

COMP9321: **Data services engineering**

Term1, 2023

**Week 3: Data Visualisation
(Principles and Basic Techniques)**

Early Babylonian world map (600 BC)



These concentric circles that represent the ocean, named “bitter water” or the “salt sea.”

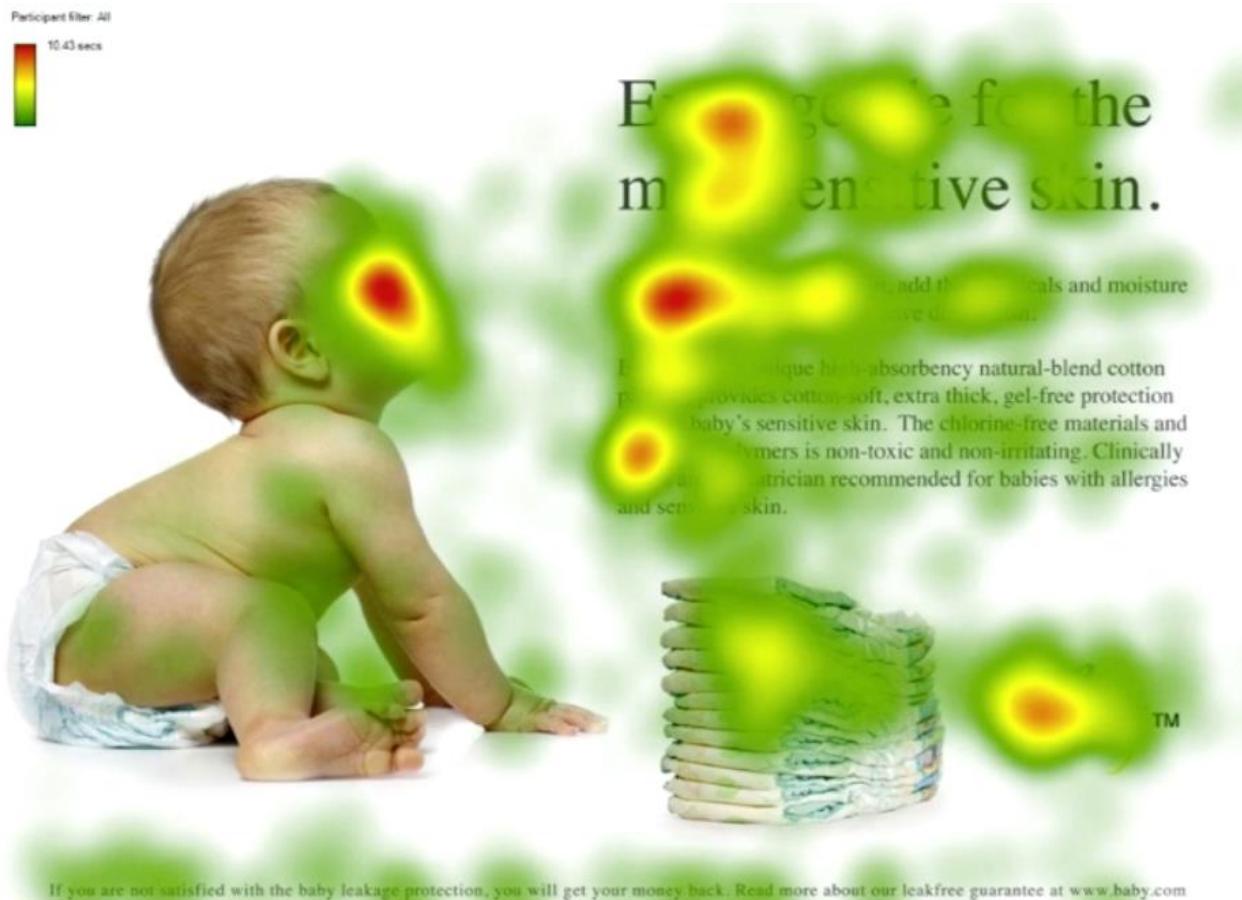
an early interpretation of the layout of the world

Network Attacks



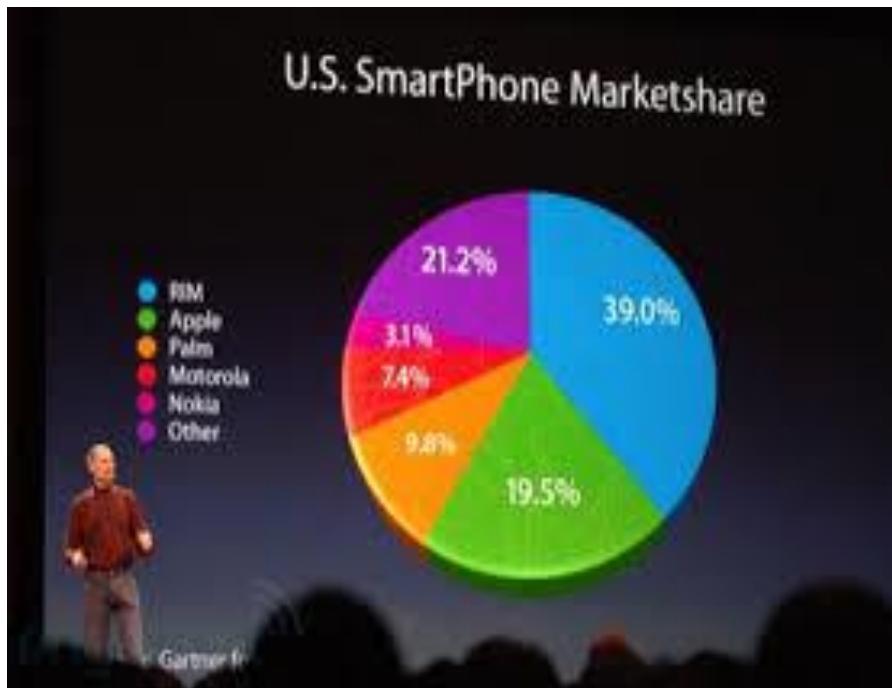
Visualisation isn't just about graphics

Highly competent visualisation “tricks” can affect what you see and what you pay attention to:



When Steve Jobs says ...

- Again ... playing with human visual perception
- 21.2% versus 19.5% slices of the pie



Apple SmartPhone Market Update, Macworld keynote (2008)

In this lecture ...

Often, visualization is considered highly specialized area and getting it right takes skilled knowledge from multi disciplinary areas (statistics, graphic design, understanding of human perception of visual elements, or sometimes understanding of human psychology)

In most cases, the topic will be a course by itself...

Of course, we cannot get to that level of details here ... But if you are doing some data analysis or writing an application that is data-driven, most likely you'd run into some visualization tasks.

What I intend to convey in this lecture is two parts:

First : the basic principles of 'good and competent' visualization

Second: Introduction to Matplotlib library, we actually get to see the basic building blocks of visualization techniques which are useful for further exploration of the area if you are interested ...

Presentation as a service

Of course, there is another important point to make.

Once you know how to visualise data, what comes naturally after that is to offer that knowledge as a service (API)

It's known as "Presentation" or "Visualisation" as a service.

"Visualisation on the Cloud"

- e.g., <https://www.highcharts.com>
- e.g., Google Map (good example of presentation as a service)
- On request, its response can contain either "presentation logic + data", or already visualised data in graphics/HTML

So for this course context, the concept of "presentation as a service" is more interesting than the visualisation techniques themselves.

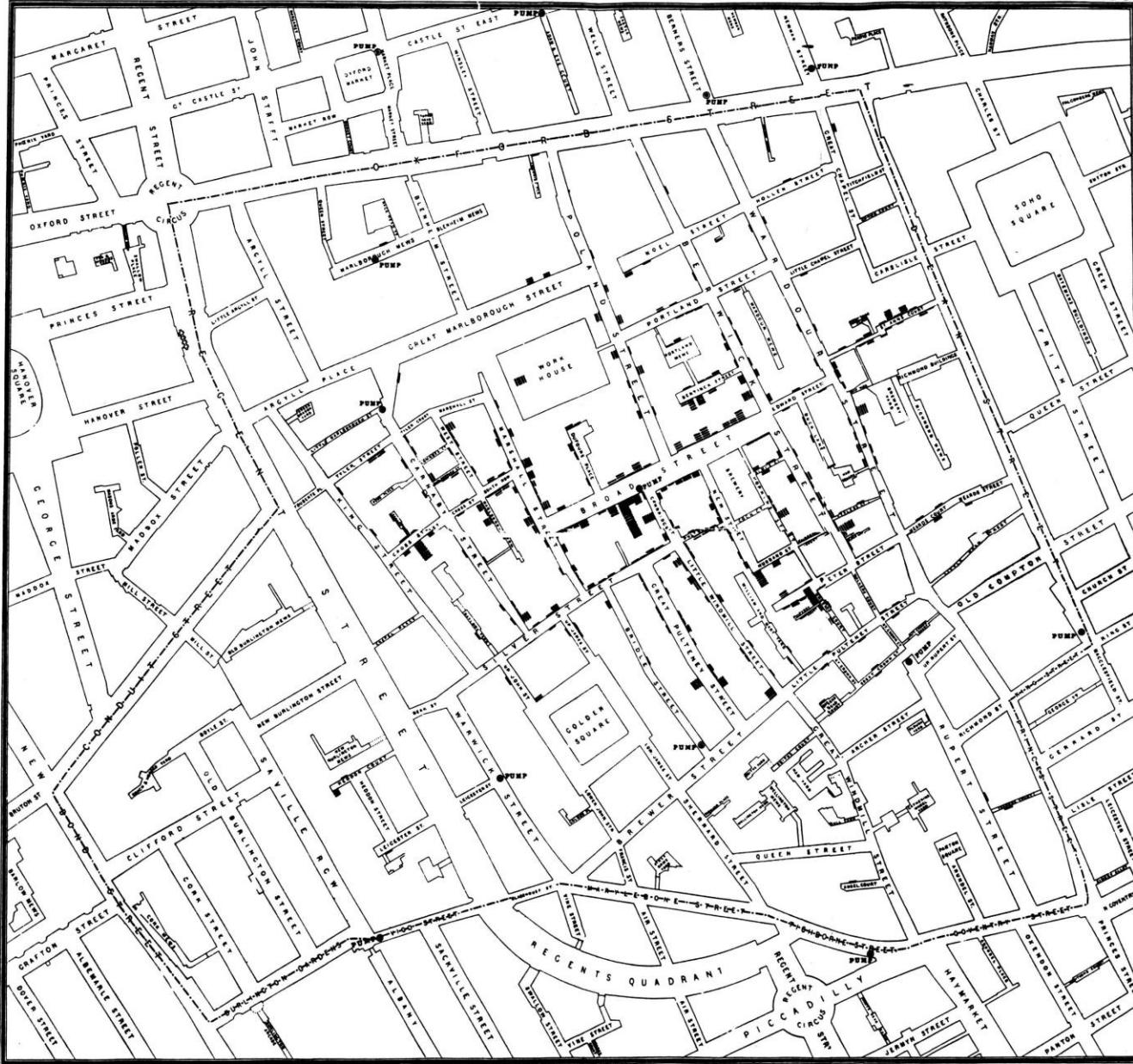
What is Data Visualization

Data visualization is the process of converting raw data into easily understood pictures of information that enable fast and effective decisions.

The study of visual representations of data to reinforce human cognition.

“Help people understand the, structure, relationships meaning in data.”

Techniques: Charts, Graphs, Maps



What is Visualisation

Visualization transforms data into images that effectively and accurately represent information about the data.

