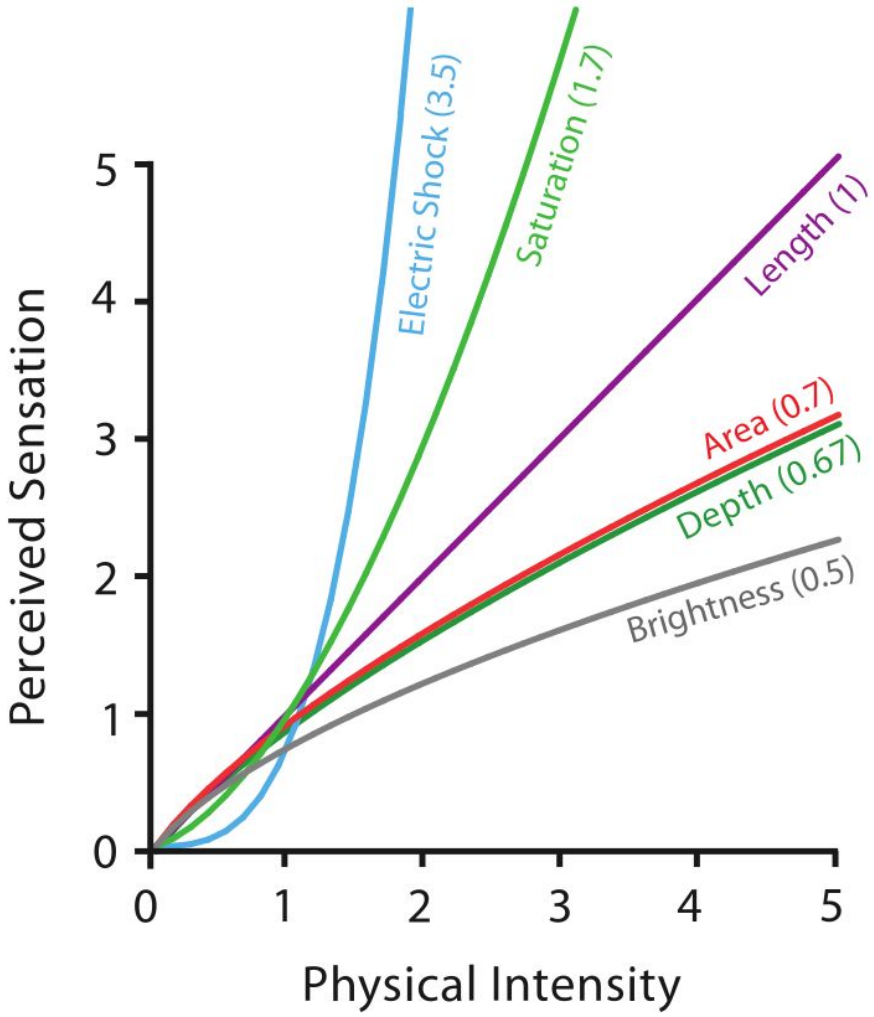


Munzner

Recap: effectiveness ranking

- How do we determine the ranking?
  - Accuracy
  - Discriminability
  - Separability
  - Popout

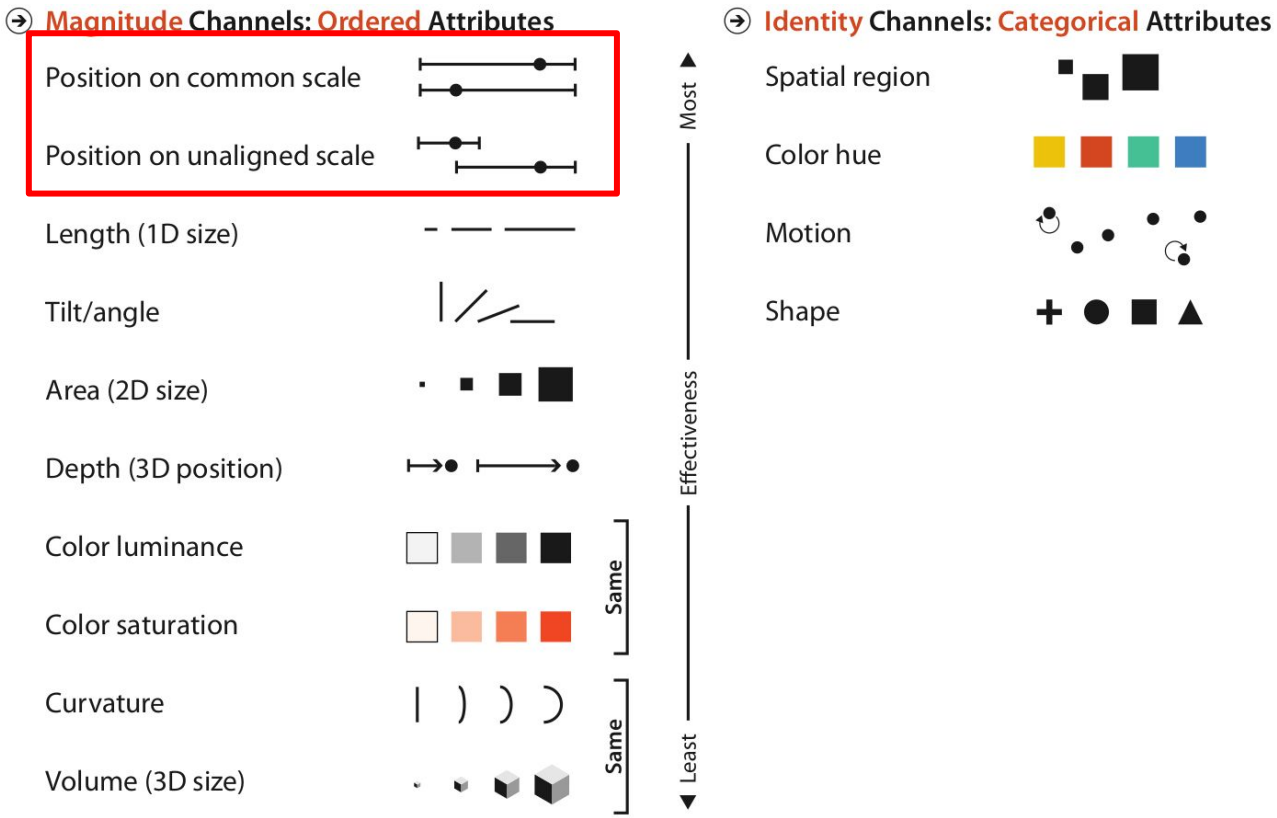
Recap: Steven's psychophysical law



What do we mean by arranging space?

Arranging space

- Spatial channels for visual encoding
- Most effective encoding choice



Arranging space

- Spatial channels for visual encoding
- Most effective encoding choice ↔ tied to effectiveness principle

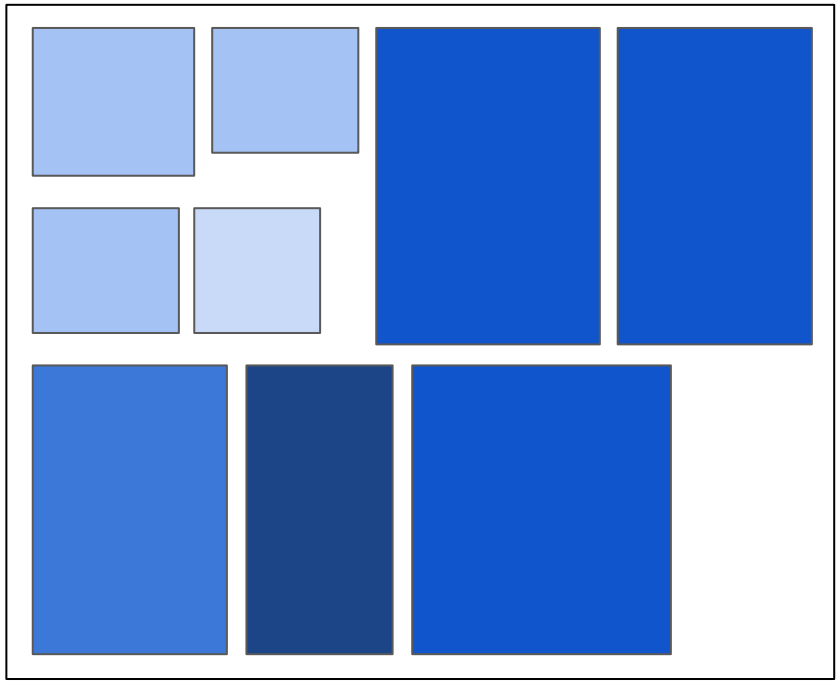
Effectiveness principle

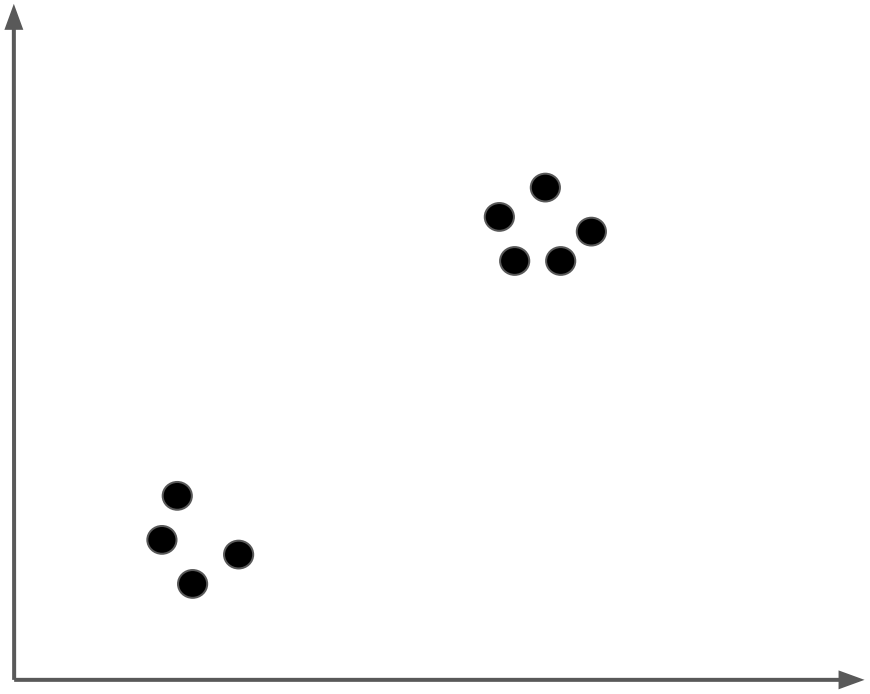
The **most important attributes/features** should be encoded with the **most effective channels** in order to be most noticeable.

Arranging space

- Spatial channels for visual encoding
- Most effective encoding choice ↔ tied to effectiveness principle
- Spatial channel dominates the users mental model of the data set.

What's more "natural"?





Readings

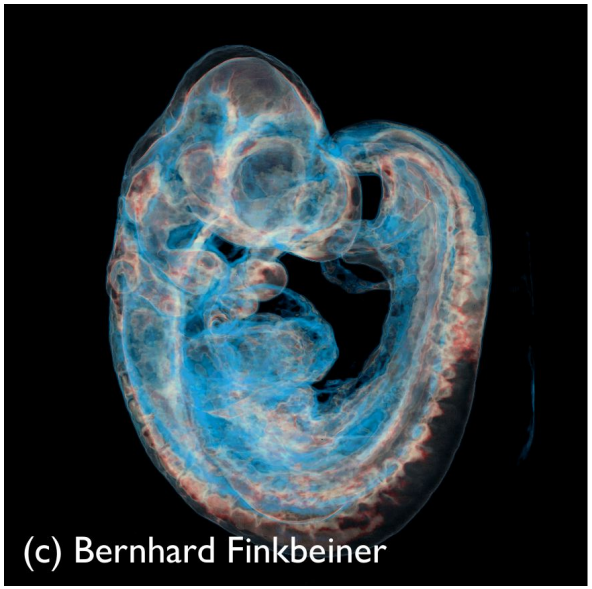
- Munzner, “Visualization Analysis and Design”:
  - Chapter 7 (Arrange Tables)
  - Chapter 8 (Arrange Spatial Data)

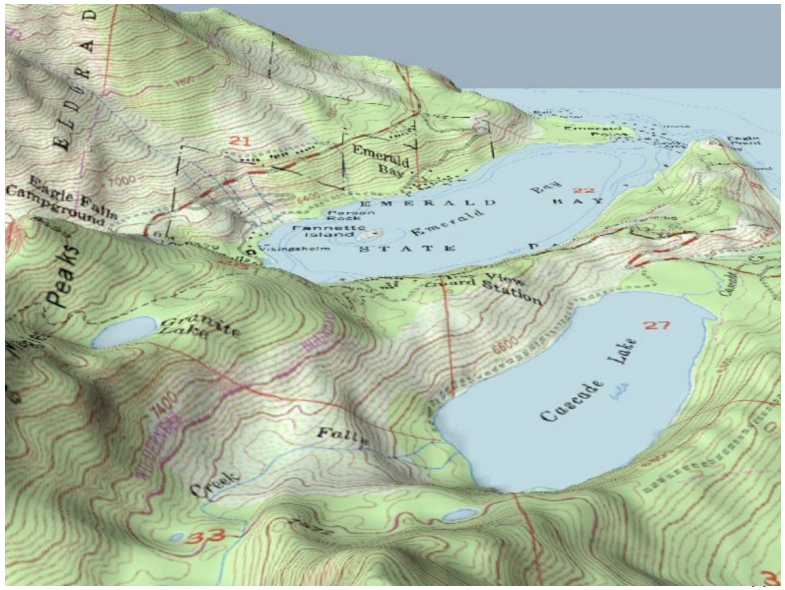
Overview

- Quantitative vs. categorical attributes
- Keys/attributes: the importance of ordering
  - list (1D) vs. matrix (2D) vs. partition / subdivide
  - (multiple D)
- Spatial layout
  - Rectilinear
  - Parallel
  - Radial
- Spacefilling

Spatial attributes

- 1D - line graphs
- 2D - cartographic views
- 3D - volumes
- scalar vs. vector vs. tensor data

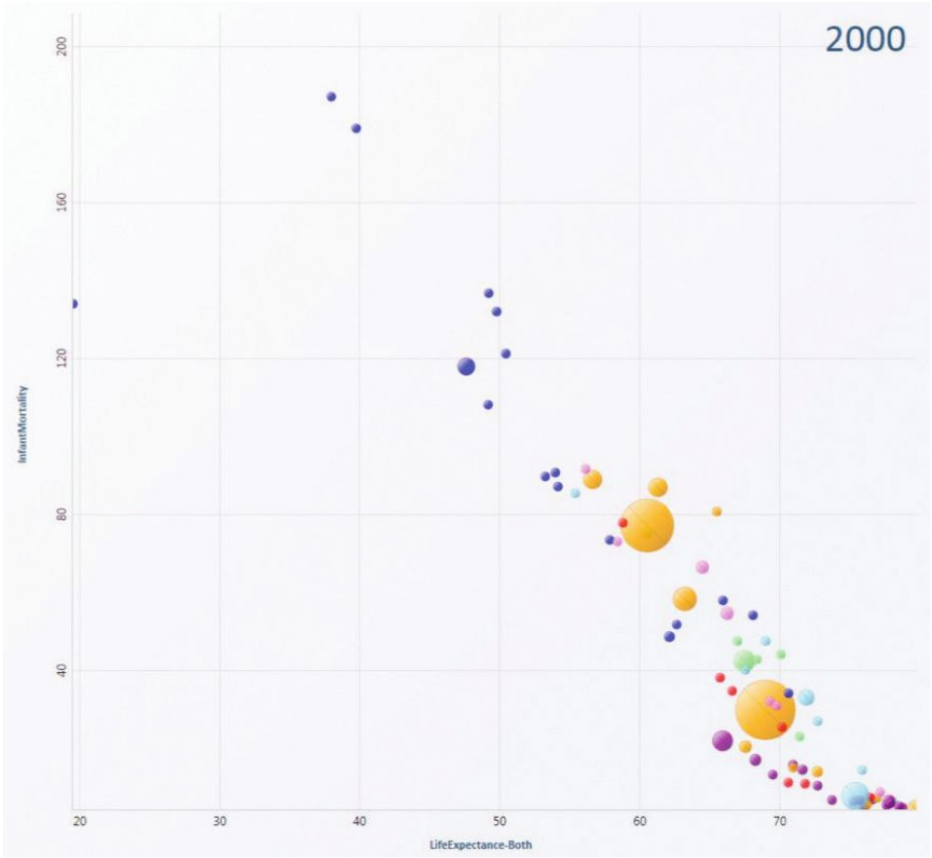




Quantitative vs. categorical data

Quantitative vs. categorical

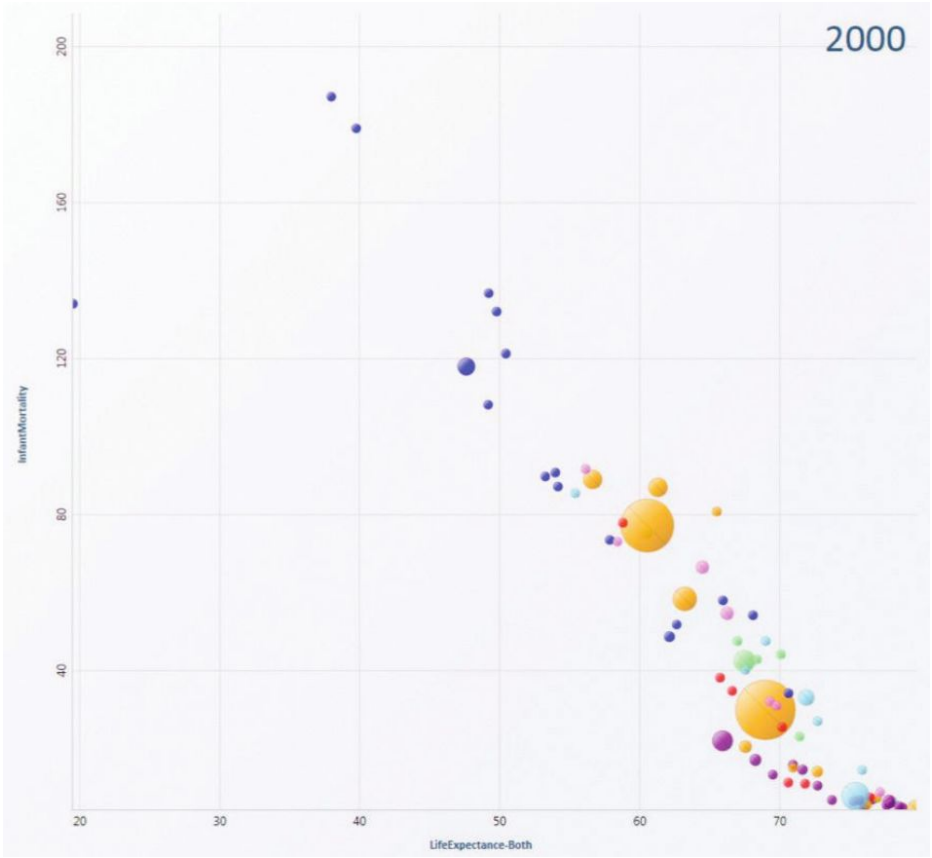
- quantitative: express 
  - e.g. dot plot, scatterplot



Quantitative vs. categorical

- quantitative: express 
  - e.g. dot plot, scatterplot

How does the **effectiveness principle** apply here?



