



Information Visualization

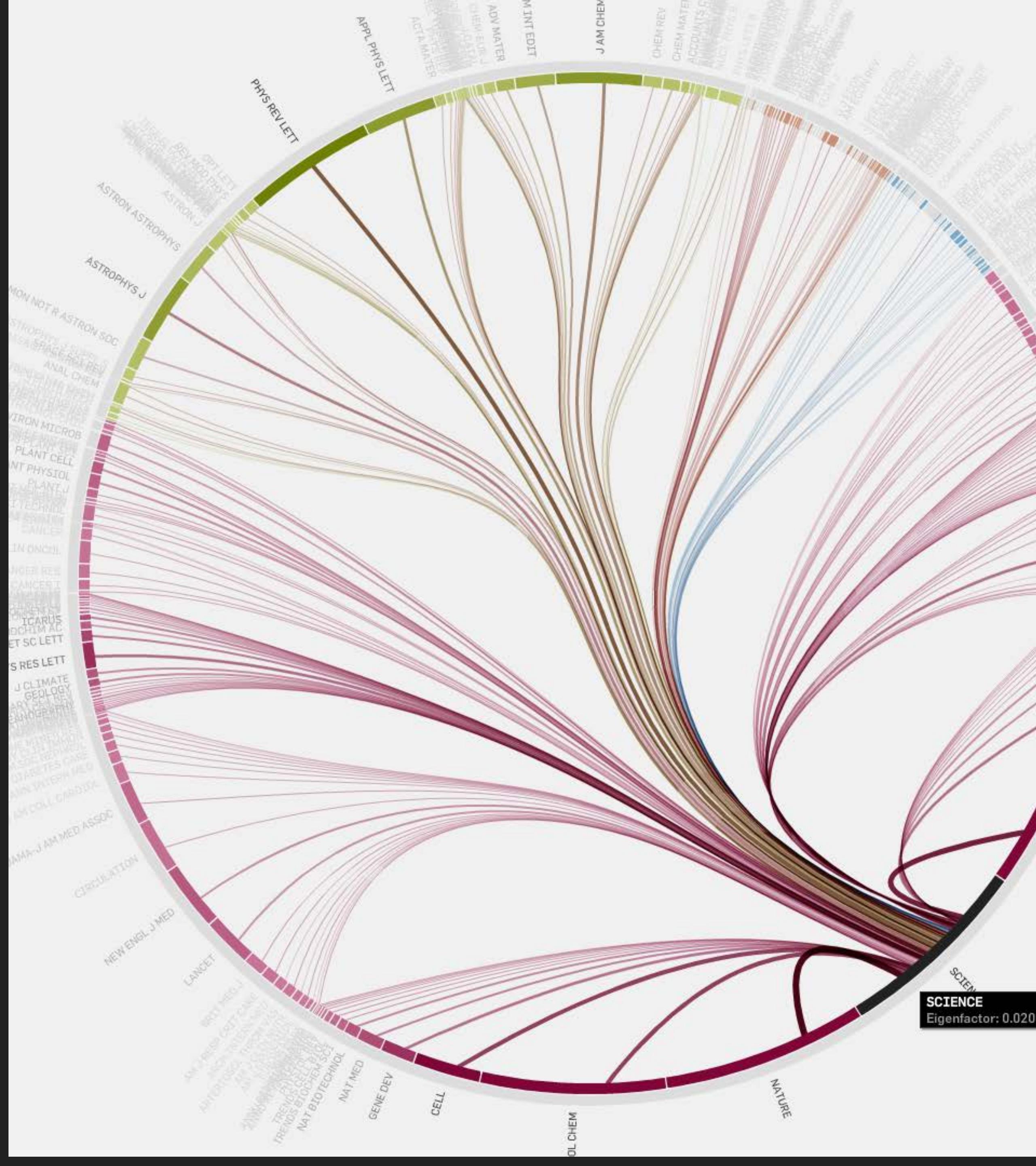
01- Introduction | SS2021

Dr.-Ing. Mandy Keck
Professor of User Experience und Interaction Design
Degree Programme Human-Centered Computing
Department Software Engineering
University of Applied Sciences Upper Austria, Hagenberg Campus

mandy.keck@fh-hagenberg.at
Room FH 1.217

INTRODUCTION

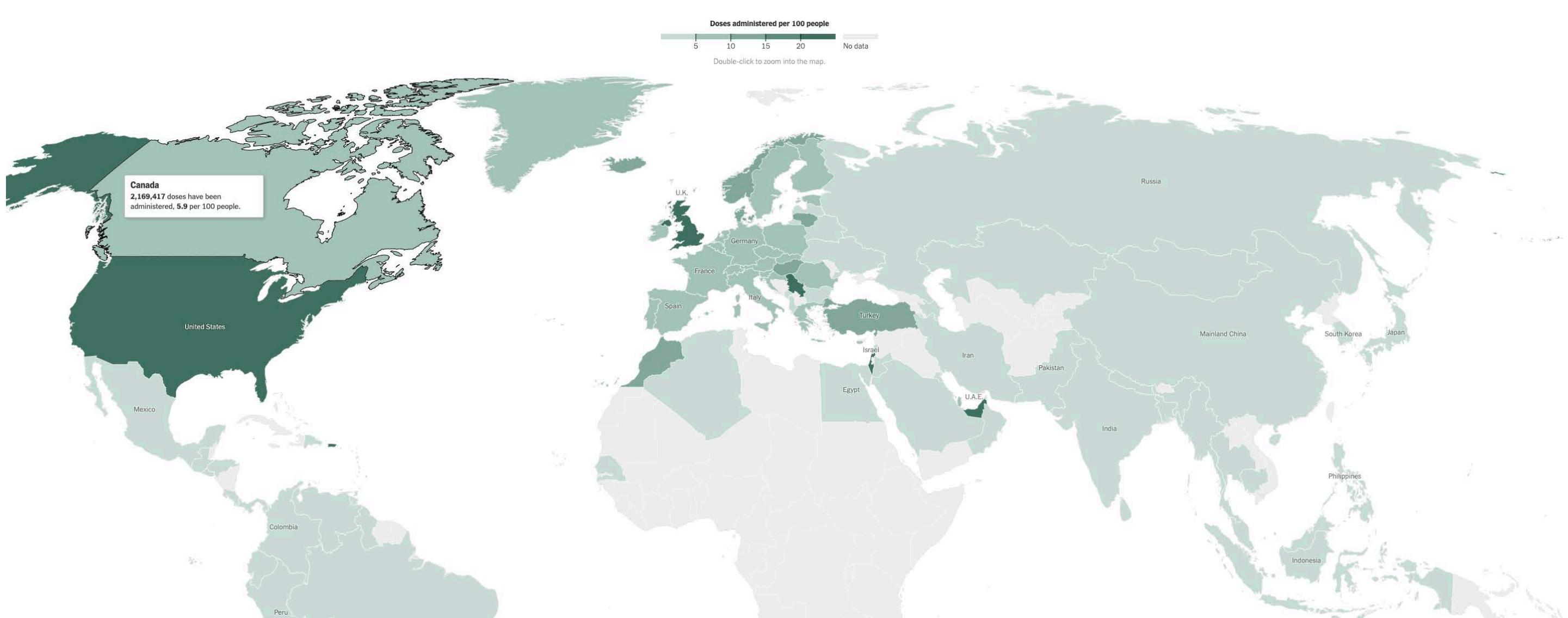
Information Visualization



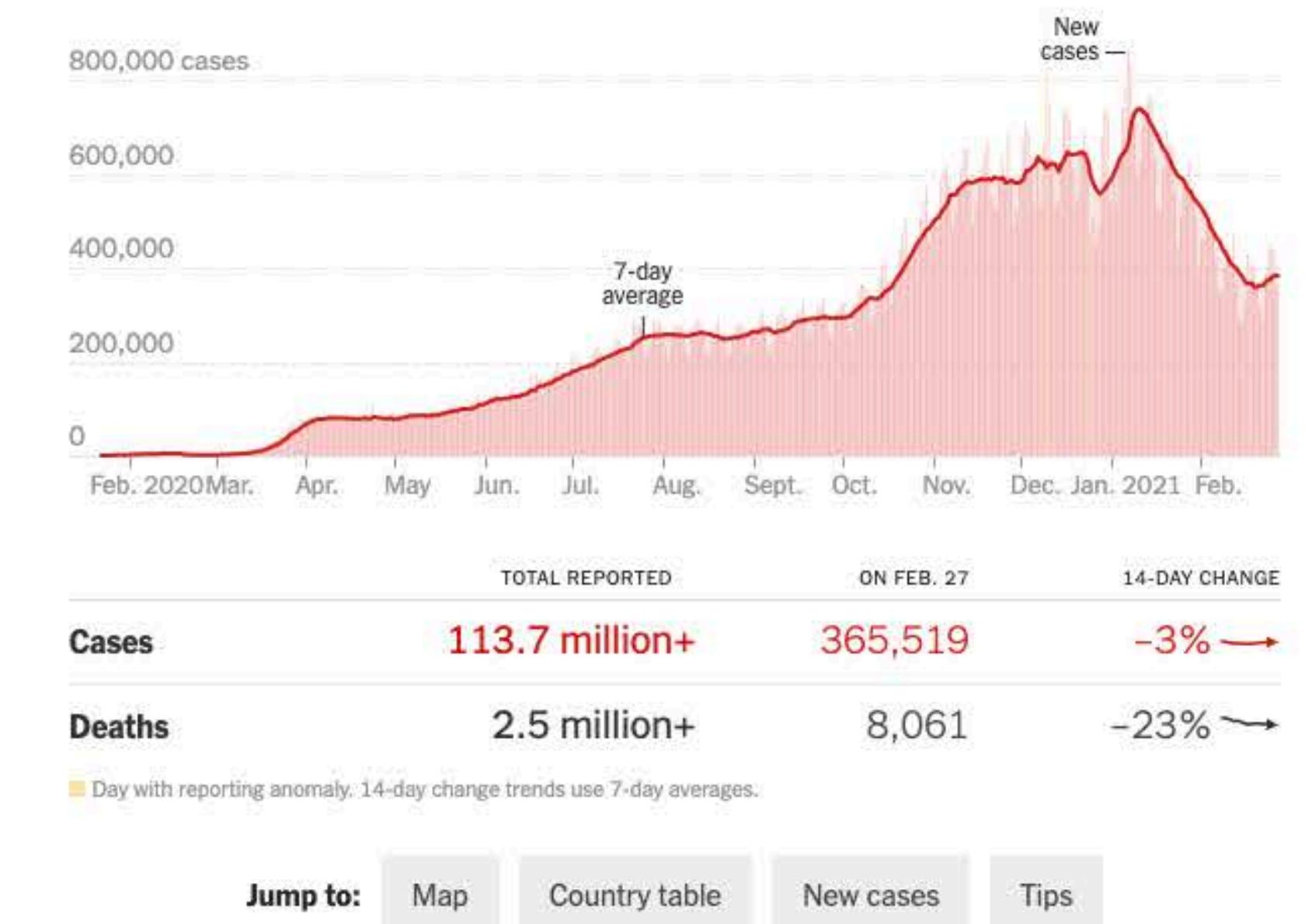
Example

Coronavirus World Map: Tracking the Global Outbreak

Updated February 28, 2021, 1:22 A.M. E.T.



<https://www.nytimes.com/interactive/2021/world/covid-vaccinations-tracker.html>



The [coronavirus pandemic](#) has sickened more than 113,777,400 people, according to official counts. As of Sunday morning, at least 2,524,800 people have died from coronavirus.

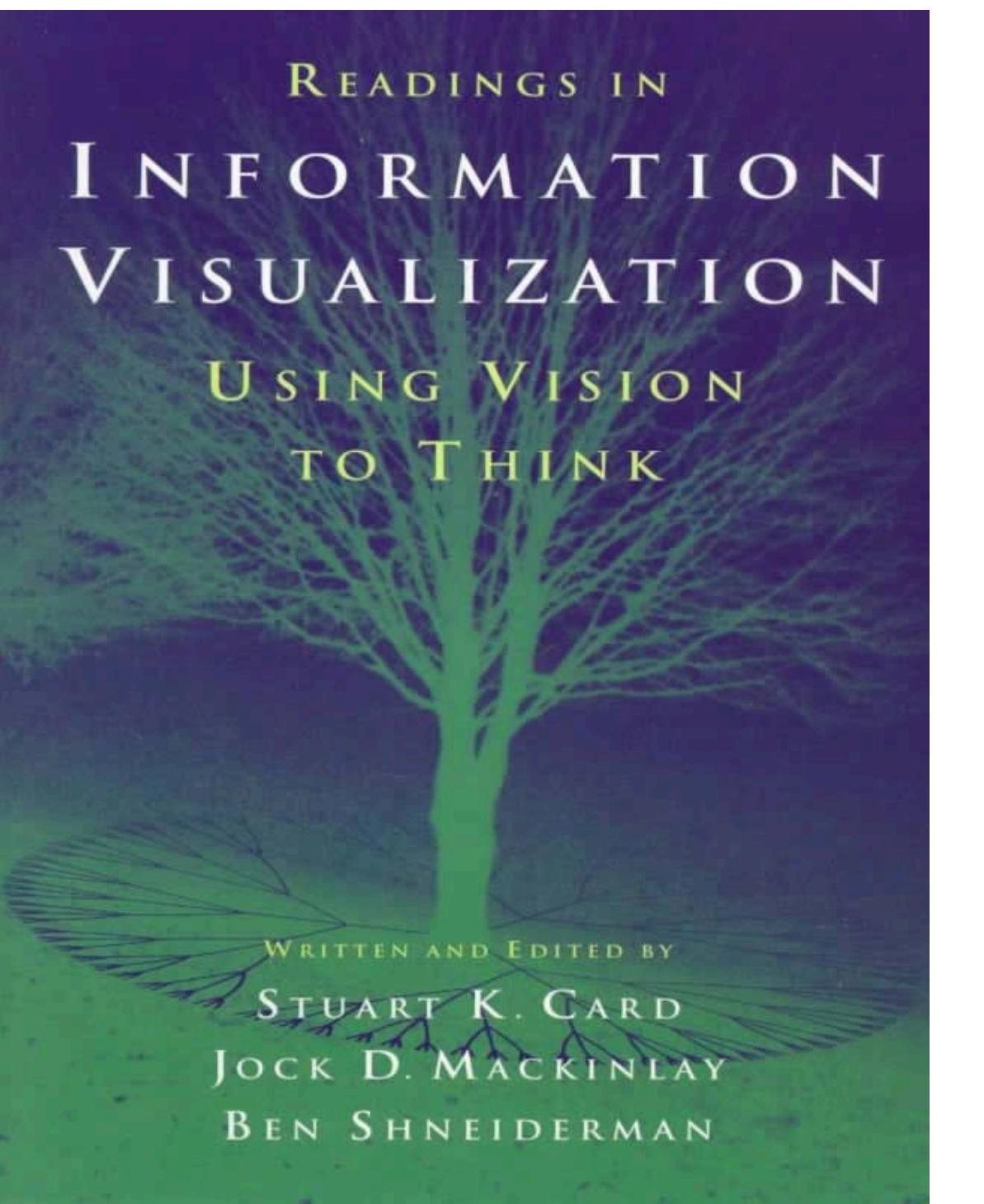
[See vaccinations by country on our new world tracker page.](#)



<https://www.nytimes.com/interactive/2020/world/coronavirus-maps.html>

What is Information Visualization?

»The use of computer-supported, interactive, visual representations of abstract data to amplify cognition.« [CARD ET AL. 1999]



What is Information Visualization?

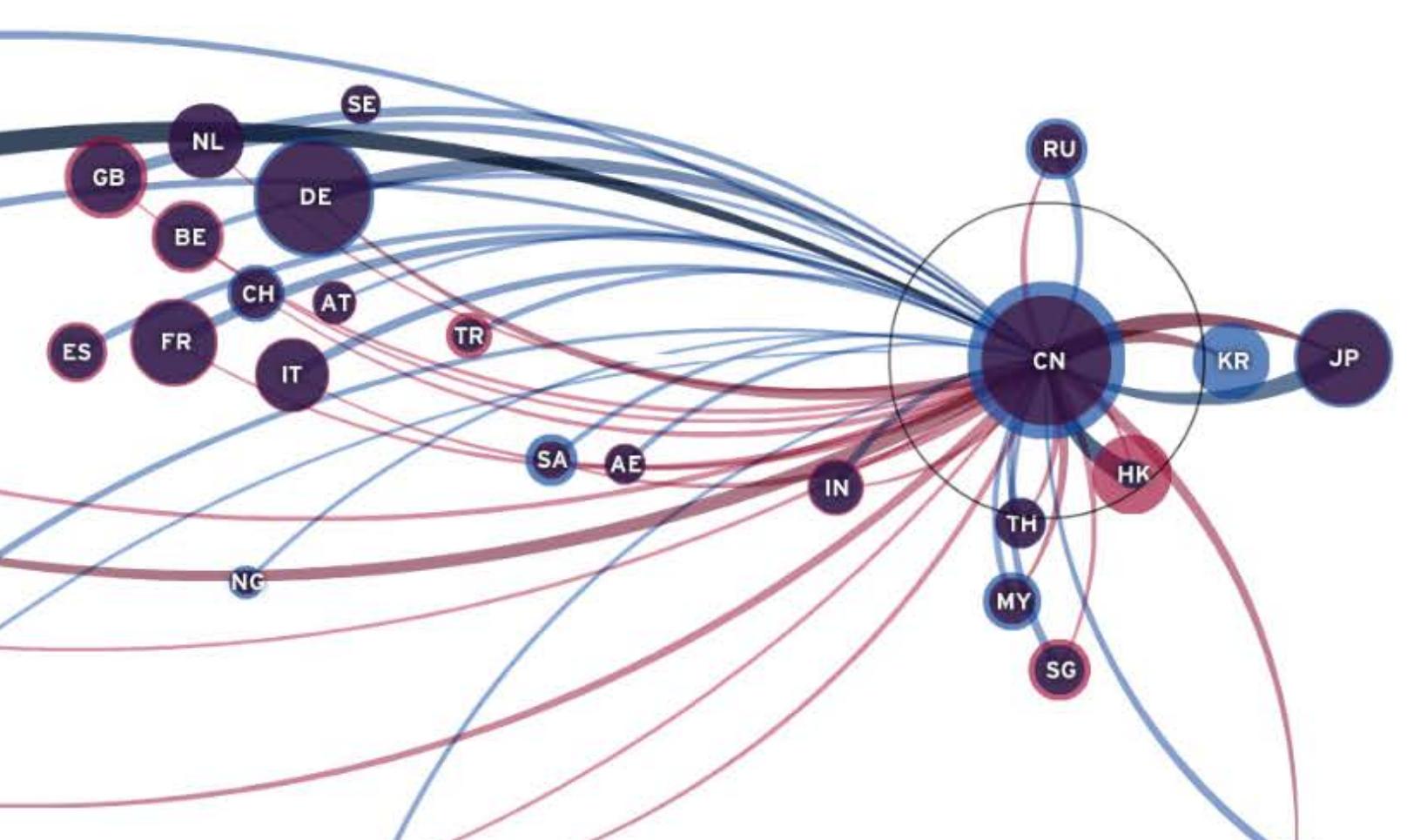
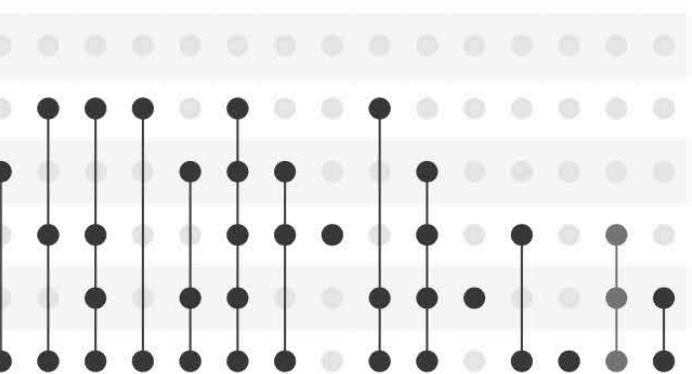
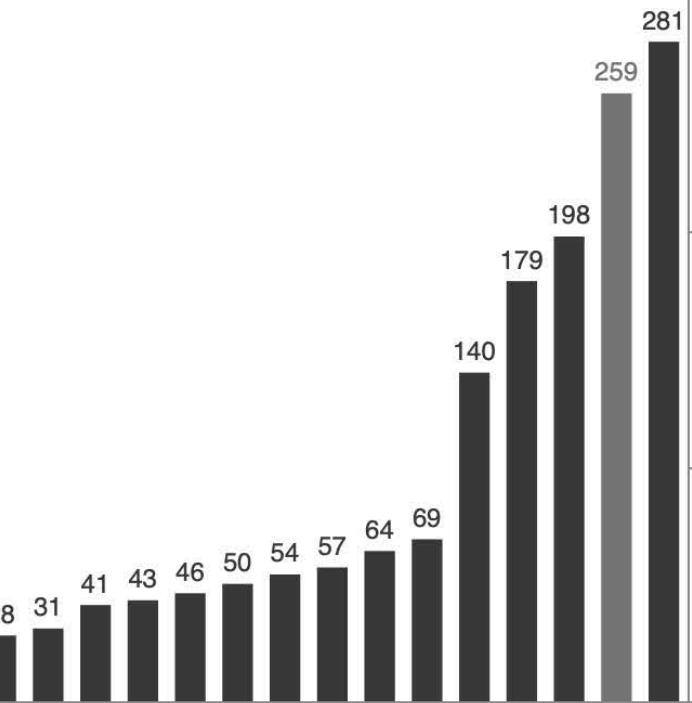
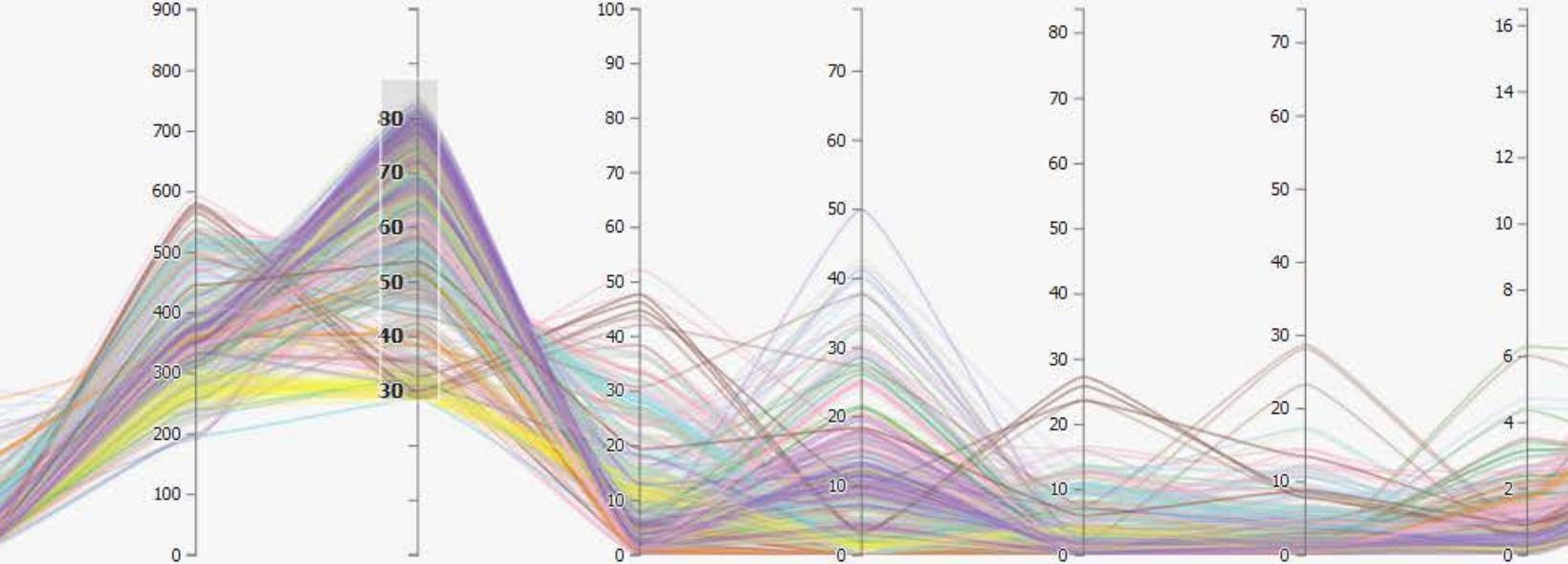
»The use of **computer-supported**, interactive, **visual representations** of abstract data to amplify cognition.« [CARD ET AL. 1999]

Computer-supported:

- ▶ supported by algorithms to analyze huge amounts of data

Visual representation:

- ▶ utilizes human visual perception

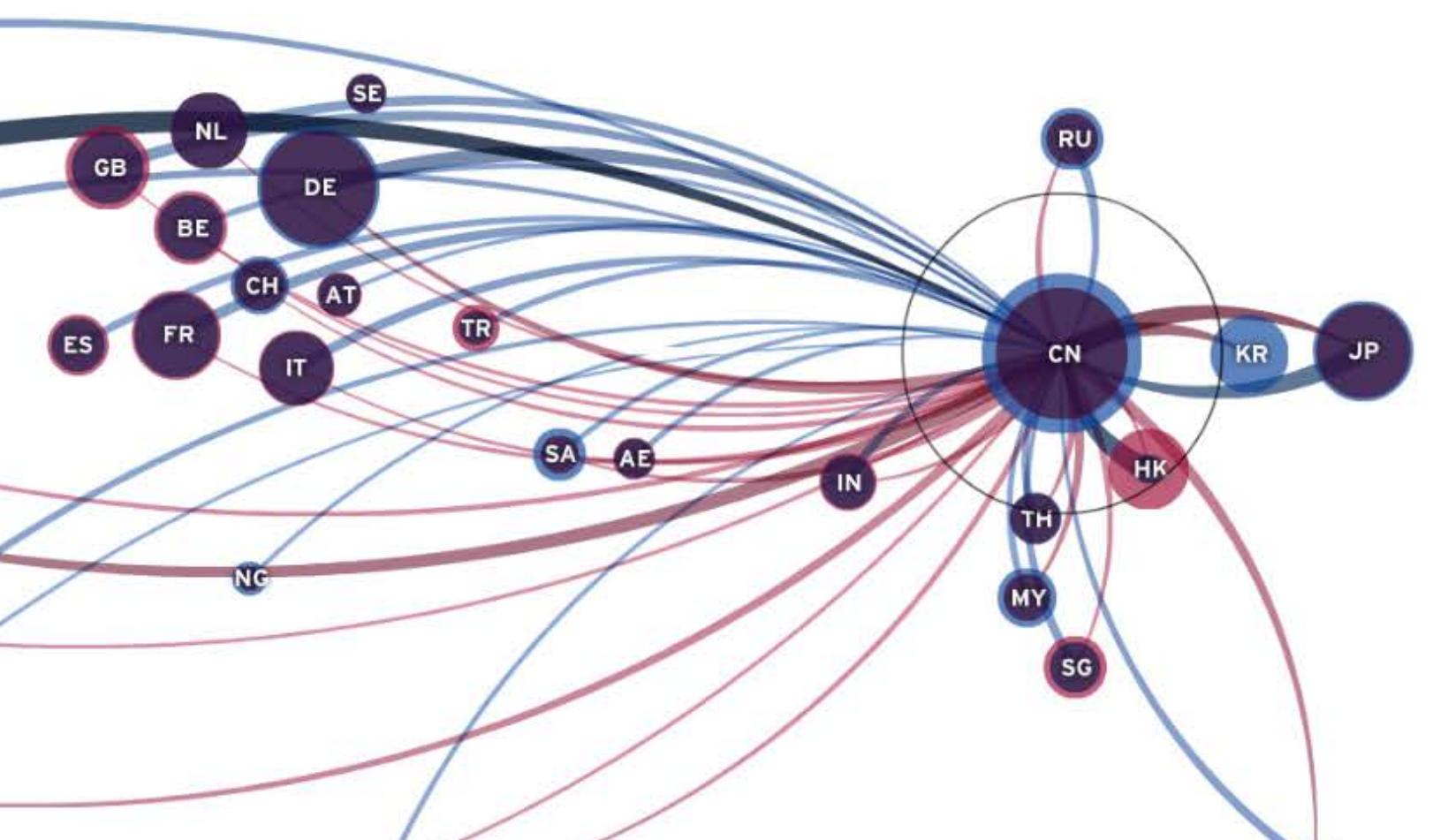
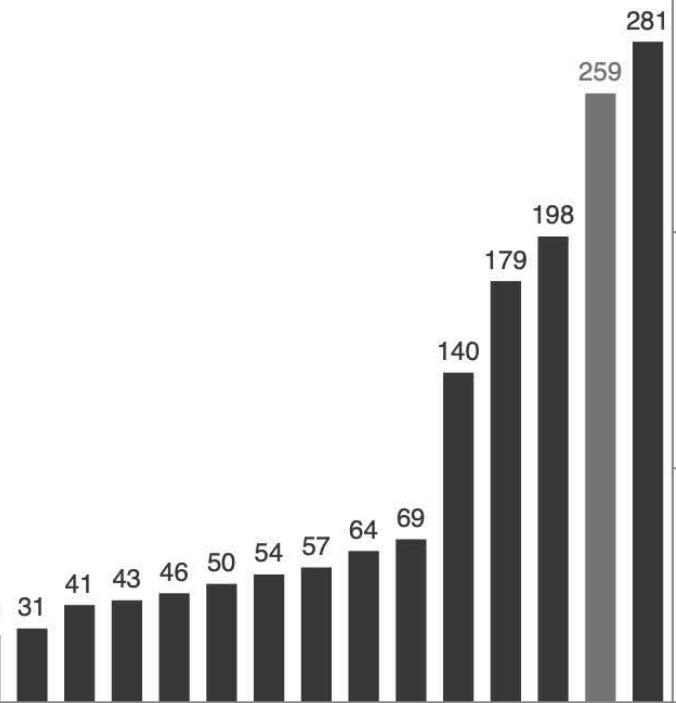
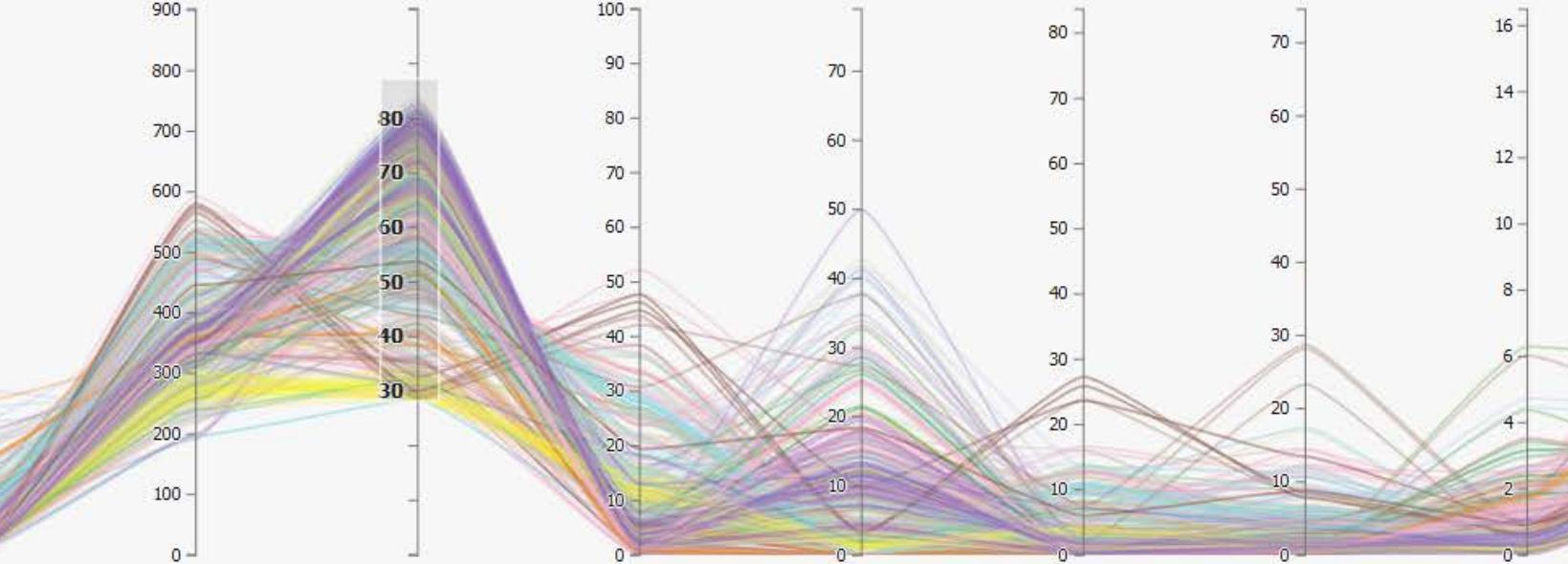


What is Information Visualization?

»The use of computer-supported, interactive, **visual** representations of abstract data to amplify cognition.« [CARD ET AL. 1999]

Visualization [WARE 2020]:

- ▶ constructing a visual image in the mind
- ▶ a graphical representation of data or concepts: an external artifact supporting decision-making

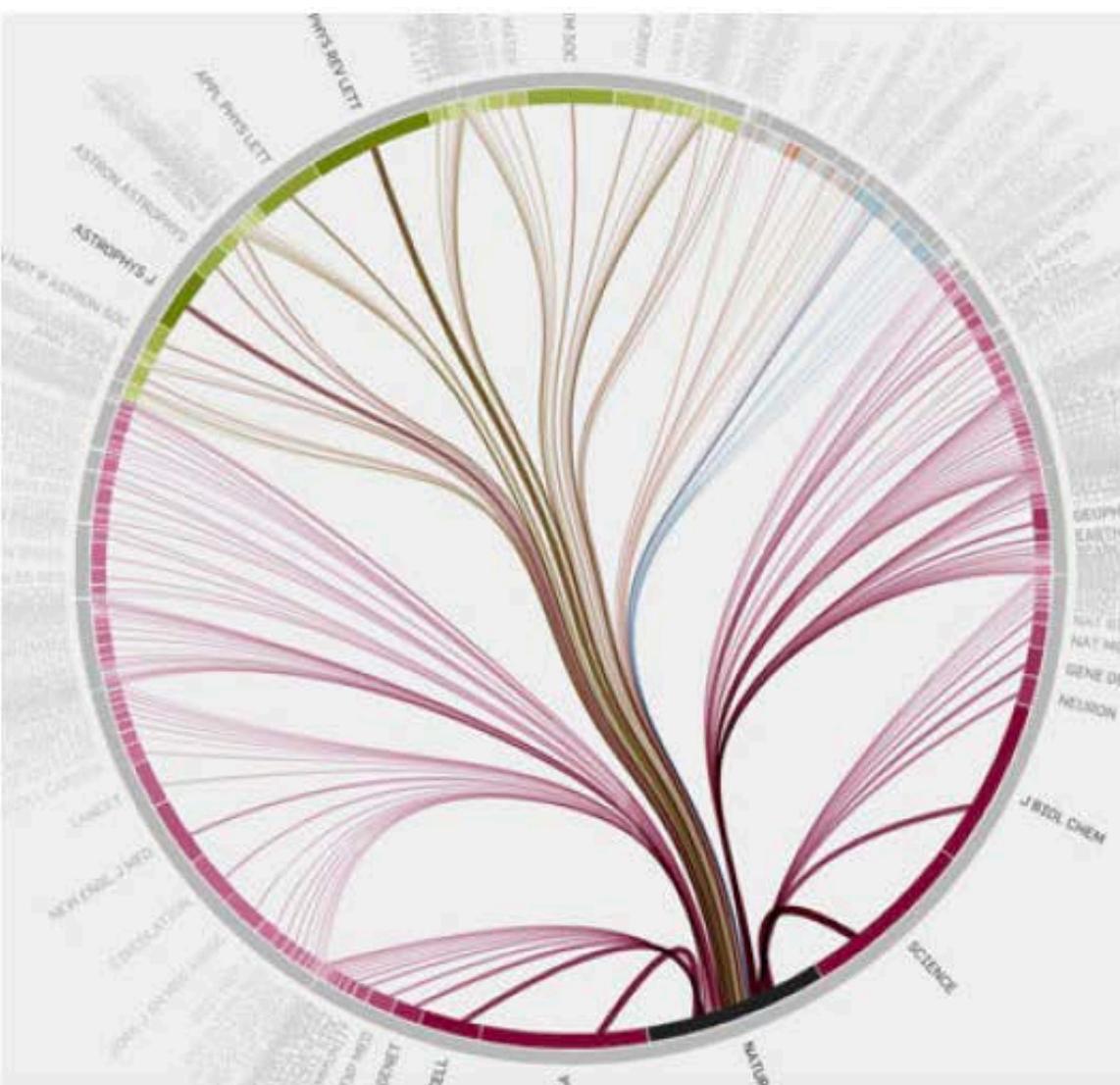
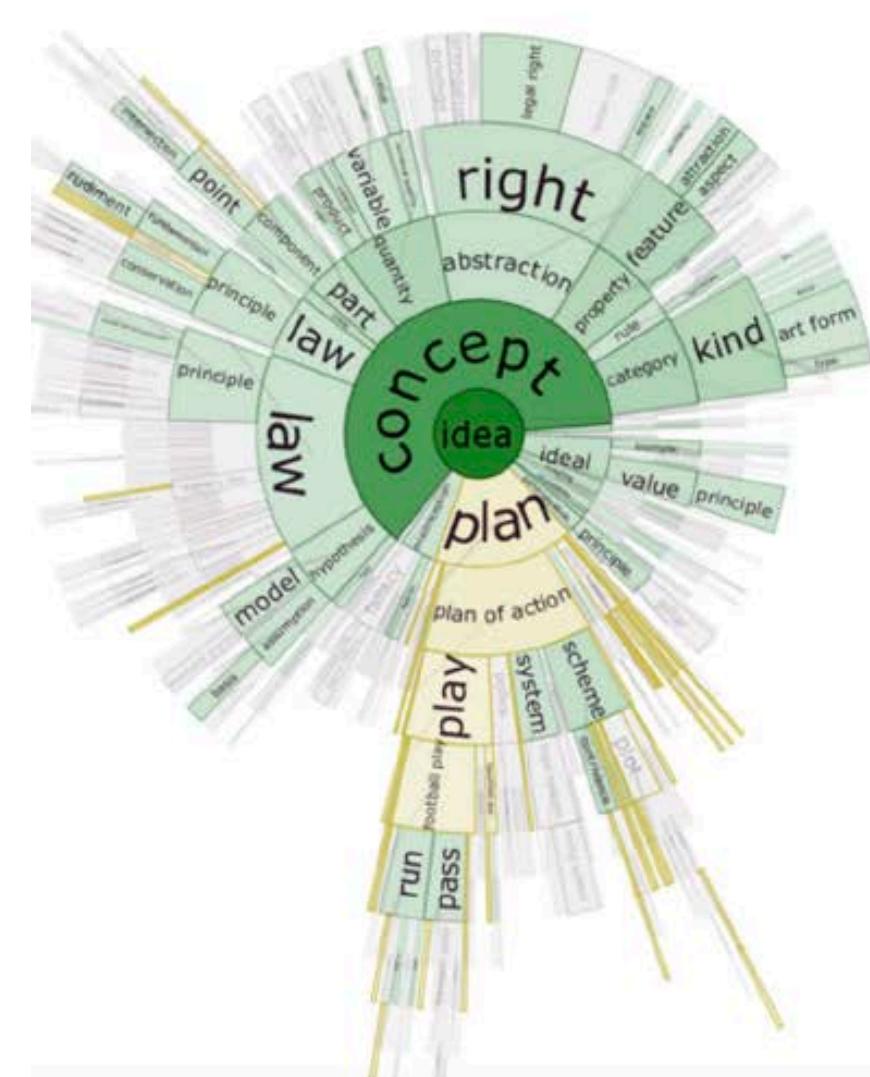


What is Information Visualization?