Insight

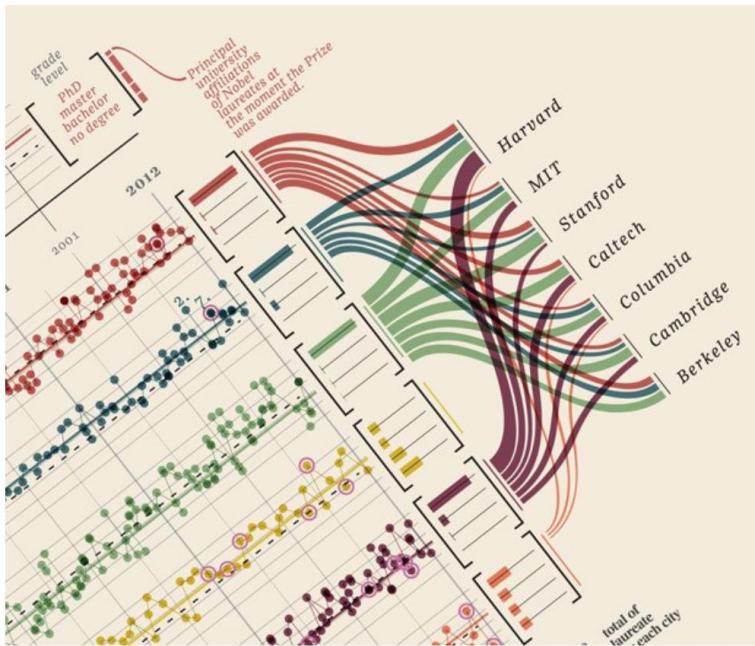
What is visualisation

Three types of goals for visualization – ... to explore

Nothing is known ... Visualisation is used for data exploration/discovery ...

e.g., A Visual History of Nobel Prizes and Notable Laureates, 1901-2012

<https://www.brainpickings.org/2012/11/29/giorgia-lupi-noble-prizes-visualization/>

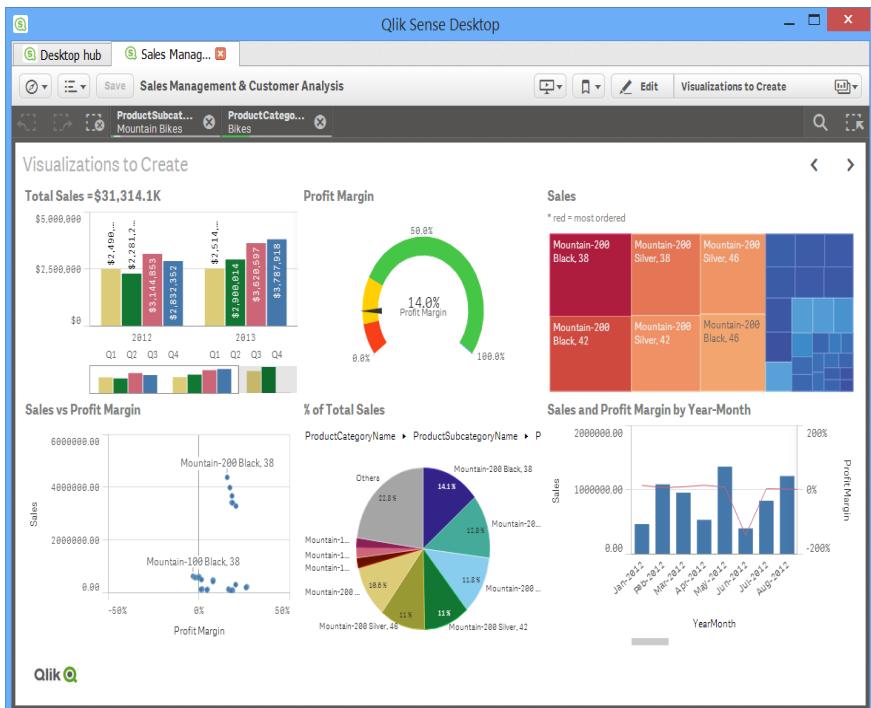
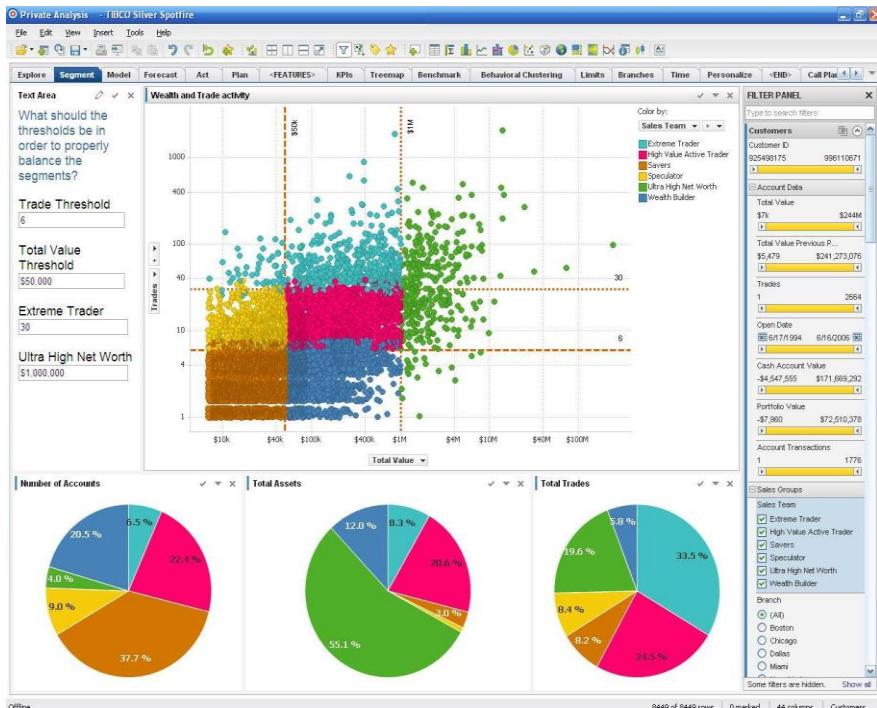


What is visualisation

Three types of goals for visualization – ... to analyse

You have some hypotheses. Visualisation is used for Verification or Falsification

You'd normally use what is classified as “data analysis and visualisation” tools (- a range of data source connectivity, built-in quick visualisation graphs, etc.)



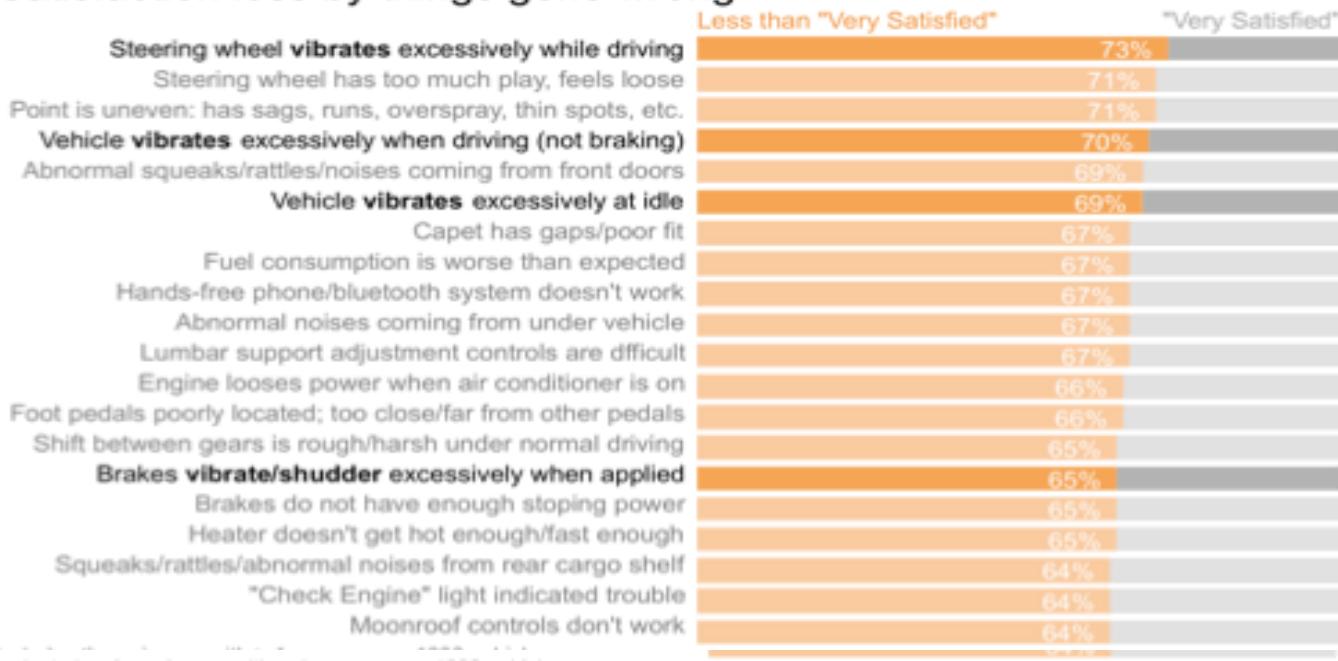
What is visualisation

Three types of goals for visualization – ... to explain

You do know what the data contains ... Visualisation is used for “effective” communication of “results” – Making them clear for the audience

Comment about **vibration**...

Satisfaction loss by things gone wrong



Data Visualisation

Referring to any visual representation of data that is:

- algorithmically drawn (may have custom touches but is largely rendered with the help of computerized methods);
- easy to regenerate with different data (the same form may be repurposed to represent different datasets with similar dimensions or characteristics);
- often aesthetically simple (data is not decorated); and
- relatively data-rich (large volumes of data are welcome and viable, in contrast to infographics).

Anatomy of A Visualization

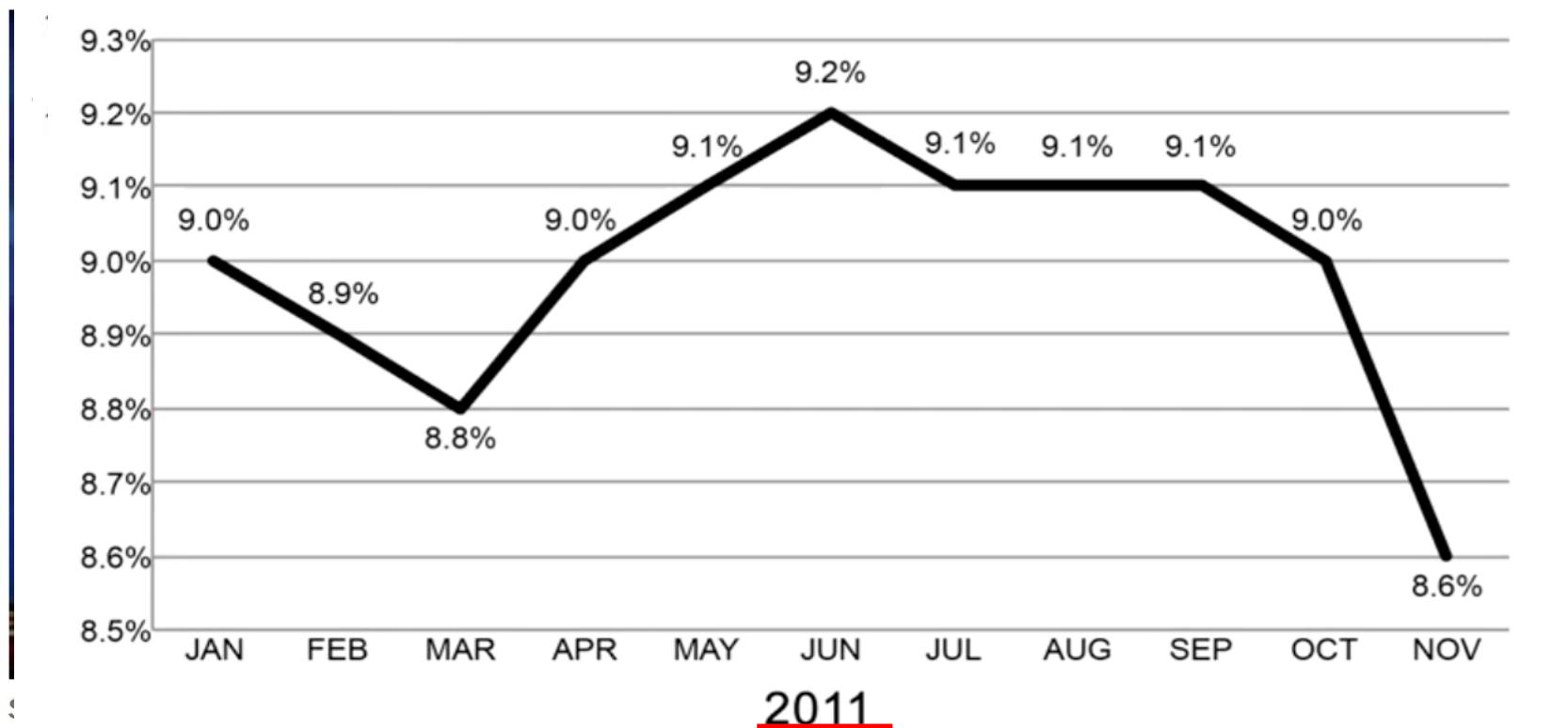
1. Title
2. X-Axis
3. Y-Axis
4. Series
5. Data Points