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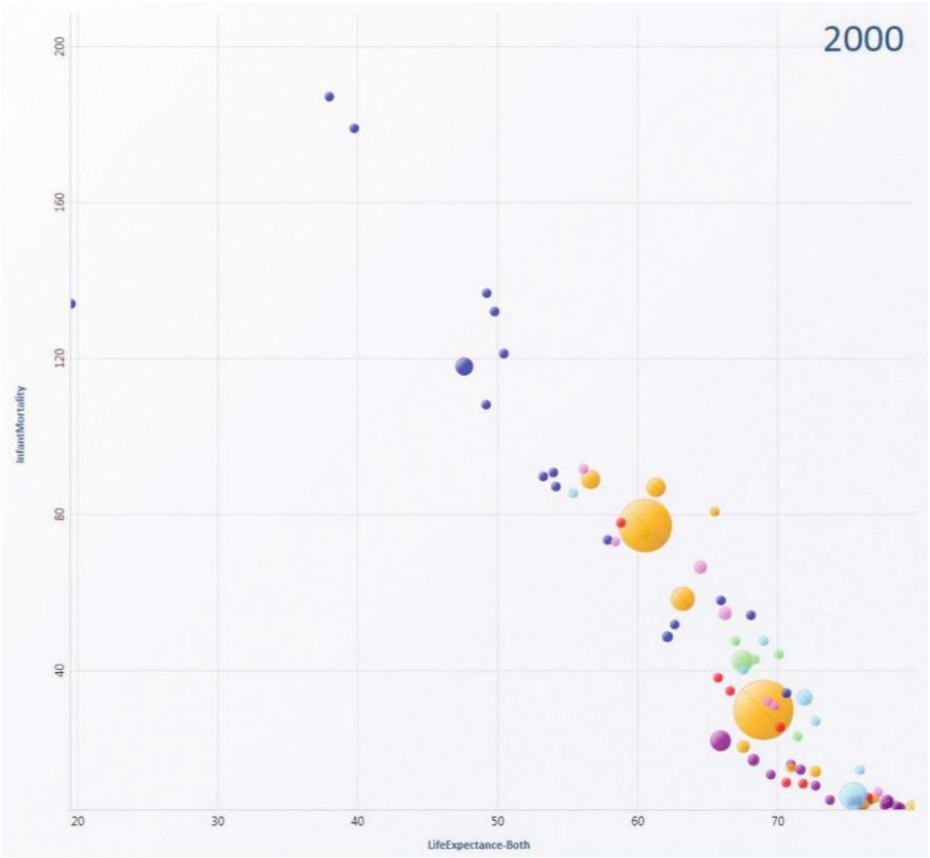


Attributes

- Life expectancy
- Infant mortality
- Country size
- Continent

How to use the spatial channel for **categorical** data?

Quantitative vs. categorical

- Encoding categorical attributes like quantitative ones forces order that does not exist!
  - ↳ violates *principle of expressiveness*

Principle of expressiveness

The visual encoding should express all of, and only, the information in the dataset attributes.

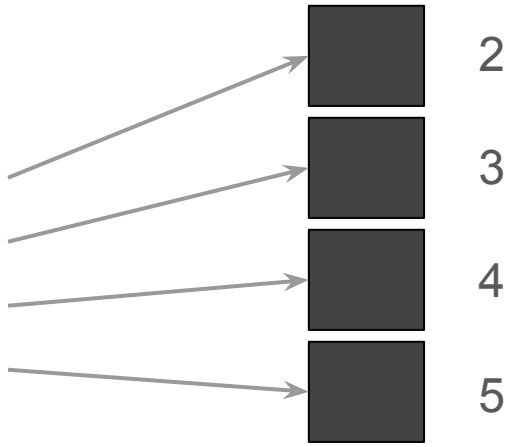
Quantitative vs. categorical

- quantitative: express 
  - e.g. dot plot, scatterplot
- Categorical
  - separate 2D space into regions
  - order along an axis
  - align along an axis

Separate 2D space into regions

- Regions: bounded areas distinct from another
- Draw all items with same value into one region

	A	B
1	Name	Age
2	Kevin	15
3	Lucy	24
4	Marc	11
5	Maria	13



➔ Separate

Quantitative vs. categorical

- Categorical
  - separate 2D space into regions
  - order along an axis
  - align along an axis

1D keys

- 1 key - 1 value → one region per key-value pair

	A	B
1	Name	Age
2	Kevin	15
3	Lucy	24
4	Marc	11
5	Maria	13

→

→ Arrange region into 1D list alignment

→ Now add channel

1D keys

- 1 key - 1 value → one region per key-value pair

	A	B
1	Name	Age
2	Kevin	15
3	Lucy	24
4	Marc	11
5	Maria	13

→

→ Arrange region into 1D list alignment

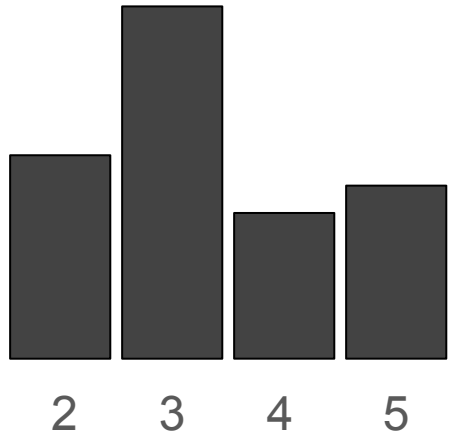
→ Now add channel: Color

1D keys

- 1 key - 1 value → one region per key-value pair

	A	B
1	Name	Age
2	Kevin	15
3	Lucy	24
4	Marc	11
5	Maria	13

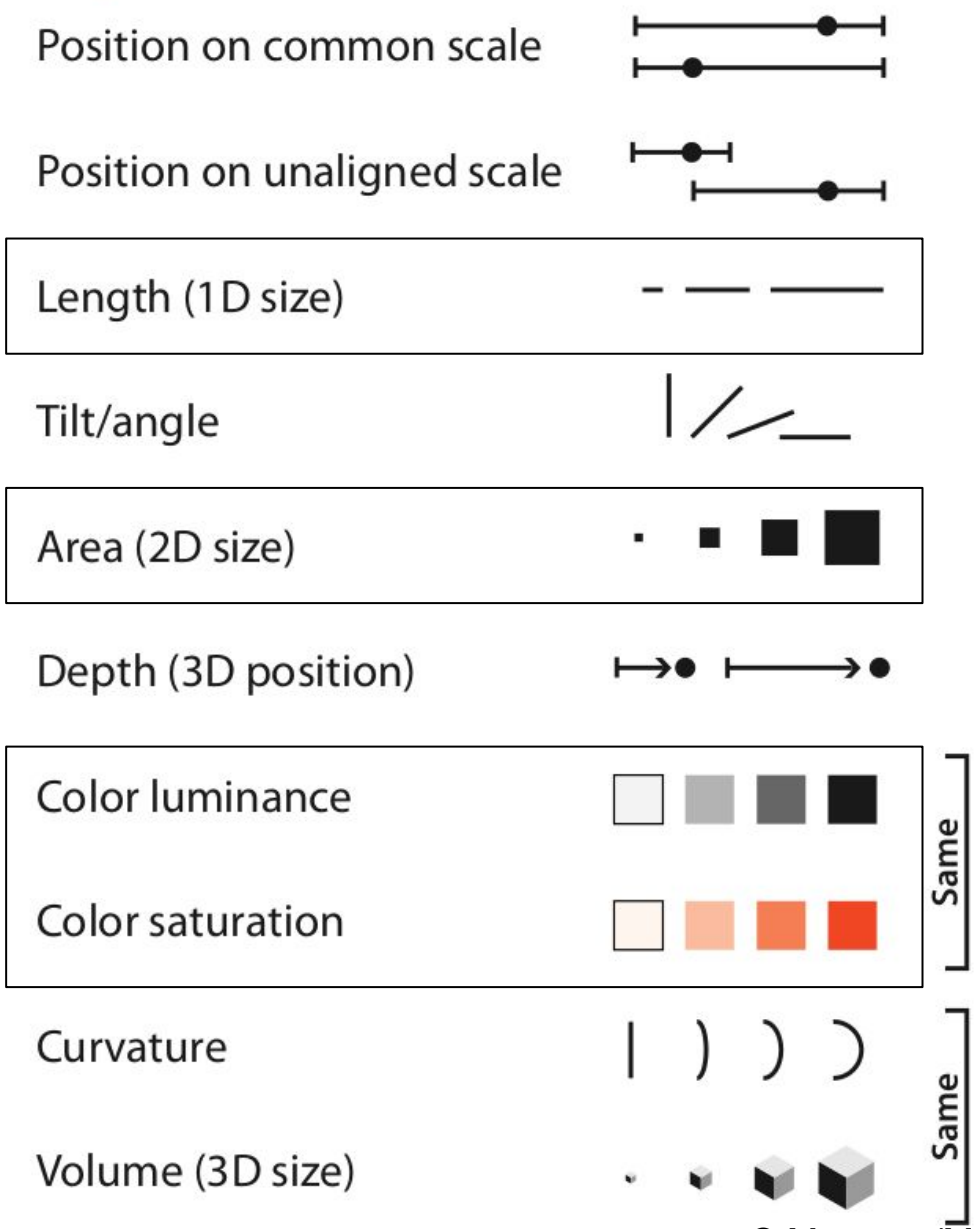
→

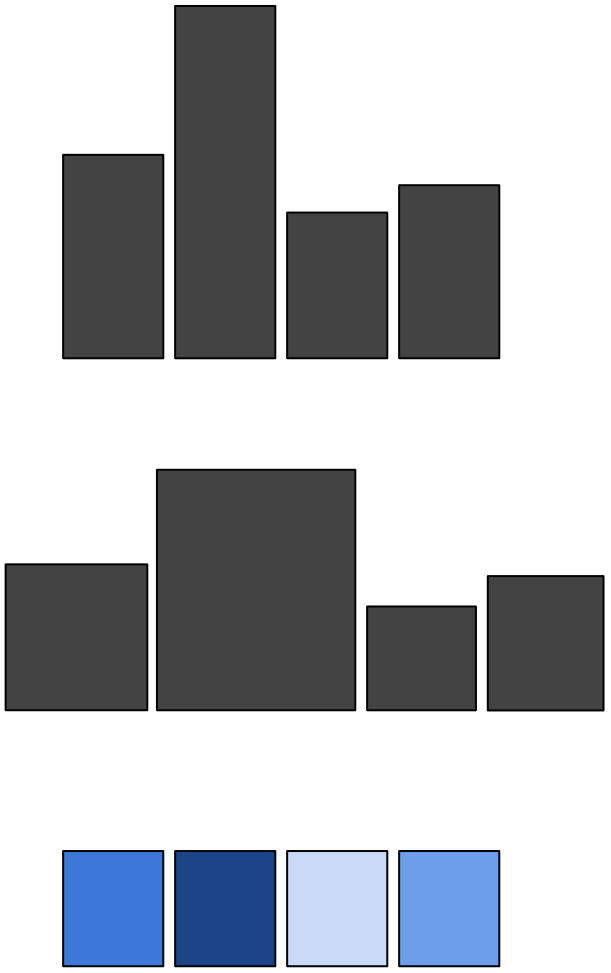


→ Arrange region into 1D list alignment

→ Now add channel: Length

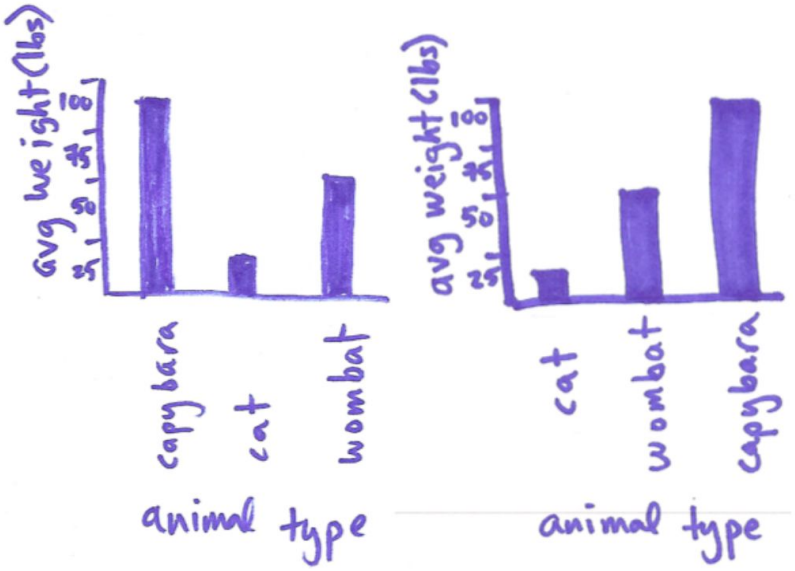
Magnitude Channels: Ordered Attributes





1D keys

- categorical: bar charts
  - aligned / ordered



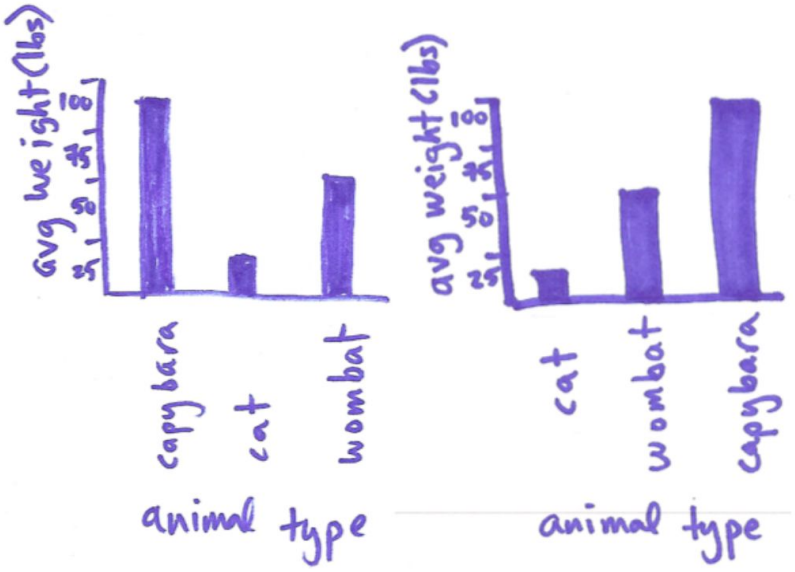
Bar chart
Line marks
Length channel

?

?

