

# Using Visual Perception

to find patterns in data and drive insight

Alex Gurvich, Ph.D.  
NASA Scientific Visualization Studio  
R Gov. & Public Sector, Oct. 29, 2024

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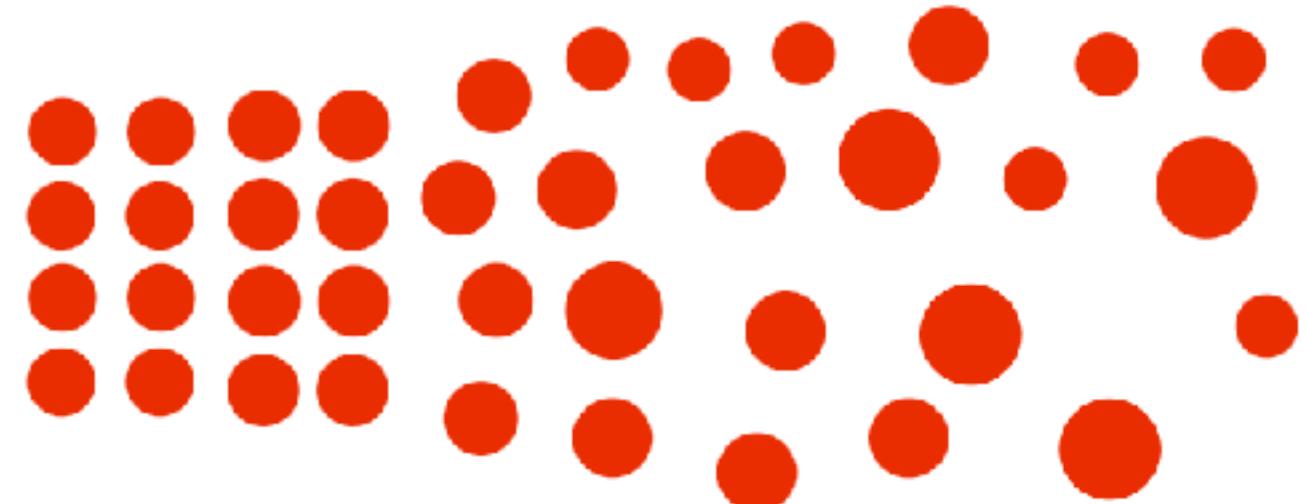
# Using Visual Perception

to ~~find~~ patterns in data and drive insight  
help others

a.k.a. a book report evangelizing the  
work of Northwestern professor  
[Steve Franconeri's](#)

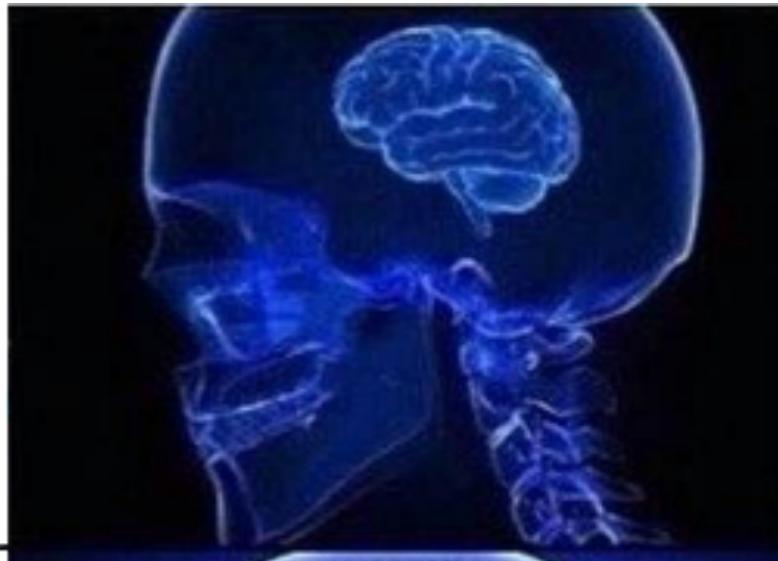
Visual Thinking  
Lab

We study visual thinking: how it works, and how  
education + design can make it work better.

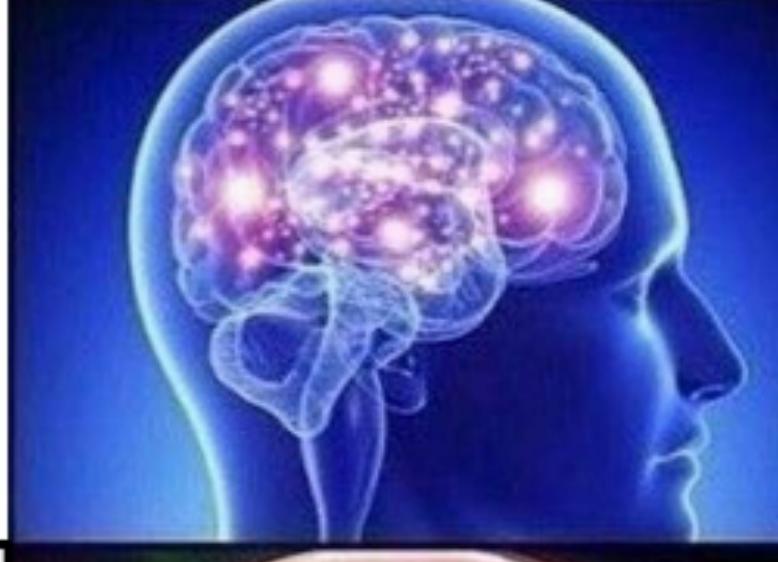


When I was in grad school I attended a workshop and saw one of Steve's presentations and it inspired me to become a data visualizer.

**BEFORE  
STEVE'S TALK AT  
NU IDEAS FSS  
2017 VIZ WORKSHOP**



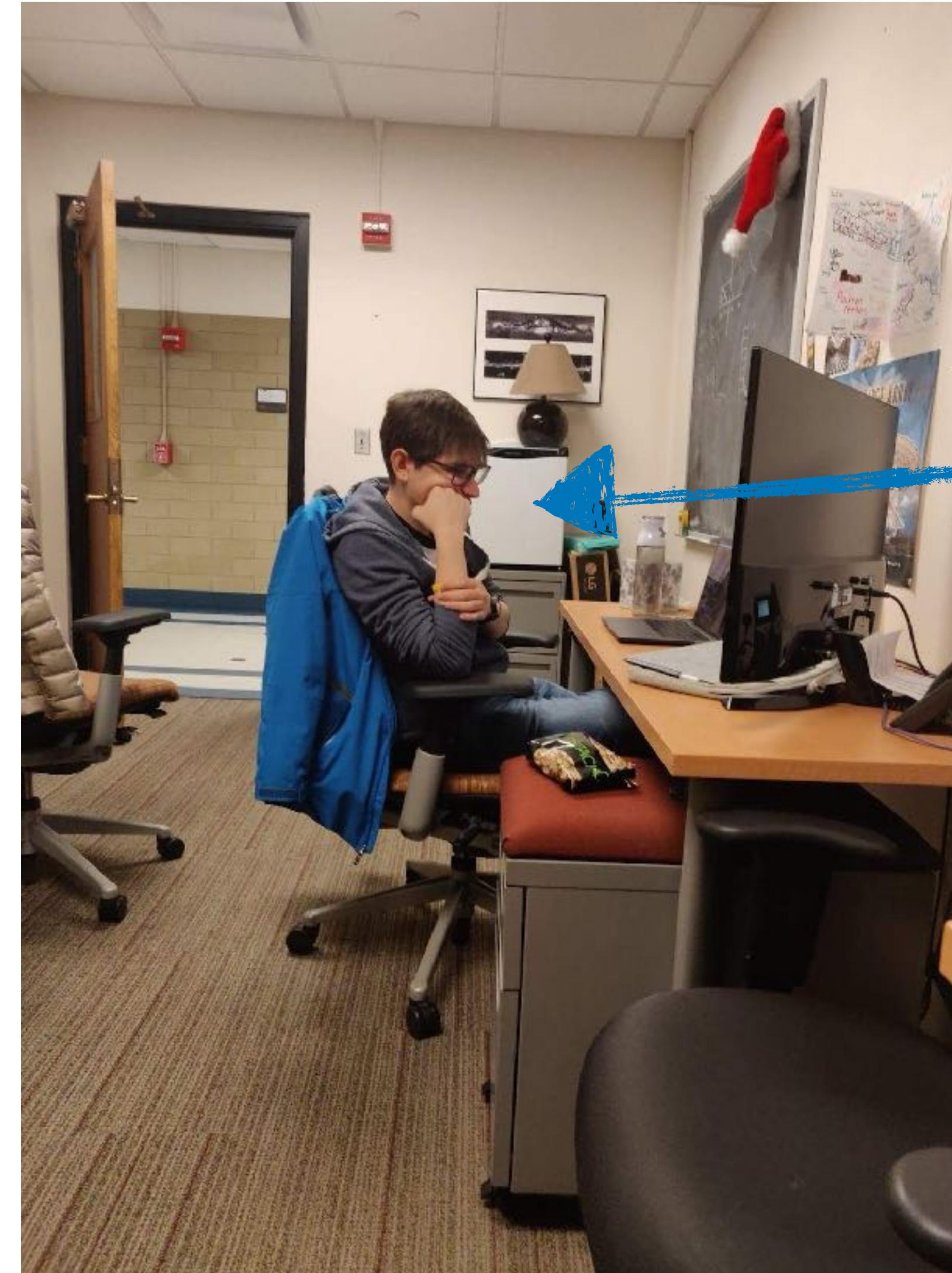
**AFTER STEVE'S  
TALK AT NU  
IDEAS FSS  
2017 VIZ WORKSHOP**



**AFTER  
STEVE'S TALK  
AT OUTLIER 2024**



**AFTER  
PREPARING THIS  
PRESENTATION**



**me in grad school  
@ NU on my way  
to deciding to  
become a  
data visualizer**

Humans are **hardwired** to quickly process visual information  
for **aggregate stats**, as visualizers we want to take advantage of this.

**without even having to focus, your  
brain has turned on a powerful **parallel  
processing engine** to analyze the photo  
on the right.**



Humans are **hardwired** to quickly process visual information for aggregate stats, as visualizers we want to take advantage of this.

without even having to focus, your brain has turned on a powerful **parallel processing engine** to analyze the photo on the right.

**you can quickly and automatically identify clusters, relative sizes, and the overall number of objects.**



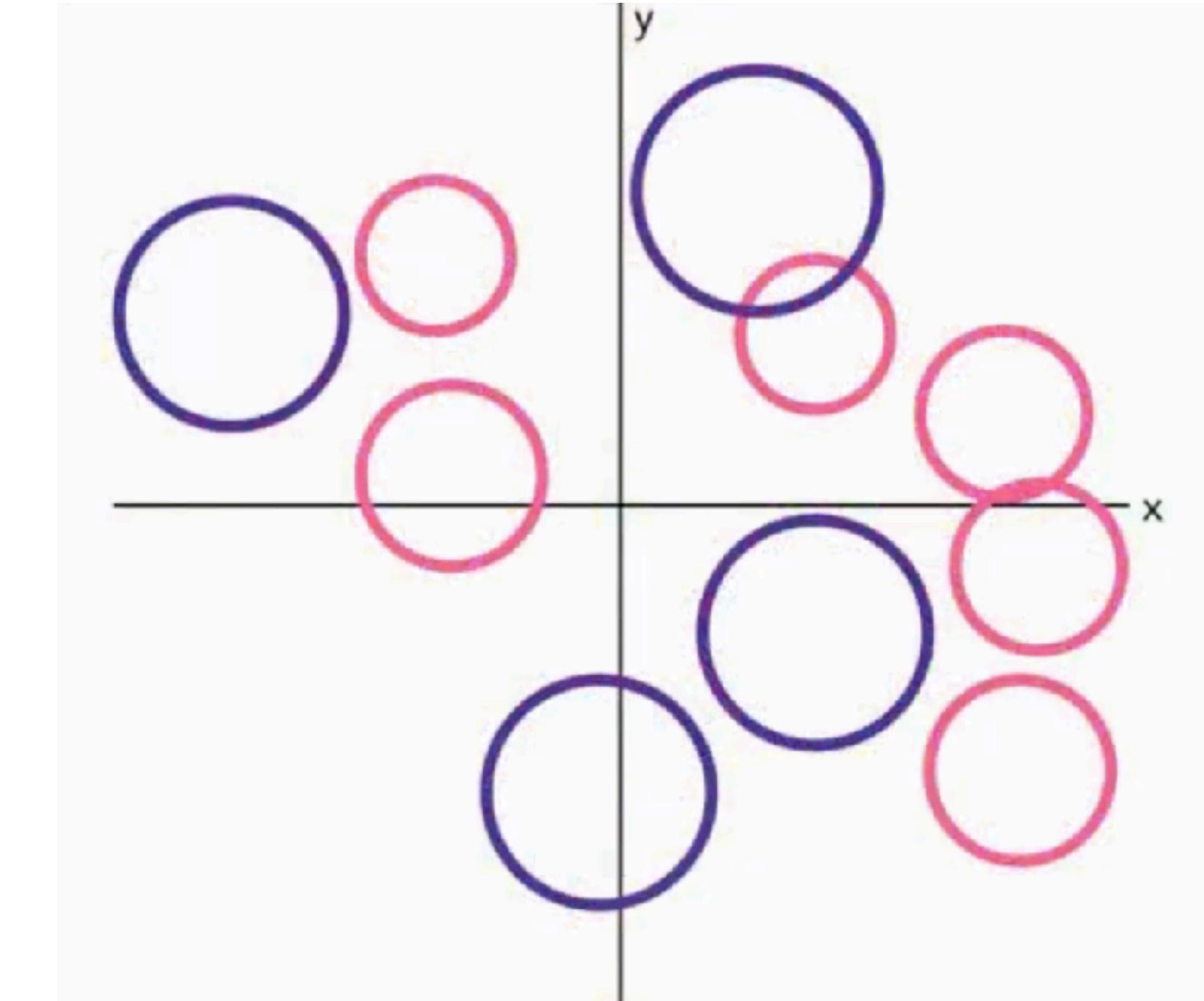
Humans are **hardwired** to quickly process visual information for aggregate stats, as visualizers we want to take advantage of this.

