Data Visualization

FOUNDATIONS

Outline

What is data visualization?

Why visualize data?

Historical visualizations

The three principles of good visualization design
- Trustworthiness
- Accessibility
- Elegance

What is data visualization?

Definition

The presentation of data in graphical form to facilitate understanding

https://en.wikipedia.org/wiki/Data_visualization

Distinctions in terminology

Data visualization ≈ information visualization

- Data + meaning = information
- When a distinction is made (we will not make it)
  - Data visualization is concerned with numerical data
  - Information visualization is concerned with abstract data structures

Scientific Visualization

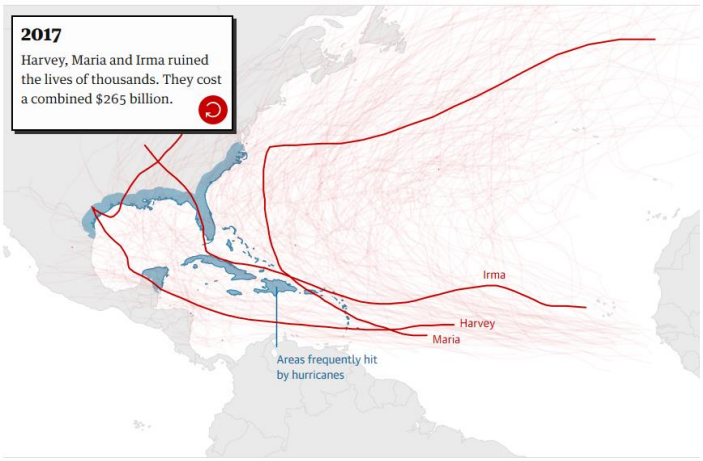
- Visualization of 3-D phenomena for scientific purposes

Infographics

- Use different graphics for explanation (charts, illustrations, photo-imagery)
- Traditionally created for print consumption (static)
- Sometimes hard to discern from data visualization

5

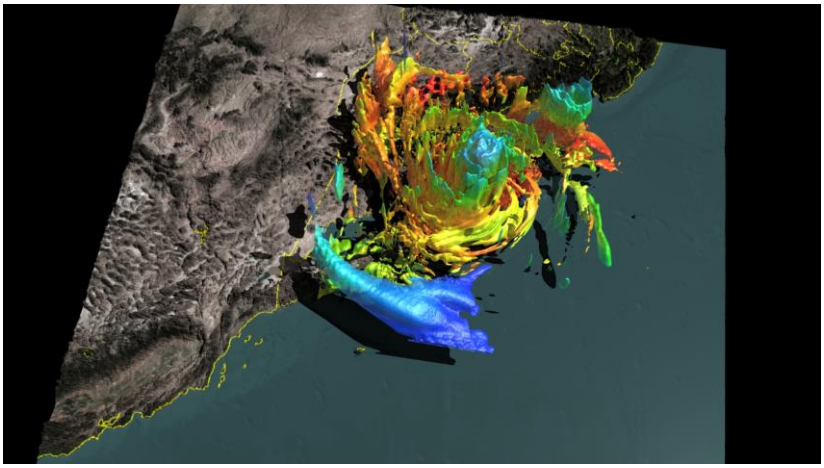
Data visualization example



https://www.theguardian.com/weather/ng-interactive/2018/sep/11/atlantic-hurricanes-are-storms-getting-worse

