Data and Image Models

DSC 106: Data Visualization

Sam Lau

UC San Diego

Slides adapted with permission from Arvind Satyanarayan

Announcements

Lab 1 due **Friday**!

Project 1 checkpoint due Tuesday, 10/07.

Final Project Showcase tentatively scheduled for Tues Dec 9, 11:30am-2:30pm in the HDSI MPR.

DSTL (Sam's Lab) has an info session tomorrow at 11am in the HDSI MPR.

FAQs on course logistics:

1. Can I get participation if I attend a different lecture than the one I enrolled? Yes, as long as there are seats in the room.
2. We do look through Classbuzz responses and don't count responses that aren't attempting to answer the question (e.g. "idk").
3. Can I use ChatGPT / CoPilot? Yes, and use with caution!

A note about using ChatGPT

We need to be having high quality conversations about AI: what it can and can't do, its many risks and pitfalls and how to integrate it into society in the most beneficial ways possible.

Strawman: "Don't call it AI! It's not actually intelligent—it's just spicy autocomplete."

Which one was generated by ChatGPT?

As artificial intelligence continues to transform our world, it is crucial to approach its development and deployment with caution, recognizing the potential for unintended harms alongside its vast promise.

From biased decisions to privacy risks, AI misuse demands proactive oversight and thoughtful regulation.

A note about using ChatGPT

If it’s super obvious your writeup is AI generated without any editing, you will lose 50% of the writeup score.

If it looks obviously AI-generated to the staff, it will also look AI-generated to professional data scientists.

Advice from past students

If you want to be ambitious, it's really easy to do that in this class! Try and create something you're proud of. It's worth it. :)

Go to OH and use AI!!

The rubric is there to guide you, but you won’t get anything from this class if your main objective is to simply get all the points. Be creative and take risks with what you visualize.

Most common advice:

Just please start your labs and projects early because I feel like if I did, a lot of headache of doing stuff on the last day would be eliminated :)

Project 1: Expository visualization

Create **one static visualization** for a dataset (see course website).

Pick a **guiding question**, use it to title your vis.

Design a **static visualization** for that question.

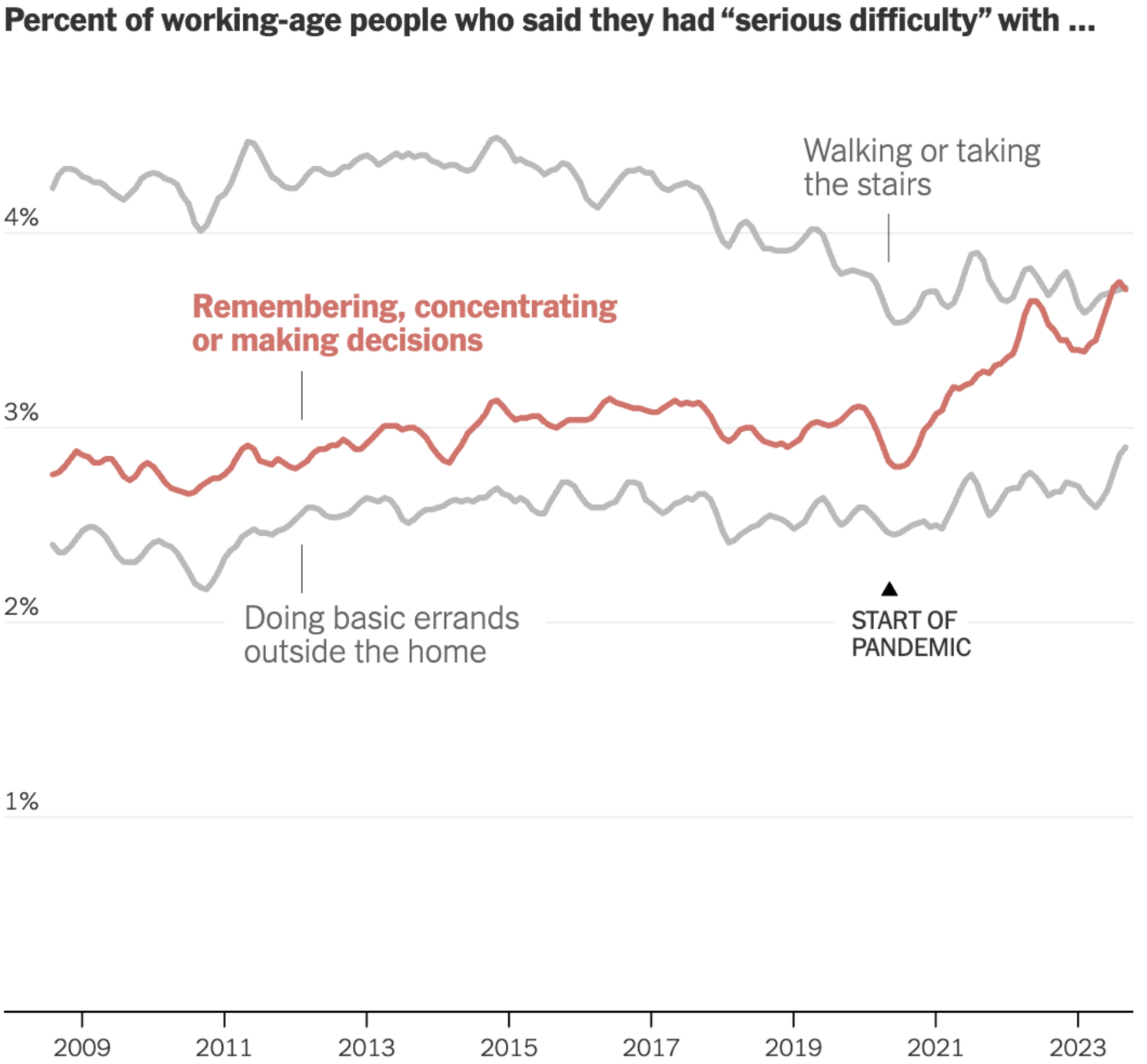
You are free to **use any tools** (inc. Python, Tableau, pen & paper).