**size and shape and colore distributions berries example**  
can be done in ~130ms, eyes moving up and down takes 250ms

without even having to focus, your brain has turned on a powerful **parallel processing engine** to analyze the photo on the right.

you can quickly and automatically identify **clusters**, **relative sizes**, and the **overall number** of objects.

**we want to hijack the visual system**, which evolved to avoid predators and forage for food, to instead find **complex relationships** in abstract data



The **language center** of our brain isn't as fast as the visual processing center and presents a **bottleneck** to data interpretation.

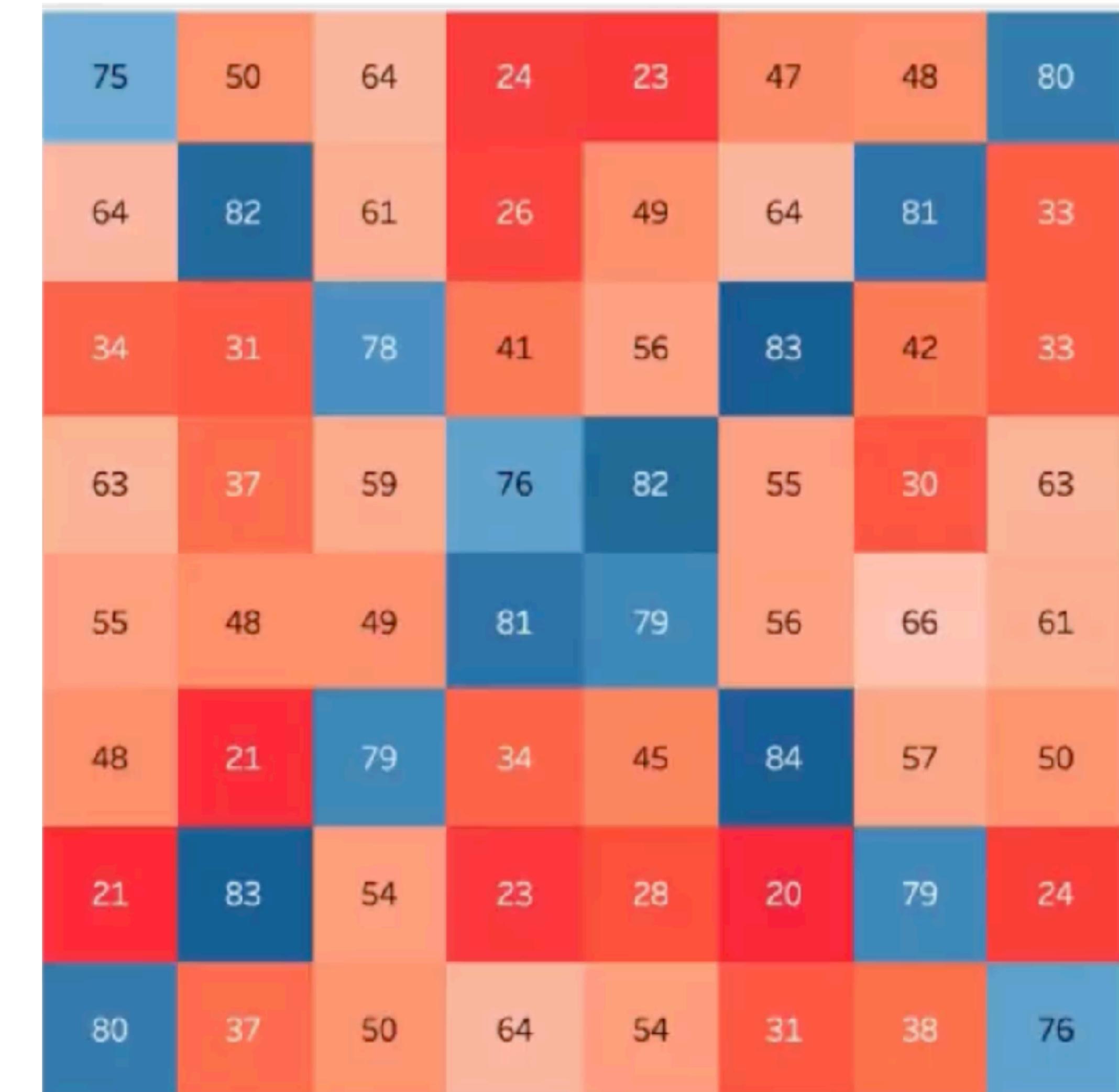
**Identifying a pattern in a table of numbers is difficult on its own, and requires the language processing center of the brain, which is slower than the visual processing center.**

75	50	64	24	23	47	48	80
64	82	61	26	49	64	81	33
34	31	78	41	56	83	42	33
63	37	59	76	82	55	30	63
55	48	49	81	79	56	66	61
48	21	79	34	45	84	57	50
21	83	54	23	28	20	79	24
80	37	50	64	54	31	38	76

The **language center** of our brain isn't as fast as the visual processing center and presents a **bottleneck** to data interpretation.

Identifying a **pattern** in a **table of numbers** is difficult on its own, and requires the **language processing center** of the brain, which is slower than the **visual processing center**.

applying **conditional formatting** makes the **pattern** immediately jump out.

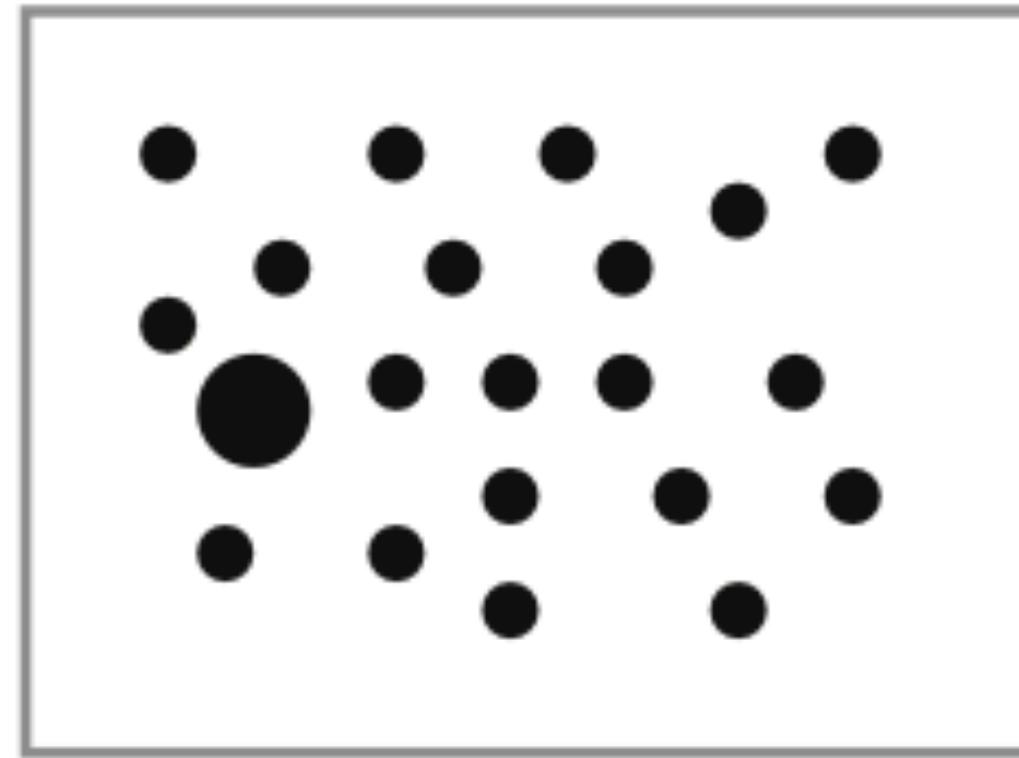


Fast visual processing happens at the intersection of preattentive processing and the Gestalt Principles.

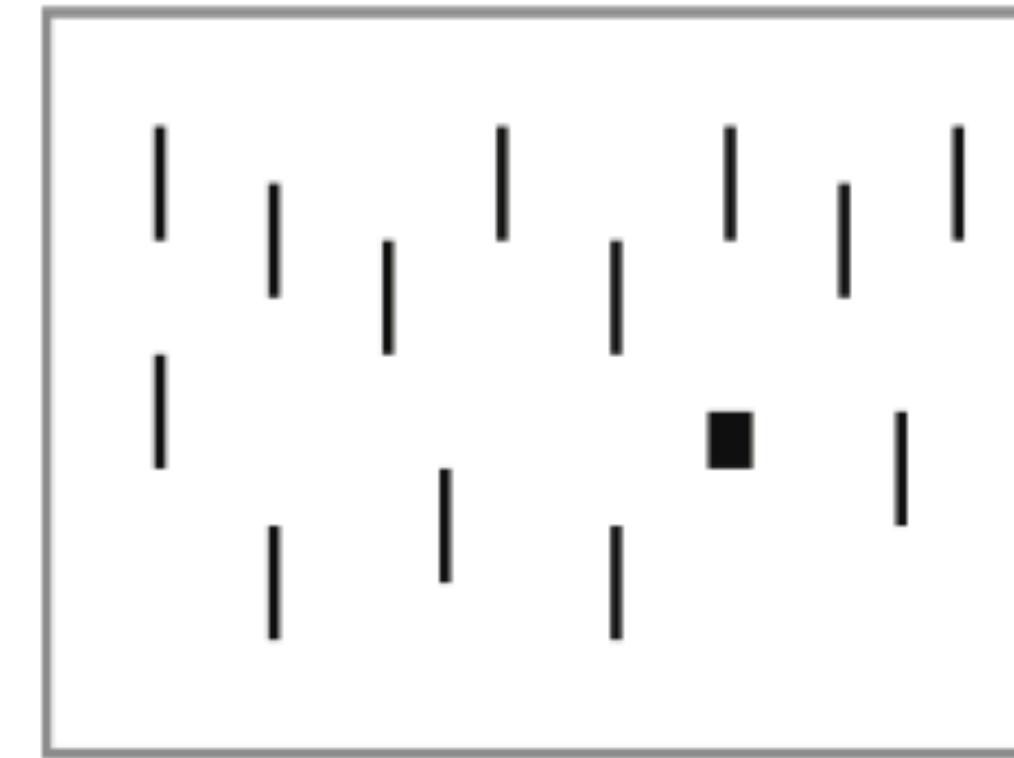
# Preattentive Processing      Gestalt Principles

Preattentive processing is the **set of filters** we apply to our visual input **before** we pass it to our brain to **interpret**.