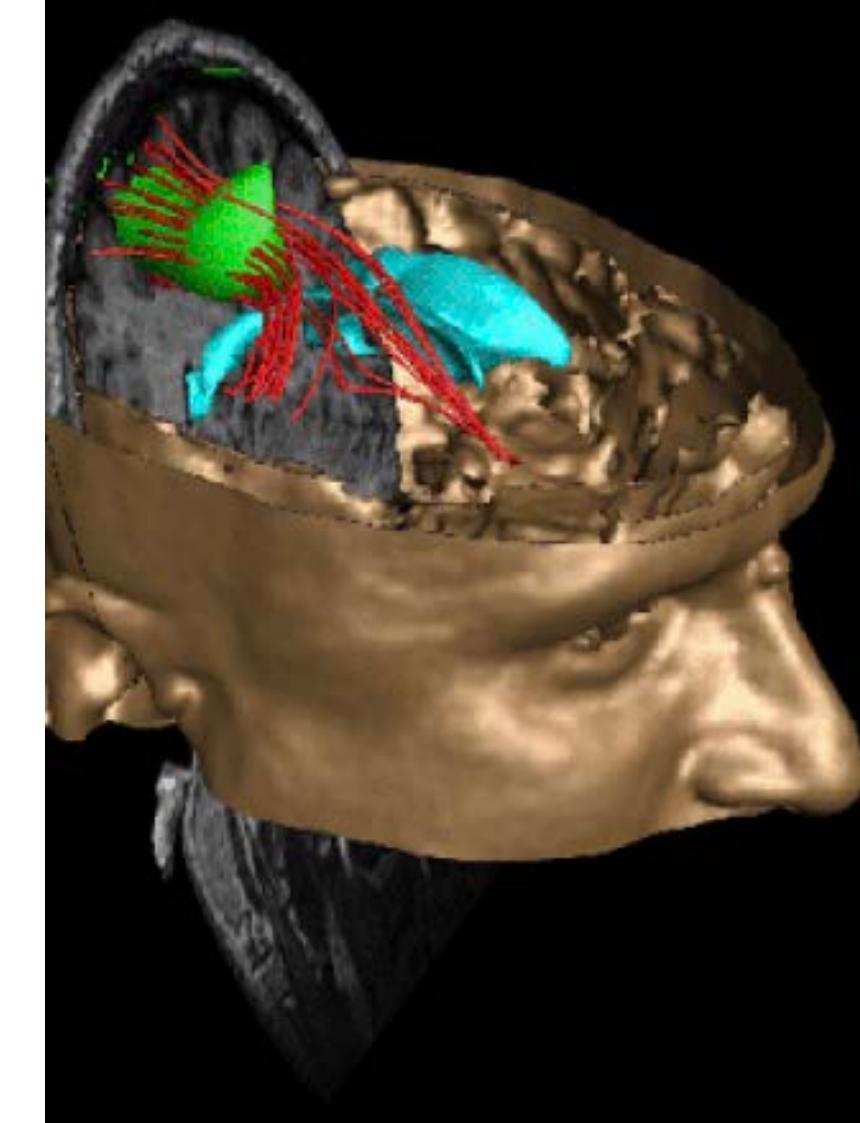
»The use of computer-supported, interactive, visual representations of **abstract data** to amplify cognition.« [CARD ET AL. 1999]

Abstract data:

- ▶ data with no obvious/ natural visual representation

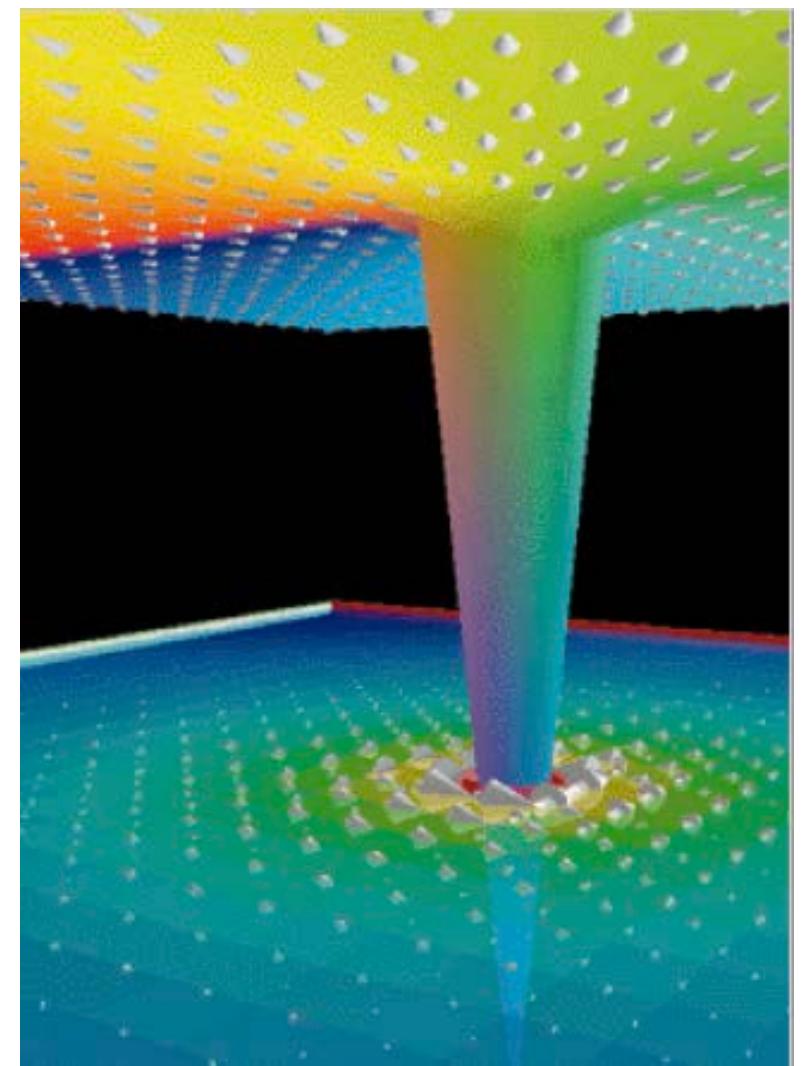


e.g. relations, time, duration, project properties



Scientific Visualization:

Visualizing physical or geometric phenomena



Data Visualization:

Information Visualization (InfoVis) + Scientific Visualization (SciVis)

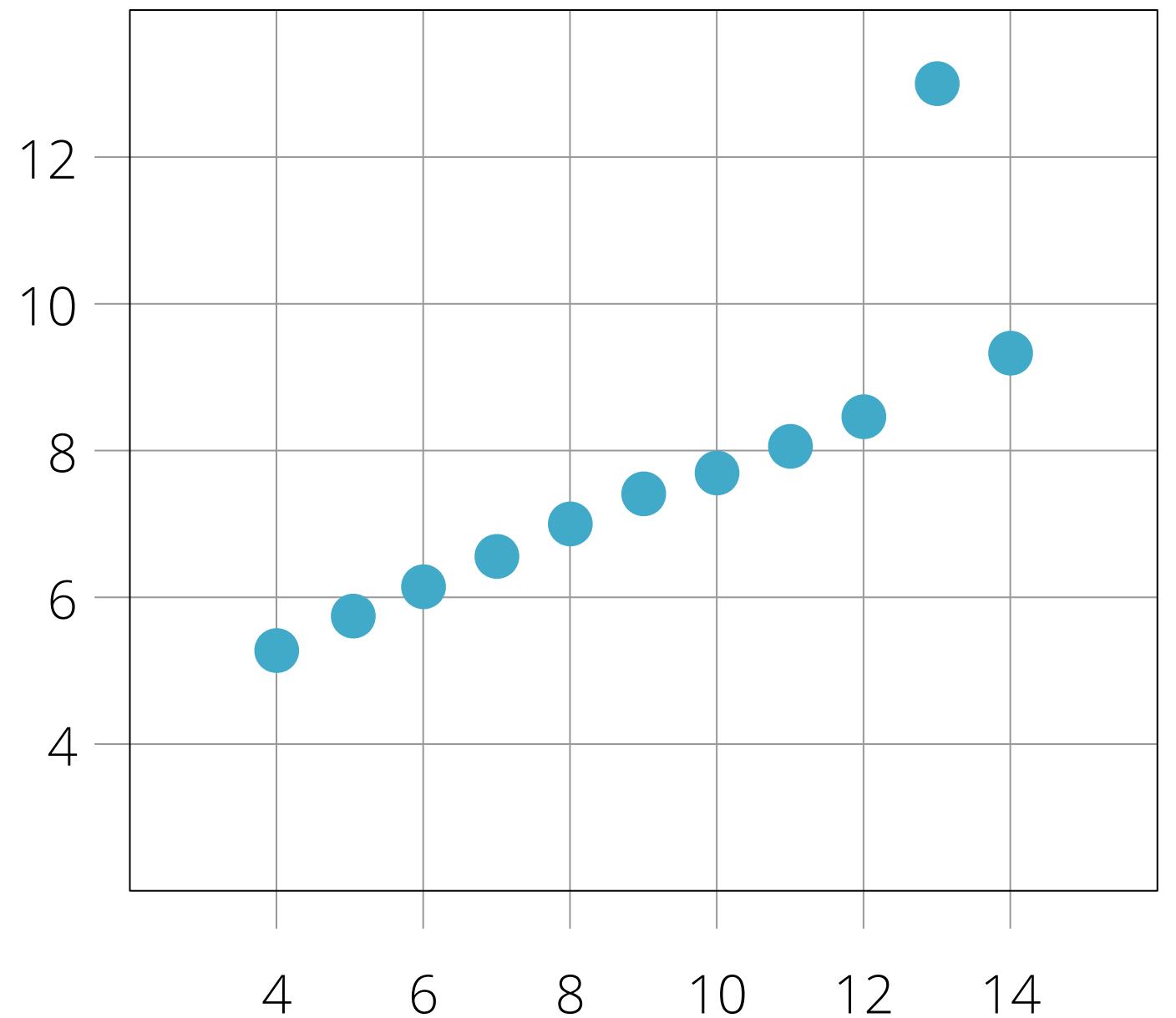
What is Information Visualization?

»The use of computer-supported, interactive, visual representations of abstract data to **amplify cognition**.« [CARD ET AL. 1999]

- ▶ **Visual externalizations** can help us to solve tasks more easily, such as identifying trends and outliers in data

»*The purpose of information visualization is to amplify cognitive performance, not just to create interesting pictures. Information visualizations should do for the mind what automobiles do for the feet.*« [CARD 2007]

X	Y
10.0	7.46
8.0	6.77
13.0	12.74
9.0	7.11
11.0	7.81
14.0	8.84
6.0	6.08
4.0	5.39
12.0	8.15
7.0	6.42
5.0	5.73



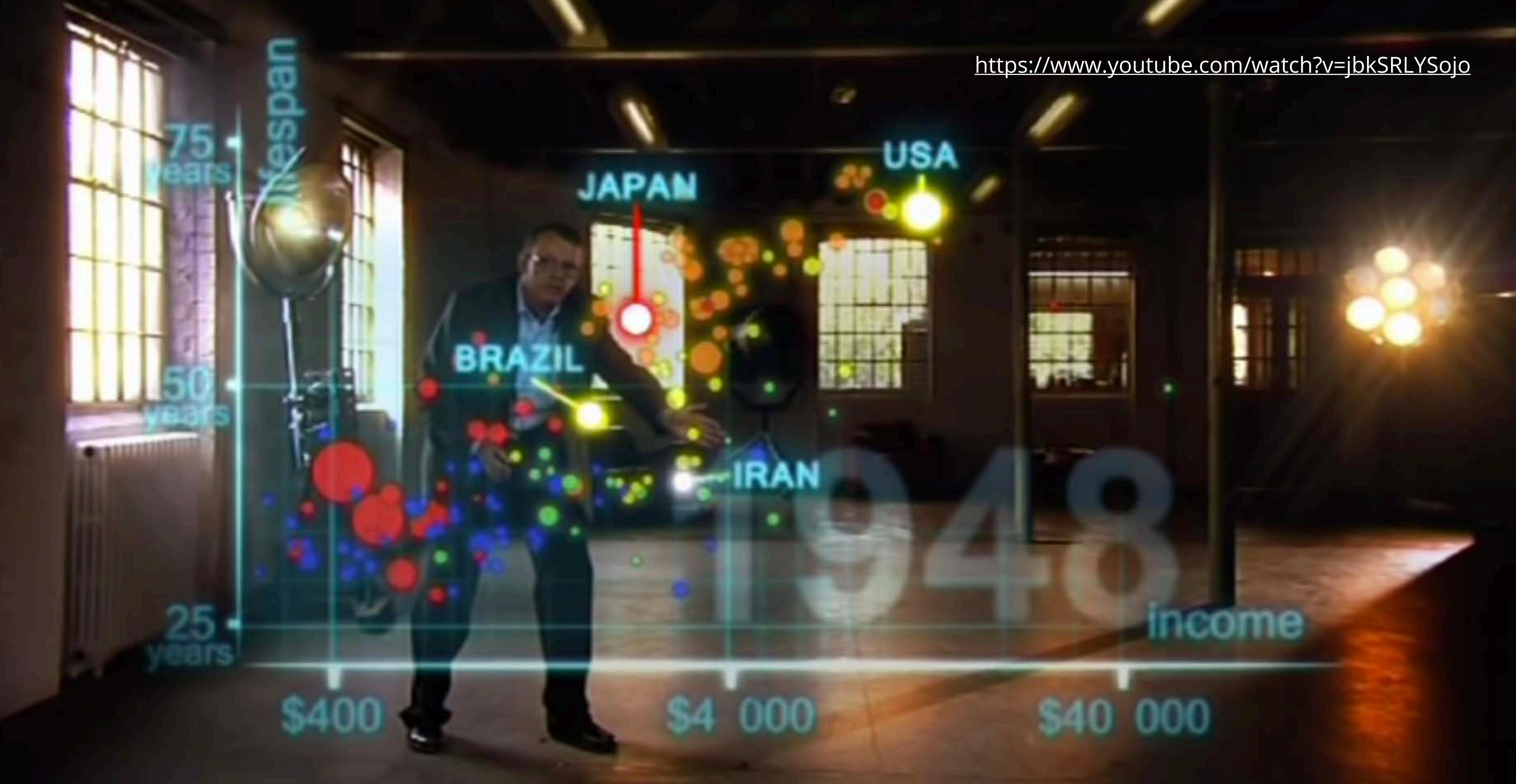
What is Information Visualization?

»The use of computer-supported, **interactive**, visual representations of abstract data to amplify cognition.« [CARD ET AL. 1999]

Interactive:

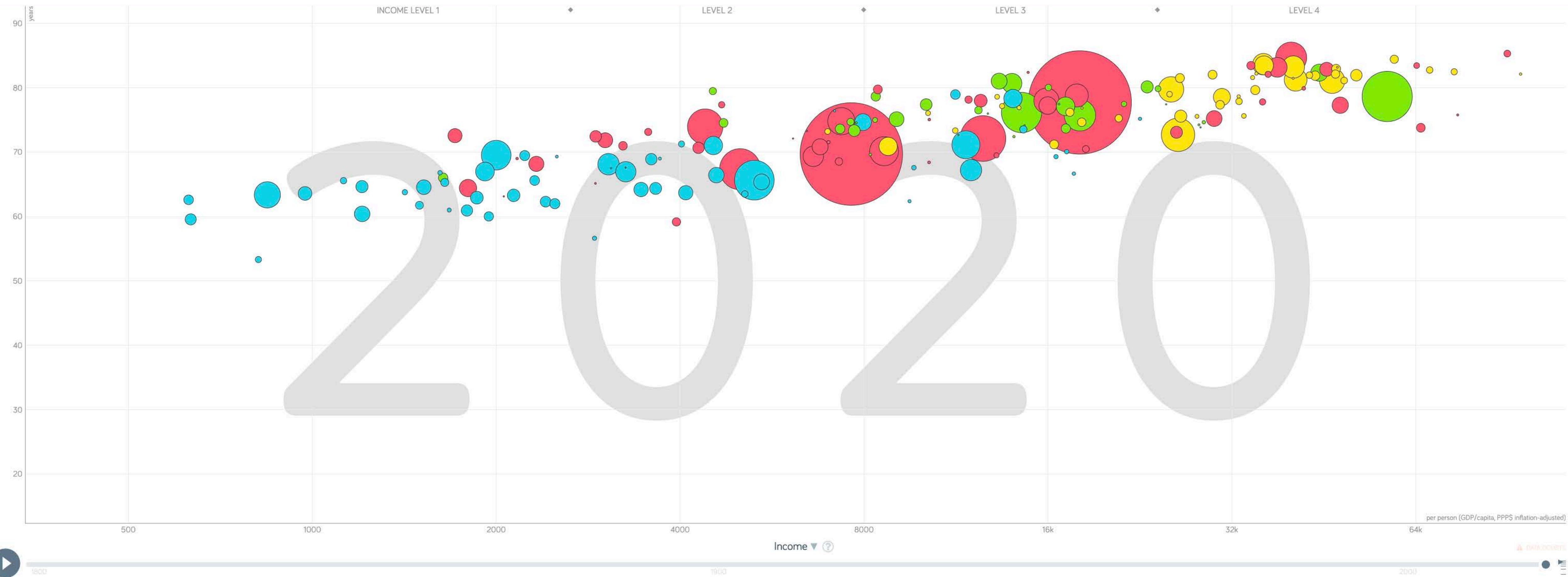
- ▶ to explore patterns and relationships in data
- ▶ users can change WHAT is visualized and
- ▶ HOW it is visualized

<https://www.youtube.com/watch?v=jbkSRLYSojo>



Gapminder

<https://www.gapminder.org/tools/>



How do you take your coffee?

118ml 177ml 355ml

Infographics



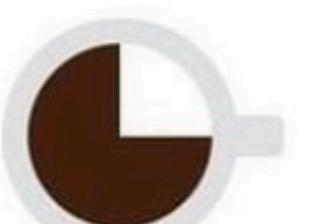
Espresso
1 espresso shot



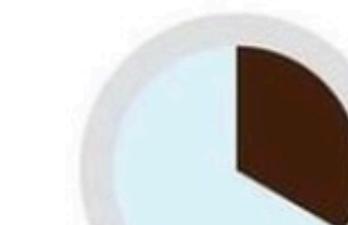
Double Espresso
2 espresso shots



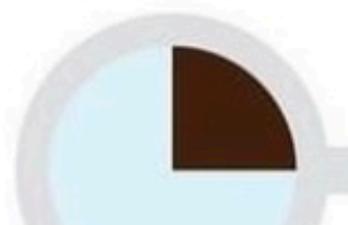
Macchiato
7/8 espresso
1/8 foamed milk



Cortado
3/4 espresso
1/4 steamed milk



Americano
1/3 espresso
2/3 hot water



Long Black
1/4 espresso
3/4 hot water



Cappuccino
1/2 espresso
1/2 steamed milk + foam



Flat White
1/2 espresso
1/2 steamed milk



Mocha
1/3 espresso
2/3 milk + chocolate



Vienna
2 espresso shots
+ whipped cream



Affogato
2 espresso shots
+ vanilla ice cream



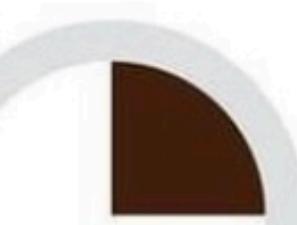
Irish Coffee
1/2 espresso
1/2 Irish whisky



Red Eye
1/2 espresso
1/2 drip coffee



Black Eye
2/3 espresso
1/3 drip coffee



Latte
1/4 espresso
3/4 steamed milk



Iced Coffee
Black coffee
+ ice

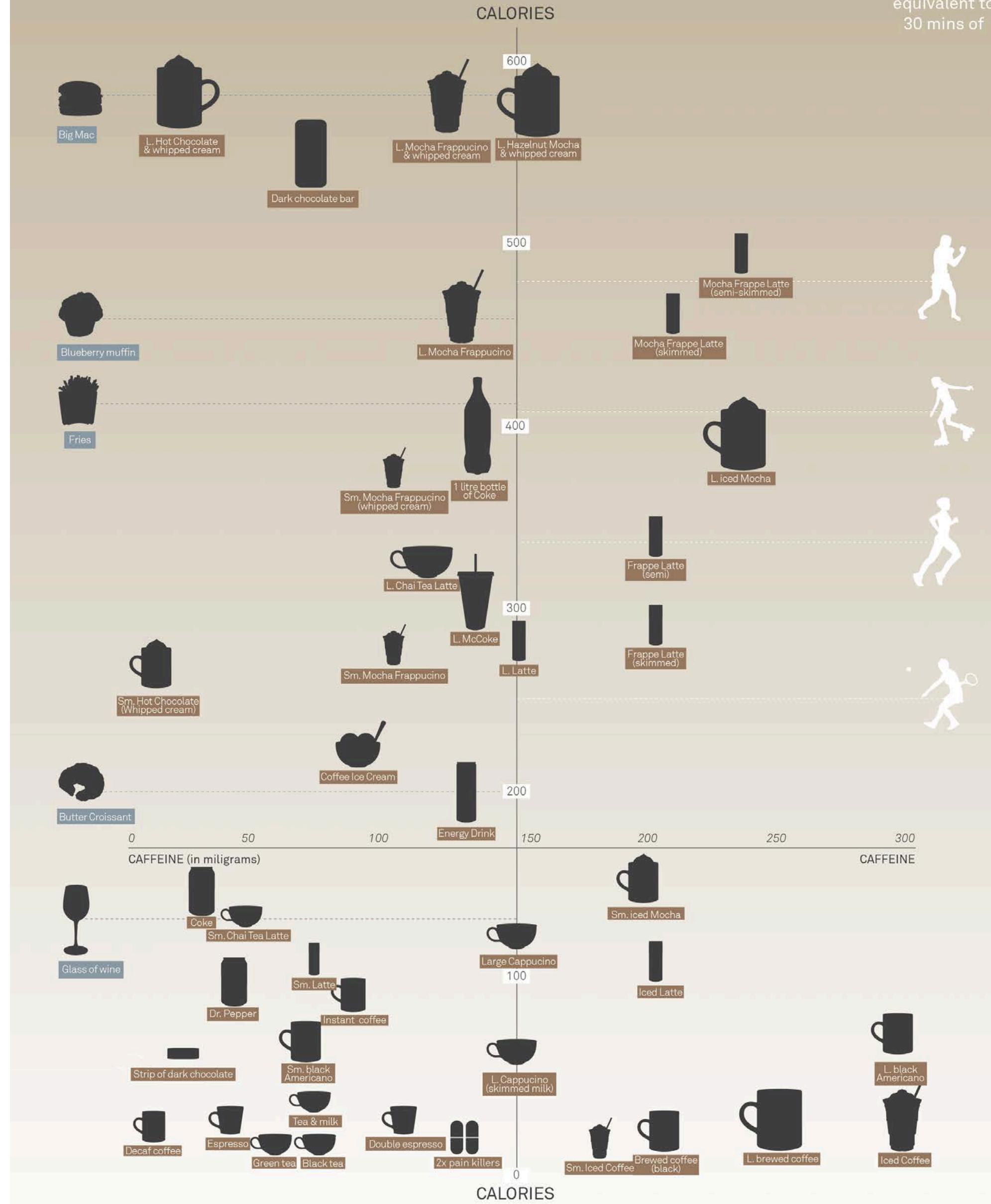
Infographics

- ▶ we need to differentiate between non-interactive infographics and interactive information visualizations
- ▶ Infographics were traditionally created for print consumption, in newspapers or magazines
- ▶ Best infographics explain things graphically - systems, events, stories - and could reasonably be termed explanation graphics [KIRK 2019]

source: <https://informationisbeautiful.net/visualizations/caffeine-and-calories/>

The Buzz vs The Bulge

Caffeine and calories

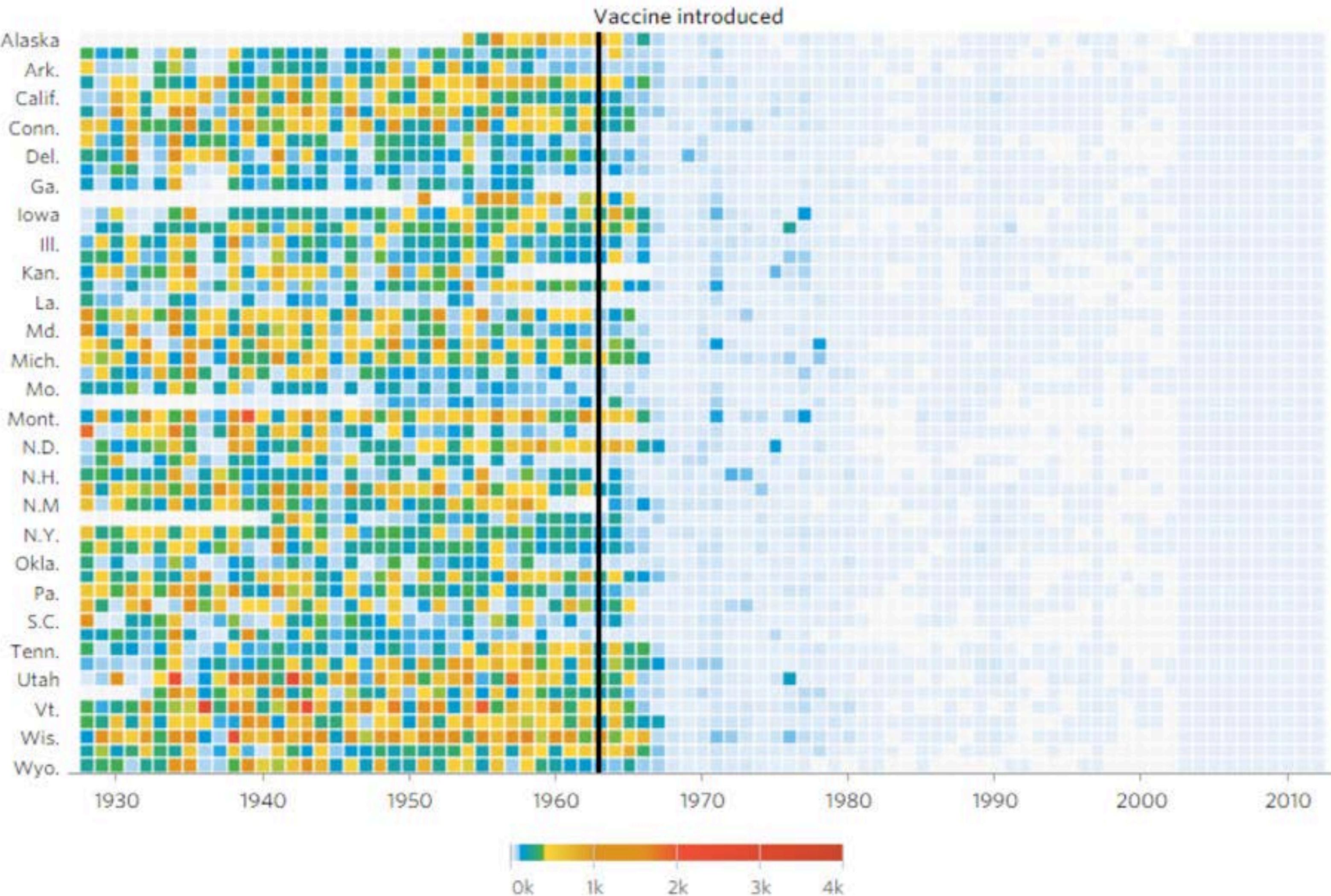


Infographics

Measles

Dov Friedman, Tynan DeBold (2015):
Vaccines and Infectious Diseases,

source: <https://www.informationisbeautifulawards.com/showcase/660-vaccines-and-infectious-diseases>



Infographics

VITAMIN D

WHERE DOES IT COME FROM?

sunlight



contains

ULTRAVIOLET RADIATION (UV)

two main types

UVA

UVB

UVA Ages your skin

UVB Burns your skin

but also creates

Vitamin D

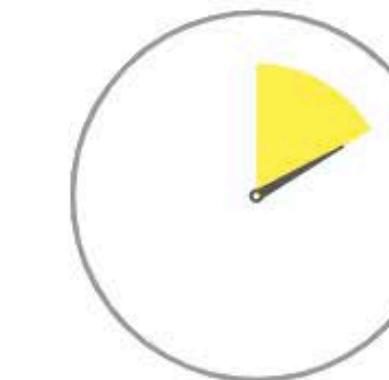
essential for health of
bones, teeth & muscles

source: US National Institute of Health

In Decent Exposure

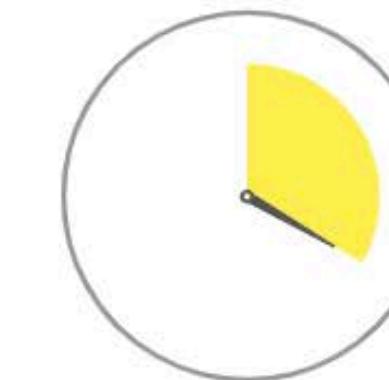
HOW MUCH SUNLIGHT DO YOU NEED **2-3 TIMES PER WEEK** TO MAKE ENOUGH VITAMIN D?

SUMMER



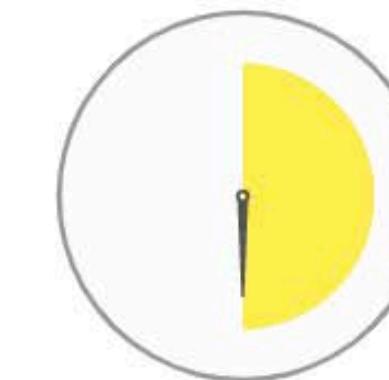
10 MINS

SPRING / AUTUMN



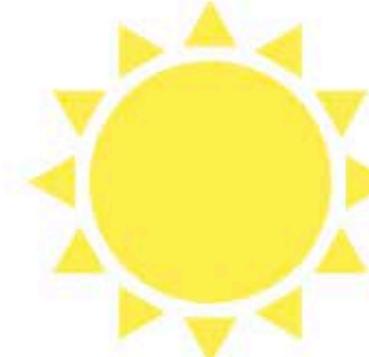
20 MINS

WINTER



30 MINS

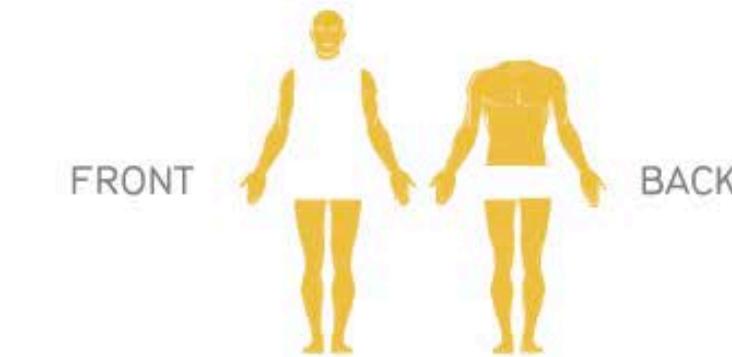
WHERE?



OUTSIDE!

UVB does not
penetrate glass

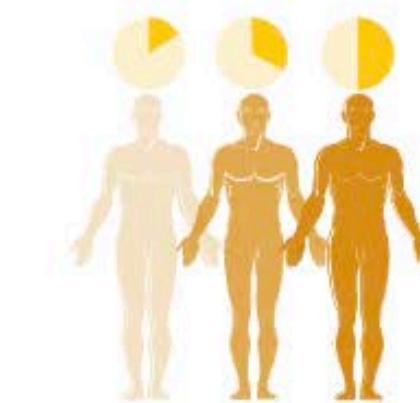
HOW?



FACE, ARMS, LEGS or BACK

No sunscreen
(SPF 30+ diminishes Vit D synthesis 97%)
always apply sunscreen after 10-30m of sun exposure

WHO?



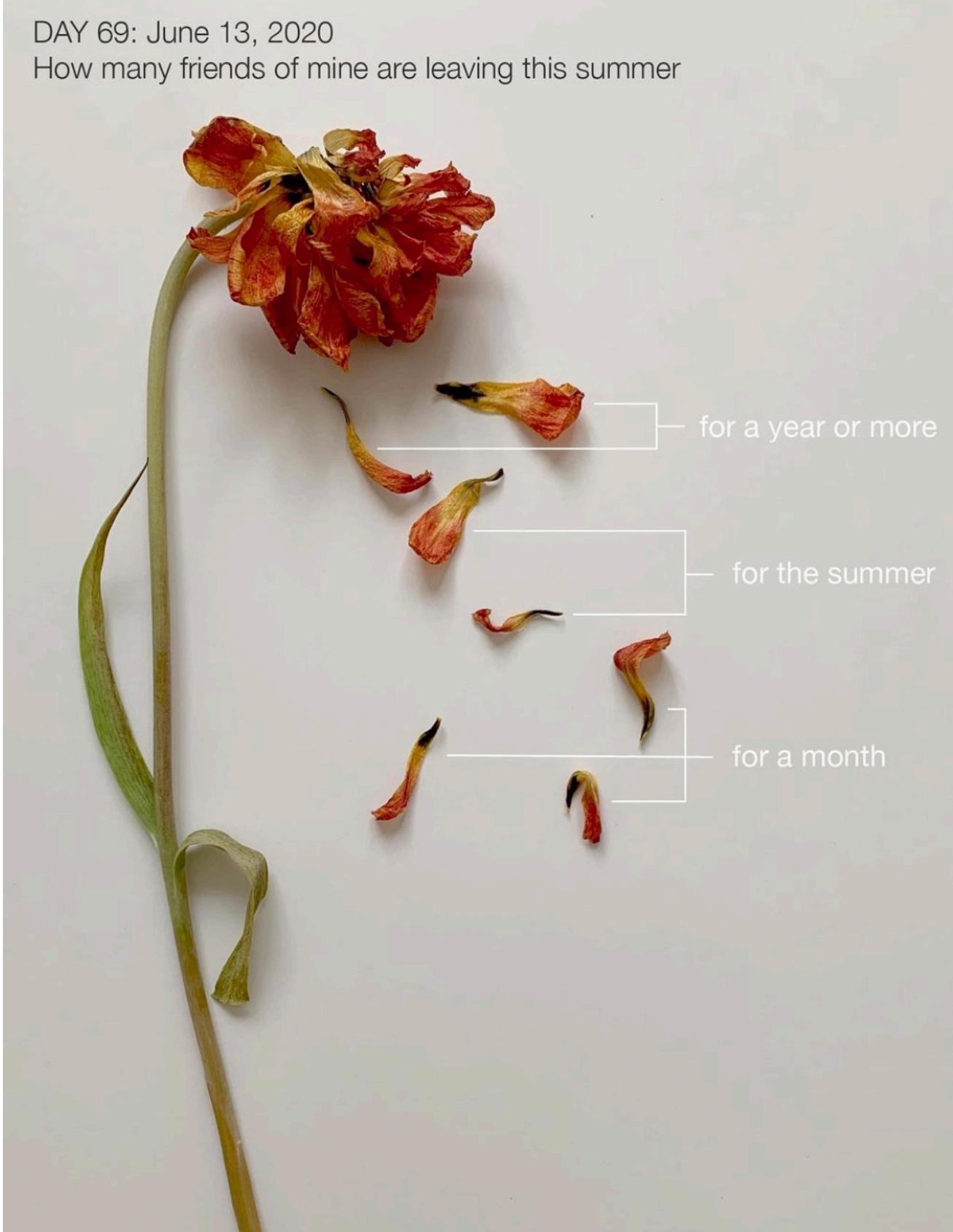
DARKER SKIN

Requires longer
exposure (2-3x)

sources: University of Manchester, US National Institute of Health

source: <https://informationisbeautiful.net/visualizations/vitamin-d/>

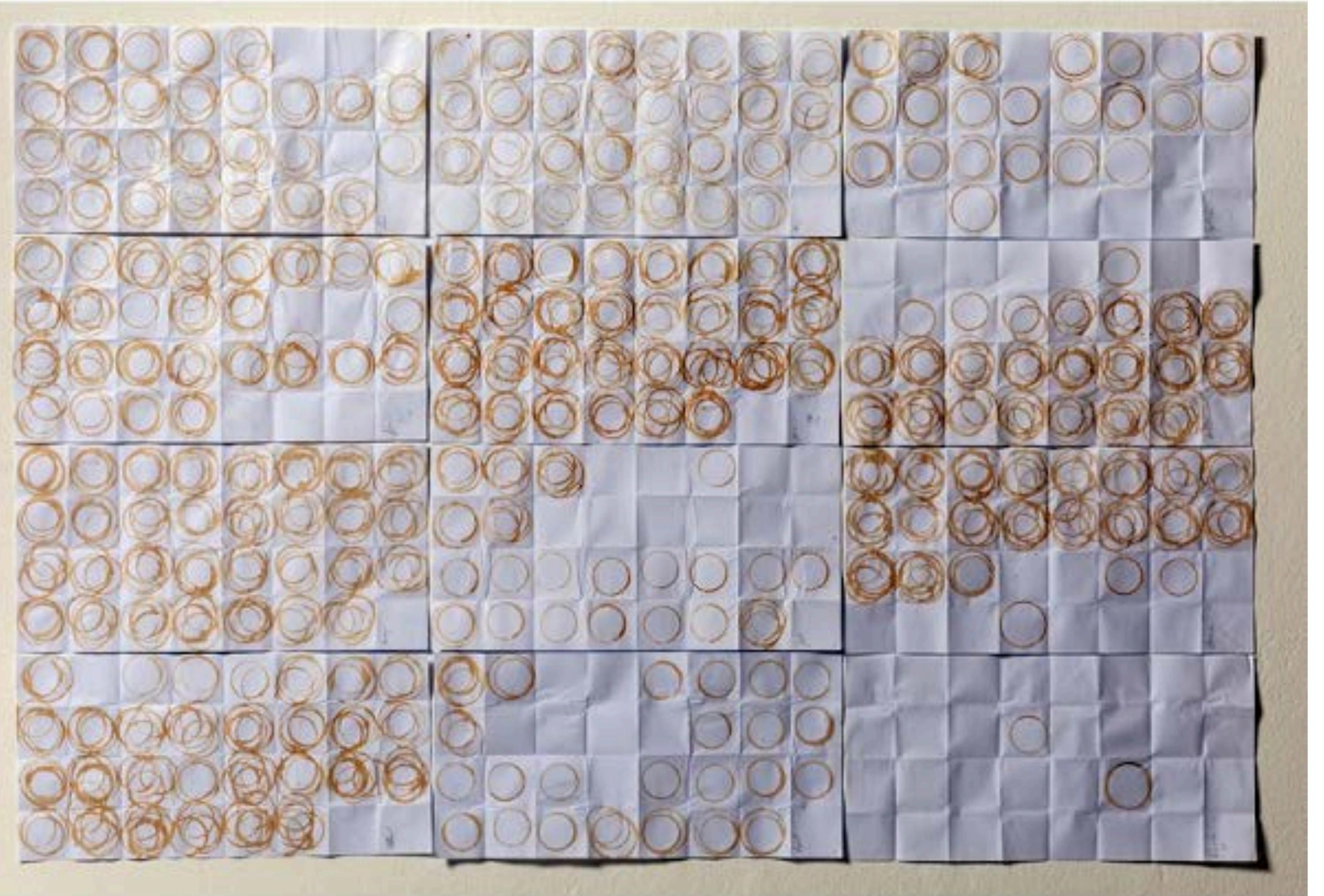
Infographics



Infographics

Jaime Serra (2013):
Daily coffee

source:
[http://visualoop.com/blog/28792/
portfolio-of-the-week-jaim...](http://visualoop.com/blog/28792/portfolio-of-the-week-jaim...)