1D keys

- categorical: bar charts
  - aligned / ordered

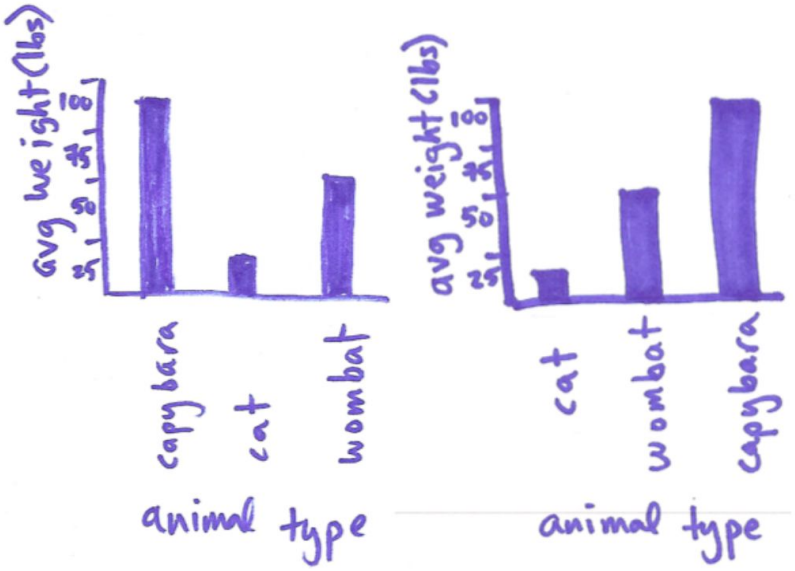


Lookup value

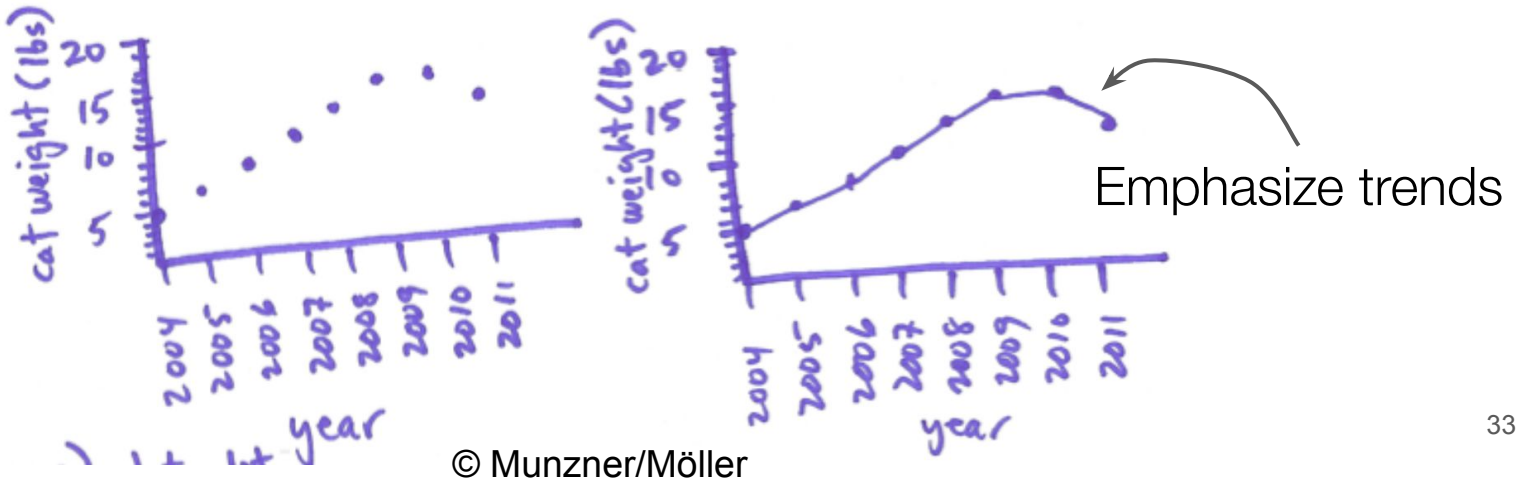
Spot trends

1D keys

- categorical: bar charts
  - aligned / ordered



- quantitative/ ordered: dot plot / line chart

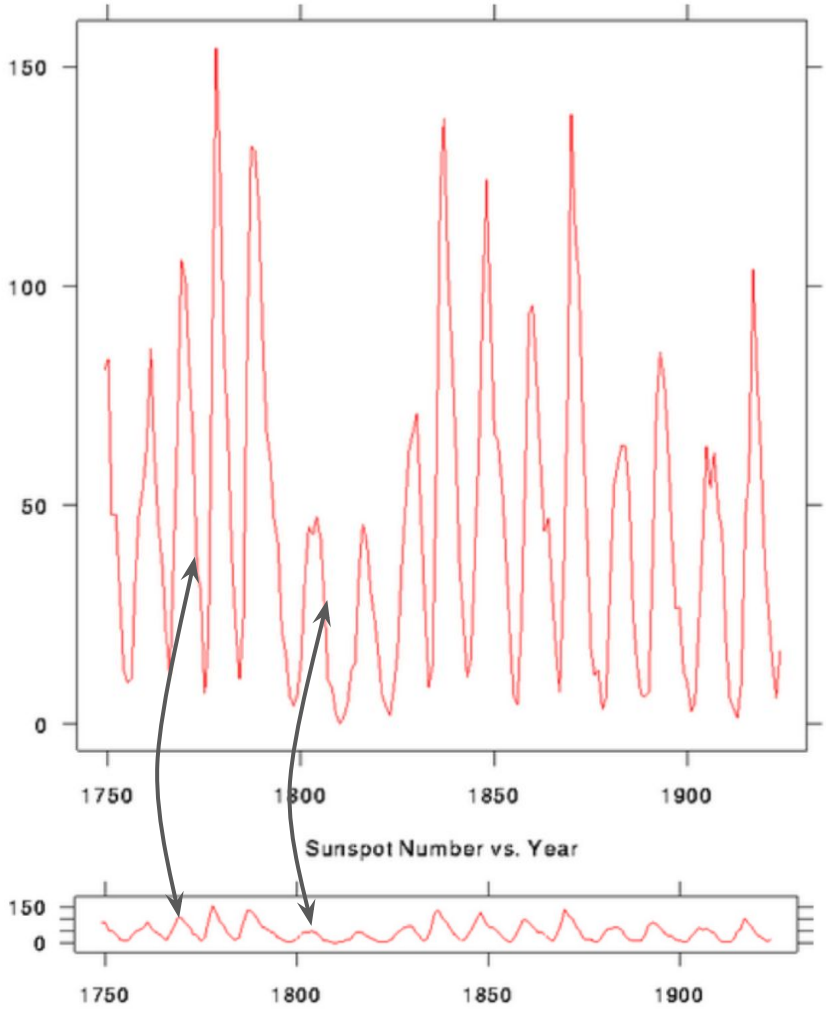


Line graphs

1. Aspect ratio
2. Expressiveness principle

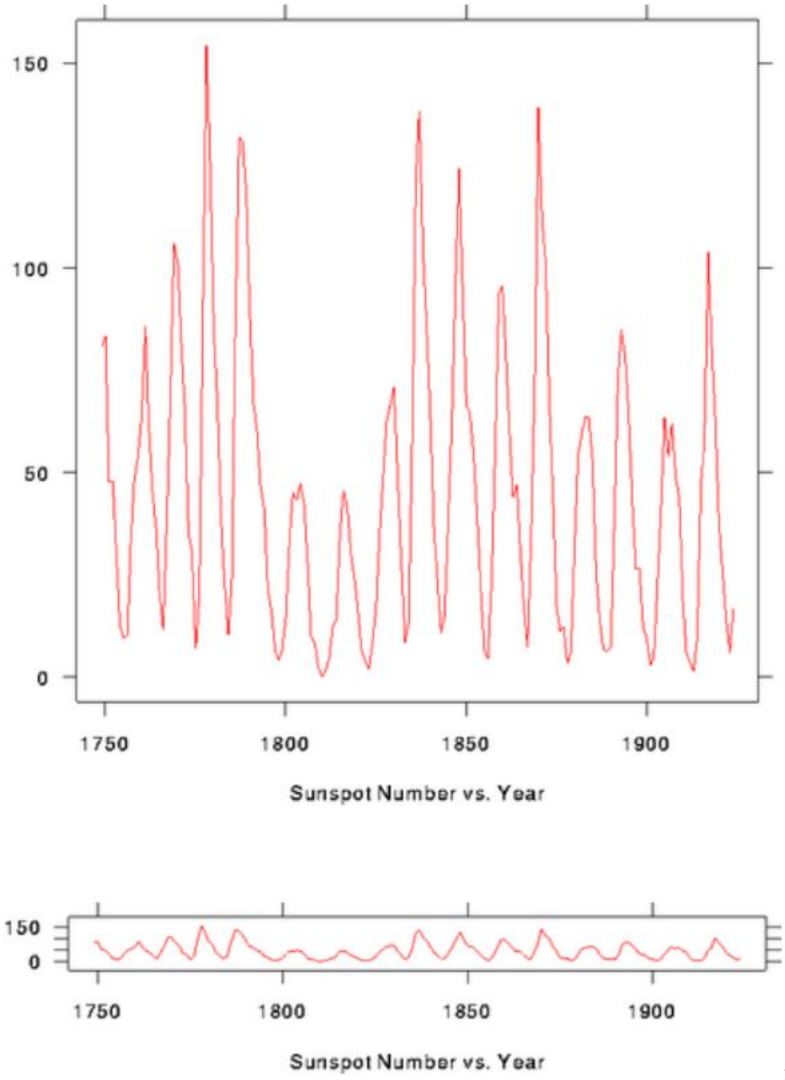
Line plots: aspect ratio

- Aspect ratio is important
- Which of these two lines is steeper, 1 or 2?
- Did the aspect ratio influence the difficulty of the task?



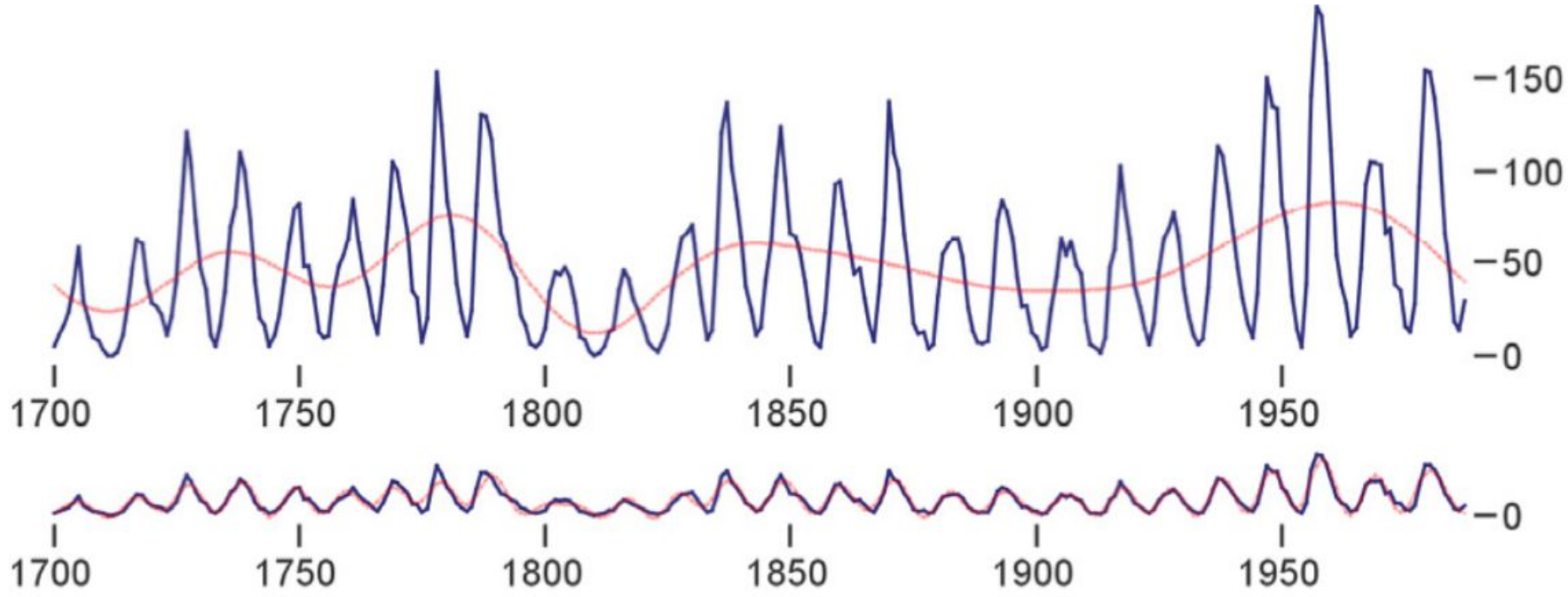
Banking to 45 degrees

- Perceptual principle:
  - Most accurate angle judgement at 45°
- Maximize the number of line segments that fall close to 45°
  → adjust aspect ratio accordingly



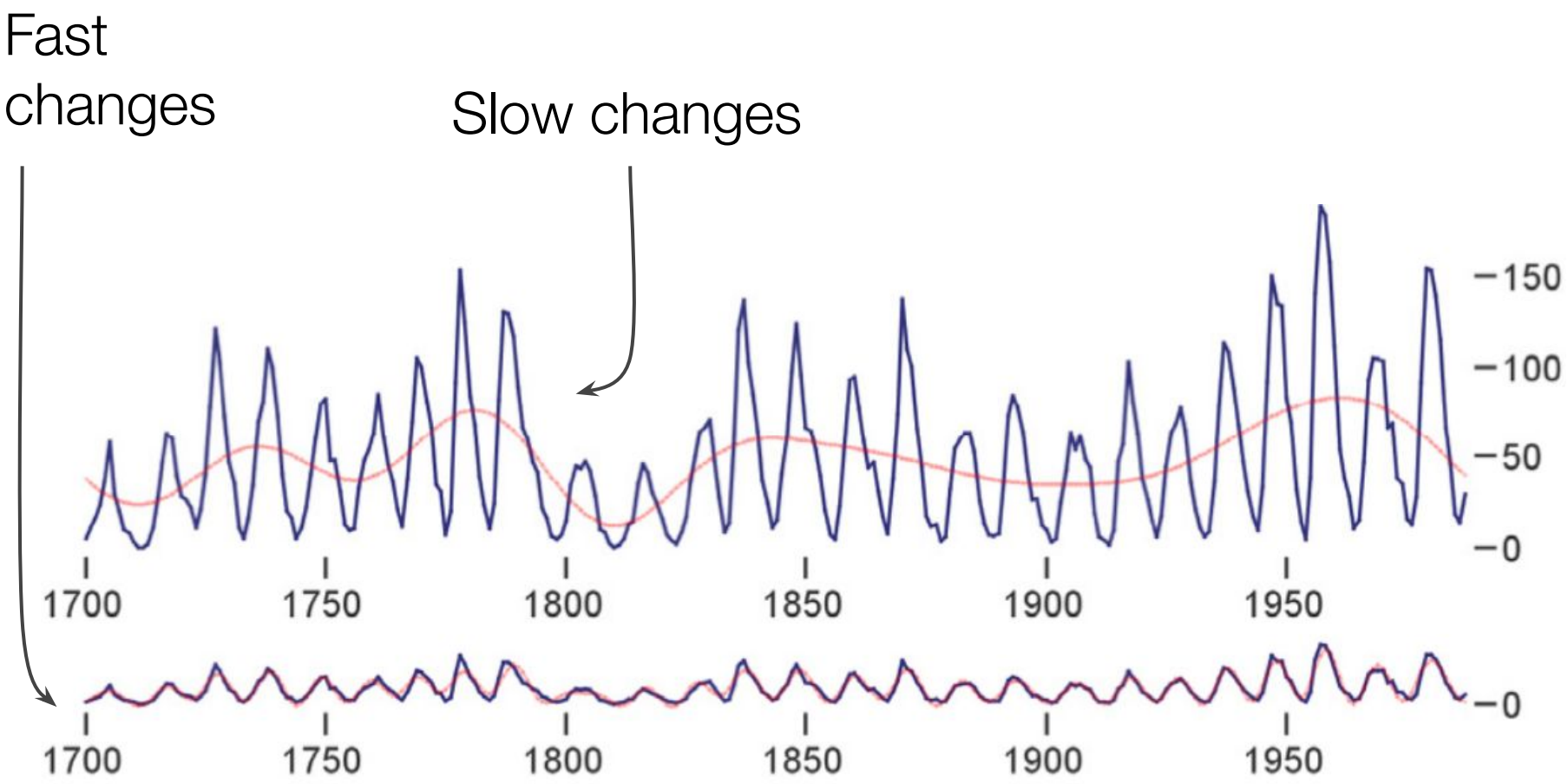
Banking to 45 degrees

What is the difference between the two ARs?



Multi-Scale Banking to 45 Degrees. Heer and Agrawala, Proc InfoVis 2006 vis.berkeley.edu/papers/banking

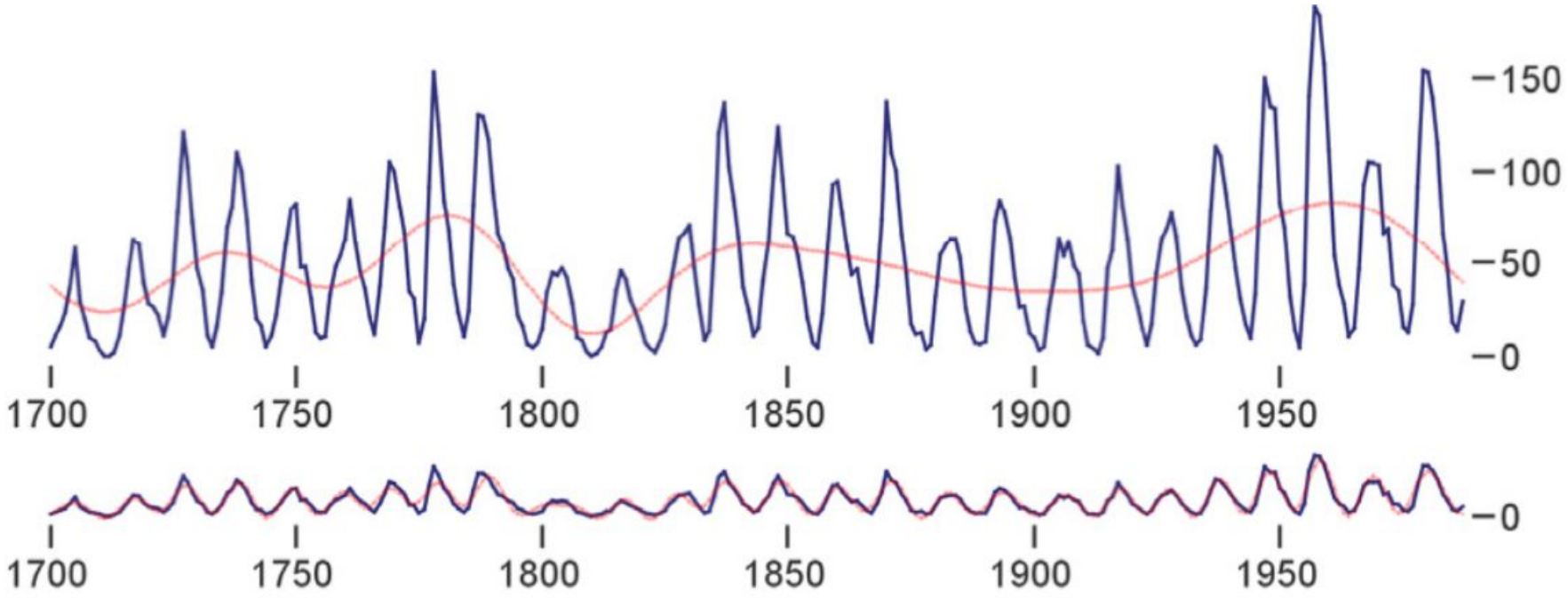
Banking to 45 degrees



Multi-Scale Banking to 45 Degrees. Heer and Agrawala, Proc InfoVis 2006 vis.berkeley.edu/papers/banking