So what makes a good visualisation

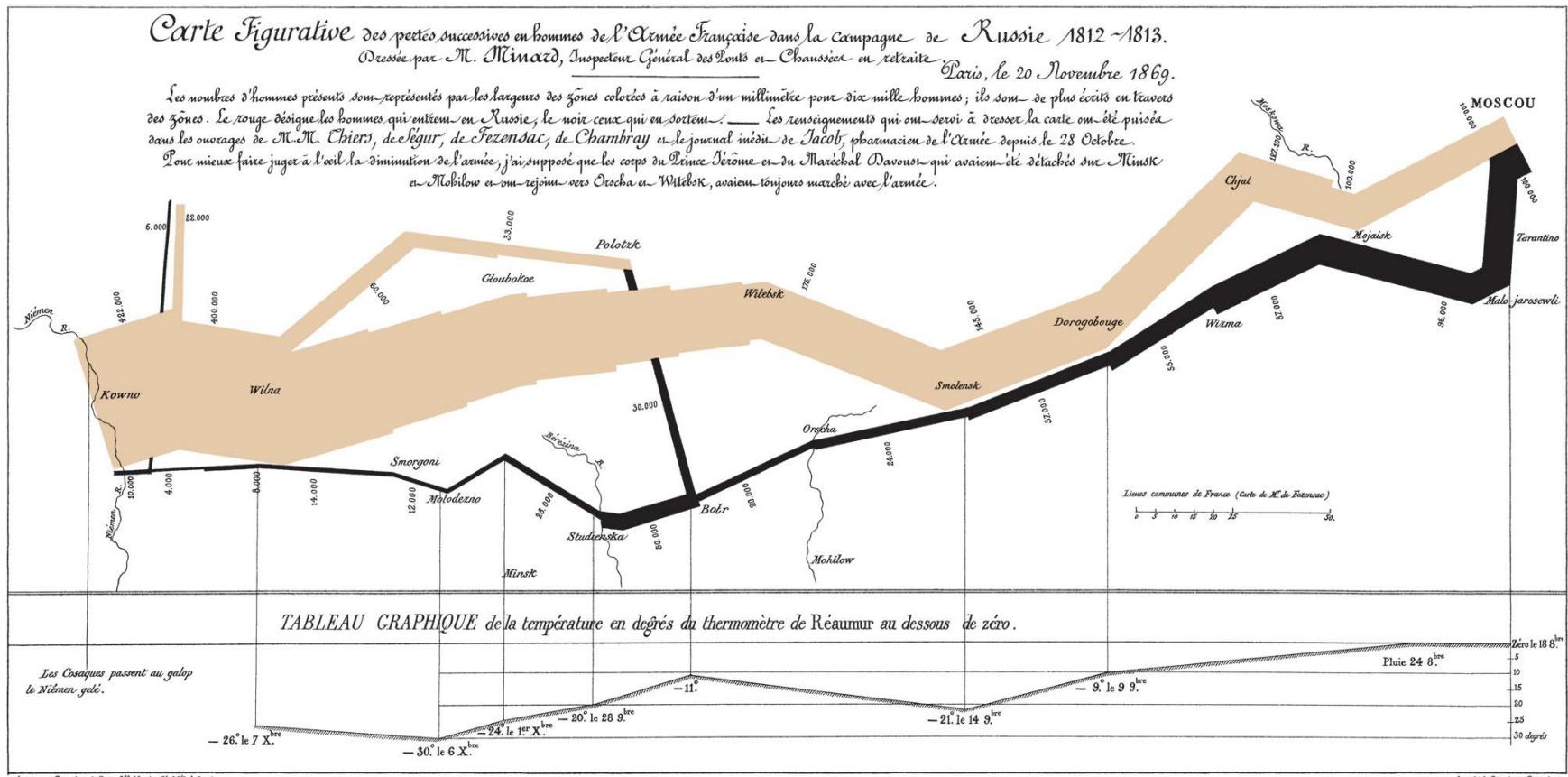
Accuracy, Story, Knowledge: Aim to create a visualisation that are accurate, tell a good story, and provide real knowledge to the audience.

The Unemployment Rate Under President Obama



So what makes a good visualisation

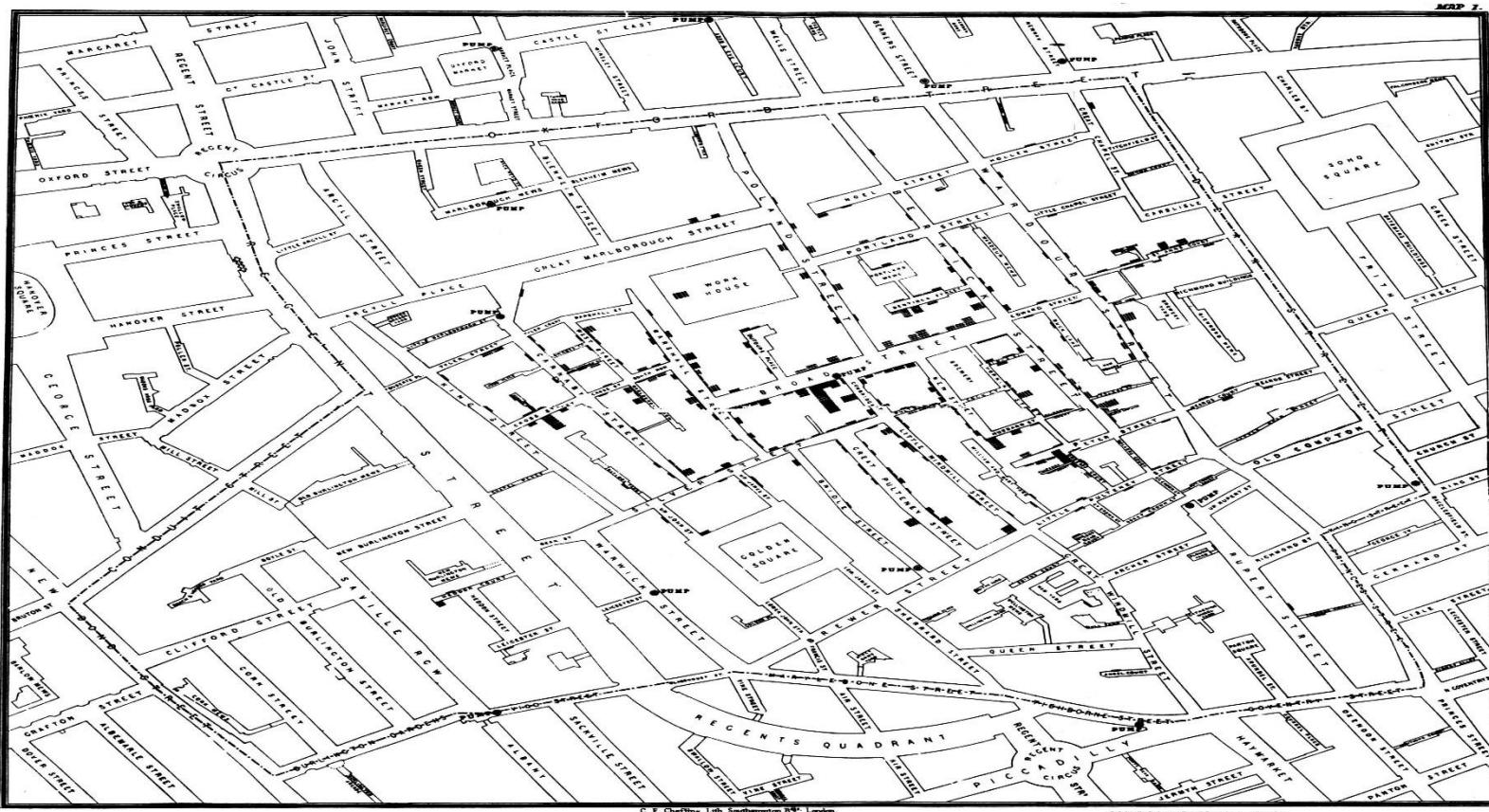
Accuracy, **Story**, Knowledge: Aim to create a visualisation that are accurate, tell a good story, and provide real knowledge to the audience.



The Minard Map - "The best statistical graphic ever drawn"

So what makes a good visualisation

Accuracy, Story, **Knowledge**: Aim to create a visualisation that are accurate, tell a good story, and provide real knowledge to the audience.

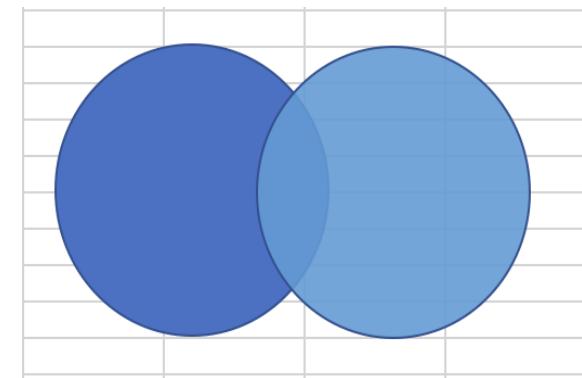
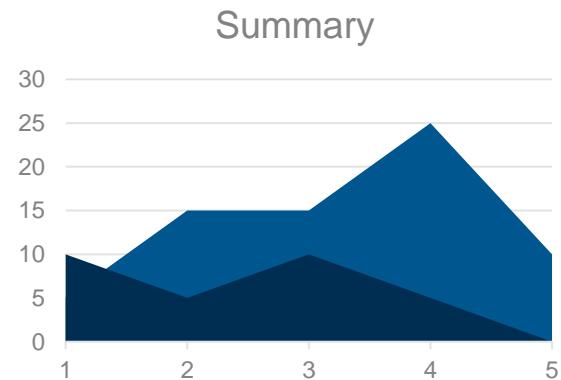
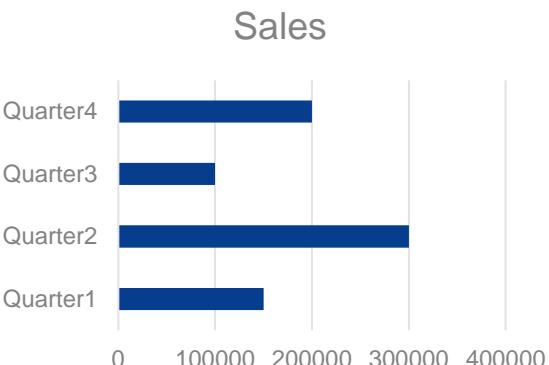
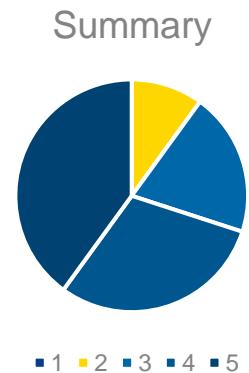


Widely attributed to creating the field of Epidemiology

Some of the basics ... “Charts vs. Graphs”

Often used interchangeably, but they are different in terms of the “visualisation techniques involved”.

	Lights	Desk	Table	Monitor
Exhibit 1	x	✓	x	x
Exhibit 2	✓	✓	✓	x
Exhibit 3	✓	x	x	✓
Exhibit 4	✓	✓	✓	✓
Exhibit 5	✓	✓	x	x
Exhibit 6	x	x	x	✓
Exhibit 7	✓	✓	x	✓
Exhibit 8	✓	x	✓	x
Exhibit 9	✓	x	✓	x
Exhibit 10	✓	✓	x	x
Exhibit 11	✓	✓	x	✓
Exhibit 12	✓	x	✓	✓
Exhibit 13	x	x	x	x



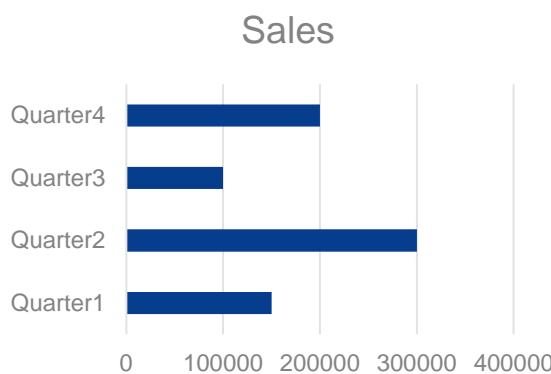
Some of the basics ... “Charts vs. Graphs”

	Lights	Desk	Table	Monitor
Exhibit 1	X	✓	X	X
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Exhibit 3	✓	X	X	✓
Exhibit 4	✓	✓	✓	✓
Exhibit 5	✓	✓	X	X
Exhibit 6	X	X	X	✓
Exhibit 7	✓	✓	X	✓
Exhibit 8	✓	X	✓	X
Exhibit 9	✓	X	✓	X
Exhibit 10	✓	✓	X	X
Exhibit 11	✓	✓	X	✓
Exhibit 12	✓	X	✓	✓
Exhibit 13	X	X	X	X