Problems with aggregate statistics

Anscombe's quartet:

Francis Anscombe (1973)

X1	Y1	X2	Y2	X3	Y3	X4	Y4
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

Statistical description:

Mean of x: 9

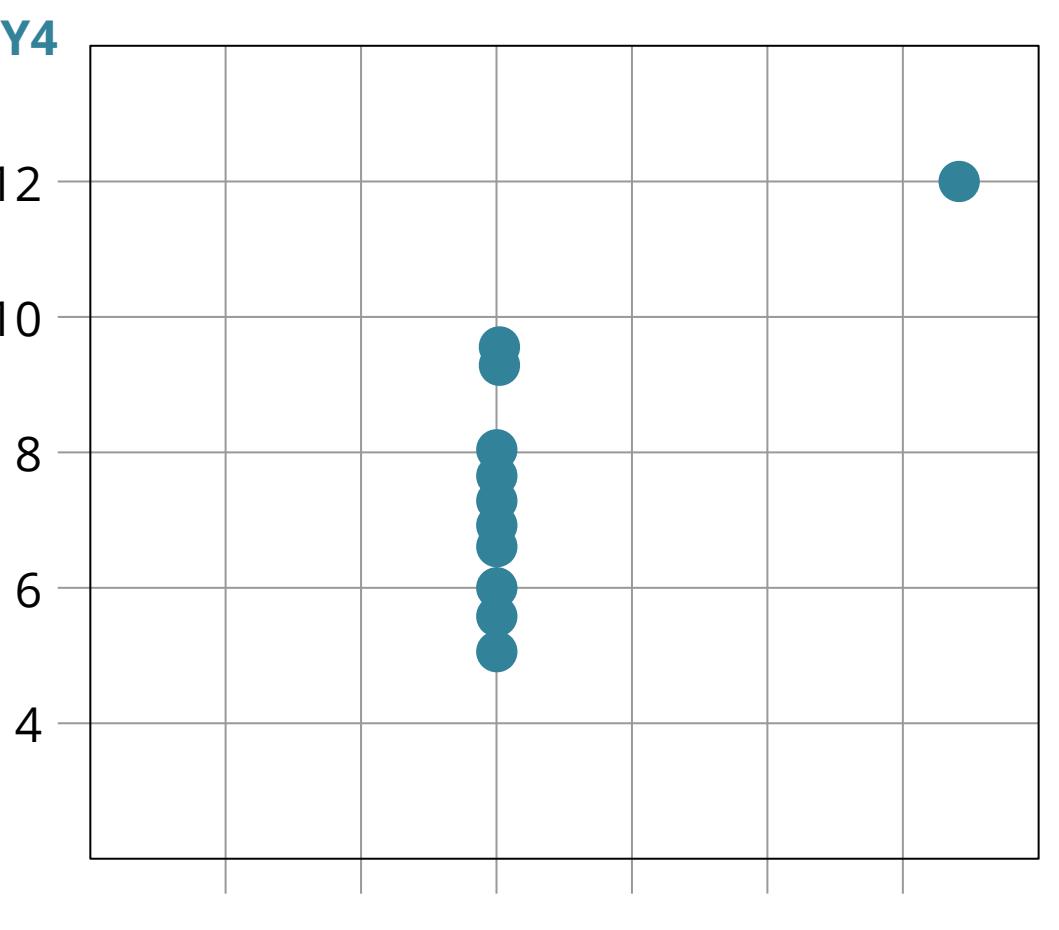
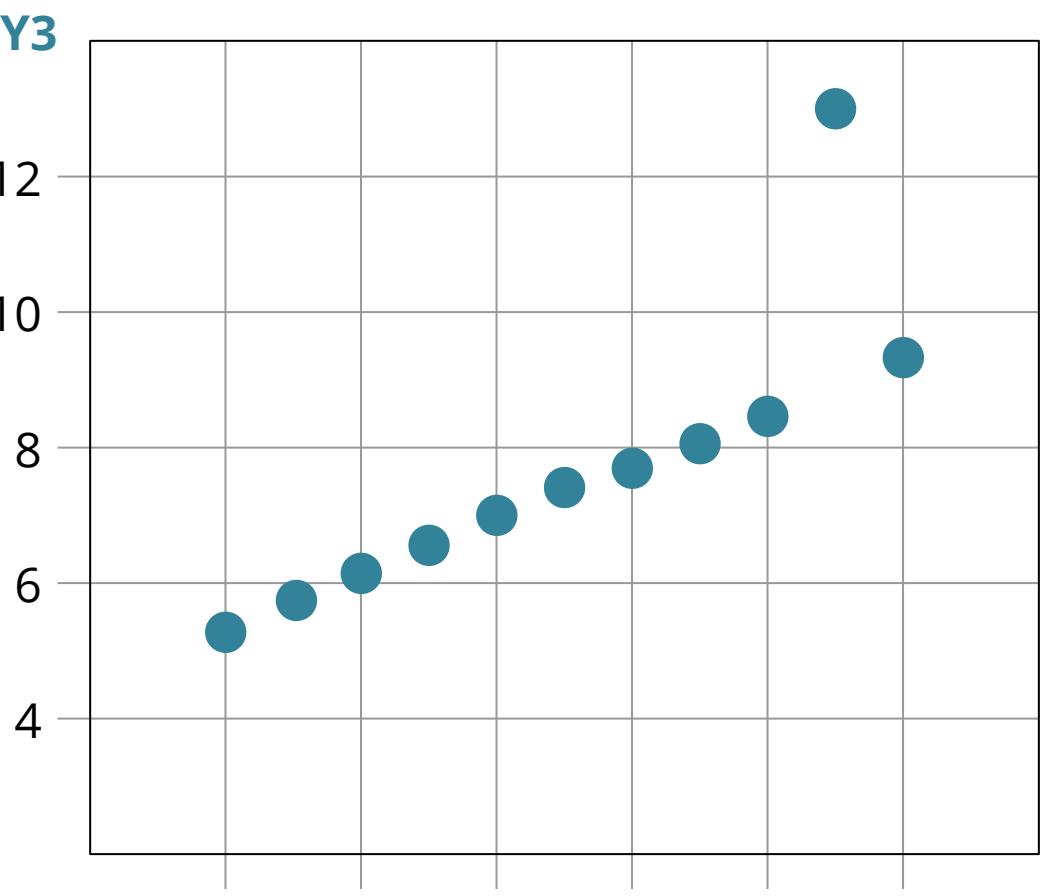
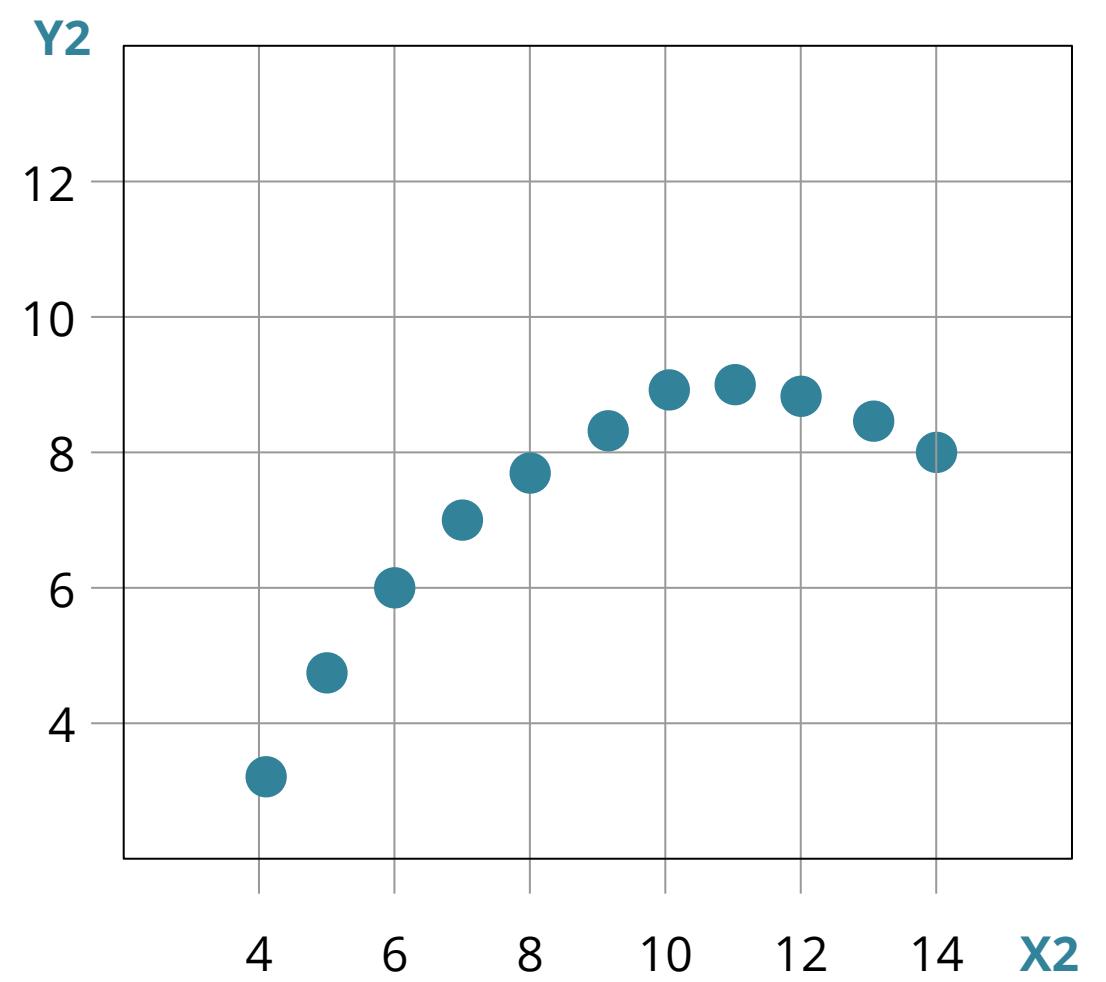
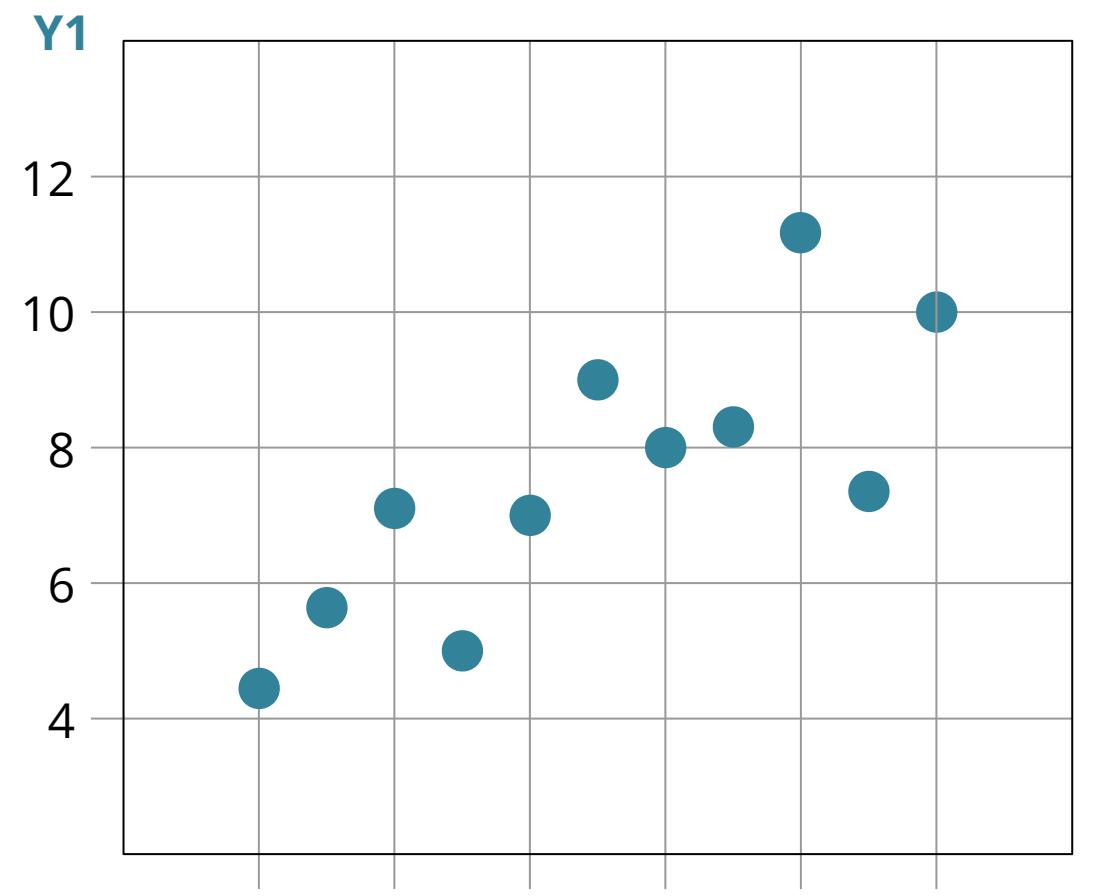
Variance of x: 11

Mean of y: 7.5

Variance of y: 4.12

Correlation: 0.816

Utilizing the human visual perception to identify patterns, clusters, gaps, outliers



Purpose of a Visualization

Communicate insights,
inspire new thinking about a problem

Explanation



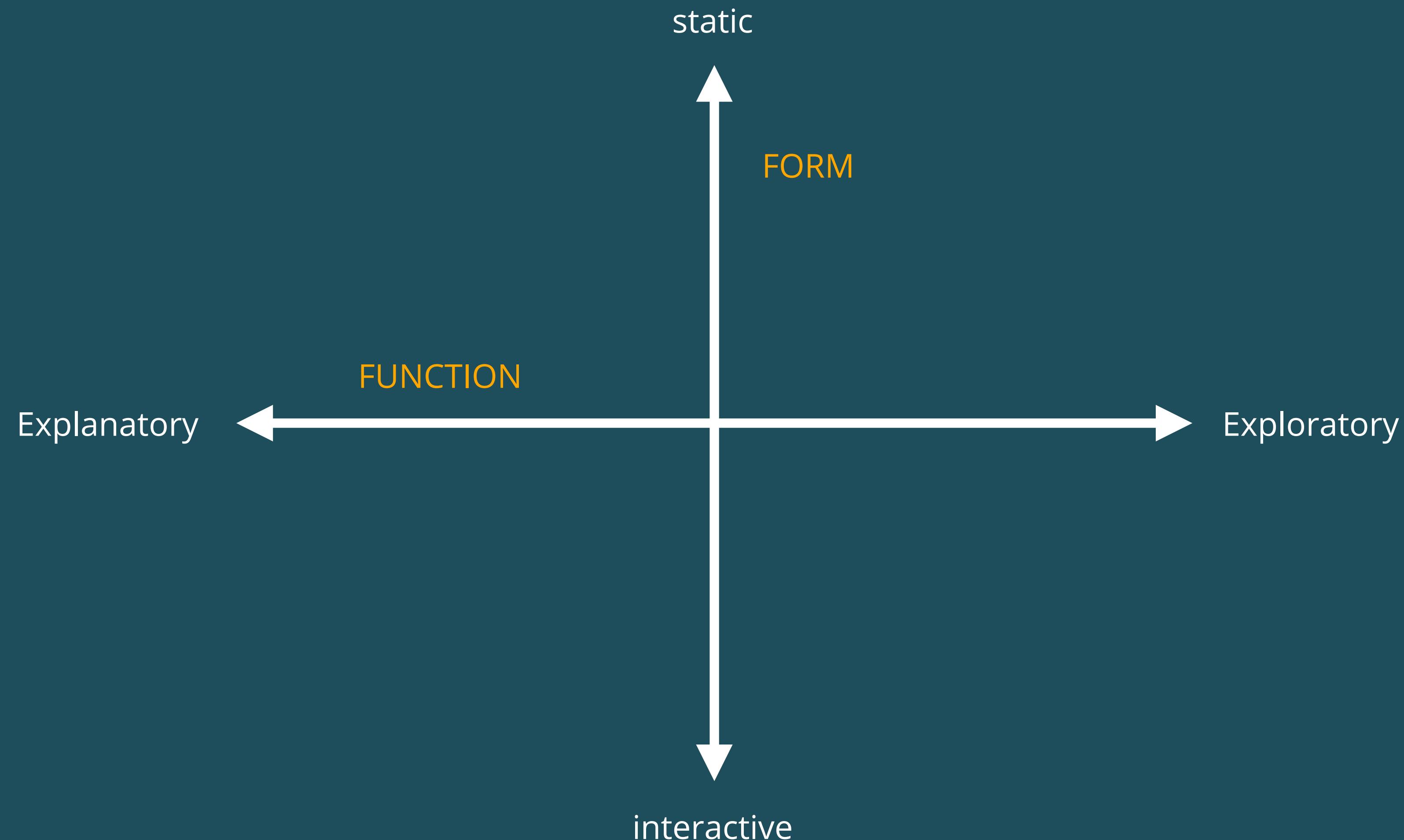
Explorative Analysis:
undirected search in data,
goal: to provide hypotheses

Exploration / Analysis

Confirmative Analysis:
goal-oriented examination of the
hypotheses, goal: confirmation or
rejection of hypotheses

[KEIM ET AL. 2006, SCHWABISH 2021]

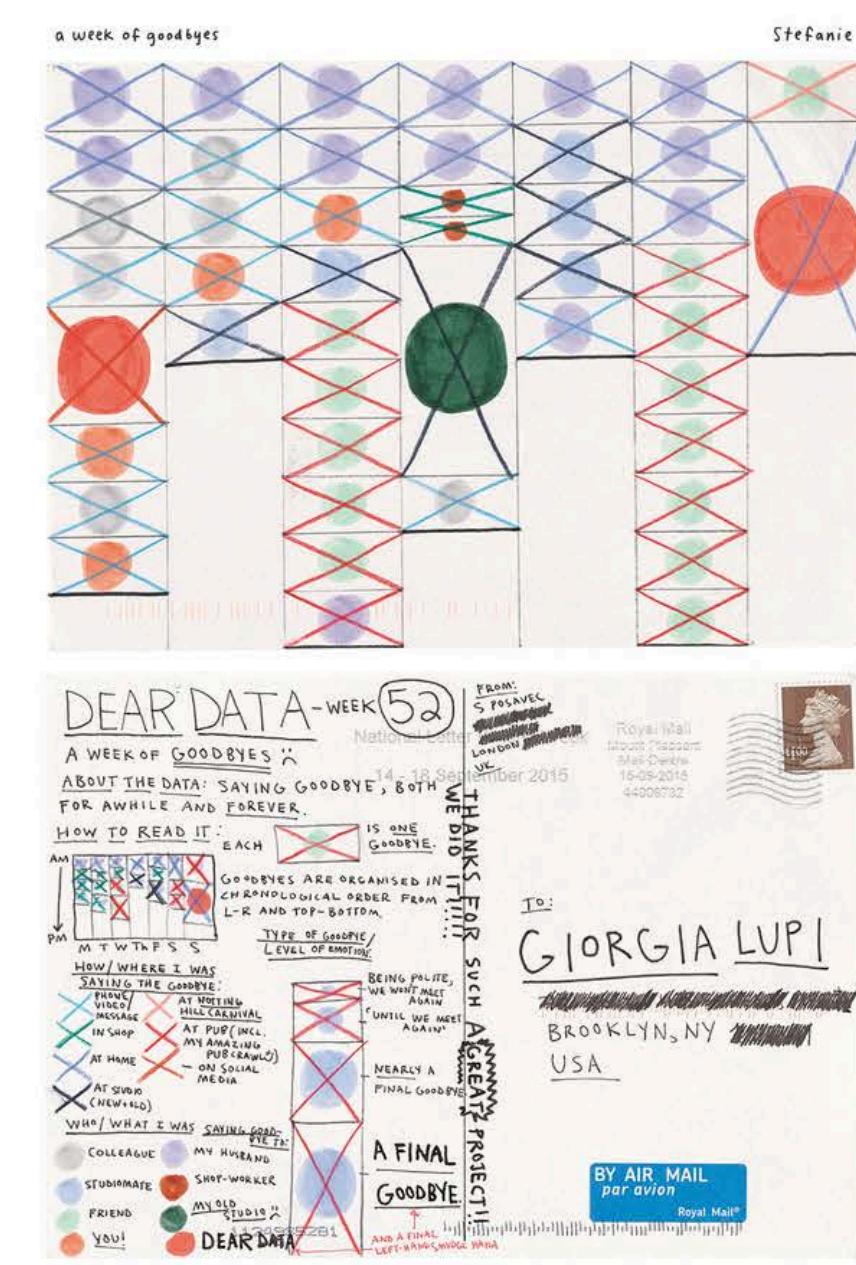
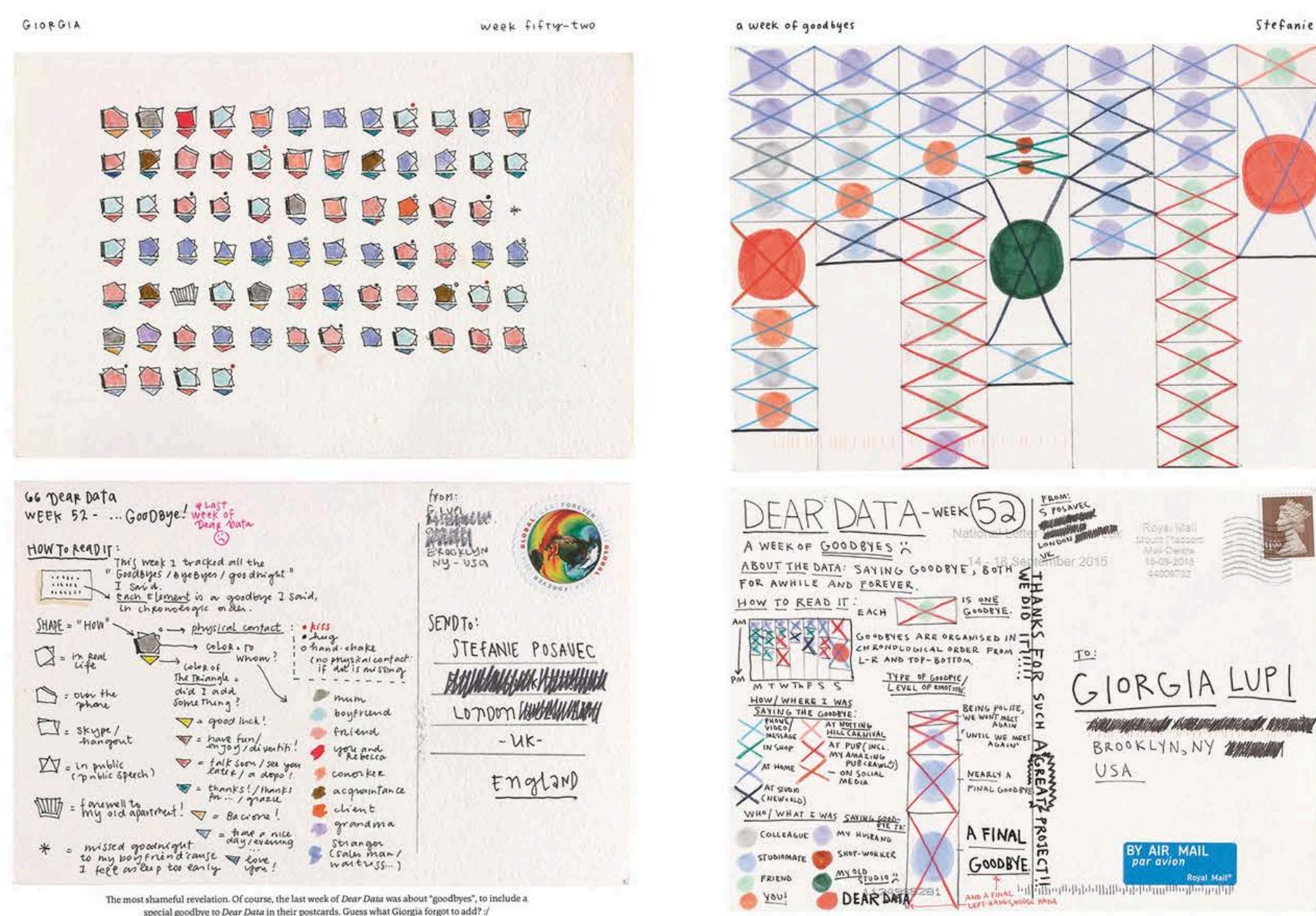
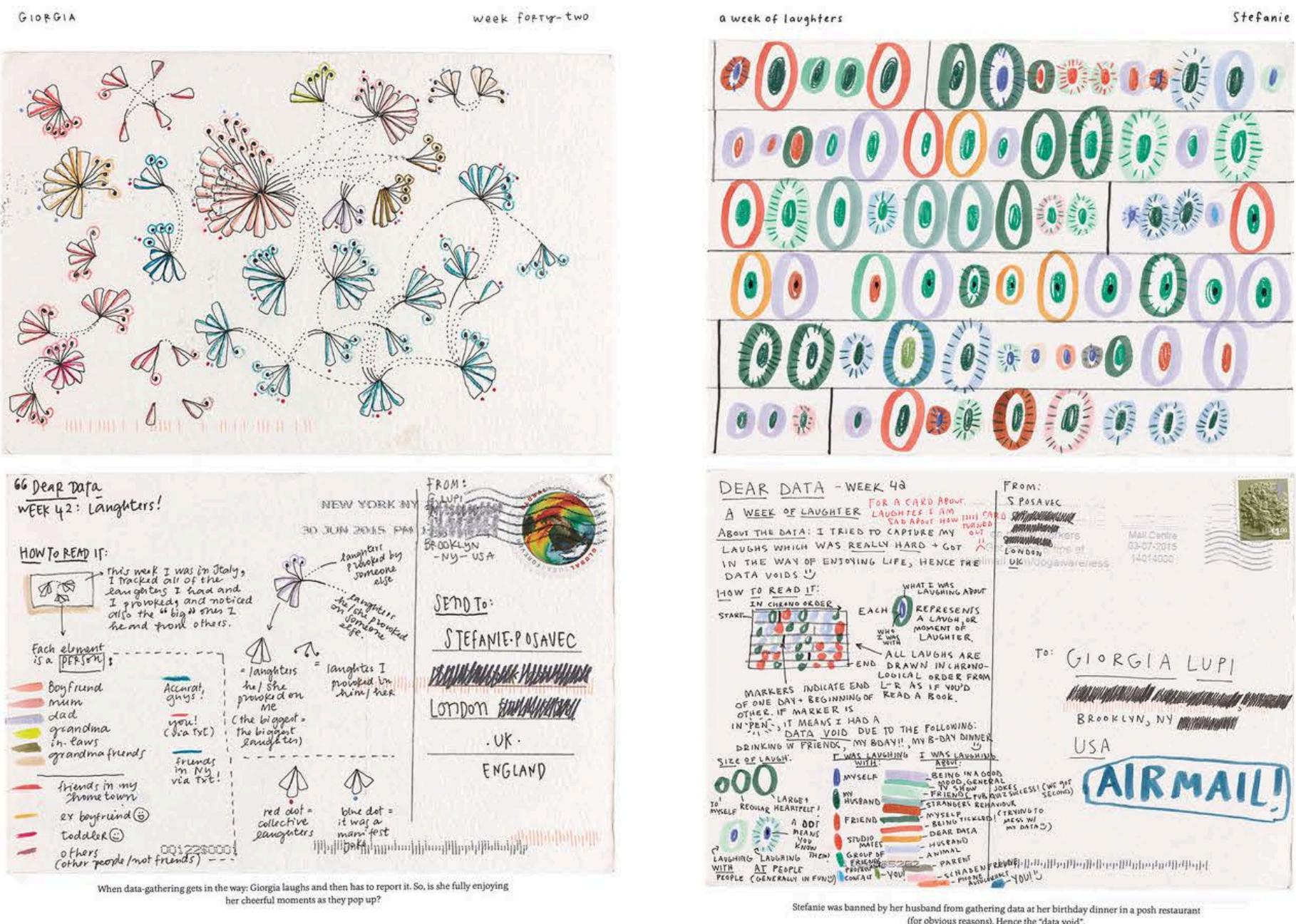
Form and Function



[SCHWABISH 2021]

Static

Giorgia Lupi & Stefanie Posavec (2016):
Dear Data
 source:
<http://www.dear-data.com/>



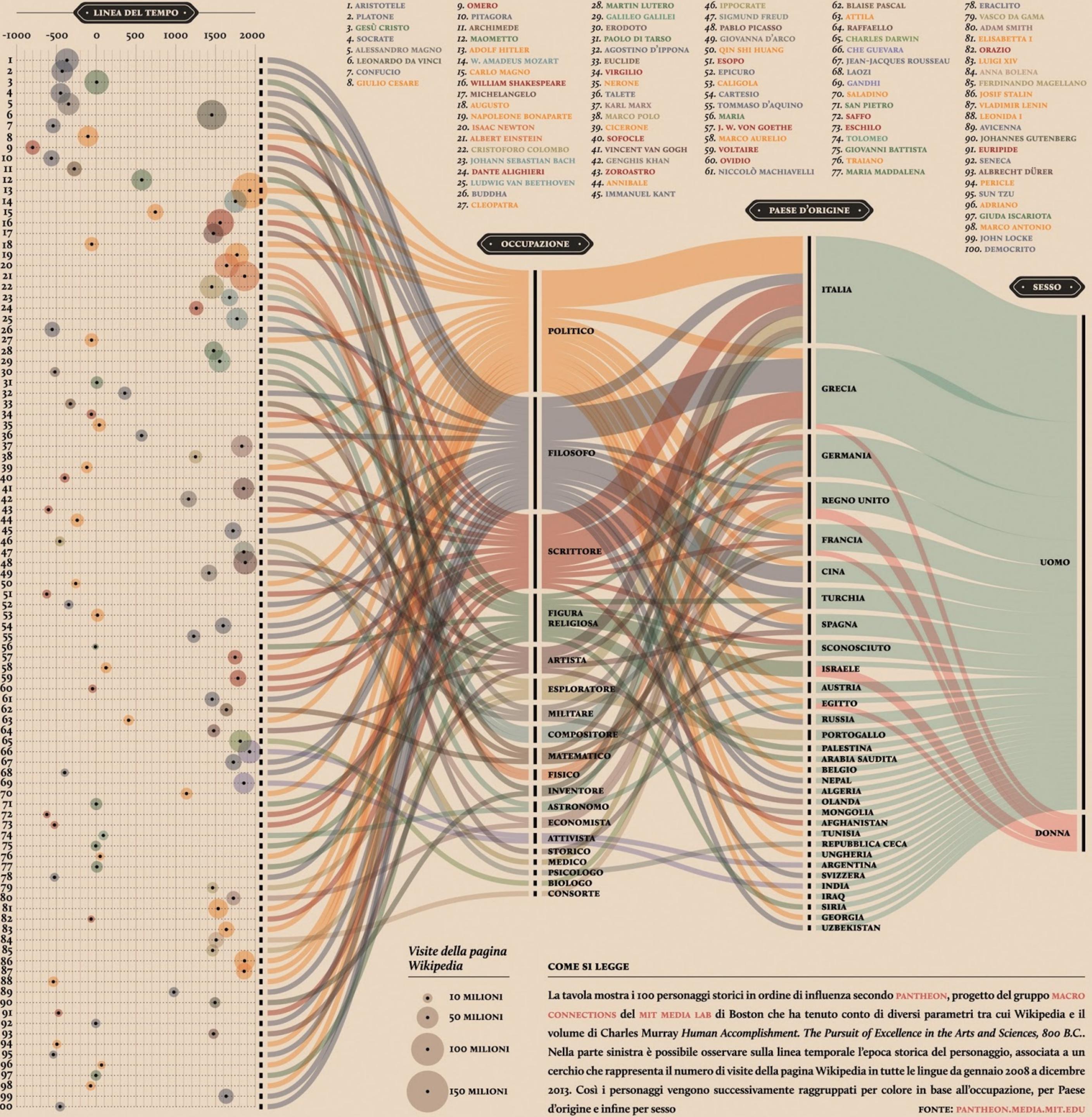
Dear Data

<https://www.youtube.com/watch?v=iqaVe1MCTIA&t=193s>



Static & Exploratory

Valerio Pellegrini (2015): 100 historical figures in order of influence according to Pantheon, a macro-connections group project of the MIT Media Lab of Boston



Static & Exploratory

Nobels no degrees

This visualization explores Nobel Prizes and graduate qualifications from 1901 to 1912, by analysing the age of recipients at the time prizes were awarded, average age evolution through time and among categories, graduation grades, main university affiliations and the principal hometowns of the graduates.

How to read it?

Each dot represents a Nobel laureate, each recipient is positioned according to the year the prize was awarded (x axis) and age of the person at the time of the award (y axis).

Nobels no degrees:

Giorgia Lupi, Simone Quadri, Gabriele Rossi, Davide Ciuffi, Federica Fragapane, Francesco Majno <https://www.informationisbeautifulawards.com/showcase/204-nobels-no-degrees>

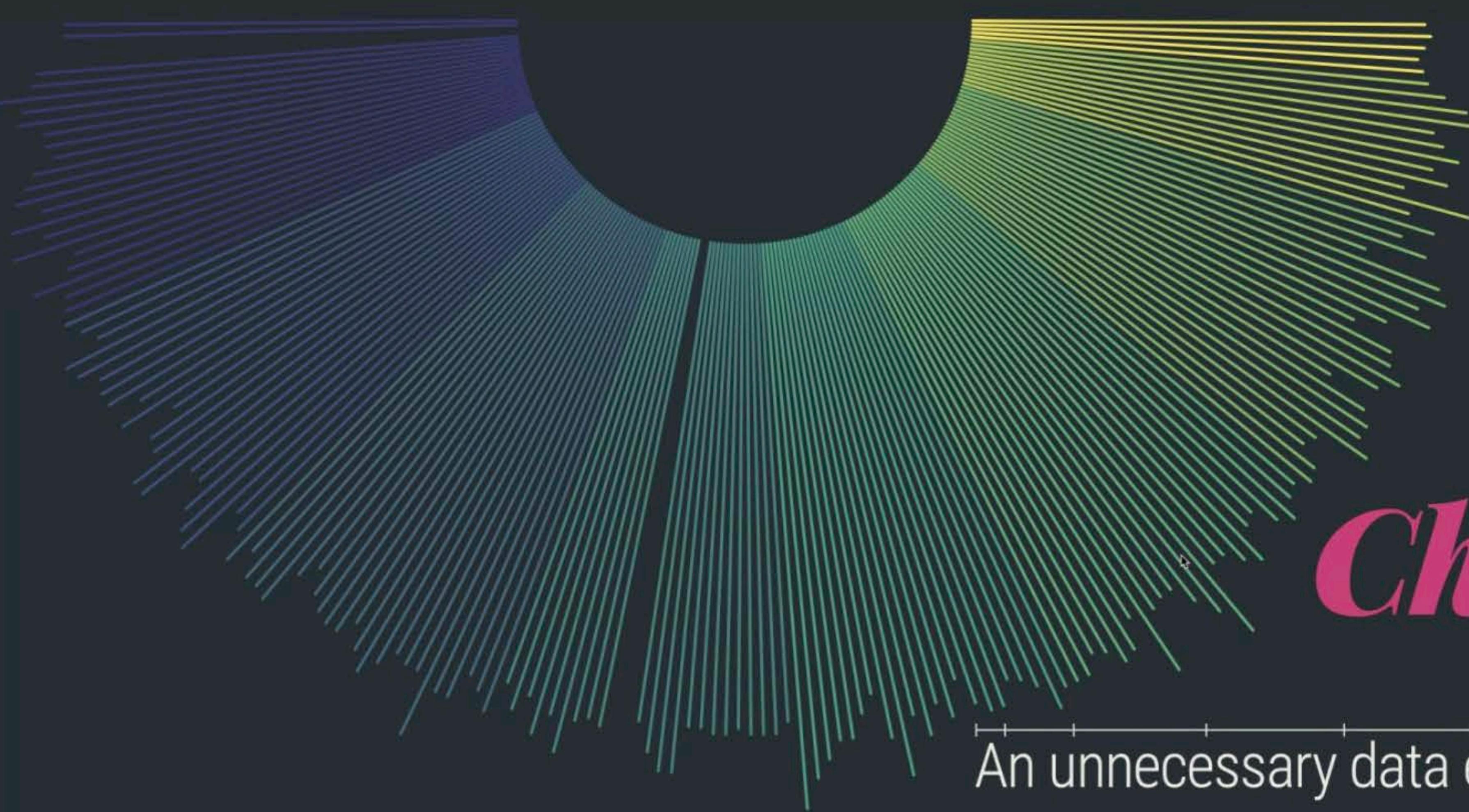


Interactive & Exploratory

<https://github.com/visualengineers/glyphboard>



Explanatory Visualization

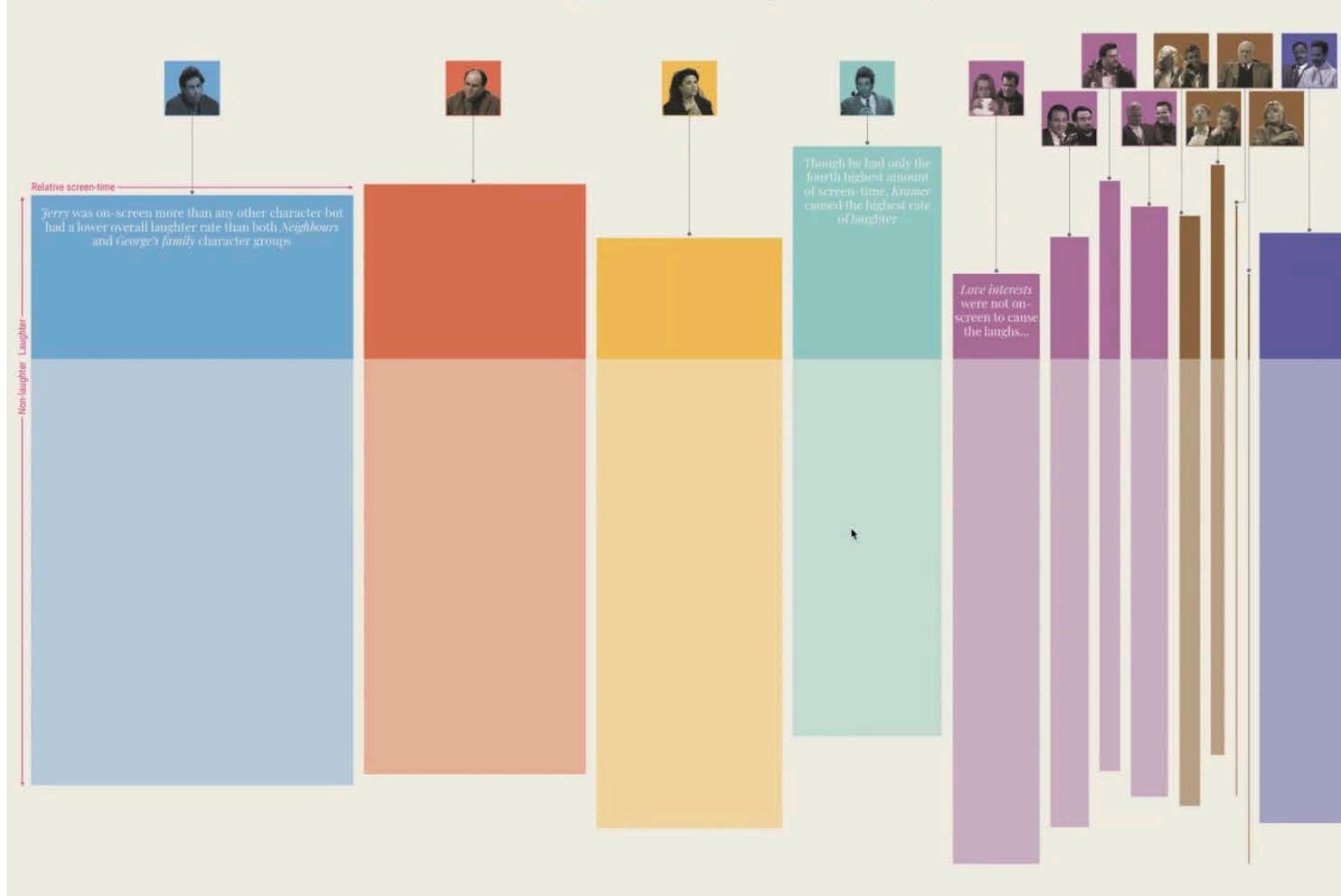


*The
Seinfeld
Chronicles*

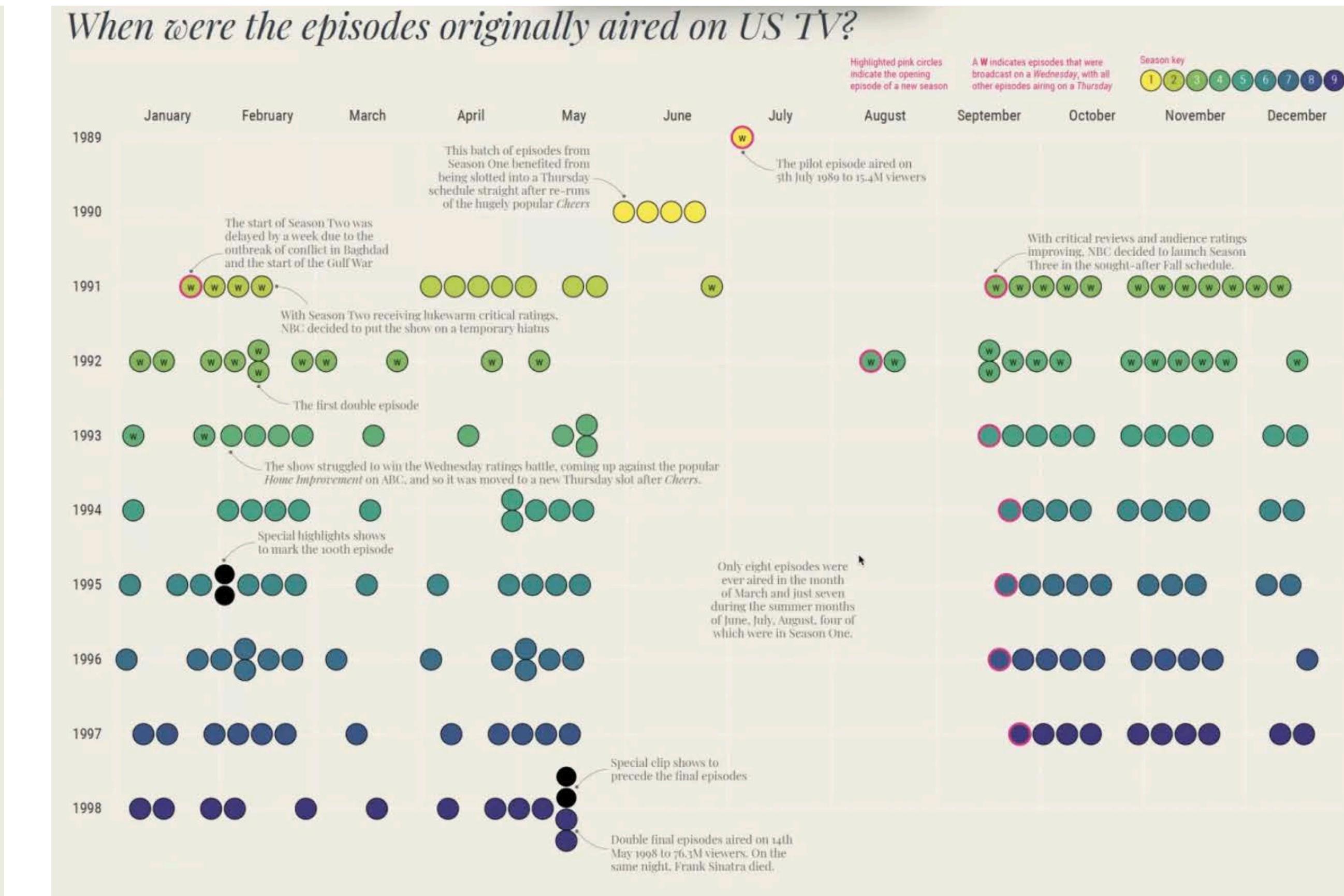
An unnecessary data exploration **by Andy Kirk**

Static & Explanatory

How did relative screen-time correspond to laughter rate for each character?



When were the episodes originally aired on US TV?



The Seinfeld Chronicles: An unnecessary data exploration by Andy Kirk

Explanatory Visualization (Animated)

An Ocean Away

Angelica Schuyler is Alexander Hamilton's sister-in-law, the one who introduces Alexander to her sister Eliza Schuyler. Angelica and Alexander's relationship is ambiguously flirtatious from the very start, their exchanges in *Satisfied* punctuated by mutual understanding - that they're both never satisfied.

Their flirtation is amplified in *Take A Break*, the only time in the whole musical they sing together:

► And there you are, an ocean away
Do you have to live an ocean away?
Thoughts of you subside
Then I get another letter
I cannot put the notion away...

They continue as Angelica visits from London:

► You won't be an ocean away
You will only be a moment away...

And they leave us wondering: did they, or didn't they?



An Interactive Visualization of Every Line in Hamilton

<https://pudding.cool/2017/03/hamilton/index.html>

R2
D3

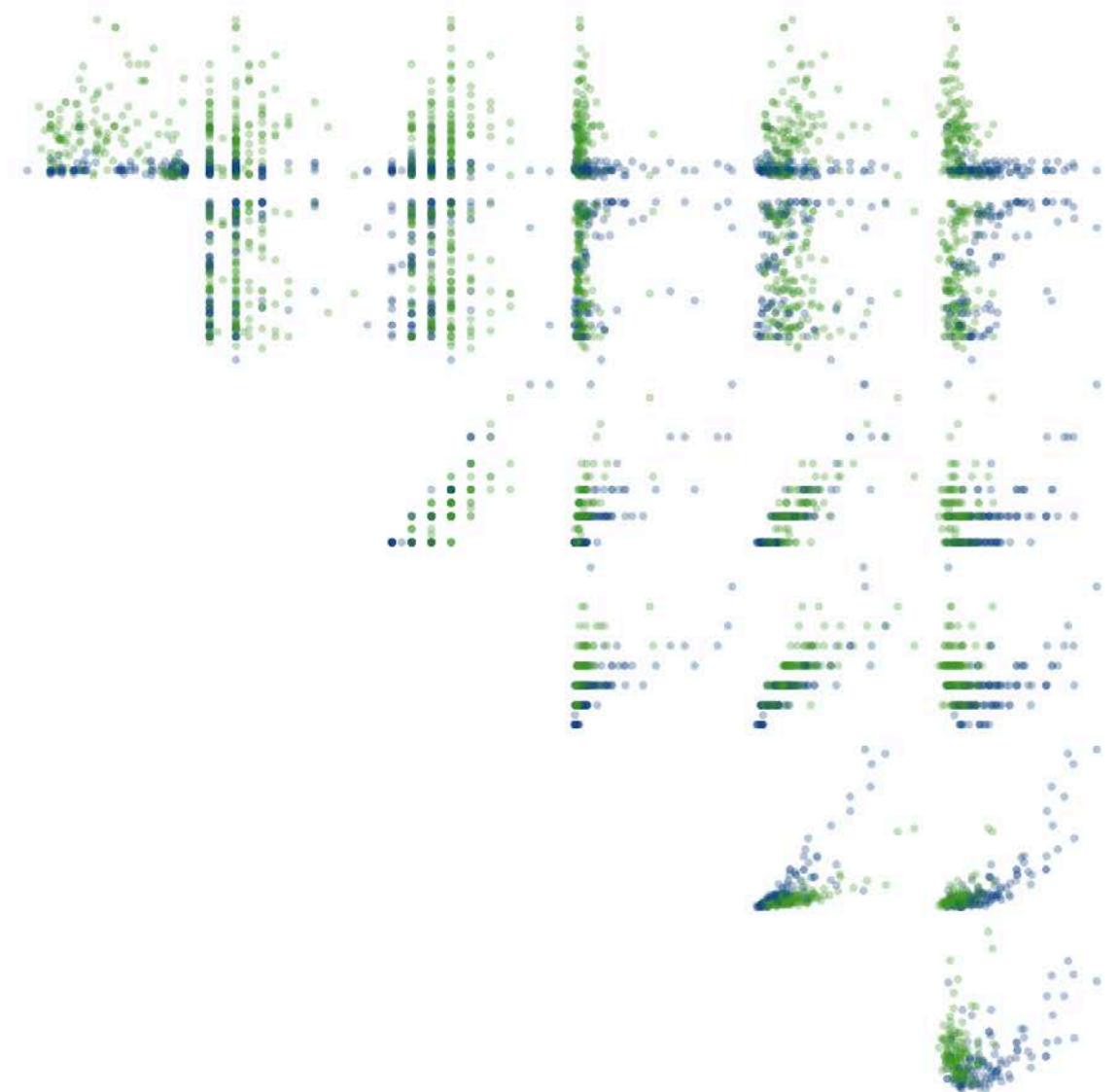
A visual introduction to machine learning

English

In machine learning, computers apply **statistical learning** techniques to automatically identify patterns in data. These techniques can be used to make highly accurate predictions.