6

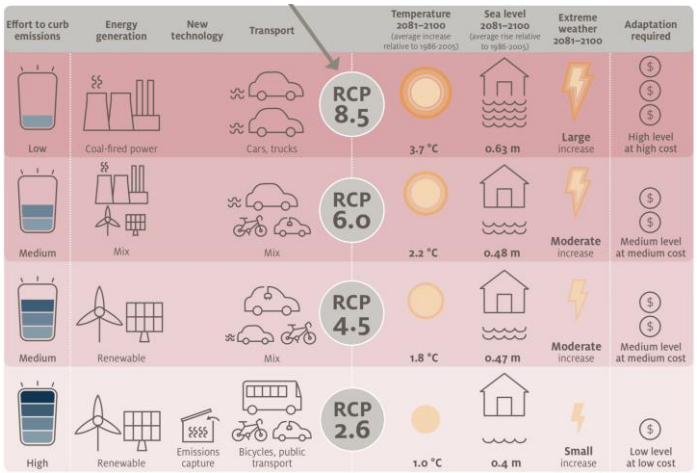
Scientific visualization example



https://www2.cisl.ucar.edu/vislab

7

Infographic example



https://coastadapt.com.au/sites/default/files/infographics/15-117-NCCARFINFOGRAPHICS-01-UPLOADED-WEB%2827Feb%29.pdf

8

Distinctions in terminology

Interchangeable use

- Chart
- Graph
- Plot
- Diagram
- Map (sometimes!)

9

Why visualize data?

'A PICTURE IS WORTH A THOUSAND WORDS'

10

Anscombe's quartet

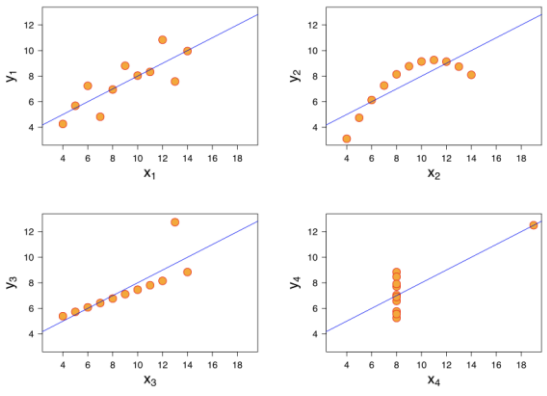
4 datasets with pairs of numbers (*x, y*) that have nearly identical simple descriptive statistics

Property	Value	Accuracy
Mean of *x*	9	exact
Sample variance of *x*	11	exact
Mean of *y*	7.50	to 2 decimal places
Sample variance of *y*	4.125	±0.003
Correlation between *x* and *y*	0.816	to 3 decimal places
Linear regression line	$y = 3.00 + 0.500x$	to 2 and 3 decimal places, respectively
Coefficient of determination of the linear regression	0.67	to 2 decimal places

F. J. Anscombe. Graphs in Statistical Analysis. *American Statistician*, 27(1):17-21, 1973
https://en.wikipedia.org/wiki/Anscombe's_quartet

Anscombe's quartet

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

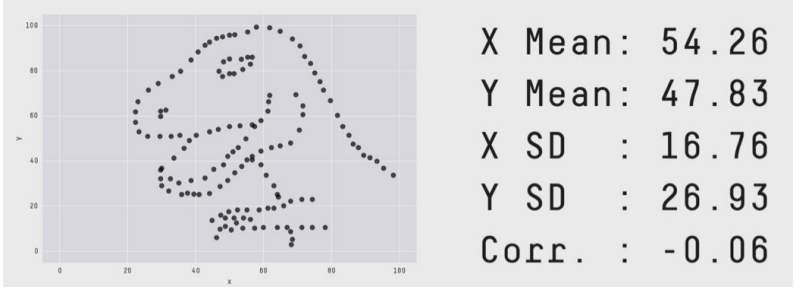


F. J. Anscombe. Graphs in Statistical Analysis. *American Statistician*, 27(1):17-21, 1973
https://en.wikipedia.org/wiki/Anscombe's_quartet

Datasaurus

DrawMyData tool for teaching stats and data science by Robert Grant: http://robertgrantstats.co.uk/drawmydata.html