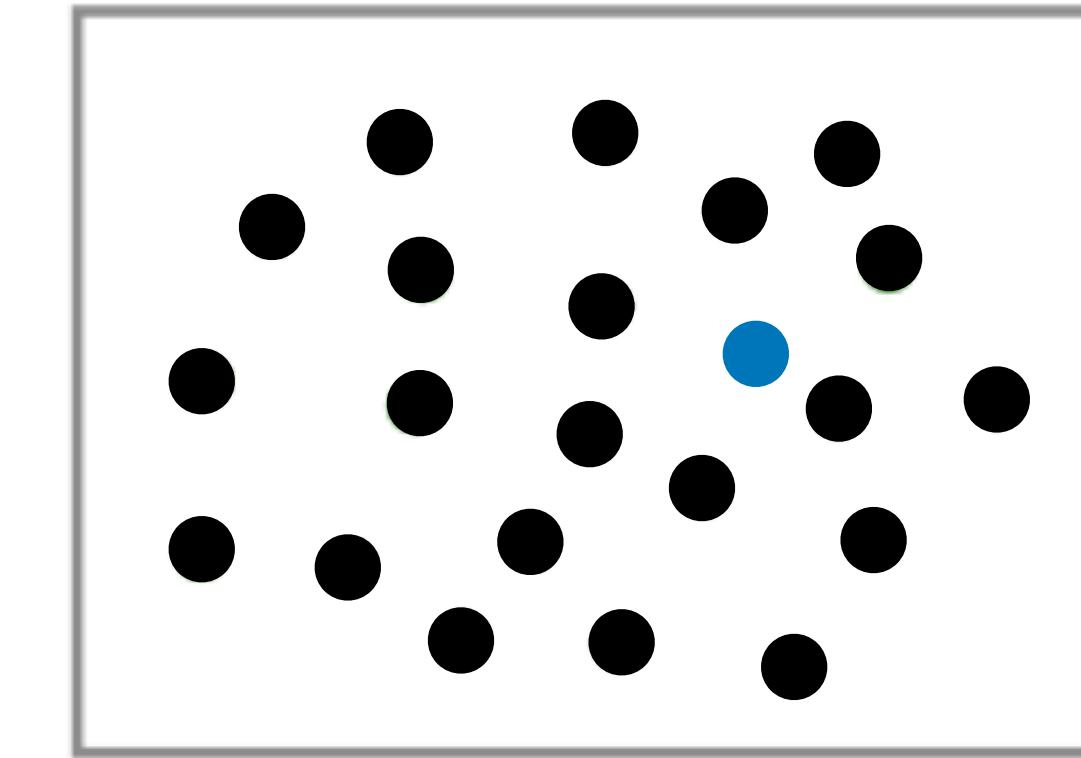
**Area**



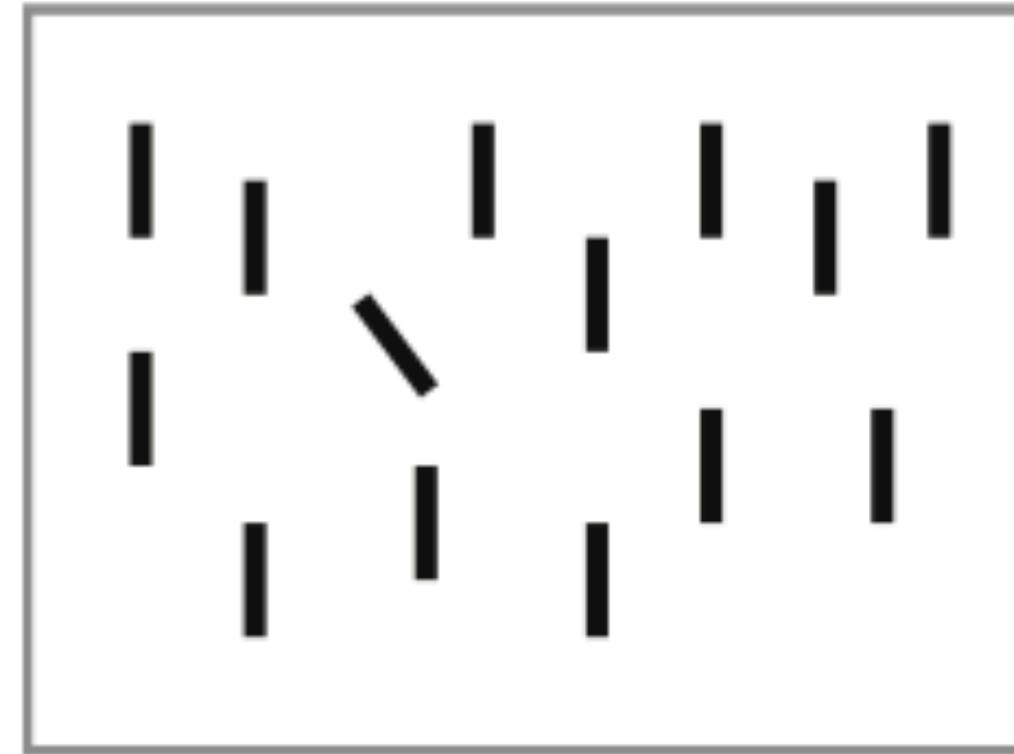
**Shape**



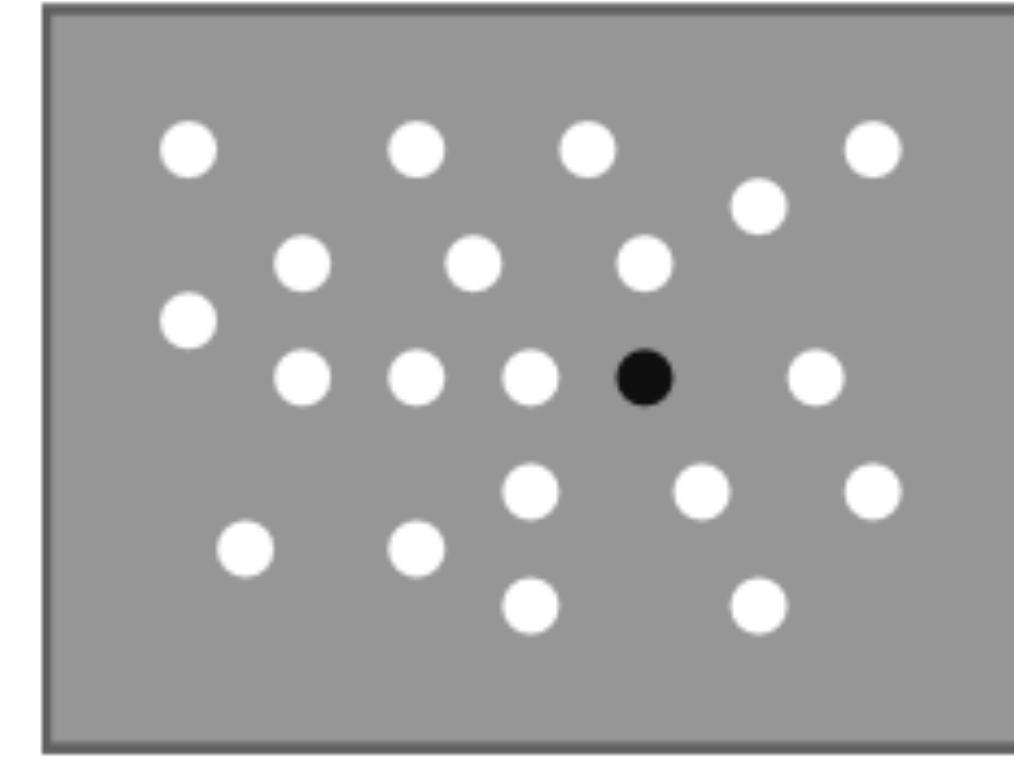
**Color**



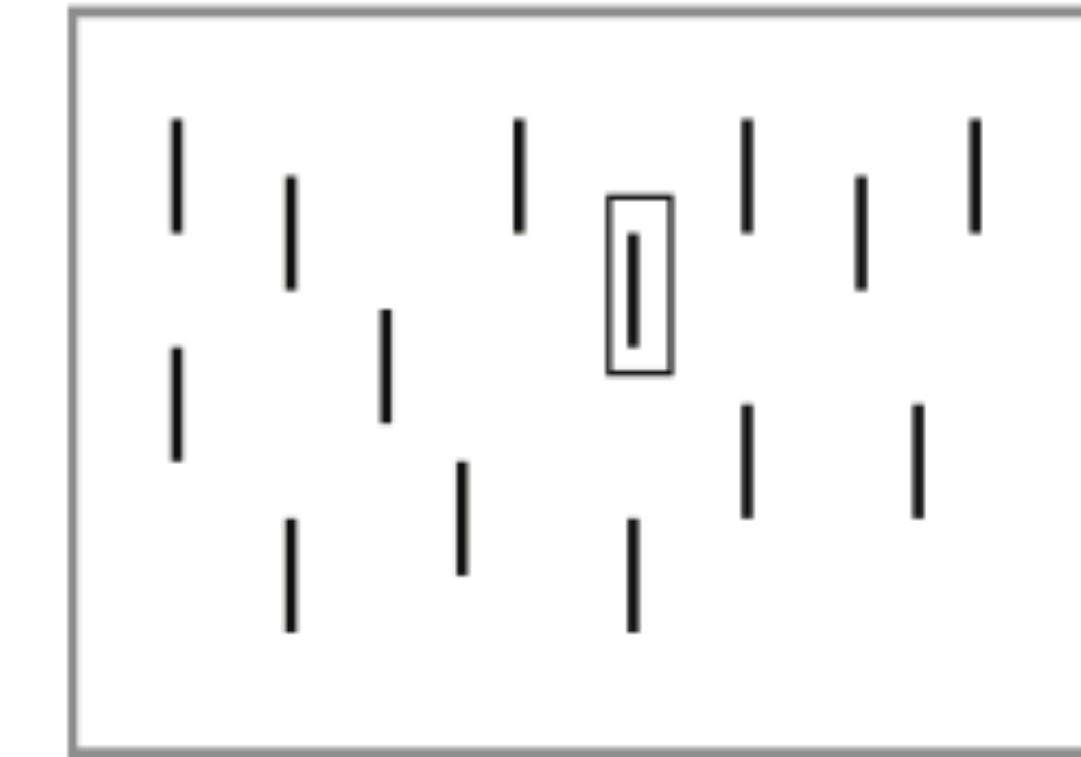
**Angle**



**Intensity**



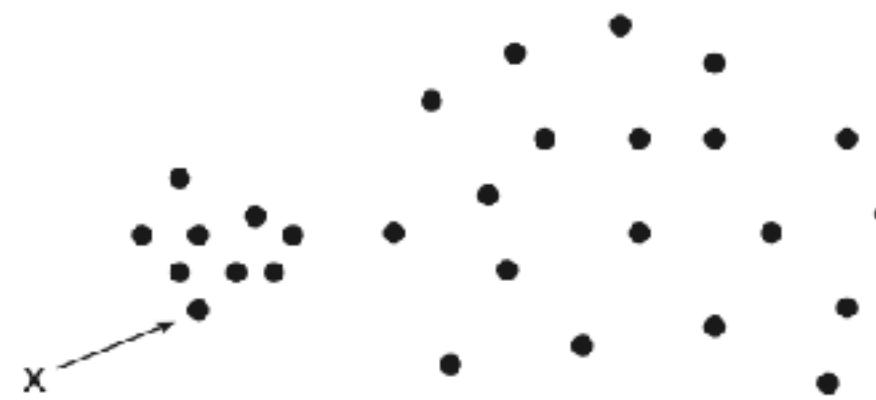
**Addition**



The Gestalt Principles codify how we **reduce cognitive effort** by perceiving an **organized whole** rather than a **collection of parts**.

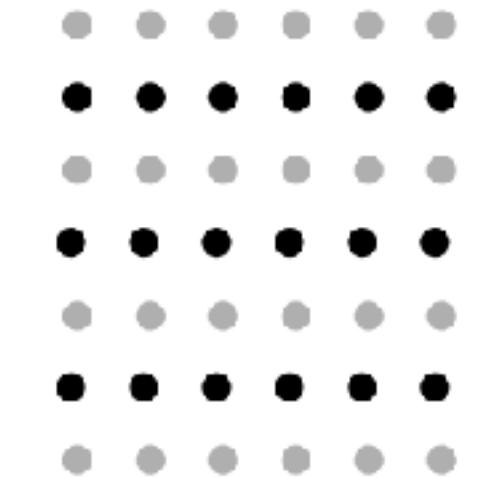
### Proximity

**elements that are close together are perceived as part of the same group.**



### Similarity

**elements that look similar (in color, shape, size, etc.) are seen as related or belonging together.**



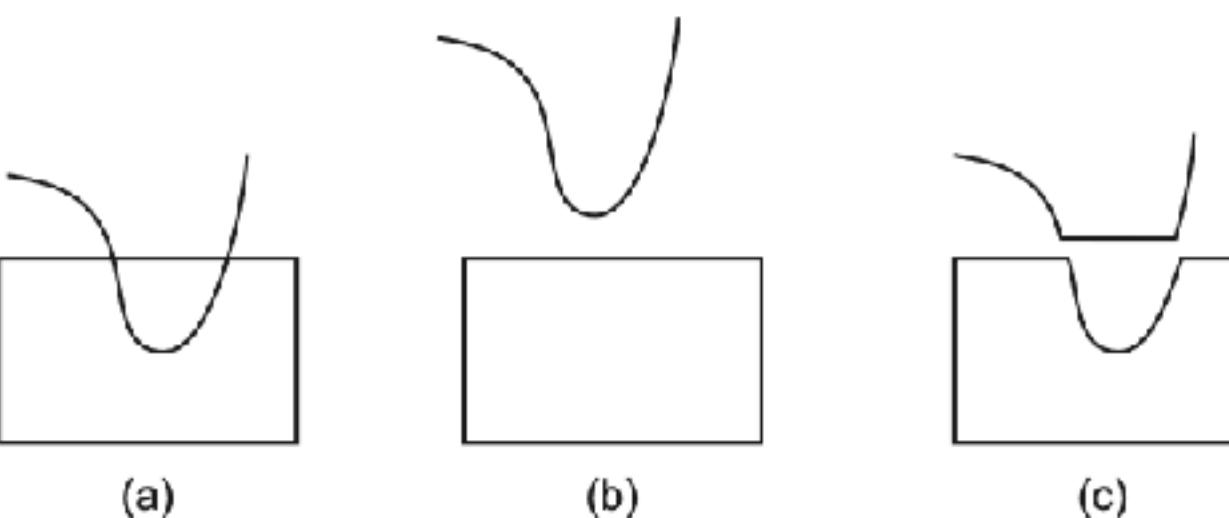
### Connectedness

**elements that are literally connected overpower other implicit groupings**



### Continuity

**our eyes naturally follow lines and paths, so elements aligned in a direction tend to be grouped.**



### Closure

**our brains fill in missing parts to see a complete, enclosed shape, so elements that suggest a closed contour are grouped.**



Effective data visualization is focused, intentional, and has high signal-to-noise for communicating concepts.