Deliverables (upload via Gradescope; see Project 1 page)

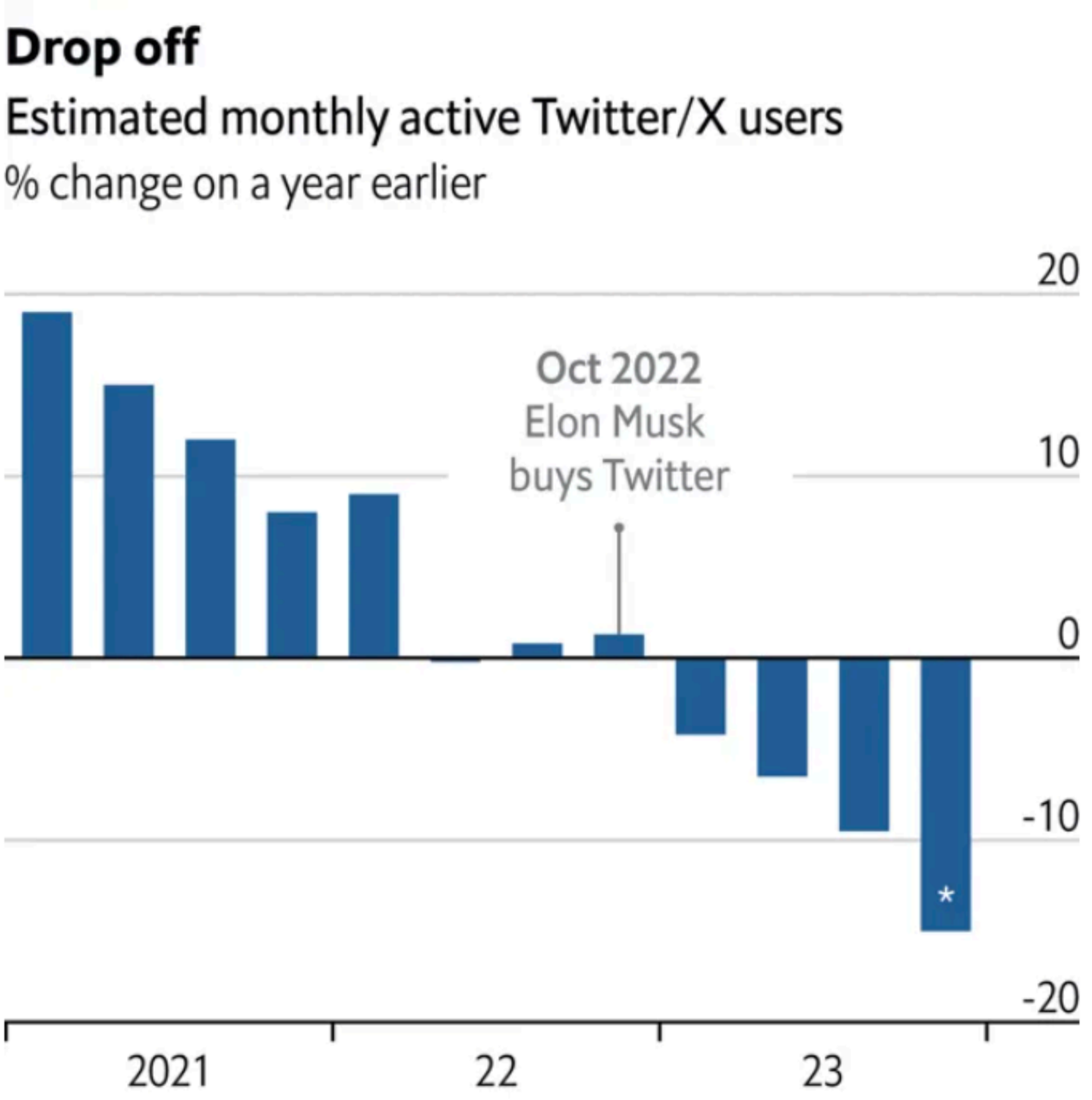
Image of your visualization (PNG or JPG format)

Short description + design rationale (≤ 4 paragraphs)

Name that chart!



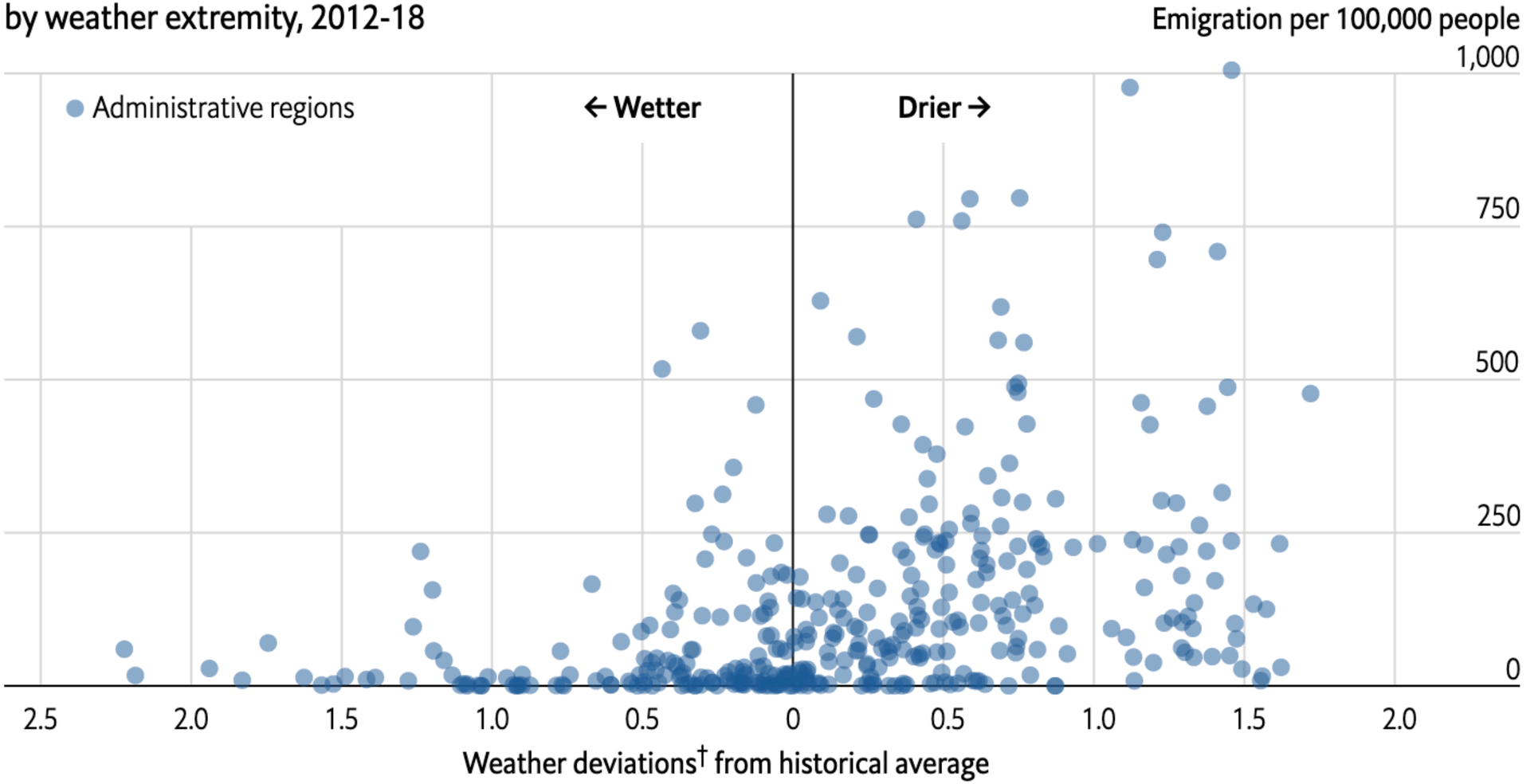
https://www.nytimes.com/2024/01/10/upshot/covid-pandemic-wave.html