Banking to 45 degrees

- frequency analysis → find dominant frequencies
- Each frequency corresponds to aspect ratio
- AR = 3.96 vs. AR = 22.35



Multi-Scale Banking to 45 Degrees. Heer and Agrawala, Proc InfoVis 2006 vis.berkeley.edu/papers/banking

Quantitative vs. categorical

- Encoding categorical attributes like quantitative ones forces order that does not exist!*
  - ↳ violates principle of expressiveness

Principle of expressiveness

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Quantitative vs. categorical

- Encoding categorical attributes like quantitative ones forces order that does not exist!*
  - ↳ violates principle of expressiveness

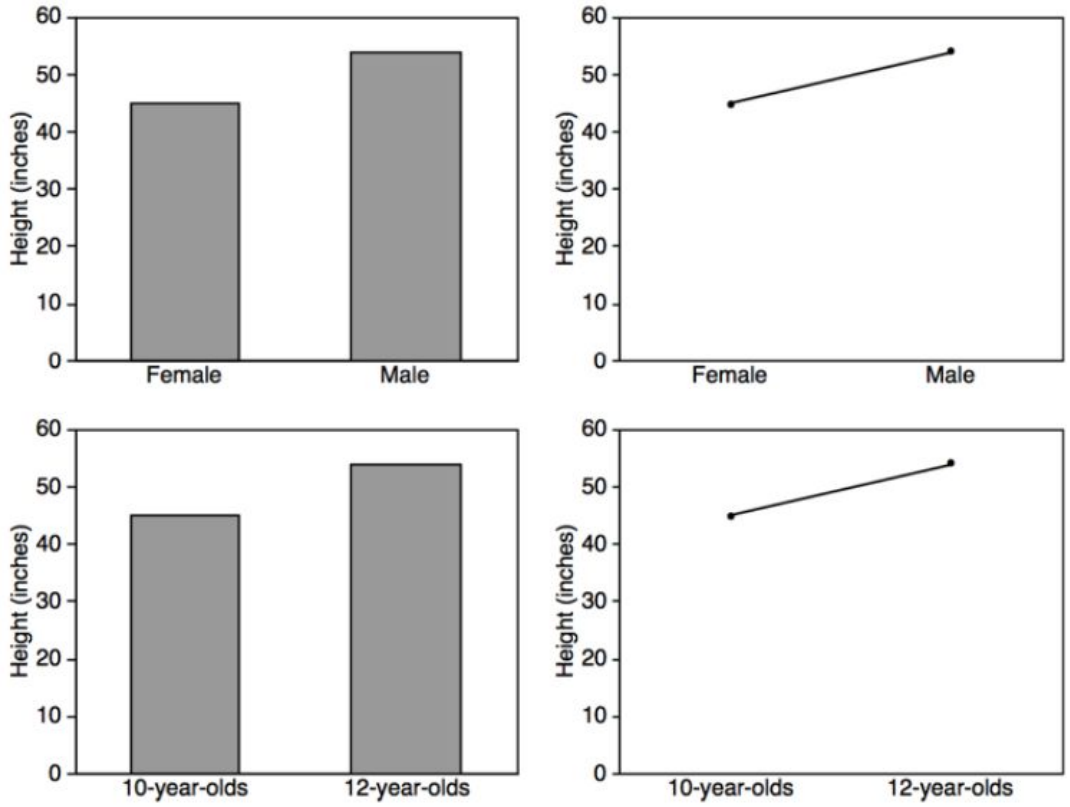
Principle of expressiveness

The visual encoding should express all of, and only, the information in the dataset attributes.

* This implication is in fact so strong that it can override common knowledge.

Bar vs. line charts

- line implies trend, not appropriate for categorical data



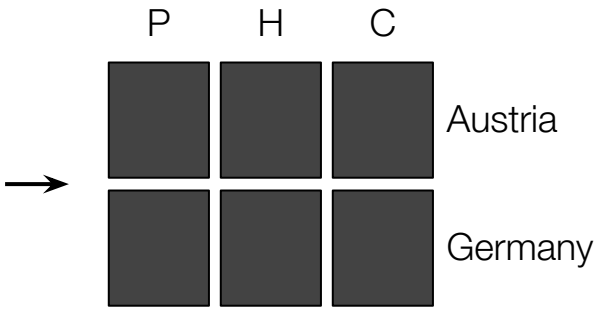
Zacks and Tversky. Bars and Lines: A Study of Graphic Communication. Memory and Cognition 27(6):1073-1079, 1999.

2D keys

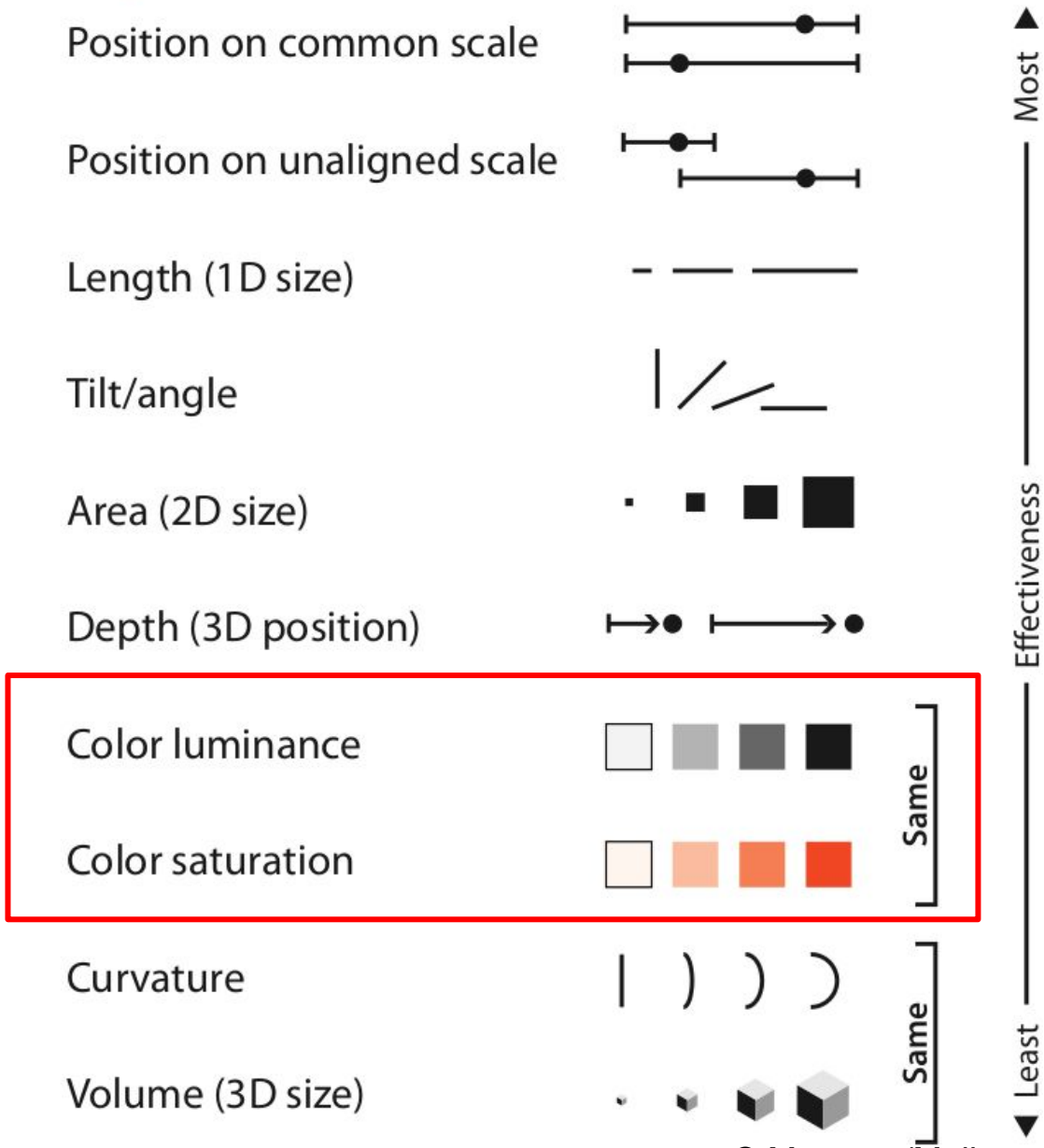
2D keys

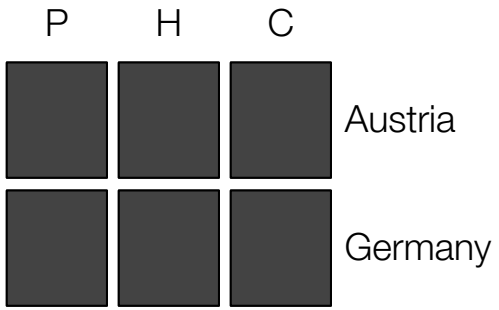
- 2 keys - 1 value → 2D matrix alignment

Country	Education level	Percentage
Austria	Primary school	99
Austria	High school	60
Austria	College	20
Germany	Primary school	98
Germany	High school	65
Germany	College	25



