

MassMutual DSDP 2018:

INTRODUCTION TO DATA VISUALIZATION

June 15, 2018

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Smith College

Introductions & background

Jordan

(he / him)



- **2017 on: Asst. Prof. in CS (Smith)**
- 2015 to 2017: Visiting Asst. Prof. in SDS (Smith)
- 2013 – 2015: Research Scientist (MITLL)
- 2010 – 2013: PhD in Visual Analytics (Tufts)
- 2008 – 2010: MSc in Educational Tech. (Tufts)
- 2004 – 2008: BA in CS and Math (Smith)

For more info, visit:

www.science.smith.edu/~jcrouser

Some housekeeping

- Workshop website:

jcrouser.github.io/MassMutual-DataVis

- Rough structure:

- 6 modules over 3 days (AM and PM)
 - Intro → Walkthrough/Lab → Explore → Share

- Assumptions:

- R/Rstudio installed
 - Basic proficiency in R

Learning objectives



1. Understand
why data vis works
(and doesn't)

2. Explore some
foundational
methods / tools

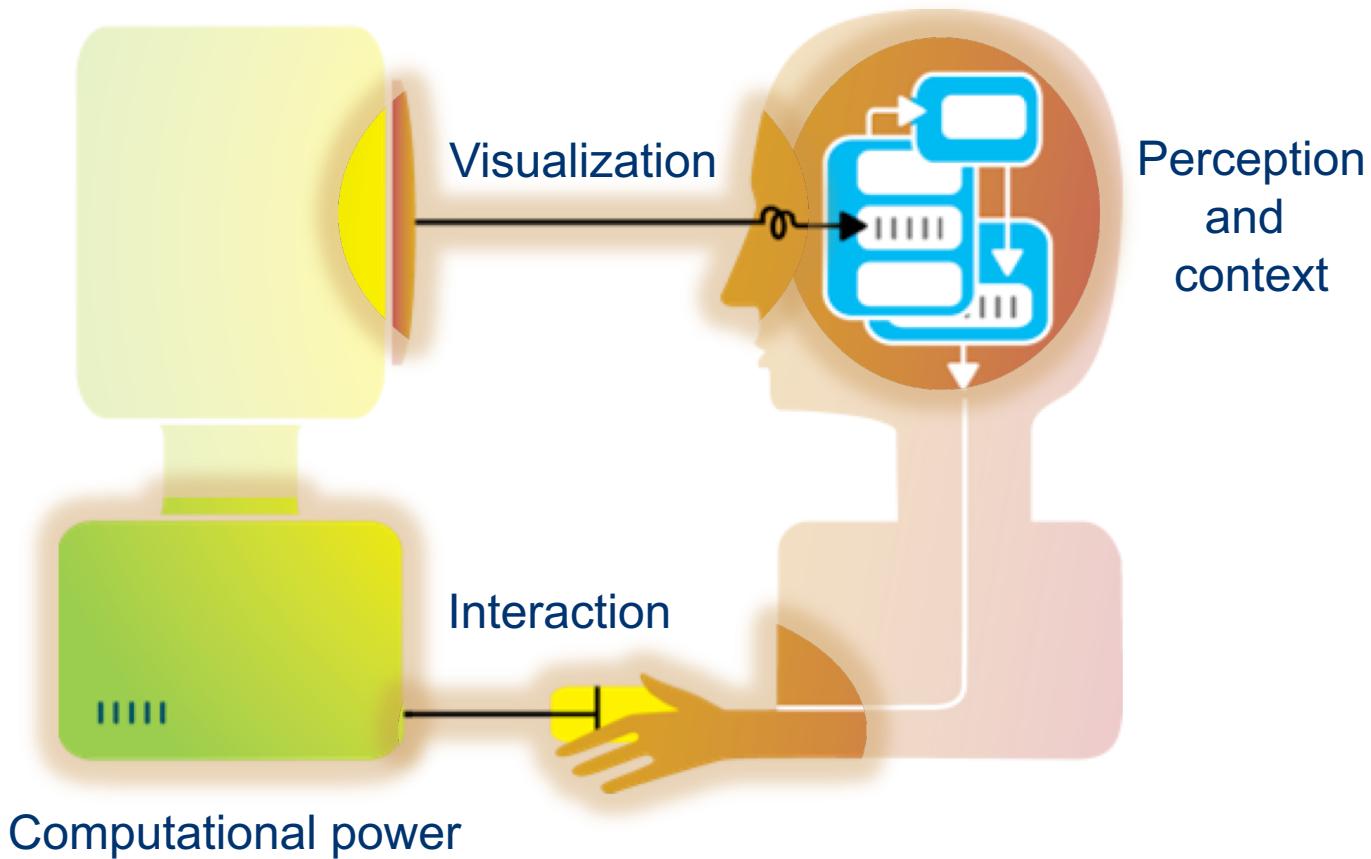
3. Opportunities to
get to know
your new team

What I do: analytical tools for messy data



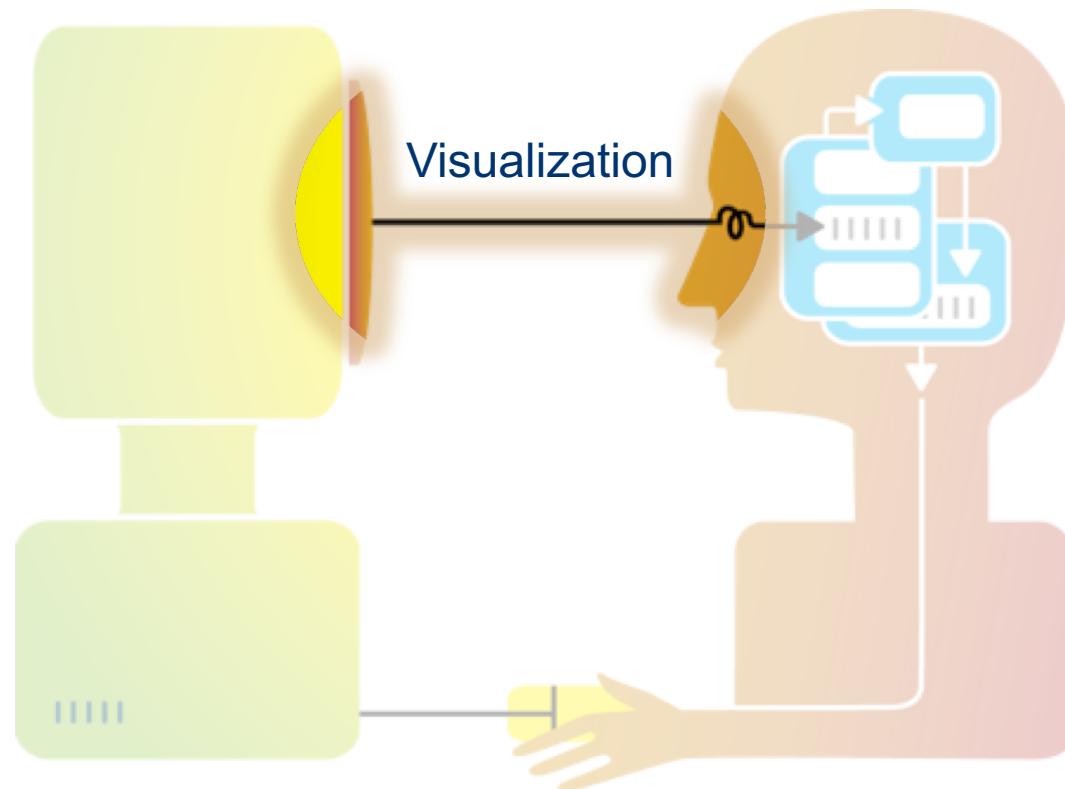
Big idea behind my research

Humans and machines have **complimentary strengths**



Focus of this workshop

How do we build **visualizations** that help humans understand patterns in data?



Interesting (non-CS) thing to know about me



I'm a big
board game
nerd
(we have a closet
in our house
dedicated to them)

3-minute biographies

About you:

- Your name and pronouns
- Your alma mater
- Your major / area of focus

3 questions:

1. What brought you to **DSDP**?
2. What's one **big thing** you hope to get out of it?
3. What's one thing about life after graduation that you find particularly **challenging / anxiety-provoking**?
-or-
3. What's one thing about you that would probably **surprise** us?

Outline

✓ Introductions

- Visualization overview
 - Flashback to early experiences in data wrangling
 - Visualization (def.)
 - Data (def.)
 - Quick history lesson
- Graphical primitives
- Visual dimensions
- Pre-lunch activity: deconstructing data graphics
- After lunch: ggplot2 crash course

What is visualization?

Google visualization

All Videos Images News Books More Search tools SafeSearch

Reading Strategy Data Quotes Sports Creative Techniques

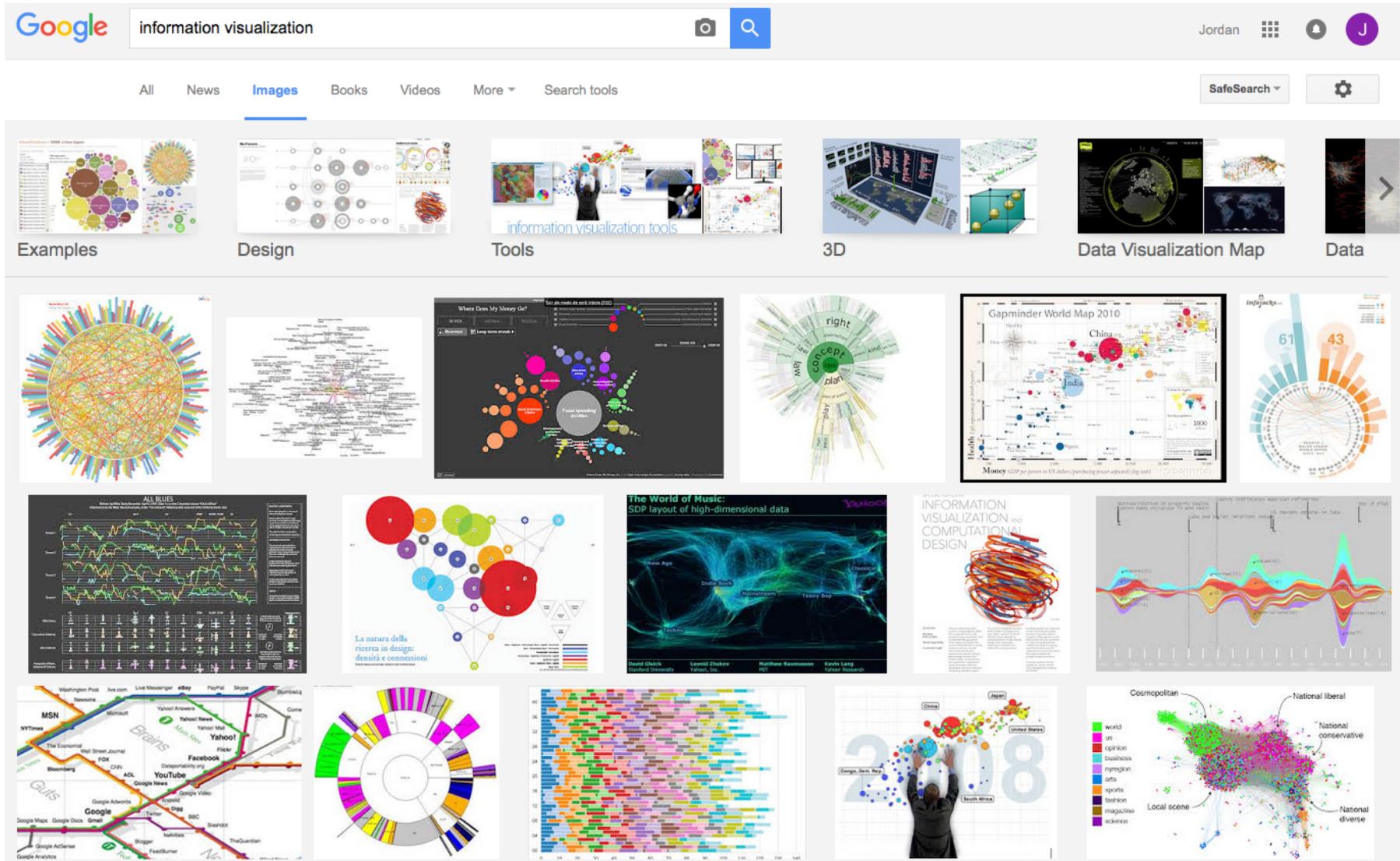
The search results page displays a grid of images under several categories:

- Reading Strategy:** An image of two children reading.
- Data:** An image of a colorful sunburst chart.
- Quotes:** A poster with the text "VISUALIZE THE MOST AMAZING LIFE GOD HAS GIVEN YOU. CLOSE YOUR EYES THEN HOLD THE VISION FOR AS LONG AS YOU CAN. THE VISION IN GOD'S HANDS...AND CONSIDER IT DONE." and "VISUALIZATION IS DAYDREAMING WITH A PURPOSE."
- Sports:** An image of a man performing a handstand.
- Creative:** An image of a person standing on a beach with a colorful cloud effect above them, next to a book titled "The Visualization Workbook".
- Techniques:** An image of a person's head with a brain composed of various icons.

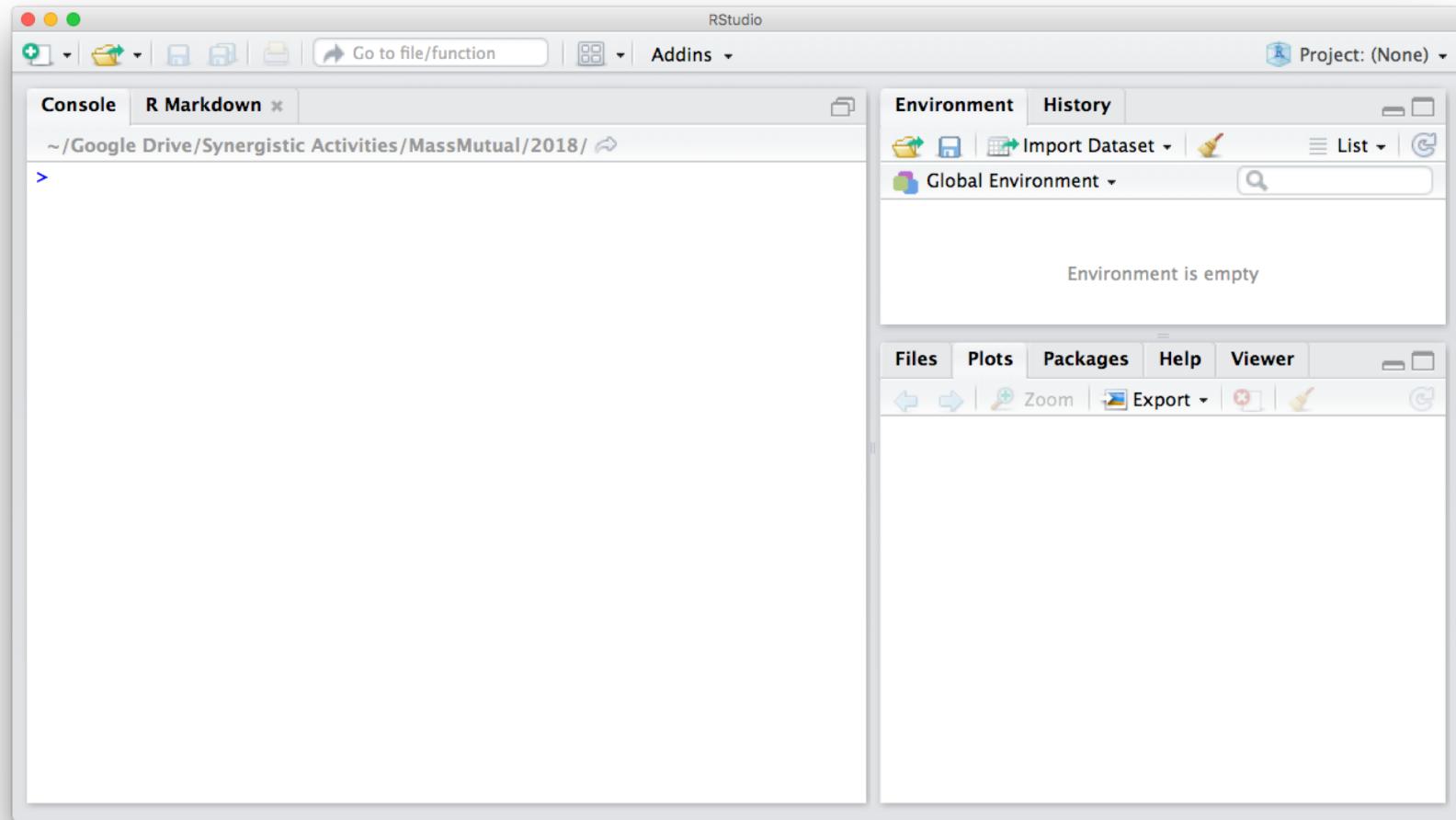
Below these are more images:

- A family of four standing in a field with icons of a house, car, bicycle, and a person above them.
- A close-up of a human eye with a green iris.
- A complex, colorful visualization of a network or data structure.
- A close-up of a human eye looking forward.
- A woman's face with her hand resting against her forehead.
- A close-up of a human eye with a rainbow-colored iris.
- A complex, abstract visualization of a network or data structure.
- A woman's face with a wireframe overlay.
- A bar chart with "PRESENT" and "FUTURE" labels, with a silhouette of a person standing between them.
- A collage of words related to visualization: "future", "see", "clear", "life", "dreams", "want", "exactly", "détail", "perfect", "now", "person", "already", "create", "imagination", "practice", "use", "vision", "goals", "envision", "things", "positive", "crystal", "visualization", "mental", "mind", "imagine", "visualize", "desire", "online".
- An image of a network graph with text: "exciting!", "beautiful!", "technical!", "BUT", "[what does it mean?]".
- A close-up of a human eye with the text "THE POWER OF VISUALIZATIONS" overlaid.
- A silhouette of a person's head with gears inside, with question marks floating around it.
- A colorful, glowing visualization of a person's profile with the word "visualization" written on it.
- A silhouette of a person's head with gears inside.
- A couple looking at a large screen displaying a globe.
- A globe visualization.