**"...induce the viewer to think about the substance rather than about the methodology, graphic design, the technology of graphic production, or something else"**

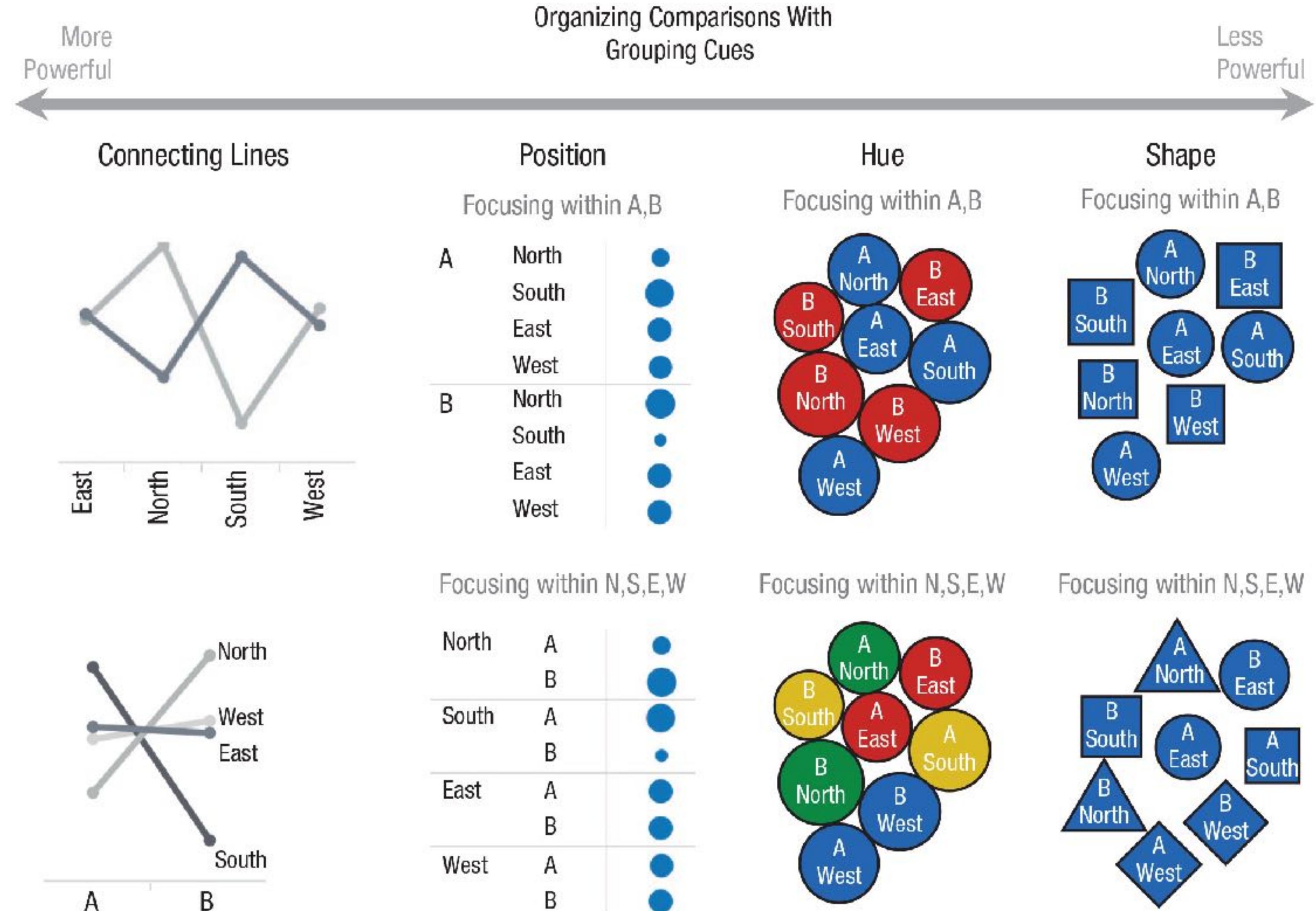
- Edward Tufte, *The Visual Display of Quantitative Information*

**"A visualization that is designed to guide viewers to make the "right" visual comparisons can lead those viewers to make [more] meaningful insights than they would make on their own."**

- Franconeri+21

Take advantage of preattentive processing and the Gestalt Principles to guide viewers to the comparisons, and insights, you want them to take.

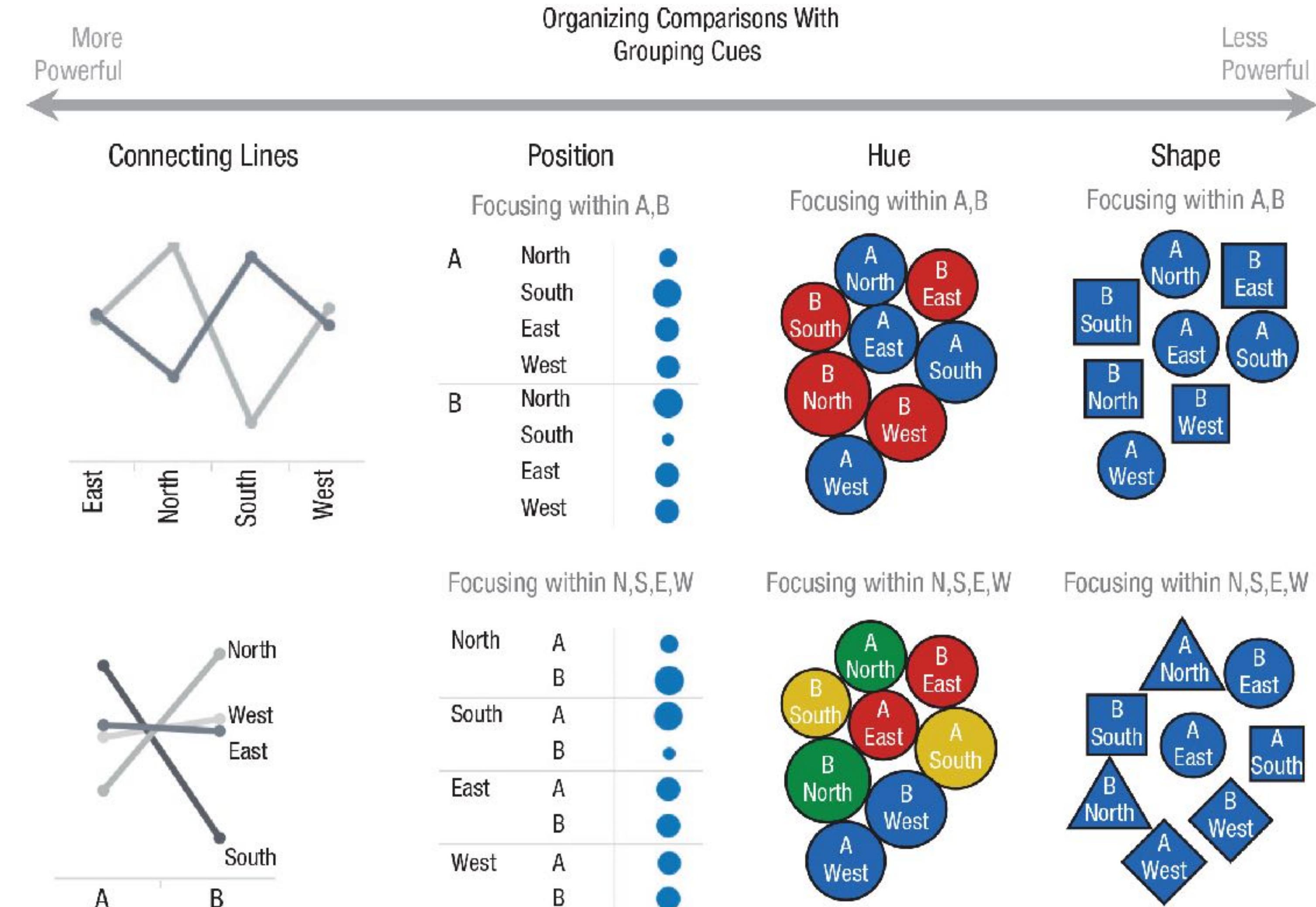
**use grouping and attention  
directing cues to guide focus  
toward the takeaways**



Take advantage of preattentive processing and the Gestalt Principles to guide viewers to the comparisons, and insights, you want them to take.

**use grouping and attention directing cues to guide focus toward the takeaways**

**the curse of expertise is that we are bad at guessing what is hard for people to see in the data we're familiar with**

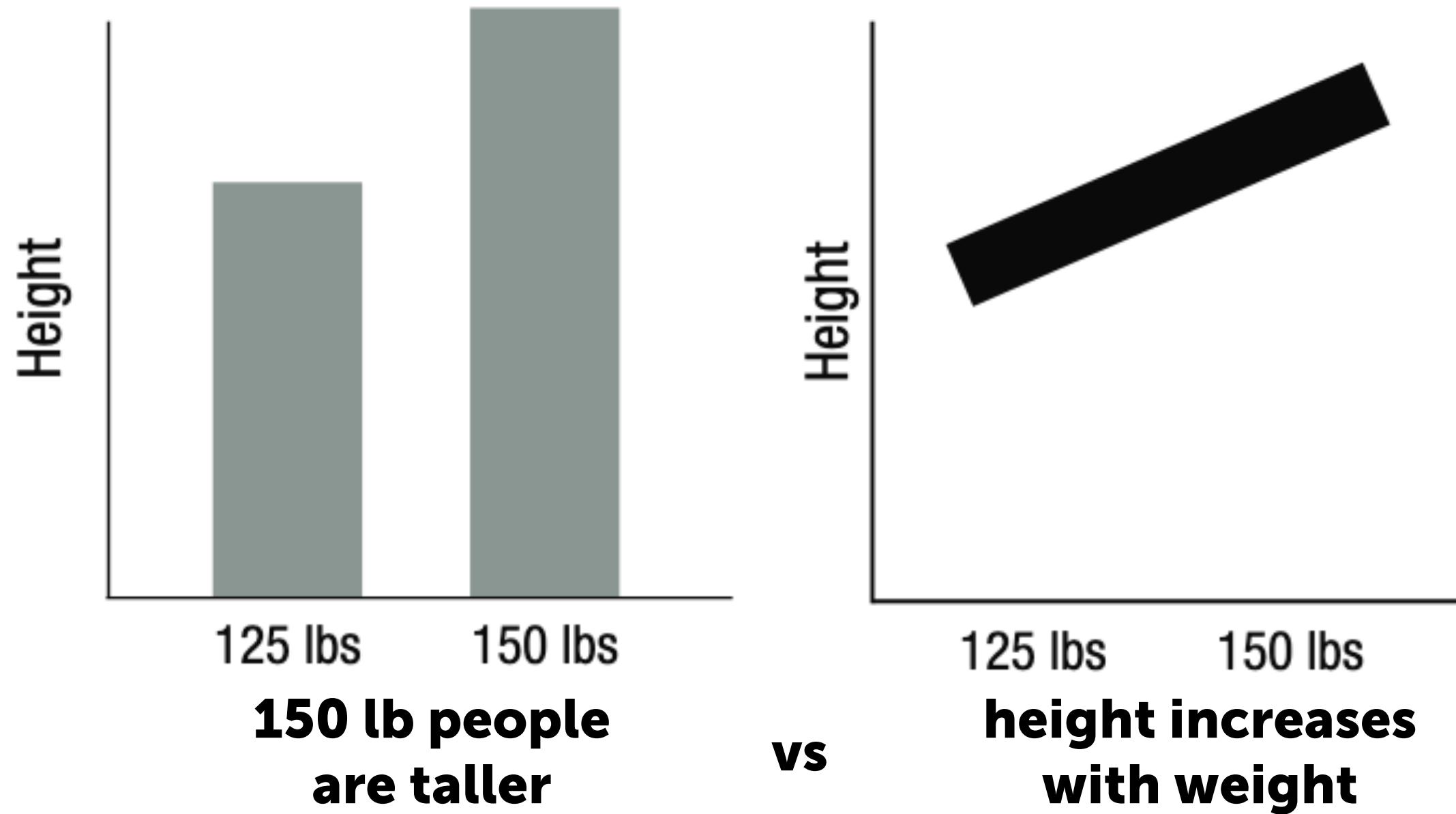


# Takeaway messages can be influenced by choice of visualization and grouping.

What Does the Chart Say? Grouping Cues Guide Viewer Comparisons and Conclusions in Bar Charts  
Cindy Xiong Bearfield, Chase Stokes, Andrew Lovett, and Steven Franconeri