https://www.economist.com/graphic-detail/2023/12/20/has-twitter-now-x-become-more-right-wing

Spotting a trend

Emigration from the Northern Triangle* to United States, by weather extremity, 2012-18

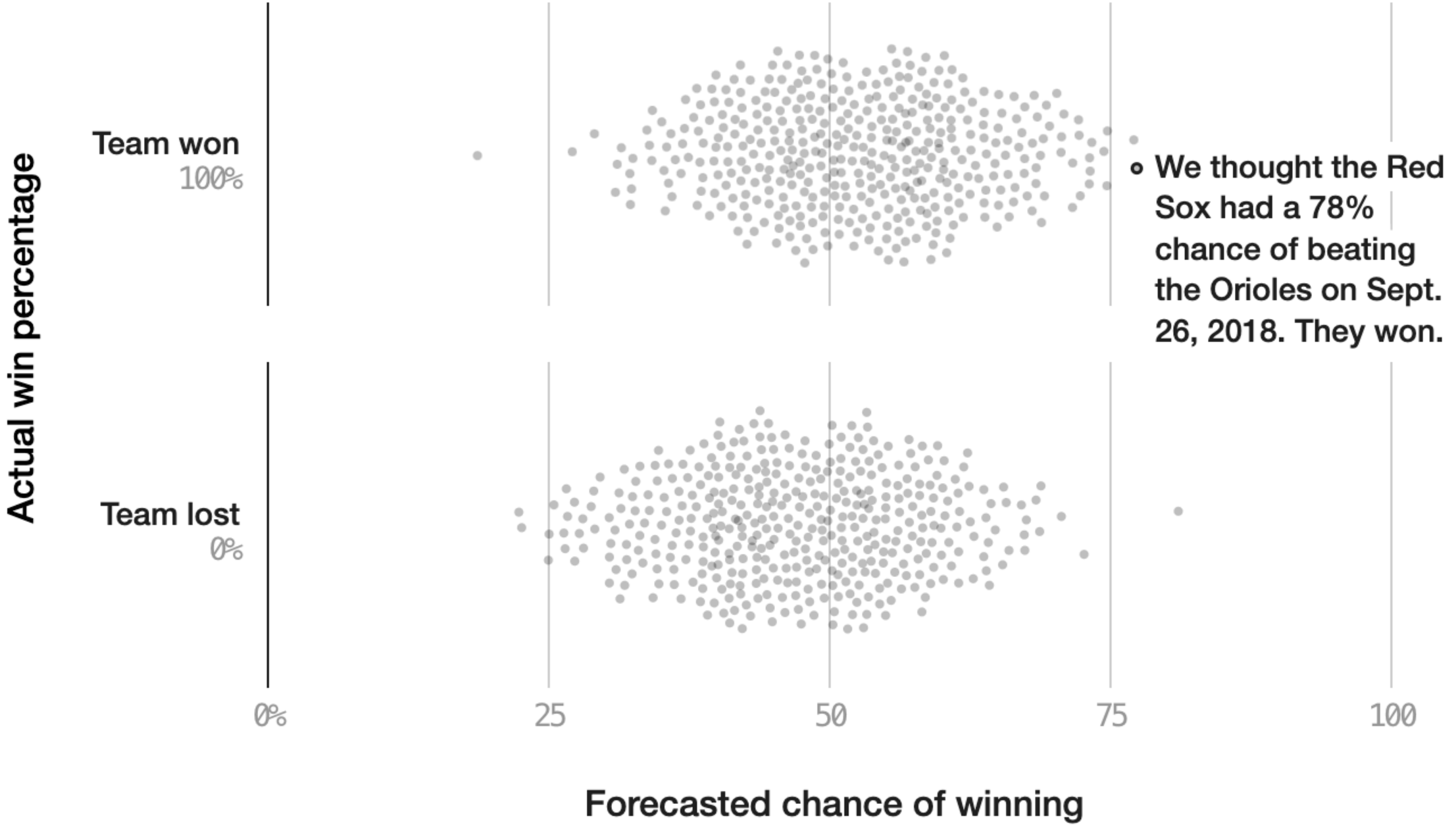


*El Salvador, Guatemala and Honduras †Using the Standardised Precipitation-Evapotranspiration Index three-month average