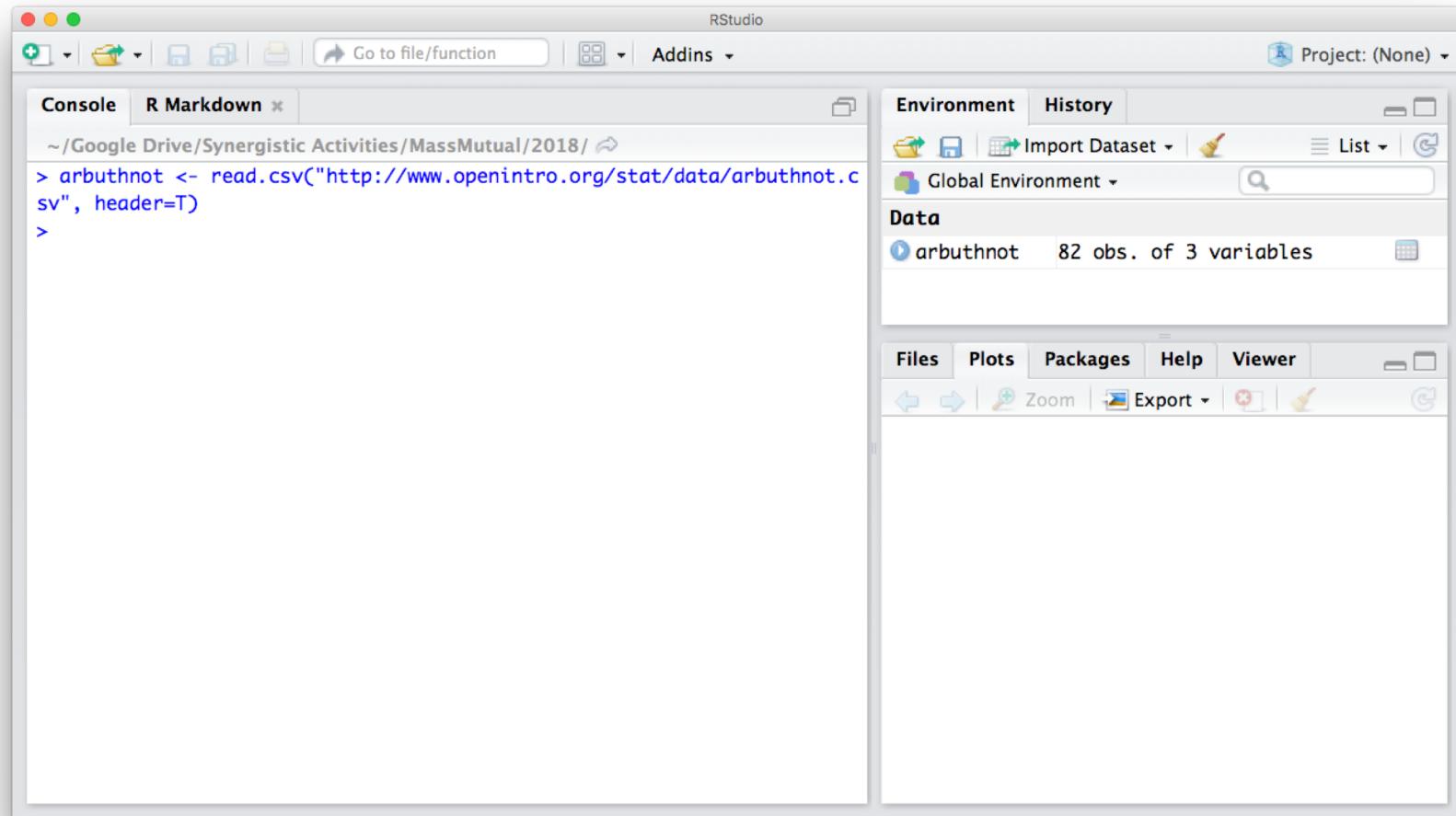
What is visualization?



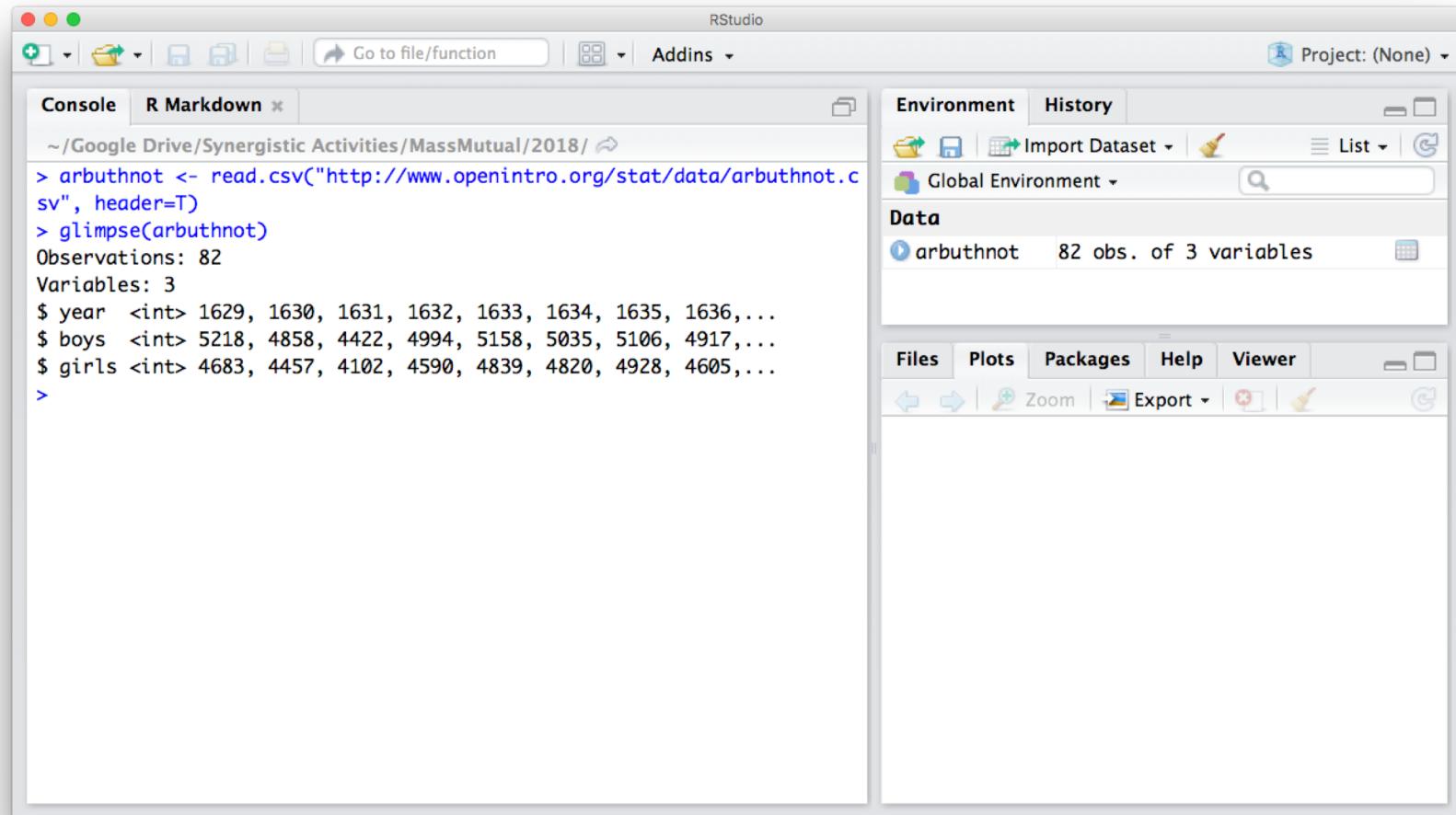
Flashback...



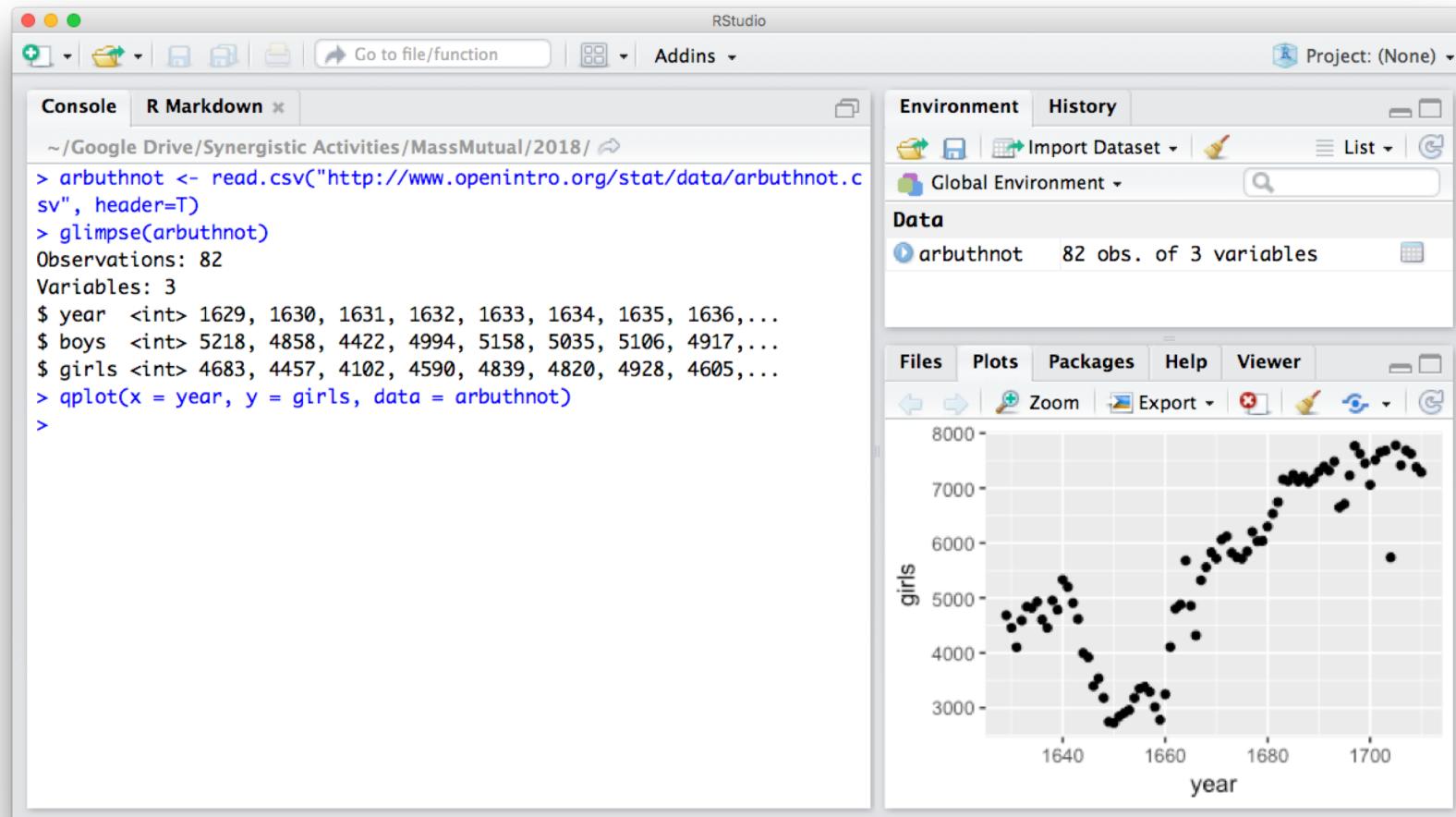
Flashback...



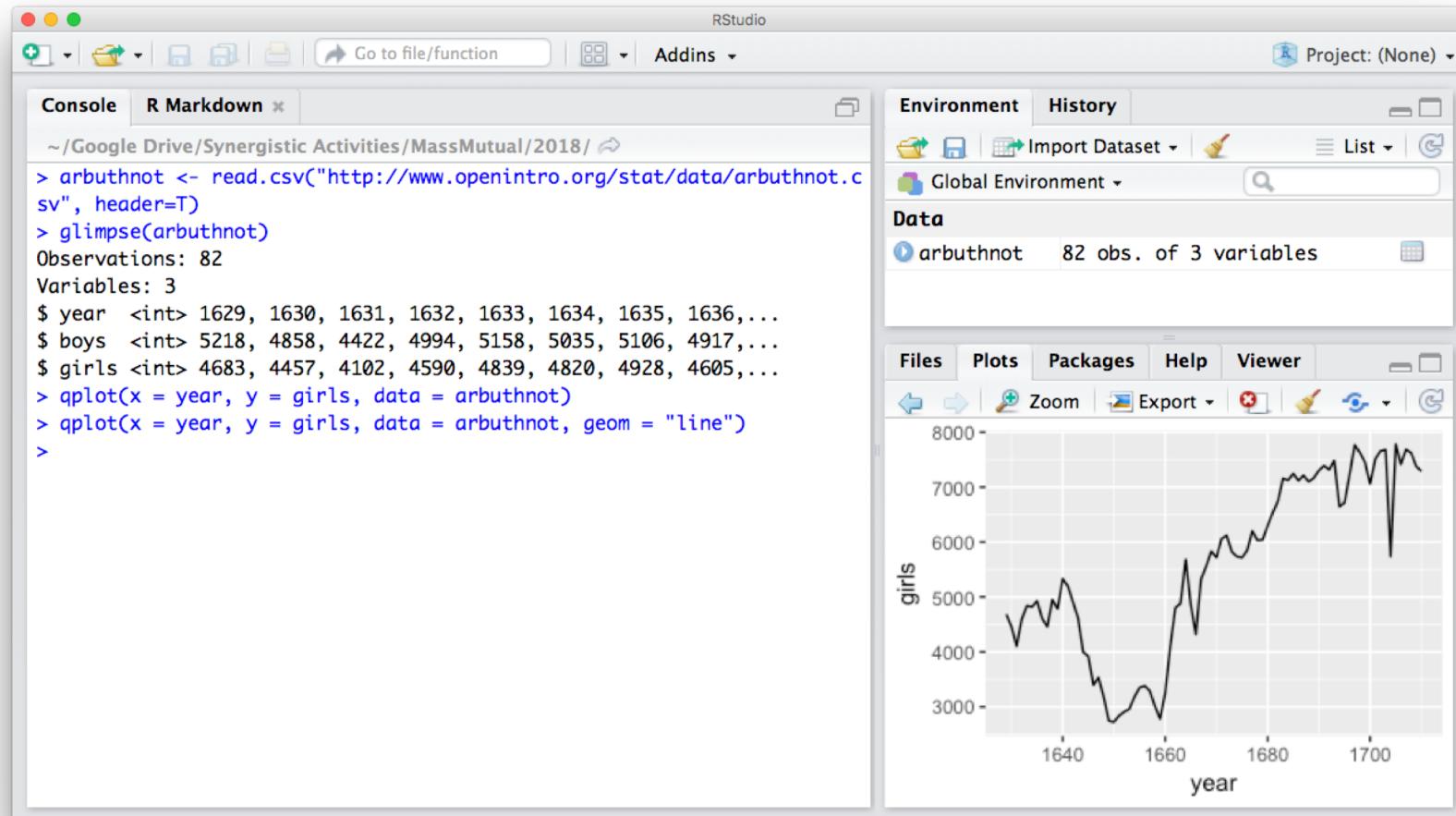
Flashback...



Flashback...



Flashback...