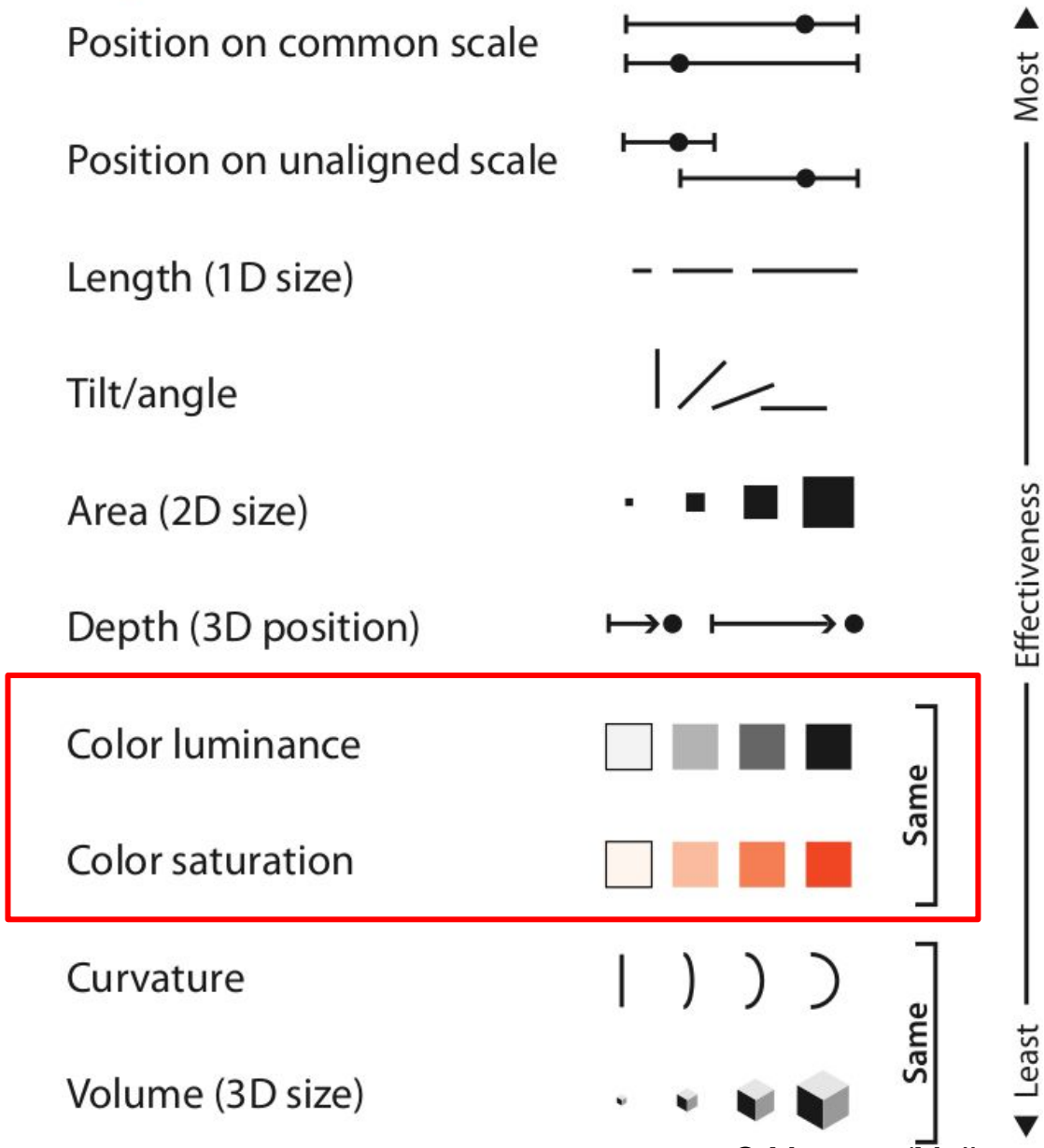
Magnitude Channels: Ordered Attributes

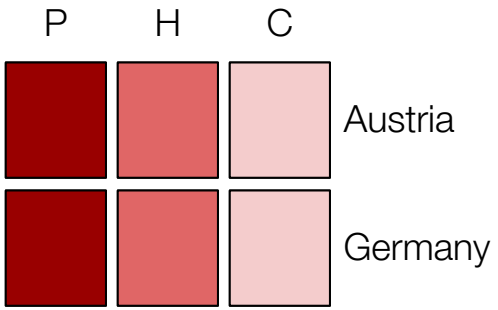




→ Heatmap

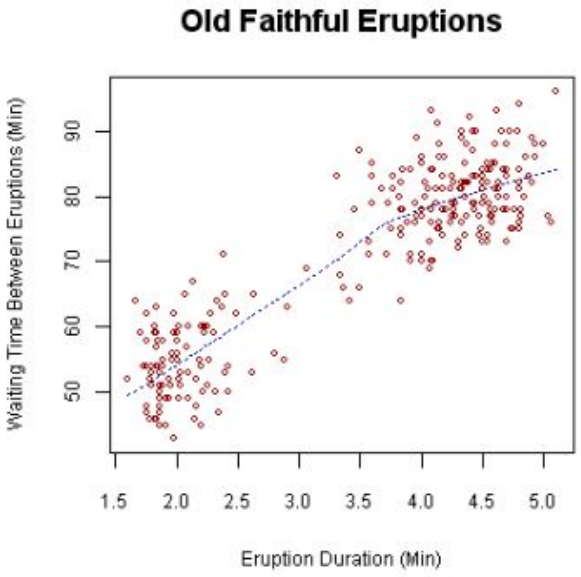
Magnitude Channels: Ordered Attributes

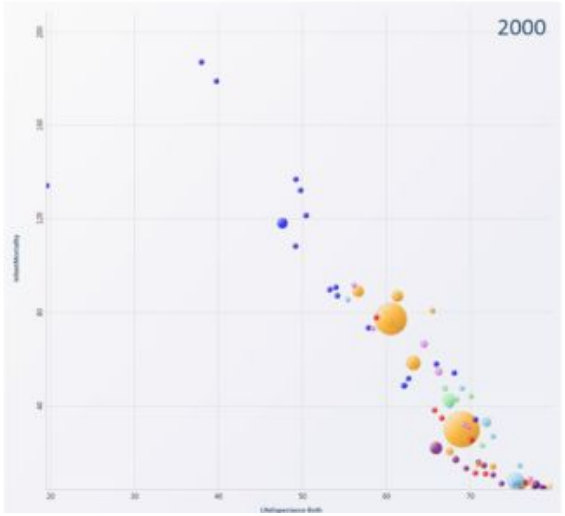




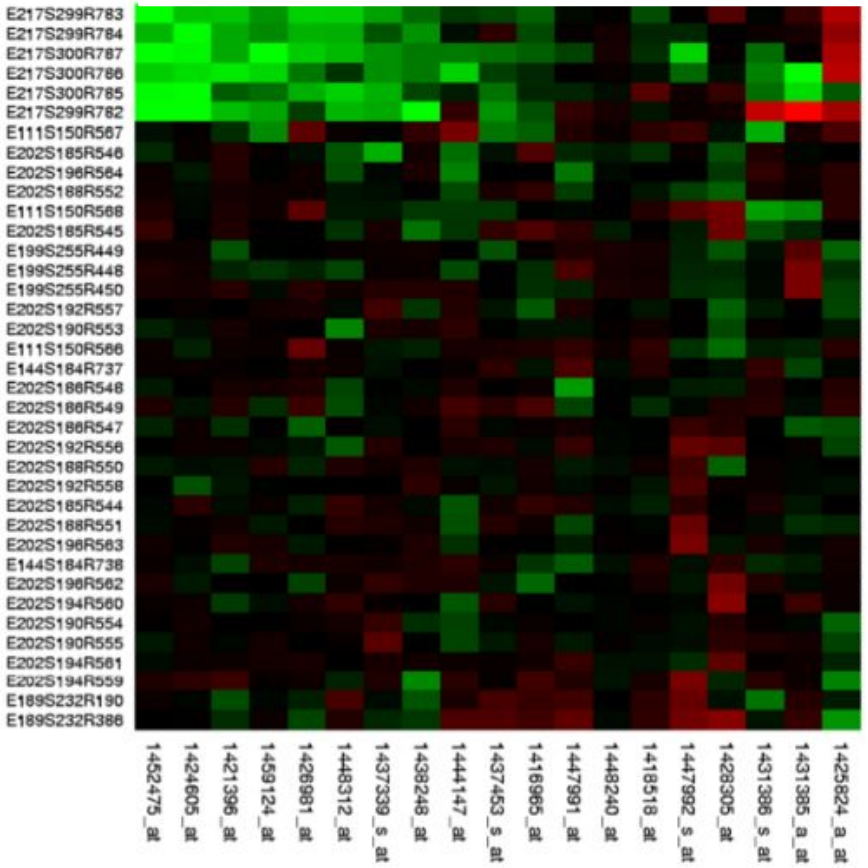
→ Heatmap

2D keys examples: tasks, size

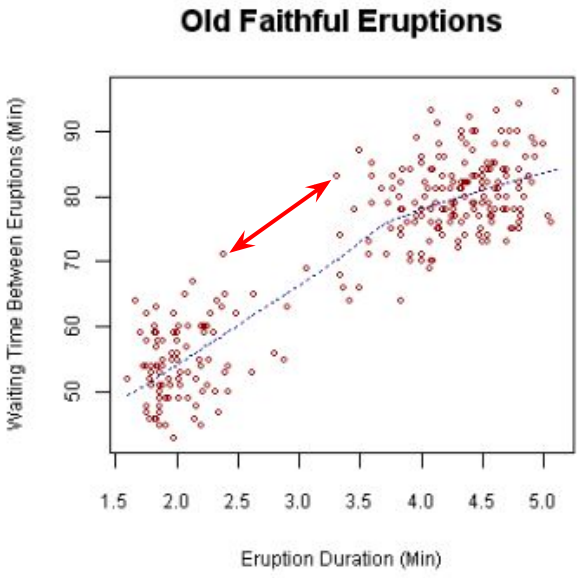


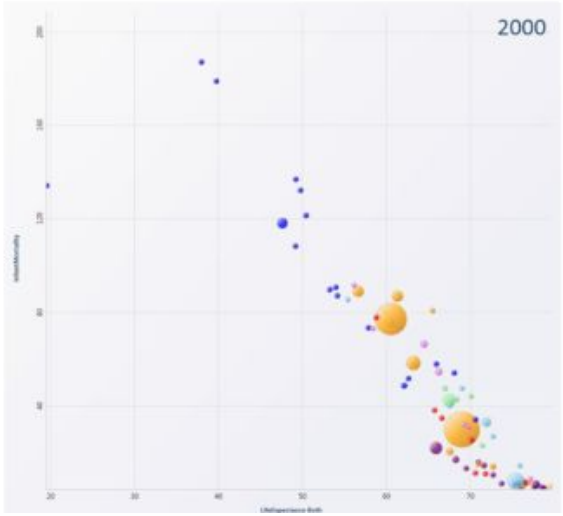


Heatmap

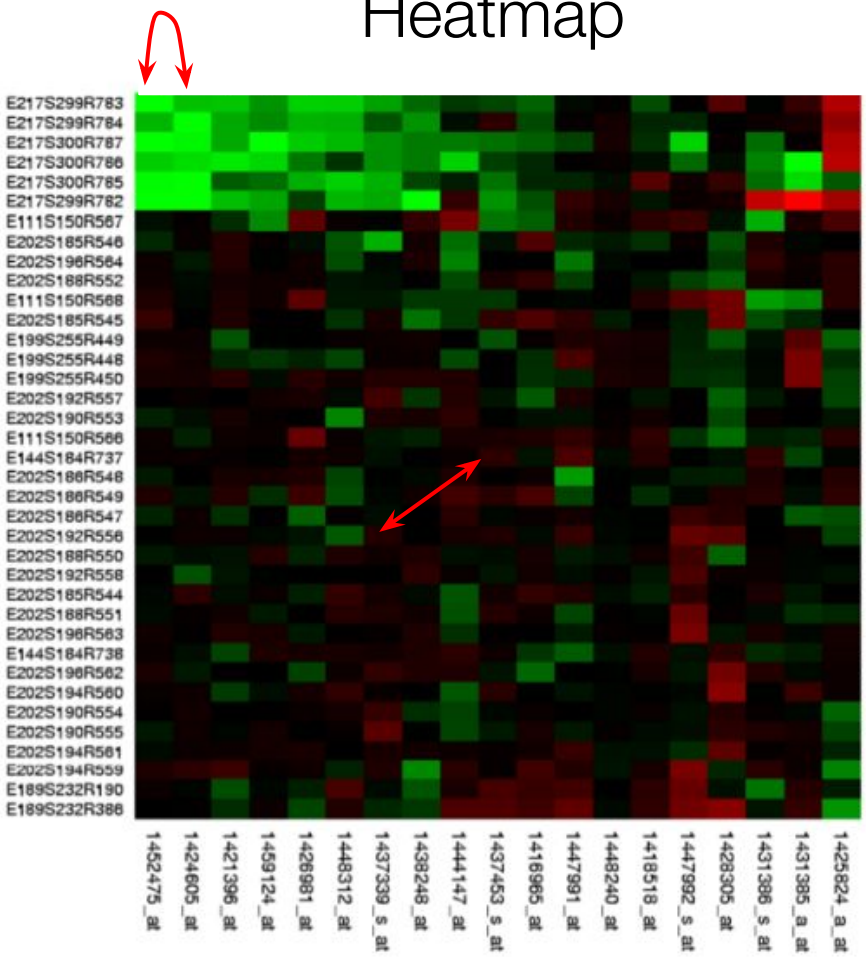


Meaning of distances



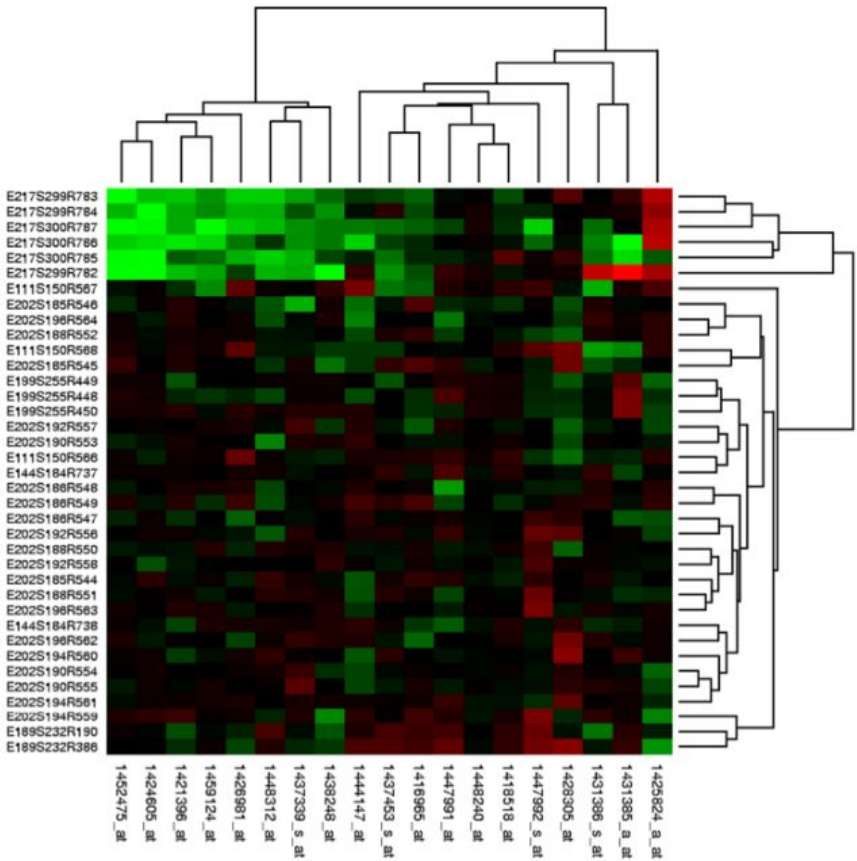


Heatmap



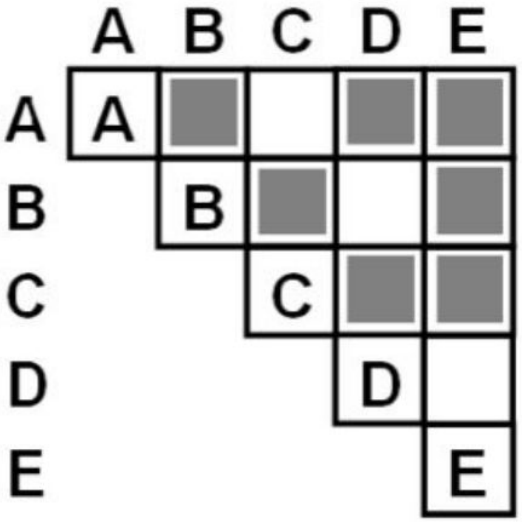
Heatmaps

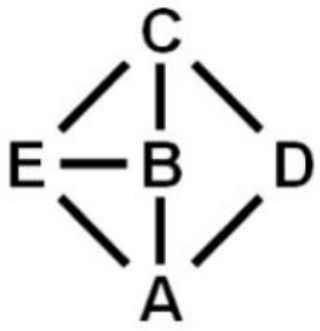
- Find structure in data
  - Outliers, clusters, etc.
  - Needs sorted rows & columns
    → cluster heatmap
- Very compact
  - Limit: area mark=pixel
  - Good data overview



2D matrix arrangement - graph

- Value attribute: link exists yes/no
- Weighted networks: e.g. color coding
- Undirected networks: half matrix
- Directed networks: full matrix
- Avoids hairball effect





Multiple keys

Multiple keys: partitioning / subdivide

- e.g. 2 keys
  - use two perpendicular axes OR
  - use alignment on one axes
    - separate by key 1 first and then by key 2
- also known as **dimensional stacking**

Dimensional stacking: 2D

two perpendicular axes

Country	Education level	Percentage
Austria	Primary school	99
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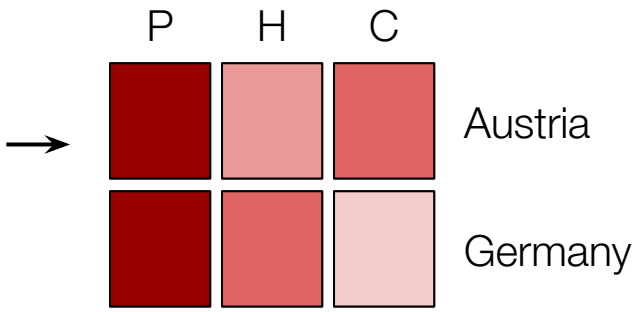
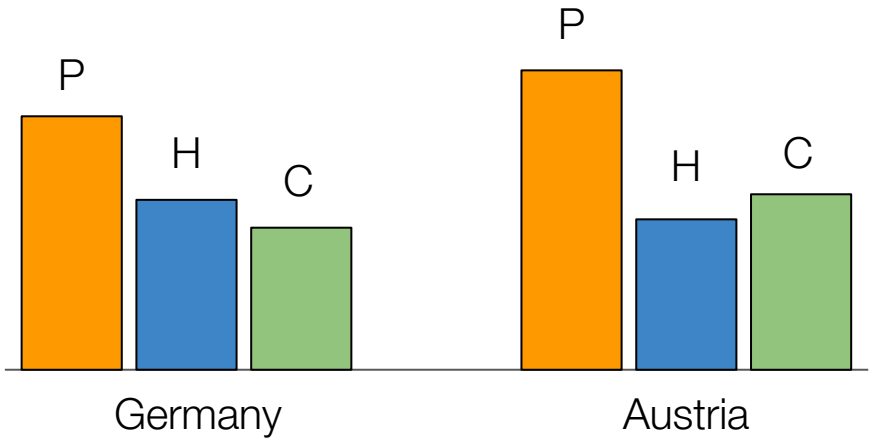
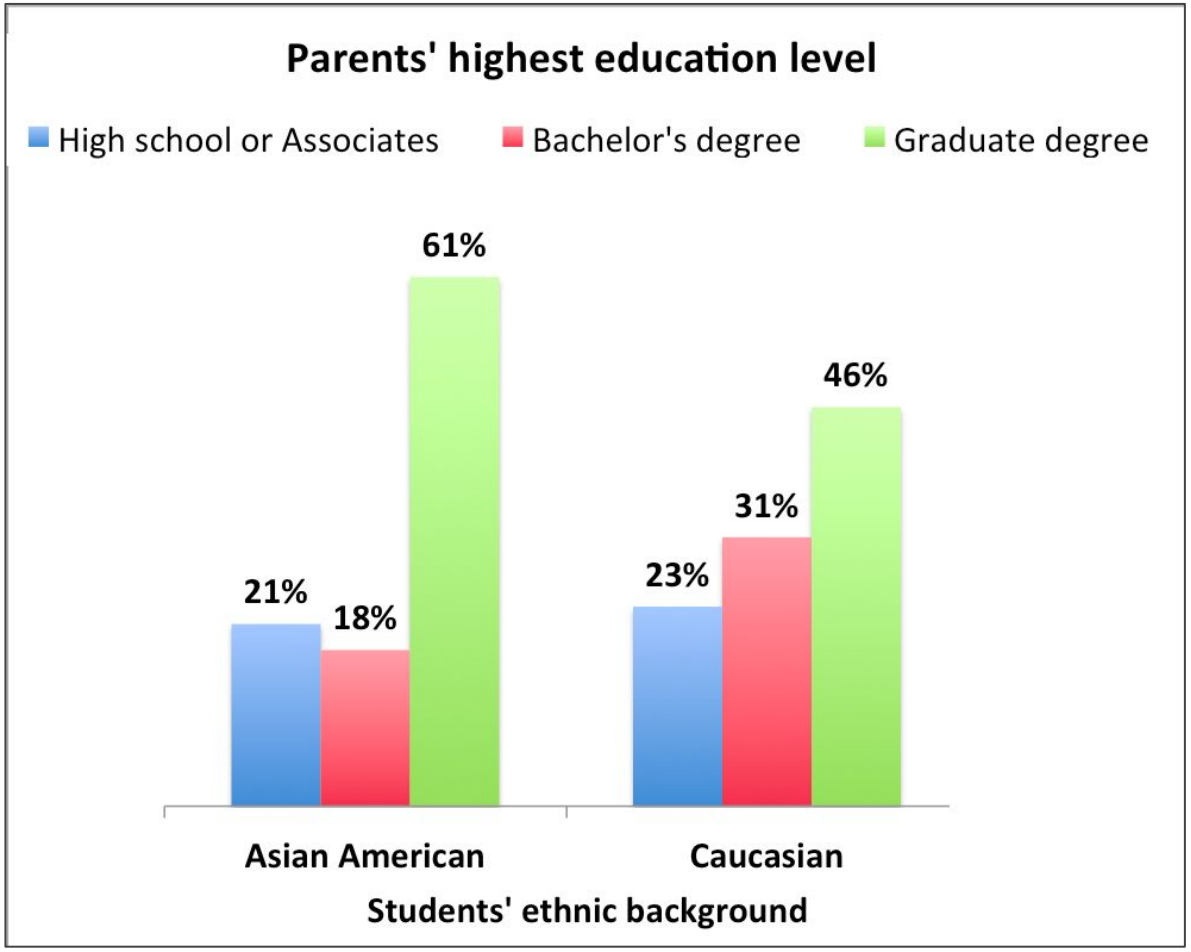
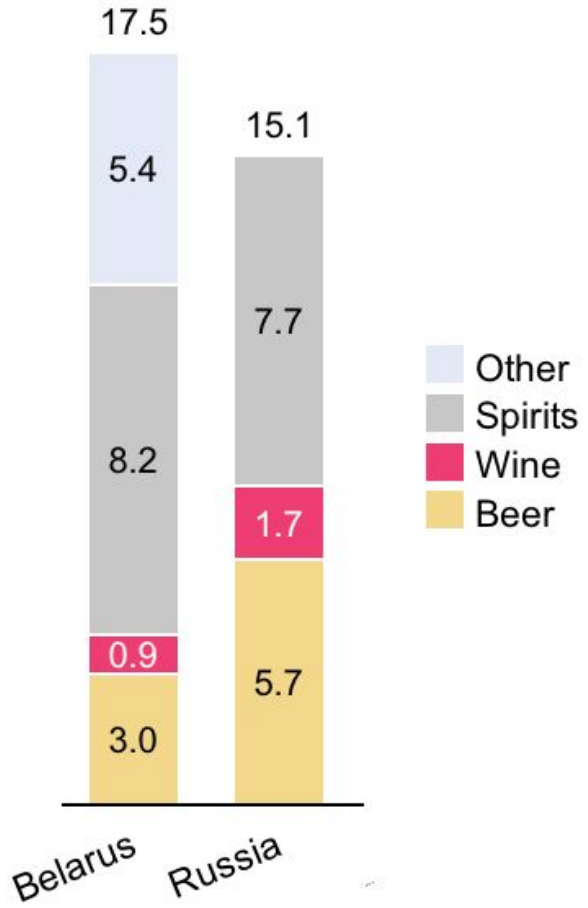


alignment on one axes



2D keys - 1D list alignment





© https://cra.org/crn/wp-content/uploads/sites/7/2015/06/Feb-2015.png

Source: Wikipedia, 2010

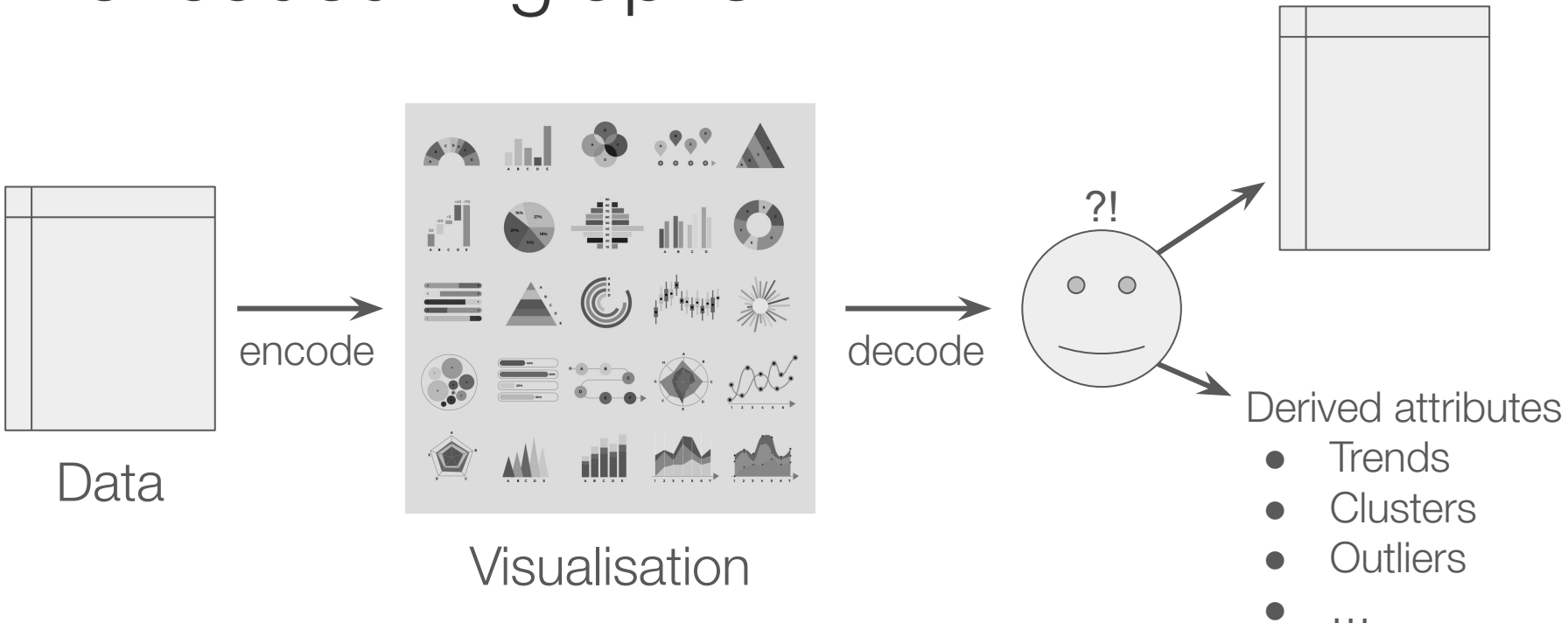
What is the “correct/best” way to display your data?