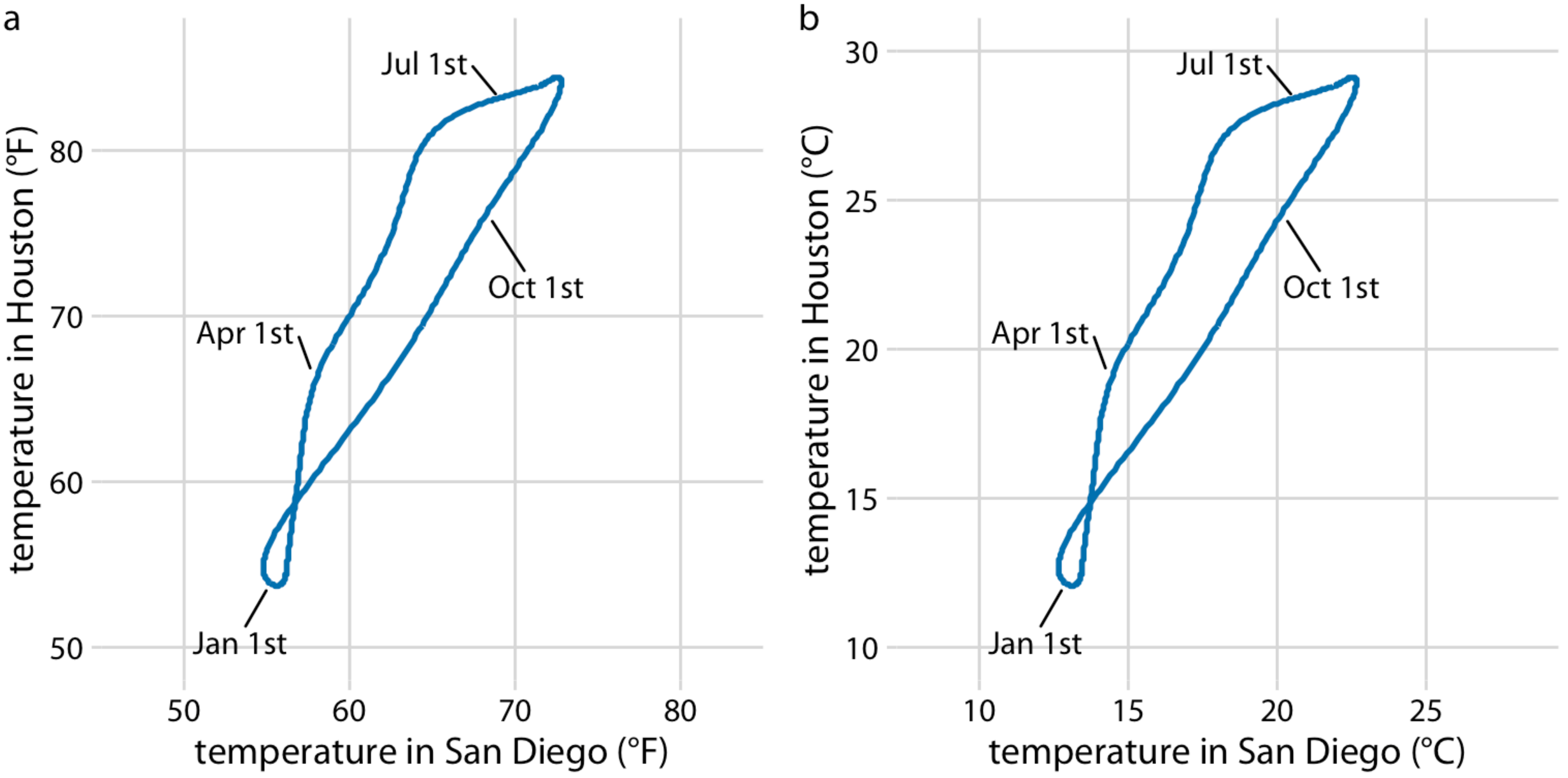
Source: "Dry growing seasons predicted Central American migration to the US from 2012 to 2018", by A. Linke et al., 2023

https://www.economist.com/graphic-detail/2023/11/17/why-central-americans-migrate-to-the-united-states-when-they-do

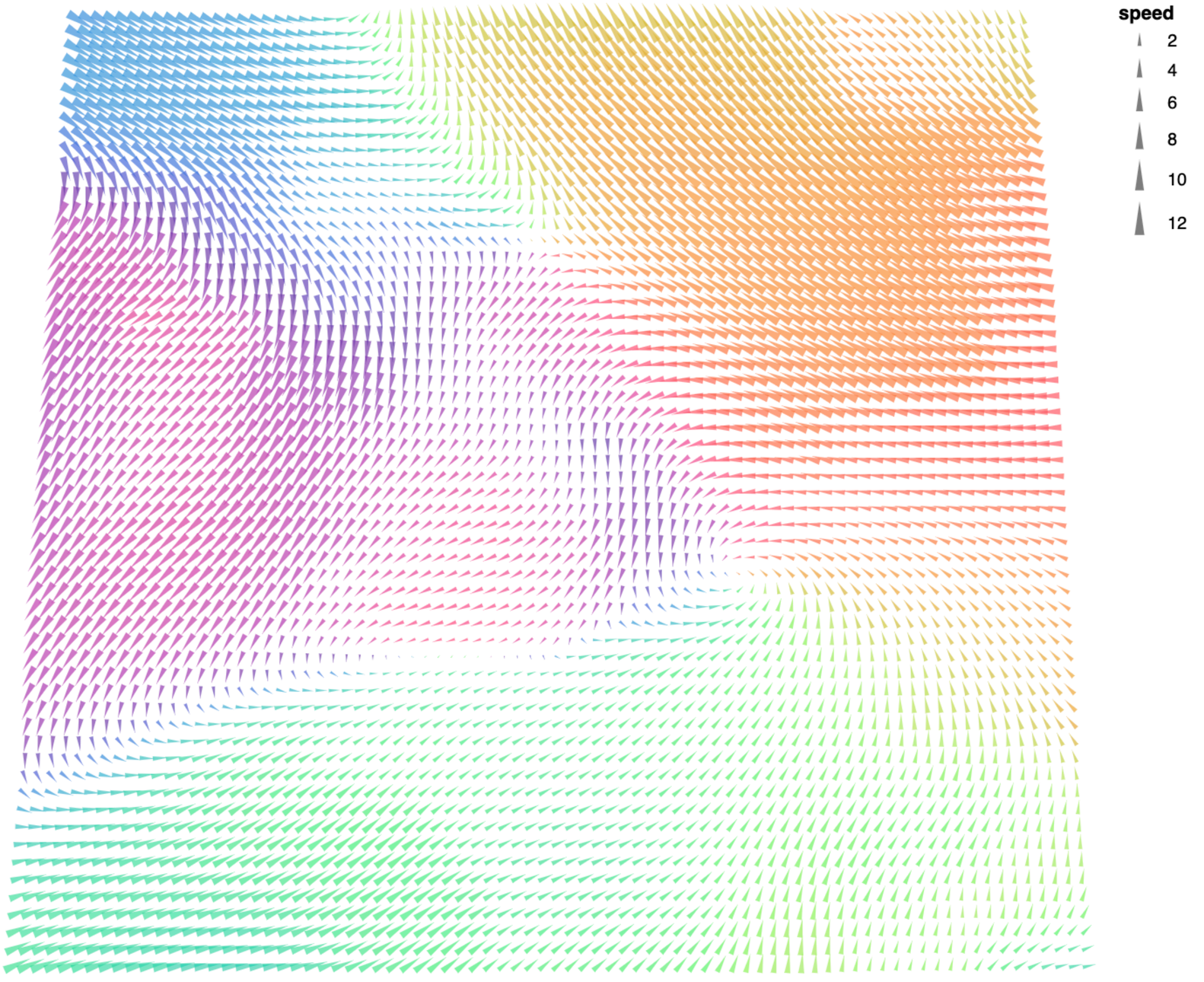
https://www.nature.com/articles/s41598-023-43668-9