arxiv:2310.02076

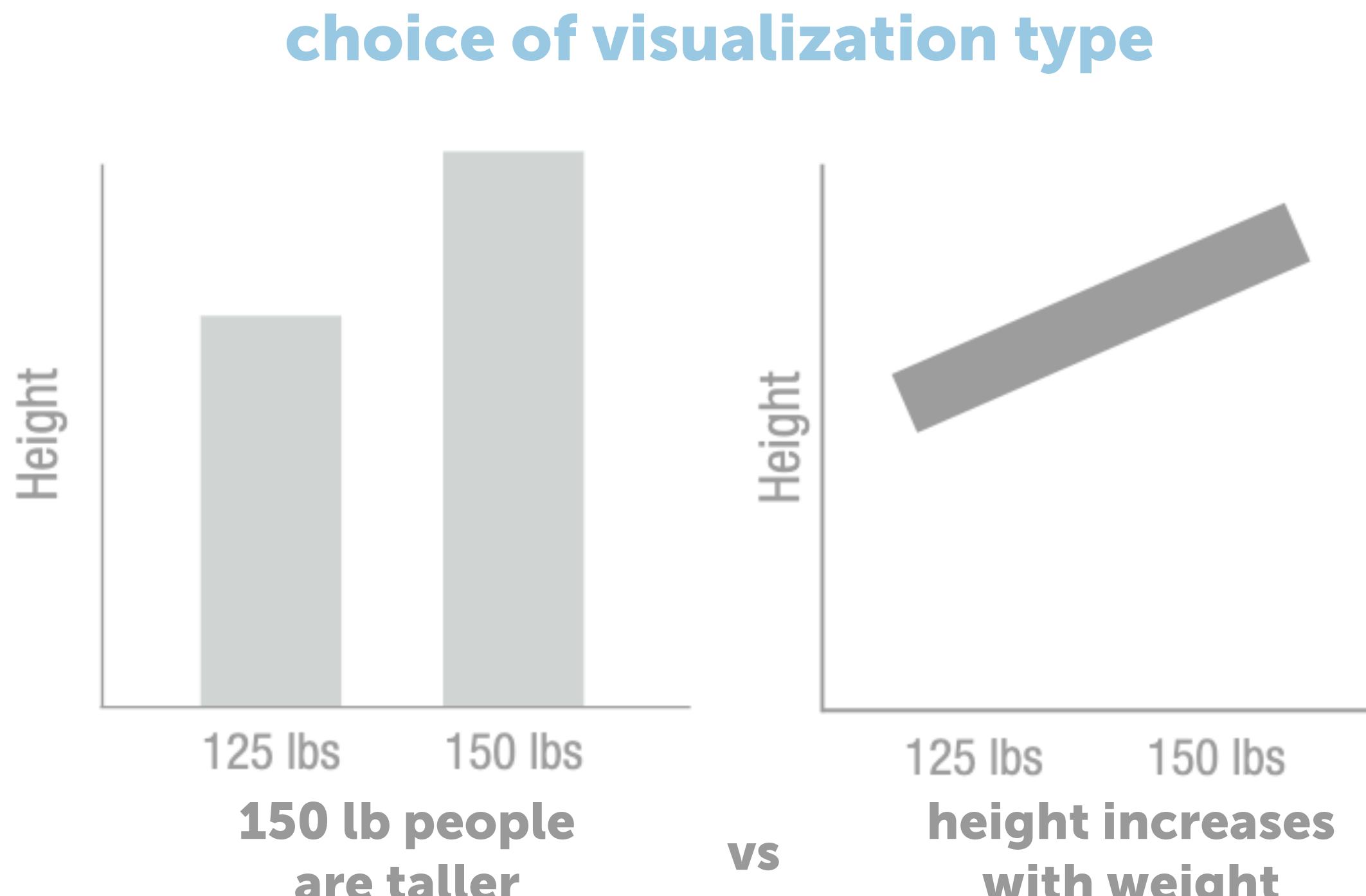
## choice of visualization type



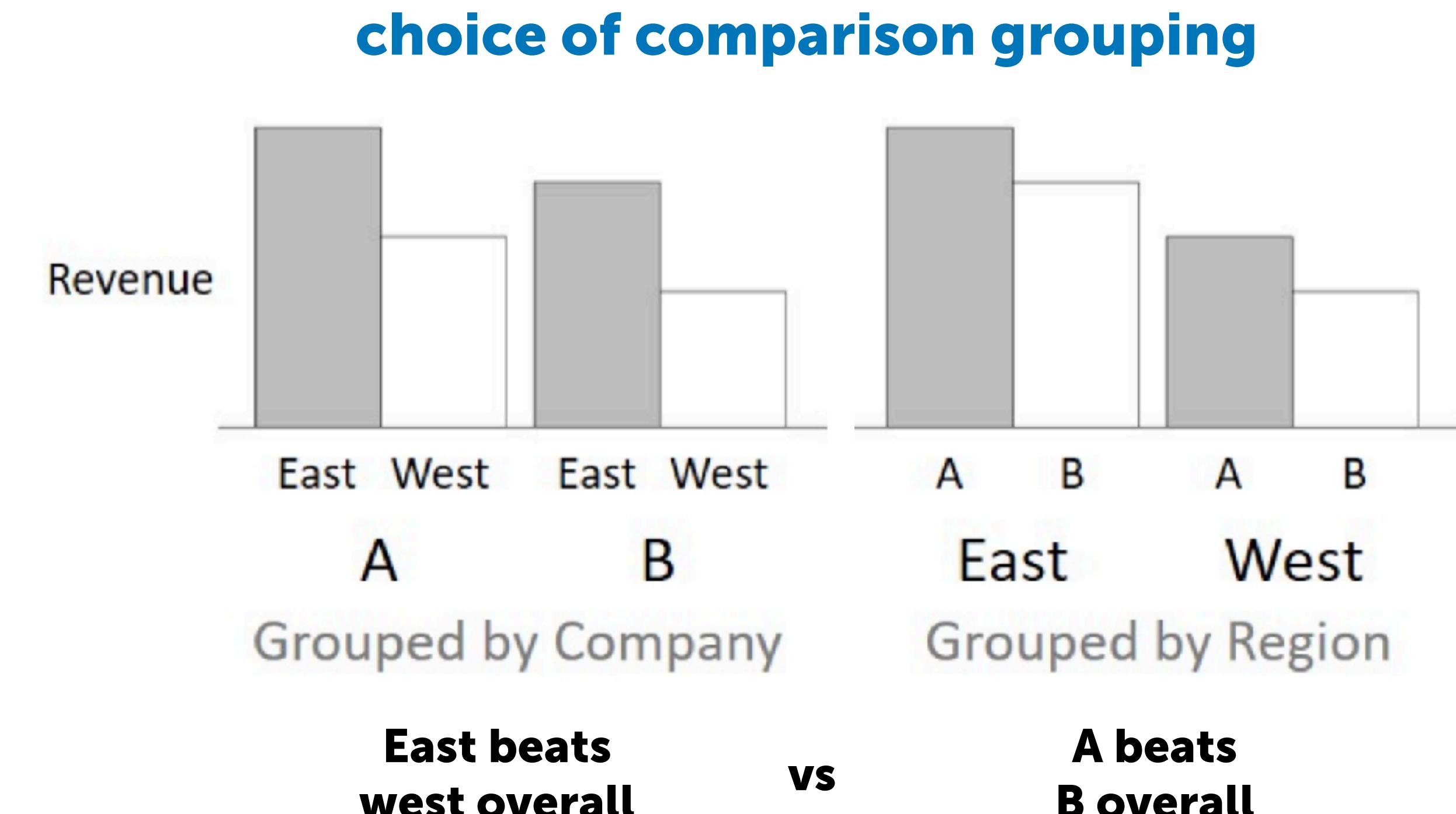
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Franconeri+21, Fig. 18



Bearfield+23, Fig. 3

The translation from **visual** to **verbal** is slow, semantic links from **data** to **meaning** activate the **language center** of the brain.

## Reading a Graph Is Like Reading a Paragraph

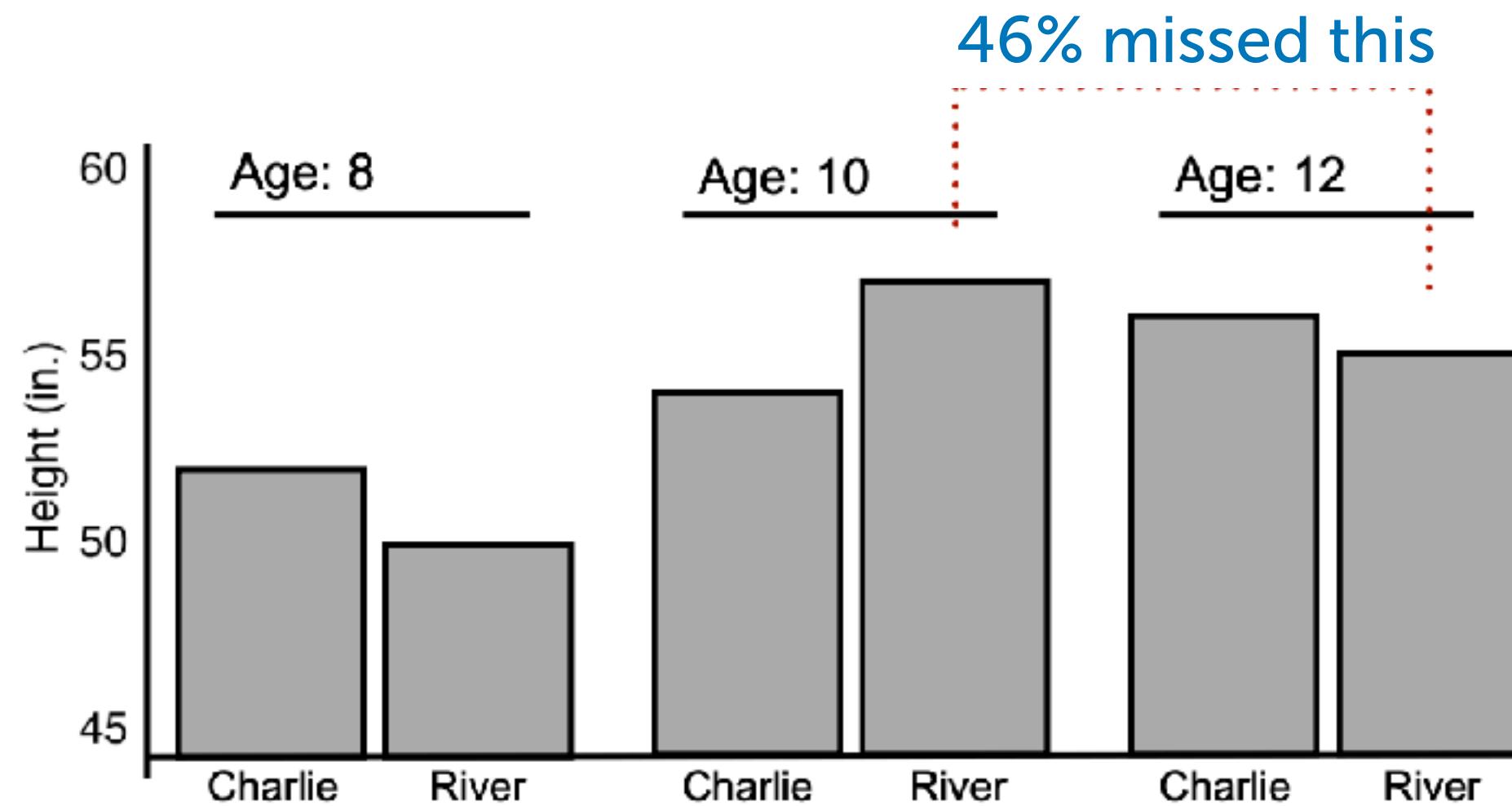
Tal Boger<sup>1</sup> and Steven Franconeri<sup>2</sup>

<sup>1</sup> Department of Psychological & Brain Sciences, Johns Hopkins University

<sup>2</sup> Department of Psychology, Northwestern University

[doi.org/10.1037%2Fxge0001604](https://doi.org/10.1037%2Fxge0001604)

### Hides **improbable relationship**



The translation from **visual** to **verbal** is slow, semantic links from **data** to **meaning** activate the **language center** of the brain.