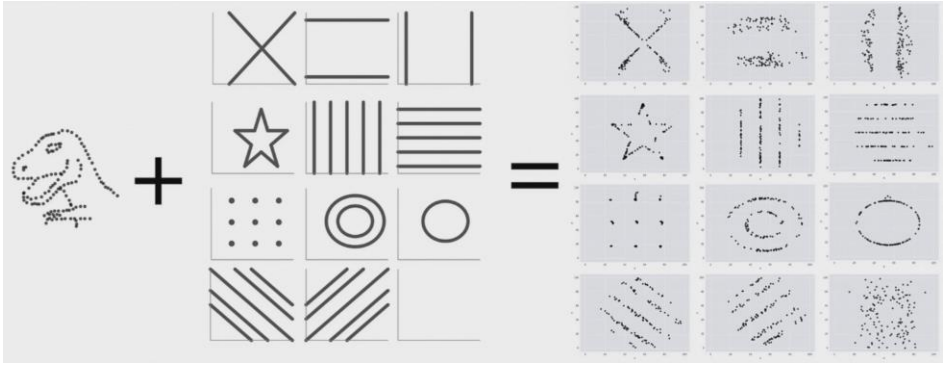
Datasaurus by Alberto Cairo



http://www.thefunctionalart.com/2016/08/download-datasaurus-never-trust-summary.html
https://www.autodeskresearch.com/publications/samestats

13

Datasaurus dozen



Never trust summary statistics alone, always visualize your data

https://www.autodeskresearch.com/publications/samestats

14

Cholera outbreak in London

- In 1854, more than 600 people died of cholera in London's Soho district
- Cause of the disease was unknown at the time
- Two competing theories
  - Cholera is spread by air (predominant)
  - Cholera is spread by water
- Physician John Snow gathered patient data and found the infected water pump
- To convince authorities to close the water pump, he drew a dot distribution map
  - One infected person = one 'dot' (actually short line)
  - Denoted the locations of the water pumps

15

Cholera outbreak in London

Cholera cases clustered around a public water pump on Broad Street

Jo(h)n Snow saved the day!