Graphical perception

- The visual decoding of information encoded in graphs

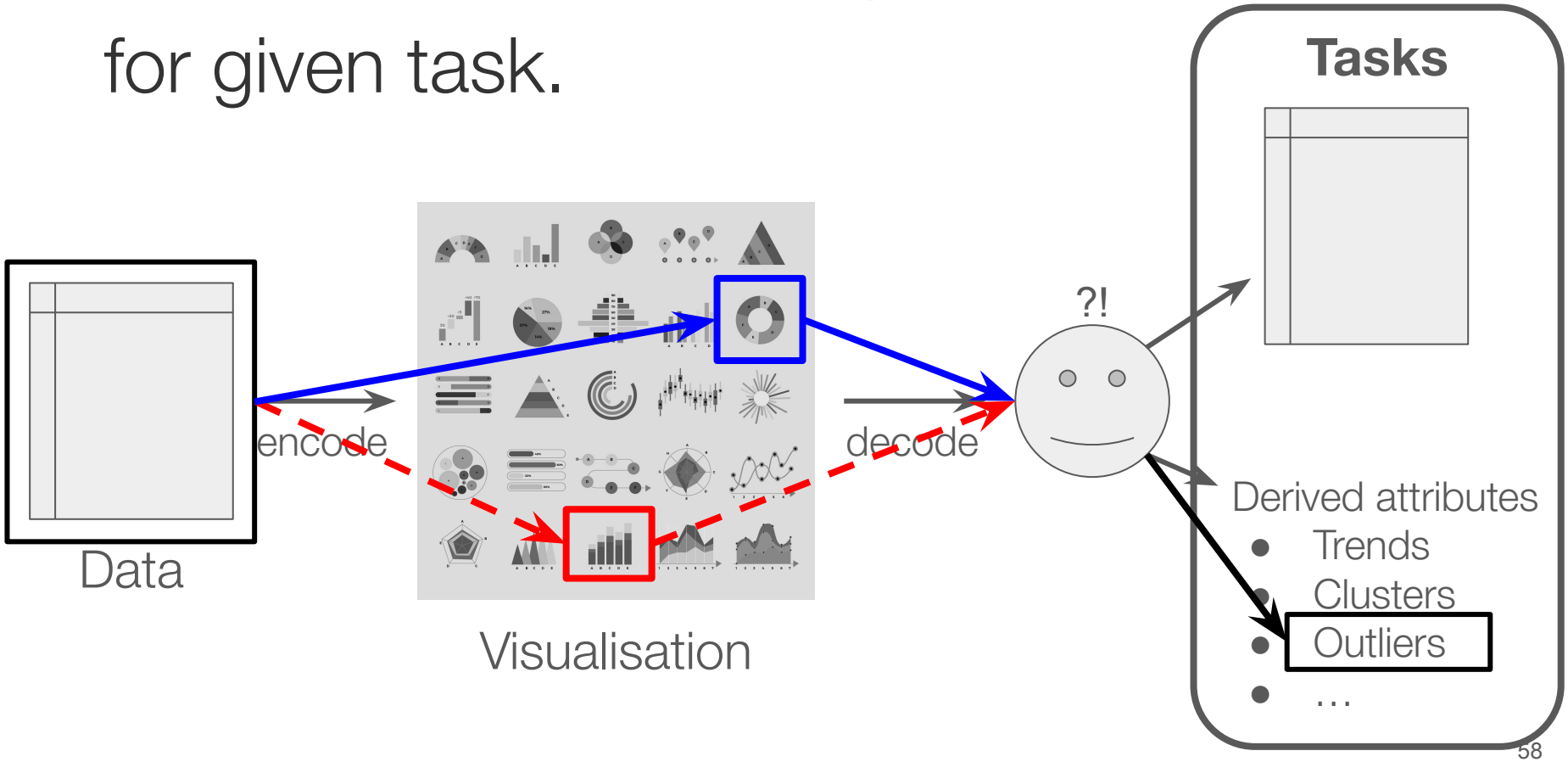
Graphical perception

- The visual decoding of information encoded in graphs



“Best” way to visualise data

- accurately decodes displayed information for given task.



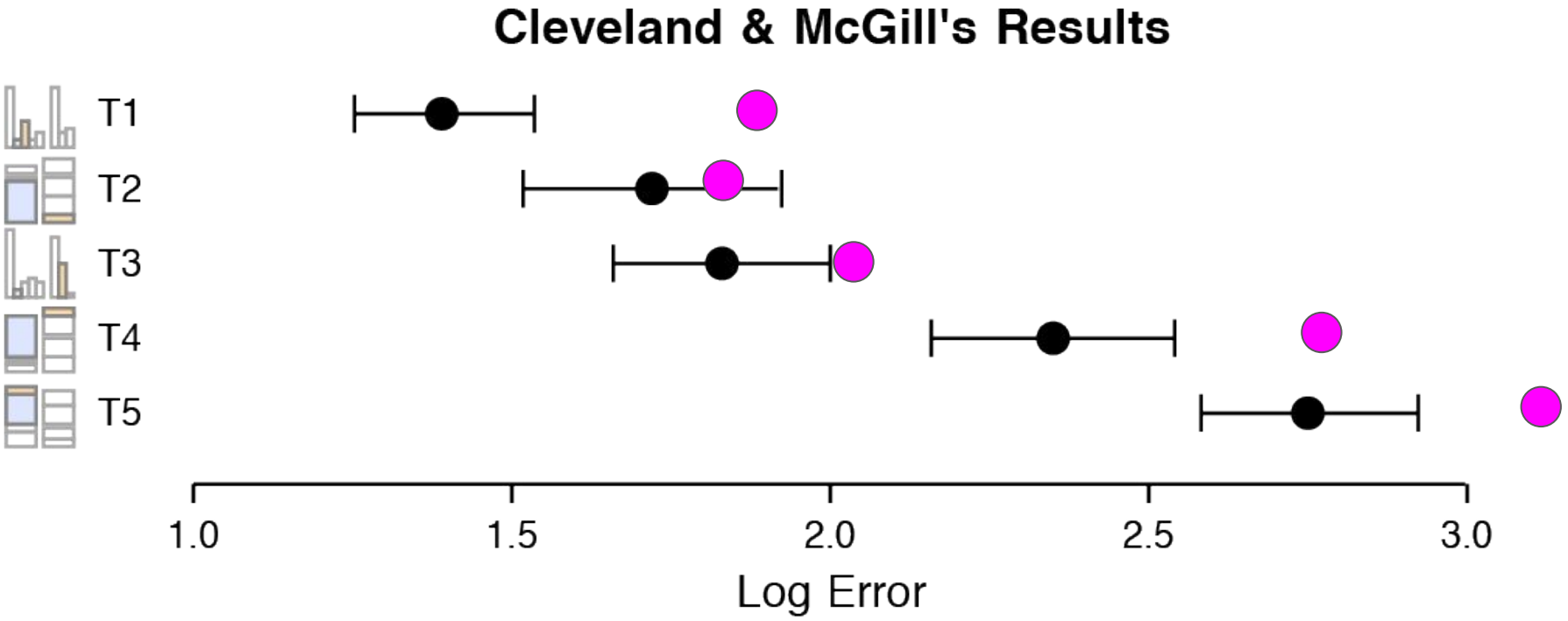
Graphical perception

- Visual decoding of information encoded in graphs
- Human capacity to visually interpret information on graphs and charts → *aim to maximize it*
  - ↳ Graph & encoding choice determines ability to obtain “correct” information from chart

Experiment: graphical perception

- Goal: Investigate effect the different layouts on the ability/task to **compare**
- Study
  - make a quick visual judgment
  - judge the percentage difference of two highlighted bars
  - 3 seconds for each task

Results

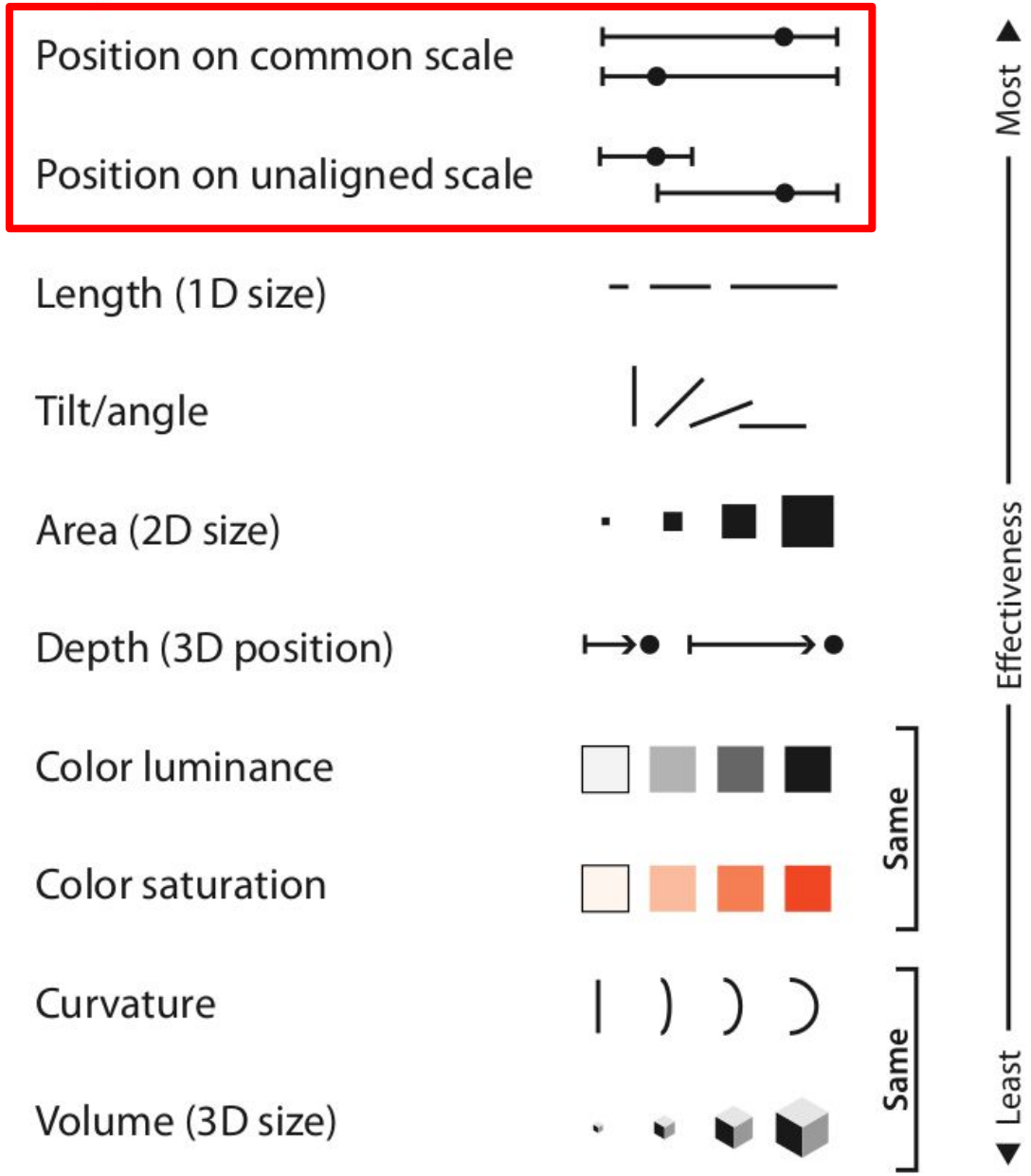


- Cleveland & McGill's results
- Your results

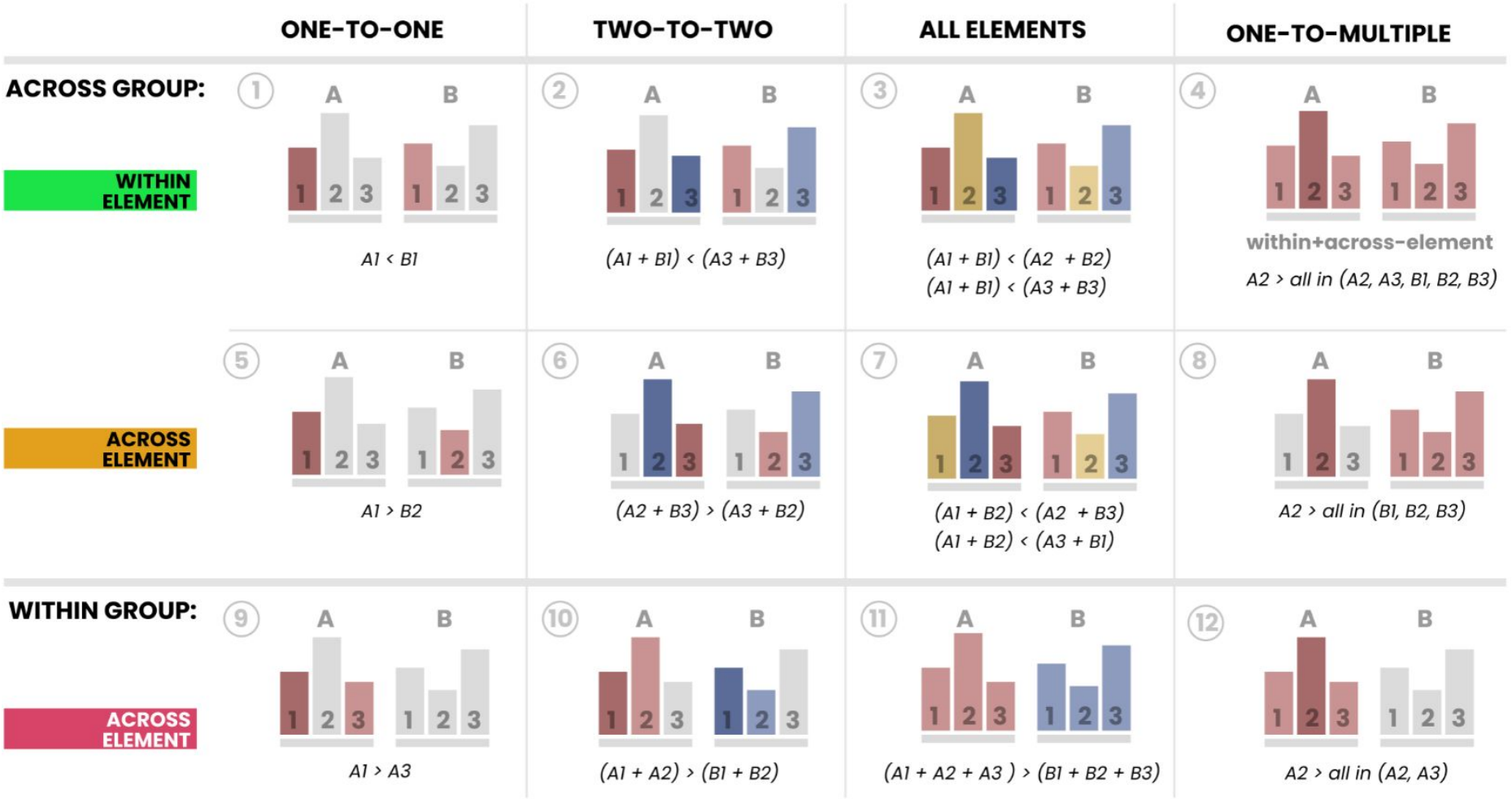
Results summary

- Comparing by using **aligned position channel** against a common scale is the most accurately perceived visual channel.
- Comparing by using **unaligned position channel** adds mental overhead of due to different start and the end of each bar → reduced accuracy.