Keep scrolling. Using a data set about homes, we will create a machine learning model to distinguish homes in New York from homes in San Francisco.

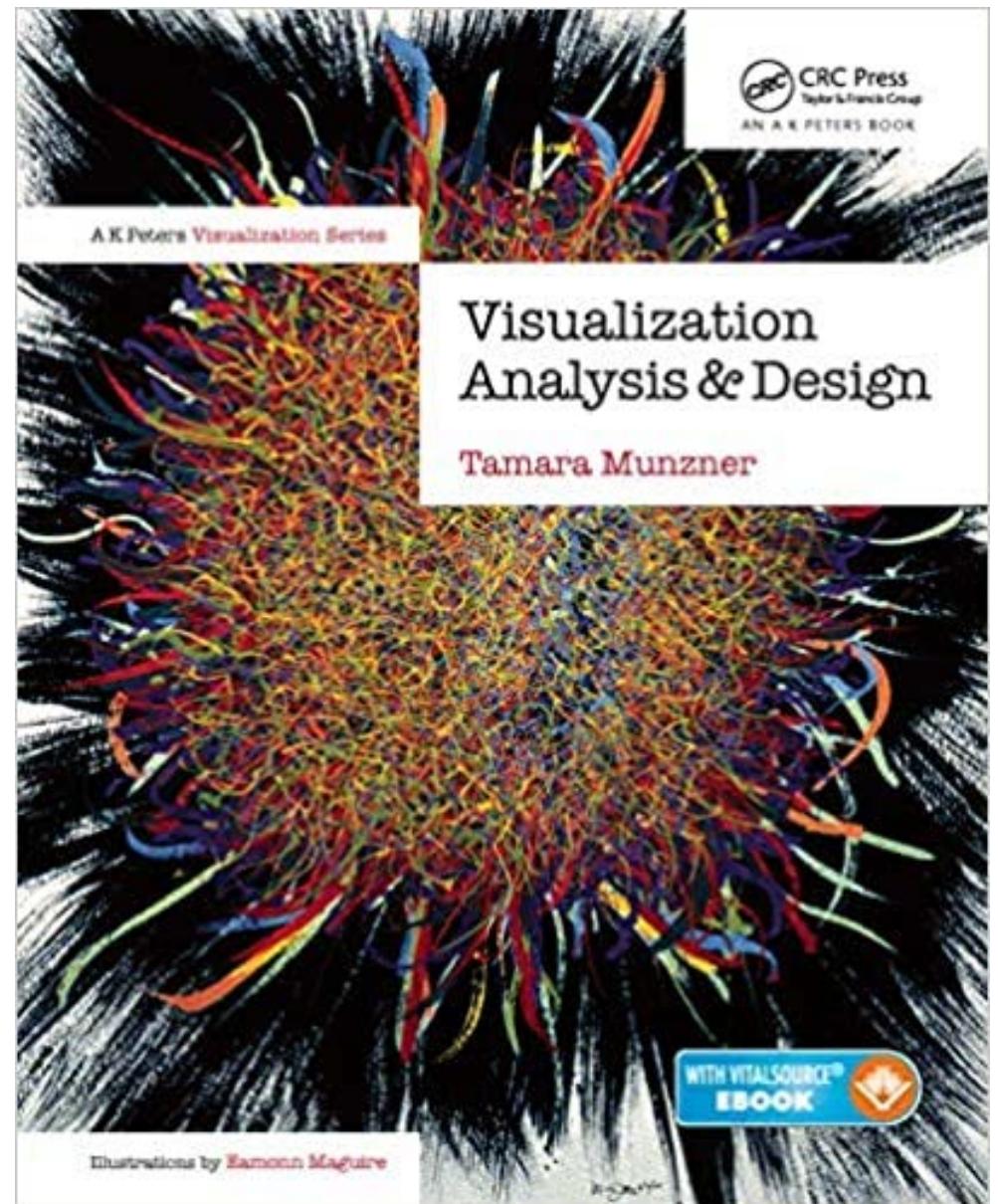
SCROLL



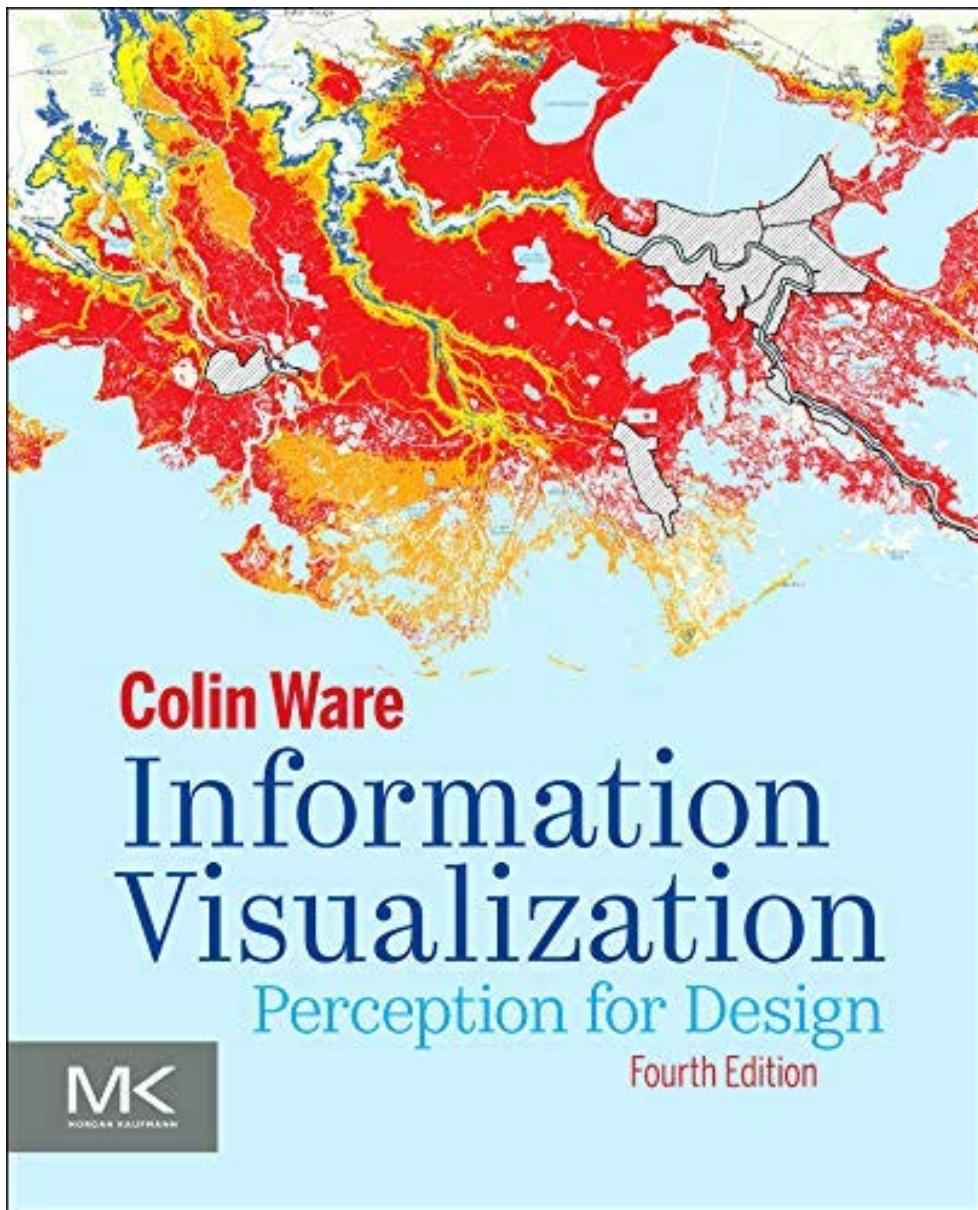
Introduction to Machine Learning

www.r2d3.us/visual-intro-to-machine-learning-part-1/

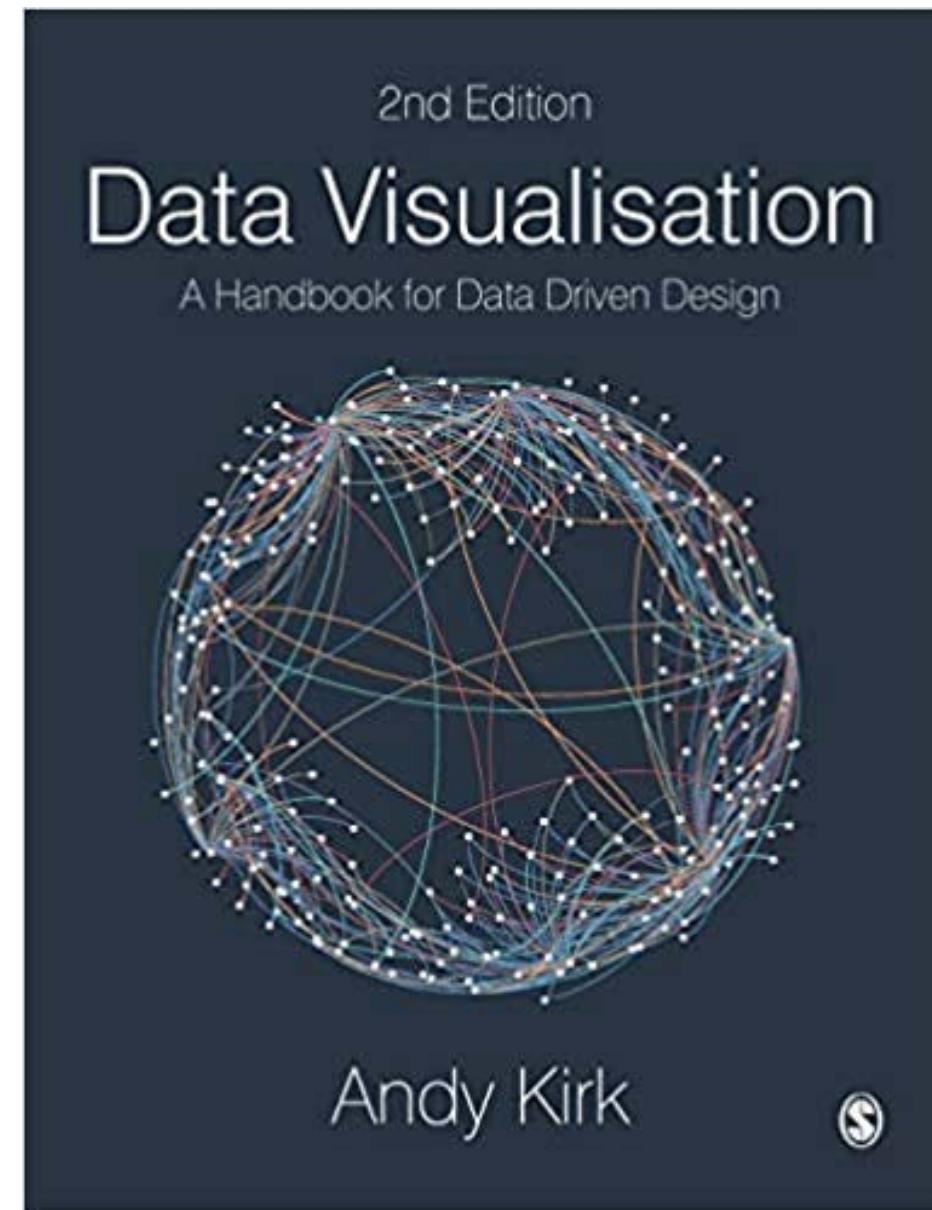
Books



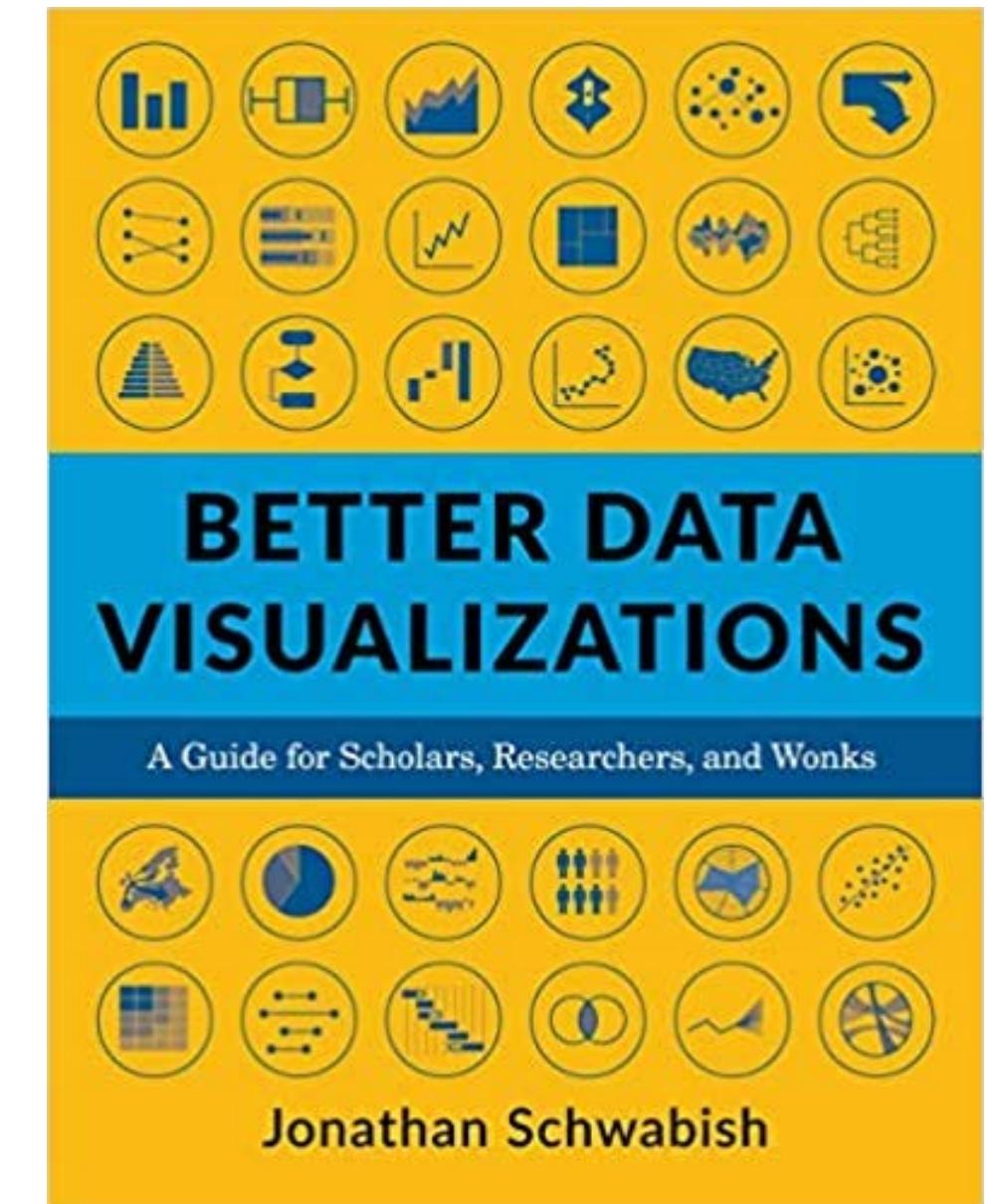
Tamara Munzner:
Visualization Analysis
and Design (2014)



Colin Ware:
Information Visualization
(2020)

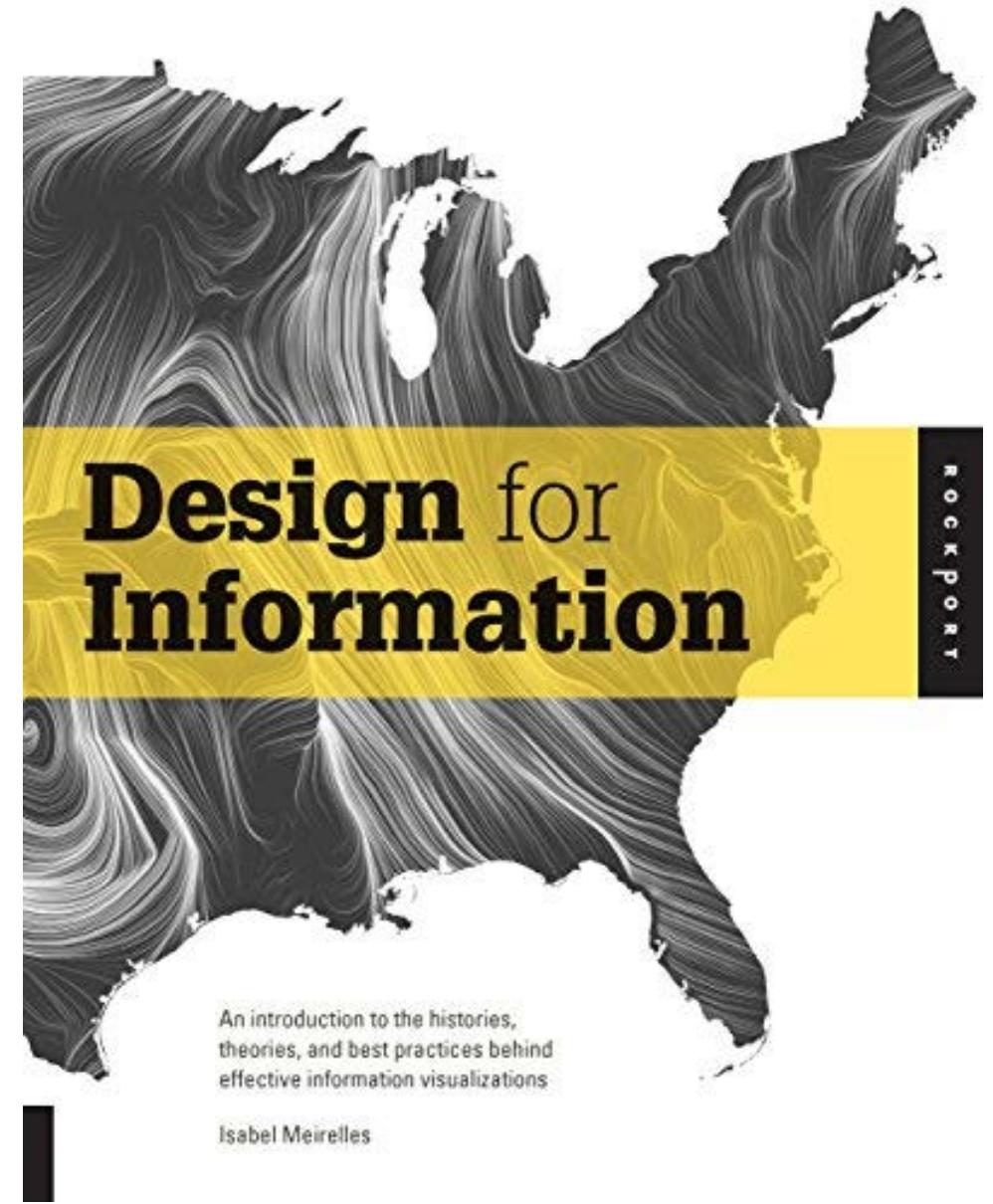


Andy Kirk:
Data Visualisation
(2019)

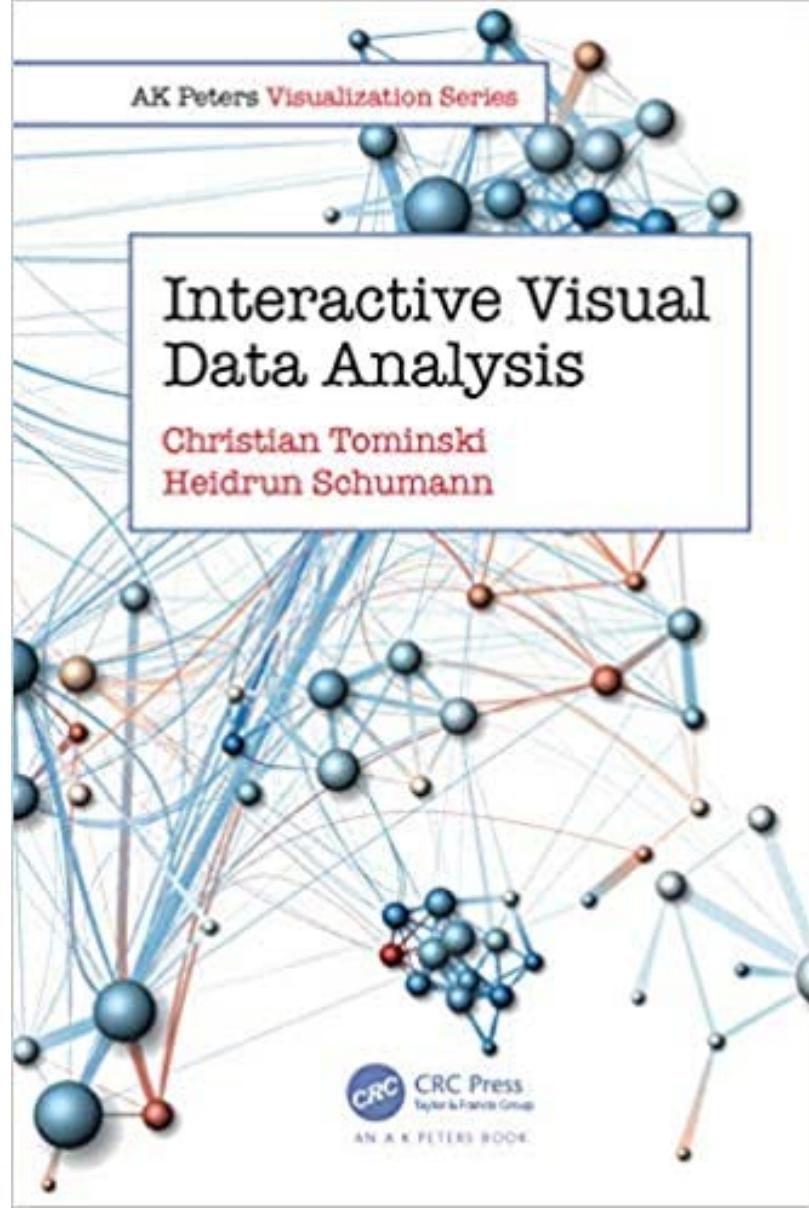


Jonathan Schwabish:
Better Data
Visualizations (2021)

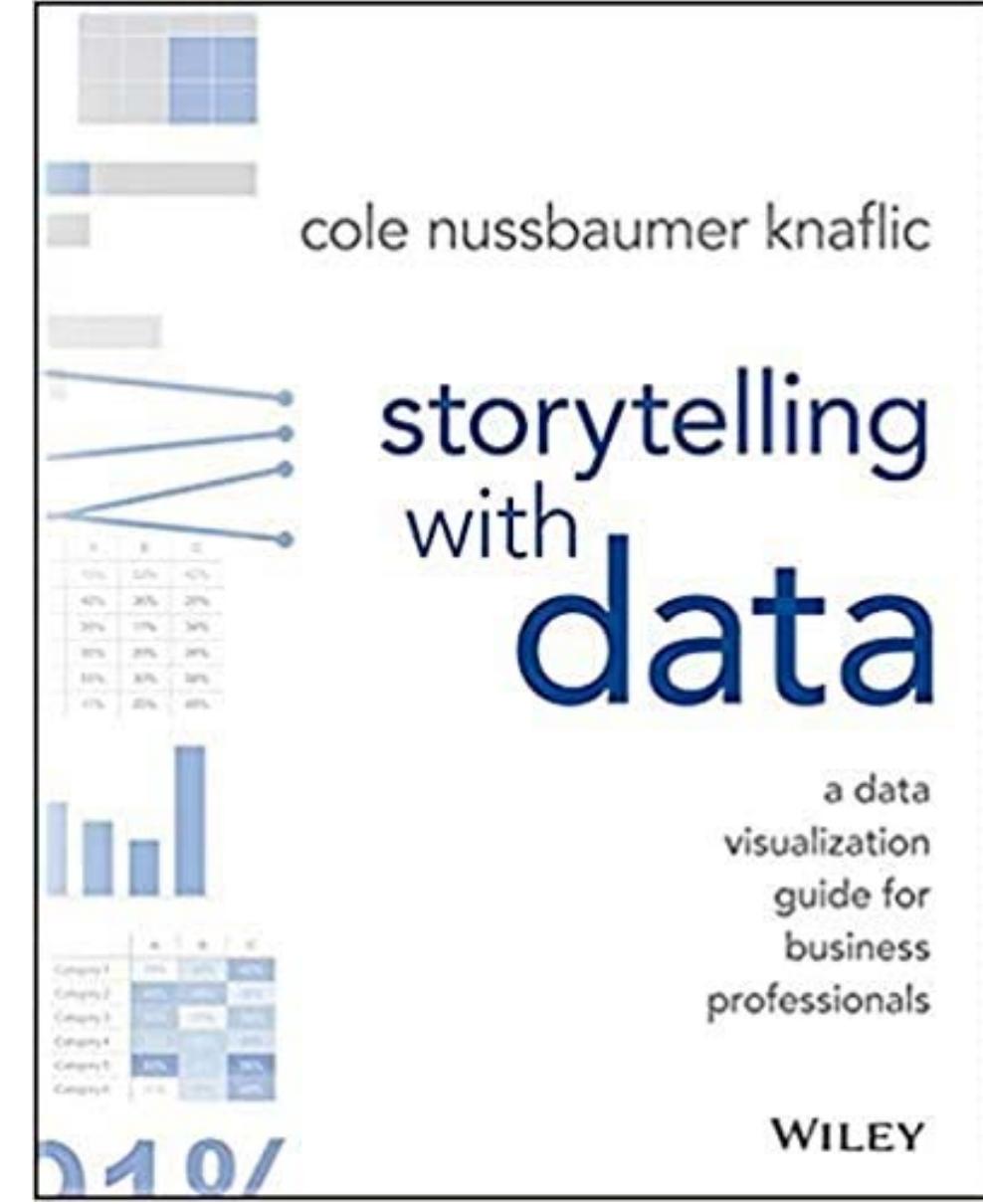
Books



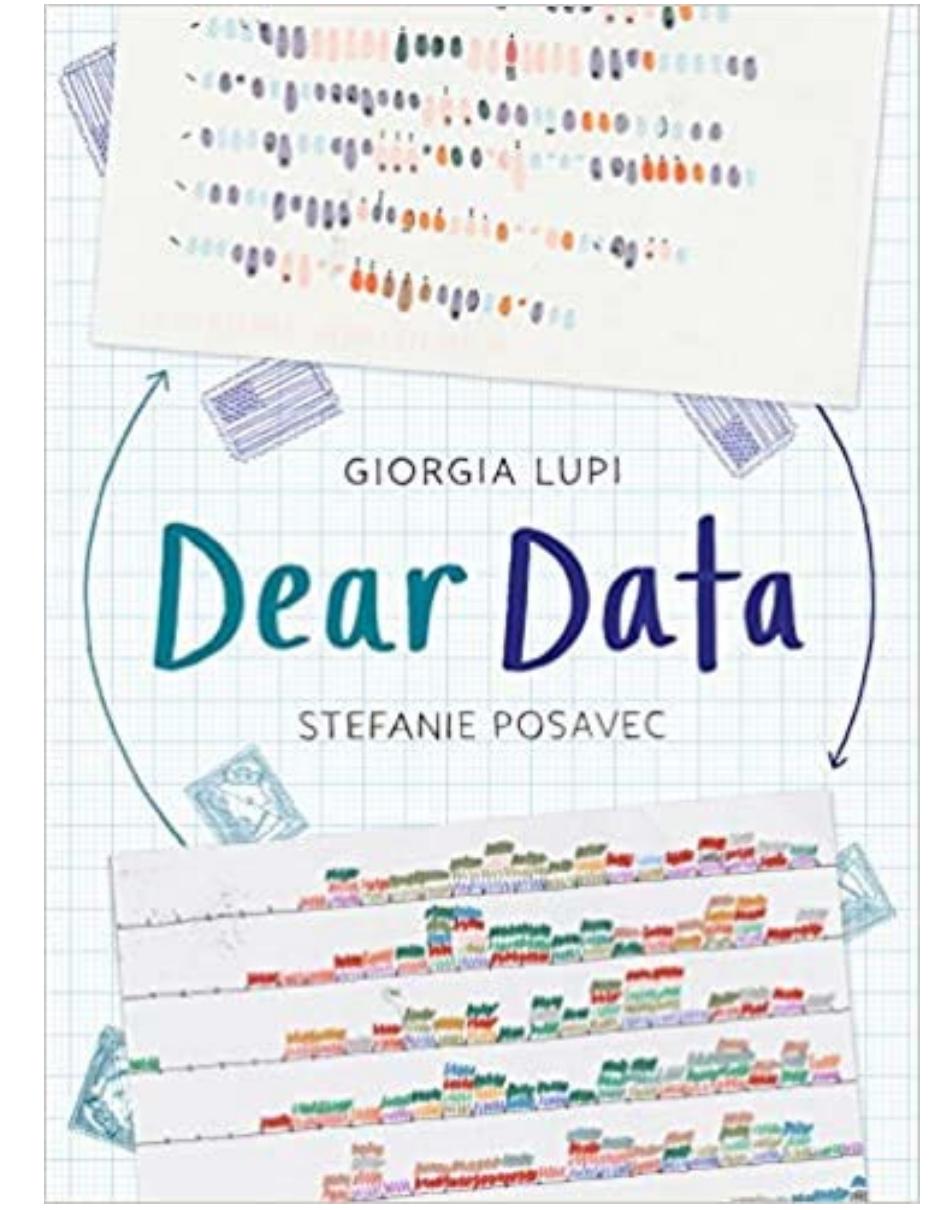
Isabel Meirelles:
Design for Information
(2013)



C. Tominski & H. Schumann:
Interactive Visual Data
Analysis (2020)



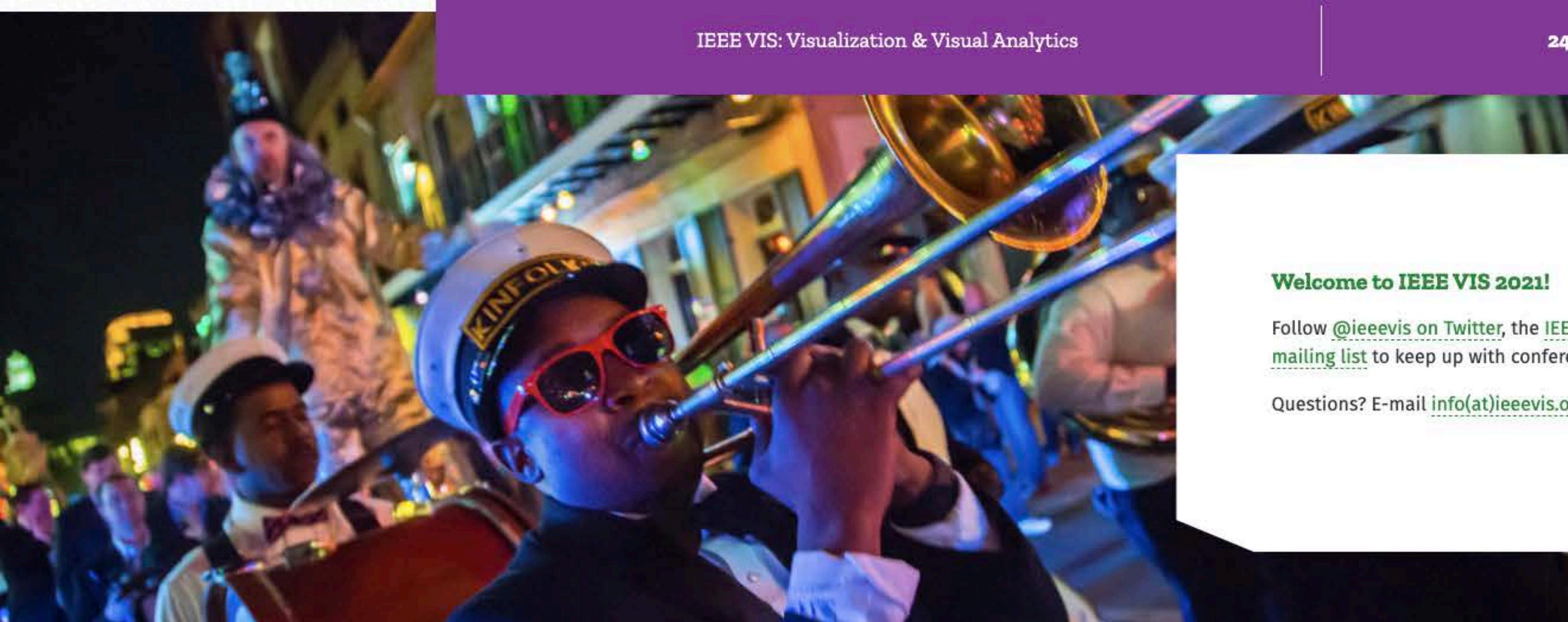
Cole Nussbaumer Knaflic:
Storytelling with data
(2015)



Giorgia Lupi & Stefanie
Posavec: Dear Data
(2016)



the premier forum for
advances in visualization and
visual analytics

A photograph of a band performing on a street at night. A man in the foreground is playing a brass instrument, wearing a blue shirt and red sunglasses. Other musicians are visible in the background under colorful stage lights.

IEEE VIS: Visualization & Visual Analytics

24-29 October 2021 in New Orleans, LA, USA

Welcome to IEEE VIS 2021!

Follow [@ieeveis](#) on Twitter, the [IEEE VIS page](#) on Facebook, or [sign up to our mailing list](#) to keep up with conference activities and announcements.

Questions? E-mail [info\(at\)ieeveis.org](mailto:info(at)ieeveis.org)



Home

EuroVis 2021 is held as a **virtual conference**.

Welcome to EuroVis 2021

The 23rd edition of EuroVis will be organized as a virtual conference. While we initially planned to conduct the conference in a hybrid form, with a limited attendance on-site, the current developments of the global health crisis made it increasingly unlikely that a physical meeting can take place. We are looking forward to bring the visualization community together in an exciting virtual format!

The EuroVis 2021 will be hosted by the University of Zurich in collaboration with FAU Erlangen-Nuremberg and ETH Zurich. EuroVis is the annual Visualization Conference organized by the Eurographics Working Group on Data Visualization. It has been a Eurographics and IEEE co-supported international visualization symposium held in Europe annually since 1999, as a conference since 2012.



The exciting and vibrant field of Visualization is an increasingly important research area due to its wide range of applications in many disciplines. In general, our ability to collect, store, and archive data vastly exceeds our ability to derive useful knowledge and insight from it. This is a ubiquitous problem. Data visualization is key to gaining an understanding of large, complex data sets by exploiting

Twitter

Tweets by [@EuroVisConf](#)



EuroVis
[@EuroVisConf](#)

EuroVis 2021 is virtual only! Up until now, we prepared for both a hybrid and a virtual format. Unfortunately, we cannot host a physical meeting on-site in Zurich due to the pandemic. Looking forward to a great virtual conference! [eurovis.org](#)



Feb 6, 2021



EuroVis
[@EuroVisConf](#)

EuroVis 2021 is planned as a hybrid conference! Find out more at [eurovis.org](#). #eurovis21



Dec 18, 2020



EuroVis
[@EuroVisConf](#)

EuroVis 2021 Full Papers submission deadline is approaching! See [eurovis.org/index.php/for... for submission instructions](#). Please submit your abstracts.

Visualization inspiration

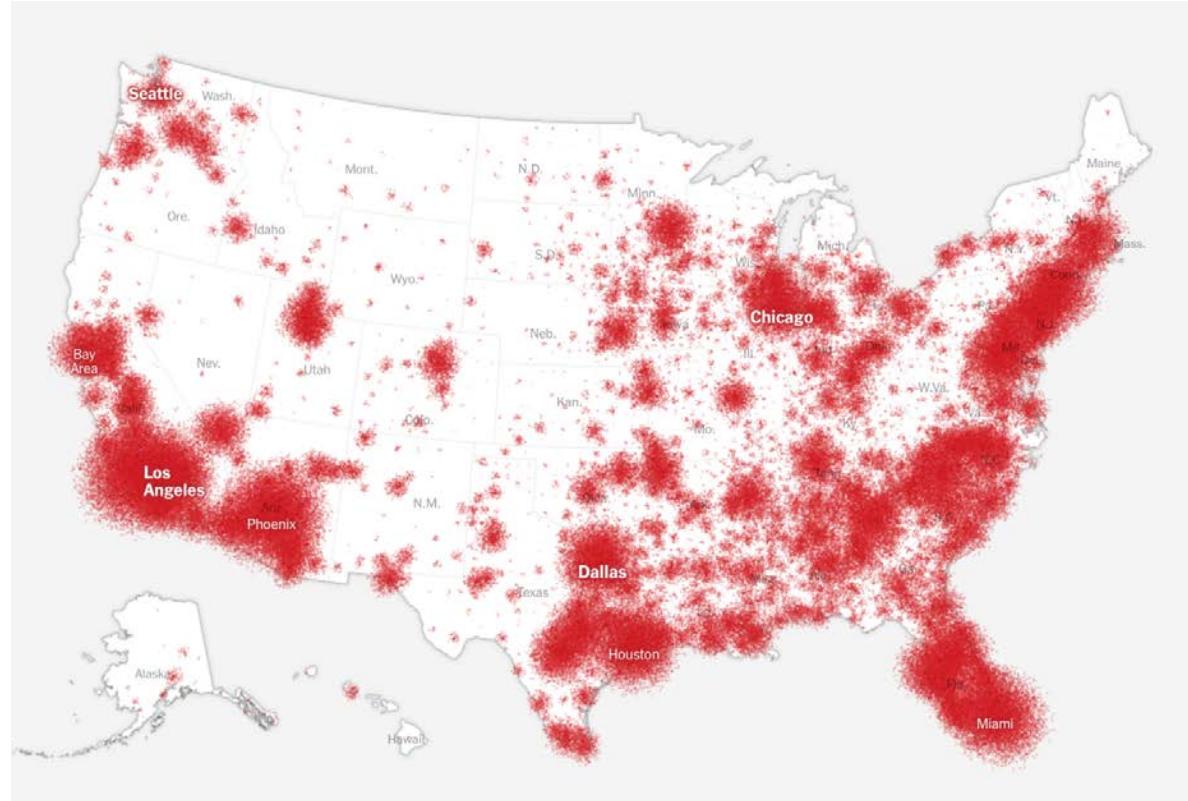
Twitter & Instagram: #infovis #ieeveis
#dataviz #datavis

Online communities: Data Visualization Society Data Vis Book Club

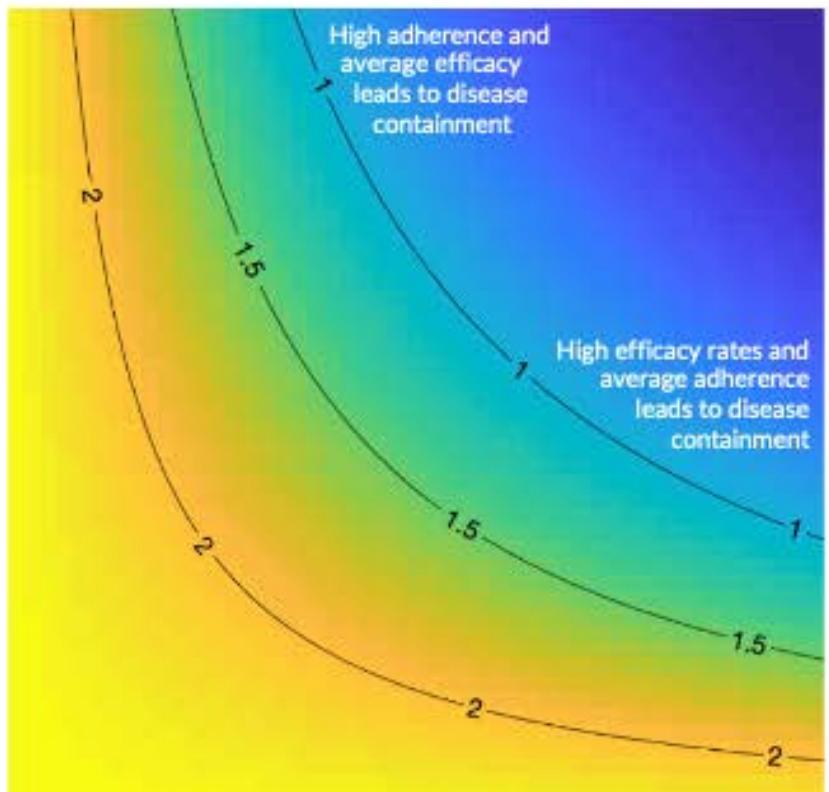
<https://www.pinterest.de/zoukini2645/datenvisualisierung/>