## Reading a Graph Is Like Reading a Paragraph

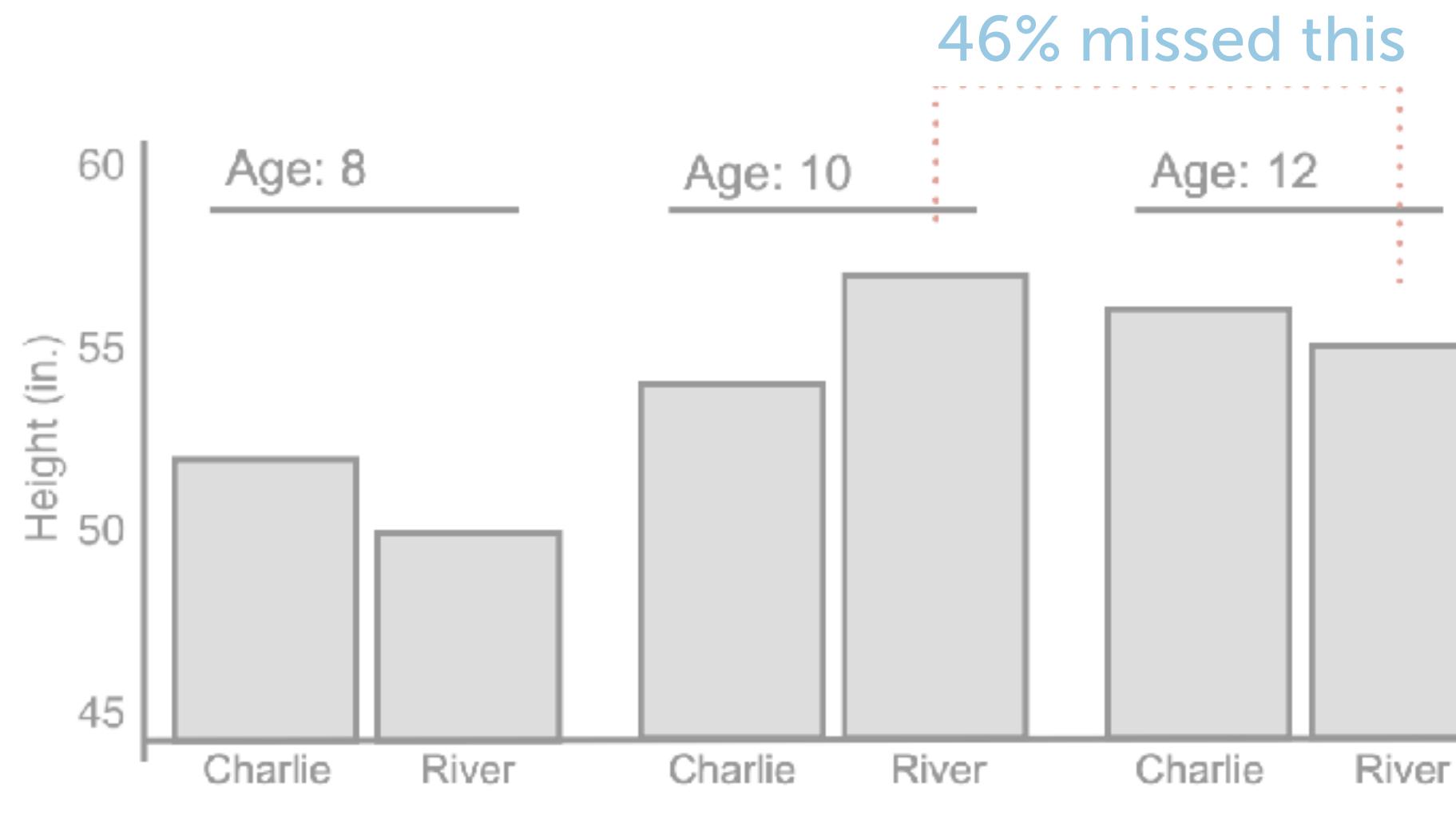
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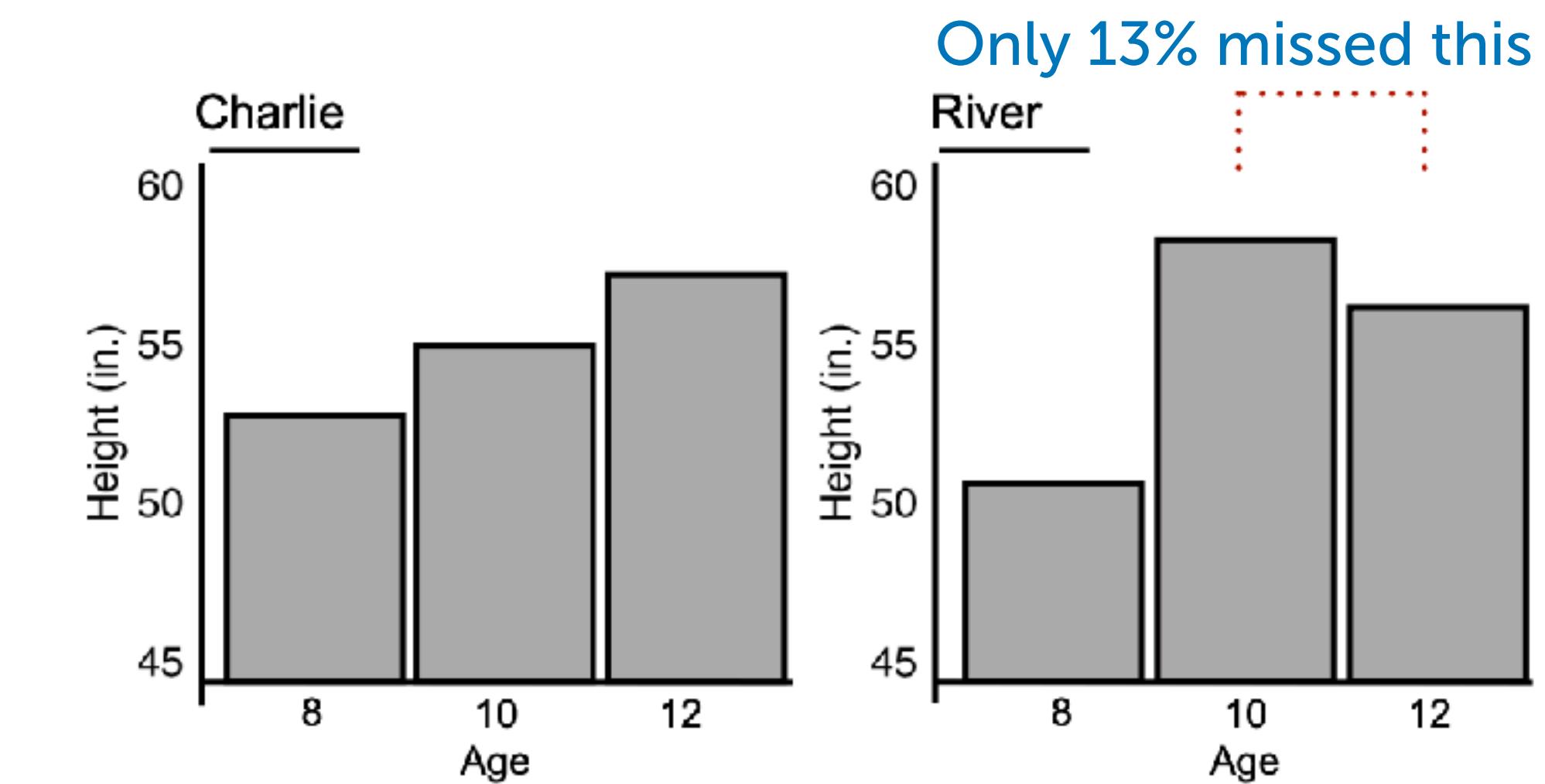
<sup>2</sup> Department of Psychology, Northwestern University

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Hides improbable relationship