https://en.wikipedia.org/wiki/File:Snow-cholera-map-1.jpg

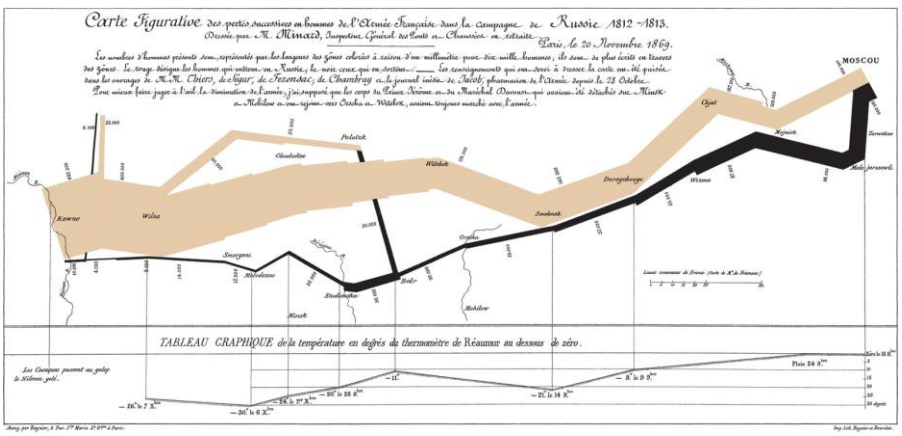
16

Historical Visualizations

https://medium.com/nightingale/historicdv/home

17

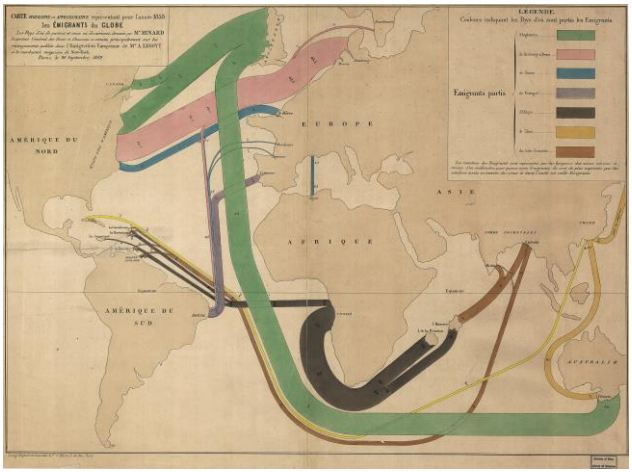
Napoleon's Russian campaign of 1812



C. J. Minard. *Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie*, 1812–1813, 1869.

18

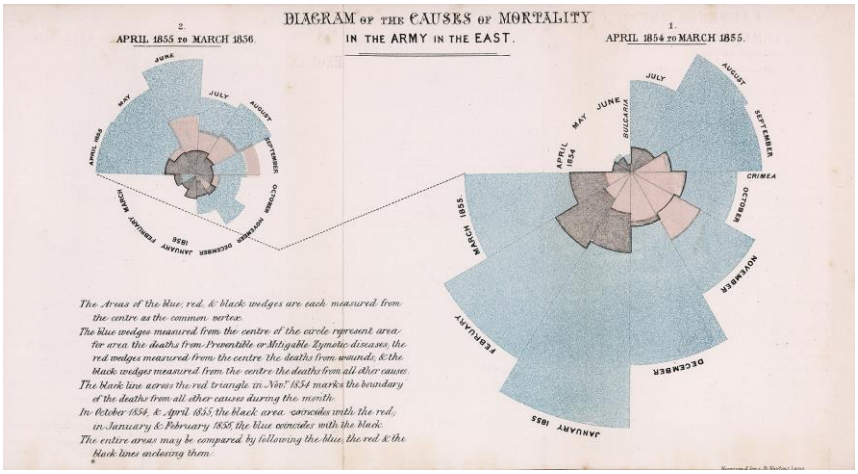
Immigration patterns



C. J. Minard. *Les Émigrants du Globe*, 1858.

19

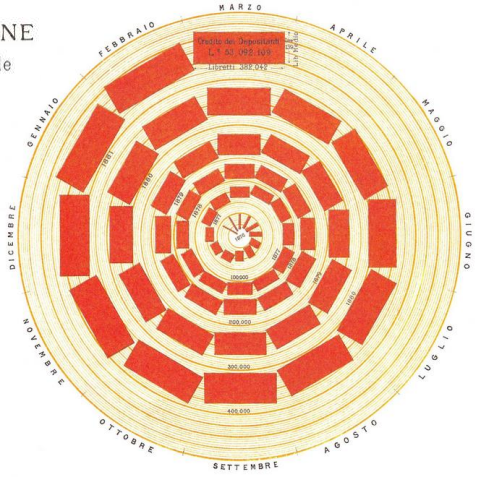
Causes of mortality in the army in the East



20

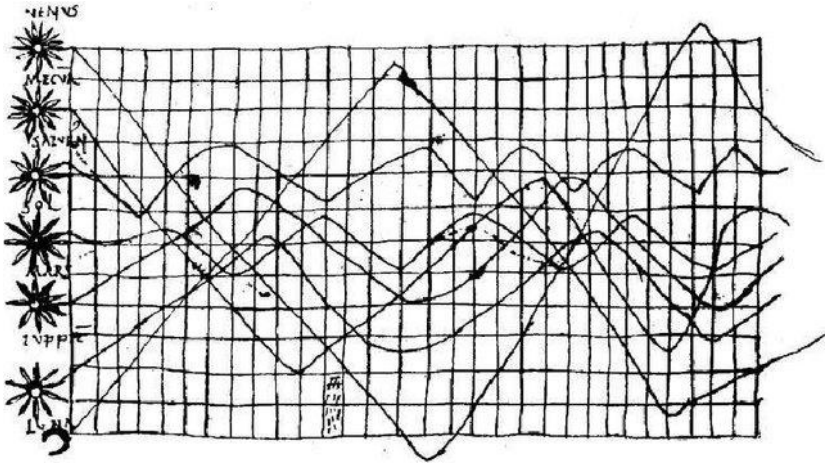
Italian postal savings

CASSE POSTALI DI RISPARMIO ITALIANE
Numero dei Libretti, Libretto medio e Deposito totale
al fine di ogni mese