Magnitude Channels: Ordered Attributes

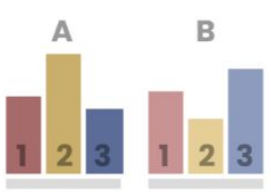


Apply what you just learned



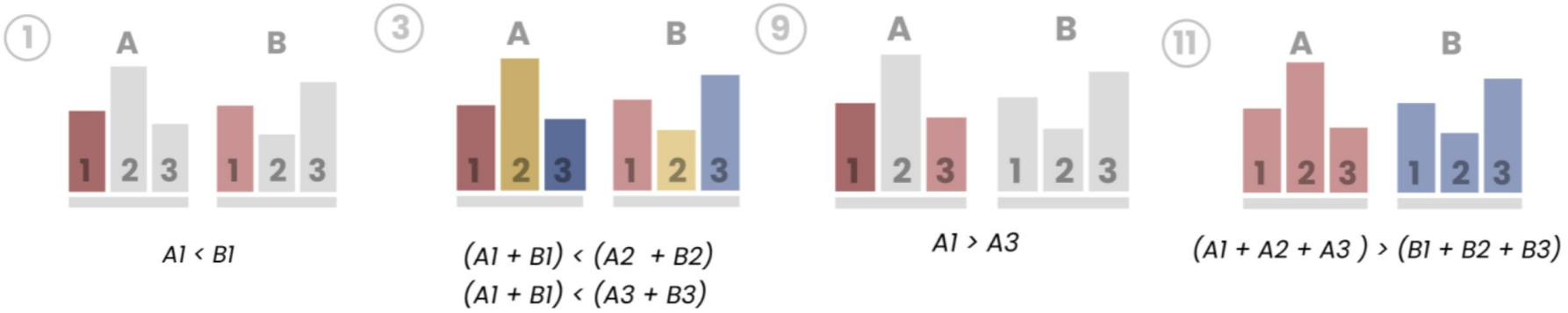
C. Xiong, et al.,"Visual Arrangements of Bar Charts Influence Comparisons in Viewer Takeaways" in IEEE Transactions on Visualization & Computer Graphics, vol. , no. 01, 2021, pp. 1-1, 5555.

Apply what you just learned

	ONE-TO-ONE	TWO-TO-TWO	ALL ELEMENTS	ONE-TO-MULTIPLE
ACROSS GROUP: **WITHIN ELEMENT**	1  *A1 < B1*		3  *(A1 + B1) < (A2 + B2)* *(A1 + B1) < (A3 + B3)*	
ACROSS ELEMENT				
WITHIN GROUP: **ACROSS ELEMENT**	9  *A1 > A3*		11  *(A1 + A2 + A3) > (B1 + B2 + B3)*	

C. Xiong, et al.,"Visual Arrangements of Bar Charts Influence Comparisons in Viewer Takeaways" in IEEE Transactions on Visualization & Computer Graphics, vol. , no. 01, pp. 1-1, 5555.

Apply what you just learned

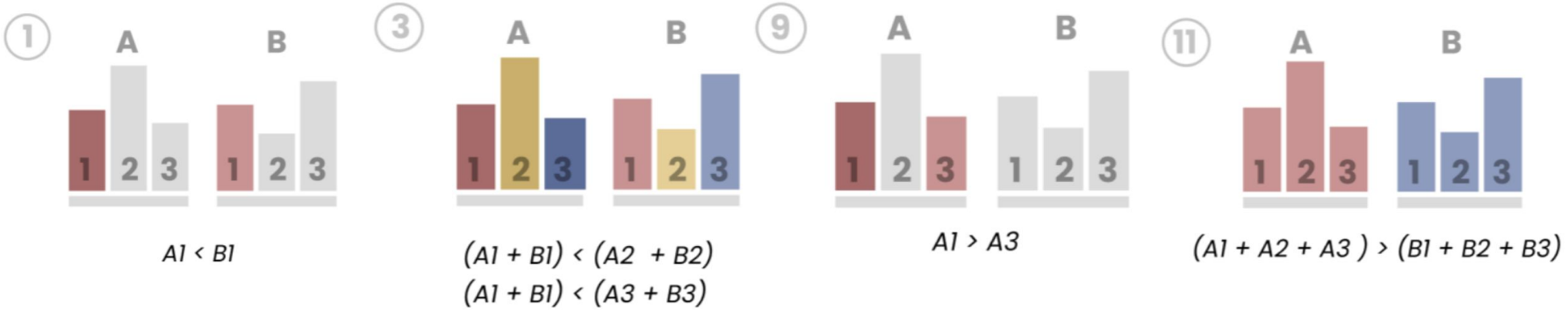


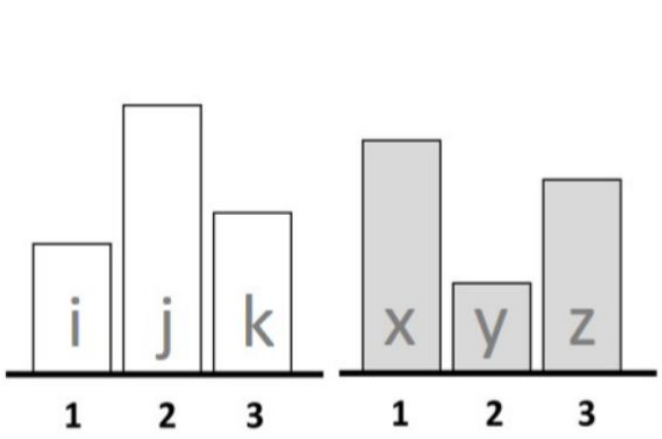
A & B Companies | 1,2,3 Continents | Bar height: revenue

1. Comparing revenue between companies A & B in continent 1.
2. Comparing total revenue of A & B in given continent.
3. Comparing revenue of company A among different continents.
4. Comparing the global revenue of company A to B

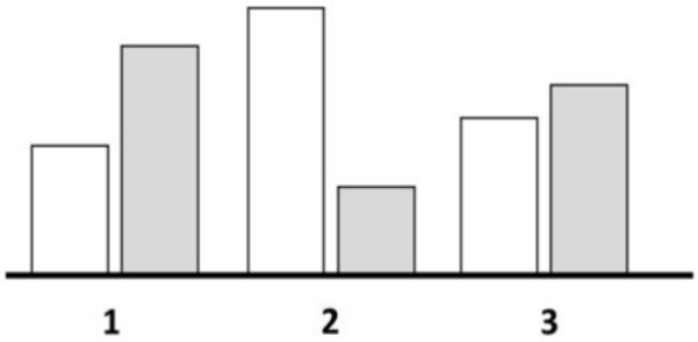
A & B Companies | 1,2,3 Continents | Bar height: revenue

Comparing revenue between companies A & B in continent 1.

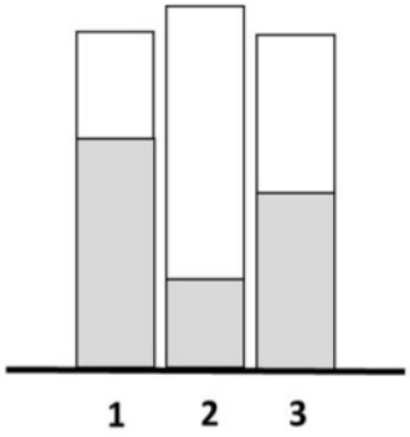




Adjacent



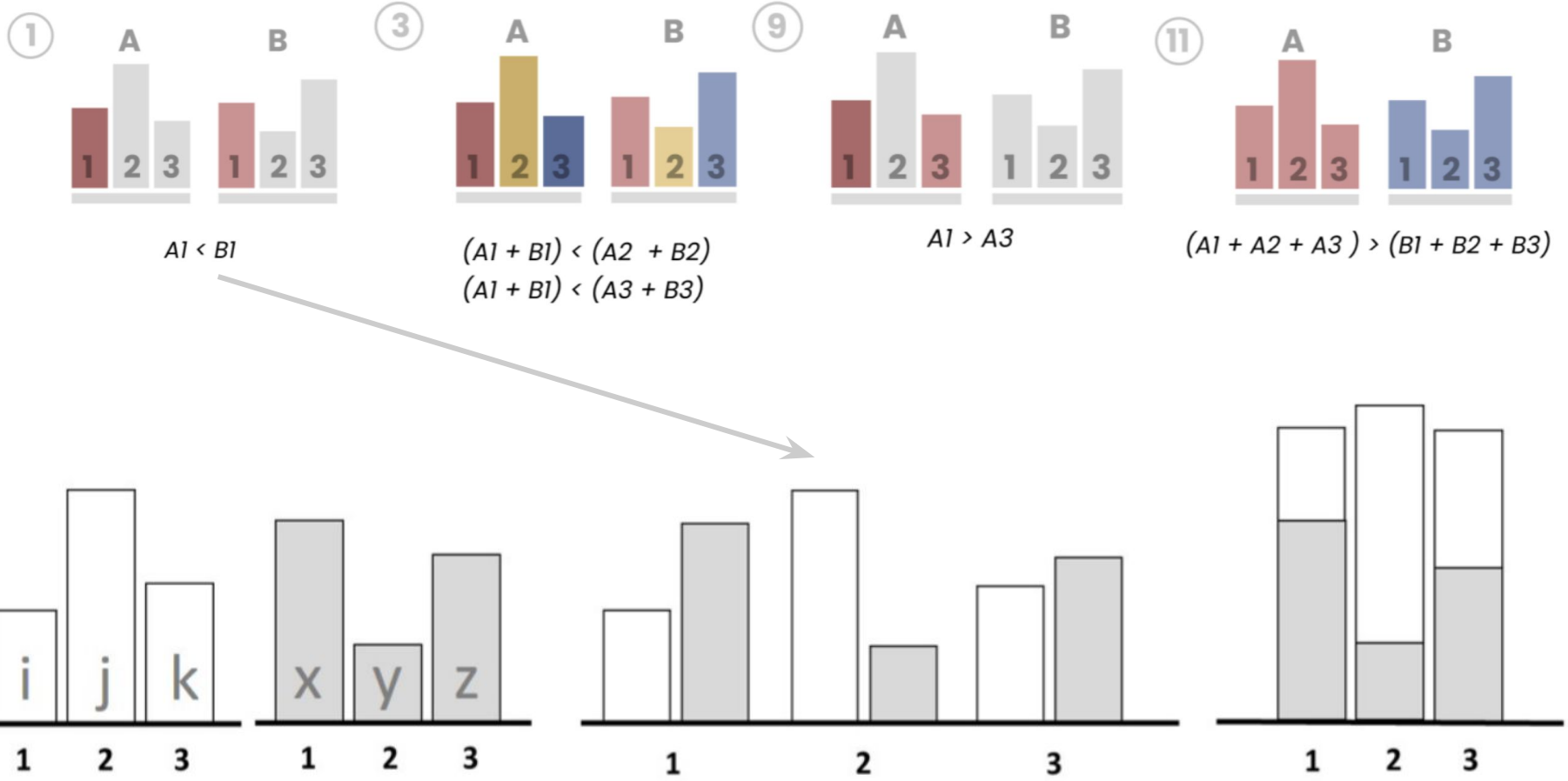
Dimensional stacking



Stacked

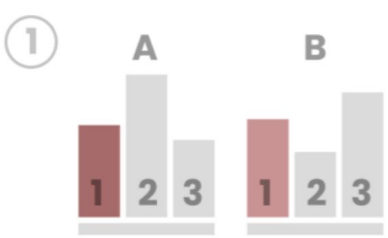
A & B Companies | 1,2,3 Continents | Bar height: revenue

Comparing revenue between companies A & B in continent 1.

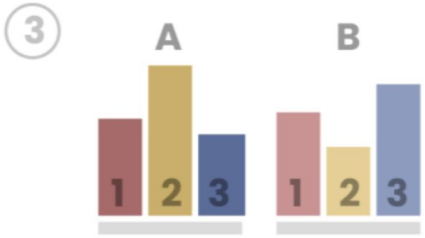


A & B Companies | 1,2,3 Continents | Bar height: revenue

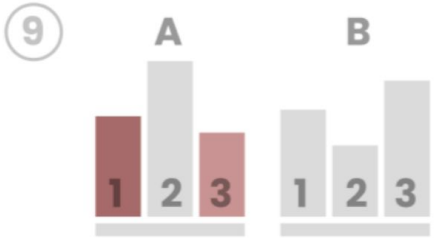
Comparing total revenue of A & B in given continent.



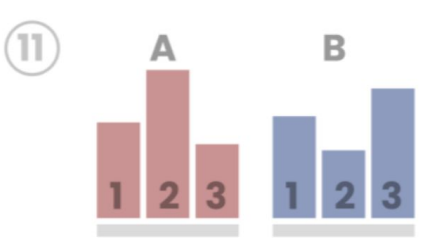
A1 < B1



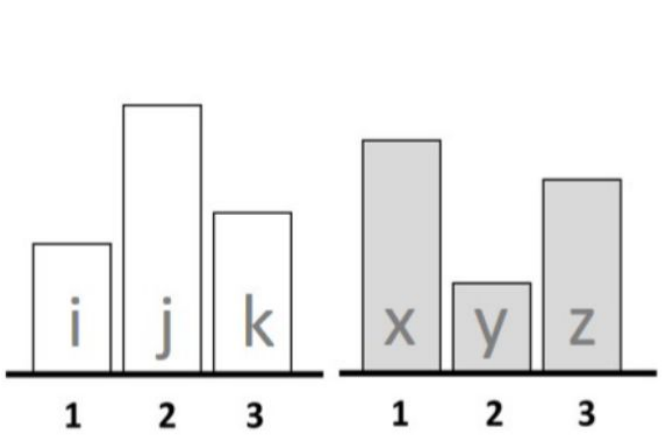
(A1 + B1) < (A2 + B2)
(A1 + B1) < (A3 + B3)



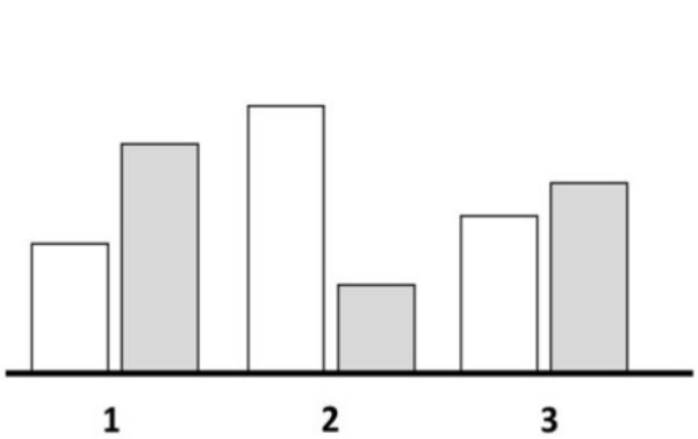
A1 > A3



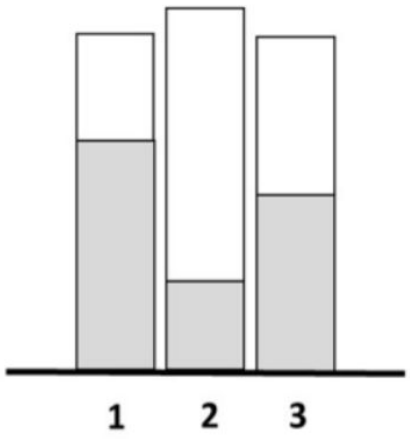
(A1 + A2 + A3) > (B1 + B2 + B3)



Adjacent



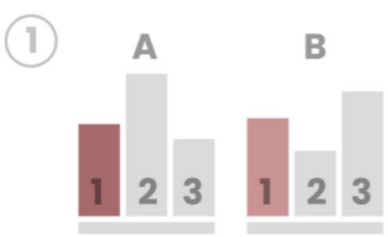
Dimensional stacking



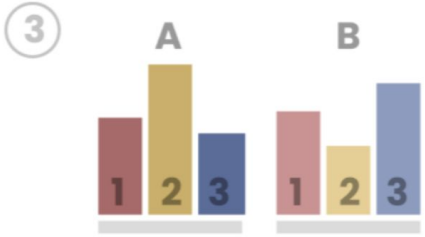
Stacked

A & B Companies | 1,2,3 Continents | Bar height: revenue

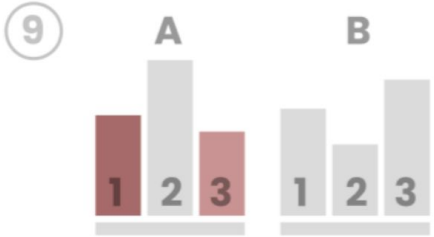
Comparing total revenue of A & B in given continent.