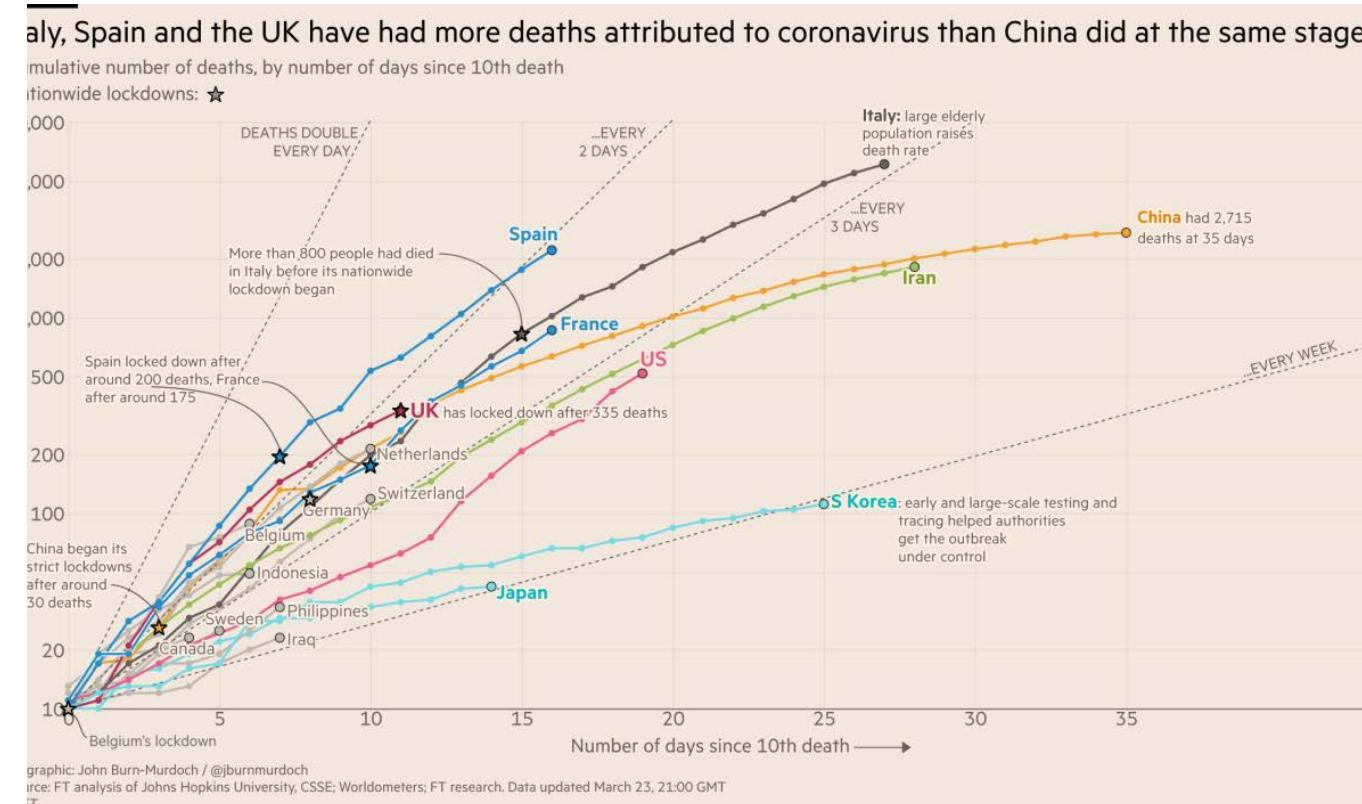
Visualization inspiration



flowingdata.com



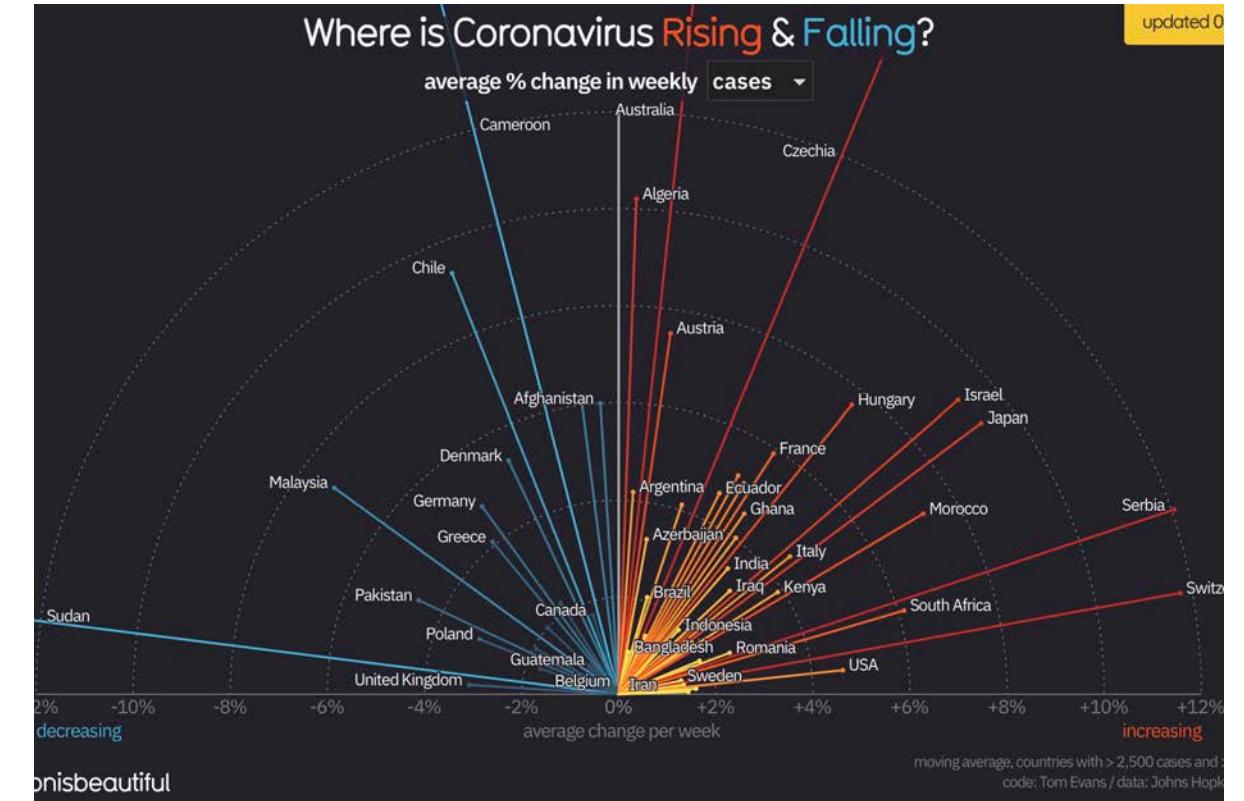
policyviz.com/blog



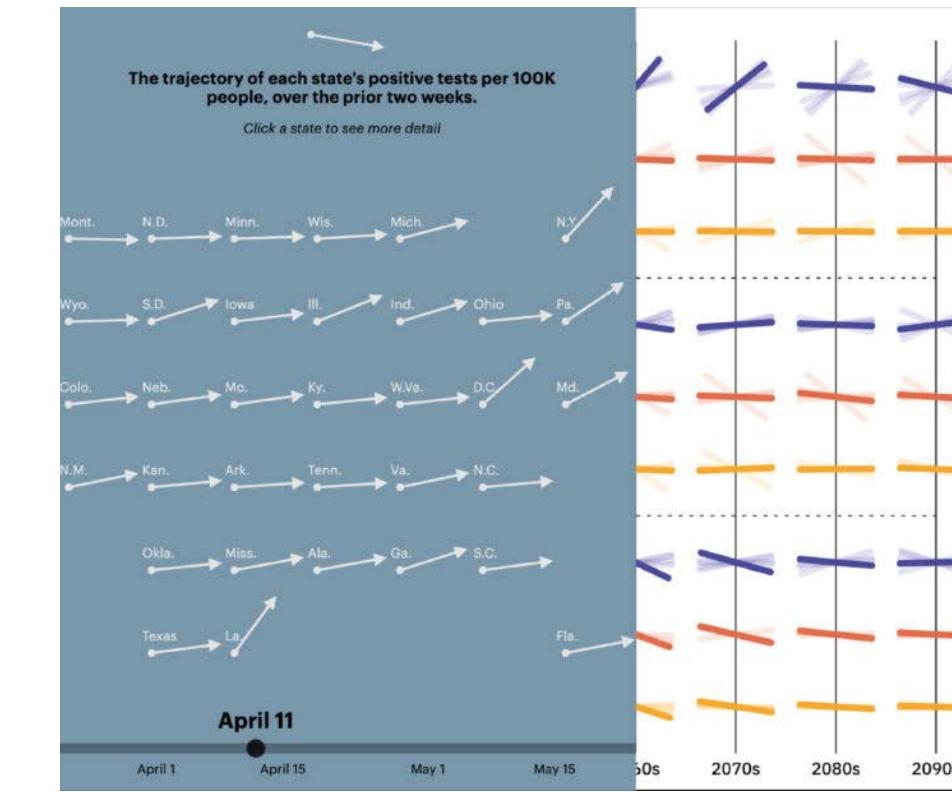
eagereyes.org



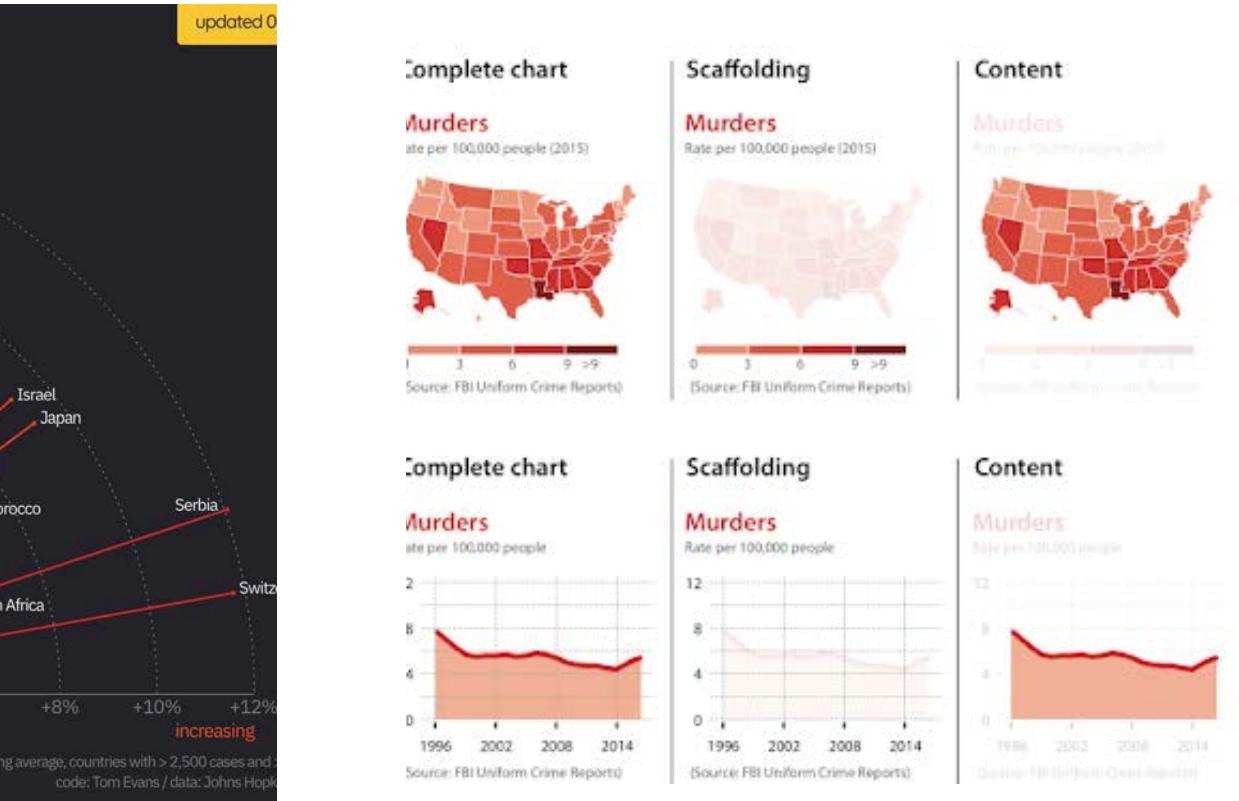
<https://truth-and-beauty.net>



informationisbeautiful.net



visualisingdata.com/blog



thefunctionalart.com



vizwiz.com



https://
www.informationisbeautiful
awards.com/

<https://ationisbeautifulawards.com/>

Awards Challenges

All 2019 2018 2017 2016 2015 2014 2013 2012

All ★ Winners Silver Gold Shortlist Bronze Rising Star Impressive Individual Best-Non-English-Language Outstanding Outfit Student

Community Most Beautiful

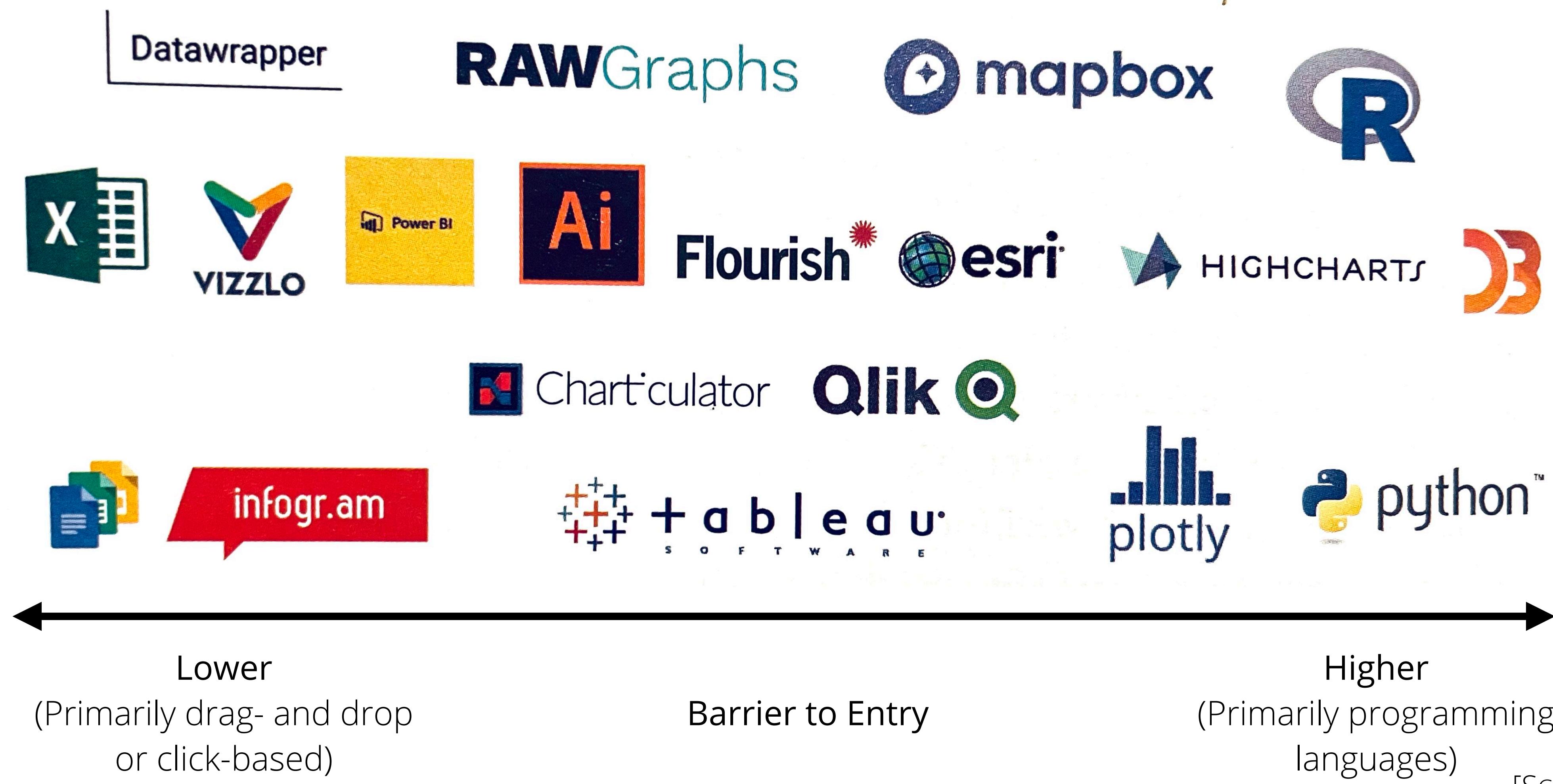
All Arts, Entertainment & Culture Humanitarian Leisure, Games & Sport Maps, Places & Spaces News & Current Affairs People, Language & Identity

Politics & Global Visualization & Information Design Science & Technology Unusual

Western Europe and East Asia—Climate in Pictures
Age of Arctic Sea Ice
Weekly data 1996 — 2018
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 20100 20101 20102 20103 20104 20105 20106 20107 20108 20109 20110 20111 20112 20113 20114 20115 20116 20117 20118 20119 20120 20121 20122 20123 20124 20125 20126 20127 20128 20129 20130 20131 20132 20133 20134 20135 20136 20137 20138 20139 20140 20141 20142 20143 20144 20145 20146 20147 20148 20149 20150 20151 20152 20153 20154 20155 20156 20157 20158 20159 20160 20161 20162 20163 20164 20165 20166 20167 20168 20169 20170 20171 20172 20173 20174 20175 20176 20177 20178 20179 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InfoVis Tools



InfoVis Tools

<https://vistools.net/>

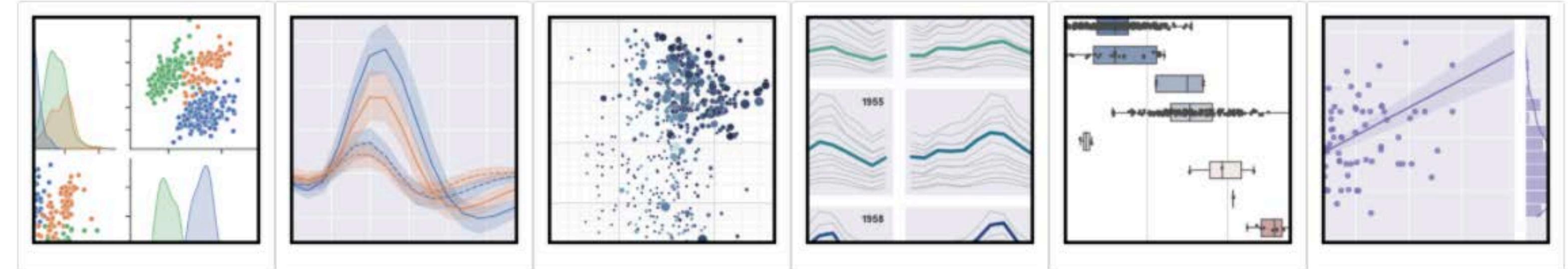
VISBROWSER	ADD A TOOL	ABOUT	Search		
AVAILABILITY	PROGRAMMING SKILLS	PLATFORM	FEATURES	TYPE OF DATA	VISUALIZATION
34 Free 28 Open source 18 Paid	23 None 11 Javascript 6 Python 2 Java 10 Other 1 Matlab 4 R	17 Apple 20 Windows 12 Linux 22 Web 8 Library 1 Other	23 Web-publishing 28 File exports 10 Other 11 Wizard 9 PDF Export	33 Numeric 25 Geographic 29 Temporal 12 Text 18 Other 5 Network	11 Networks 25 Maps 32 Basic charts 17 Advanced charts 16 Other 16 Storytelling
<p>COLORBREWER https://colorbrewer2.org/ Intended for use as a diagnostic tool for evaluating the robustness of individual colour schemes.</p>	<p>IWANTHUE https://medialab.github.io/iwanthue/ Colors for data scientists. Generate and refine palettes of optimally distinct colors.</p>	<p>RSTUDIO https://rstudio.com/ RStudio is an integrated development environment for R, a programming language for statistical computing and graphics.</p>	<p>CHARTBLOCKS https://www.chartblocks.com/en/ Build a chart in minutes in the easy to use chart designer, choosing from dozens of chart types and then customising it to your needs.</p>	<p>GEPHI https://gephi.org/ Gephi is an open-source network analysis and visualization software package written in Java on the NetBeans platform.</p>	
<p>VEGA-LITE https://vega.github.io/vega-lite/ Vega-Lite is a high-level grammar of interactive graphics. It provides a concise JSON syntax for rapidly generating visualizations to support analysis. Vega-Lite specifications can be compiled to Vega.</p>	<p>BOKEH https://docs.bokeh.org/ Bokeh is an interactive visualization library for modern web browsers.</p>	<p>DATA ILLUSTRATOR http://data-illustrator.com/ Create infographics and data visualizations without programming.</p>	<p>CHARTICULATOR https://charticulator.com/index.html Allows you to create bespoke chart designs without the need for any programming.</p>	<p>PROCESSING https://processing.org/ Processing is a flexible software sketchbook and a language for learning how to code within the context of the visual arts.</p>	

Python



<https://plotly.com/python/>

seaborn: statistical data visualization



<https://seaborn.pydata.org/>

Plotly Python Open Source Graphing Library

Plotly's Python graphing library makes interactive, publication-quality graphs. Examples of how to make line plots, scatter plots, area charts, bar charts, error bars, box plots, histograms, heatmaps, subplots, multiple-axes, polar charts, and bubble charts.

Plotly.py is [free and open source](#) and you can [view the source](#), [report issues](#) or [contribute on GitHub](#).

Our recommended IDE for Plotly's Python graphing library is Dash Enterprise's [Data Science Workspaces](#), which has both Jupyter notebook and Python code file support. [Find out if your company is using Dash Enterprise](#).

[Install Dash Enterprise on Azure](#) | [Install Dash Enterprise on AWS](#)

Fundamentals

More Fundamentals »

Fundamentals

- Basic Charts
- Statistical Charts
- Artificial Intelligence and Machine Learning
- Scientific Charts
- Financial Charts
- Maps
- 3D Charts
- Subplots
- Animations

The Figure Data Structure

Creating and Updating Figures

Displaying Figures

Plotly Express

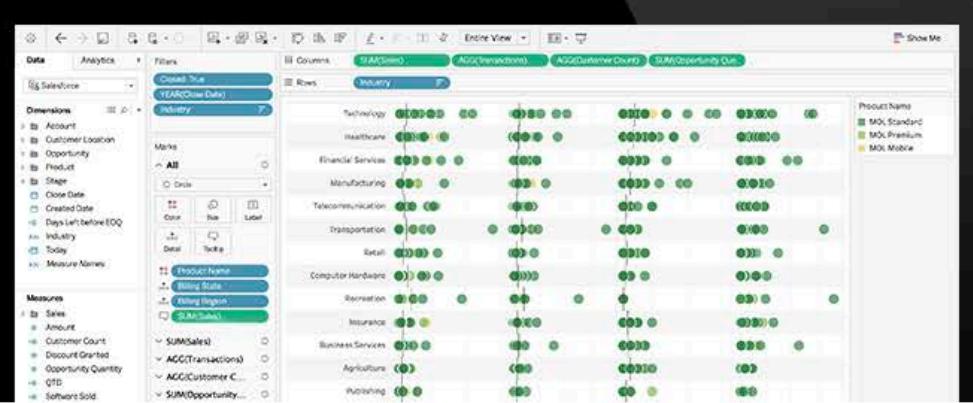
Analytical Apps with Dash

A horizontal row of four small plots demonstrating various features of the Plotly library. 1. A sunburst chart showing hierarchical data. 2. A circular plot with multiple overlapping colored circles. 3. A bar chart titled "US Export of Plastic Strip". 4. A dashboard interface with multiple charts and controls.

Tableau

 Warum Tableau? Lösungen Partner

Tableau Desktop: Tableau jetzt 14 Tage kostenlos testen

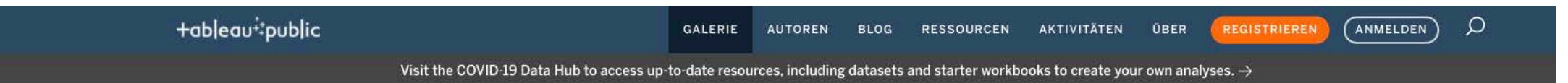


Verlängern Sie Ihren Tableau-Testzeitraum

Tableau Prep Builder: Bereiten Sie Ihre Daten für die Analyse vor
Mit Tableau Prep Builder können Sie Ihre Daten zuverlässig kombinieren, in das richtige Format bringen und optimal aufbereiten.

Tableau Online: Auf in die Cloud
Vergessen Sie die Hardwareeinrichtung. Tableau Online ist eine gehostete Version von Tableau Server.

<https://www.tableau.com/de-de/products/>



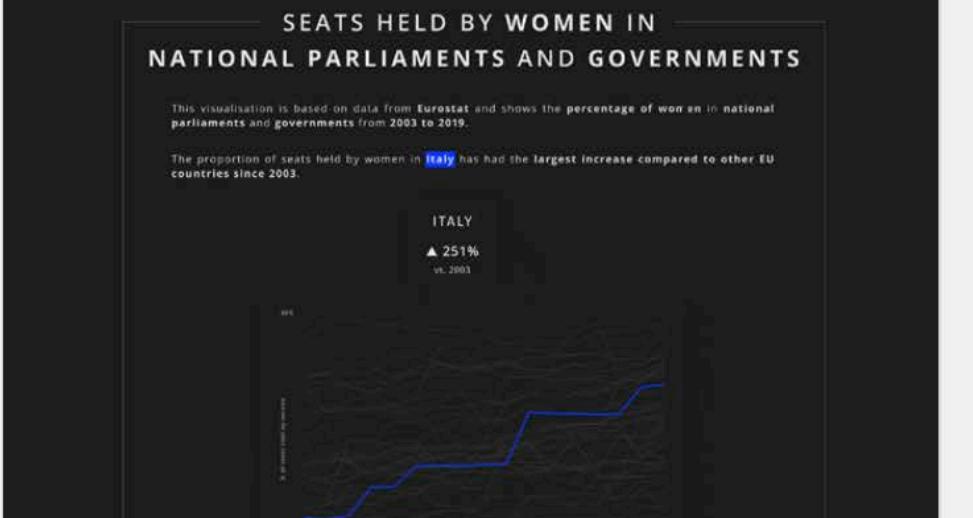
Visit the COVID-19 Data Hub to access up-to-date resources, including datasets and starter workbooks to create your own analyses. →

Galerie / Im Fokus

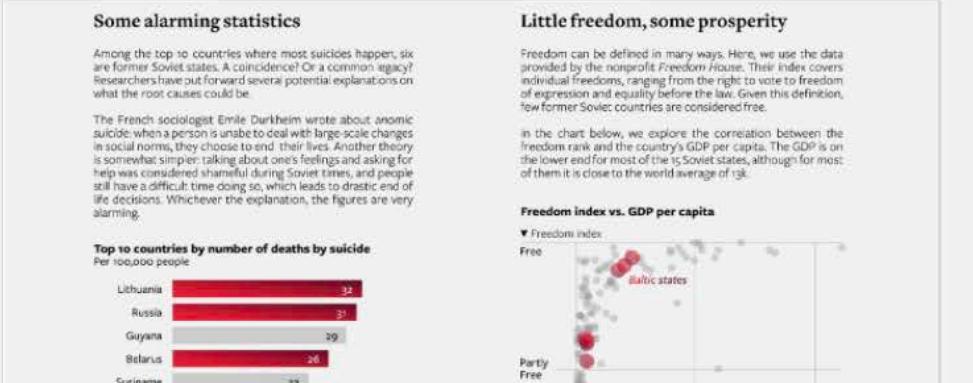
Tolle Beispiele für mit Tableau Public erstellte Datenvisualisierungen aus dem gesamten Internet.

Visualisierung des Tages

All



Seats Held by Women in National Parliaments and Governments
In Italy, women representation in national parliament has grown by 251% since 2003. In honor of #WomensHistoryMonth, explore this #MakeoverMonday visualization by Priya Padham to see the proportion of seats held by women in national governments across the European Union.
Veröffentlicht am: 5. März 2021

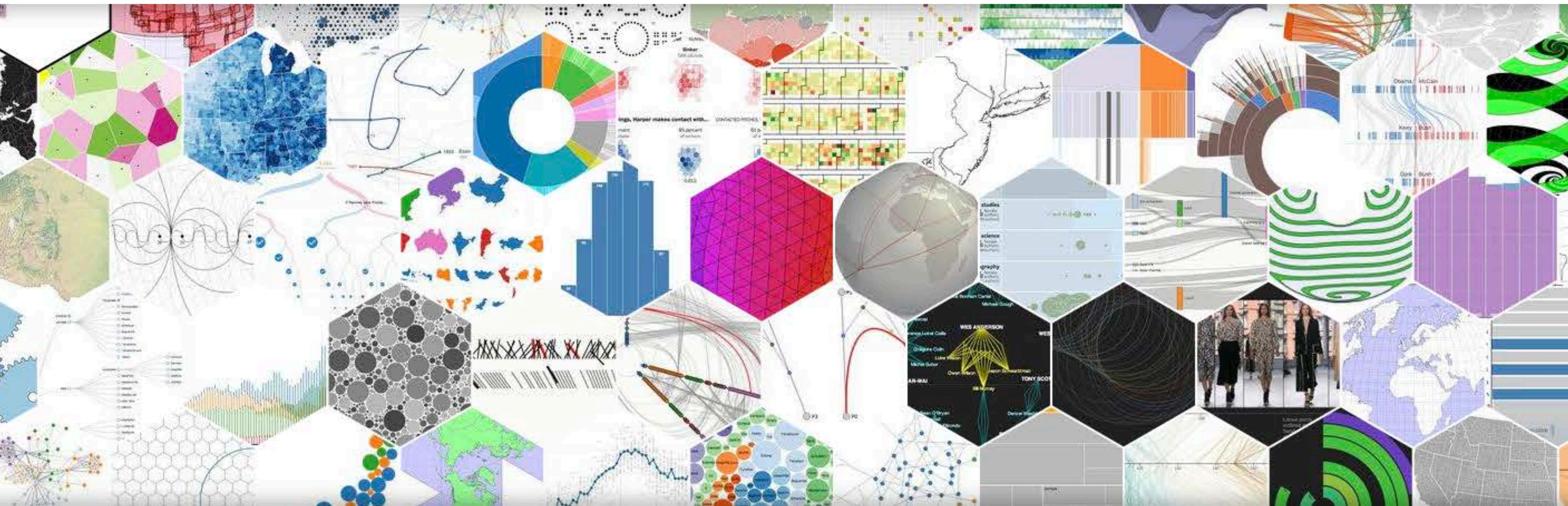


The Soviet Legacy
After WWII, the Soviet Union took control of 15 countries— influencing the lives of nearly 291 million people. Explore this visualization by Evelina Judekyte to see the economic and social effects of these countries 30 years after the collapse of the Soviet Union.
Veröffentlicht am: 4. März 2021

<https://public.tableau.com/de-de/gallery/>

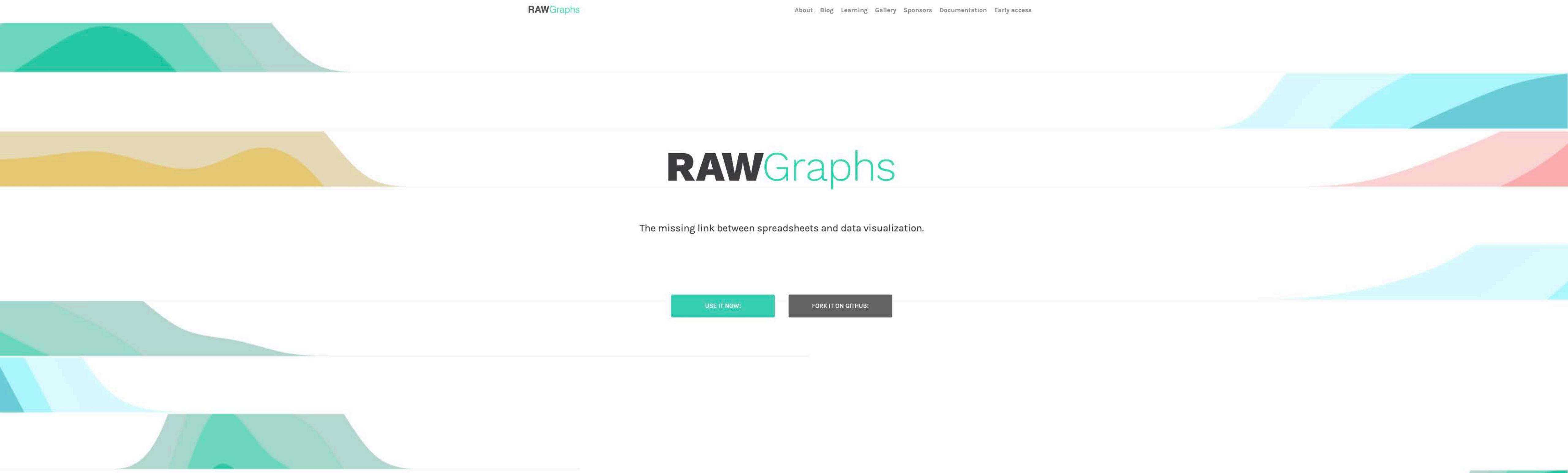
D3 - Data-driven Documents

<https://d3js.org/>



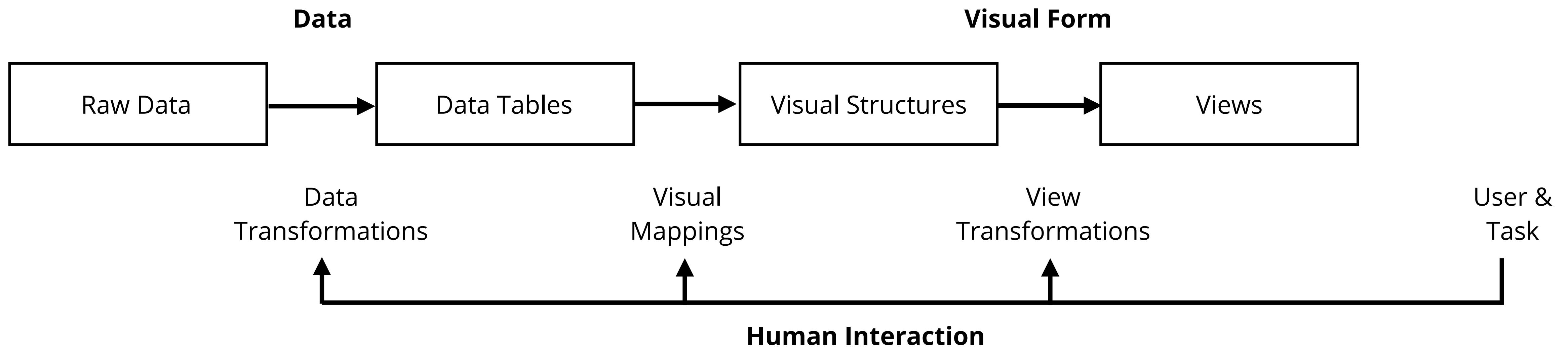
Raw Graphs

<https://rawgraphs.io/>



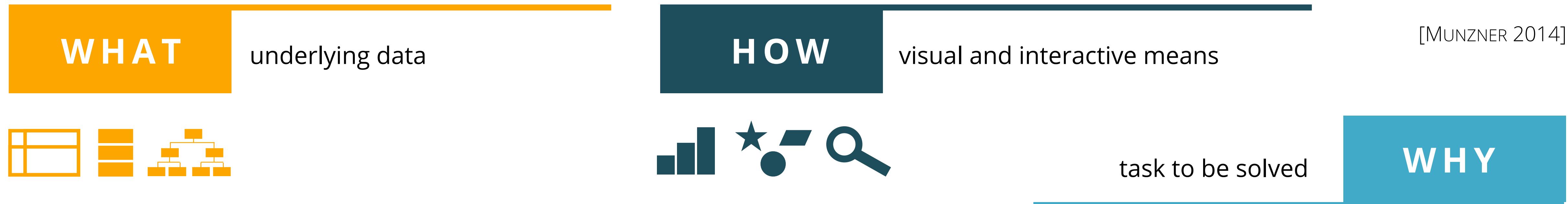
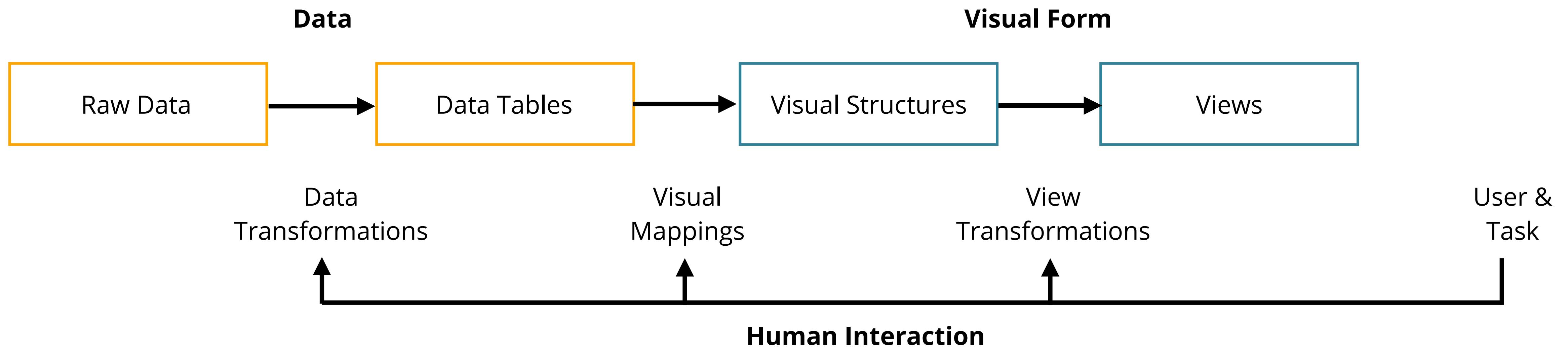
Visualization pipeline

Reference Model for
Visualization [CARD ET AL. 1999]



Visualization pipeline

Reference Model for
Visualization [CARD ET AL. 1999]



Five Ws

[TOMINSKI & SCHUMANN 2020]

WHAT

data are to be analyzed?

e.g. data types and characteristics

subject

WHY

are the data analyzed?

e.g. identifying extreme values or outliers

objective

WHO

will analyze the data?

e.g. domain expert, data analyst

WHERE

will the data be analyzed?

e.g. interactive surfaces, large display walls

context

WHEN

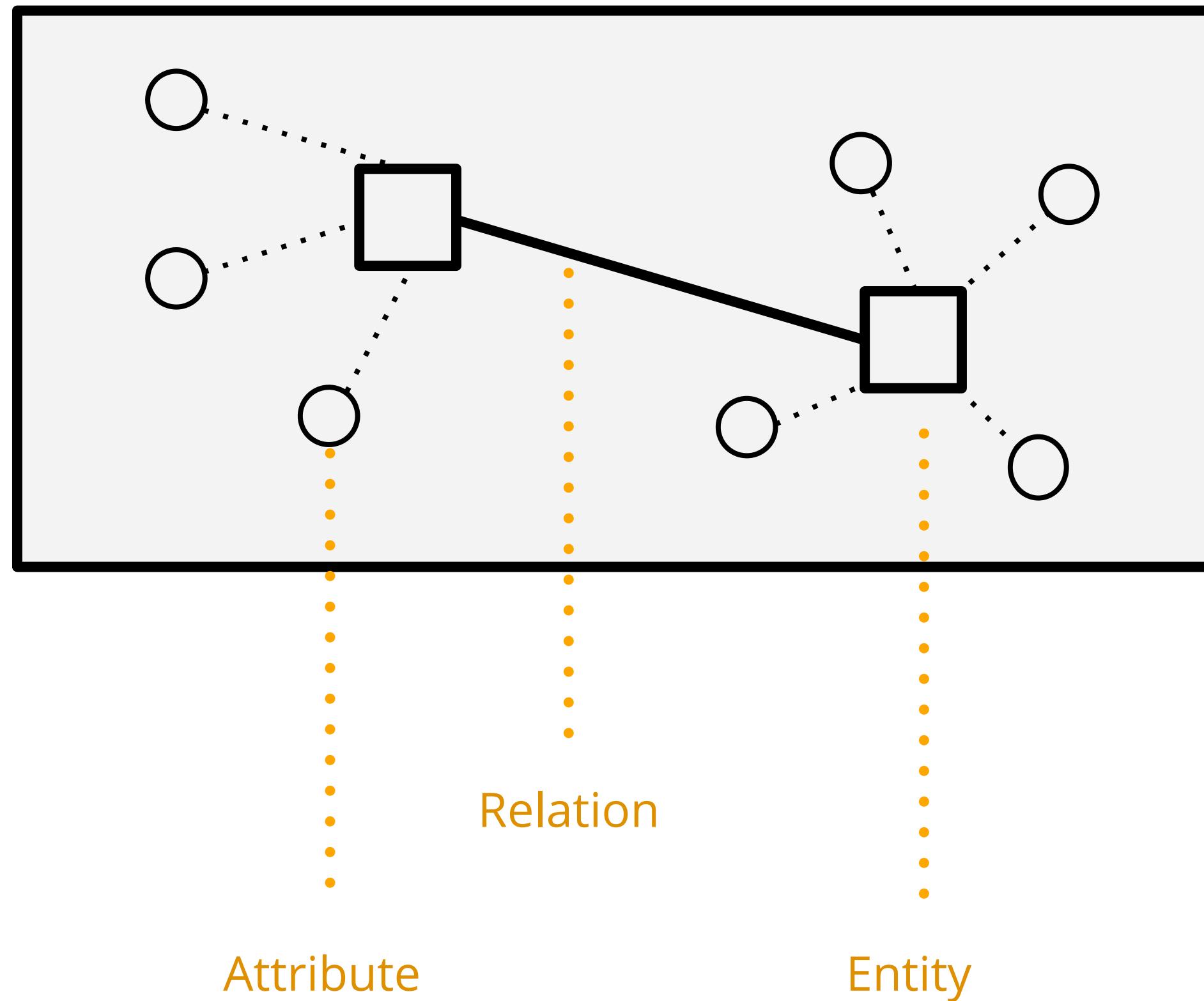
will the data be analyzed?

e.g. following a domain-specific workflow

WHAT

Data sets and types

WHAT: Data abstraction



Data can be divided into **entities (items)** and **relationships (links)** [WARE 2020].

Entities are the objects we wish to visualize.

Relations define the **structures** and **patterns** that relate entities to another.