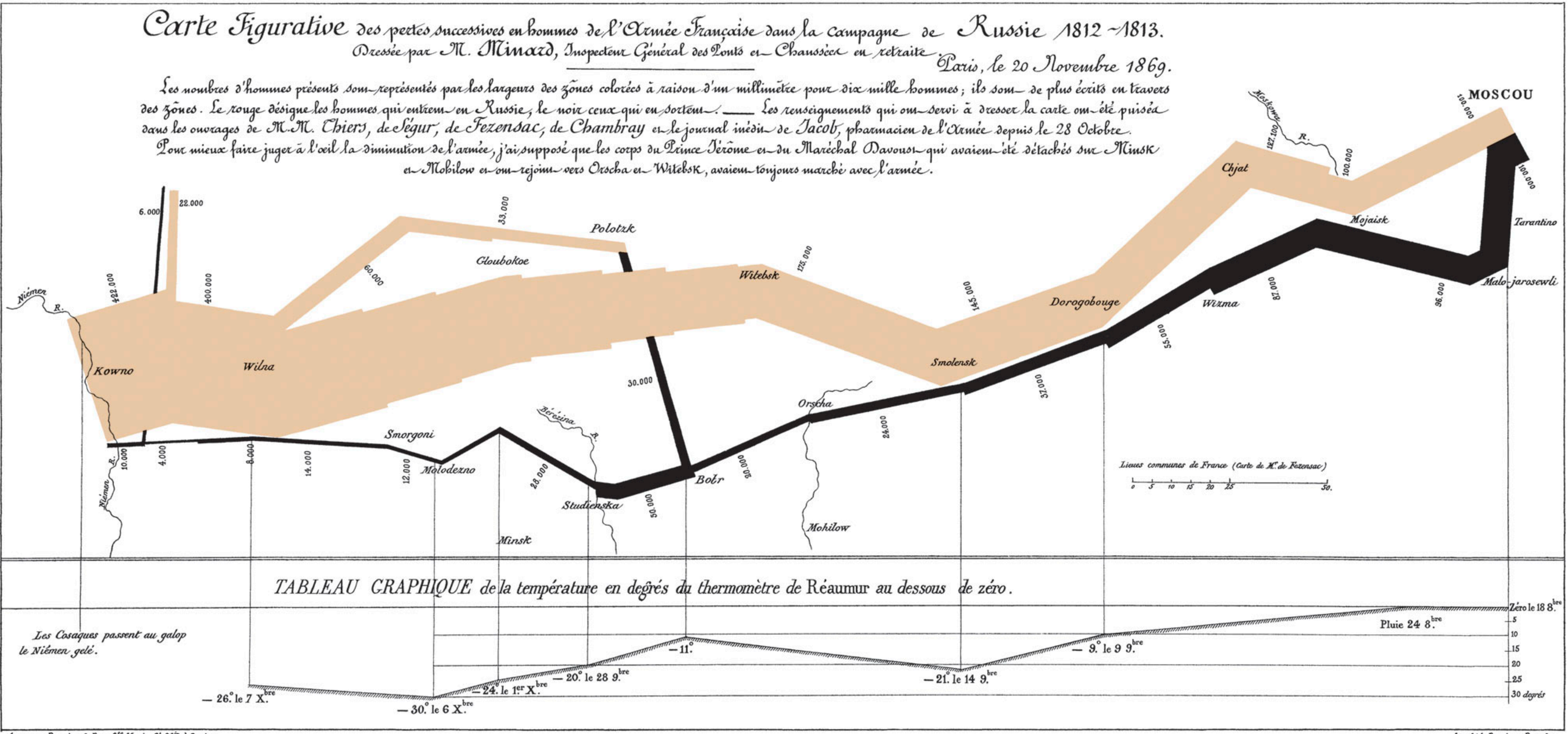
https://projects.fivethirtyeight.com/checking-our-work/



https://clauswilke.com/dataviz/coordinate-systems-axes.html#fig:temperature-normals-Houston-San-Diego



https://vega.github.io/vega-lite/examples/point_angle_windvector.html



[Charles Minard, 1869]

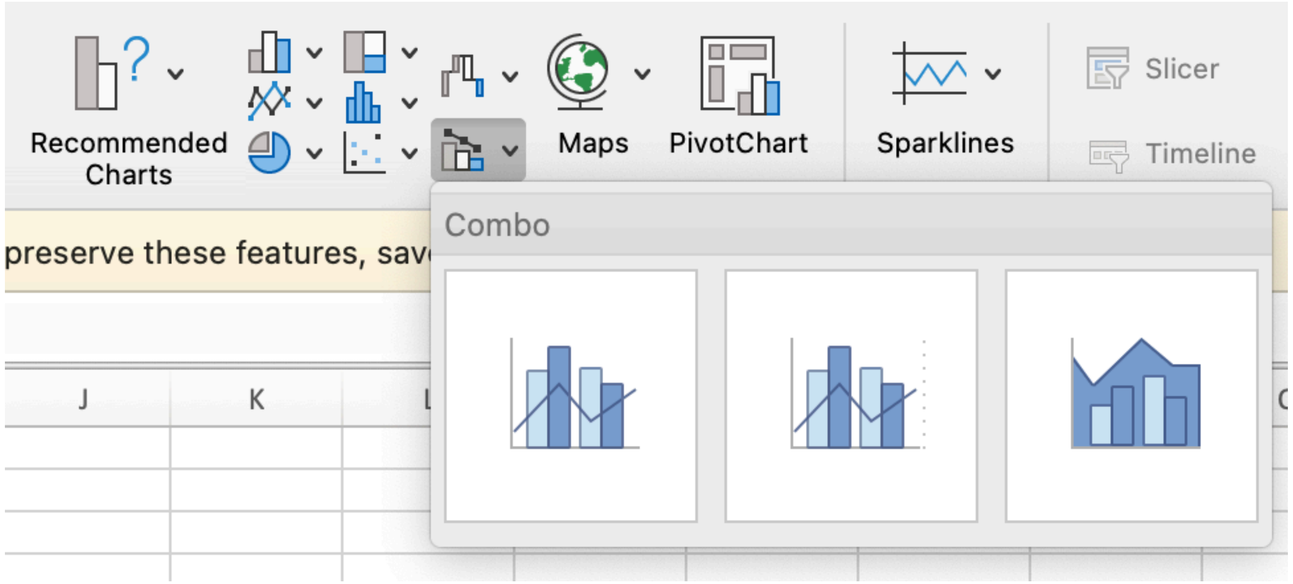

Recommended Charts
Maps
PivotChart
Sparklines
Slicer
Timeline
Combo
preserve these features, sav
J
K