Question

What makes these
“visualizations” **useful?**

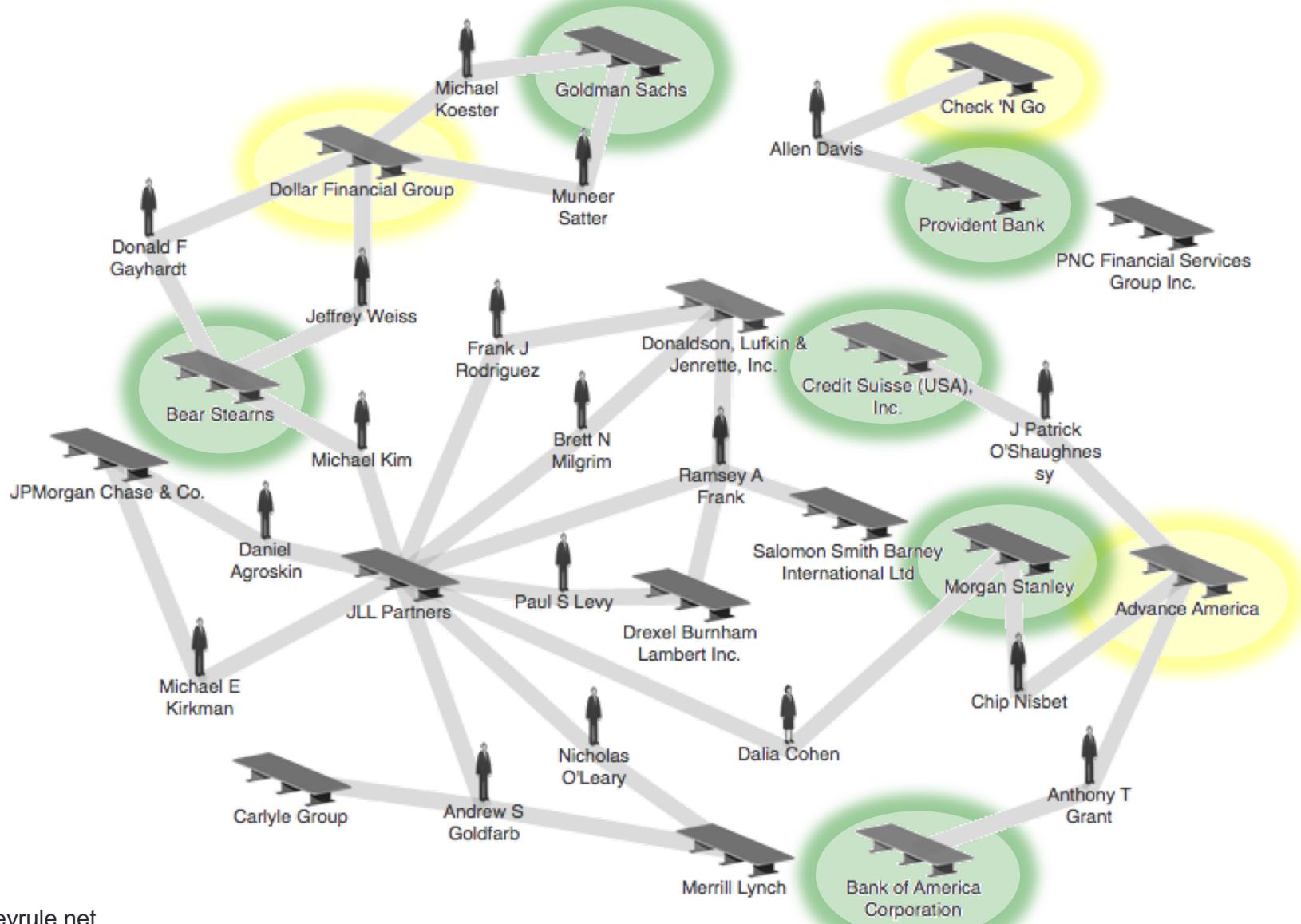


Do they help you spot trends?



More info here: http://en.wikipedia.org/wiki/1854_Broad_Street_cholera_outbreak

Do they help you explore?



Do they tell a story?



Hans Rosling's 200 Countries, 200 Years, 4 Minutes – The Joy of Stats – BBC Four
<https://www.youtube.com/watch?v=jbkSRLYSOjo>

Visualization (def.)

**Visual
representations**
of data that
reinforce human
cognition



Data (def.)

a set of *variables* that capture various aspects of the world:



*Tuition rates, enrollment numbers,
public vs. private, etc.*

Data (def.)

and a corresponding set of *observations* (a.k.a. *records*) over these variables. For example:



*tuition = \$46,288, enrollment = 2,563,
private, etc.*

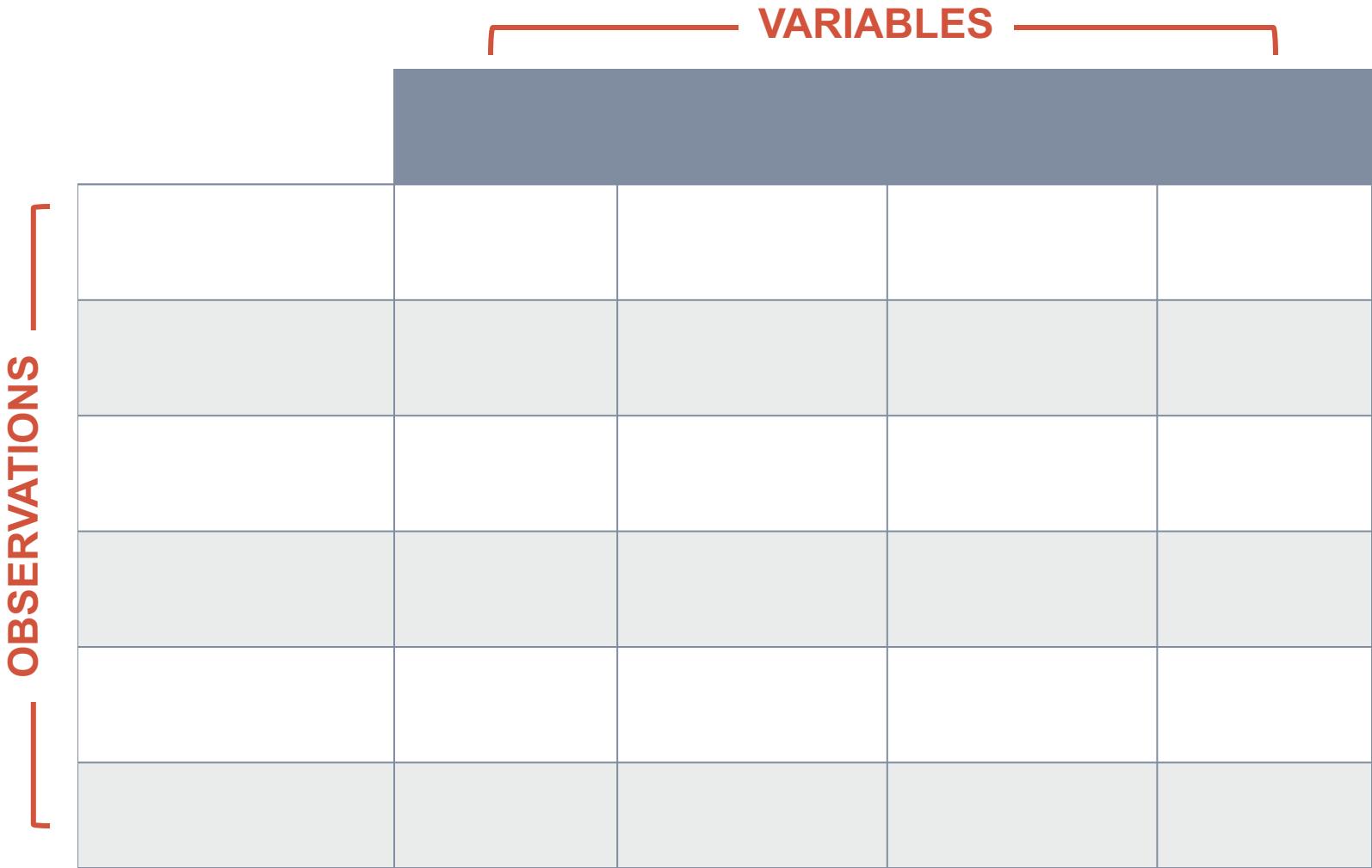
Data (def.)

and a corresponding set of *observations* (a.k.a. *records*) over these variables. For example:



*tuition = \$16,115, enrollment = 28,635,
public, etc.*

One way to think about this:

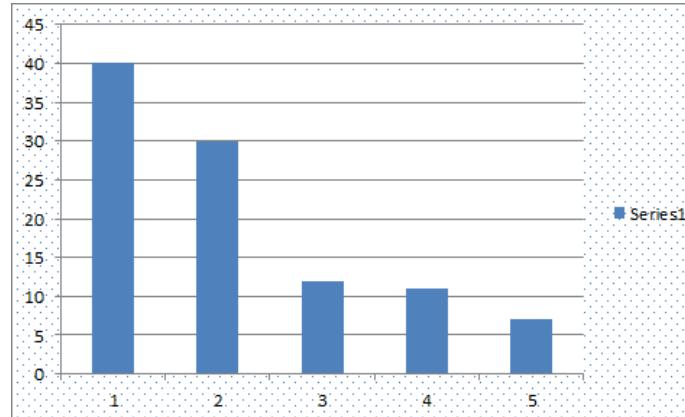
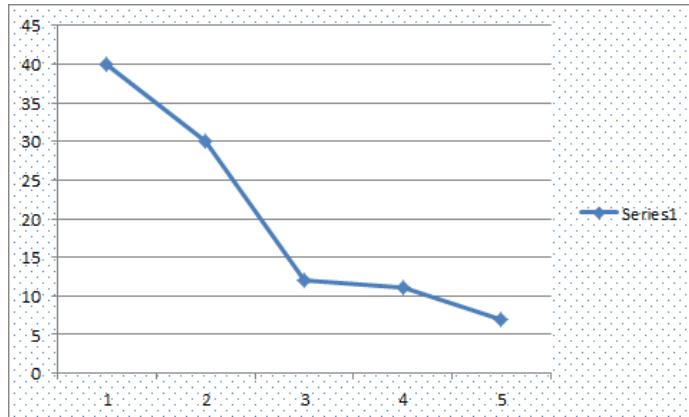
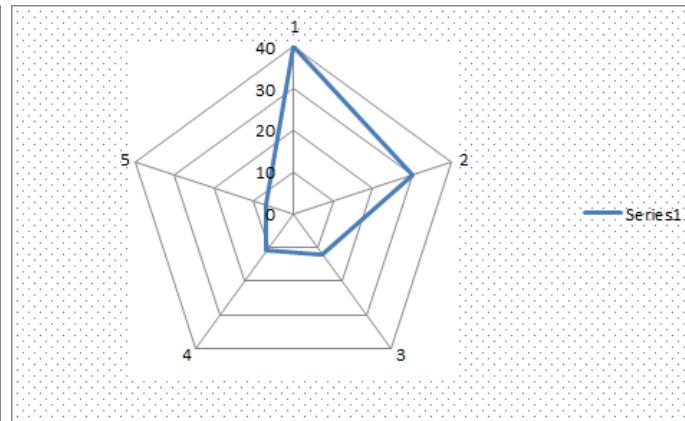
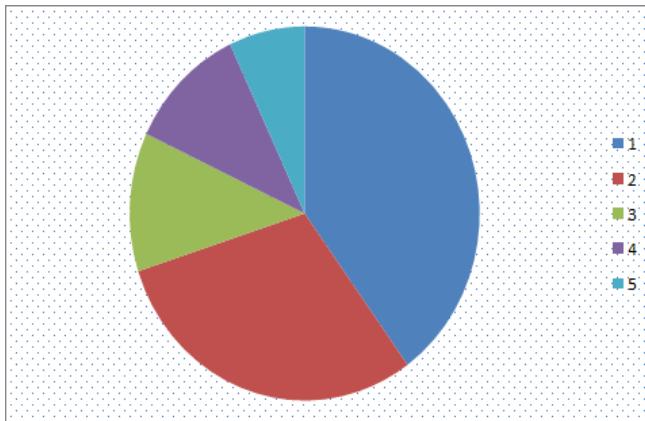


Why is this important?

- Data have dimensions
- Visualizations have dimensions, too
- To build visualizations, we need to **map** data dimensions to visual dimensions

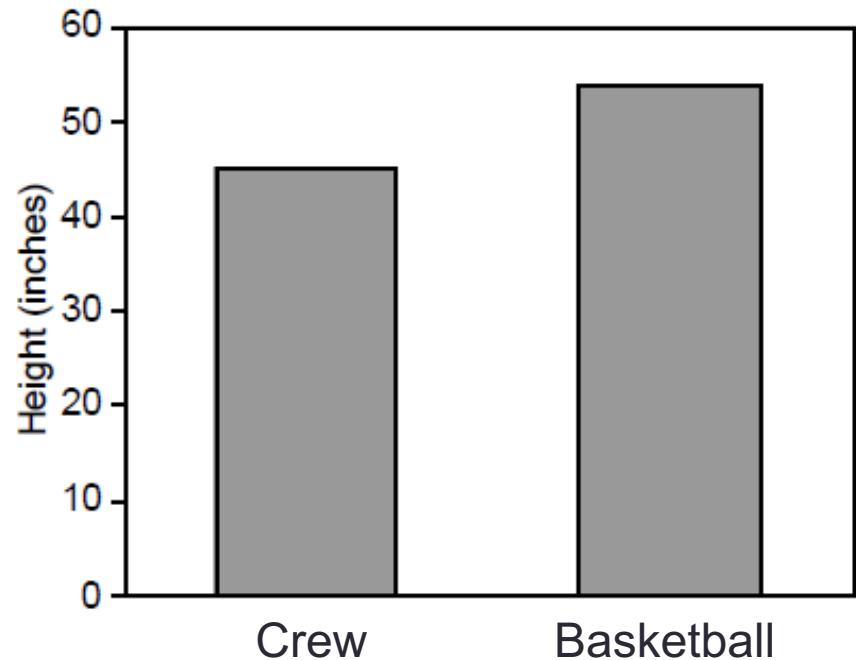
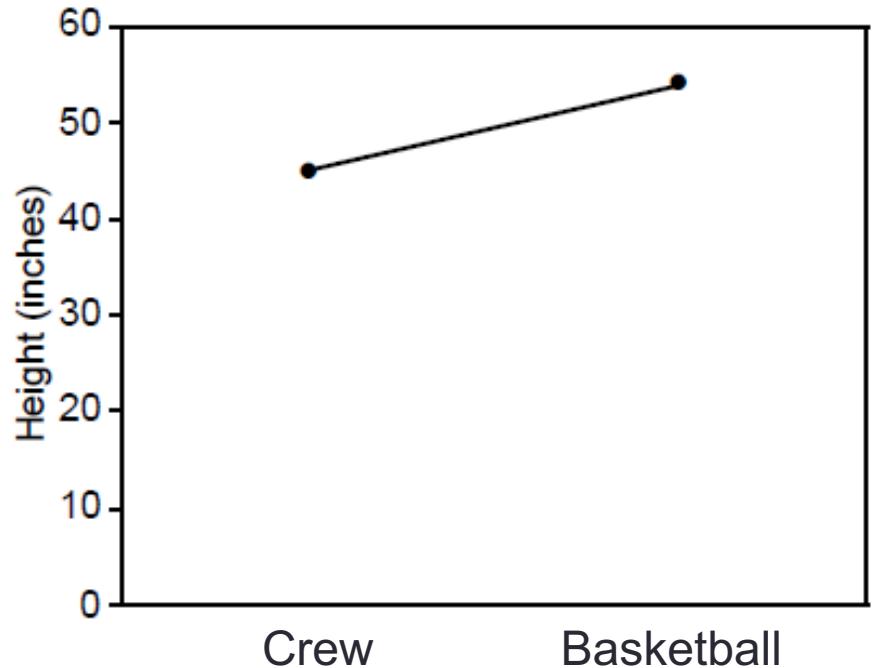
Key question for this workshop

Which **data dimension** should be mapped
to which **visual dimension**?

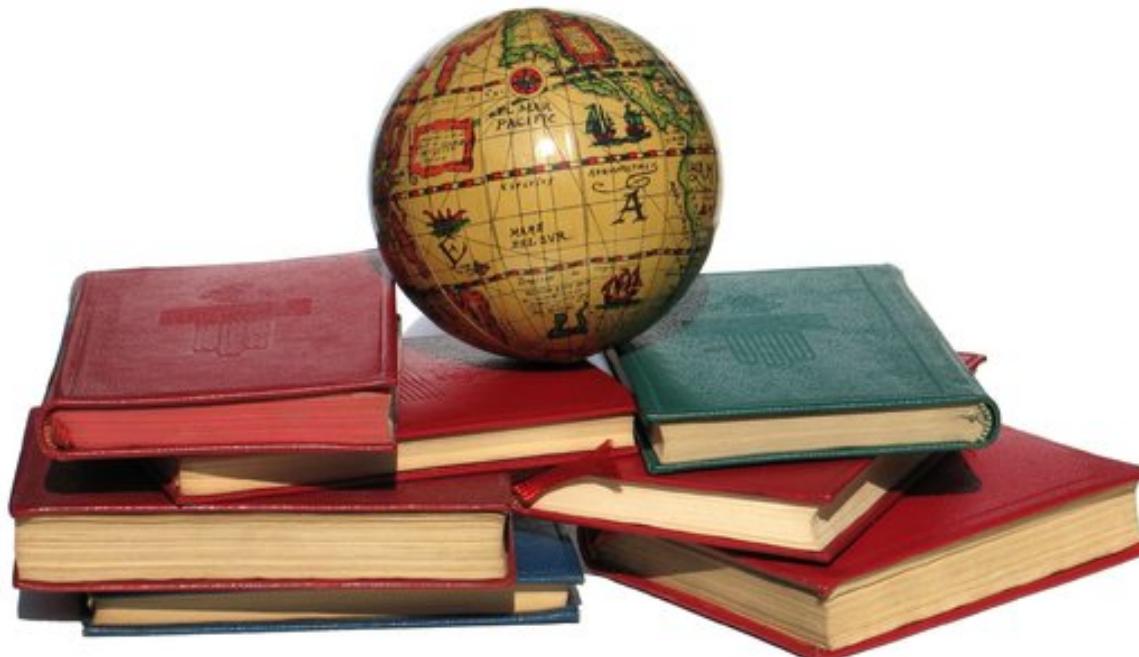


Answer: it depends

Average Height for Youth Sports Participants



A quick history lesson...