A. Gabaglio. *Teoria Generale della Statistica*, 1888. 21

Planetary movements



M. Friendly. A Brief History of Data Visualization, *Handbook of Computational Statistics: Data Visualization*, 2006. 22

Purposes of data visualization

Analyze data to support reasoning
- Develop and assess hypotheses
- Discover errors in data
- Find patterns and correlations

Communicate information to others
- Present an argument or tell a story
- Inspire

23

The three principles of good visualization design

24

Good visualization design is

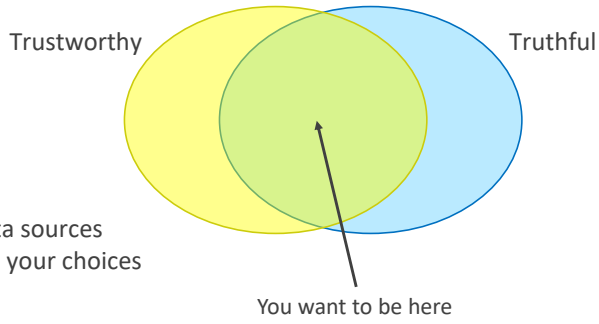
1. Trustworthy

2. Accessible

3. Elegant

Trustworthiness

Trust ≠ truth



Trustworthiness

Lying with visualization is easy

Intentionally and unintentionally

27

How charts lie?

Dubious data

Misrepresenting data

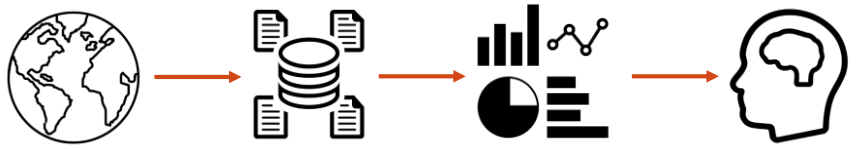
Cherry-picking data

Ignoring uncertainty

Confirmation bias

28

How charts lie?



Dubious data

Misrepresenting data

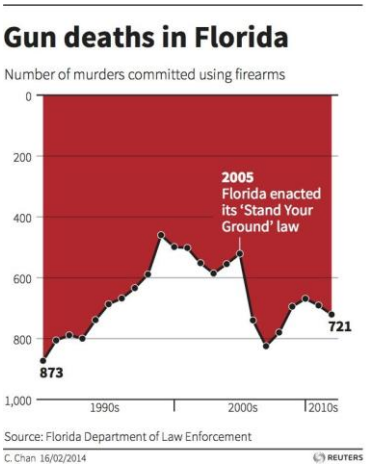
Cherry-picking data

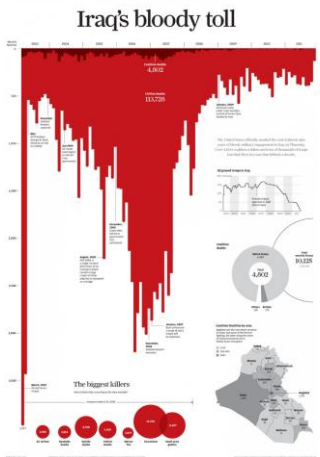
Ignoring uncertainty

Confirmation bias

29

Inverted y axis





http://www.businessinsider.com/gun-deaths-in-florida-increased-with-stand-your-ground-2014-2
http://www.scmp.com/infographics/article/1284683/iraqs-bloody-toll