Both rely on an established, repeated pattern to show data

e.g., Bar: repeating equal width rectangles along a scale of information

e.g., Comparison Chart: repeating Tick/Cross along a scale of information



Graphs: rely on X or Y or both axes to make sense. At least one of these axes is numeric. Graph draws correlation between these axes by plotting points along the grid

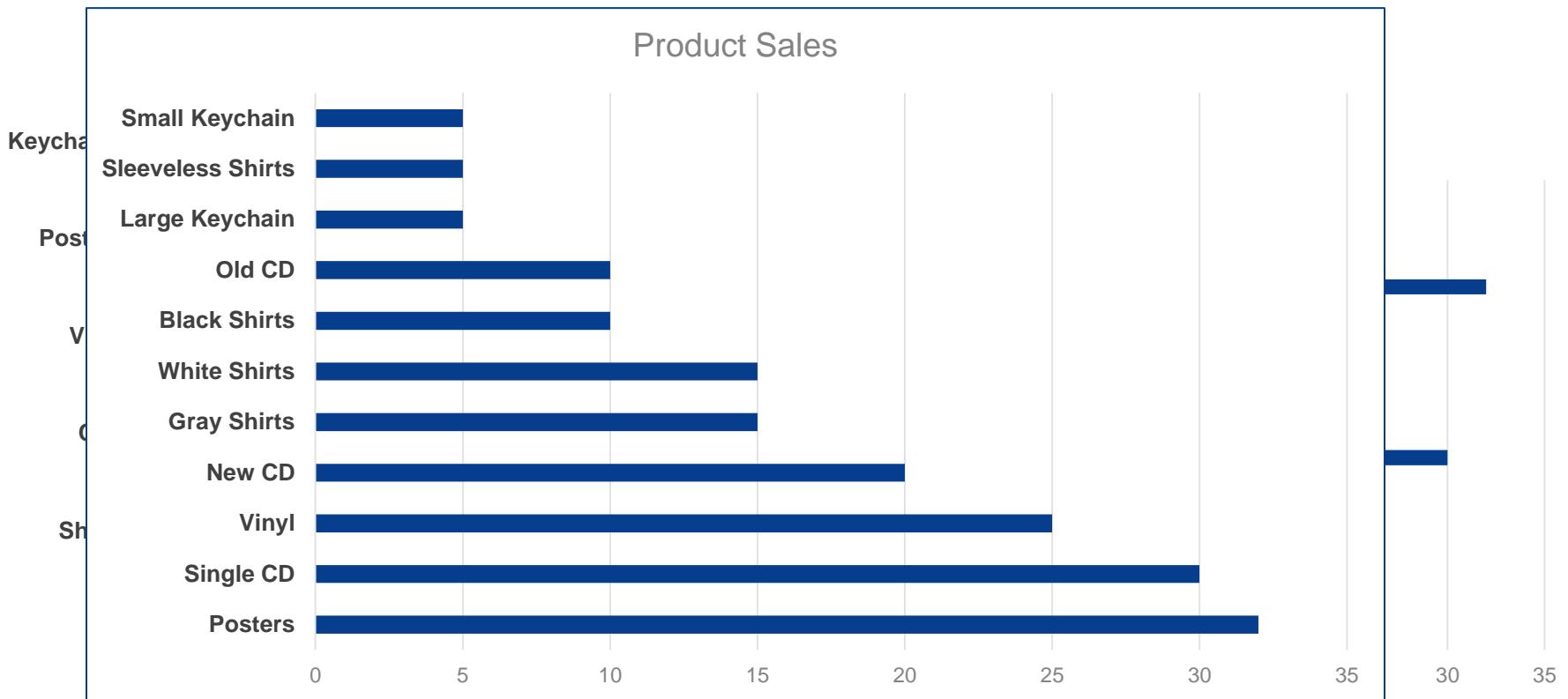
Charts: not restricted by X/Y axes, not necessarily numerical

Which ones are charts? Which ones are graphs?

Some of the basics ... Organising data

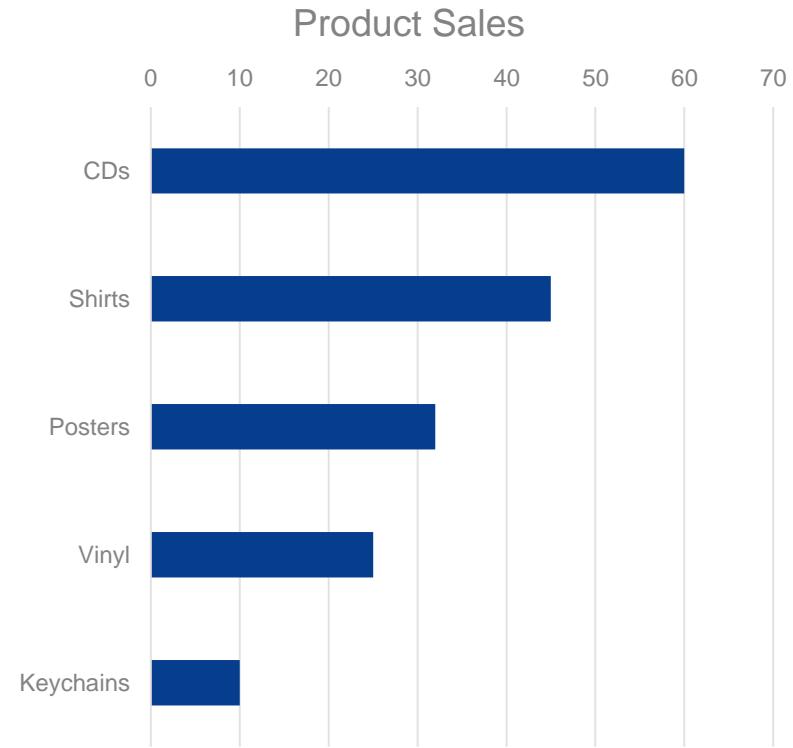
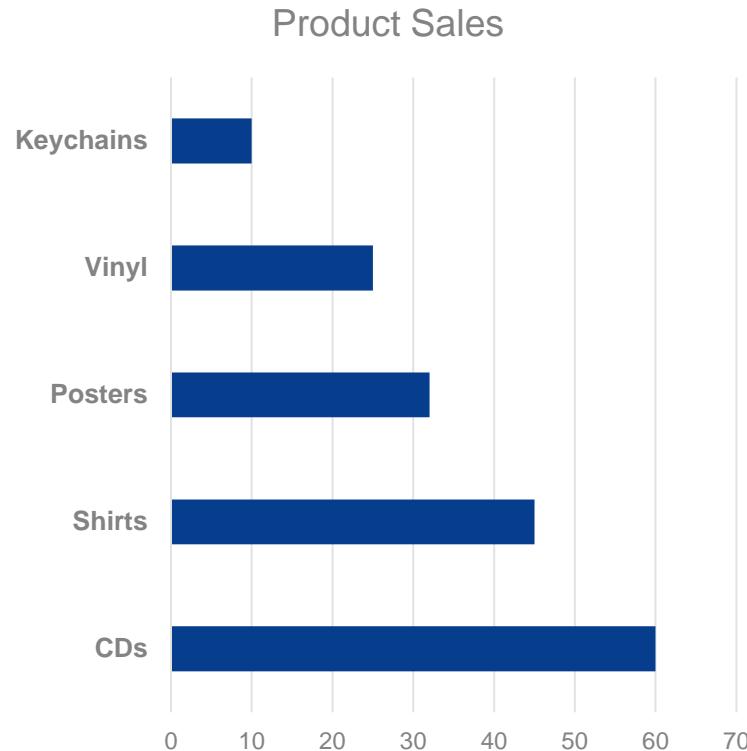
Imagine a merchandise sales figure by an artist:

T-shirts: 45, CD: 60, Vinyl: 25, Posters: 32, Keychains: 10



Some of the basics ... Organising data

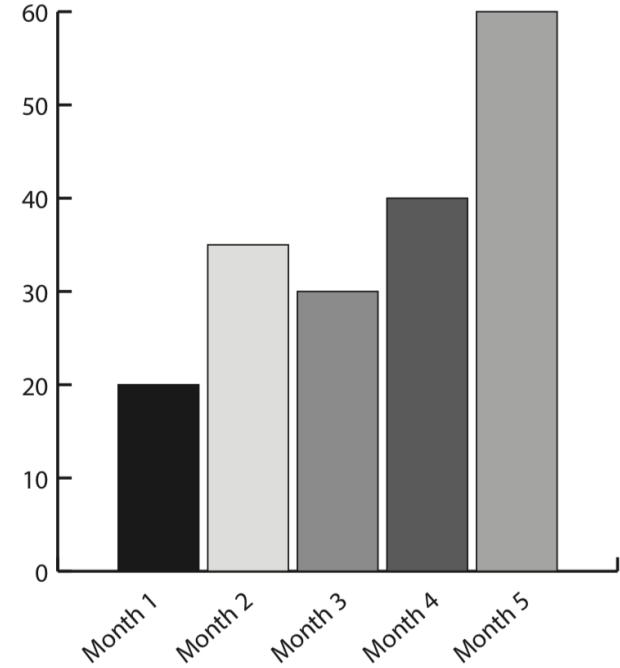
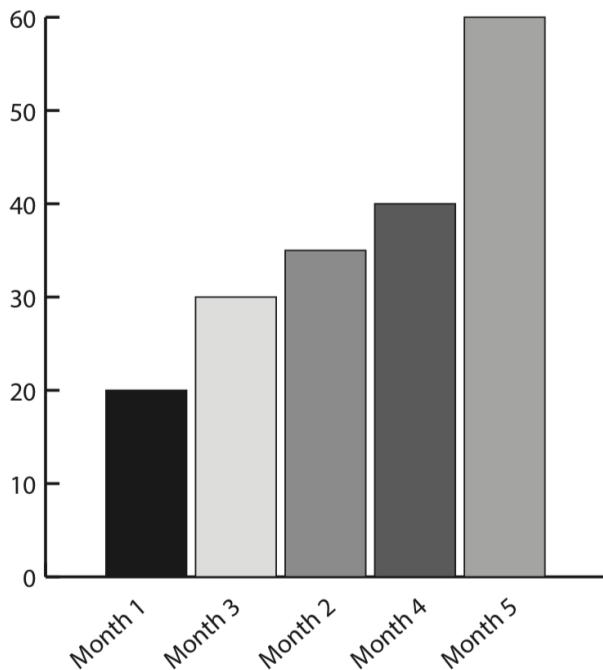
When possible always order the data ... but perception could be also tricky ...



Subjective interpretation: most people read left to right ...

Some of the basics ... Organising data

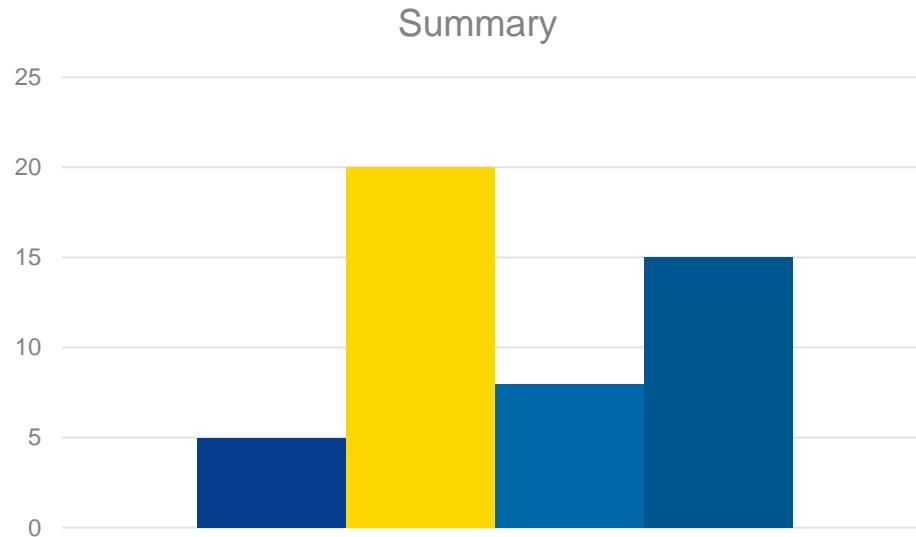
When possible always order the data ... but perception could be also tricky ...



When a line follows a "timeline", stick to the timeline ...