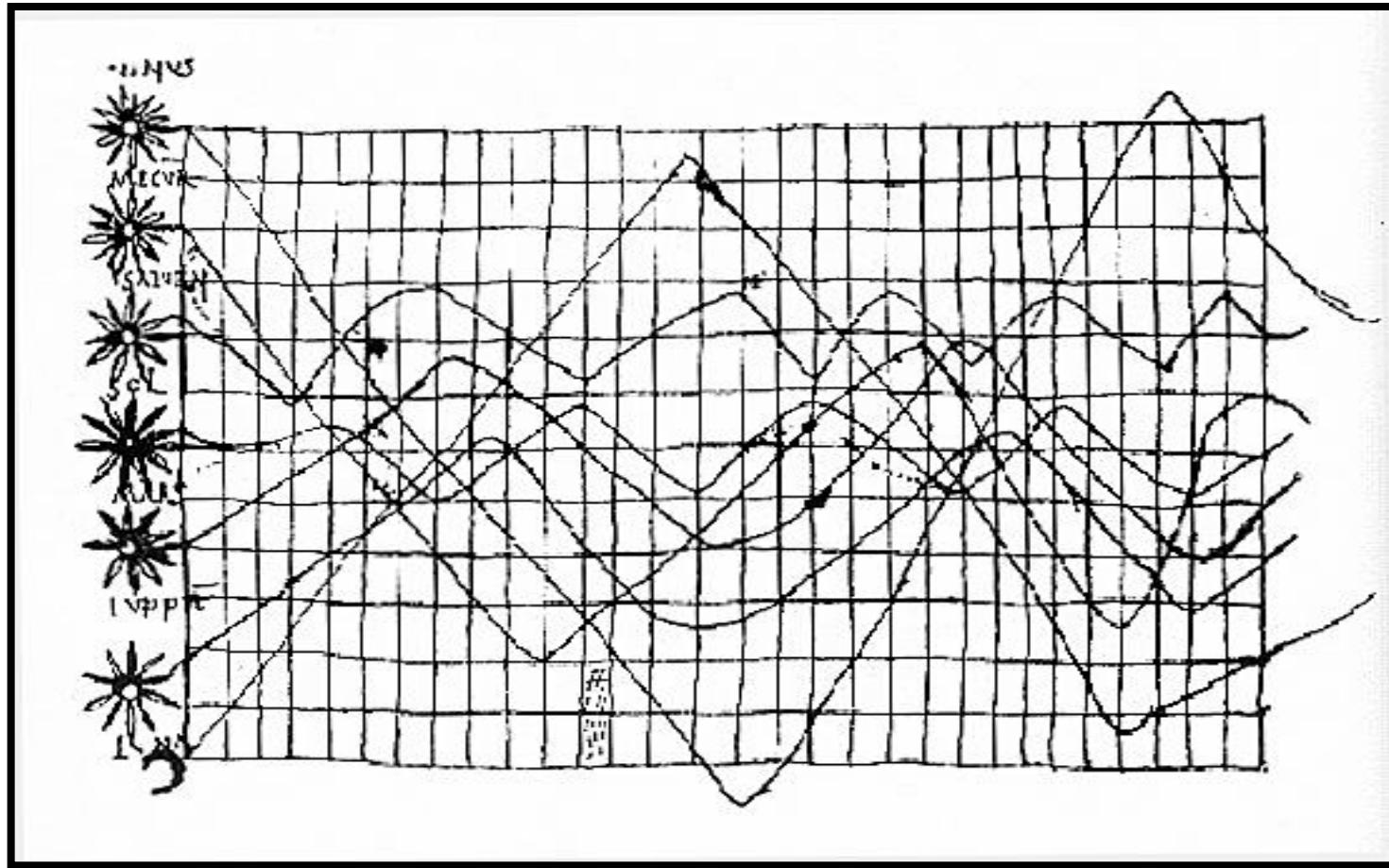


(Incomplete) History of Visualization: 15,000BC



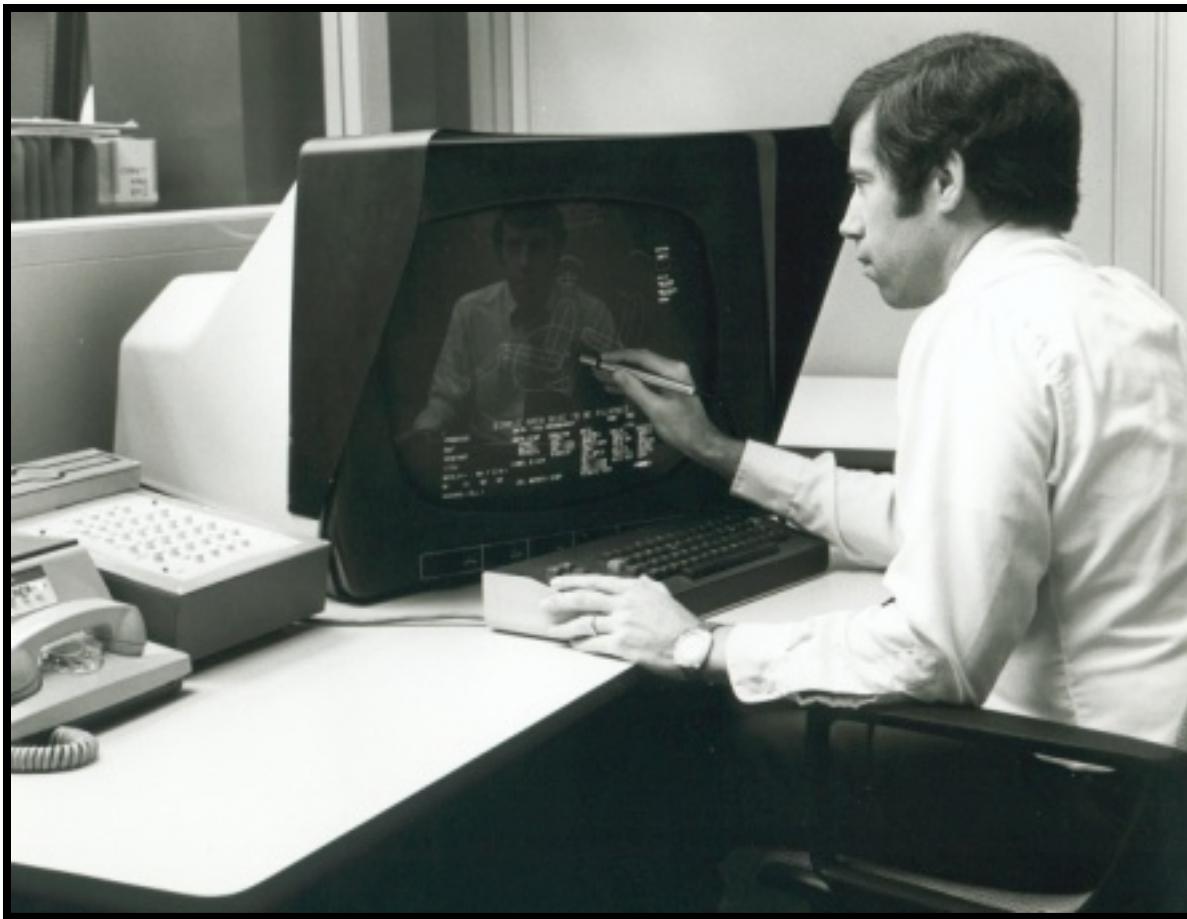
15,000 BC. Laxcaux, France

(Incomplete) History of Visualization: 900s



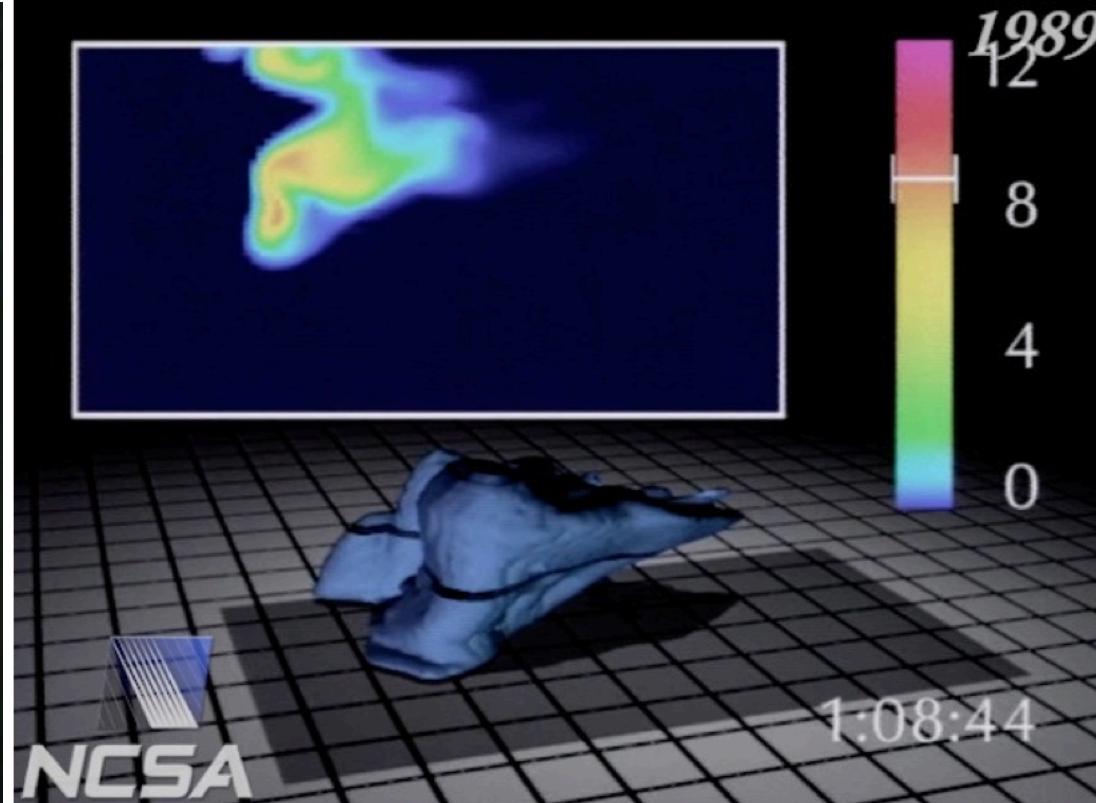
"De cursu per zodiacum", illustrator unknown

(Incomplete) History of Visualization: 1970s



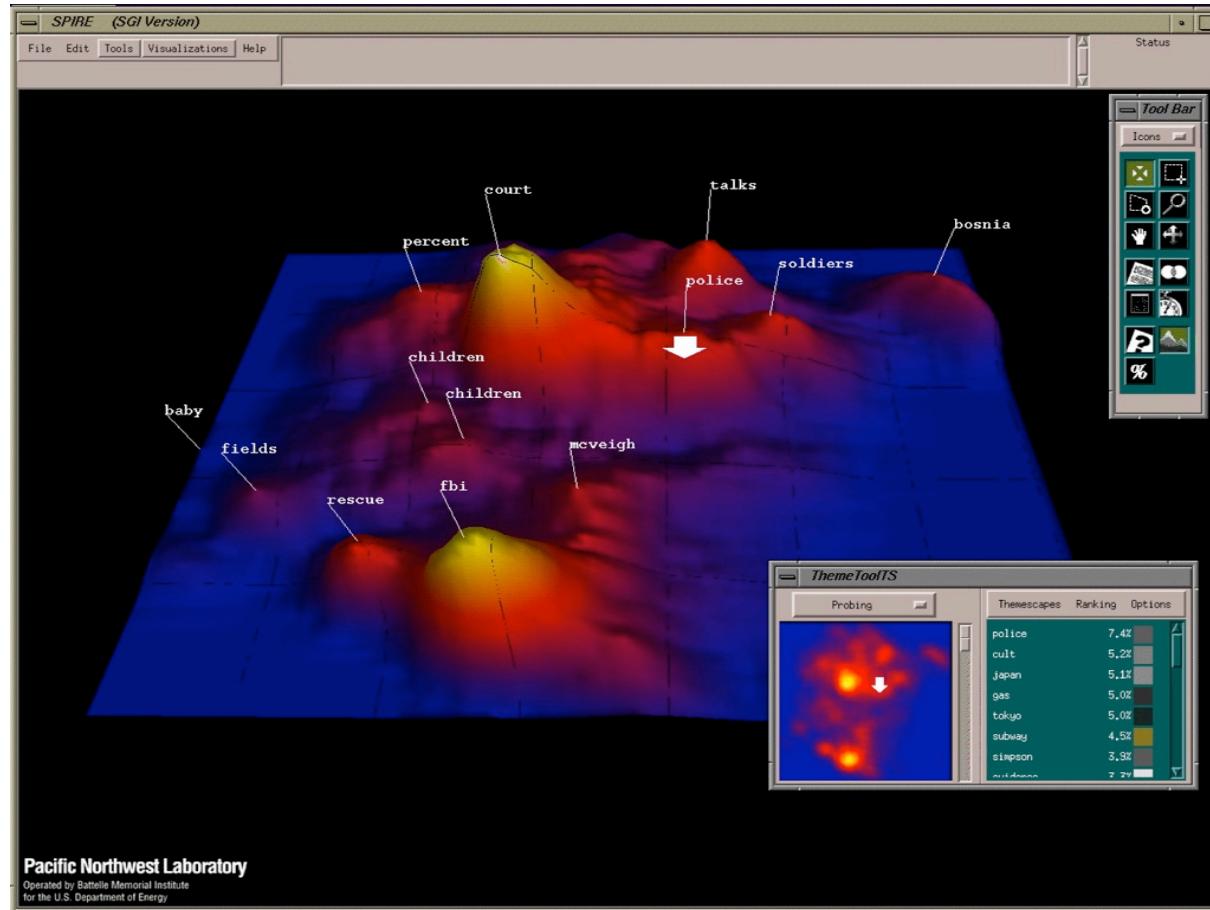
- CAD/CAM, building cars, planes, chips
- Starting to think about: 3D, animation, edu, medicine

(Incomplete) History of Visualization: 1980s



- Scientific visualization, physical phenomena
- Starting to think about: photorealism, entertainment

(Incomplete) History of Visualization: 1990s



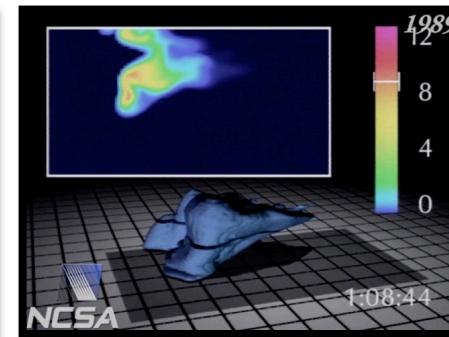
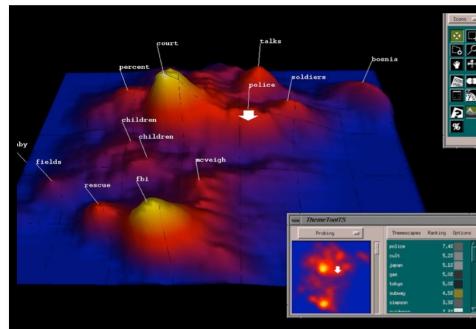
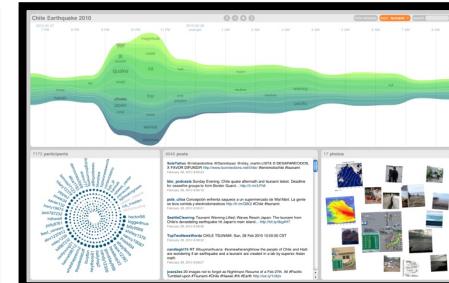
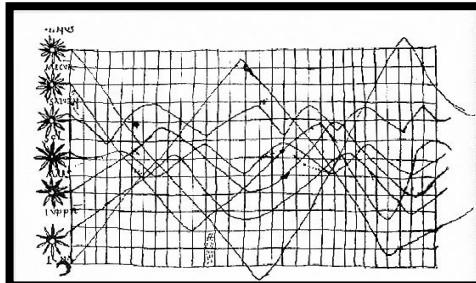
- Information visualization, storytelling
- Starting to think about: online spaces, interaction