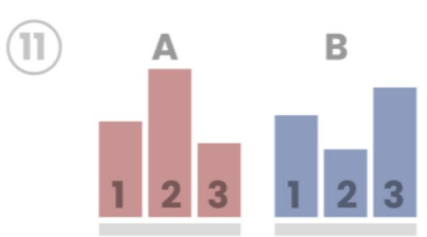
A1 < B1



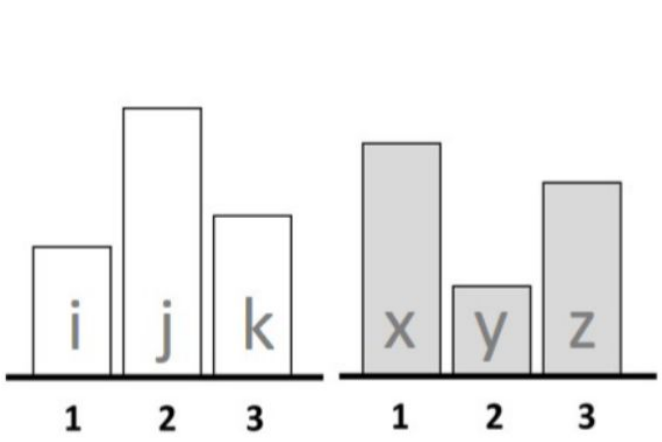
(A1 + B1) < (A2 + B2)
(A1 + B1) < (A3 + B3)



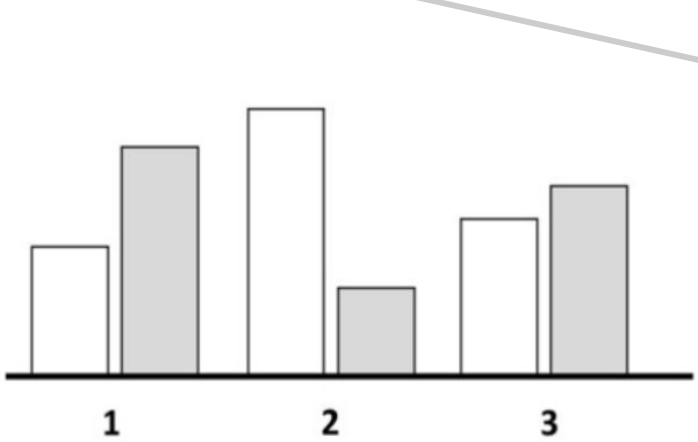
A1 > A3



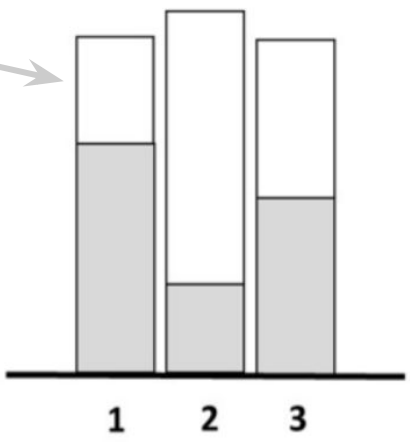
(A1 + A2 + A3) > (B1 + B2 + B3)



Adjacent



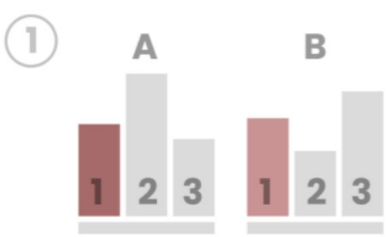
Dimensional stacking



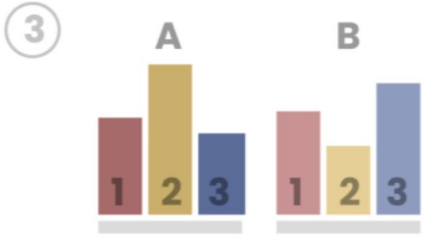
Stacked

A & B Companies | 1,2,3 Continents | Bar height: revenue

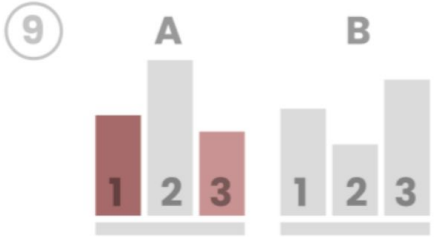
Comparing revenue of company A among different continents.



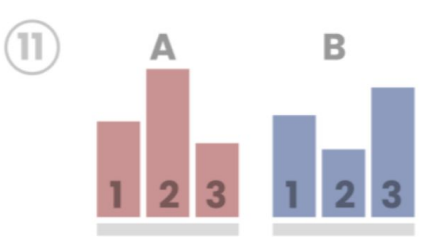
A1 < B1



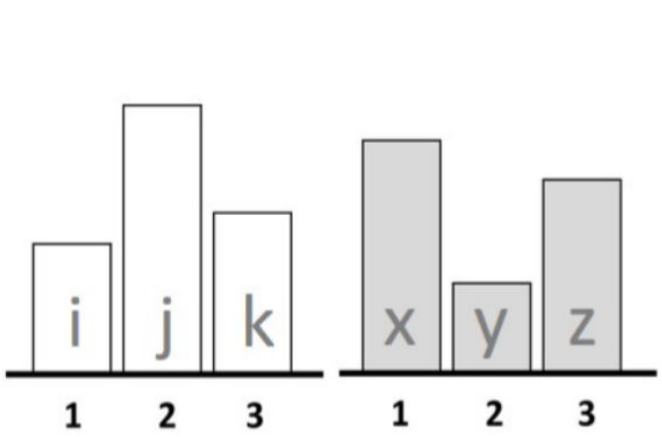
(A1 + B1) < (A2 + B2)
(A1 + B1) < (A3 + B3)



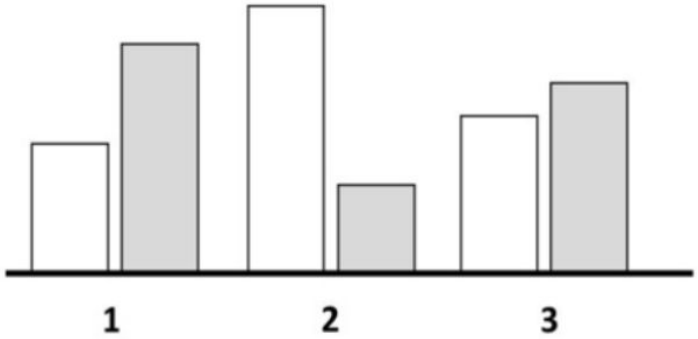
A1 > A3



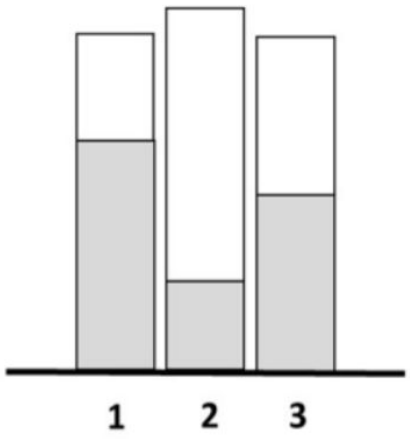
(A1 + A2 + A3) > (B1 + B2 + B3)



Adjacent



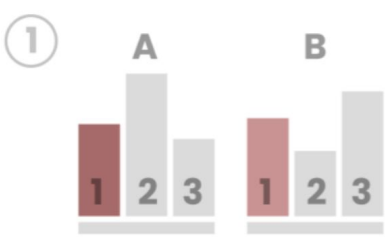
Dimensional stacking



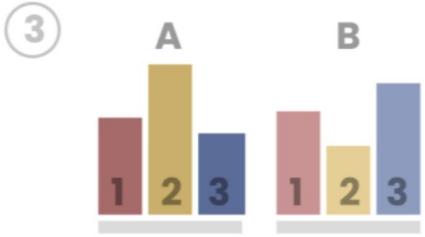
Stacked

A & B Companies | 1,2,3 Continents | Bar height: revenue

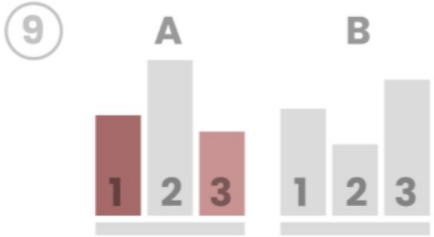
Comparing revenue of company A among different continents.



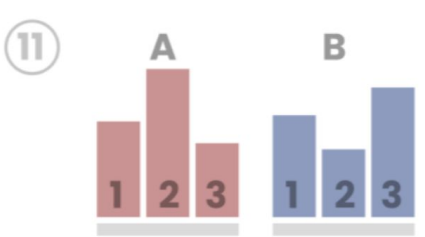
A1 < B1



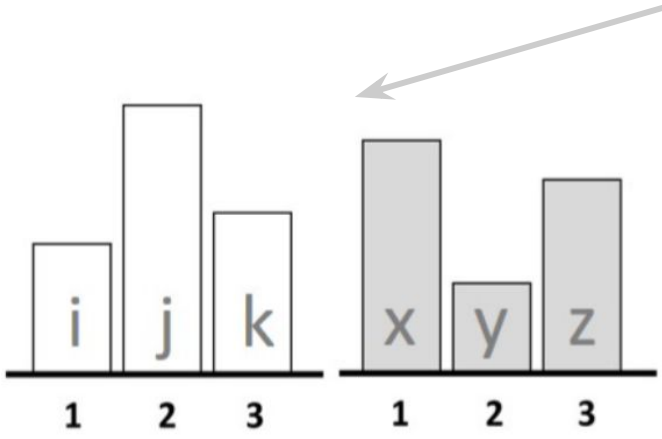
(A1 + B1) < (A2 + B2)
(A1 + B1) < (A3 + B3)



A1 > A3



(A1 + A2 + A3) > (B1 + B2 + B3)



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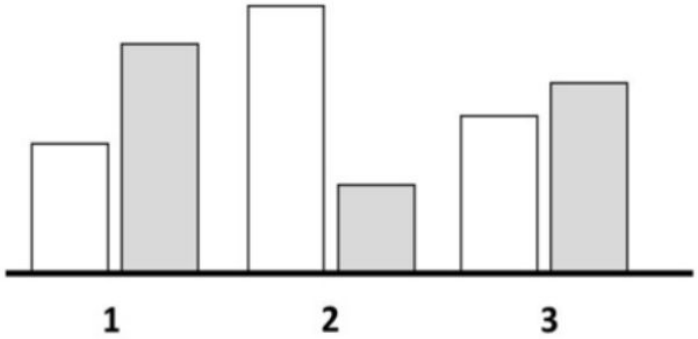
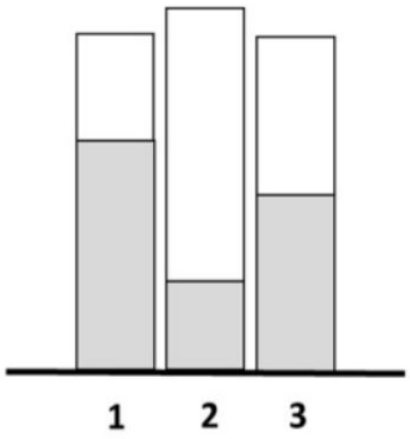


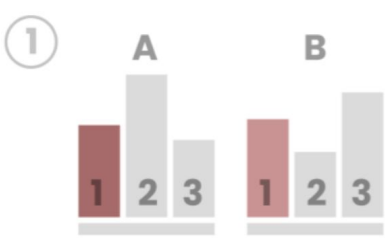
Dimensional stacking



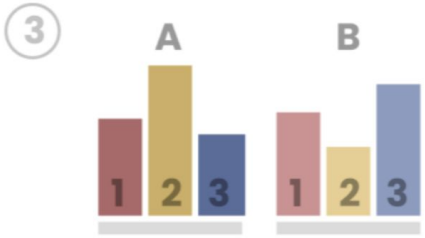
Stacked

A & B Companies | 1,2,3 Continents | Bar height: revenue

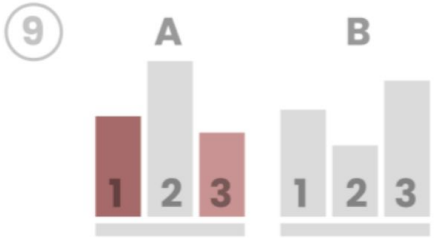
Comparing the global revenue of company A to B.



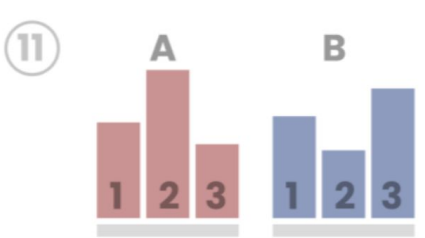
A1 < B1



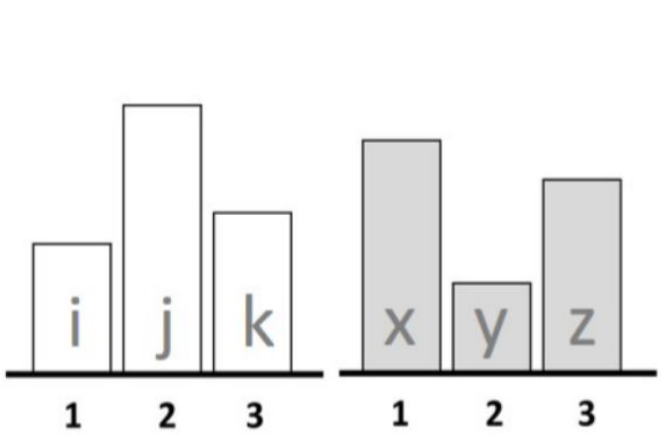
(A1 + B1) < (A2 + B2)
(A1 + B1) < (A3 + B3)



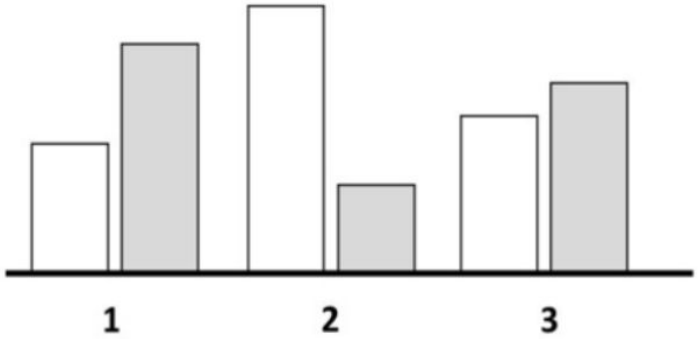
A1 > A3



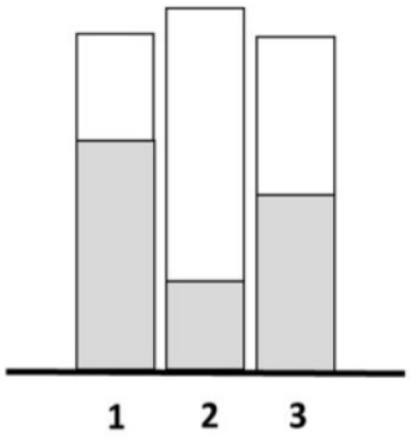
(A1 + A2 + A3) > (B1 + B2 + B3)



Adjacent



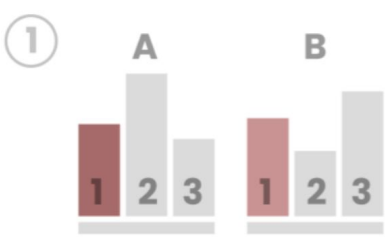
Dimensional stacking



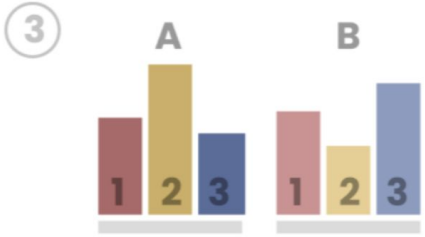
Stacked

A & B Companies | 1,2,3 Continents | Bar height: revenue

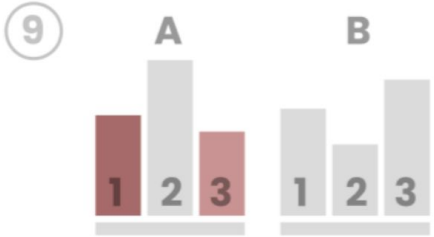
Comparing the global revenue of company A to B.



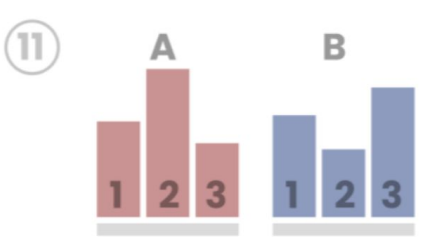
A1 < B1



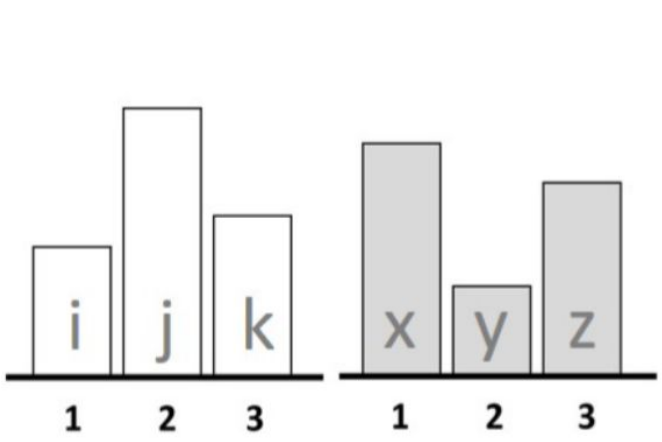
(A1 + B1) < (A2 + B2)
(A1 + B1) < (A3 + B3)



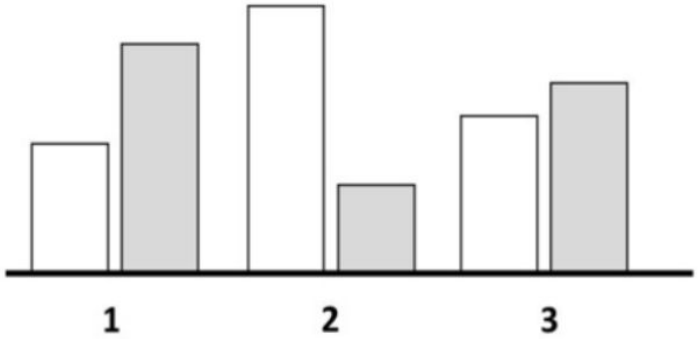
A1 > A3



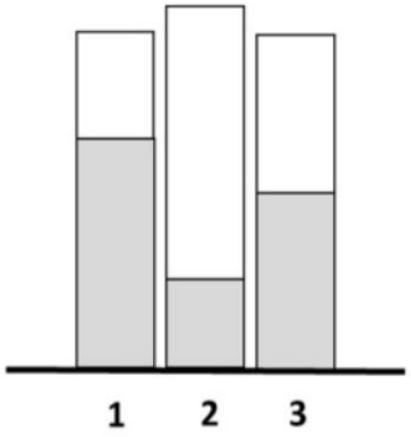
(A1 + A2 + A3) > (B1 + B2 + B3)



Adjacent



Dimensional stacking



Stacked