Chart editor
Setup
Customize
Chart type
Pie chart
Line
Area
Column
Bar
Pie
Scatter
Map
Other

Visualizing Data

Physical Data Types

`int, float, string`

Graphical **Marks**

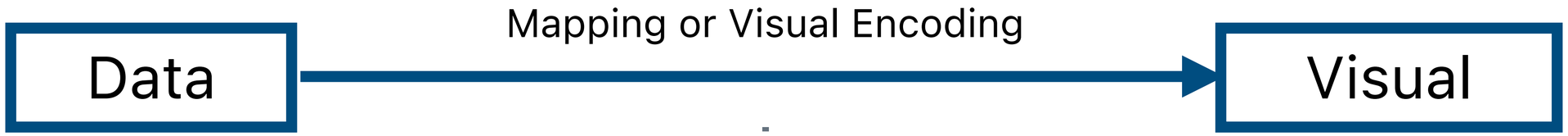
`rect, line, point, area`

Conceptual Data Types

`temperature, location`

Visual **Channels**

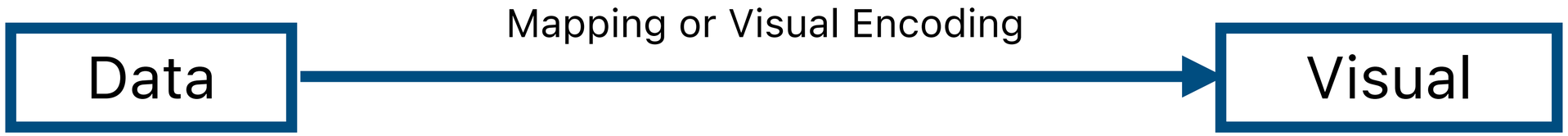
`x, y, color, opacity`



Expressiveness

A set of facts is *expressible* in a visual language if the sentences (i.e. the visualizations) in the language express all the facts in the set of data, and only the facts in the data.

Mackinlay, Jock. "Automating the design of graphical presentations of relational information." *Acm Transactions On Graphics (Tog)* 5.2 (1986): 110-141.

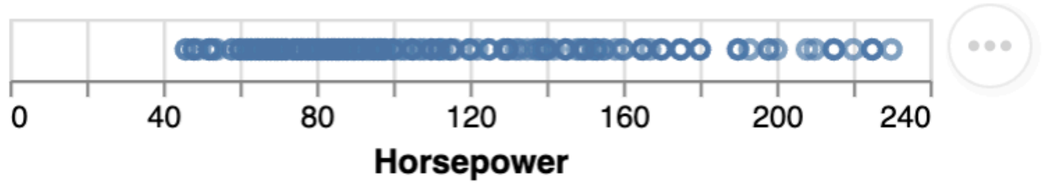


Expressiveness

Can't express the facts

A dataset with many variables may be *inexpressive* in a single horizontal dot plot because multiple records are mapped to the same position.

```
alt.Chart(source).mark_point().encode(
    x='Horsepower'
)
```



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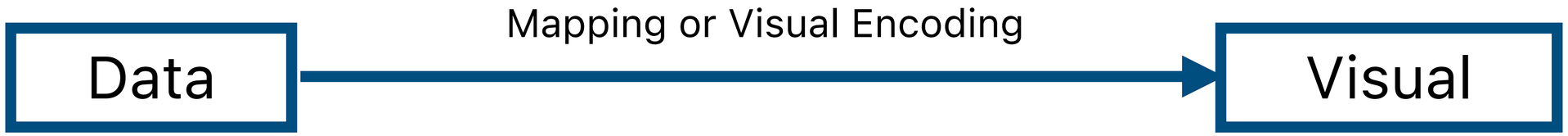
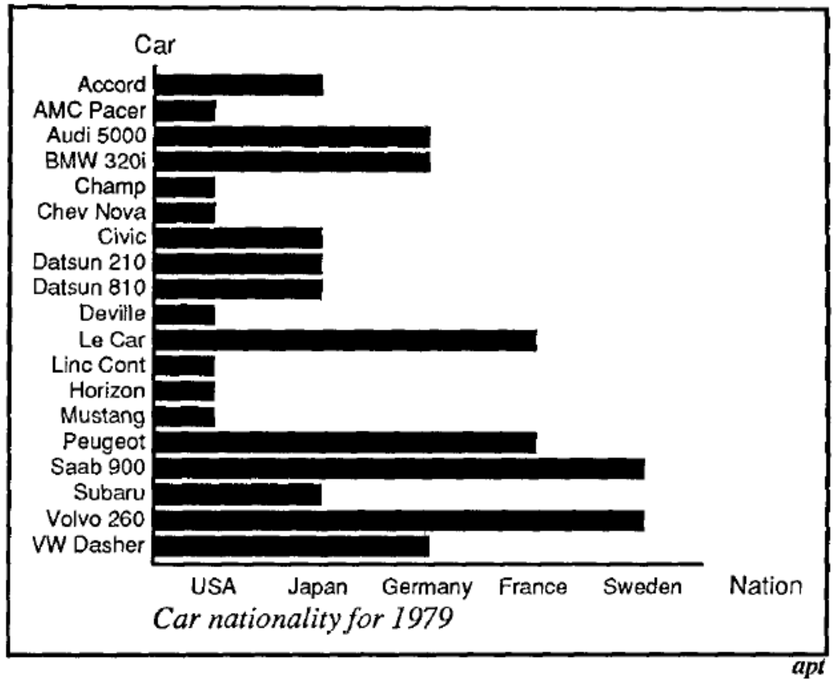
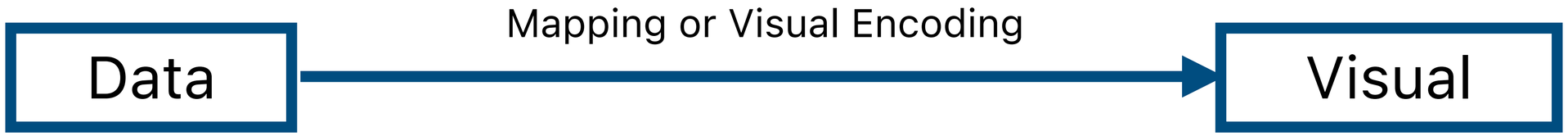