Some of the basics ... Colours important

Putting “Form (Prettiness)” before “Function”



Lots of colours could be confusing,
distracting from the information

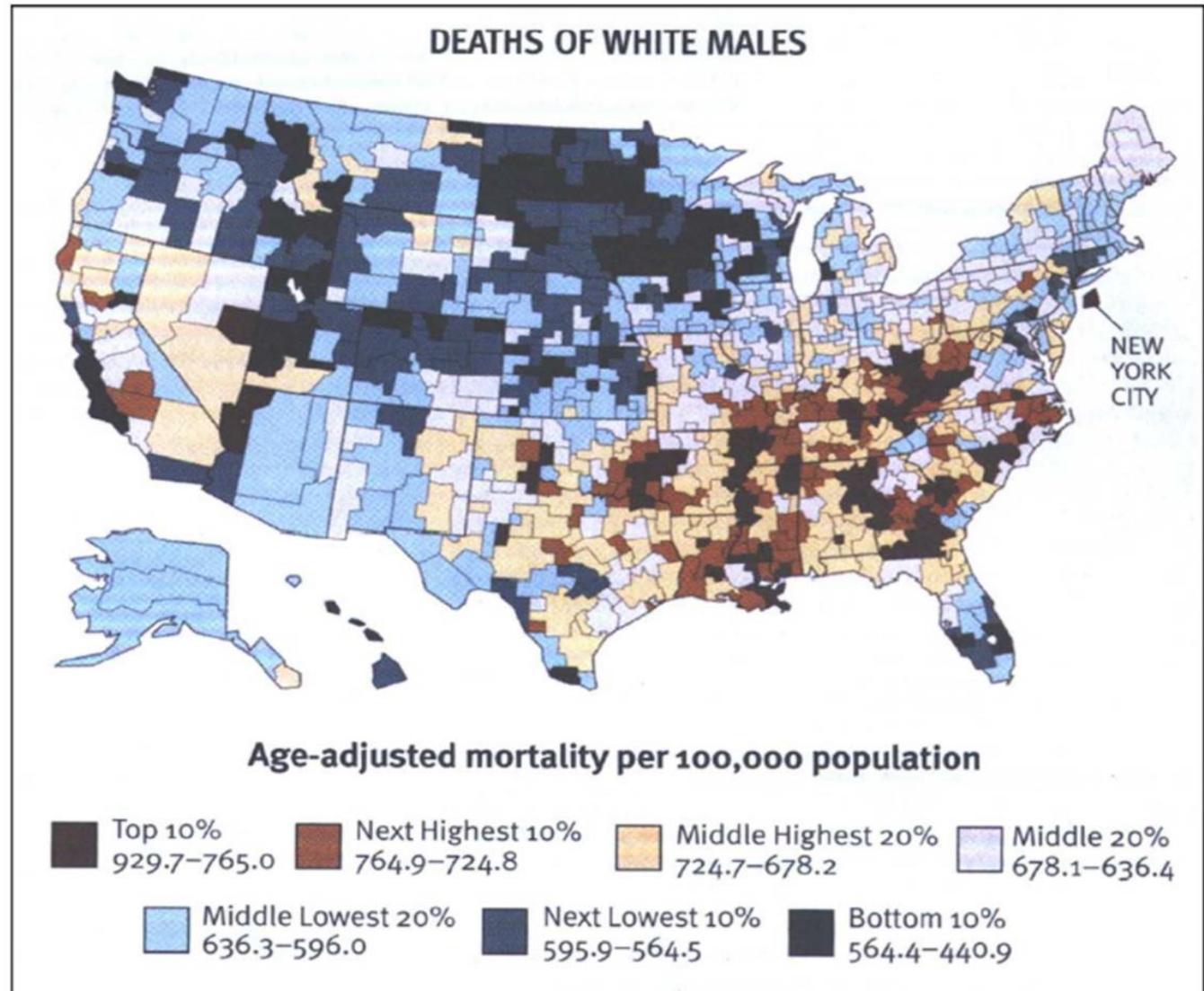
Just because you have millions of colors to
choose from

doesn't mean you must use them all ...

Some of the basics ... Colours important

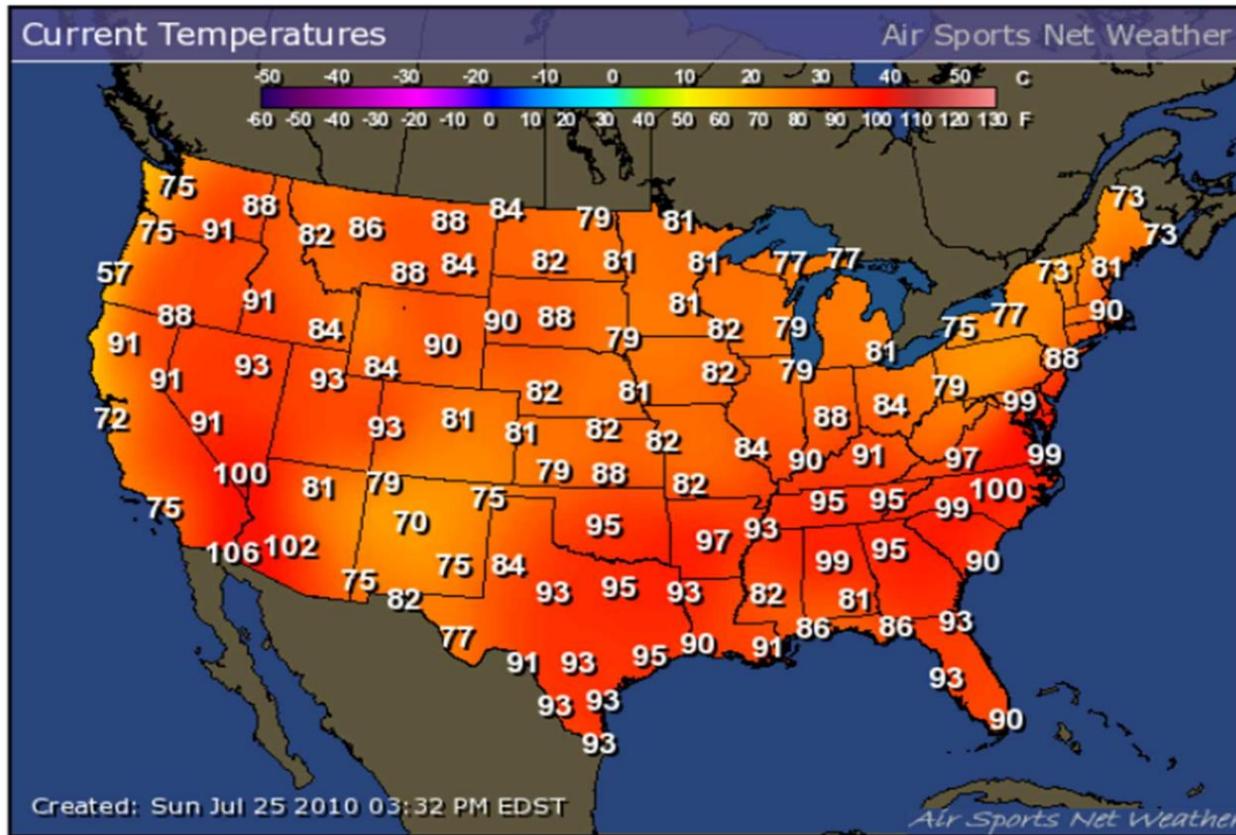
Not just about limiting
colours ...

What's wrong with this
colour map?



Some of the basics ... Colours important

**Not a bad choice of color scale,
but the Dynamic Range needs some work**



Some of the basics ... Colours important

Common advice on using colours:

most people have strong association with pre-established colour meanings. Don't go against them.

Red

Stop
Off
Dangerous
Hot
High stress
Oxygen
Shallow
Money loss

Green

On
Plants
Carbon
Moving
Money

Blue

Cool
Safe
Deep
Nitrogen

Some of the basics ... Colours important

Just to make things interesting Colour alone is not the whole picture.

I sure hope that my
life does not depend
on being able to read
this quickly and
accurately!

Some of the basics ... Colours important

What about correct contrast choice?

I would prefer that
my life depend on
being able to read *this*
quickly and
accurately!

Some of the basics ... Colours important

Colour blindness is more common than we think ... (close to 10% of generic population)



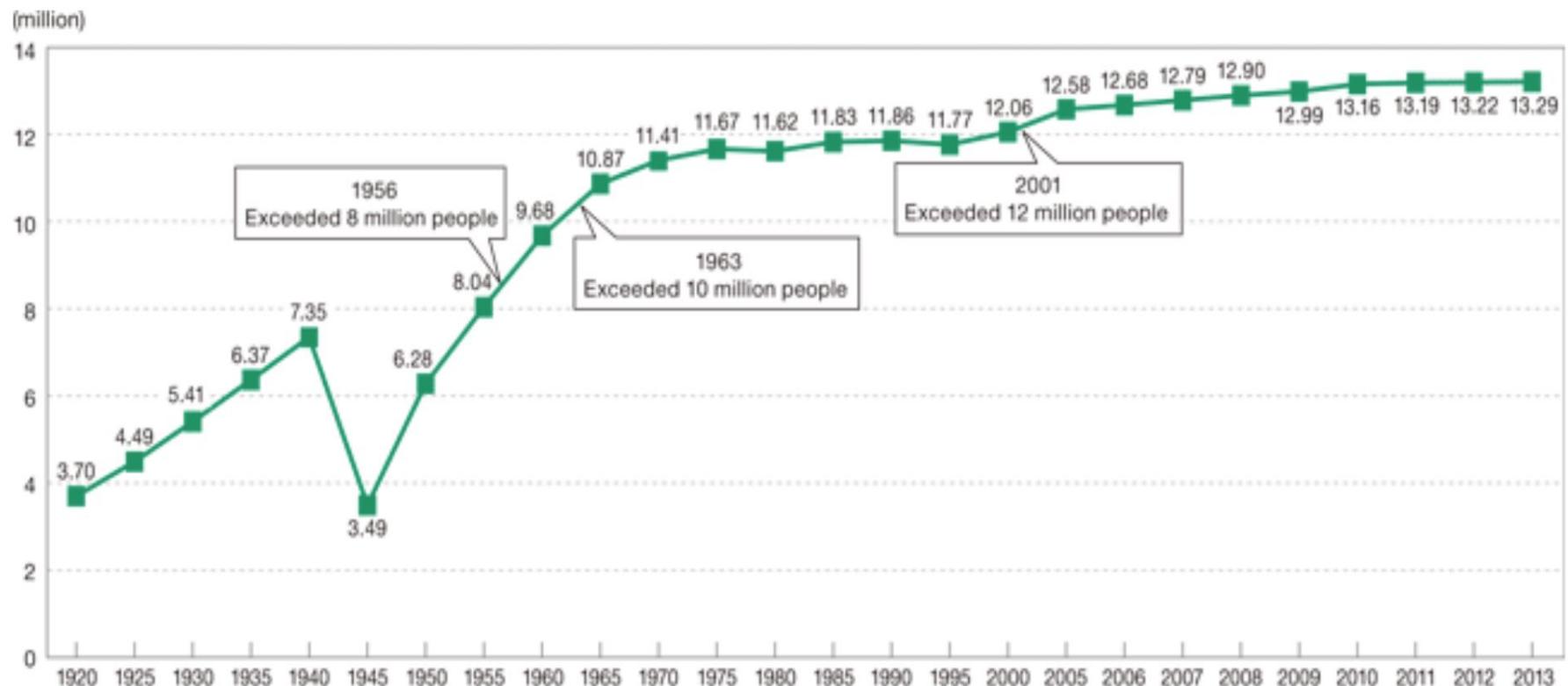
There are resources you could utilise:

e.g., <http://colorbrewer2.org/>

Tips on increasing accessibility of your visualisation:

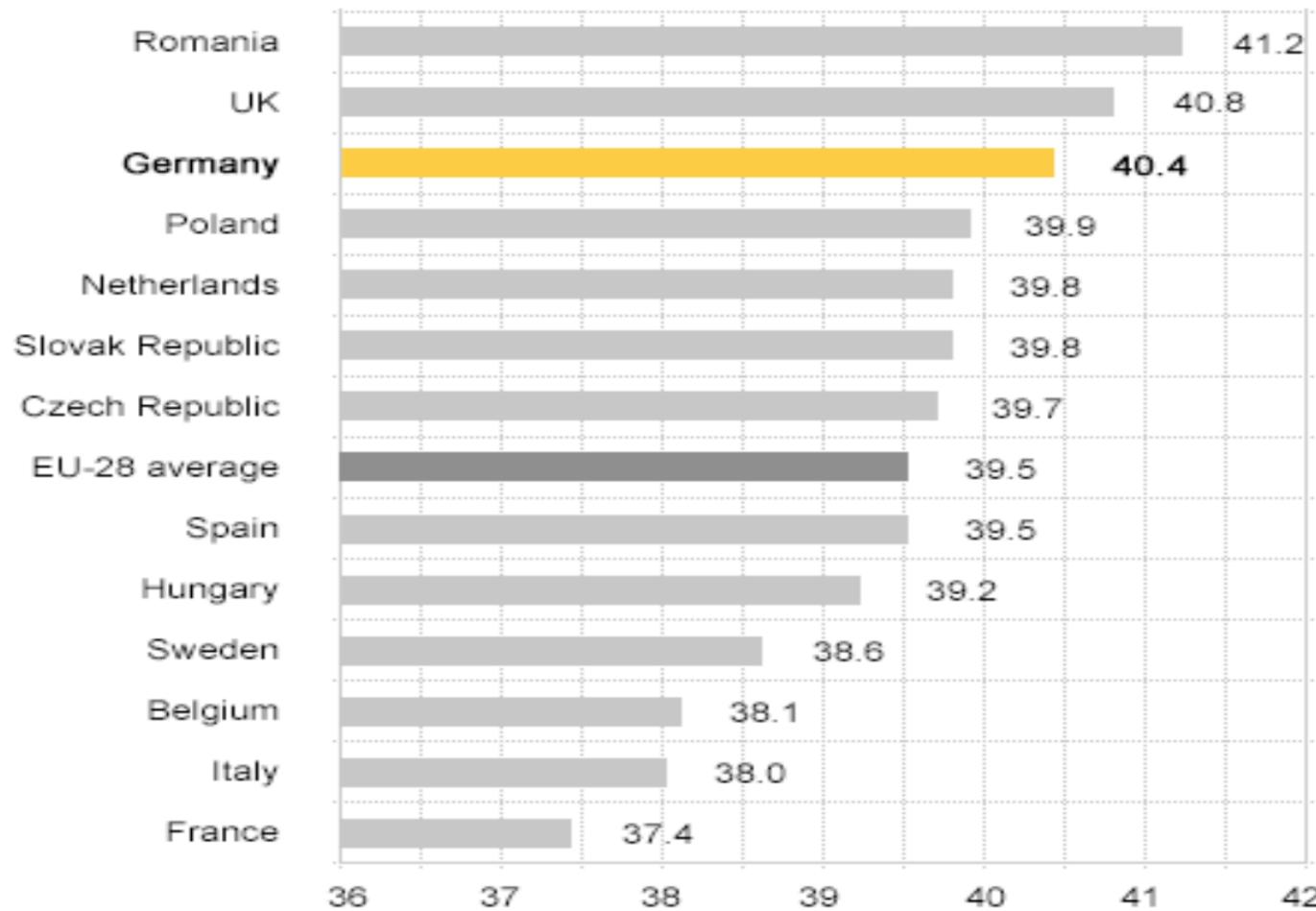
<http://blog.usabilla.com/how-to-design-for-color-blindness/>

Some of the basics ... Keep Scales consistent

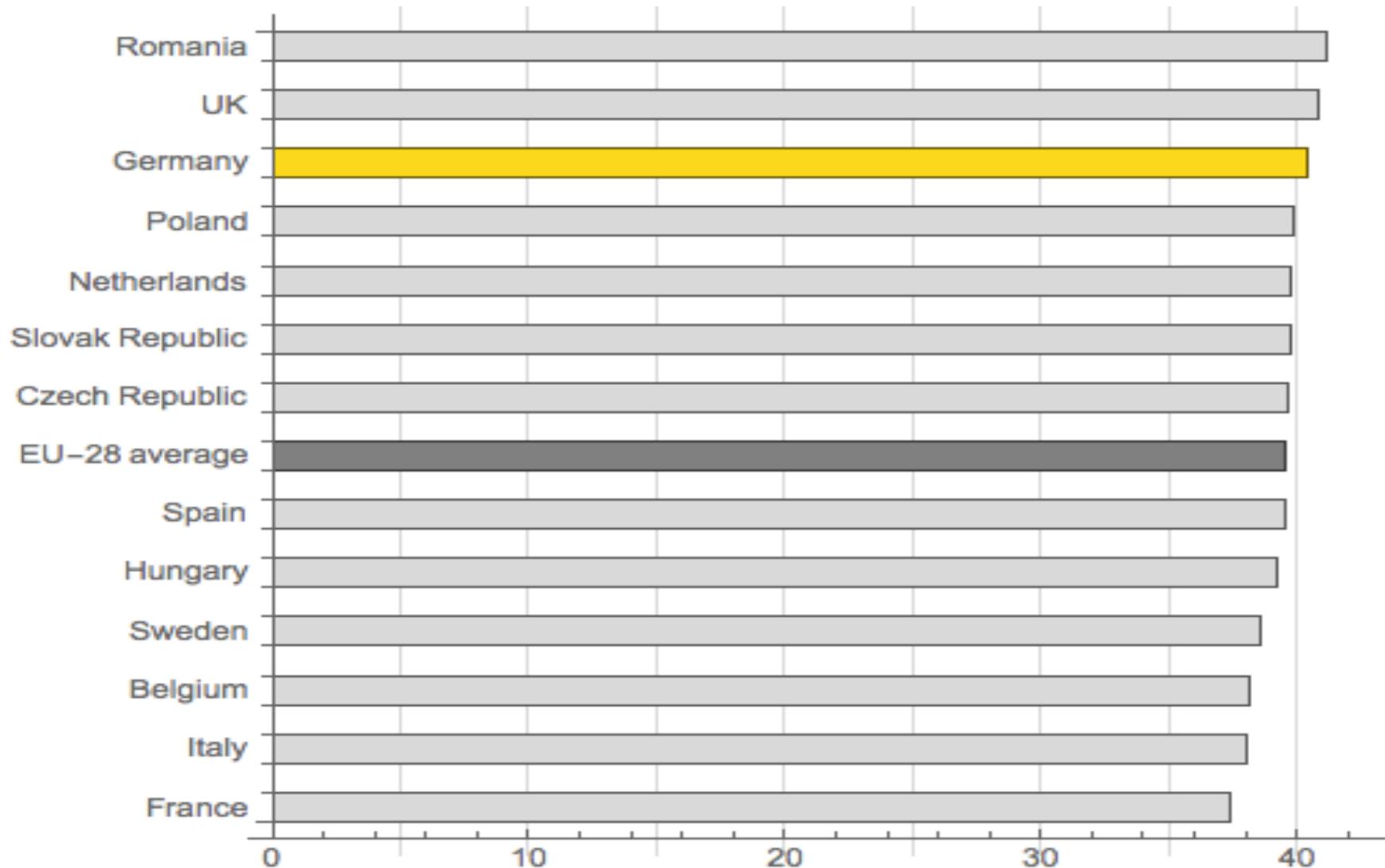


Some of the basics ... Keep scales consistent

Average number of actual weekly hours of work in main job, full-time employees, 2013



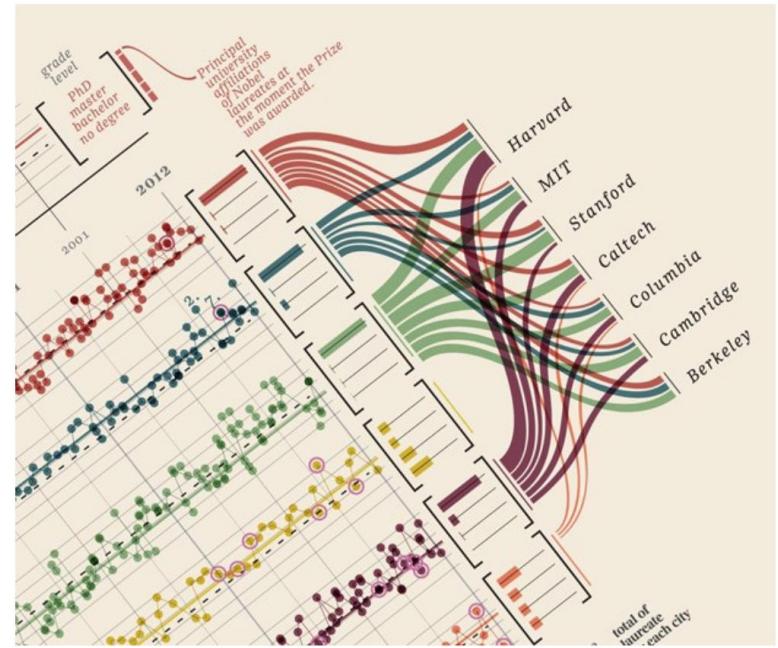
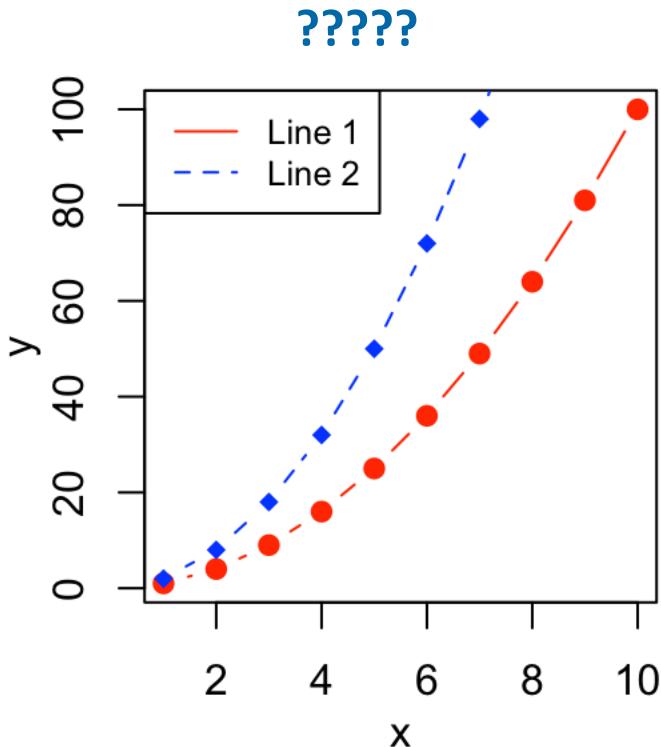
Some of the basics ... Keep scales consistent



Some of the basics ... Legend and Sources

It is absolutely necessary to include the sources of your data and correct legends to interpret your visualisation.

Without the legends, your visualisation is basically a “pretty picture” with no meaning



Preparing the data for visualisation

Data almost never comes in the exact form that you need it in

One of the common parts of the data visualisation tasks is to clean and convert the data

Some of the common data adjustments:

- Calculating indexes and ratios
- Calculating percentile
- Aggregating
- Regrouping
- Converting from Excel/CSV to JSON/XML/SQL

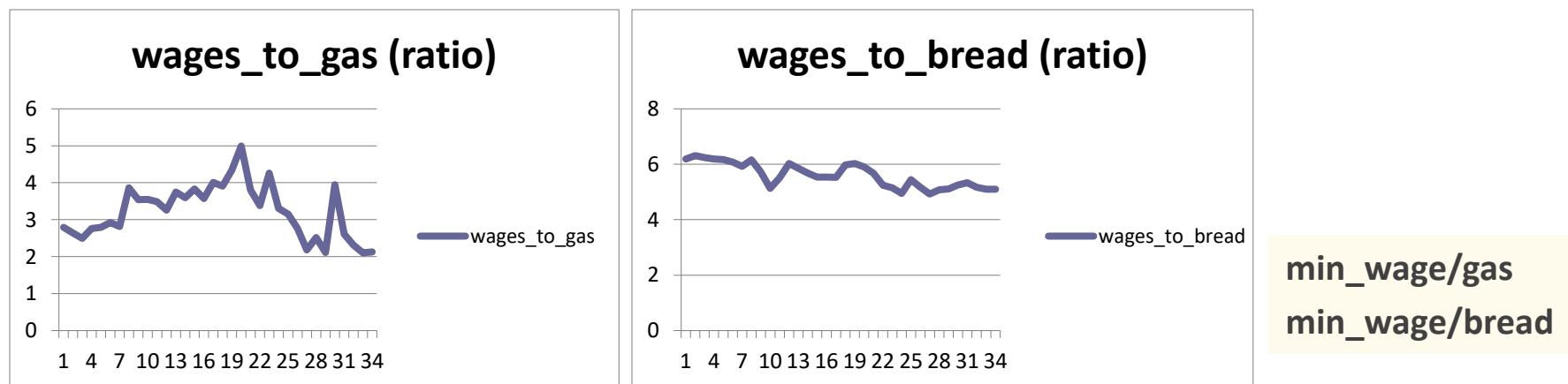
You may need simple tools, or database SQL scripting, programming scripting solutions for these.