30

Good visualization design is

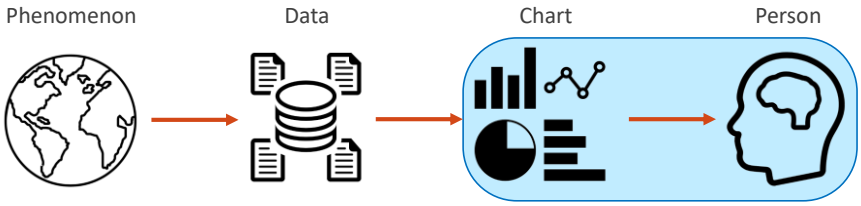
1. Trustworthy

2. Accessible

3. Elegant

A. Kirk. *Data Visualization*, SAGE Publications, 2016. 31

Accessibility



There should be no obstacles between the visualization and the person that tries to understand it

Make design choices that facilitate understanding

32

An accessible visualization

- Is tailored to the audience (their needs, expectations, expertise)

Data visualization is like family photos. If you don't know the people in the picture, the beauty of the composition won't keep your attention.

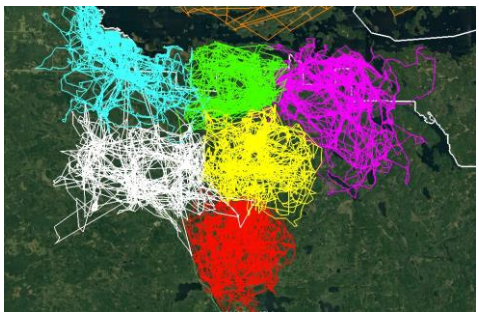
Zach Gemignani, CEO/Founder of Juice Analytics

33

An accessible visualization

- Is tailored to the audience (their needs, expectations, expertise)
- Is appropriate for the given format (print, presentation, online, …)
- Is appropriate for the given data (type and values)

Movement of wolves



https://earthlymission.com/gps-tracking-shows-how-much-wolf-packs-avoid-each-others-range/ 34

An accessible visualization

- Is tailored to the audience (their needs, expectations, expertise)
- Is appropriate for the given format (print, presentation, online, …)
- Is appropriate for the given data (type and values)
- Addresses a specific task (or tasks)
- Contains the appropriate amount of detail (clarity, not simplicity)
- Takes into account human visual processing abilities
  - Is mindful of the choice of color (and other channels)
  - Uses annotations
- Minimizes clutter ('chart junk')

35

Data-ink ratio

Above all else, show the data

Edward Tufte

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

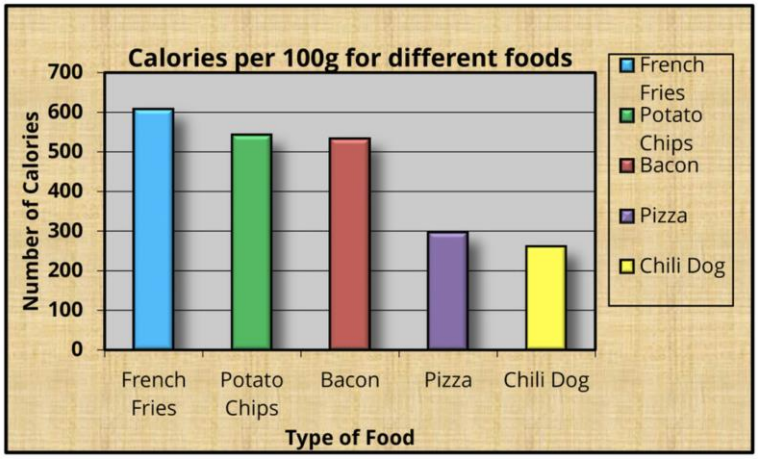
$$= \text{proportion of a graphic's ink devoted to the non-redundant display of data-information}$$

$$= \text{1.0 – proportion of a graphic that can be erased}$$

https://infovis-wiki.net/wiki/Data-Ink_Ratio

36

Remove 'chart junk'