Highlights improbable relationship



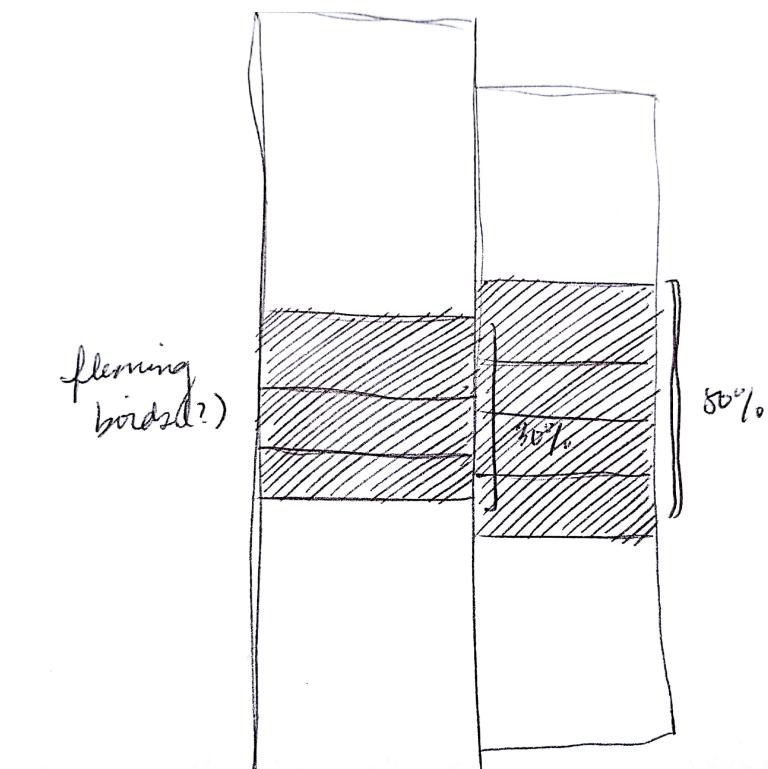
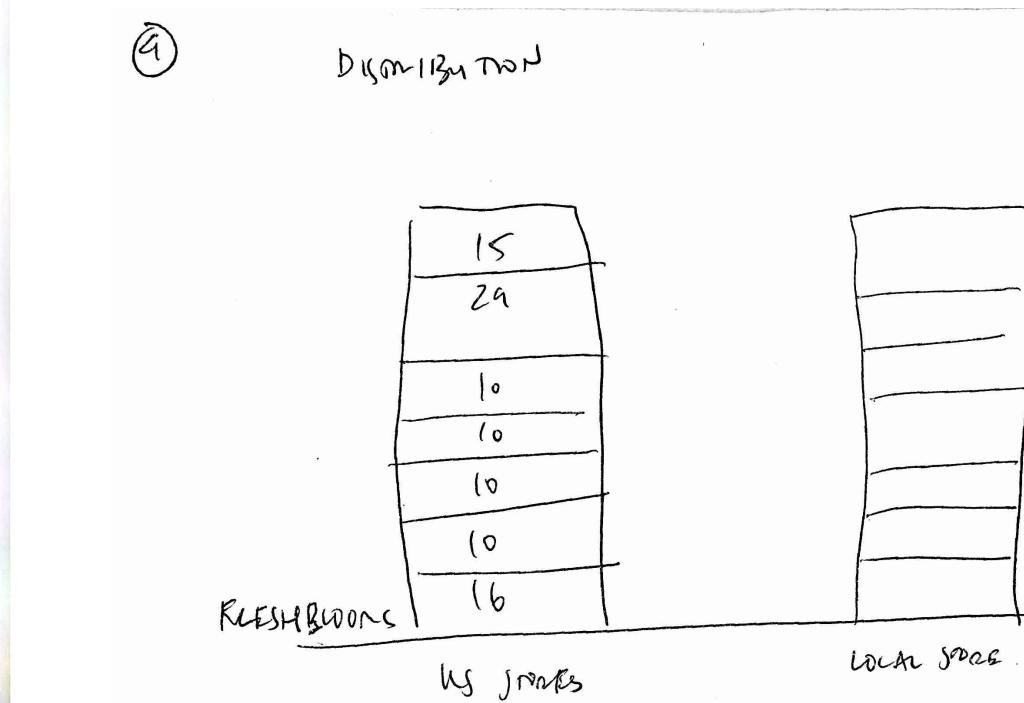
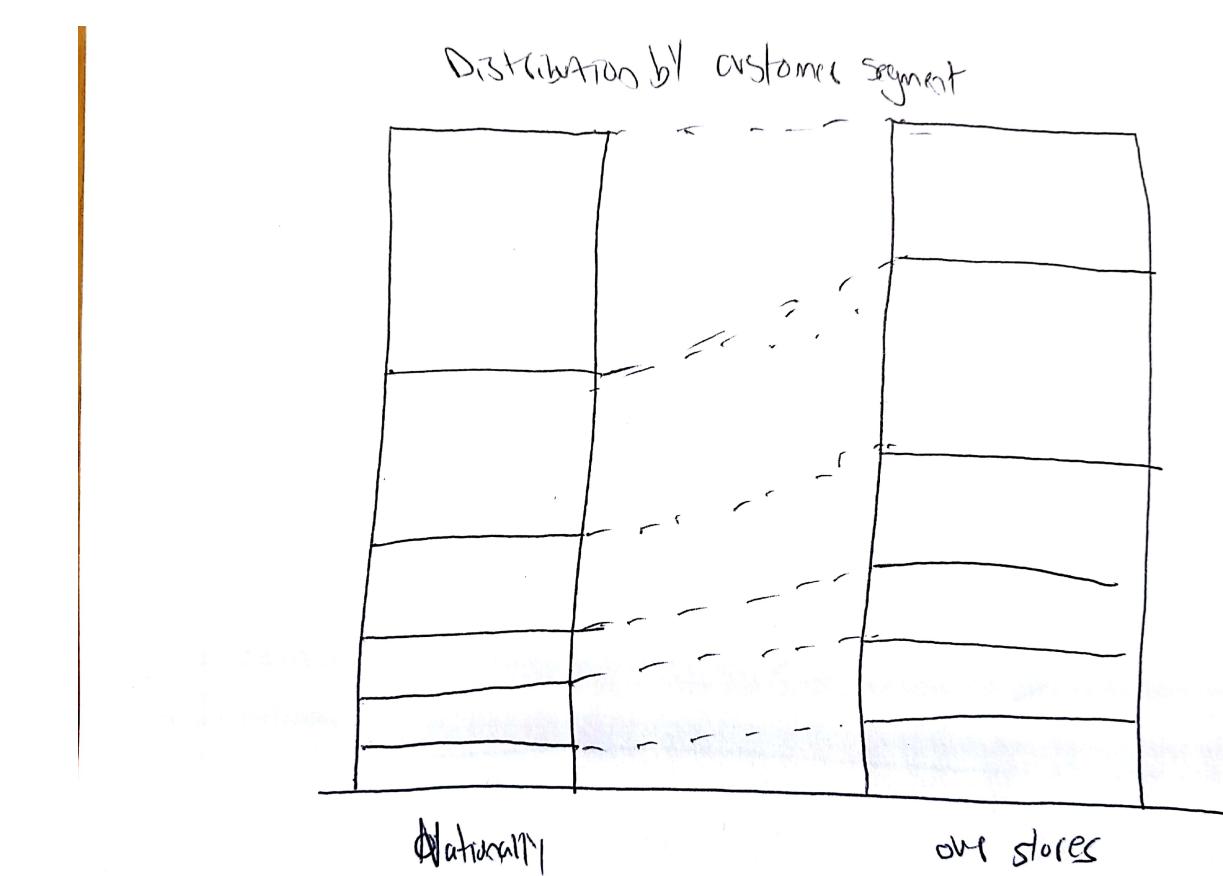
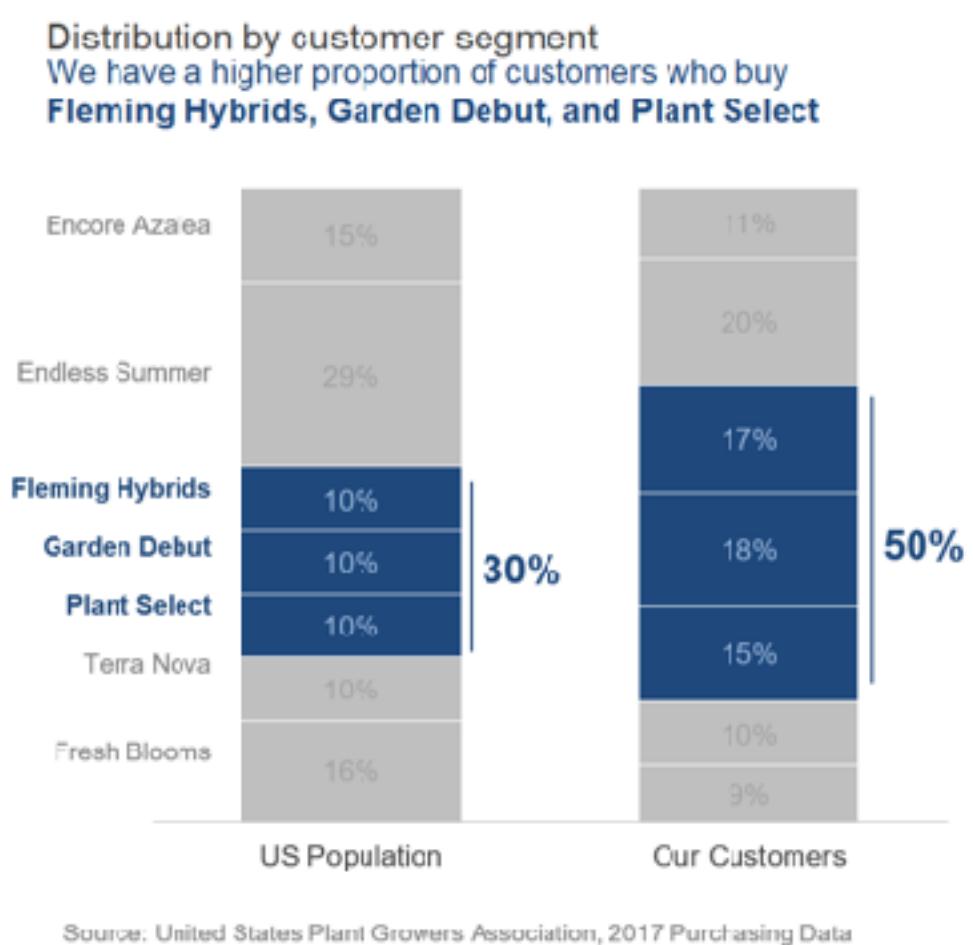
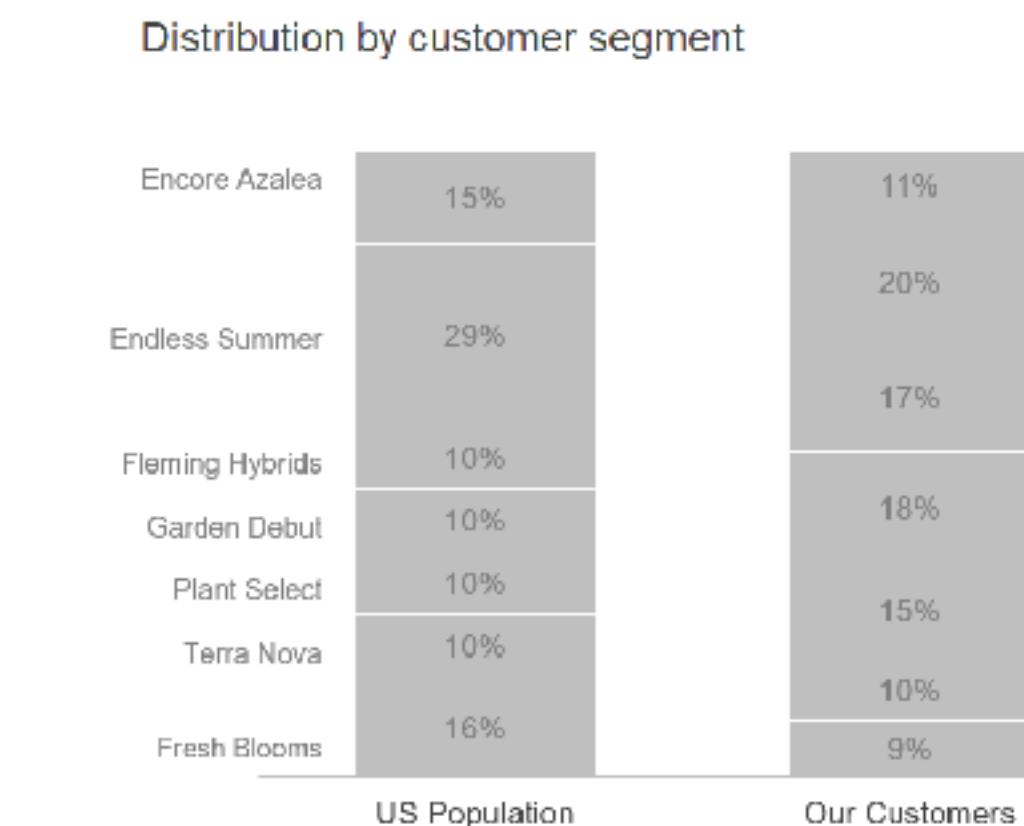
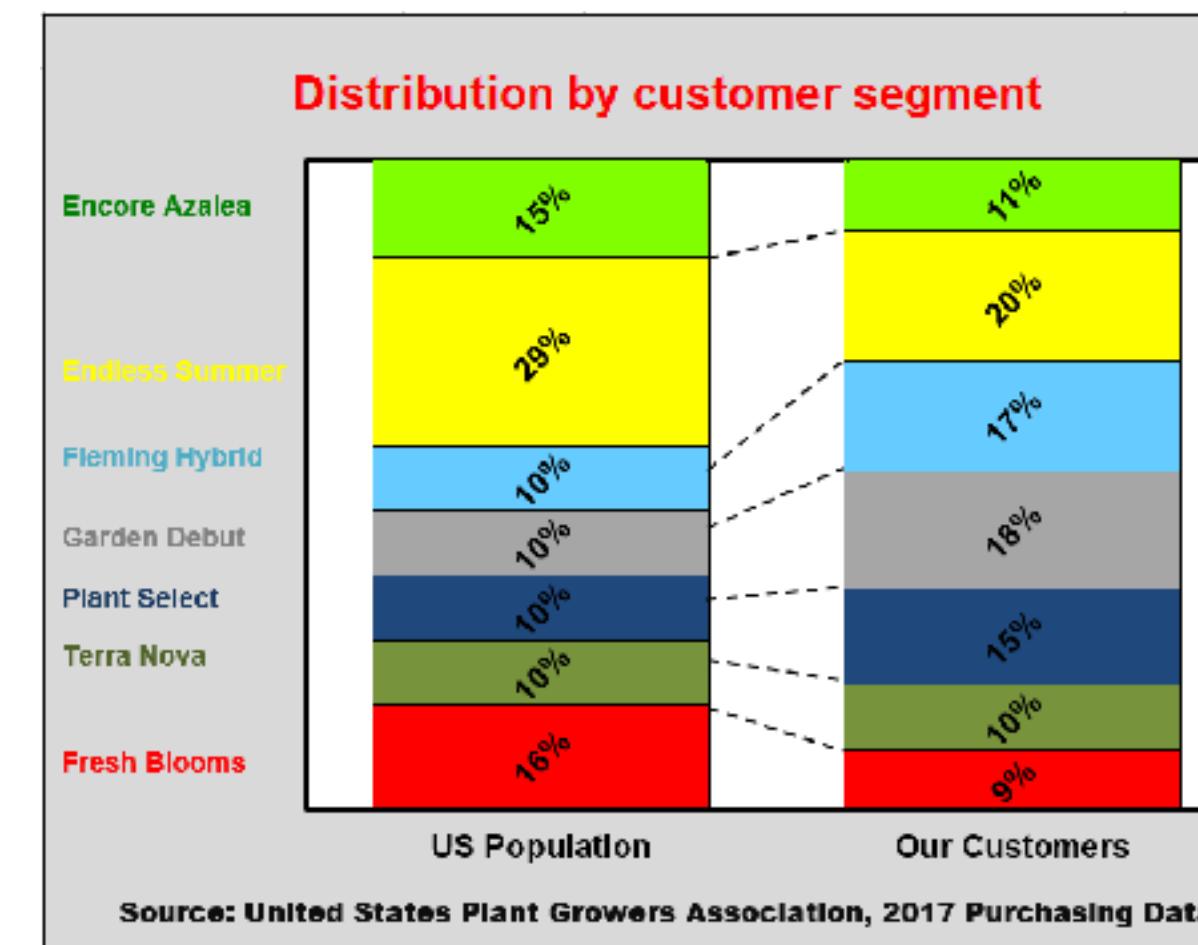
# Focusing with highlighted color, annotations, and a clear takeaway message leads to more effective comprehension and retention.

## Declutter and Focus: Empirically Evaluating Design Guidelines for Effective Data Communication

Kiran Ajani, Elsie Lee, Cindy Xiong, Cole Nussbaumer Knaflic, William Kemper, and Steven Franconeri, *Member, IEEE*

[doi.org/10.1109/TVCG.2021.3068337](https://doi.org/10.1109/TVCG.2021.3068337)

a clear headline plus color highlighting led to 3.5x more effective retention



If you enjoyed this talk and want to learn more, go watch [Steve's keynote from Outlier](#) or check out his [2021 review paper](#).



<https://youtu.be/OdHLpZQF-Zs>

[doi.org/10.1177/15291006211051956](https://doi.org/10.1177/15291006211051956)



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Public Interest  
2021, Vol. 22(5) 110–161  
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DOI: 10.1177/15291006211051956  
[www.psychologicalscience.org/PSPI](http://www.psychologicalscience.org/PSPI)



## The Science of Visual Data Communication: What Works

Steven L. Franconeri<sup>1</sup>, Lace M. Padilla<sup>2</sup>, Priti Shah<sup>3</sup>,  
Jeffrey M. Zacks<sup>4</sup>, and Jessica Hullman<sup>5</sup>

<sup>1</sup>Department of Psychology, Northwestern University; <sup>2</sup>Department of Cognitive and Information Sciences, University of California, Merced; <sup>3</sup>Department of Psychology, University of Michigan; <sup>4</sup>Department of Psychological & Brain Sciences, Washington University in St. Louis; and <sup>5</sup>Department of Computer Science, Northwestern University

**"Extracting global statistics is fast, but comparing between subsets of values is slow. Effective graphics avoid taxing working memory, guide attention, and respect familiar conventions."**

You can find [an extended version of these slides](#)  
(with extra resources) and more at [alexbgurvi.ch](http://alexbgurvi.ch)

[Steve's Talk](#) [Steve's Paper](#) [Me](#)



@alexbgurvich



alex-b-gurvich



[www.alexbgurvi.ch](http://www.alexbgurvi.ch)

**DO**

**use labels directly on the visualization**

**add annotations to features of the visualization**

**put a descriptive title with takeaway**

**use color to highlight points**

**use recognizable chart types unless  
absolutely necessary or if communicating with experts**

**DON'T**

**use complicated legends that require  
the viewer to look back and forth**

**put lots of "chartjunk" on the plot  
like extraneous axes lines**

**require viewers to compare  
things that are far away**

**require viewers make series of comparisons  
that use different perceptual filters**

# Other tools and resources that you may find useful

## Color Palette Generators

<https://colorbrewer2.org/>

<https://python-graph-gallery.com/color-palette-finder/>

<https://vis4.net/labs/multihue/>

<https://colororacle.org/>

## Books

### Cole Nussbaumer Knaflic

Storytelling with data: A data visualization guide for business professionals

### Kat Greenbrook

Data Storytellers Handbook

### Stephen Few

Data Storytellers Handbook

### Alberto Cairo

The truthful art: Data, charts, and maps for communication.

&

The Art of Insight

### Alli Torban

Chart Spark

### John Schwabish

Better data visualizations: A guide for scholars, researchers, and wonks.