(Incomplete) History of Visualization: 2000s

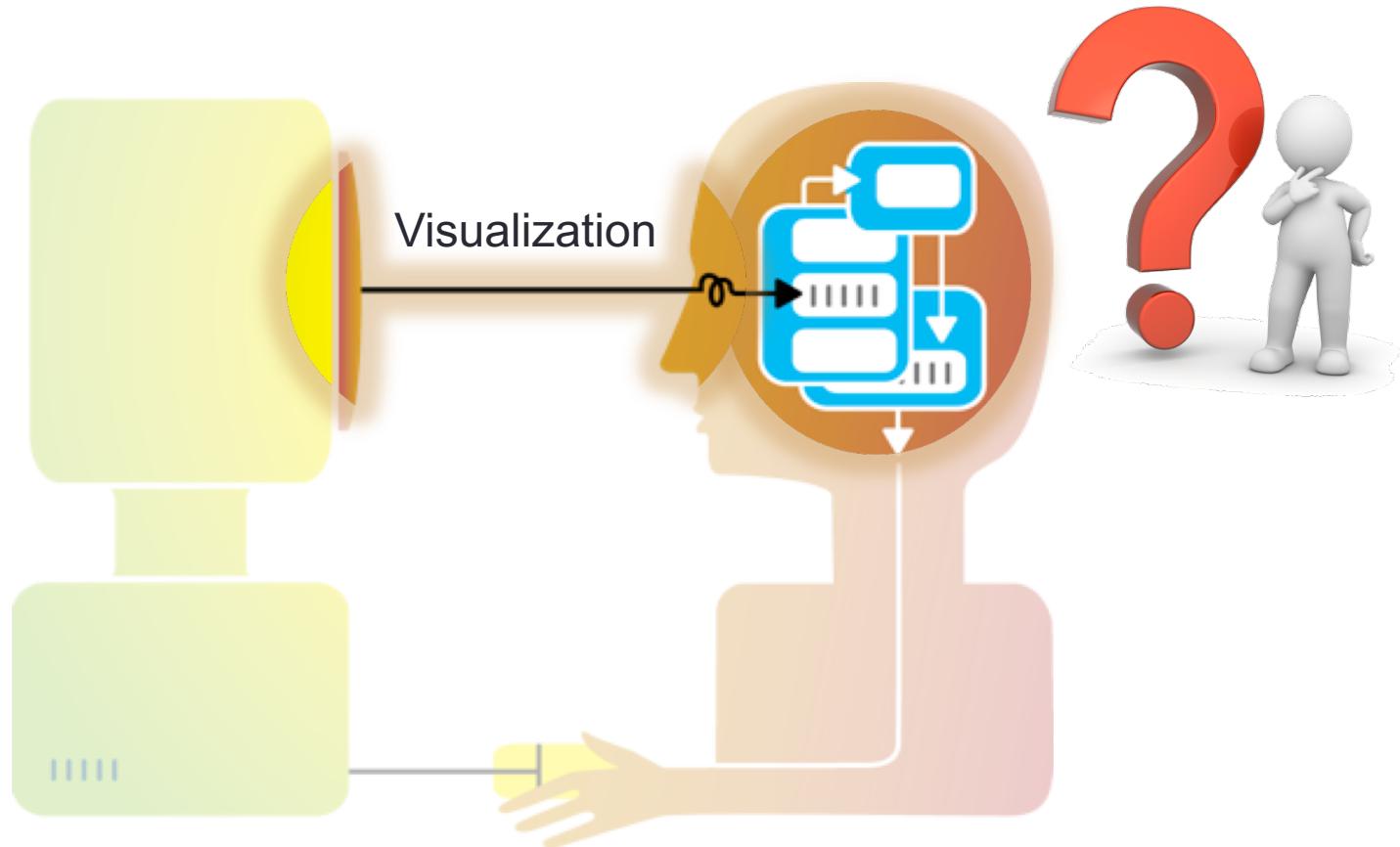


- Coordination across multiple views, interaction
- Starting to think about: sensemaking, provenance

Discussion: what are they all trying to do?



Visualization helps shape *mental models*



Information overload

- We are exposed to huge amounts of information all the time
- So much, in fact, that we can't process it all fast enough



Mental models

To cope, we construct **mental models**: abstracted, simplified versions of the world that are more manageable



Mental Models: a Sketch



1. We tend to see what we expect to see



2. Mental models form quickly, & update slowly



3. New information gets incorporated into the existing model



4. Initial exposure interferes with accurate perception



Blur size

128px

64px

32px

16px

8px

None

The good, the bad, and the ugly...

The good:

- Well-tuned mental models let us process information quickly
- Frees up more processing power to synthesize information

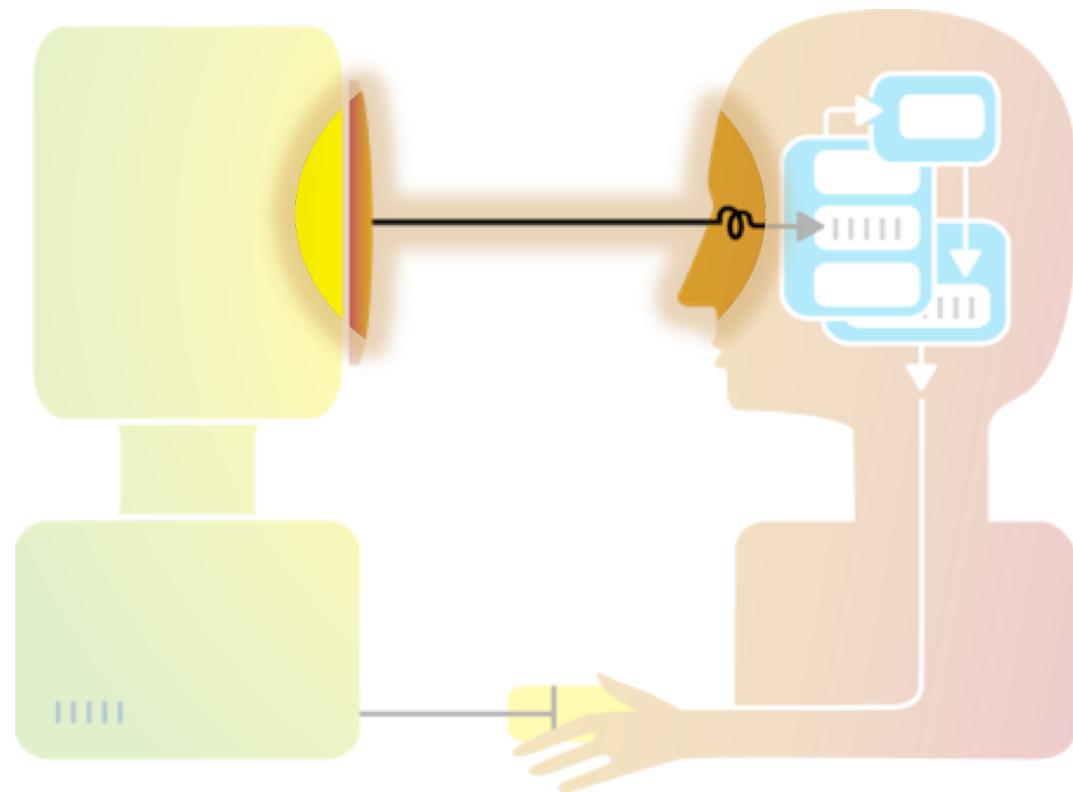
The bad:

- People (esp. experts) tend not to notice information that contradicts their mental model
- A “fresh pair of eyes” can be beneficial

The ugly:

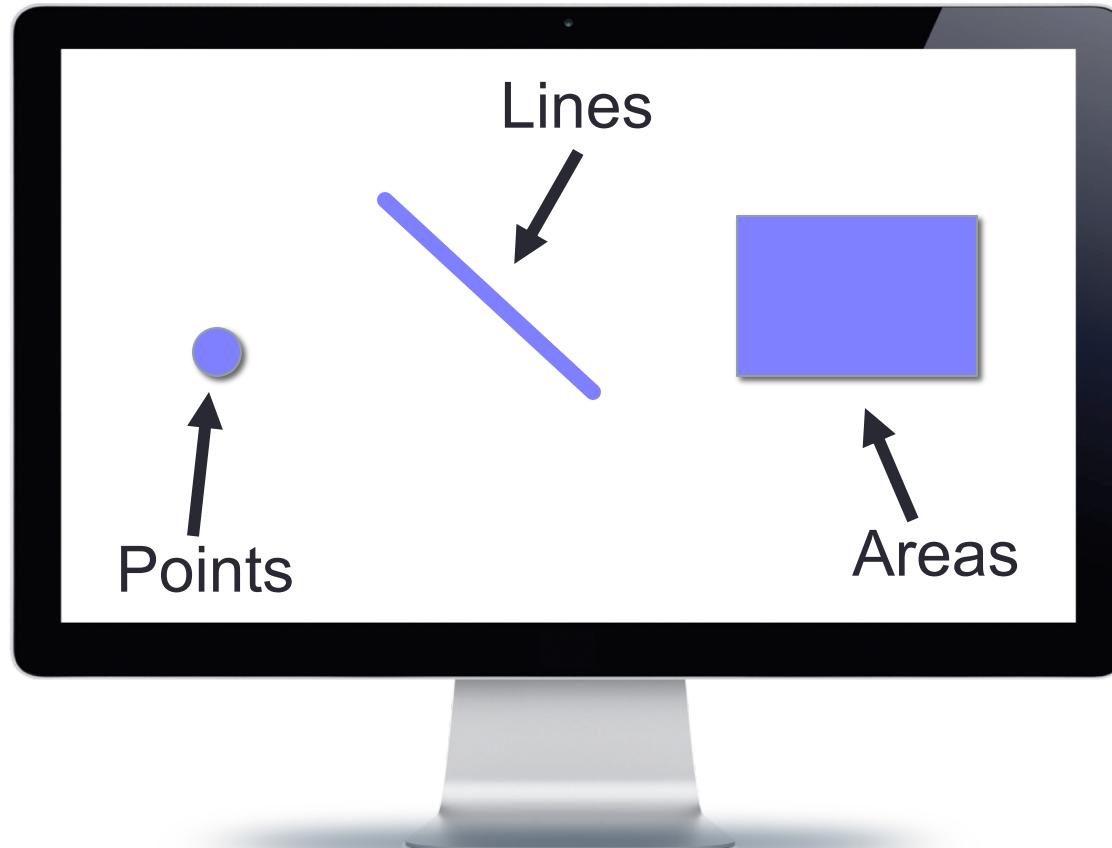
- Mental models are unavoidable: everyone has them, and they’re all different
- **Key:** be aware of how mental models form, how they shape perception, and how to support (or challenge) them

So what do we have to work with?



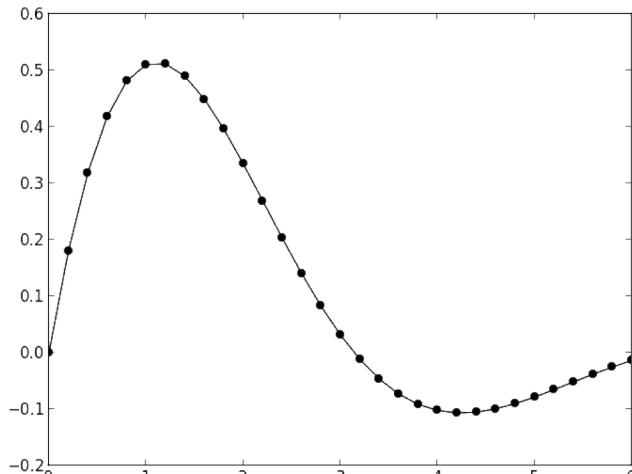
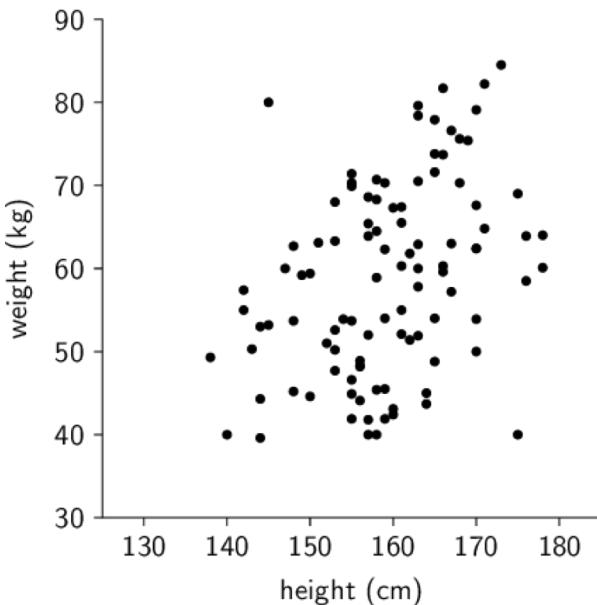
Graphical primitives

The images we draw are composed of marks: like ink



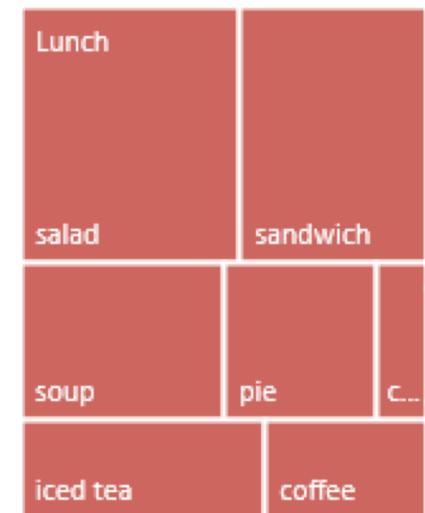
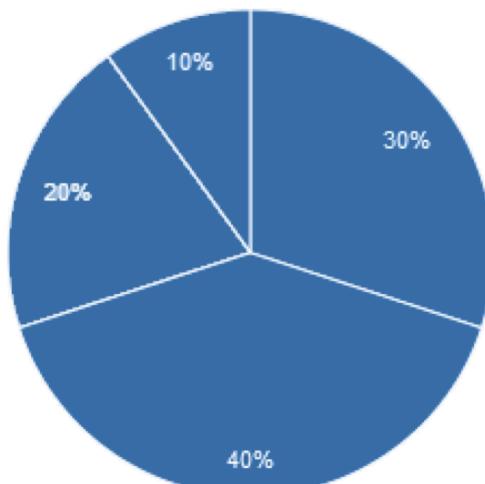
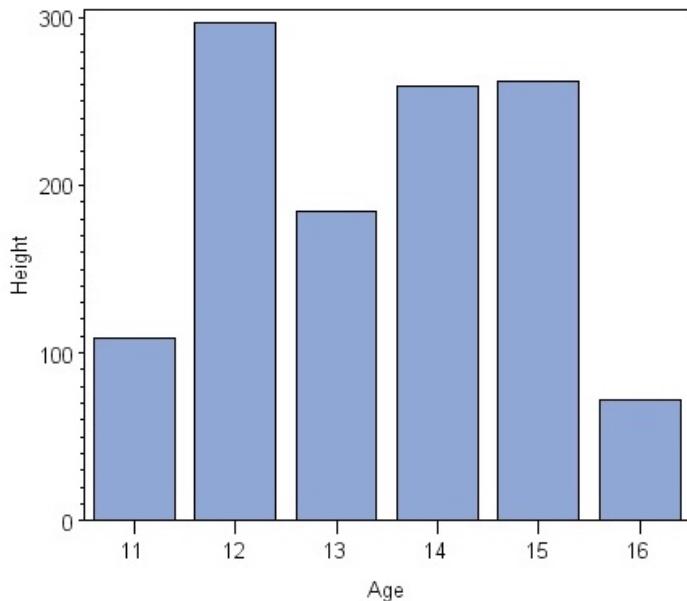
Visual dimension: position

- Encode information using **where** the mark is drawn
- Some examples:



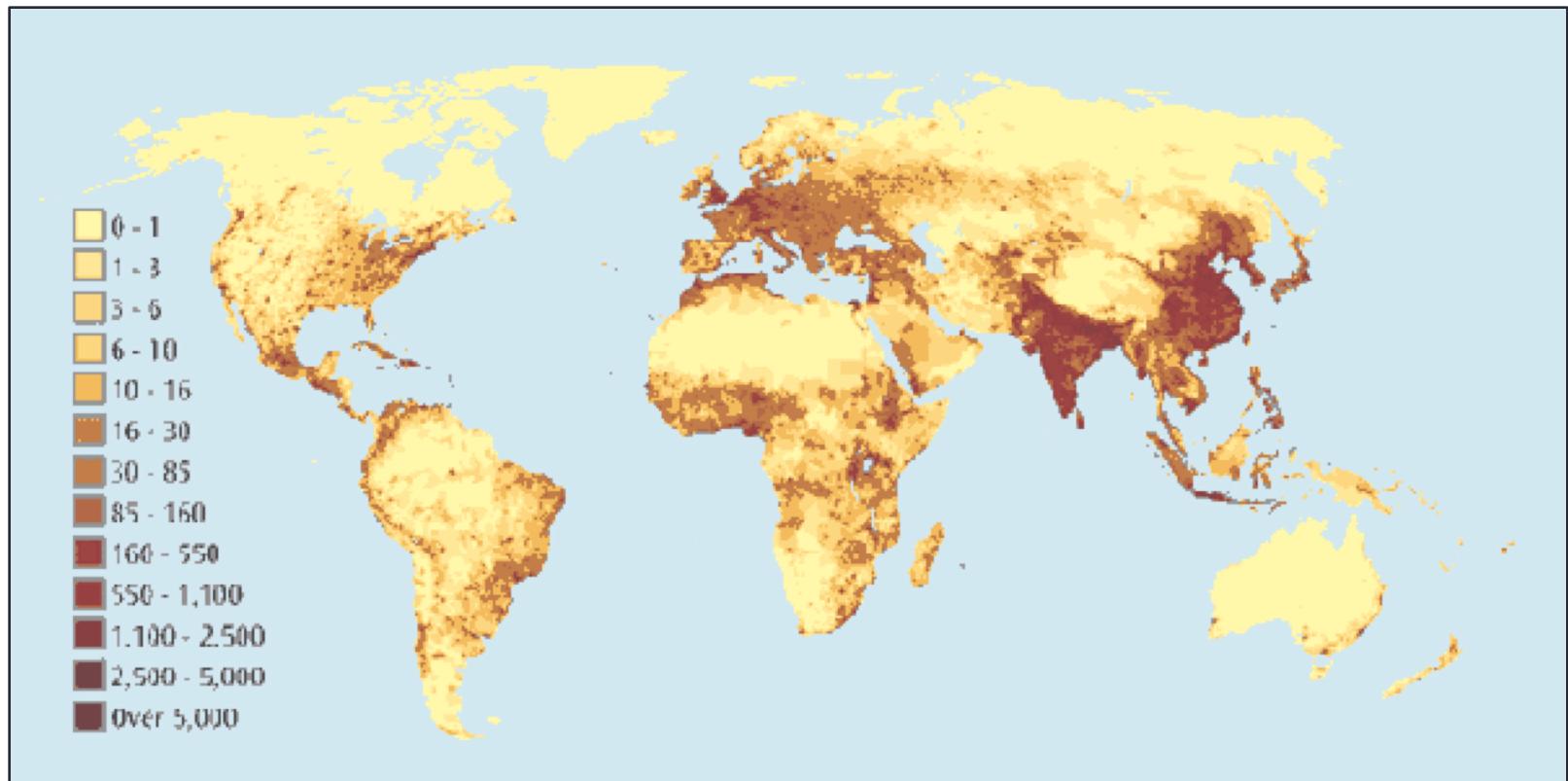
Visual dimension: size

- Encode information using **how big** the mark is drawn
- Examples:



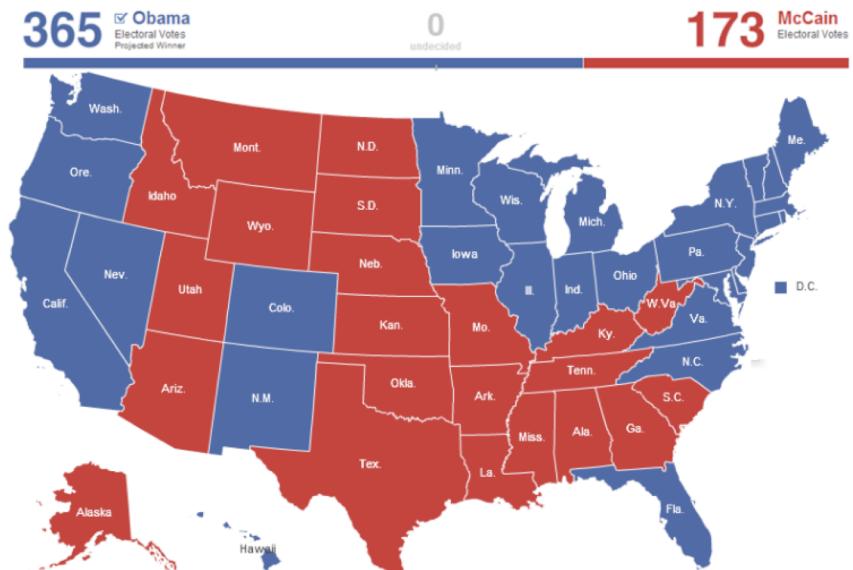
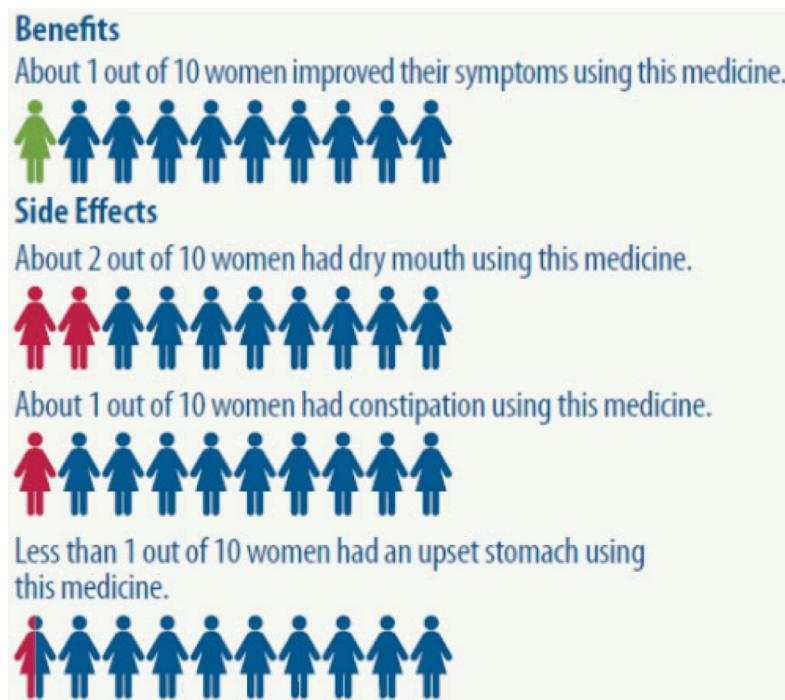
Visual dimension: value

- Encode information using **how dark** the mark is drawn
- Example:



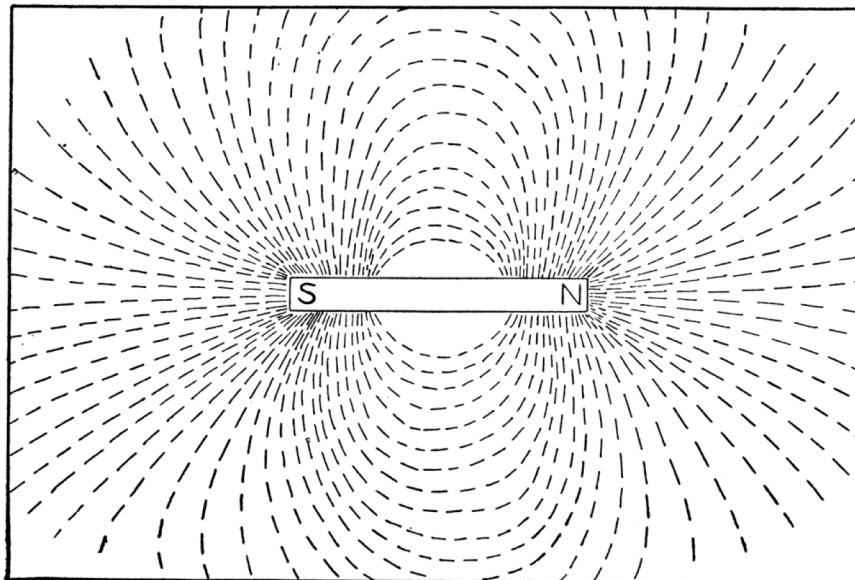
Visual dimension: color

- Encode information using the **hue** of the mark
- Examples:



Visual dimension: orientation

- Encode information using how the mark is **rotated**
- Examples:



Visual dimension: shape

- Encode information using how the mark is **shaped**
- Examples:



Discussion: visual dimensions & data type

| | Categorical | Numerical |
|-------------|-------------|-----------|
| POSITION | x x x | |
| SIZE | ■ ■ ■ | |
| VALUE | ■ ■ ■ | |
| COLOR | ■ ■ ■ | |
| ORIENTATION | ■ ■ ■ | |
| SHAPE | ■ ▲ ● | |



Pre-lunch activity: deconstructing graphics

1. Find a data visualization you think is interesting
 - Some ideas: NYTimes, VisualisingData.com, Visual.ly
 - Remember to cite your source!

2. Identify the following:
 - What is the **data** that's being visualized? Where did it come from?
 - Which **data dimensions** are mapped to which **visual dimensions**?
 - How does this **shape your understanding** of the data?
 - If you **liked** the visualization: what is it doing **well**?
 - If you **disliked** the visualization: what would you **change**?

Discussion

What makes a **good** encoding?



Principle 1: expressiveness

- Encodes **all** the facts
- Example:

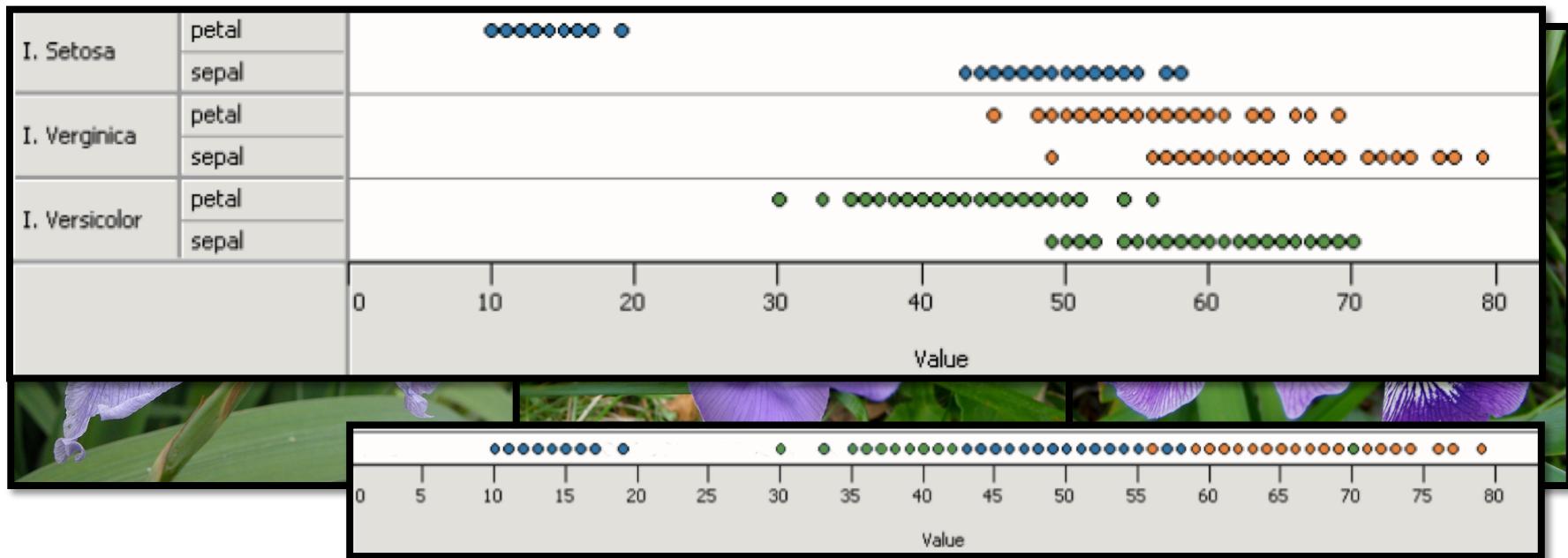
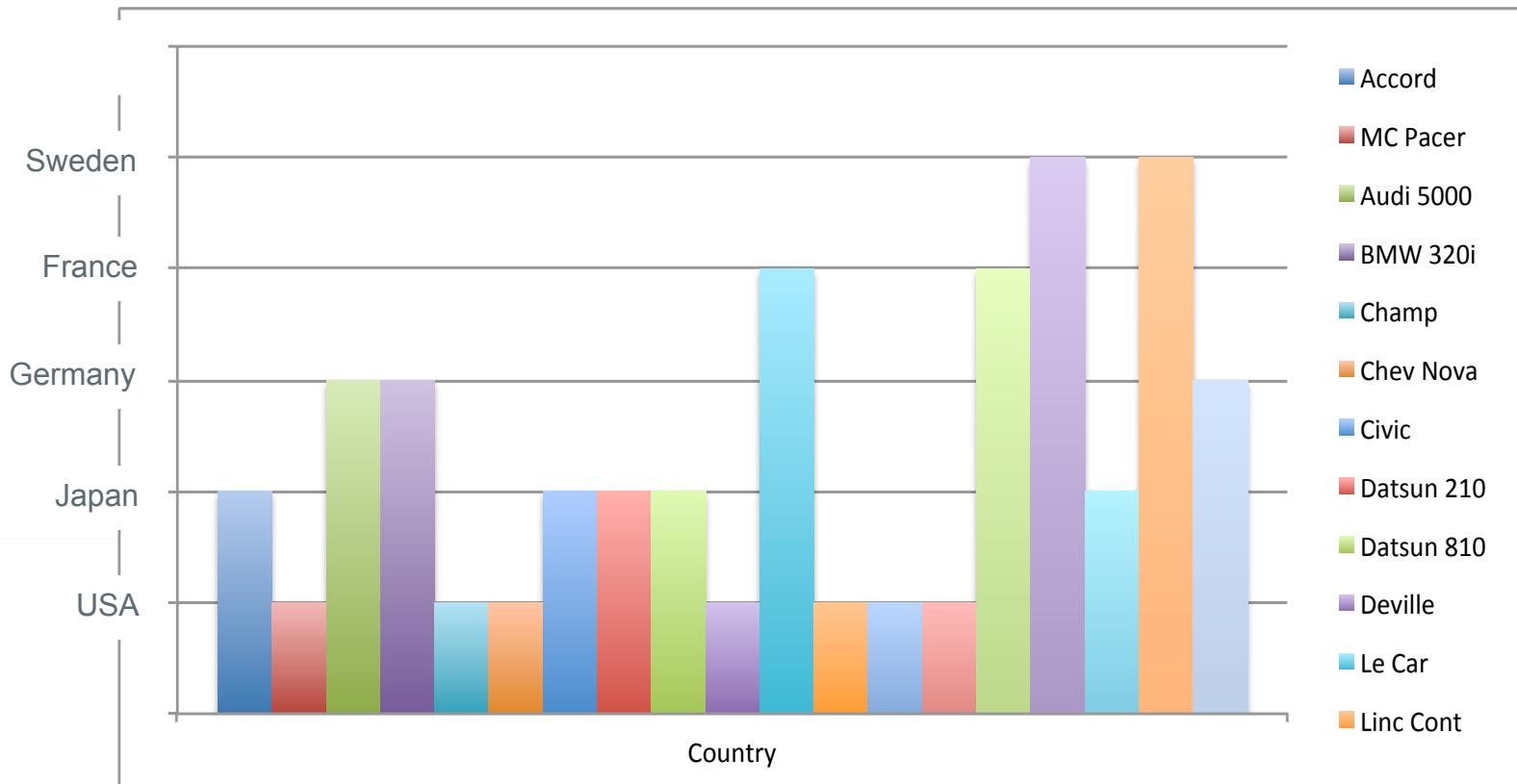


Fig. Courtesy of M Krzywinski

Principle 1: expressiveness

- Encodes **only** the facts
- Example:

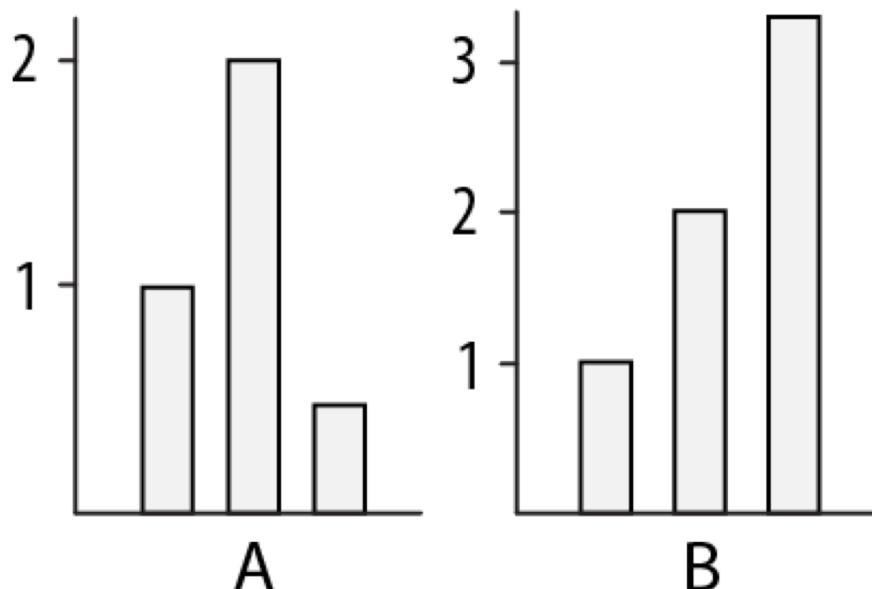


Adapted from Mackinlay J (1986) Automating the design of graphical presentations of relational information.