https://www.darkhorseanalytics.com/blog/data-looks-better-naked 37

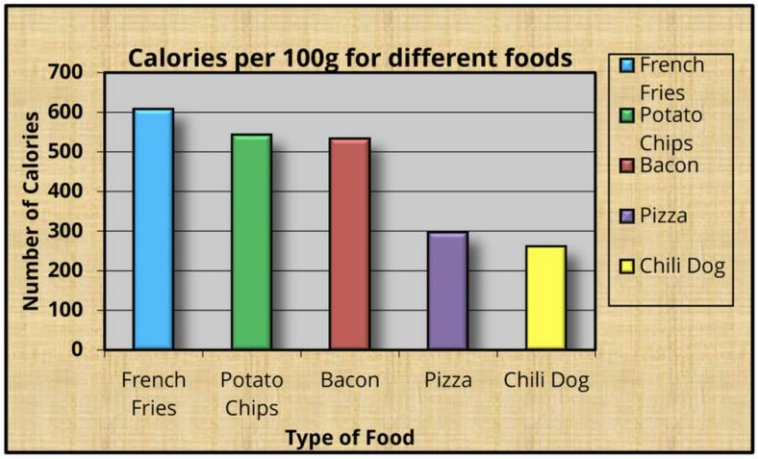
Remove 'chart junk'

Remove
to improve
(the **data-ink** ratio)

Created by Darkhorse Analytics www.darkhorseanalytics.com

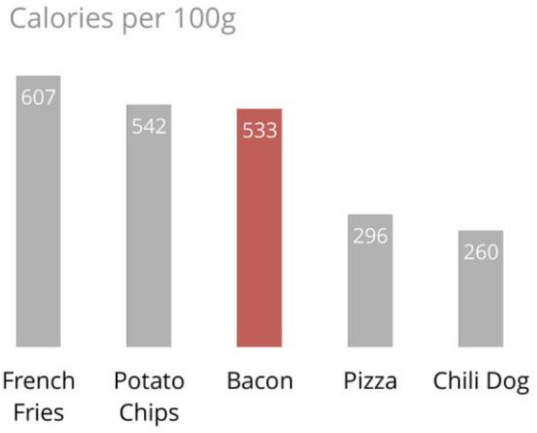
https://www.darkhorseanalytics.com/blog/data-looks-better-naked 38

Remove 'chart junk' – before



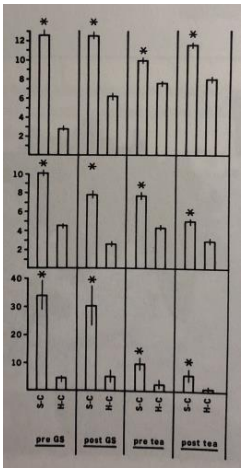
https://www.darkhorseanalytics.com/blog/data-looks-better-naked 39

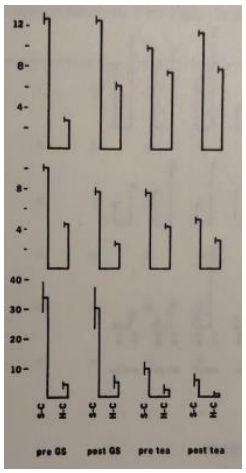
Remove 'chart junk' – after



https://www.darkhorseanalytics.com/blog/data-looks-better-naked 40

Going too far?





Minimalism relies on some familiarity of the concepts used (previous knowledge)

E. R. Tufte. *The Visual Display of Quantitative Information*. Graphics Press, Cheshire, 2015 41

Using uncommon charts

Use an uncommon chart only if it shows something that the more common ones cannot

Always have in mind the trade-off between getting the message through and spending time to explain the more 'complex' chart