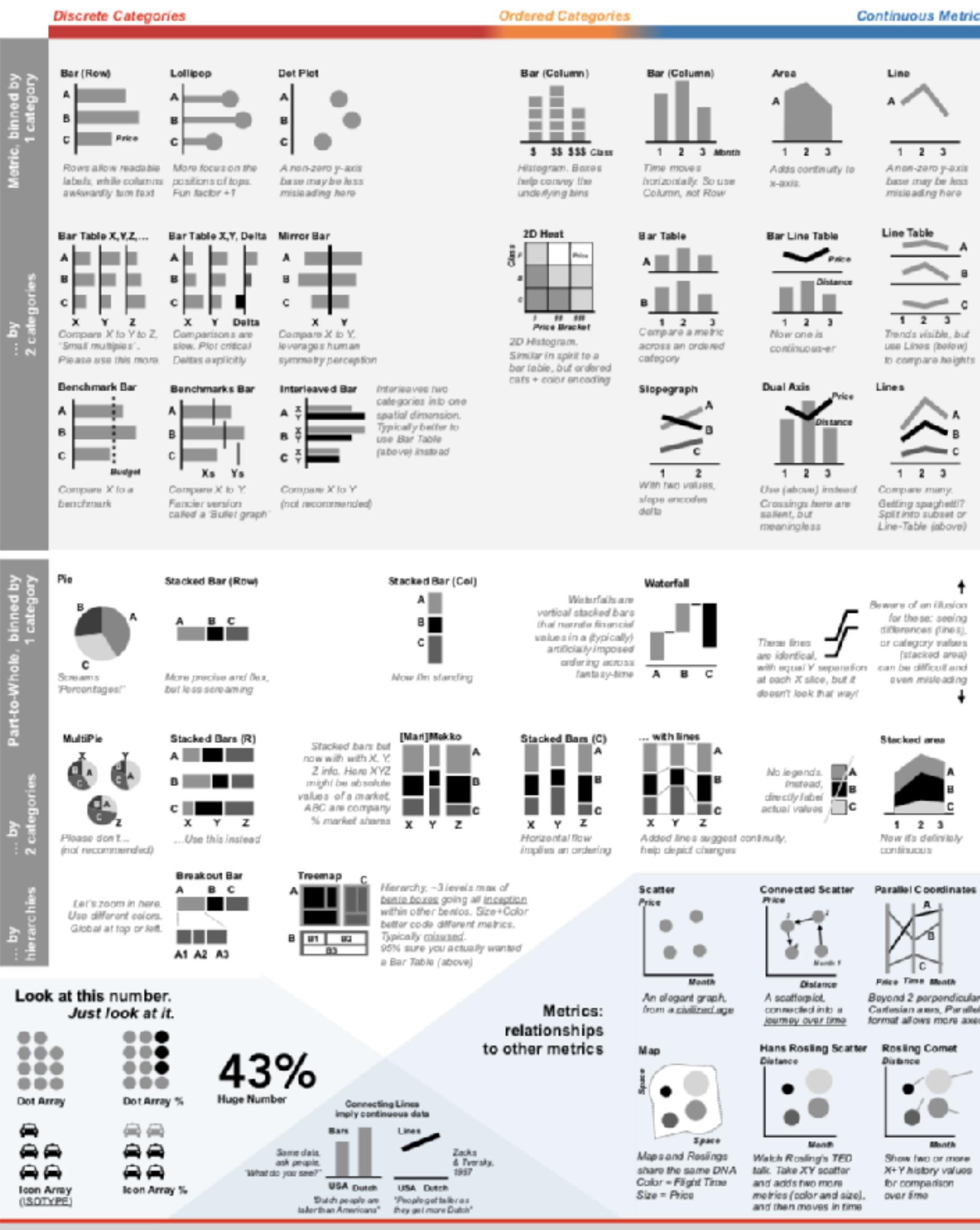
### Amanda Makulec

Big Book of Dashboards (TBD)

# Which Visualization? A Quick Reference

You have the following data (sample)  
**Discrete Categories,**  
**Ordered categories,**  
and **Continuous Metrics**

Categories		Ordered Categoricals		Continuous Metrics				
City	Airline	Class	PriceBracket	Month	Distance	FlightTime	Price	PassengerCount
Alphaville	XeroTrip	Coach	\$	1	300	120	250	100
Betastan	YoloFly	Business	\$\$	2	500	185	1,525	150
Chicago	ZeusAir	First	\$\$\$	3	650	240	4,023	200
New York	Delta	Premium Economy	\$\$\$\$	4	800	300	6,000	250



# **Steve Franconeri**



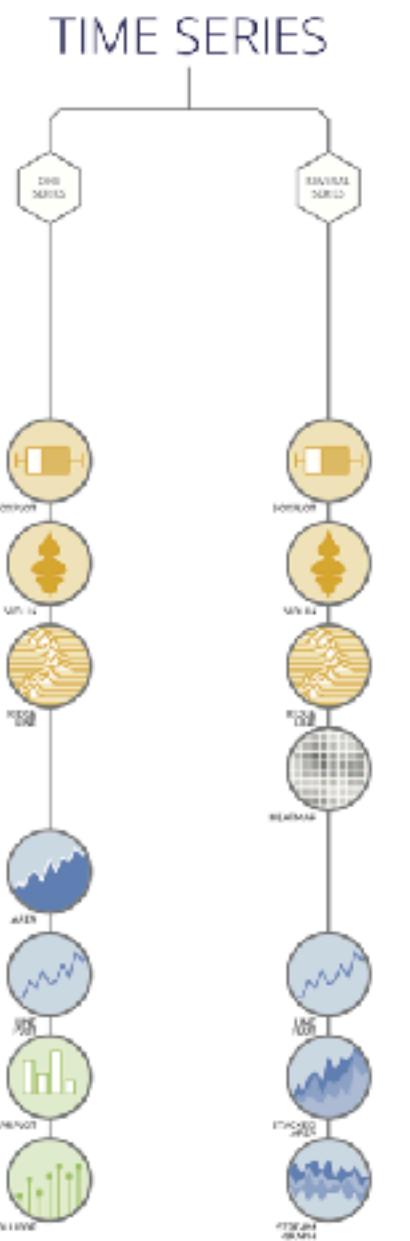
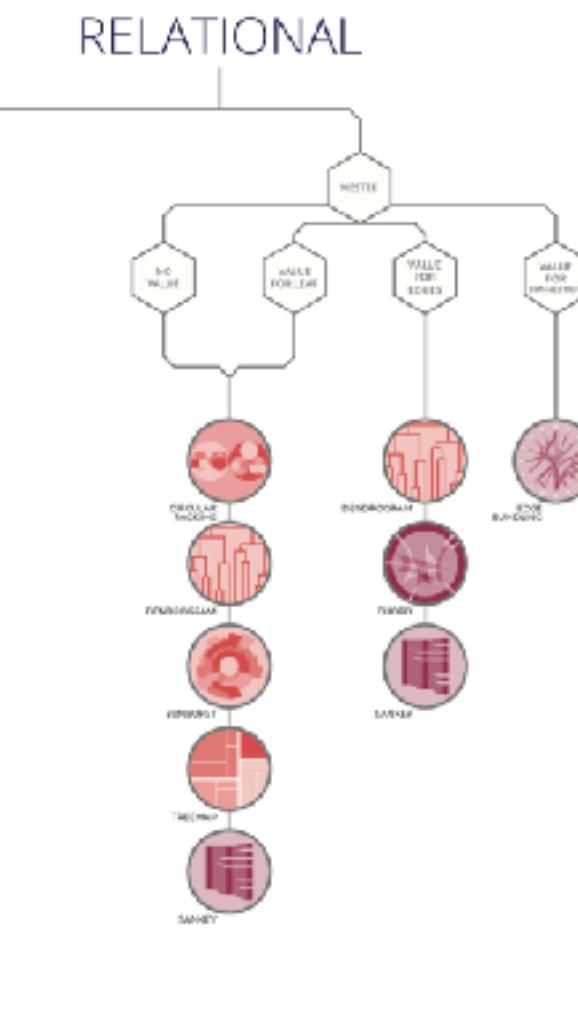
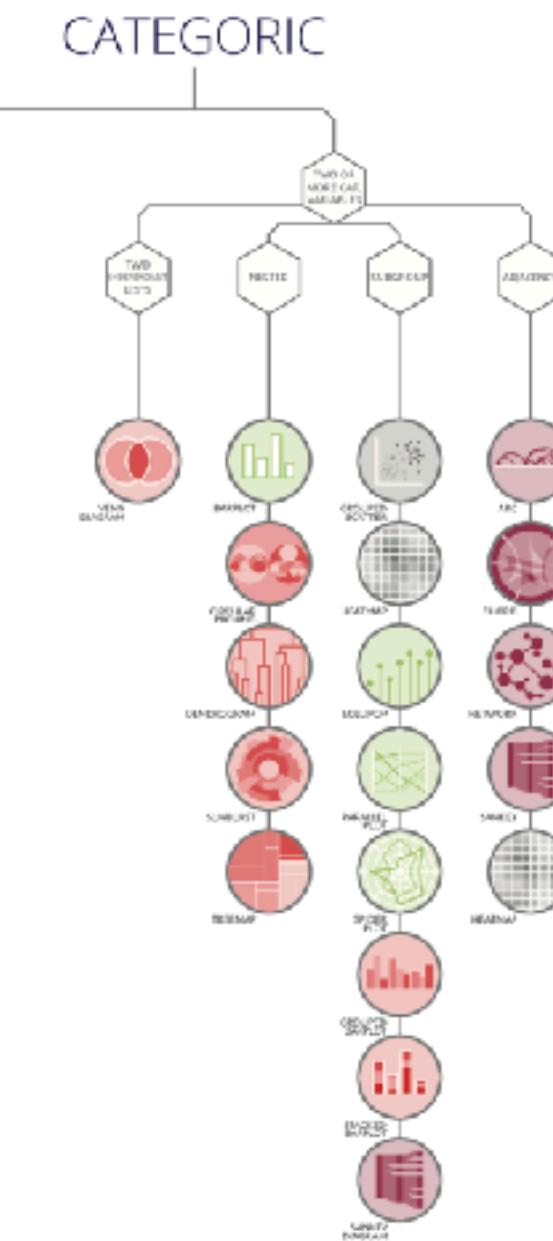
# from Data to Viz

'From Data to Viz' is a classification of chart types based on input data format. It will help you find the perfect chart in three simple steps :

- 1 Identify what type of data you have,
- 2 Go to the corresponding decision tree and follow it down to a set of possible charts.
- 3 Choose the chart from the set that will suit your data and your needs best.

Dataviz is a world with endless possibilities and this project does not claim to be exhaustive. However it should provide you with a good starting point. For an interactive version and much more, visit:

[data-to-viz.com](http://data-to-viz.com)

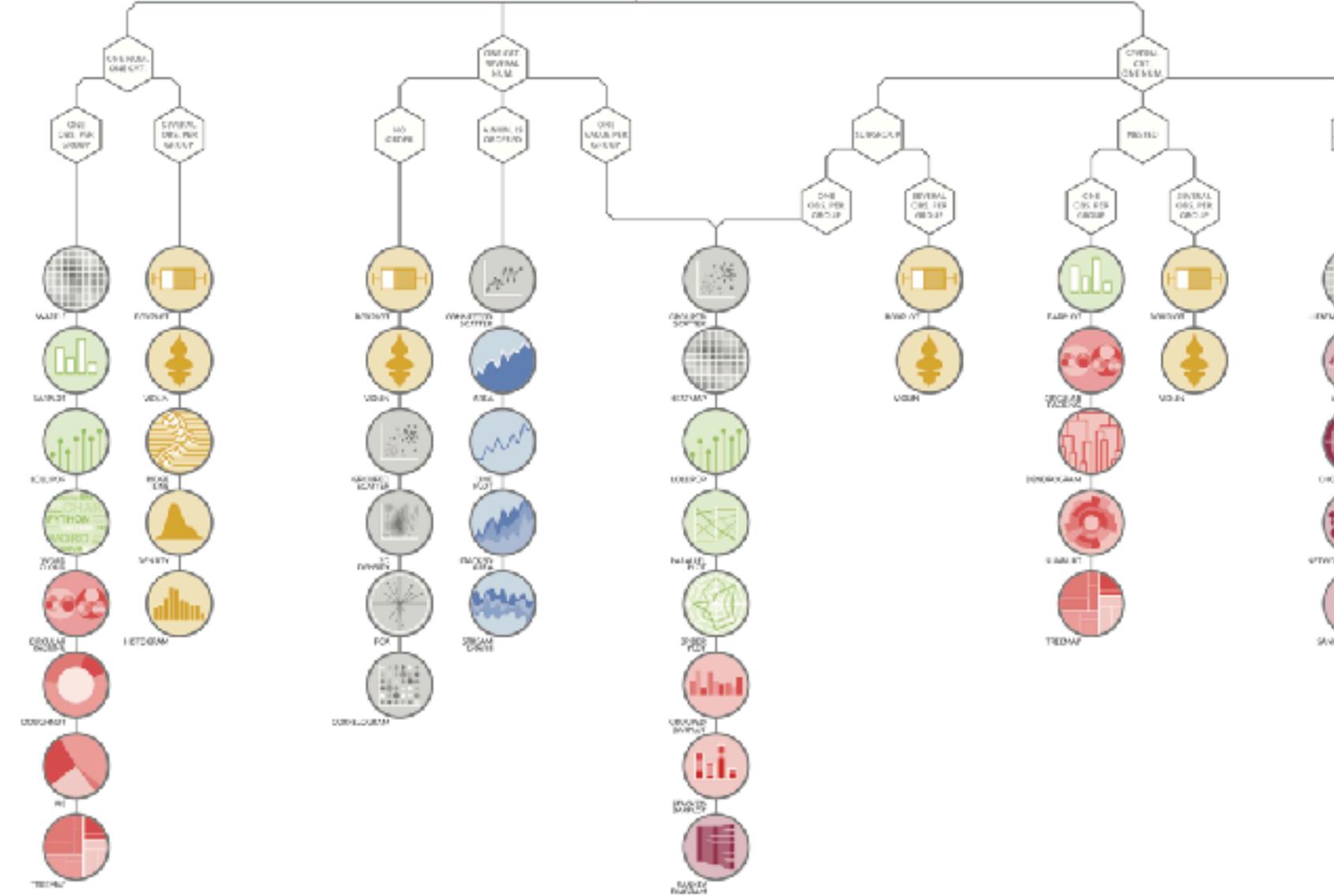


WHAT DO YOU WANT TO SHOW ?

- Distribution
- Evolution
- Correlation
- Maps
- Ranking
- Part of a whole

**Yan Holz**

## CATEGORIC AND NUMERIC



## NUMERIC