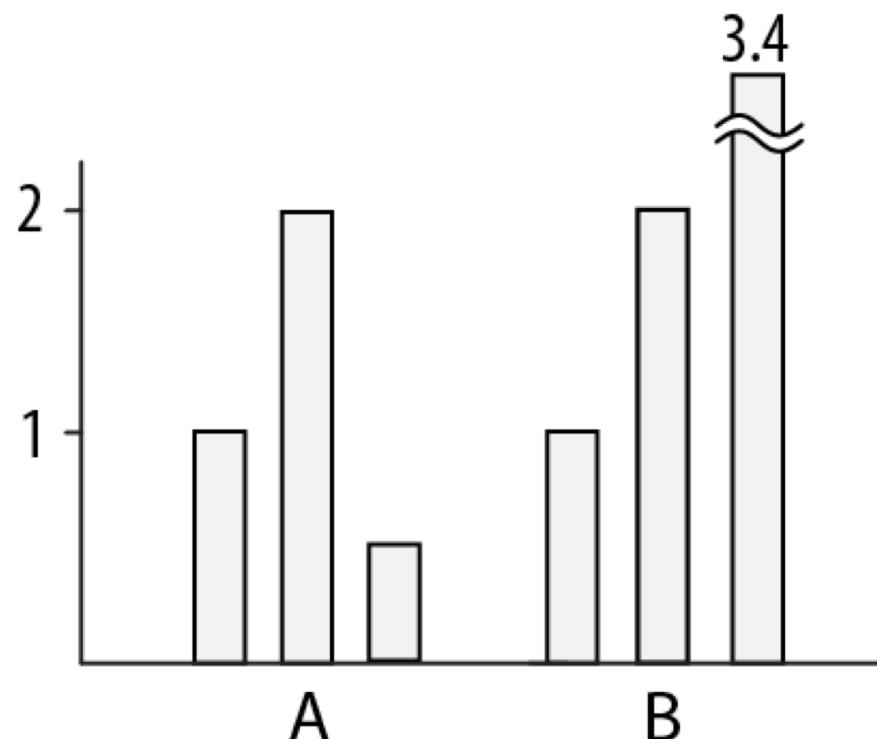
Principle 2: consistency

- Use **consistent axes** when comparing charts

misleading

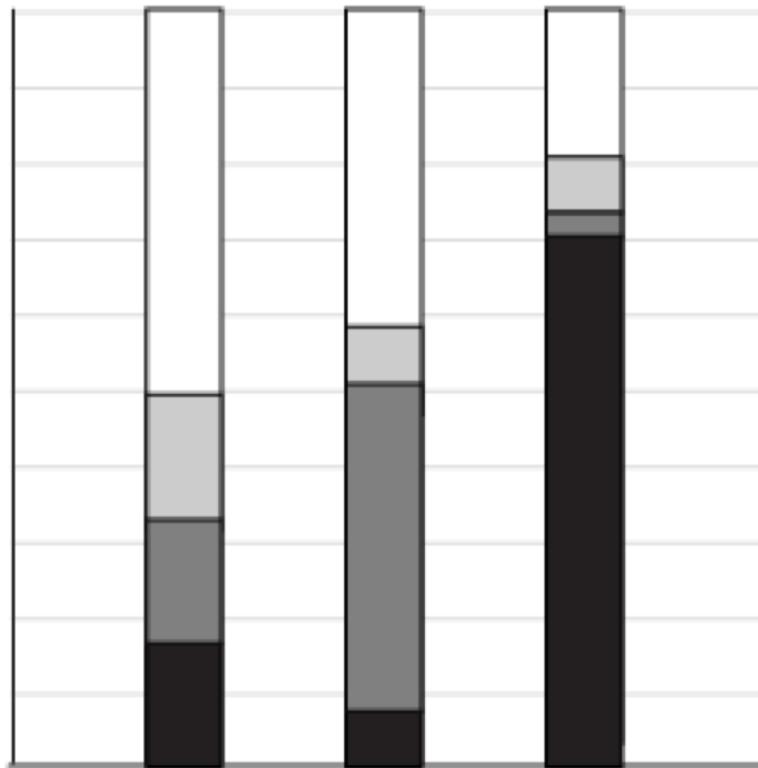


improved



Principle 2: consistency

- A note on **legends**: order items according to appearance

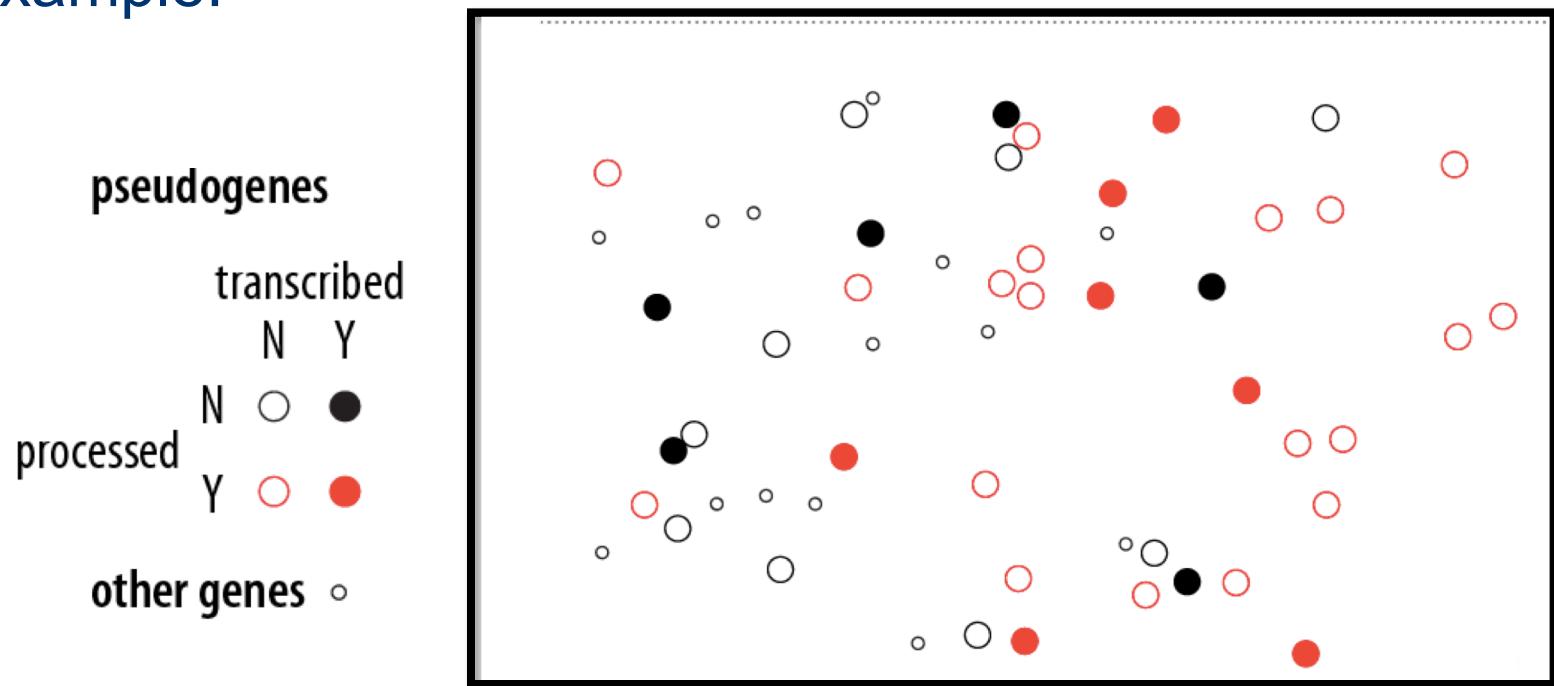


consistent inconsistent

| | | | |
|---|---|---|---|
| □ | A | ■ | A |
| □ | B | ■ | B |
| ■ | C | ■ | C |
| ■ | D | □ | D |

Principle 2: consistency

- Visual variation should **reflect and enhance** the underlying variation in the data
- Avoid **visually similar** encodings for independent variables
- Example:



Principle 2: consistency

- Uniform size and alignment reduces visual complexity and aids interpretation
- Example:

variation refactored

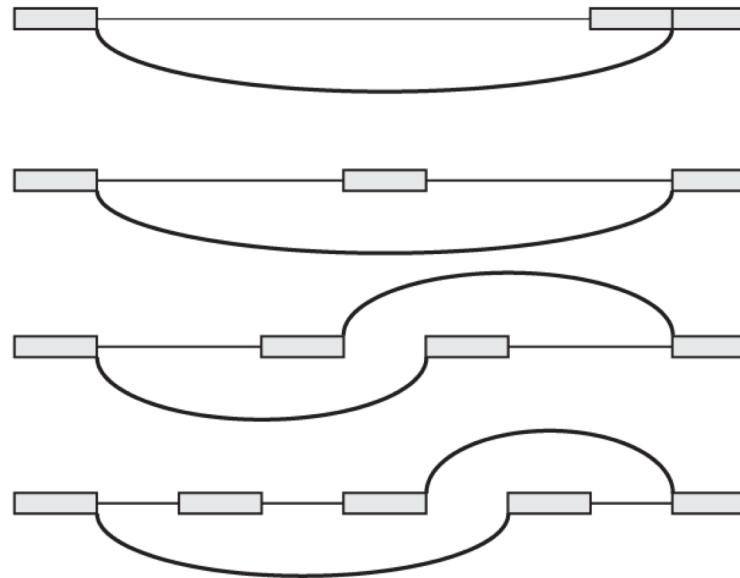
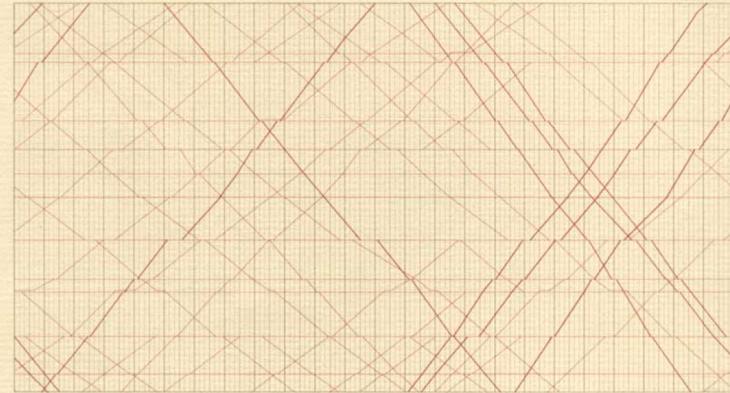


Fig. 1: Sharov AA et al. (2005) Genome-wide assembly and analysis of alternative transcripts in mouse. Genome Res 15: 748-754.

Fig. 2: M. Krzynski, behind every great visualization is a design principle, 2012

Tufte, 1983

“Above all else,
show the data.”



The Visual Display of Quantitative Information

EDWARD R. TUFTE

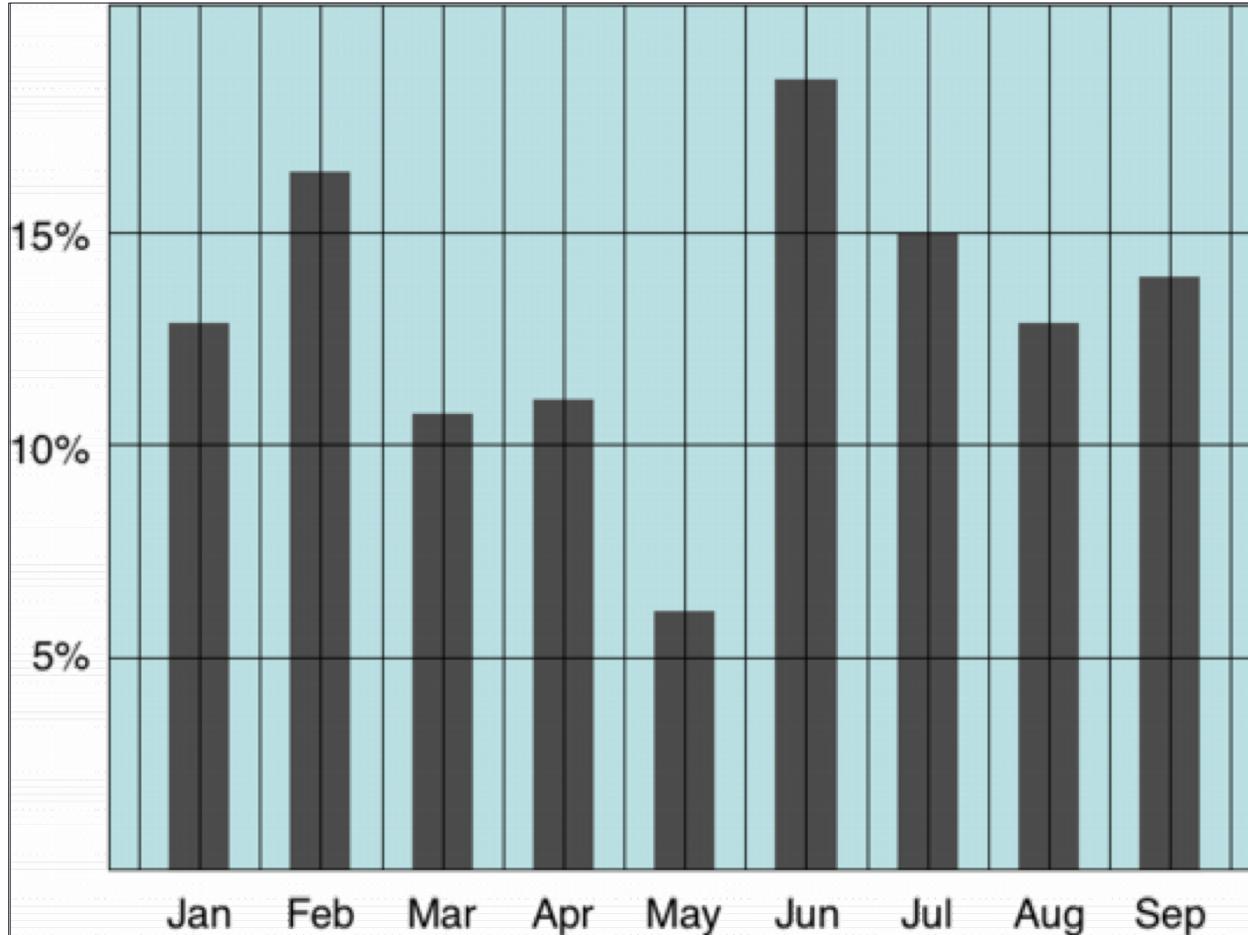
Tufte, 1983

$$\text{Data-ink ratio} = \frac{\text{Data-ink}}{\text{Total ink used to print the graphic}}$$

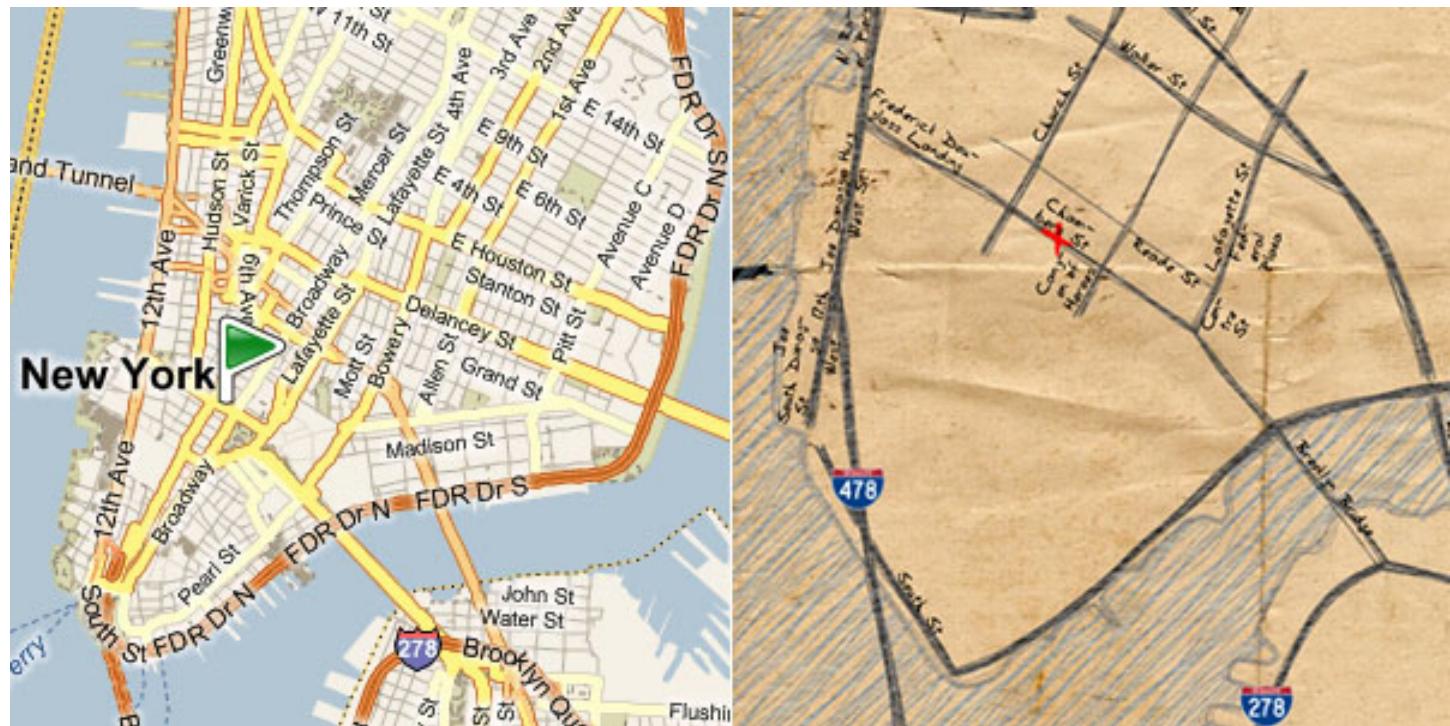
= proportion of a graphic's ink devoted to the non-redundant display of data-information

= 1 - proportion of a graphic that can be erased

Tufte: maximize the data-ink ratio



Familiar example



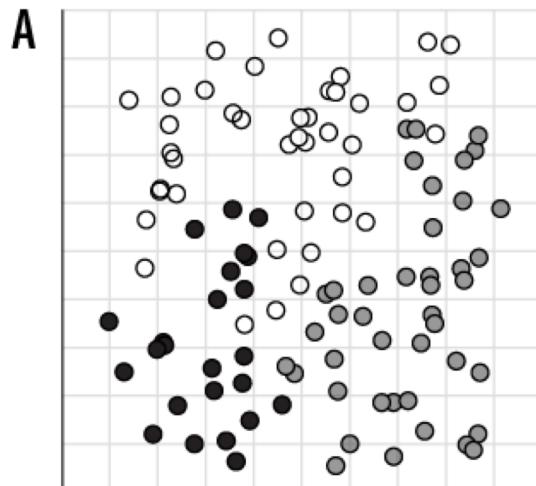
Discussion

- What do you think of the data-ink ratio?
- Consider ways to **maximize** it...