- Excel (available!)
- Tableau (commercial)
- Direct data manipulation with SQL or programming language

Preparing the data: Indexes and Ratios

Are we comparing apples with apples (or are they apples and oranges?)

- * Indexes and Ratios allow you to convert the data in a way that makes it easy to look at data side-by-side that is not necessarily easy to do in the original form



Preparing the data: Calculating Percentile

Calculating percentile makes it easier to compare numbers to each other as part of a whole
-- where you stand compared to the rest of the herd, *[relative standing](#)*

	A	B	C	G
1	Country Name	2016	Rank	Percentile
2	United States	\$ 18,624,475,000,000	1	99%
3	China	\$ 11,199,145,157,649	2	99%
4	Japan	\$ 4,940,158,776,617	3	98%
5	Germany	\$ 3,477,796,274,497	4	98%
6	United Kingdom	\$ 2,647,898,654,635	5	97%
7	France	\$ 2,465,453,975,282	6	97%
8	India	\$ 2,263,792,499,341	7	96%
9	Italy	\$ 1,858,913,163,928	8	96%
10	Brazil	\$ 1,796,186,586,414	9	95%
11	Canada	\$ 1,529,760,492,201	10	95%
12	Korea, Rep.	\$ 1,411,245,589,977	11	94%
13	Russian Federation	\$ 1,283,162,985,989	12	94%
14	Spain	\$ 1,237,255,019,654	13	93%
15	Australia	\$ 1,204,616,439,828	14	93%
16	Mexico	\$ 1,046,922,702,461	15	92%
17	Indonesia	\$ 932,259,177,765	16	92%
18	Turkey	\$ 863,711,710,427	17	91%
19	Netherlands	\$ 777,227,541,581	18	91%
20	Switzerland	\$ 668,851,296,244	19	90%

1-(ranking/total country)

1-(1/191)

1-(2/191)

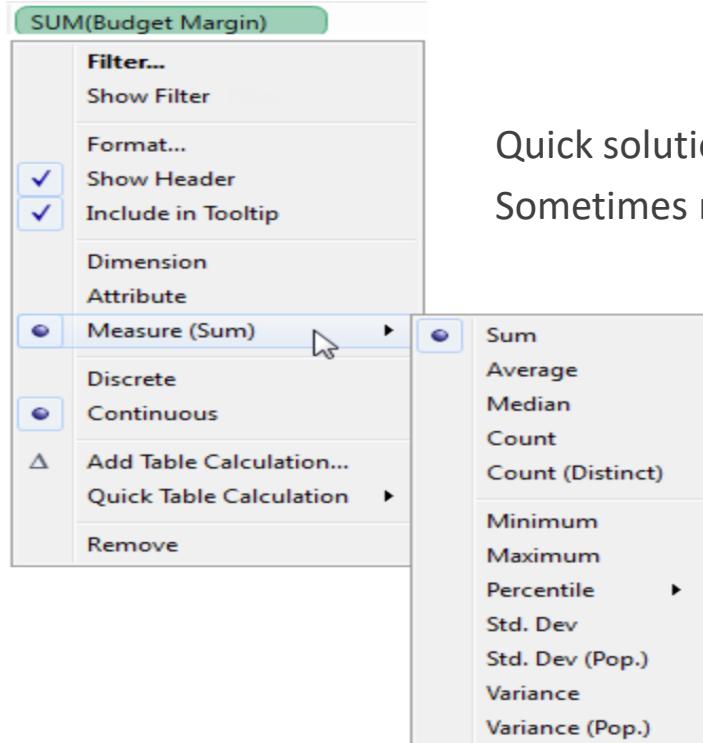
1-(3/191)

...

Preparing the data: Aggregating, Converting Data

Data aggregation is the process where raw data is gathered and expressed in a summary form for statistical analysis

For example, raw data can be aggregated over a given time period to provide statistics such as **average, minimum, maximum, sum, and count.**



Quick solution by a tool like Tableau/Excel ...

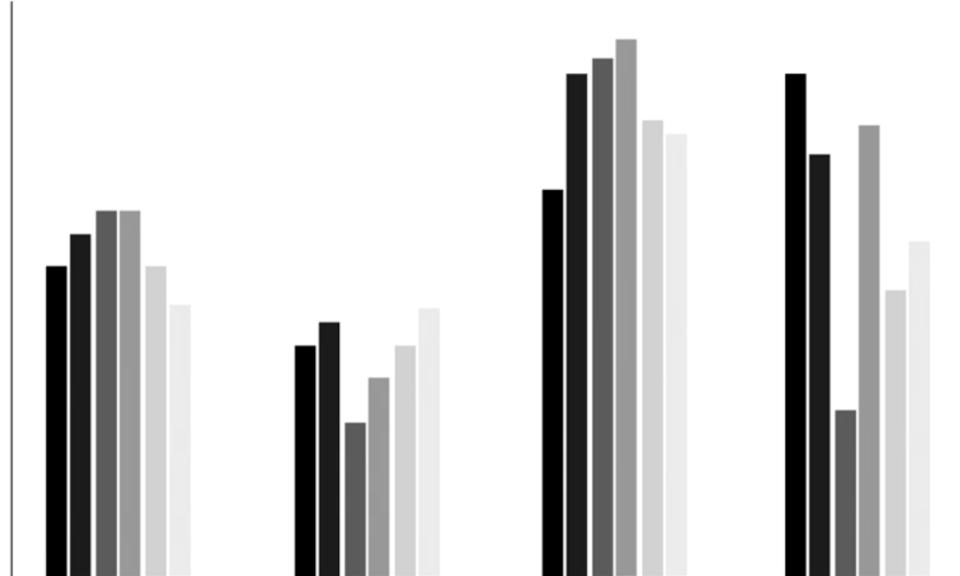
Sometimes manual SQL scripts necessary

The right paradigm

One of the most difficult things to do is figuring out which charts/graphs to use in which situation. I'd say you need to have the basic competency here – and then be aware of good alternatives.

The good old BAR Chart:

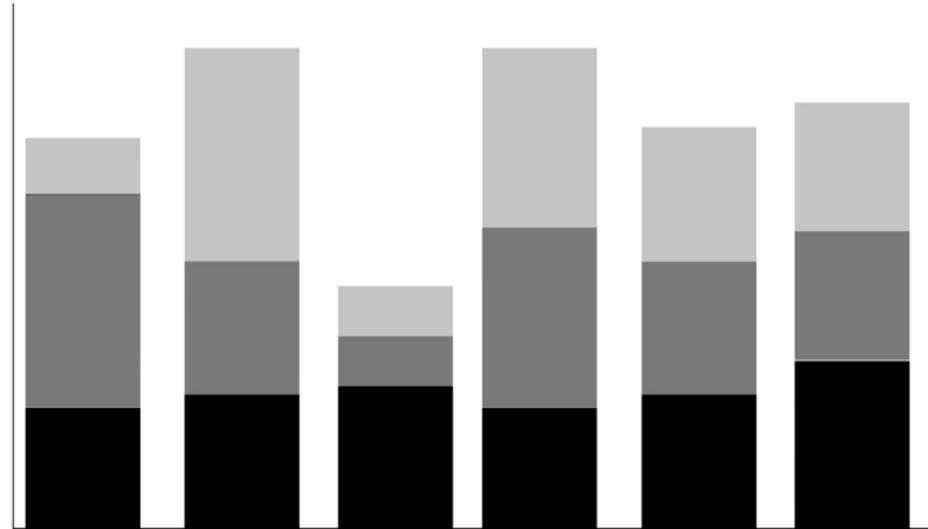
- Highly effective in terms of ‘parsing the information’
- Experts say human brain is wired to differentiate these rectangular shapes
- In fact, you should start by asking “why isn’t a bar graph enough here?”
- But when there are more variables, many “grouped” bars don’t look good



The right paradigm

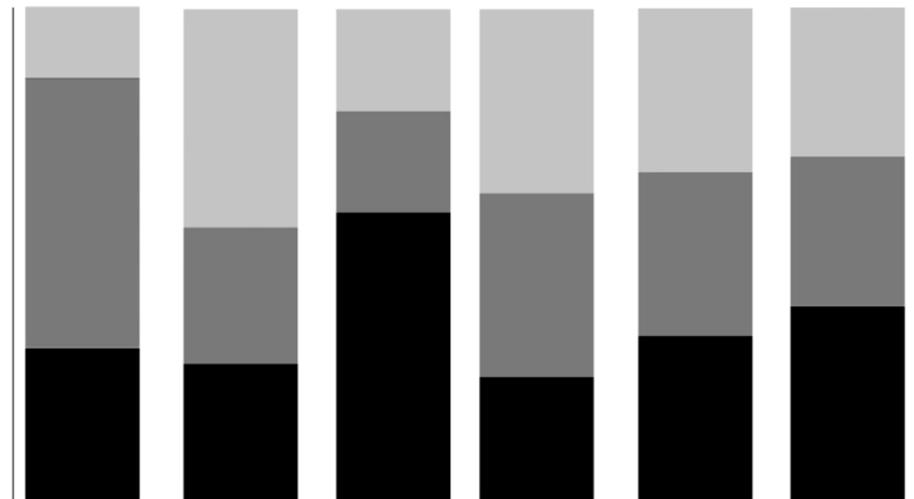
STACKED Bar Charts:

- Compare data within groups
- Whole bar represents the total value of that group, and each segment represents the value within the group



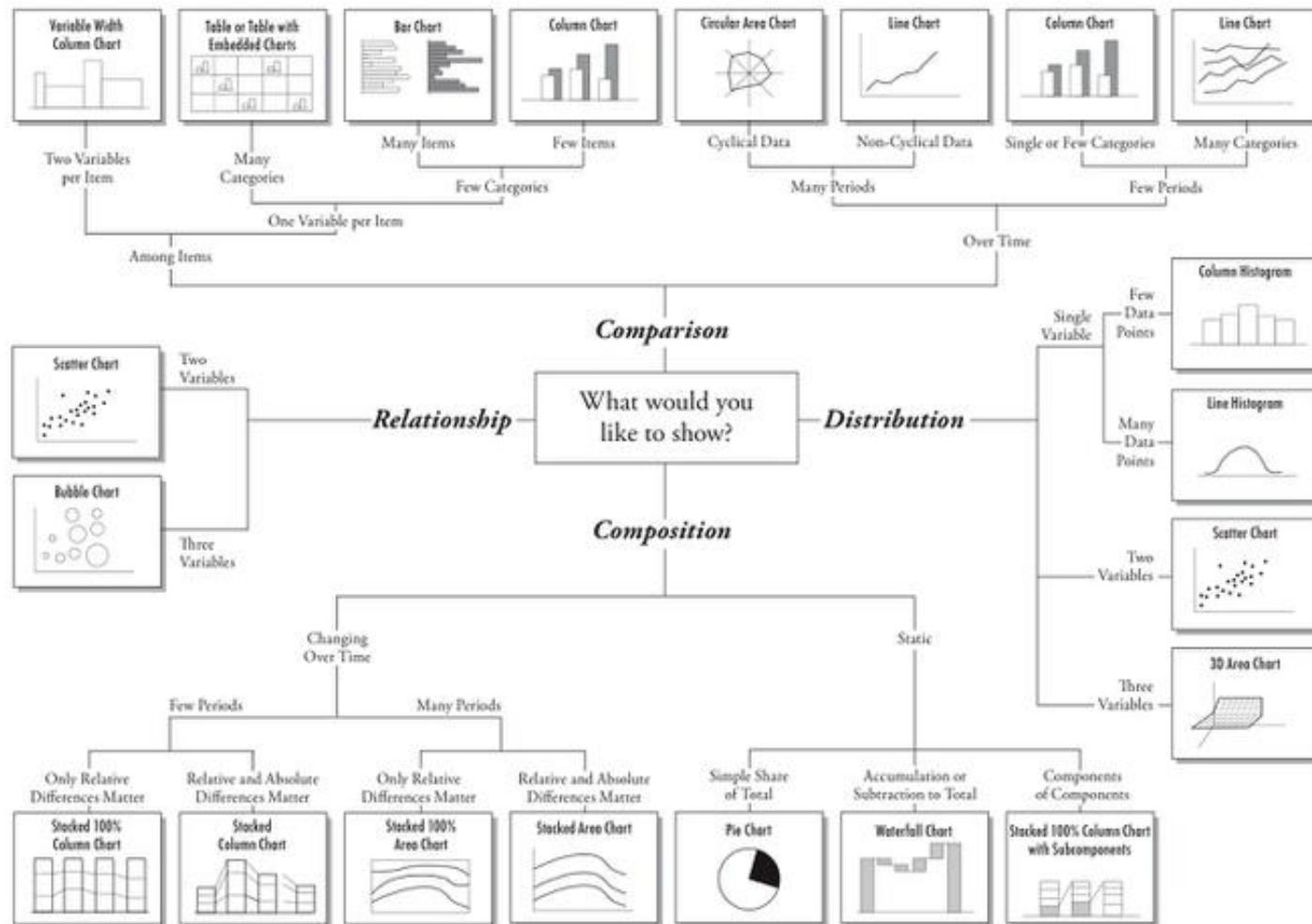
STACKED Percentage Bar Chart:

- If you want to compare relative contribution of each category to the whole
- Whole bar = 100%
- Showing relative strength of each category within the whole



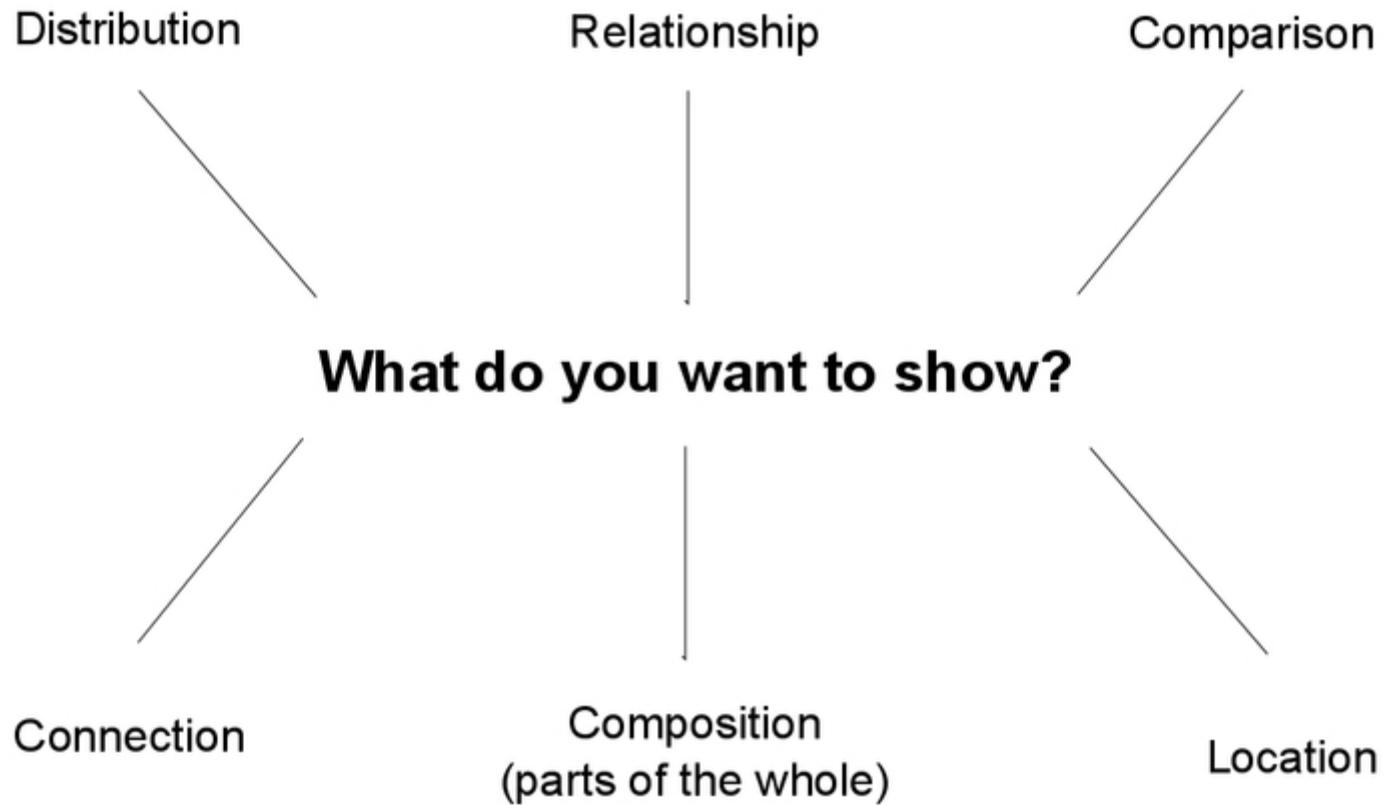
The right paradigm

Chart Suggestions—A Thought-Starter



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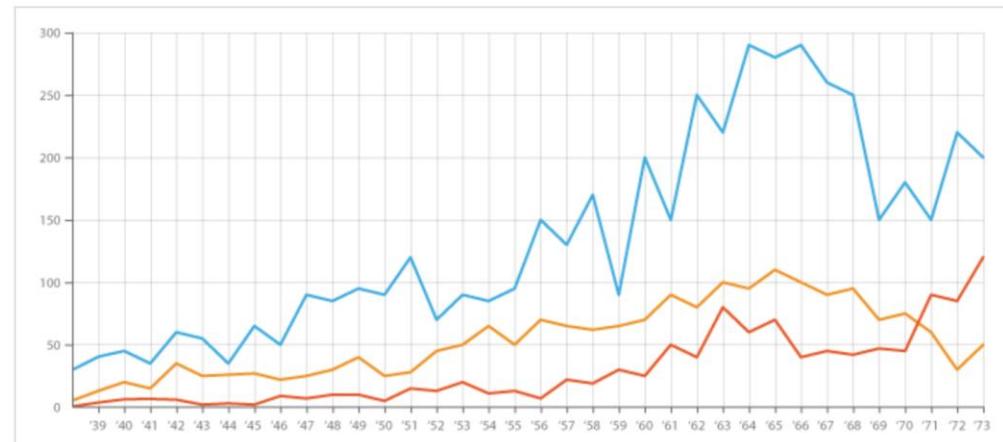
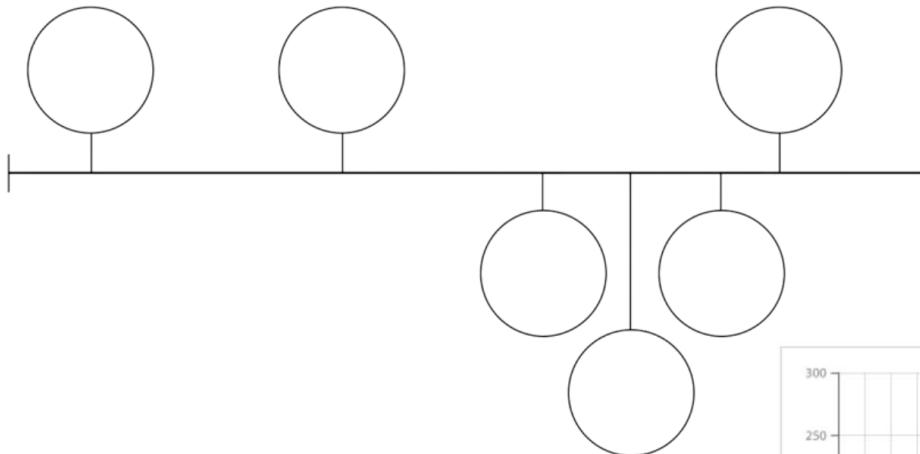
The right paradigm



The right paradigm

Line graphs:

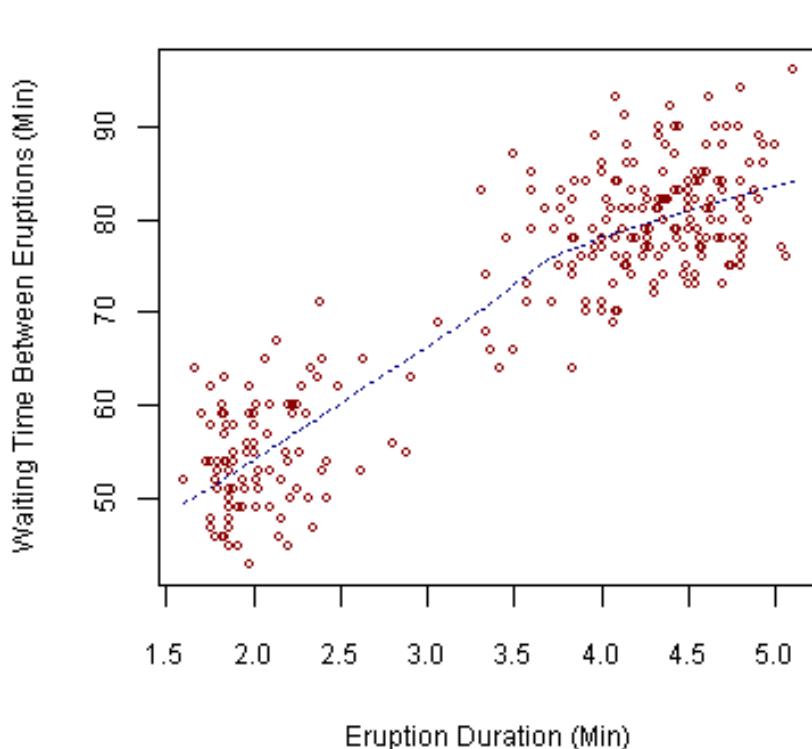
- To show values “over time” or a continuous interval
- Stories over “Timeline”



The right paradigm

Scatter Plot graphs:

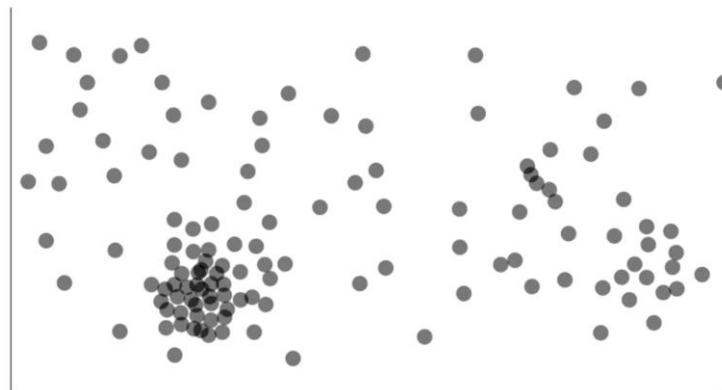
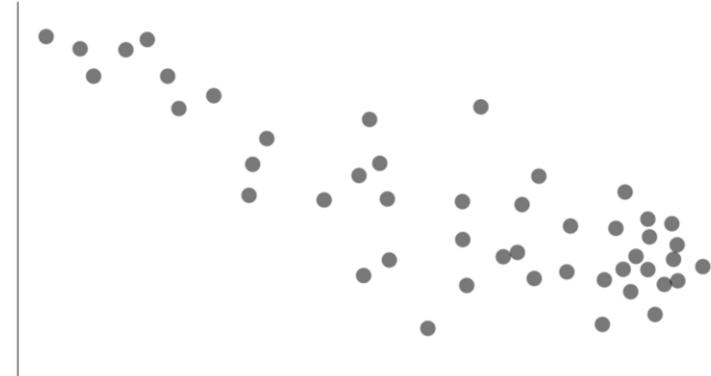
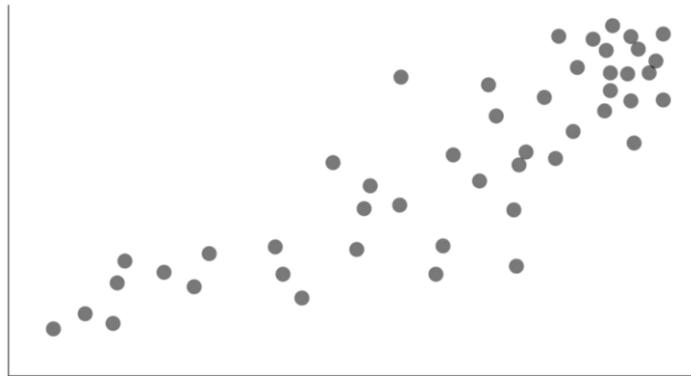
- To show two variables and their correlations (i.e., X axis vs. Y axis)



The right paradigm

Scatter Plot graphs:

- To show two variables and their correlations (i.e., X axis vs. Y axis)



No correlations, but discernible patterns



Size of the dots – third variable

Useful Read

- Book: the Functional Art by Alberto Cairo (Chapter 1,2, and 3)
- <http://jonathansoma.com/lede/algorithms-2017/classes/fuzziness-matplotlib/how-pandas-uses-matplotlib-plus-figures-axes-and-subplots/>
- <https://pythonspot.com/visualize-data-with-pandas/>