Expressiveness





Expressiveness

Expresses facts not in the data

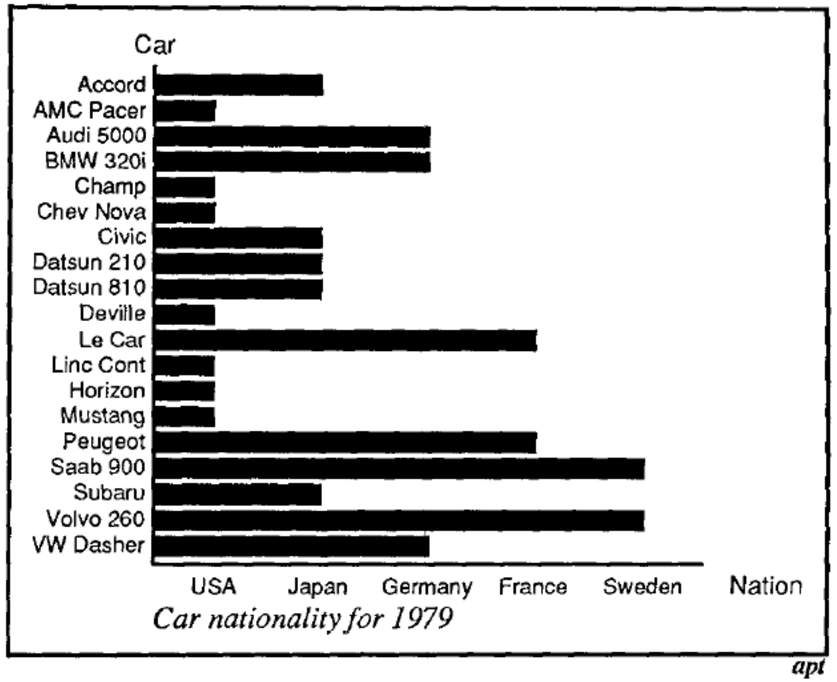
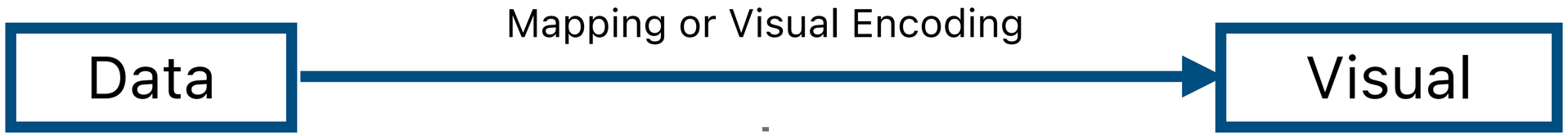


Fig. 11. Incorrect use of a bar chart for the *Nation* relation. The lengths of the bars suggest an ordering on the vertical axis, as if the USA cars were longer or better than the other cars, which is not true for the *Nation* relation.



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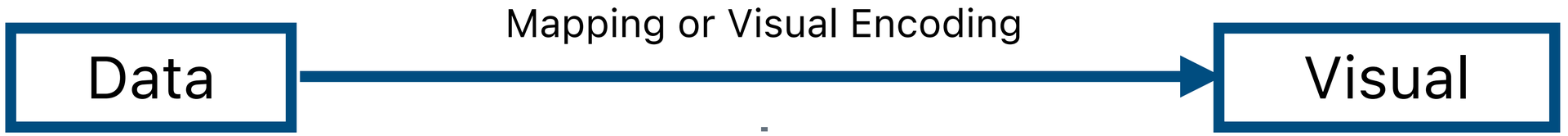

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Data models give us a way of talking about what the facts are.

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Data Models

Conceptual Models vs. Data Models

```
df = pd.read_csv('projects/proj01/weather.csv')
df
```

	city					sunshine	rain
0	San Diego				1	217	1.53
1	San Diego				2	255	0.15
2	San Diego	32.715736	-117.161087	Mar	3	234	0.57
3	San Diego	32.715736	-117.161087	Apr	4	236	1.01
4	San Diego	32.715736	-117.161087	May	5	277	0.02
...	...	...	...	...	...	...	...
67	Miami	25.761681	-80.191788	Aug	8	263	8.88
68	Miami	25.761681	-80.191788	Sep	9	216	9.86
69	Miami	25.761681	-80.191788	Oct	10	215	6.33
70	Miami	25.761681	-80.191788	Nov	11	212	3.27
71	Miami	25.761681	-80.191788	Dec	12	209	2.04

Conceptual Model: column represents hours of sunshine

Conceptual Models vs. Data Models

```
df = pd.read_csv('projects/proj01/weather.csv')
df
```

	city	lat	lon	month	monthnum	sunshine	rain
0	S				1	217	1.53
1	S				2	255	0.15
2	San Diego	32.715736	-117.161087		3	234	0.57
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Data Model:
column contains numbers

Higher level of abstraction!