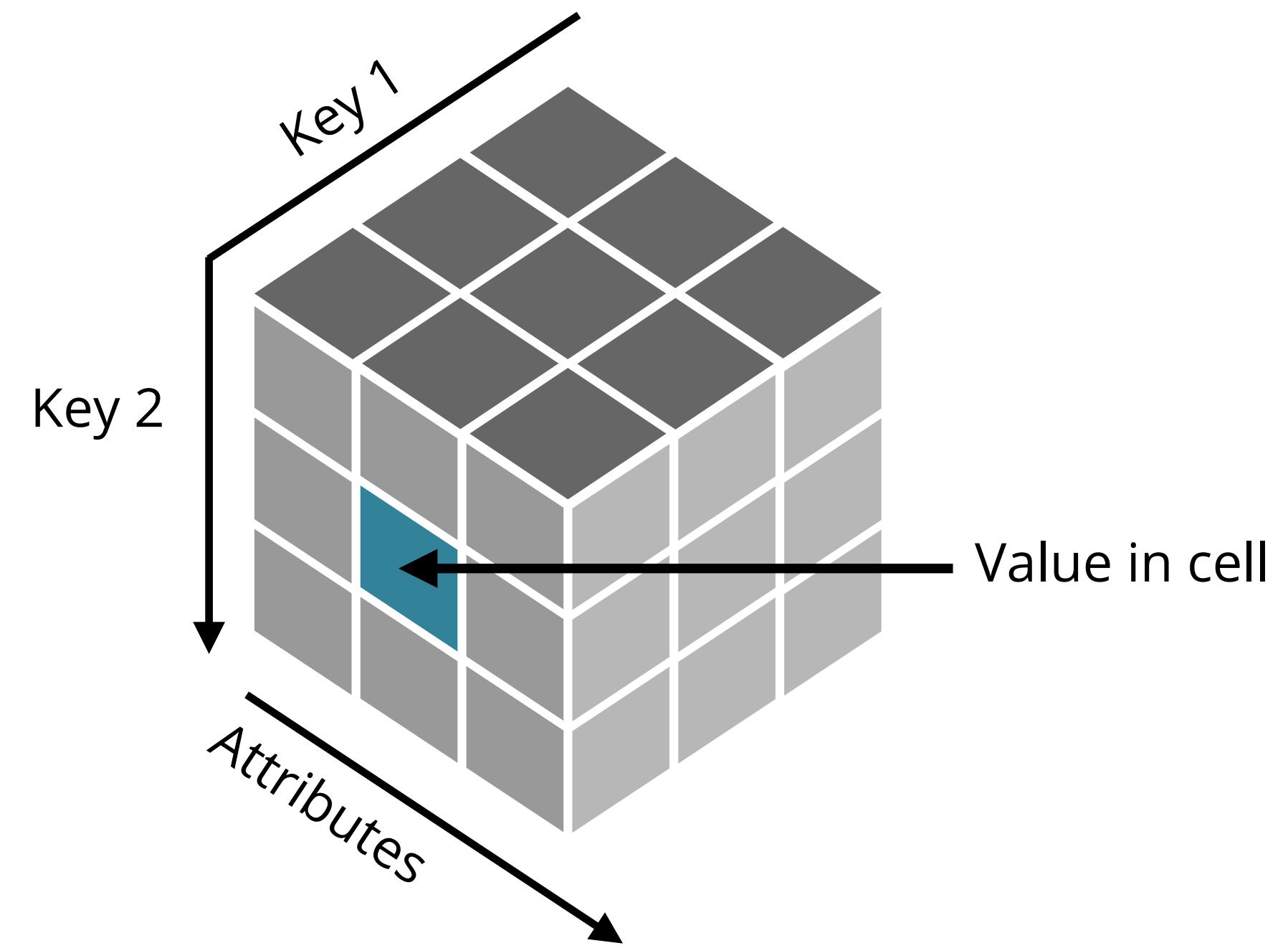
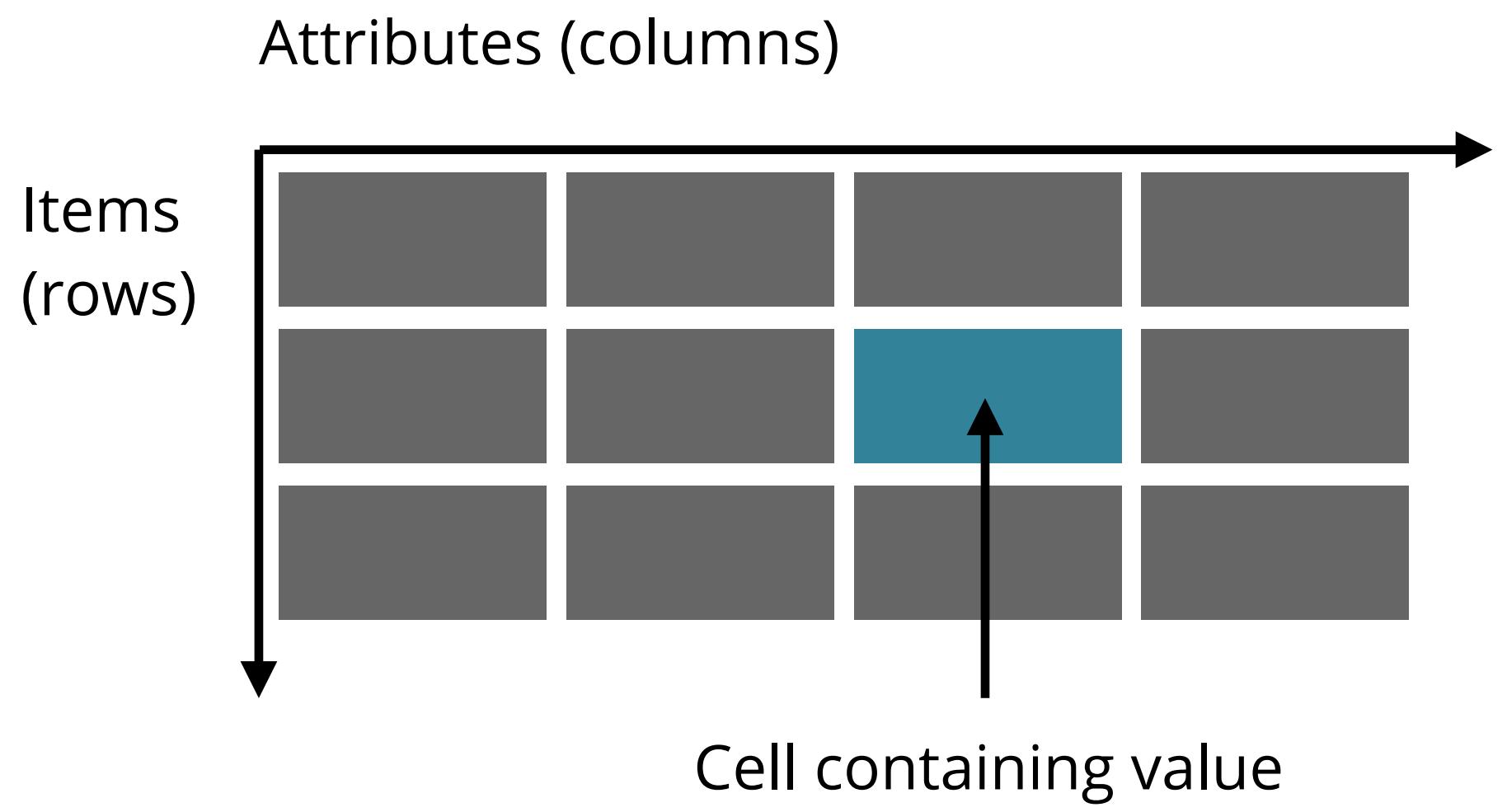
Sometimes the relationships are provided **explicitly**, sometimes discovering relationships is the very purpose of the visualization.

Both entities and relationships can have **attributes**.

Data sets

Tables:

contain items and attributes



[MUNZNER 2014]

Data tables

ID	NAME	SHIRT SIZE	FAVORITE COLOR	AGE	
1	Sebastian	S	green	23	
2	Lisa	M	purple	18	Item
3	Markus	S	blue	19	
4	Thomas	L	black	29	
5	Hans	XL	blue	17	
6	Susi	L	red	18	
7	Franziska	M	red	24	

A data tables consists of **rows** and **columns**.

The columns represent data attributes
(variables, dimension).

The row of data tables represent data tuples
(item, element, entity, object, observation).

Data space [TOMINSKI & SCHUMANN 2020, MUNZNER 2014]

Independent Variables (keys)

correspond to the *dimensions* of the space where the data have been collected, observed, or simulated.

Dependent Variables (values)

describe the *attributes* of what has been collected, observed, or simulated.

ID	NAME	SHIRT SIZE	FAVORITE COLOR	AGE
1	Sebastian	S	green	23
2	Lisa	M	purple	18
...

Independent variable = key Dependent attributes = values

key = explicit unique identifier (row number can also serve as implicit key)

Data space [TOMINSKI & SCHUMANN 2020, MUNZNER 2014]

Independent Variables (keys)

correspond to the *dimensions* of the space where the data have been collected, observed, or simulated.

Dependent Variables (values)

describe the *attributes* of what has been collected, observed, or simulated.

		Dimensions			Attribute			Item
		D1	D2	D3	A1	A2	A3	
Tuple	t ₁	54.11°	12.38°	15.03.2020	23	3	3	
	t ₂	52.32°	14.98°	16.03.2020	15	4	5	
	t _k	

(Reference space) $f: (D_1 \times D_2 \times \dots \times D_n) \longrightarrow (A_1 \times A_2 \times \dots \times A_m)$ (Attribute space)

(latitude × longitude × time) → (temperature × pressure × wind speed)

Dimensions [TOMINSKI & SCHUMANN 2020, MUNZNER 2014]

Multidimensional data

Data that consists of more than one dimension

Multivariate data

Data with one, two or more attributes are called univariate, bivariate or multivariate data.

	Dimensions			Attributes			
	D1	D2	D3	A1	A2	A3	
t ₁	54.11°	12.38°	15.03.2020	2	3	23	
t ₂	52.32°	14.98°	16.03.2020	5	4	97	Item
t _k	

Table contains k tuples of n-dimensional m-variate data

Attribute types

QUALITATIVE

[KIRK 2019]

NOMINAL

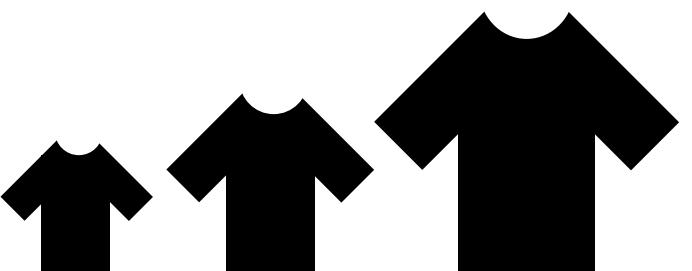


Gender: male, female

Eye color: blue, green, brown, grey

Continent: Africa, Australia, Europe, Asia, ...

ORDINAL

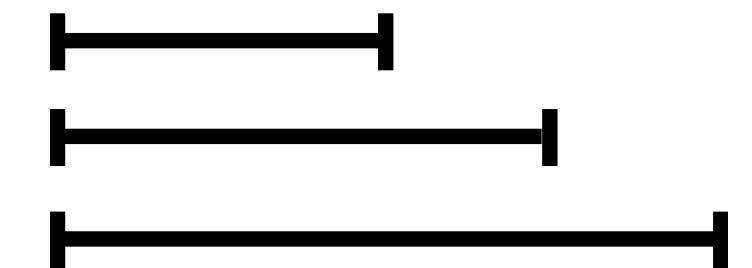


Shirt size: S, M, L, XL, ...

Education: elementary school, high school, undergraduate, graduate

Ranking: terrible, bad, average, good, very good

QUANTITATIVE



Discrete:

number of students



Continuous:

temperature measured



amount of goals

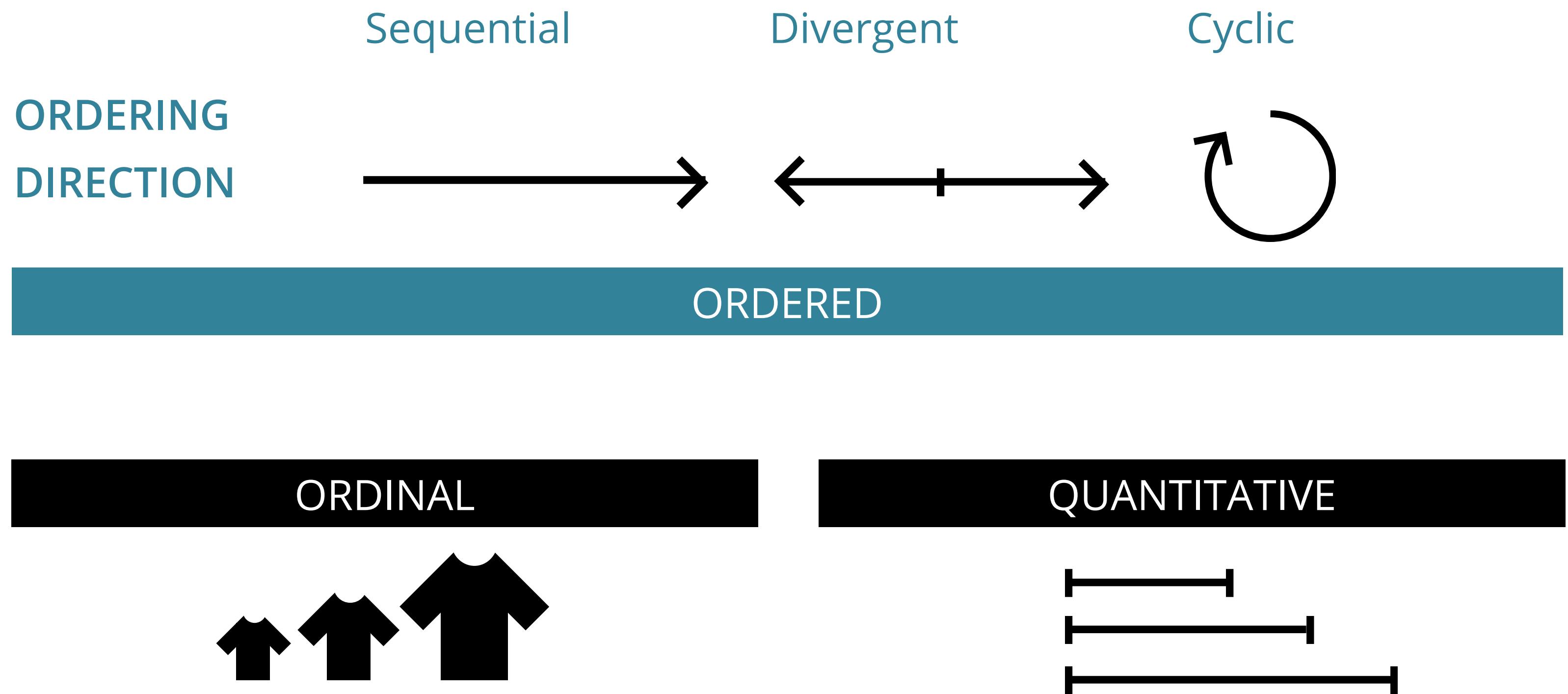


weight measured



Attribute types

[MUNZNER 2014]

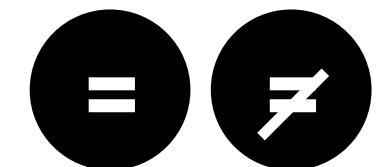


Attribute types

NOMINAL

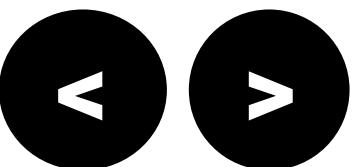
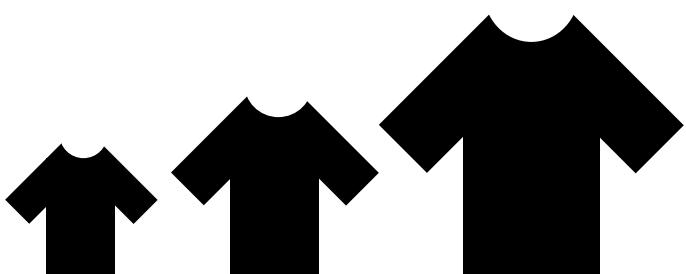


OPERATIONS



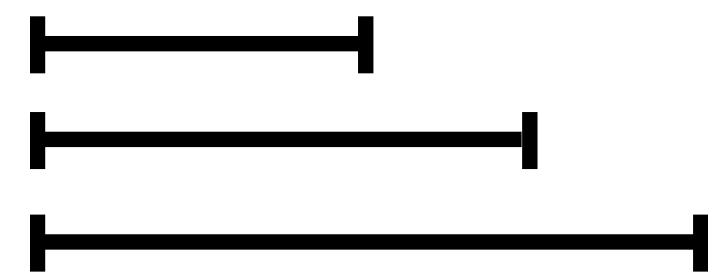
Equality

ORDINAL

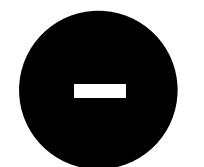


Sorting

QUANTITATIVE

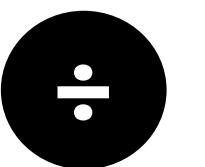


[STEVENS 1946]



Distance:

Measure distances



Relation:

Measure ratios

Attribute types: examples

ID	NAME	SHIRT SIZE	FAVORITE COLOR	AGE	
1	Sebastian	S	green	23	Nominal
2	Lisa	M	purple	18	
3	Markus	S	blue	19	
4	Thomas	L	black	29	
5	Hans	XL	blue	17	
6	Susi	L	red	18	
7	Franziska	M	red	24	Quantitative
					Ordinal

Data classes [TOMINSKI & SCHUMANN 2020]

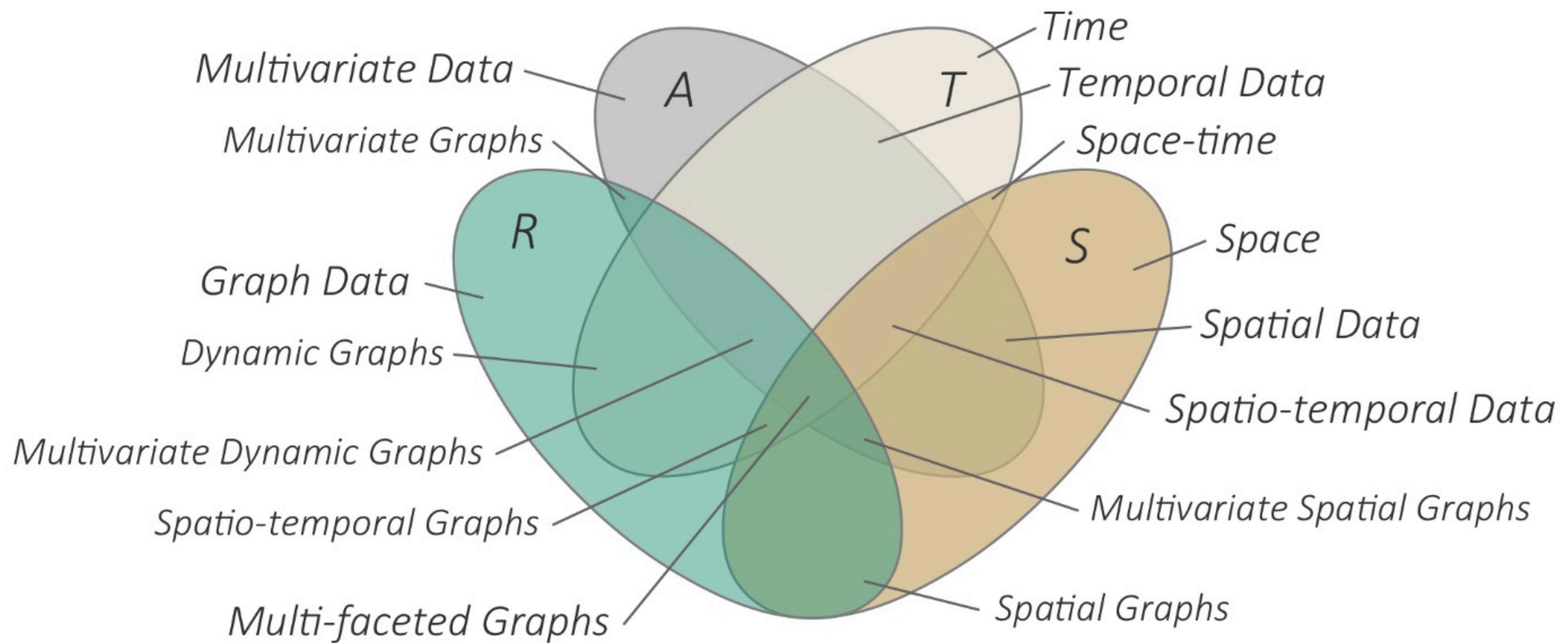
More detailed classification

A = Data Attributes

T = Time

S = Space

R = Structural Relationships



Temporal Data

[AIGNER ET AL. 2011, TOMINSKI & SCHUMANN 2020]

Characterizing time:

1. Primitives:

Instant, e.g. 19:30 Interval, e.g. Dinner 19:30 for 2 hours



2. Arrangement:

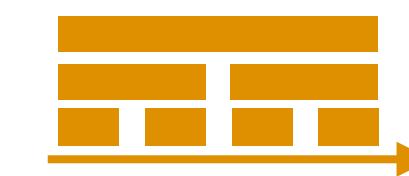
Linear



Cyclic

3. Granularity:

Single



Multiple

4. Attribute type:

Ordinal



discrete

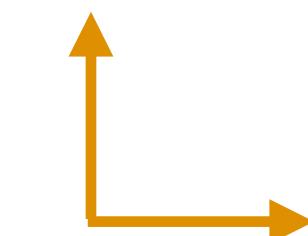


continuous

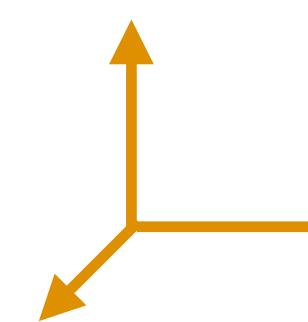
Spatial Data



Dimension:



2D (*Latitude x Longitude*)



3D (*Latitude x Longitude x Elevation*)

Granularity:



Single

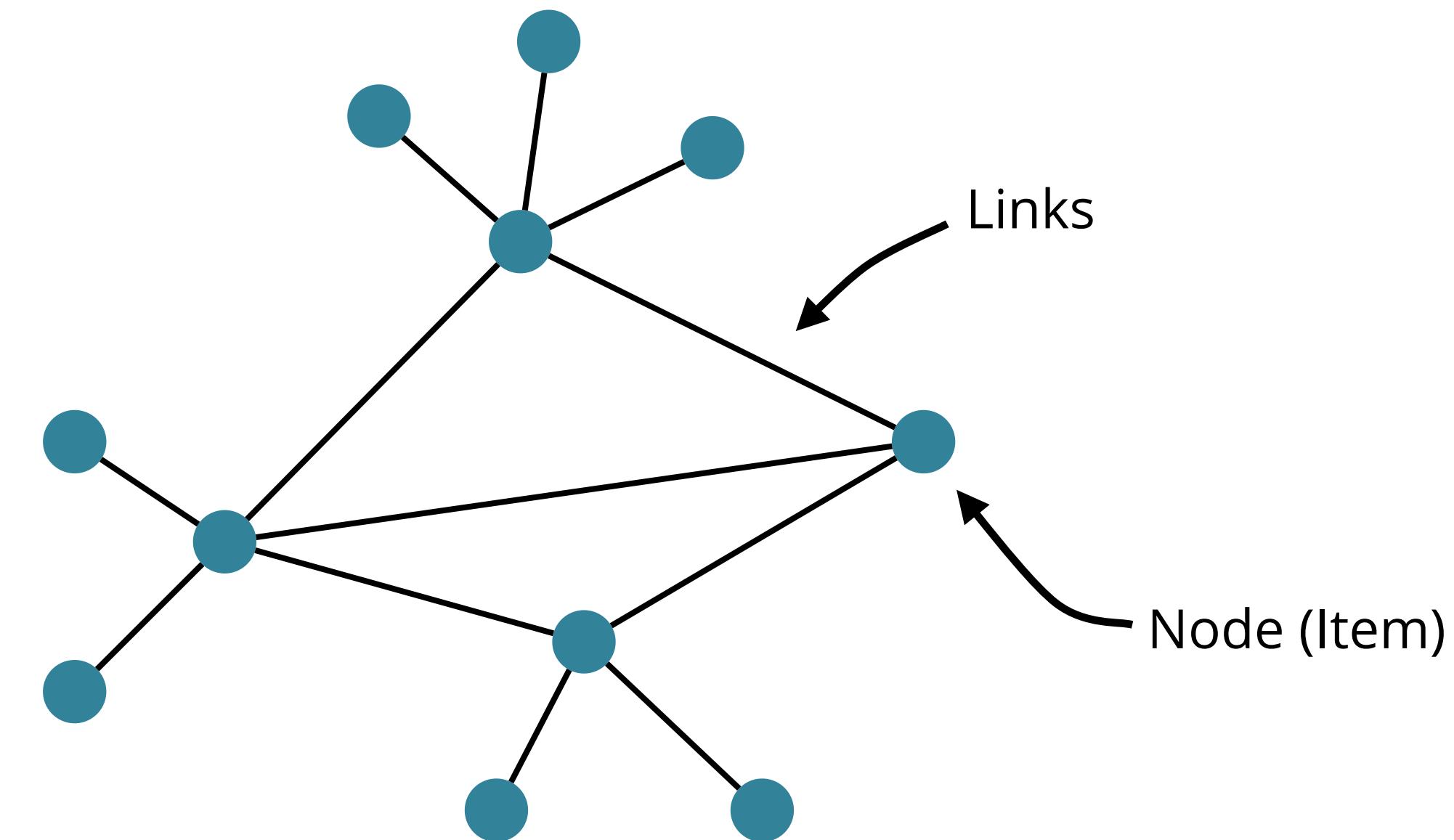


Multiple

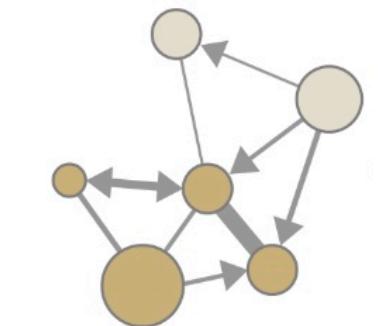
Relational Data

Network:

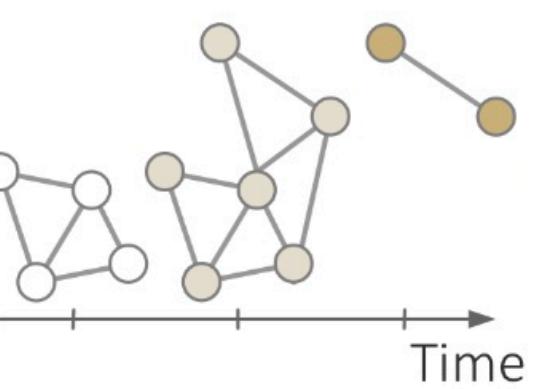
contains items – Nodes, Links, Attributes



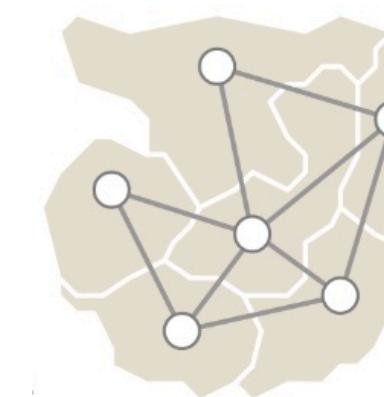
Multivariate
Graph:



Dynamic
Graph:

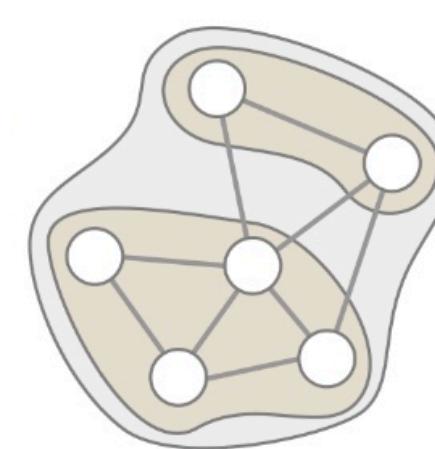


Spatial
Graph:



Trees:
each node has one parent node

Compound
Graph:



[TOMINSKI &
SCHUMANN
2020]

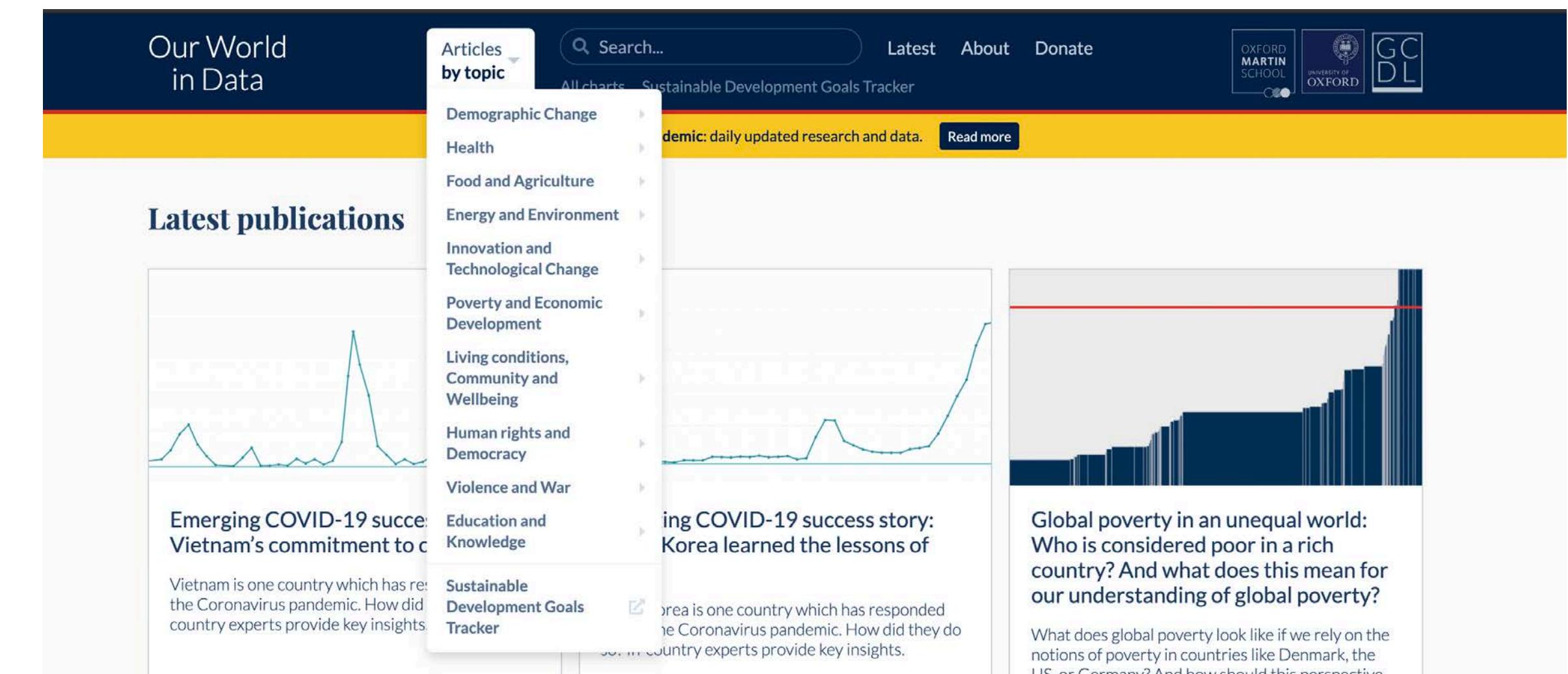
Data aquistion

Public Data Sets

<https://www.kaggle.com/datasets>

<https://ourworldindata.org/>

<https://github.com/awesomedata/awesome-public-datasets>



Covid Data Sets

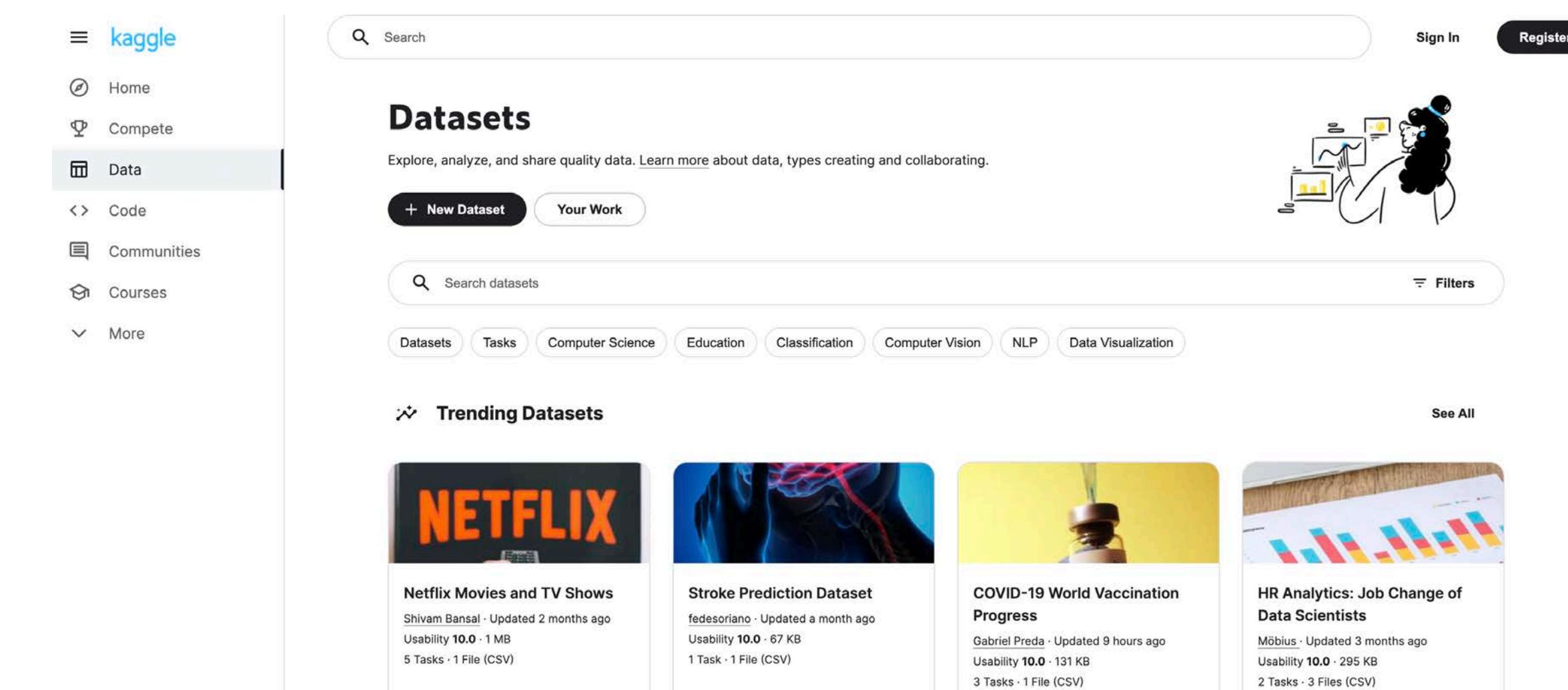
Johns Hopkins University:

<https://github.com/datasets/covid-19>

<https://datahub.io/core/covid-19>

Austria Corona Data Sets:

<https://www.data.gv.at/covid-19/>



Working with data [KIRK 2019]

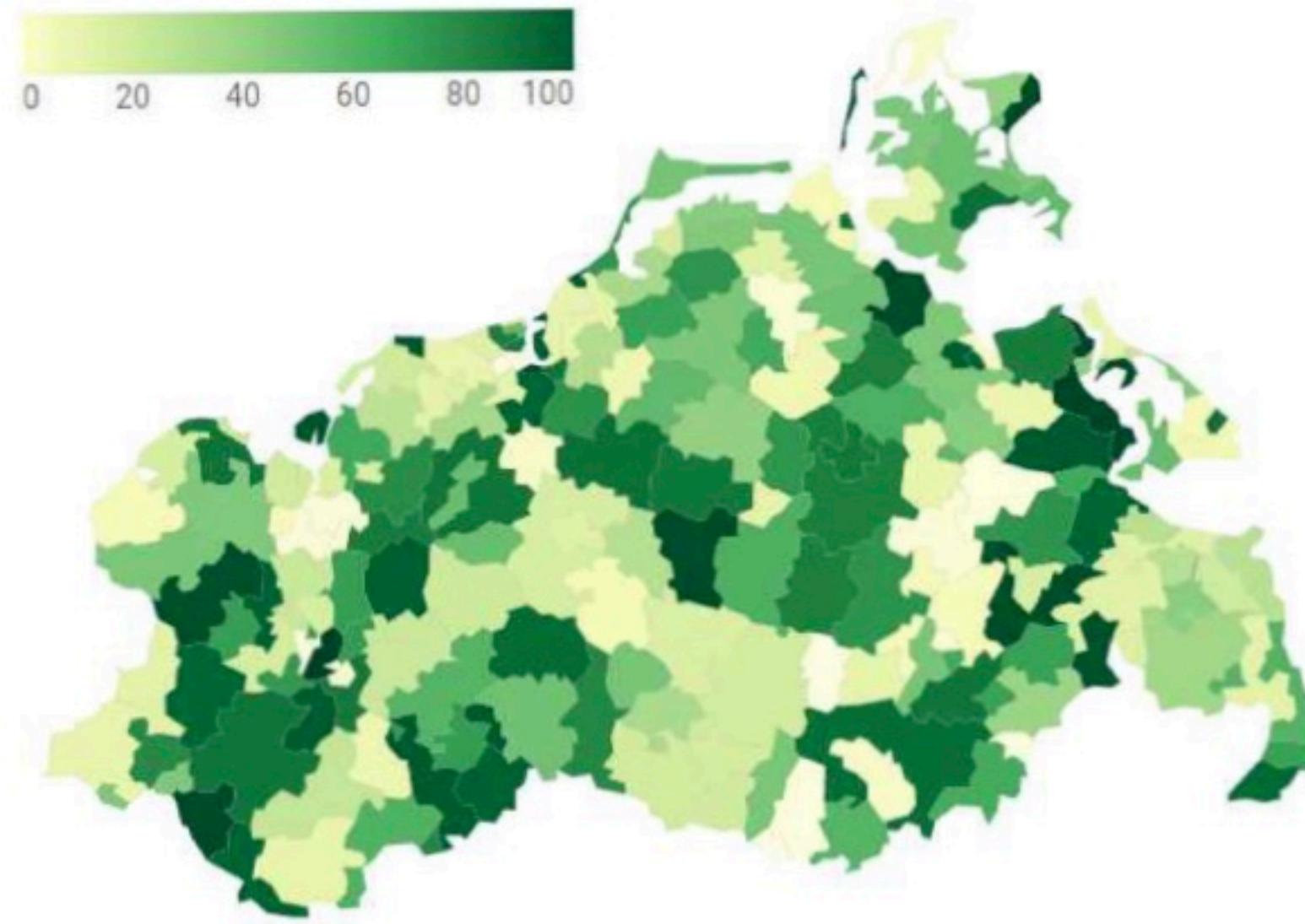
- ▶ **Data Acquisition:** different sources and methods for getting your data, e.g. manual collection, web scraping, issued to you, downloaded from the web
- ▶ **Data Examination & Familiarization:** developing an understanding of the characteristics of this critical raw material, e.g. attribute types, size, quality, semantics; talking to domain experts
- ▶ **Data Transformation:** getting data into shape:
 - **clean:** resolve data quality issues
 - **create & convert:** consider new calculations or extracting new forms of data
 - **consolidate:** involves bringing in additional data to help *expand* (more variables) or *append* (more items)
- ▶ **Data Exploration:** using visual and statistical techniques to find out what potential insights and qualities of understanding it could provide

WHY

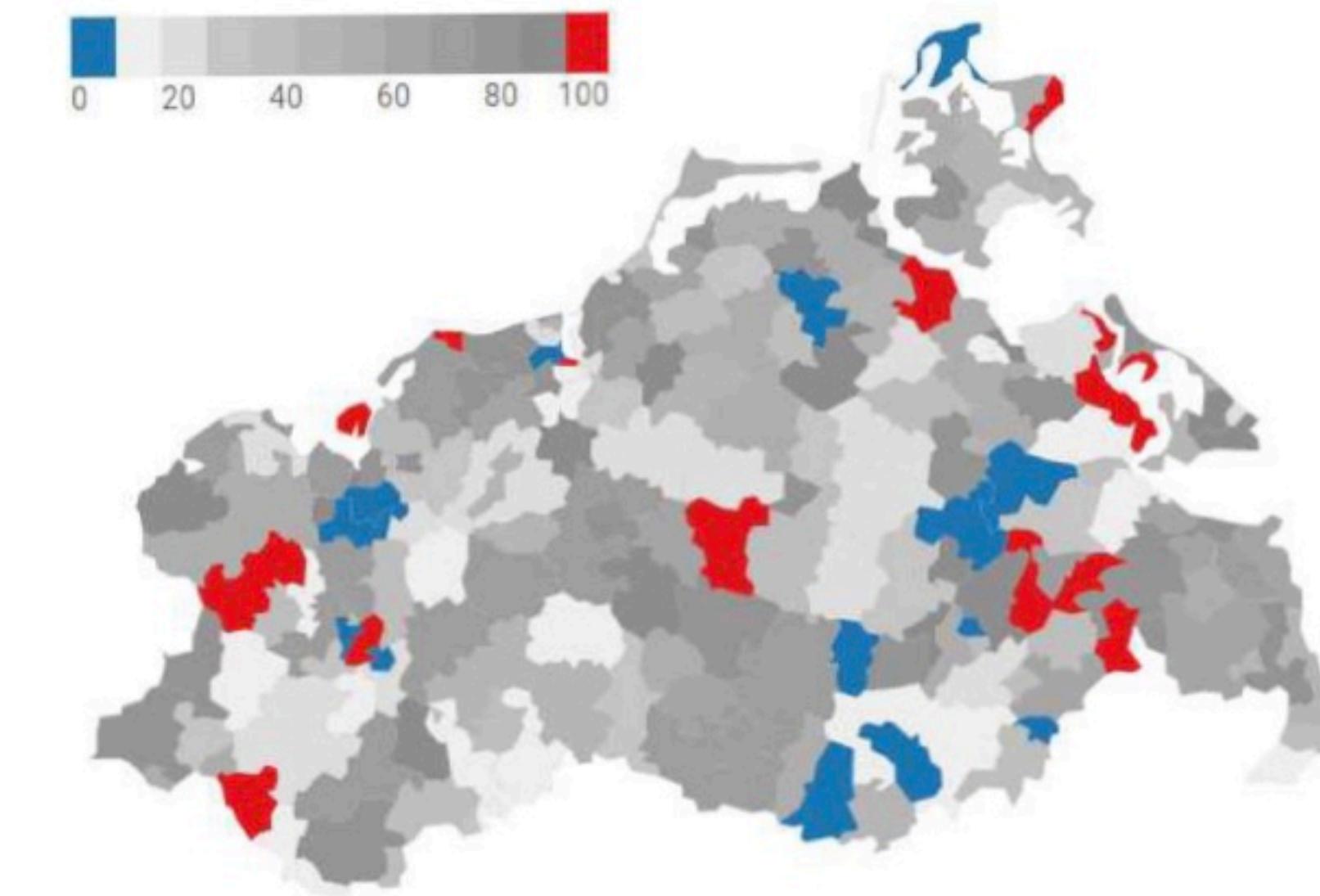
GOALS AND TASKS

WHY: GOALS AND TASKS

The generation of effective visual representations depends on the task. [TOMINSKI & SCHUMANN 2020]