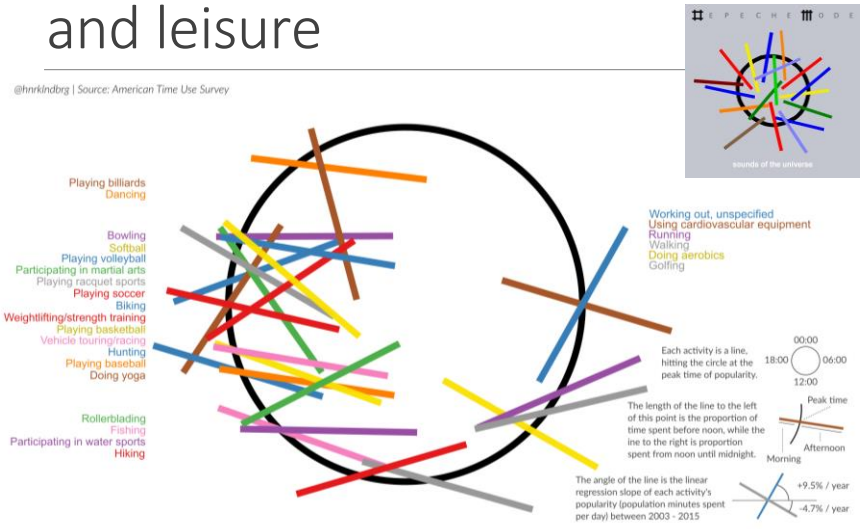
42

Peak time of day for sports and leisure

https://github.com/halhen/viz-pub/tree/master/sports-time-of-day

43

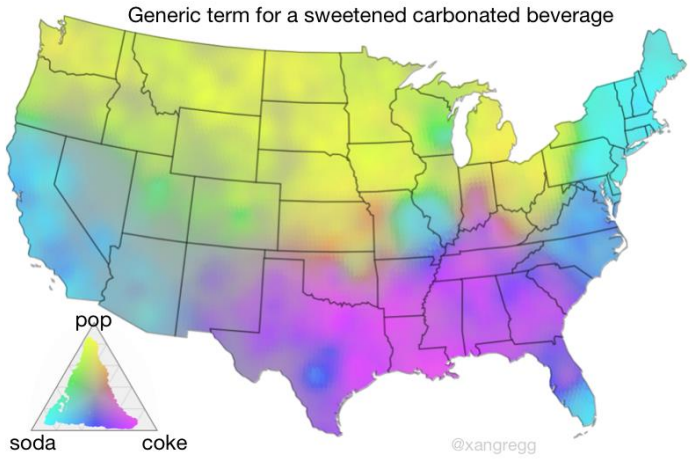
Peak time of day for sports and leisure



https://github.com/halhen/viz-pub/tree/master/sports-depeche-plot

44

Soda/coke/pop map

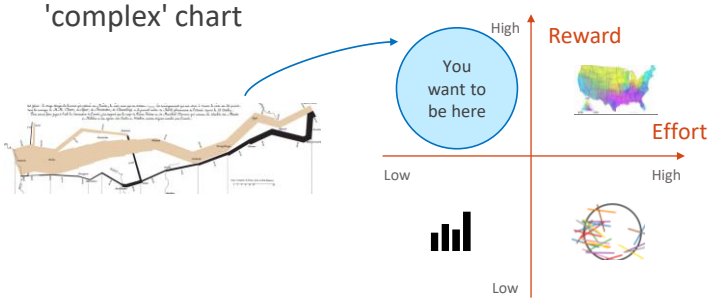


https://www.reddit.com/r/dataisbeautiful/comments/99rgnm/sodapopcoke_map_with_a_trivariate_color_encoding/

Using uncommon charts

Use an uncommon chart only if it shows something that the more common ones cannot

Always have in mind the trade-off between getting the message through and spending time to explain the more 'complex' chart



Good visualization design is

1. Trustworthy

2. Accessible

3. Elegant

Elegance

Don't make something unless it is both made necessary and useful; but if it is both necessary and useful, don't hesitate to make it beautiful.

Shaker dictum

Good design is as little design as possible

Rams' principle

Be inspired

Information is beautiful awards

Visualizing data (best of …)

New York Times' Graphics

Washington Post

Guardian's interactives

FiveThirtyEight

r/dataisbeautiful subreddit

49

Don't get overwhelmed

The best visualizations take weeks of effort by multiple people – you are not expected to perform at that level

Keep in mind what is important:

1. Trustworthiness
2. Accessibility
3. Elegance (if there's time)

50