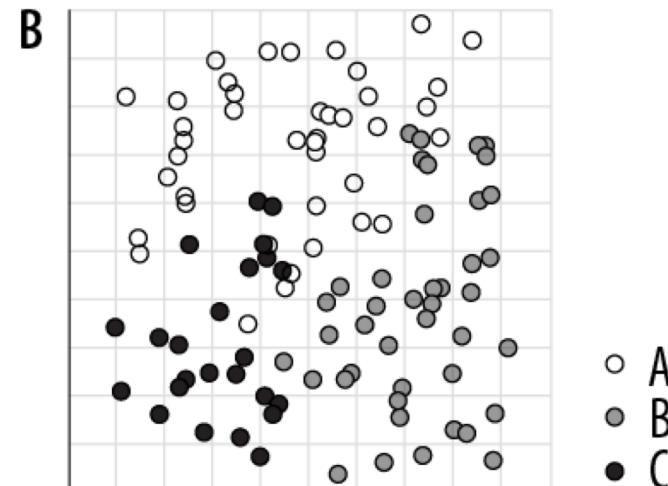


Principle 3: importance ordering

- Avoid unnecessary containment and repetition
- Example



Lorem ipsum dolor sit amet, consectetur adipiscing elit. In ut mauris quis tellus

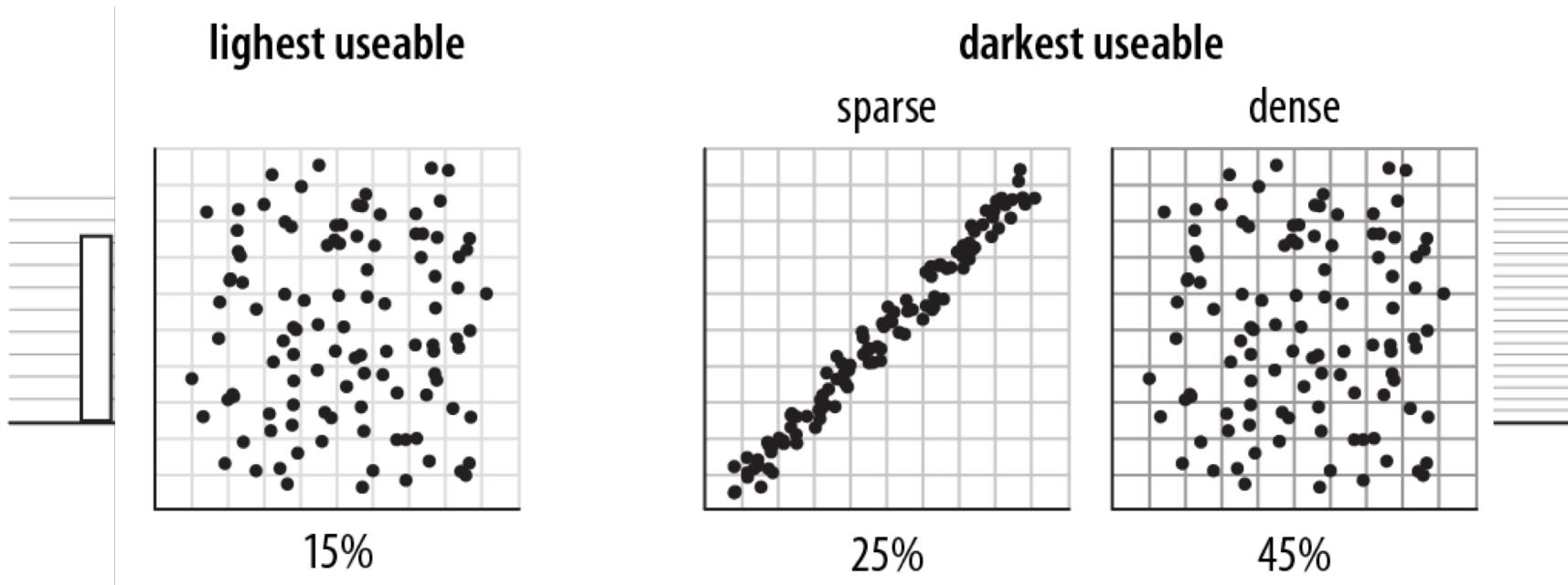


Lorem ipsum dolor sit amet, consectetur adipiscing elit. In ut mauris quis tellus

- A
- B
- C

Principle 3: importance ordering

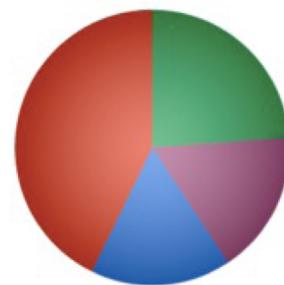
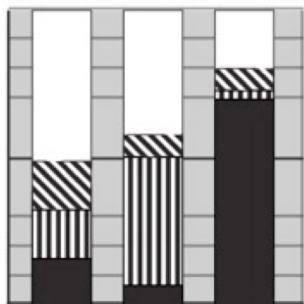
- Navigational aids shouldn't compete with data
- Avoid: **heavy axes, error bars and glyphs**



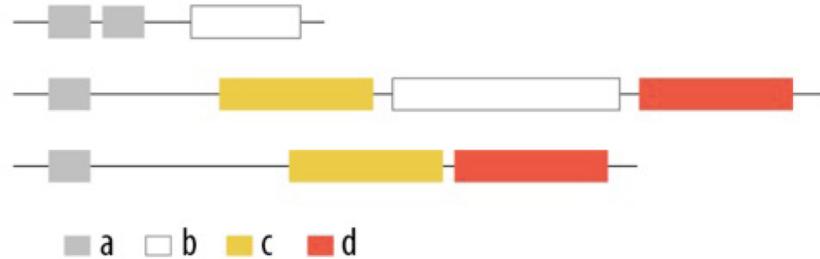
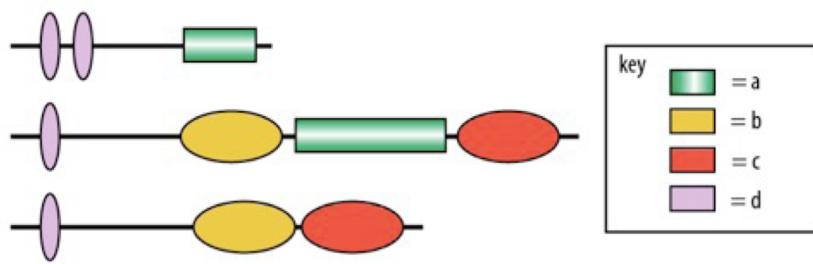
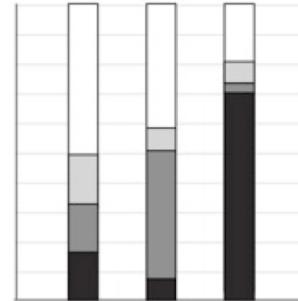
Principle 3: importance ordering

- Simplify, simplify, simplify...

chartjunk



visually concise



Sharov AA, et al (2006) Genome Res 16: 505-509.
Peterson J, et al. (2009) Genome Res 19: 2317-2323.
Thomson NR, et al. (2005) Genome Res 15: 629-640.
DB, Ko MS (2005) Genome Res 15: 748-754.

M. Krzwincki, behind every great visualization is a design principle, 2012

A caveat: “chart junk” and recall

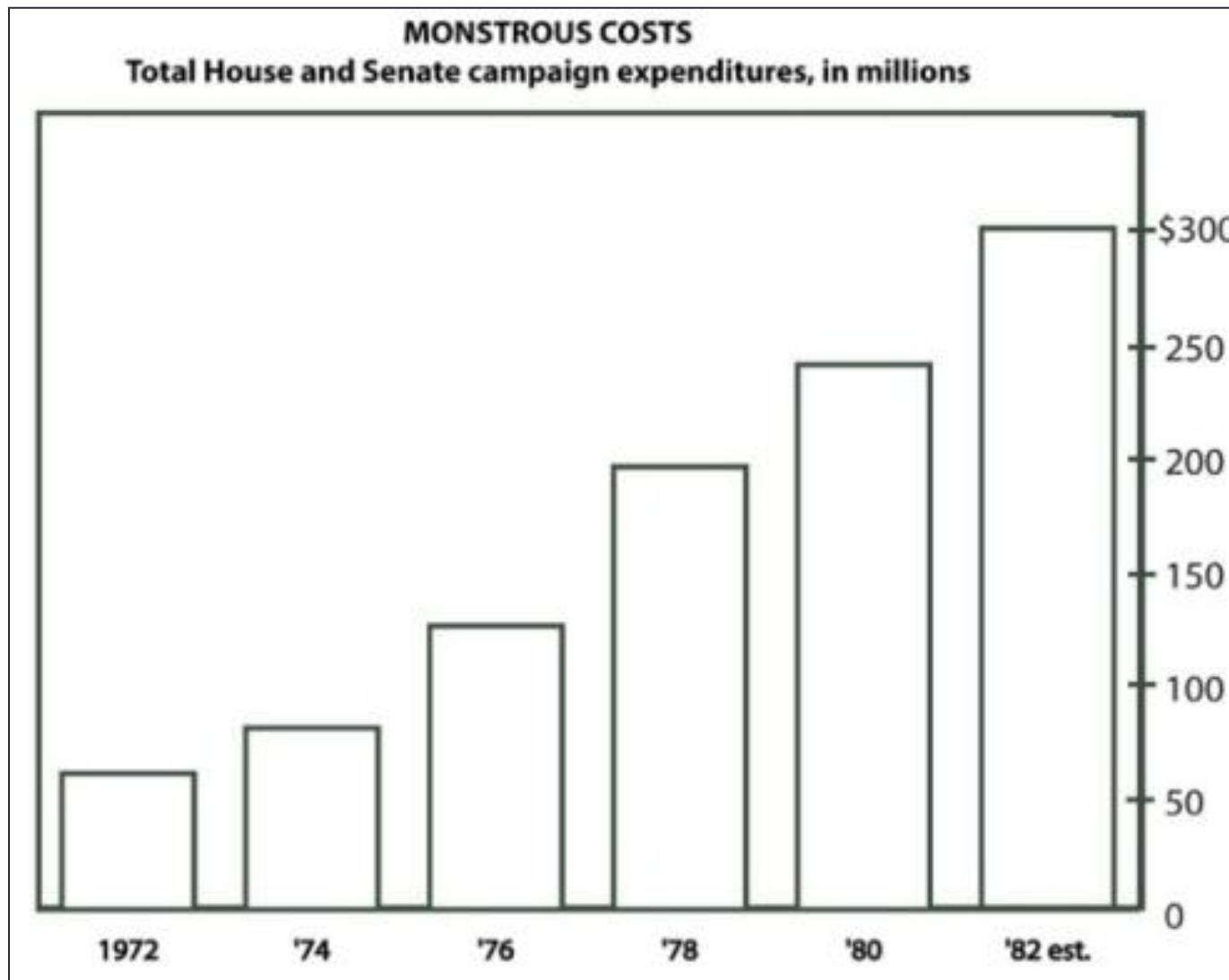


Chart junk and eye gaze

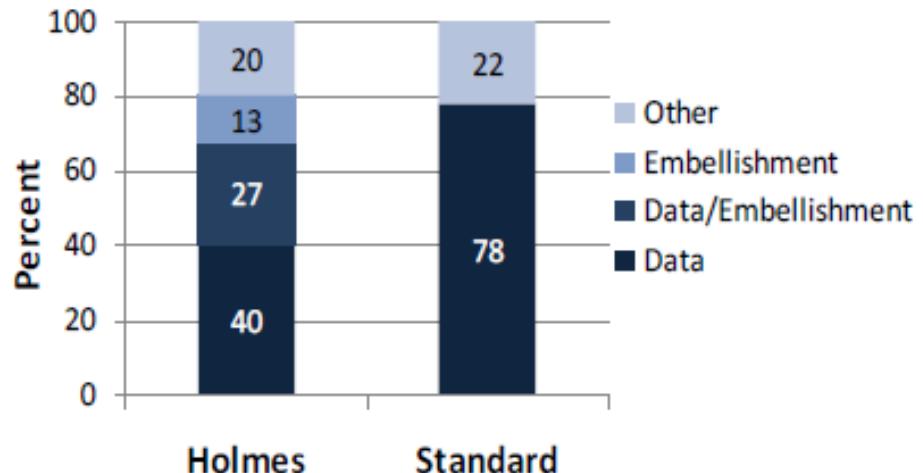
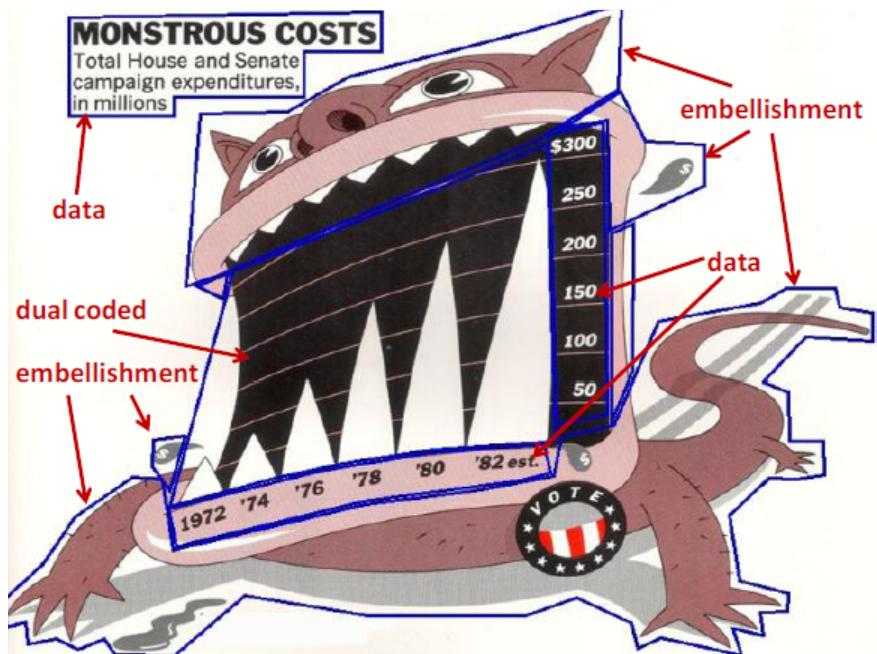
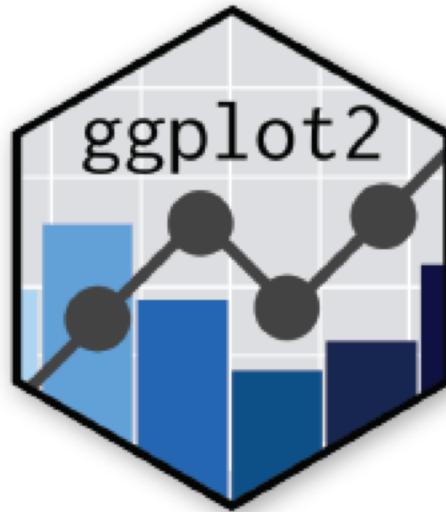


Figure 9. Percentage of on-screen time spent looking at different chart elements for Holmes and Plain charts.

After lunch



- Mini-lecture and lab: building data graphics with ggplot2
- **TODO** (if you haven't already):
 > `install.packages('ggplot2')`