Coloring suited to identifying values

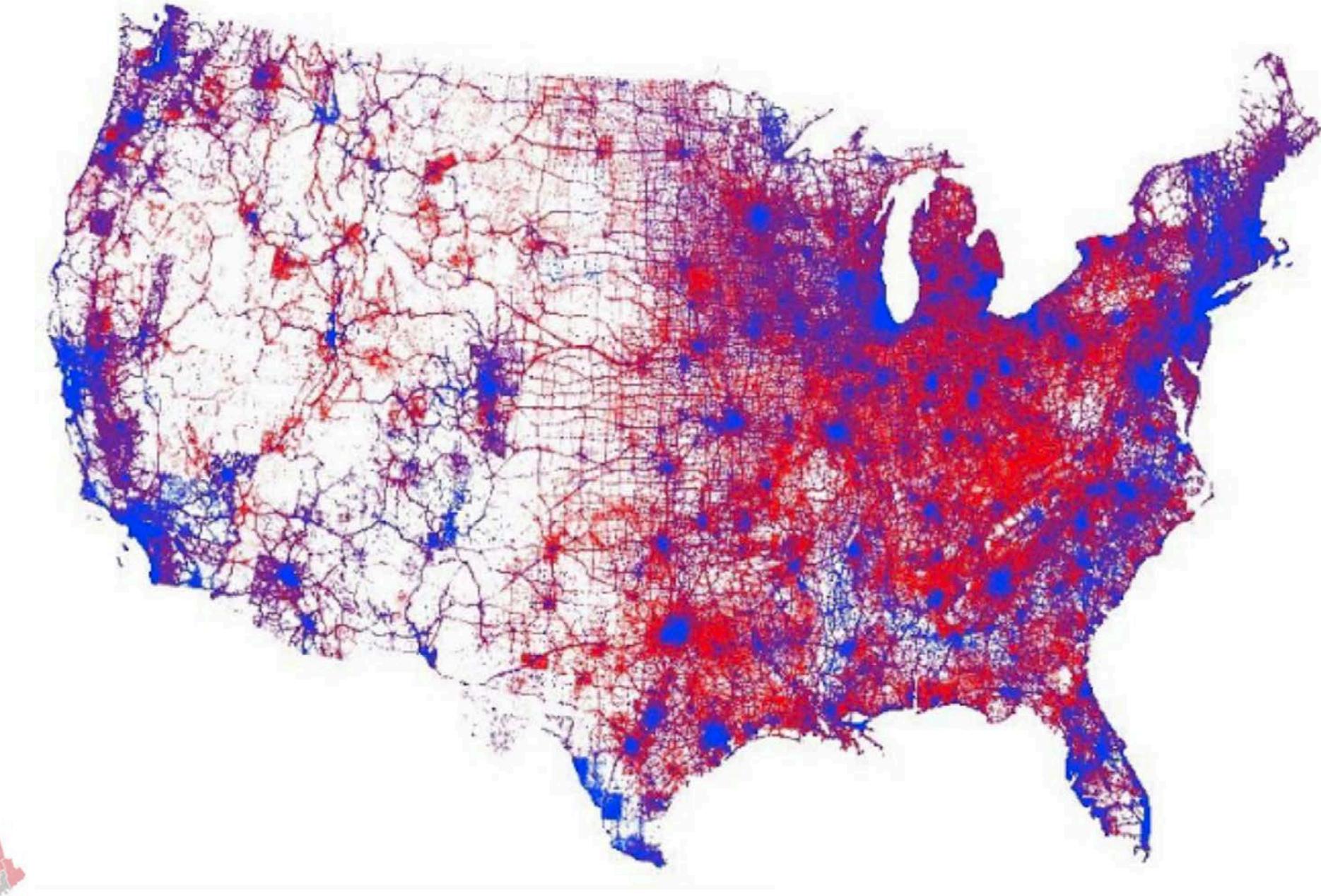
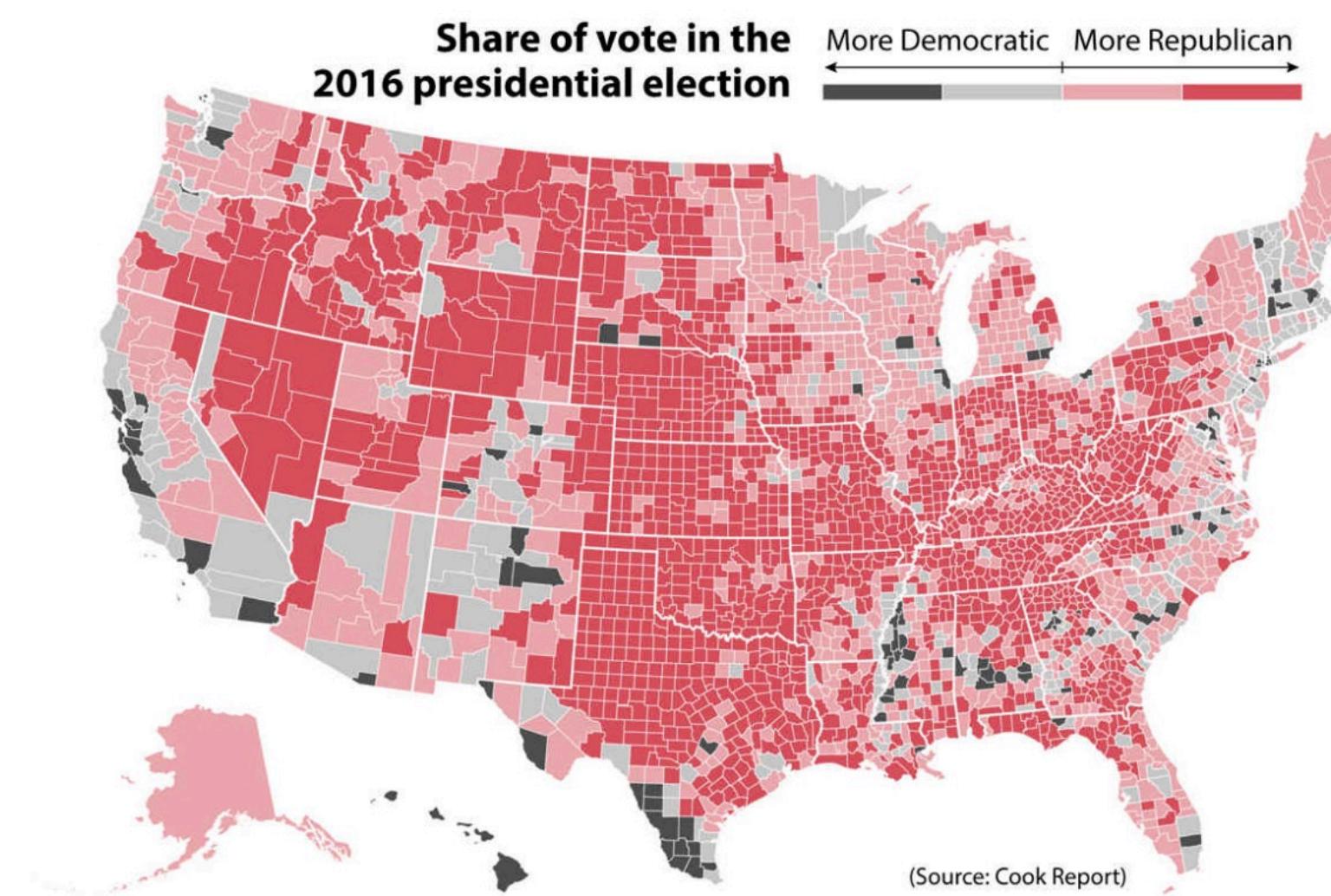


Coloring suited to locating extrema

WHY: GOALS AND TASKS



How Charts Lie [CAIRO 2019]



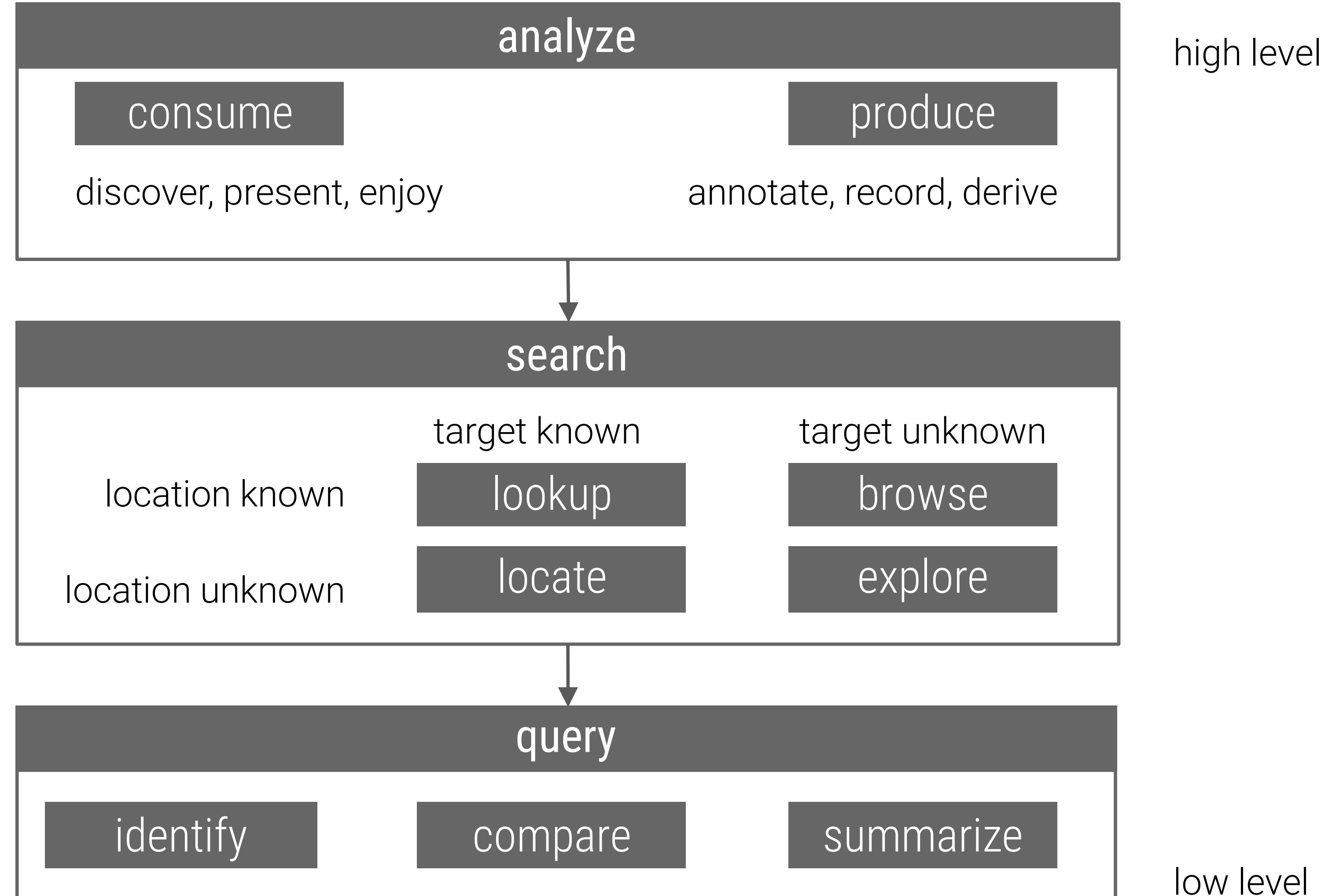
Share of the popular vote in the 2016 presidential election

Donald Trump	46.1%	62,984,825 votes
Hillary Clinton	48.2%	65,853,516 votes
Other candidates	5.7%	

WHY: Task Taxonomy [MUNZNER 2014]

Discover:

- ▶ Generate and verify hypotheses
- ▶ Results not clear in advance



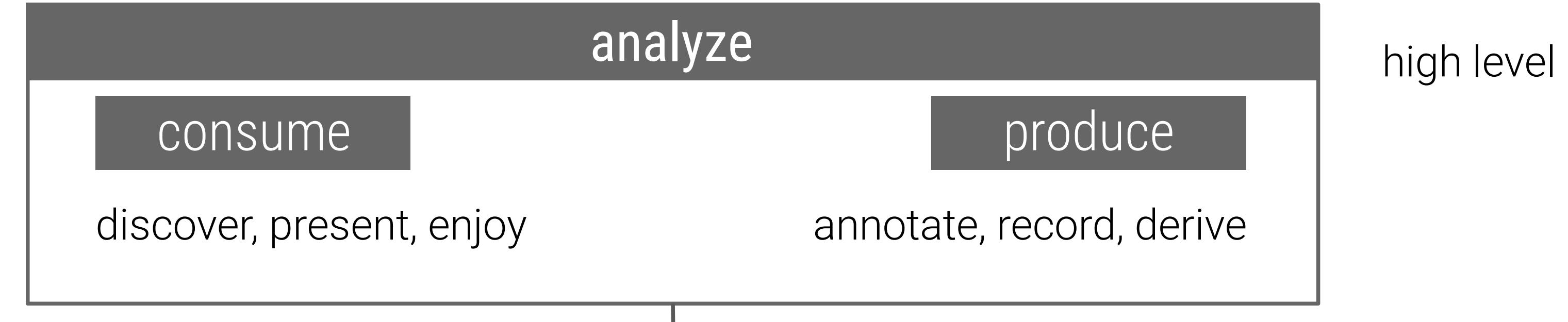
Enjoy:

- ▶ Casual use of visualizations out of curiosity

WHY: Task Taxonomy [MUNZNER 2014]

Annotate:

- ▶ Manual input of graphical or textual information

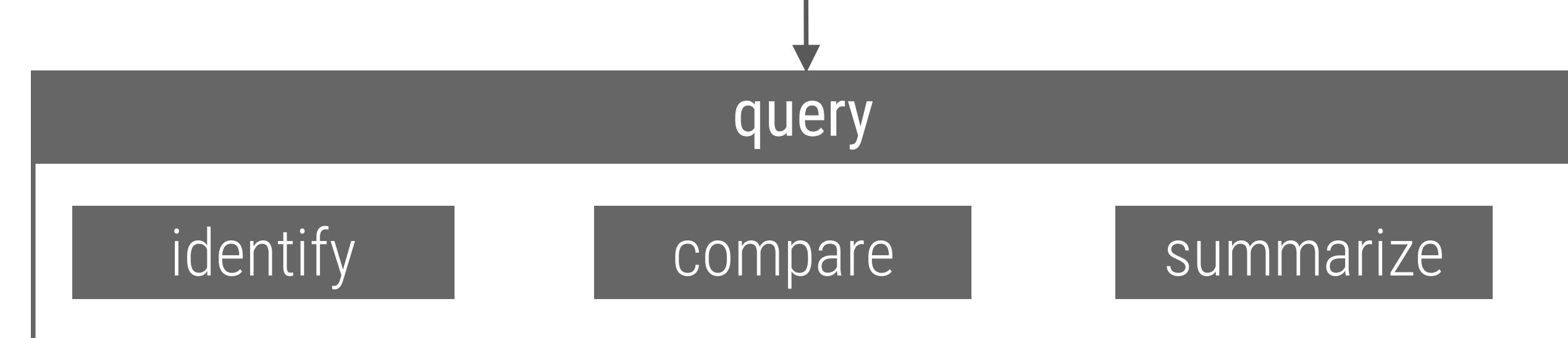
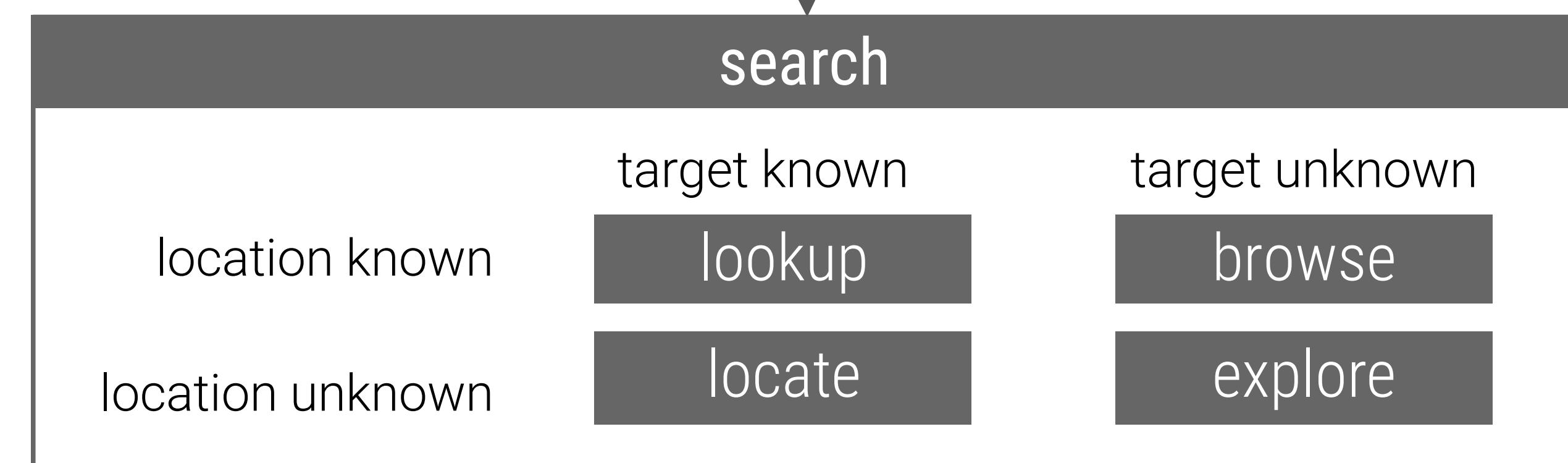


Record:

- ▶ Record data elements e.g through screenshots, lists

Derive:

- ▶ Use existing data elements to create new ones



high level

low level

WHY: Task Taxonomy [MUNZNER 2014]

Low-Level Actions with one or more elements

Identify:

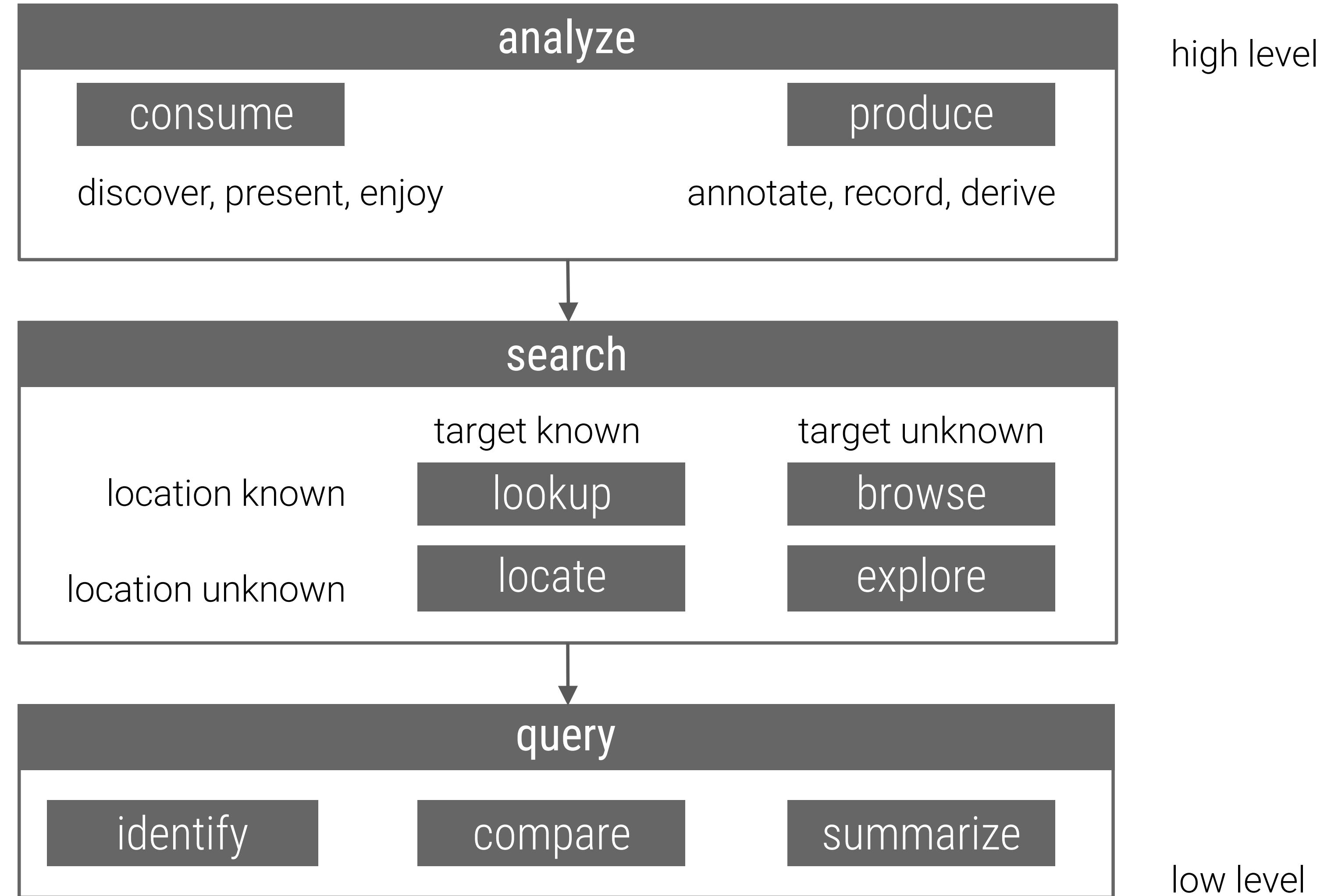
- ▶ returns the characteristics of a single element

Compare:

- ▶ inspection of several elements

Summarize:

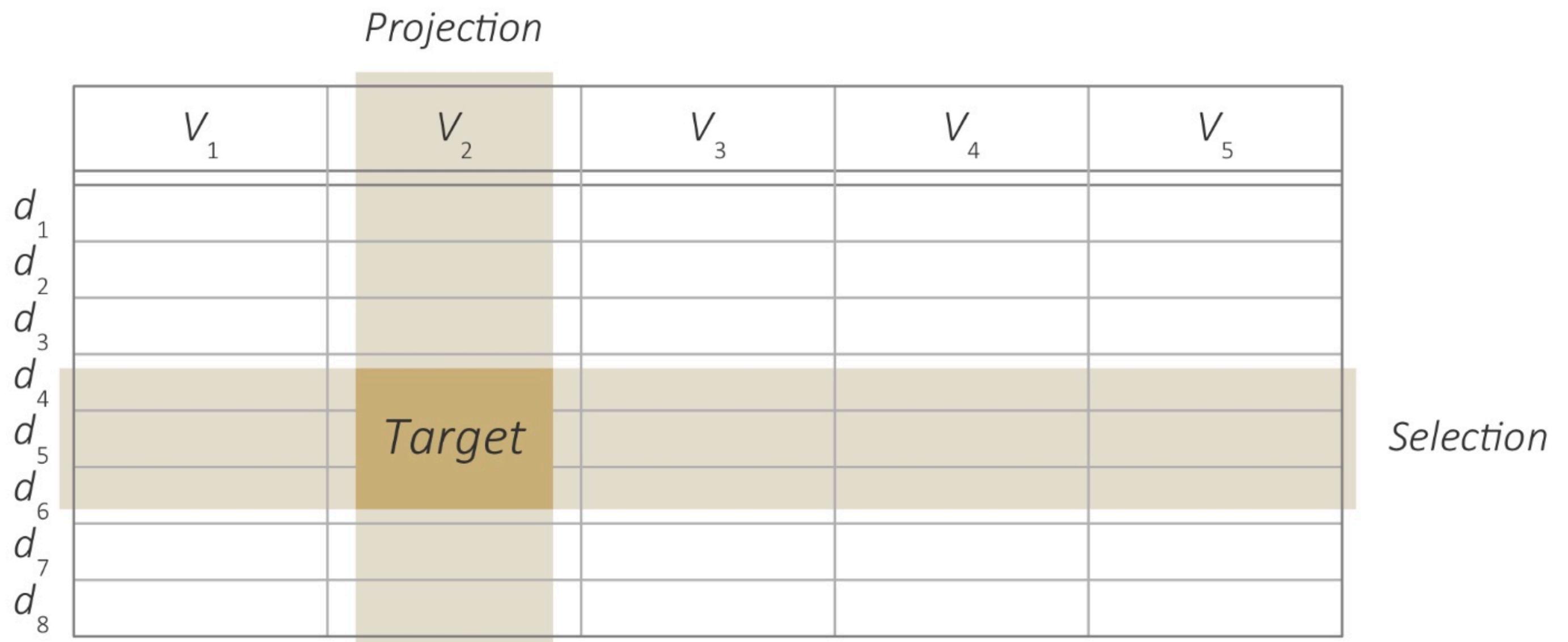
- ▶ summary of all elements



WHY + WHAT: Targets

Data of Interest: [TOMINSKI & SCHUMANN 2020]

- ▶ Subset of data that is indeed relevant to the task
- ▶ **Projection:** Restricting the view on particular variables
- ▶ **Selection:** Restricting the view on particular data elements



WHY + WHAT: Targets

Data of Interest: [TOMINSKI & SCHUMANN 2020]

- ▶ Subset of data that is indeed relevant to the task
- ▶ **Projection:** Restricting the view on particular variables
- ▶ **Selection:** Restricting the view on particular data elements

Data Granularity (different levels of detail or abstractions):

- ▶ Low level of detail (high level of abstraction): is suited to get a general overview of the data
- ▶ High level of detail (low level of abstraction): permits insights into details that cannot be seen in an overview

HOW

Visualization and Interaction

HOW

Visual Structure:

- ▶ Spatial reference system
- ▶ Visual elements

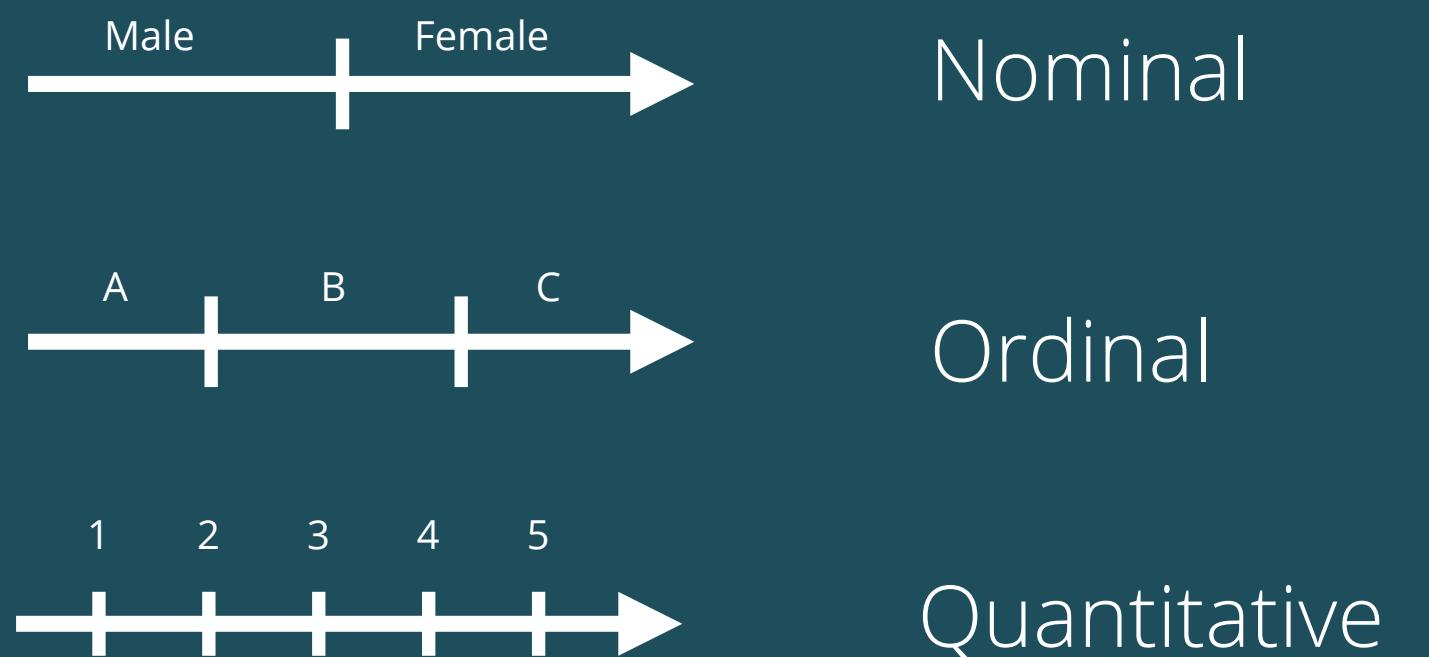
Spatial reference system: [BERTIN 1974]



Rectangular



Radial



Nominal

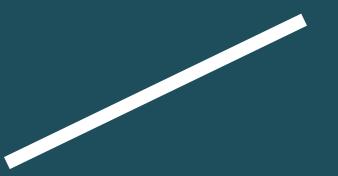
Ordinal

Quantitative

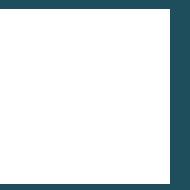
Visual Elements:



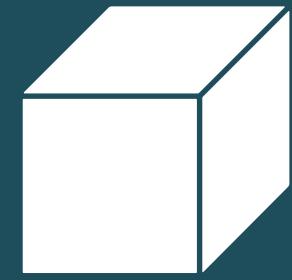
Point



Line



Area

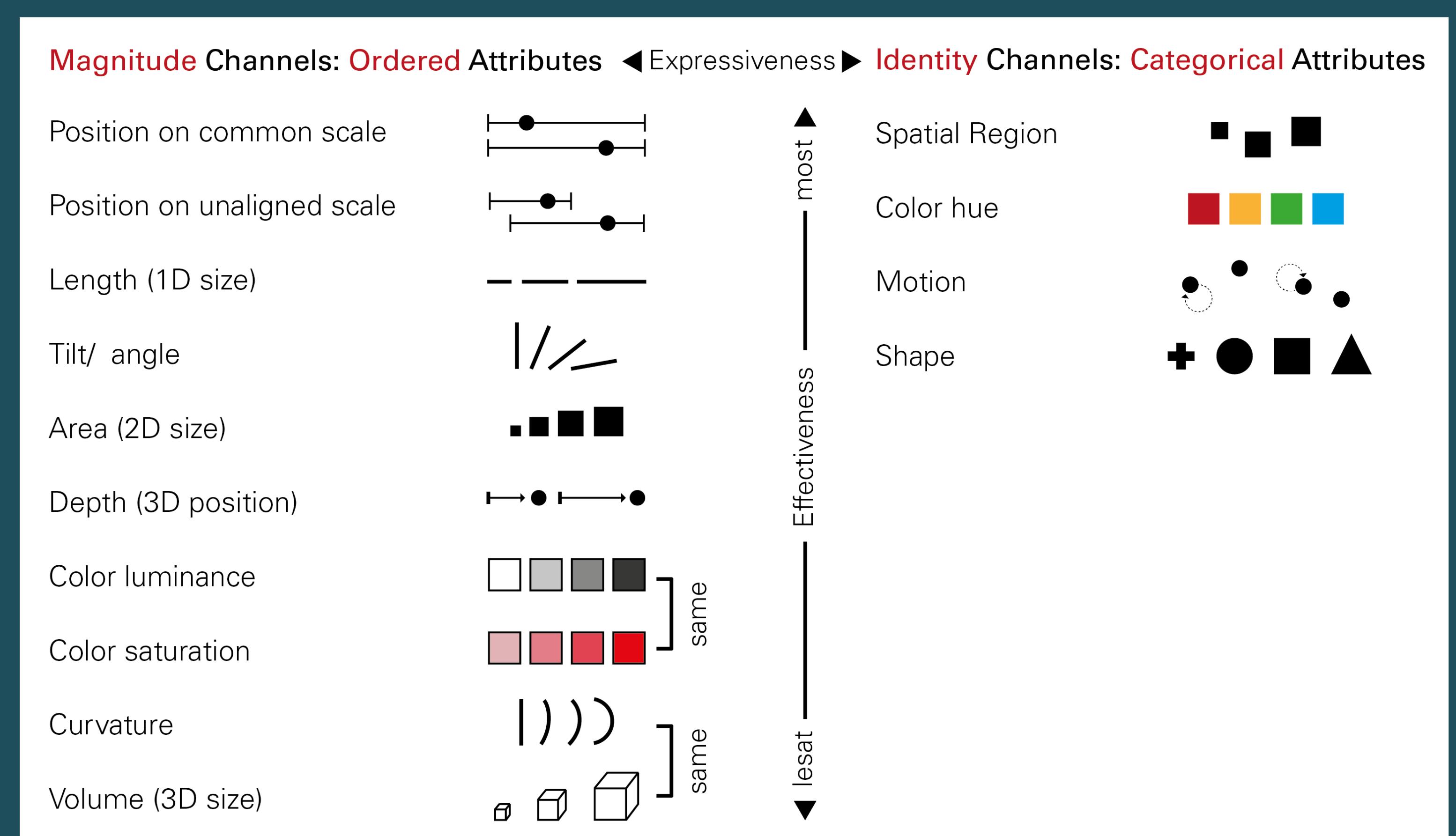


Volume

HOW

Visual Structure:

- ▶ Spatial reference system
- ▶ Visual elements
- ▶ Visual variables



Visual variables classified by expressiveness and ordered by effectiveness
[MUNZNER 2014]

HOW

Visual Structure:

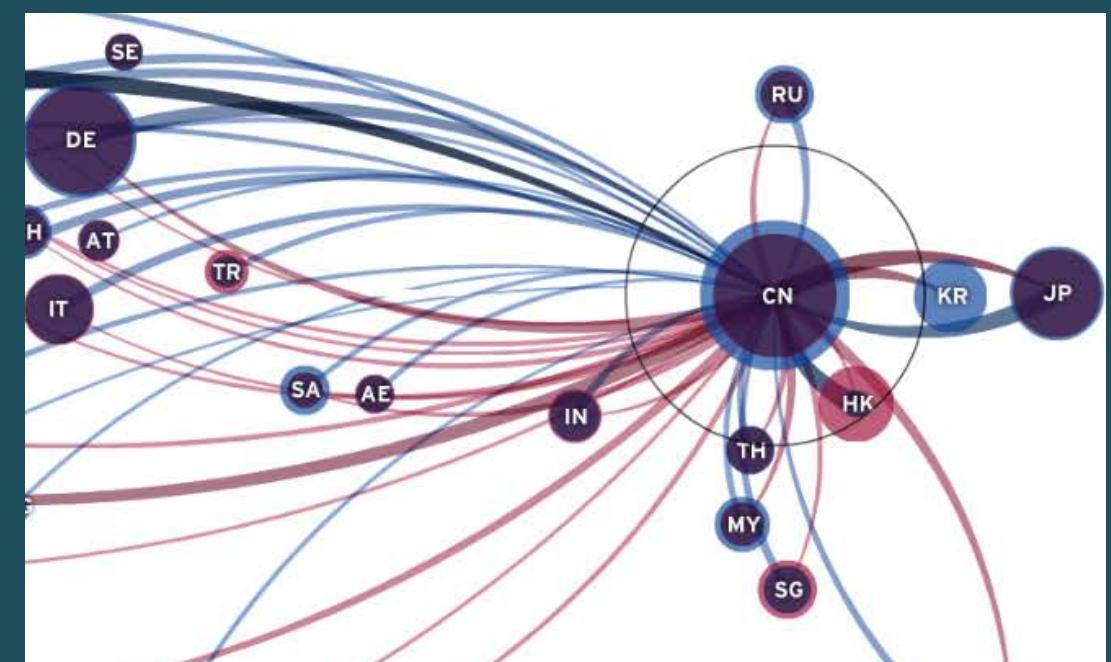
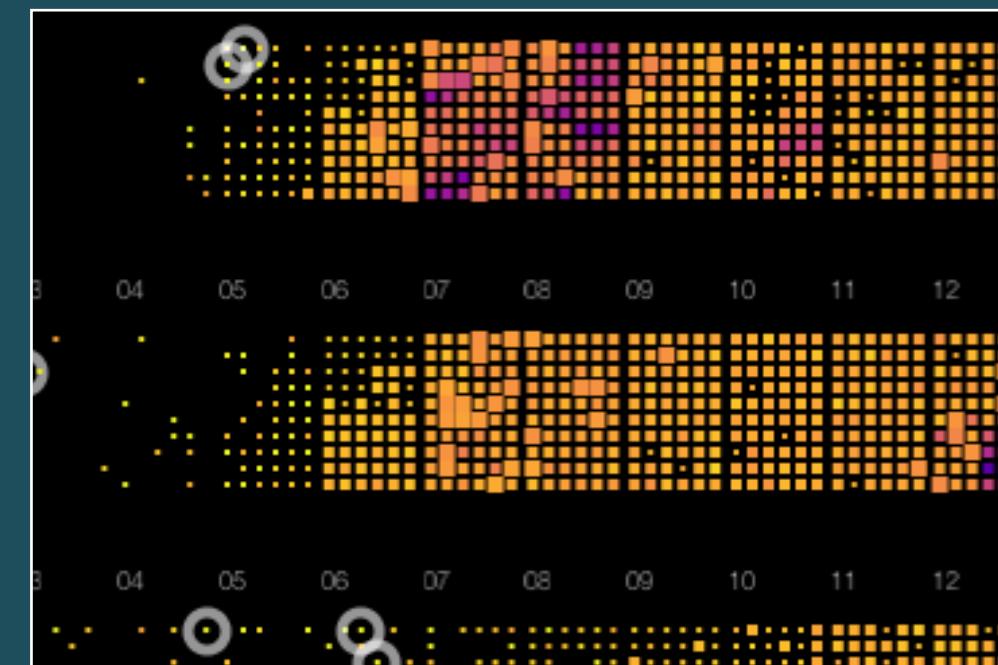
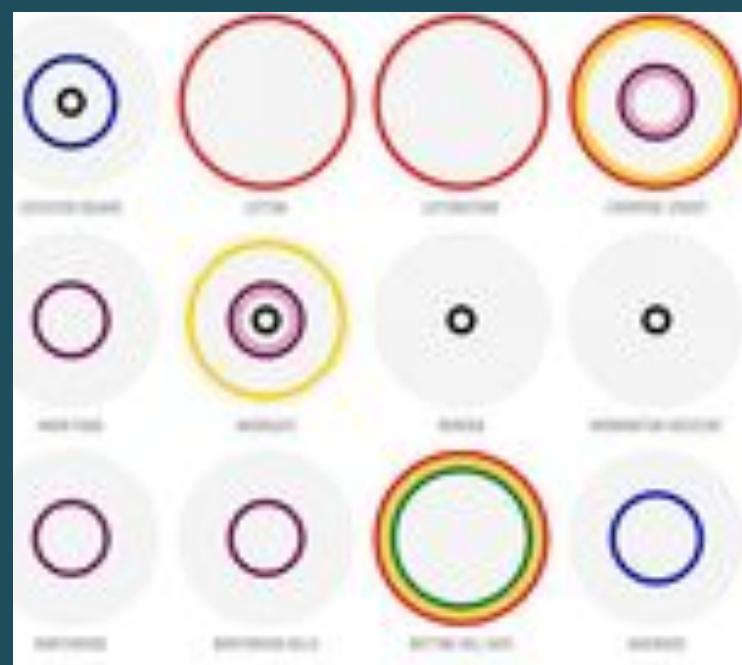
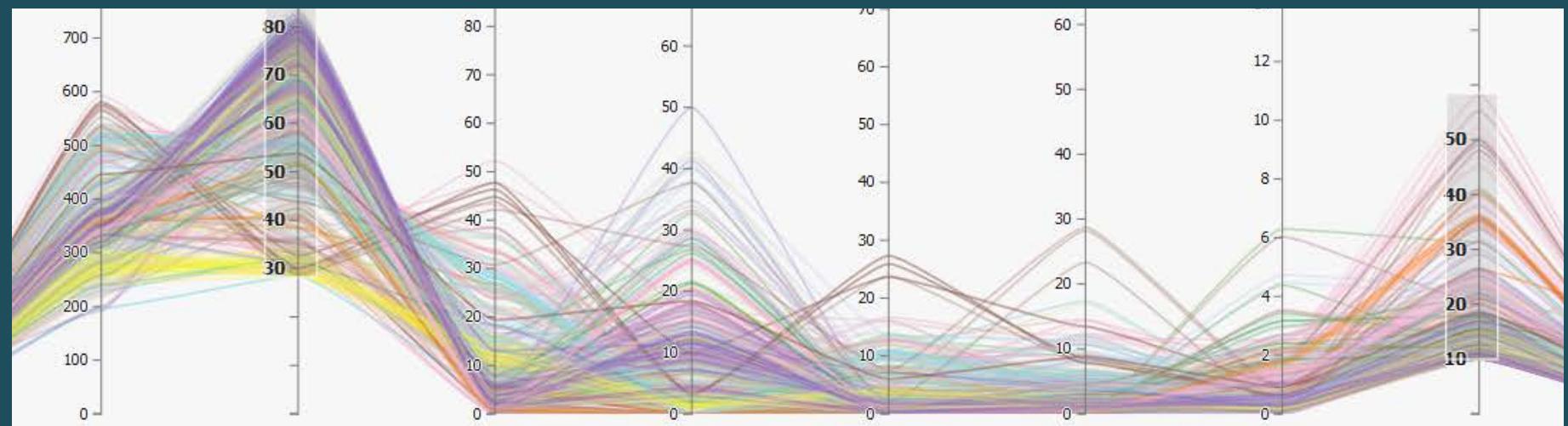
- ▶ Spatial reference system
- ▶ Visual elements
- ▶ Visual variables

Visualisation techniques

Visualisation techniques for multidimensional data sets

[KEIM 2000]:

- ▶ Geometric techniques
- ▶ Iconic Techniques
- ▶ Pixel-based techniques
- ▶ Hierarchical Techniques
- ▶ Graph-based techniques



HOW

Visual Structure:

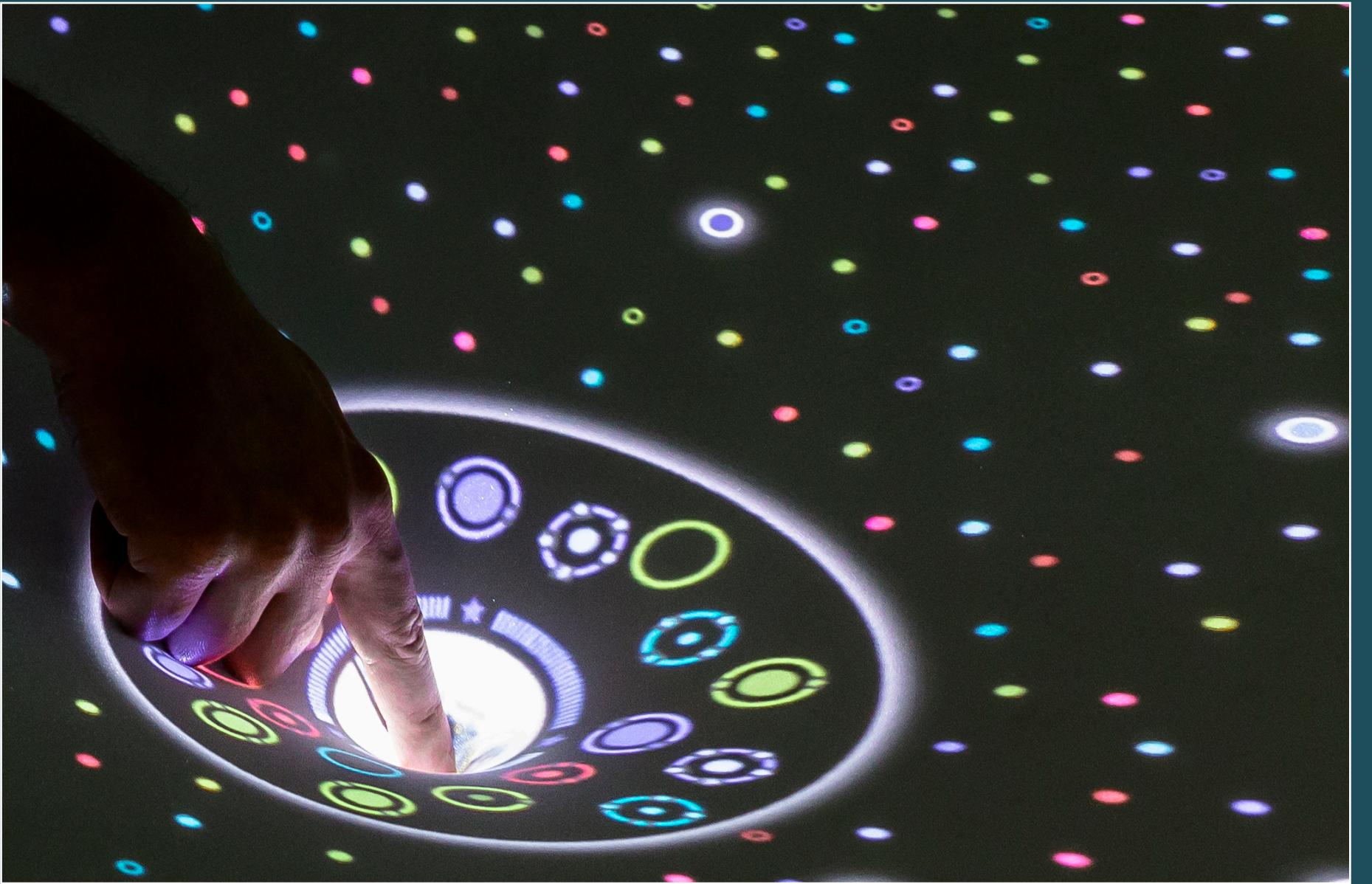
- ▶ Spatial reference system
- ▶ Visual elements
- ▶ Visual variables

Visualisation techniques

Interaction techniques

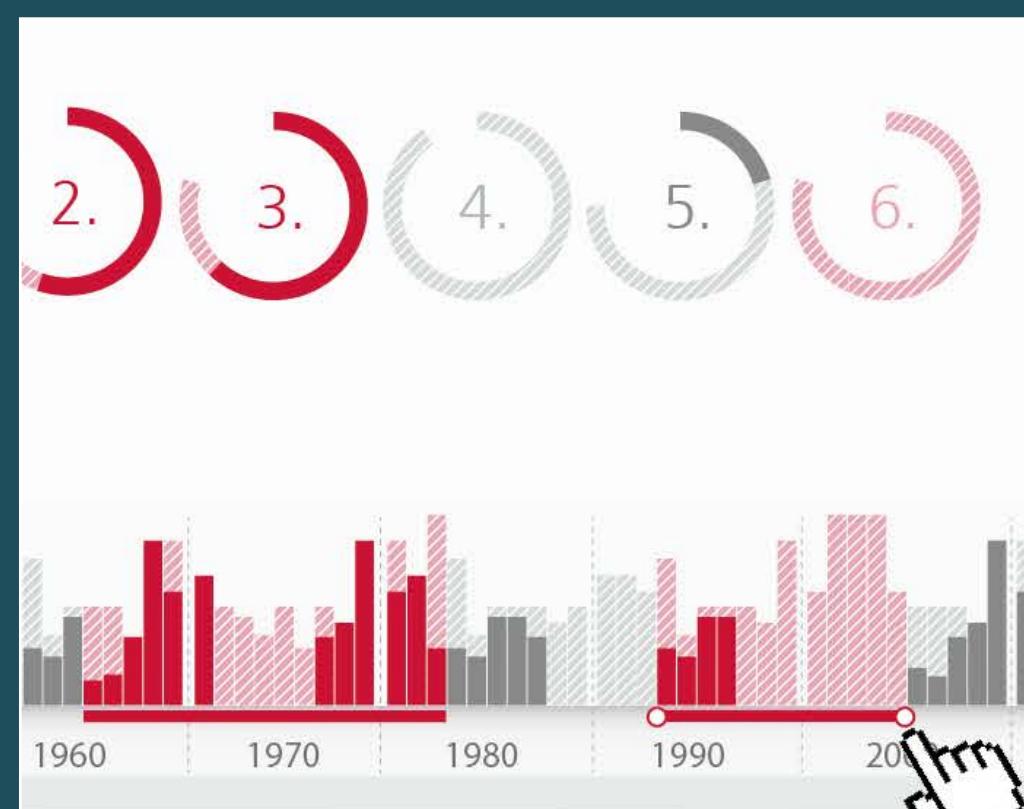
View Manipulation:

e.g. Zooming, Panning,
Rotation, Distort



Data Manipulation:

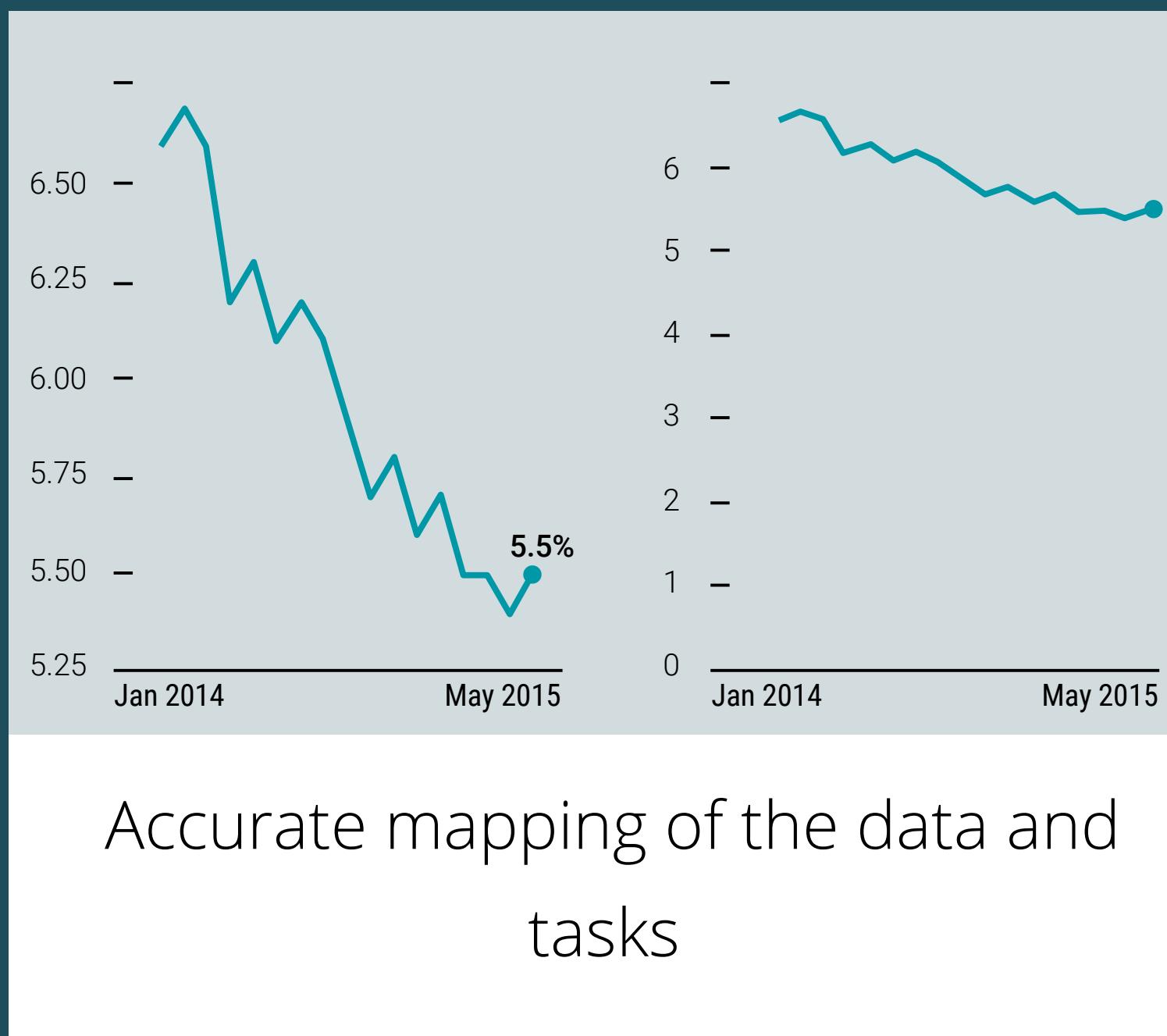
e.g. Filter, Sort,
Group, Aggregate



What makes a good visualization?

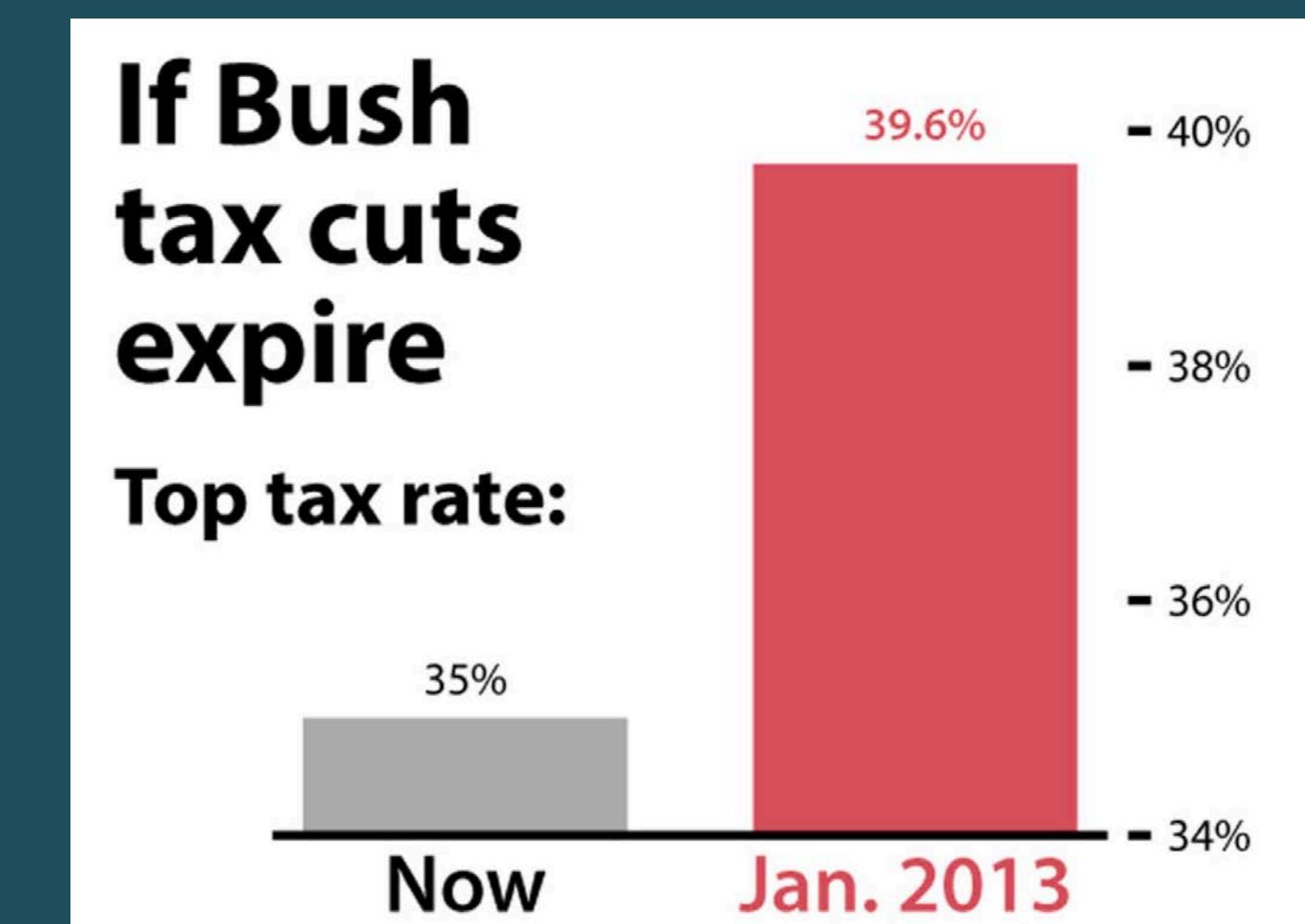
[MUNZNER 2014, CARD ET AL. 1999, TOMINSKI & SCHUMANN 2020]

Expressiveness



Expressiveness:

»The mapping of a data table to a visual structure is said to be expressive if all and only the data in the data table are also represented in the visual structure« [CARD ET AL. 1999]

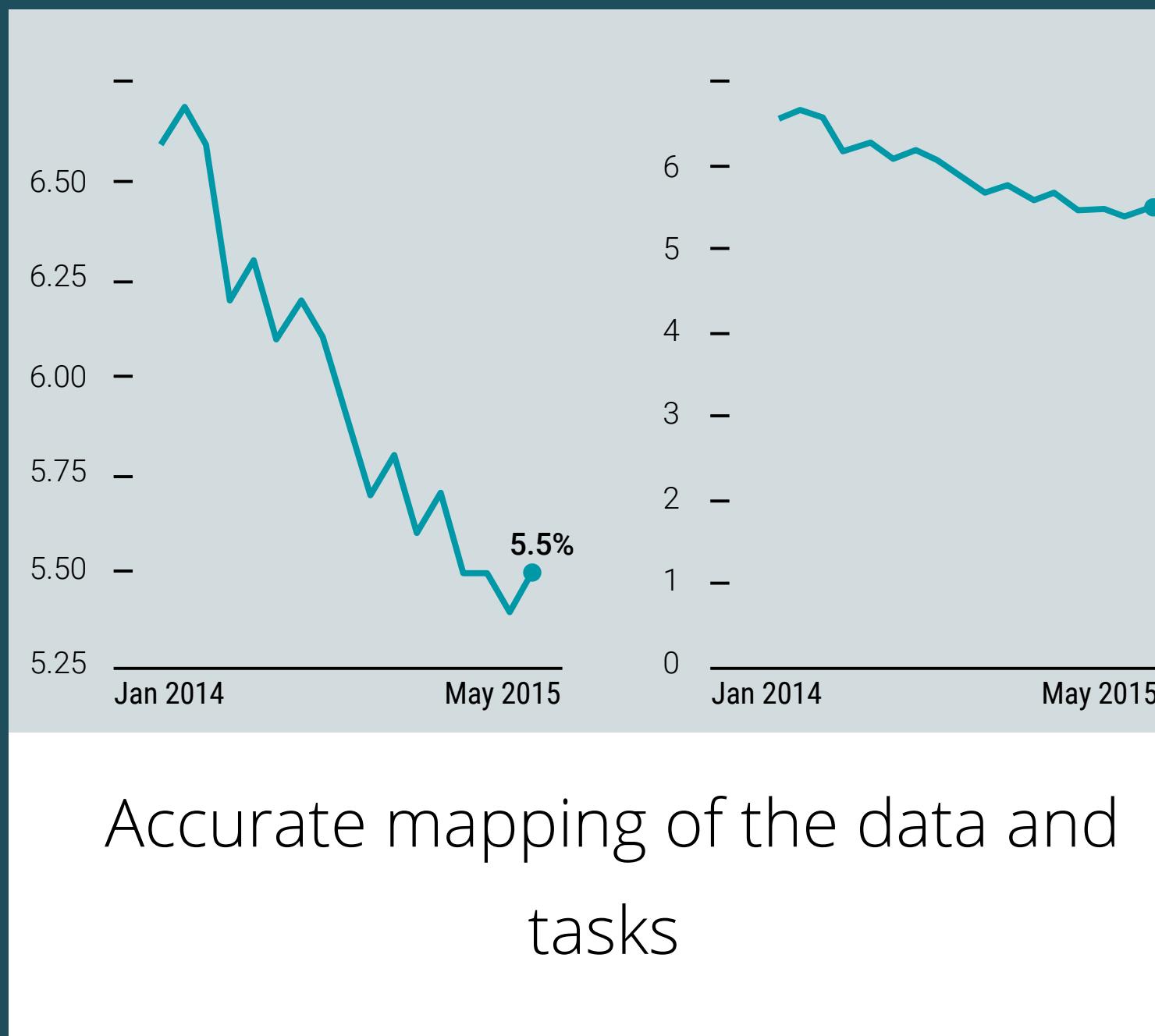


[CAIRO 2019]

What makes a good visualization?

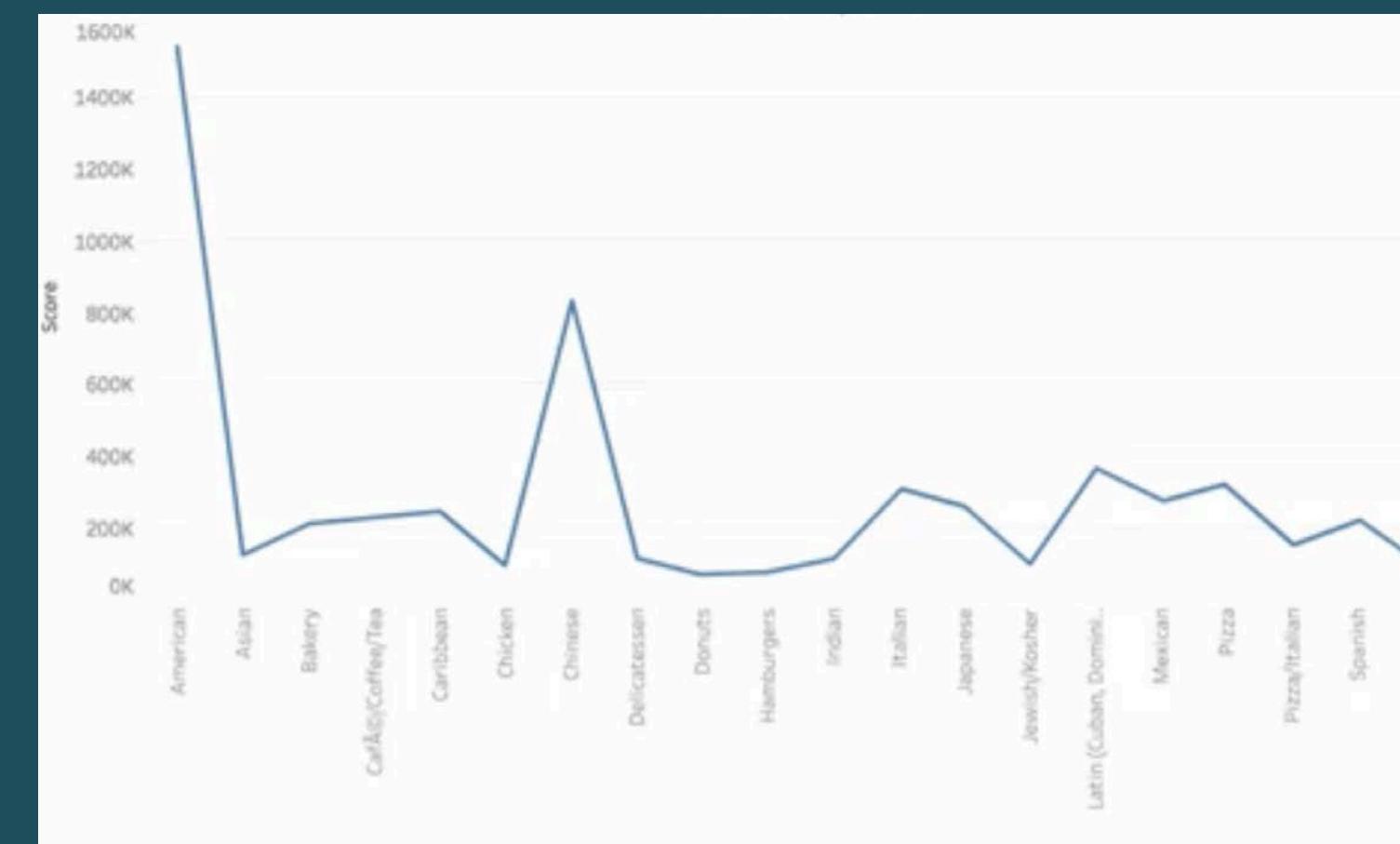
[MUNZNER 2014, CARD ET AL. 1999, TOMINSKI & SCHUMANN 2020]

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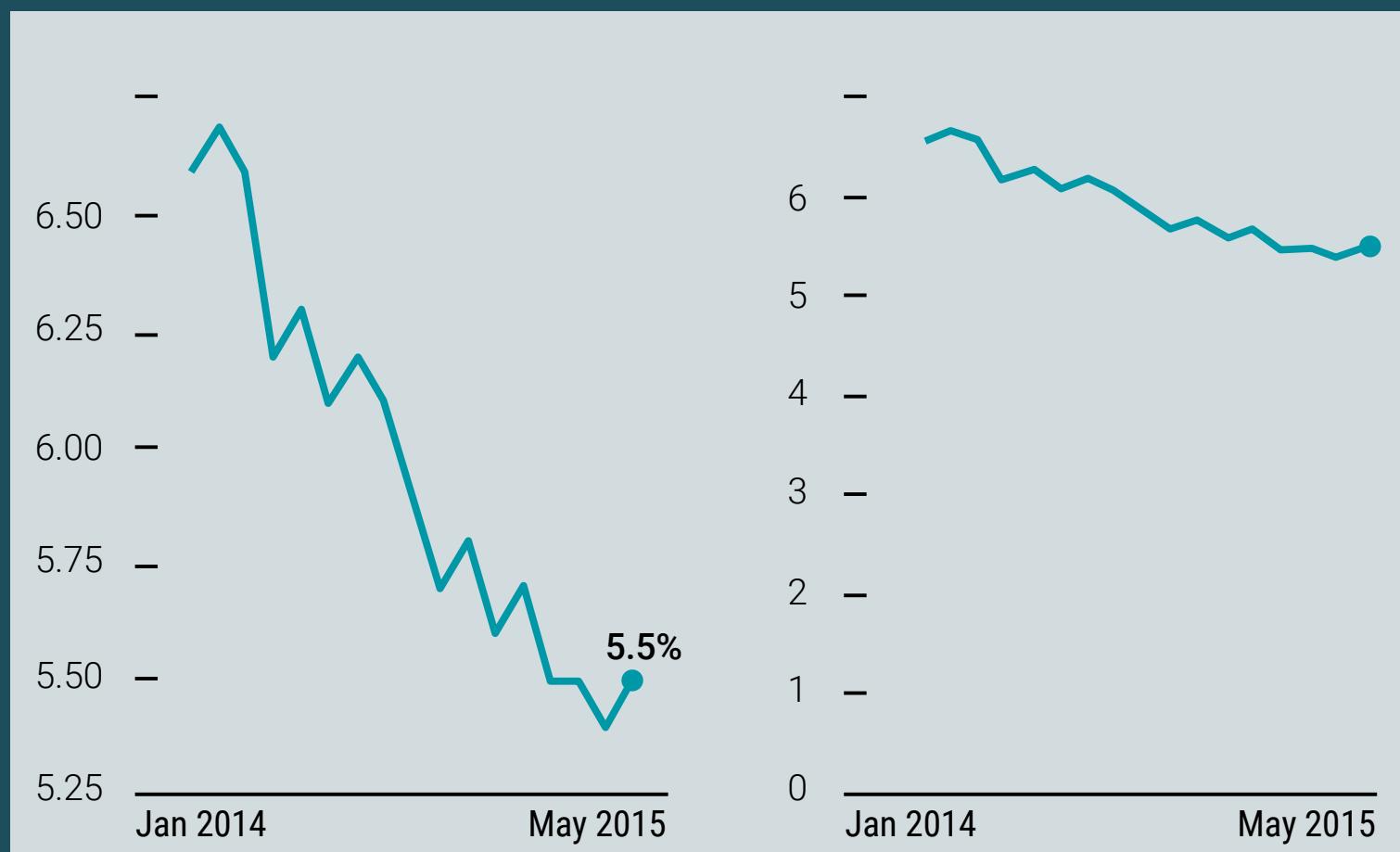


unordered data should
not appear as ordered

What makes a good visualization?

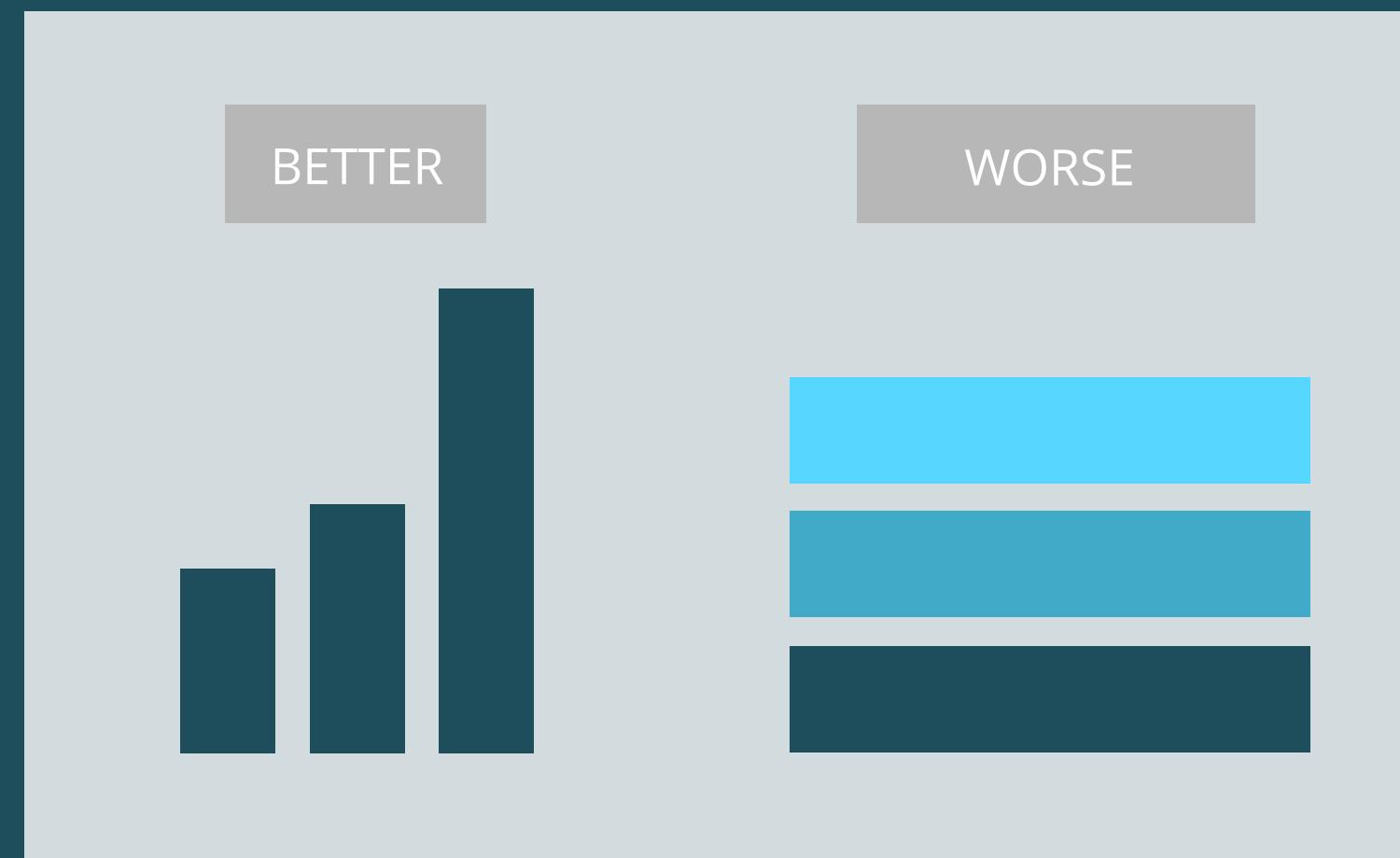
[MUNZNER 2014, CARD ET AL. 1999, TOMINSKI & SCHUMANN 2020]

Expressiveness



Accurate mapping of the data and tasks

Effectiveness



quick interpretation of the visual structure

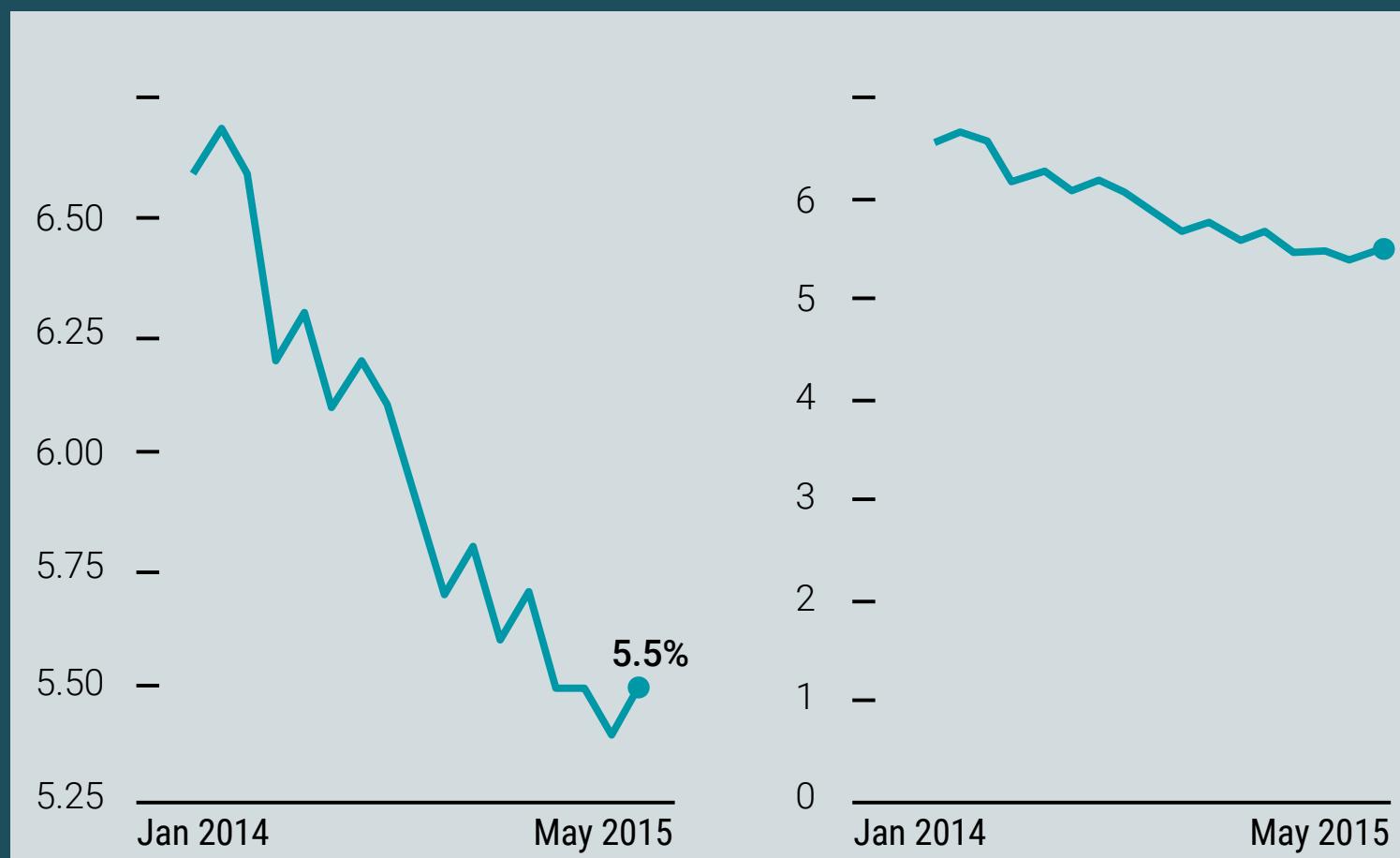
Effectiveness:

»A mapping is said to be more effective if it is faster to interpret, can convey more distinctions, or leads to fewer errors than some other mapping.« [CARD ET AL. 1999]

What makes a good visualization?

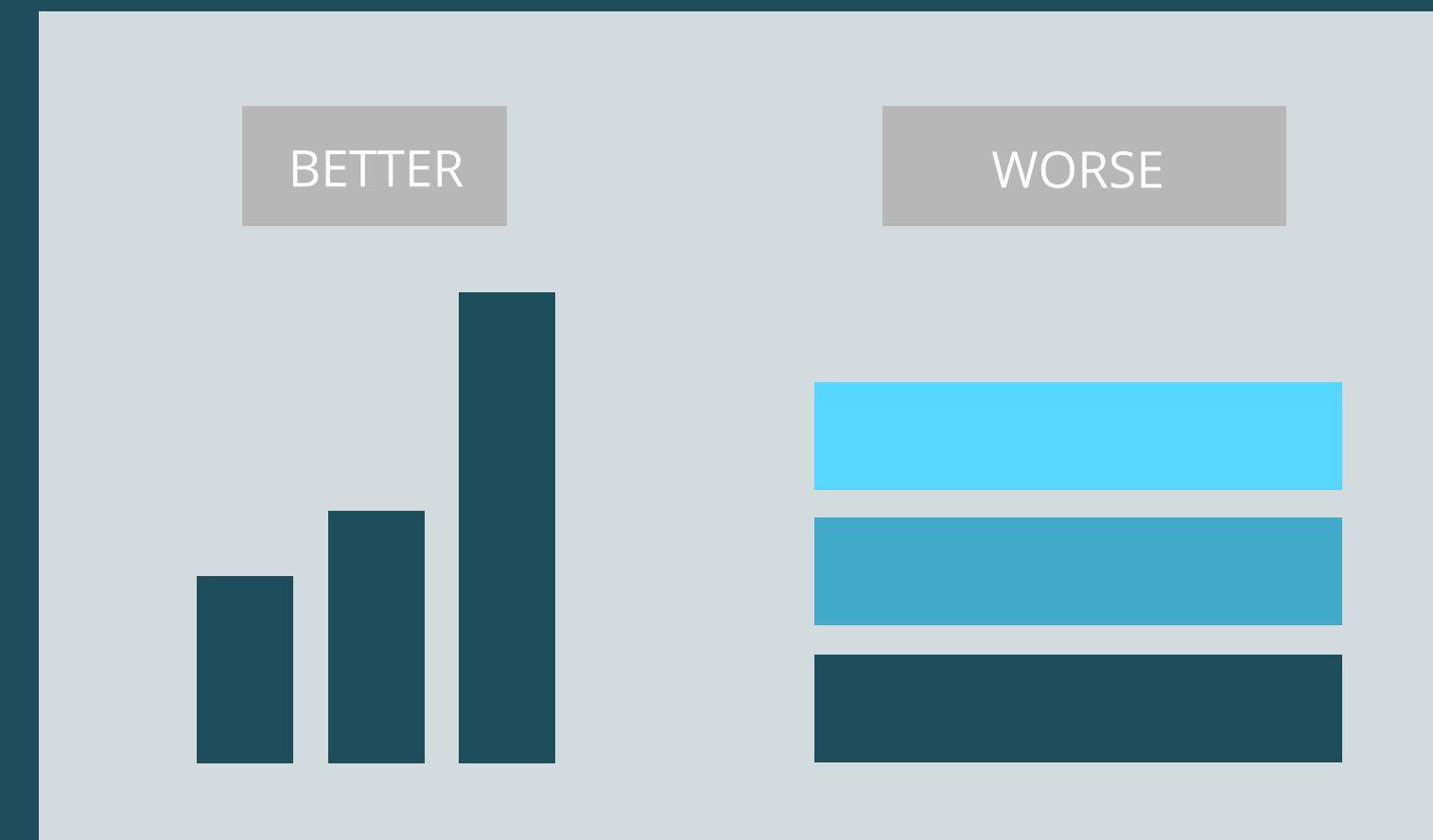
[MUNZNER 2014, CARD ET AL. 1999, TOMINSKI & SCHUMANN 2020]

Expressiveness



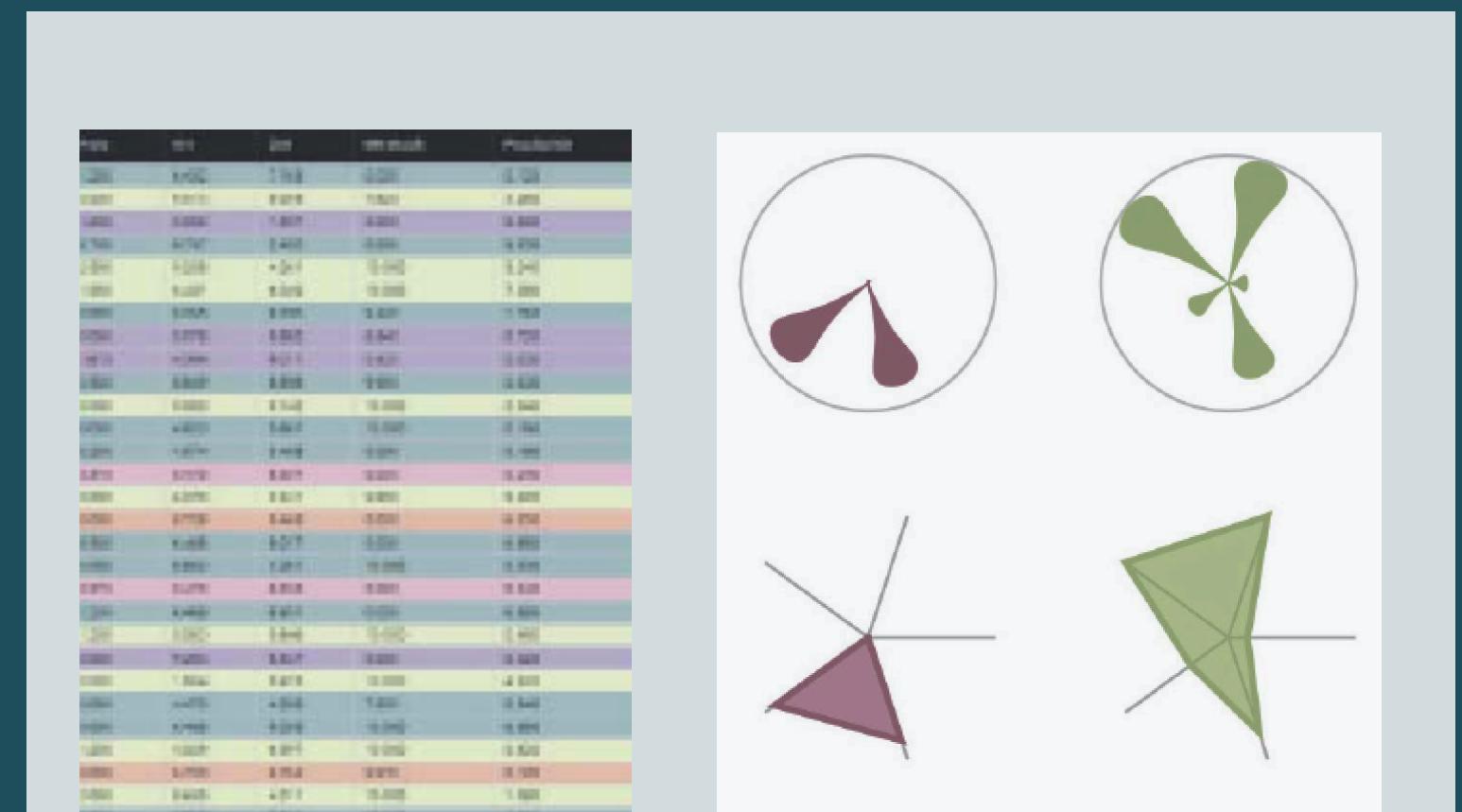
Accurate mapping of the data and tasks

Effectiveness



quick interpretation of the visual structure

Efficiency



Balancing benefits and costs

Most important: Expressiveness first! - »Above all else show the data« [TUFTE 1983]

References

- [CARD ET AL. 1999] - CARD, S., MACKINLAY, J. & SHNEIDERMAN, B.: READINGS IN INFORMATION VISUALIZATION: USING VISION TO THINK. MORGAN KAUFMANN PUBLISHERS. 1999
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- [WARE 2020] - COLIN WARE: INFORMATION VISUALIZATION: PERCEPTION FOR DESIGN, MORGAN KAUFMANN, 4TH EDITION, 2020, ISBN: 978-0-12-812875-6
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- [MUNZNER 2014] - MUNZNER, T.: VISUALIZATION ANALYSIS AND DESIGN. BOCA RATON, FL: CRC PRESS, AK PETERS VISUALIZATION SERIES. 2014
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- [STEVENS 1946] - S. S. STEVENS : ON THE THEORY OF SCALES OF MEASUREMENT, NEW SERIES, VOL. 103, NO. 2684 (JUN. 7, 1946), PP. 677-680 PUBLISHED BY: AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
- [TOMINISKI & SCHUMANN 2000] - CHRISTIAN TOMINISKI & HEIDRUN SCHUMANN: INTERACTIVE VISUAL DATA ANALYSIS, (AK PETERS VISUALIZATION SERIES), 1. AUFLAGE, 2000
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