Dataset Types

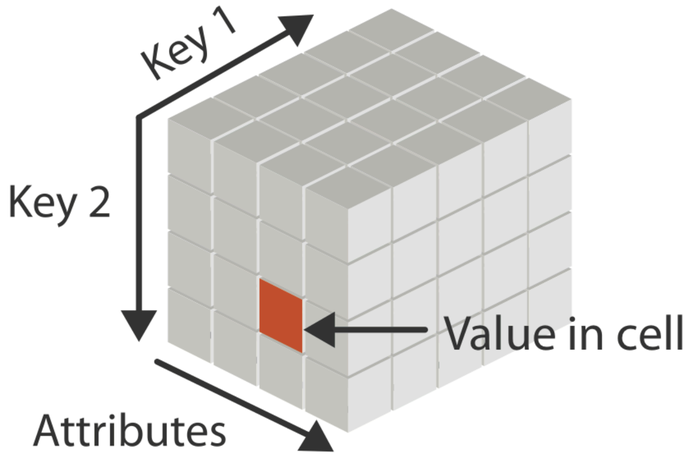
1. Tabular

columns/attributes/ variables

rows/records/items

	A	B	C	D	E	F
1	**EmployerName**	**Address**	**DiffMeanHourlyPercent**	**DiffMeanBonusPercent**	**MaleBonusPercent**	**FemaleBonusPercent**
2	1ST CHOICE STAFF RECRUITMENT LIMITED	8, St. Loyes Street, Bedford, MK40 1EP	-4.5	206.9	2	1
3	23.5 DEGREES LIMITED	Charles Watts Way, Hedge End, Southampton,	10	79	4	3
4	A. & B. GLASS COMPANY LIMITED	Chilton Industrial Estate, Sudbury, Suffolk,	15	85	61	32
5	ABACUS HOTELS LIMITED	20 Station Street, Swaffham, Norfolk,	37.8	-6.6	19.2	16.2
6	Abbeyfield Wales Society	24 Gold Tops, Newport, NP20 4PG	21.9	0	0	0
7	ABERDEEN JOURNALS LIMITED	Mastrick, Aberdeen, United Kingdom,	15.7	44.7	17.1	39.7
8	ACCESSIBLE TRANSPORT GROUP CONTRACT SERVICES LIMITED	Birmingham, West Midlands, United Kingdom,		0	0	0
9	ACEGOLD LIMITED	Norcliffe House, Station Road, Wilmslow, SK9 1BU	-5.1	0	0	0
10	Acorns Children's Hospice Trust	Wythall, Birmingham, United Kingdom,	11.2	0	0	0
11	AD Astra Academy Trust	Davison Drive, Hartlepool, Cleveland,	9.5	0	0	0
12	ADAPT BUSINESS SERVICES LIMITED	Drive, Gorseinon, Swansea, SA4 4QN	3.3	0	0	0
13	ADARE INTERNATIONAL LIMITED	Two Colton Square, Leicester, England,	18.8	71.3	11.6	10.5

cell containing value



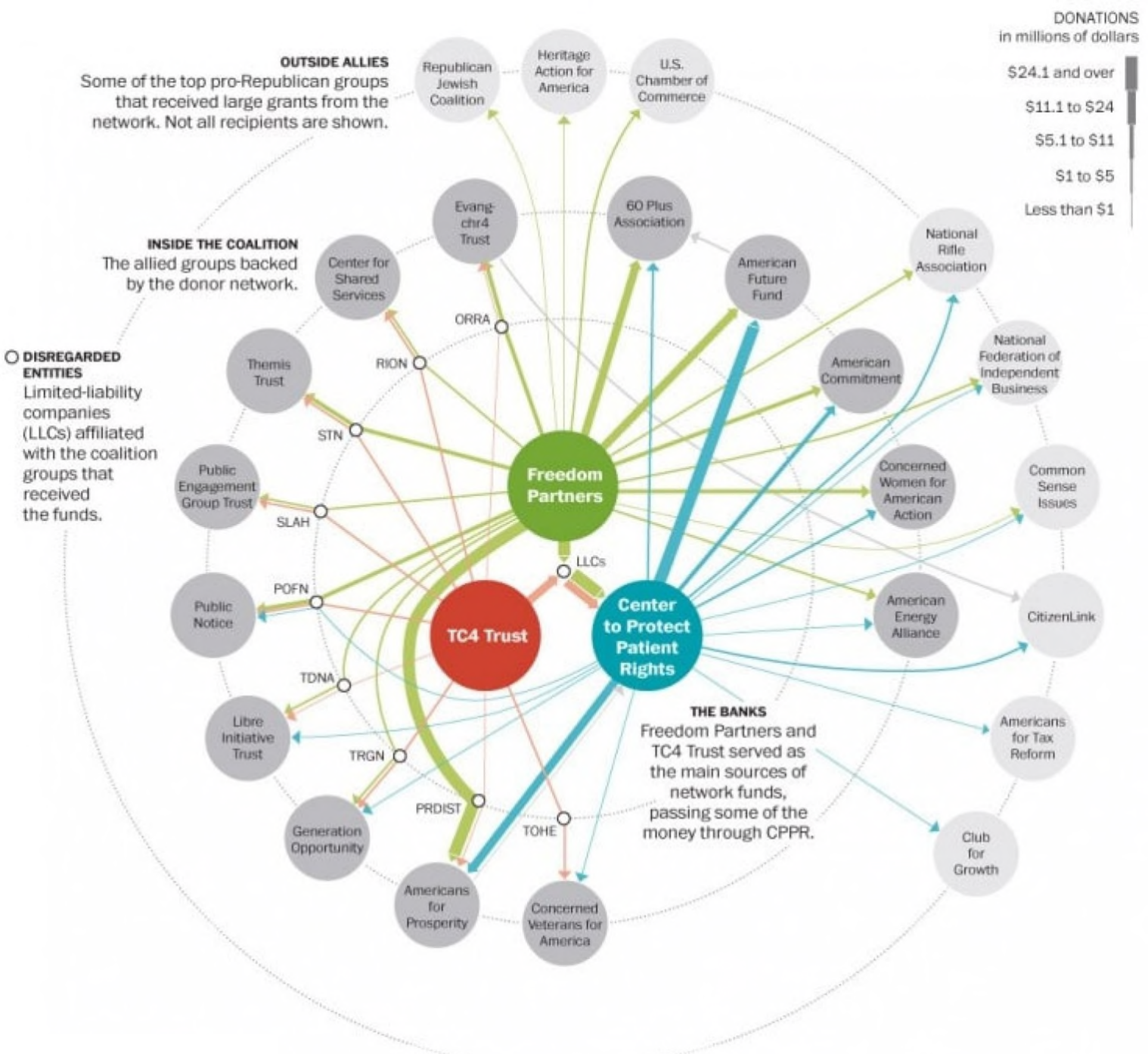
Tamara Munzner, *Visualization Analysis and Design* (2014).

Dataset Types

1. Tabular:
   collection of records with named attributes

2. Network:
   Nodes and links can also have attributes (e.g., size of nodes, thickness/directionality of links).

   Trees are special networks where each node has only one parent.



https://www.washingtonpost.com/politics/inside-the-koch-backed-political-donor-network/2014/01/05/94719296-7661-11e3-b1c5-739e63e9c9a7_graphic.html

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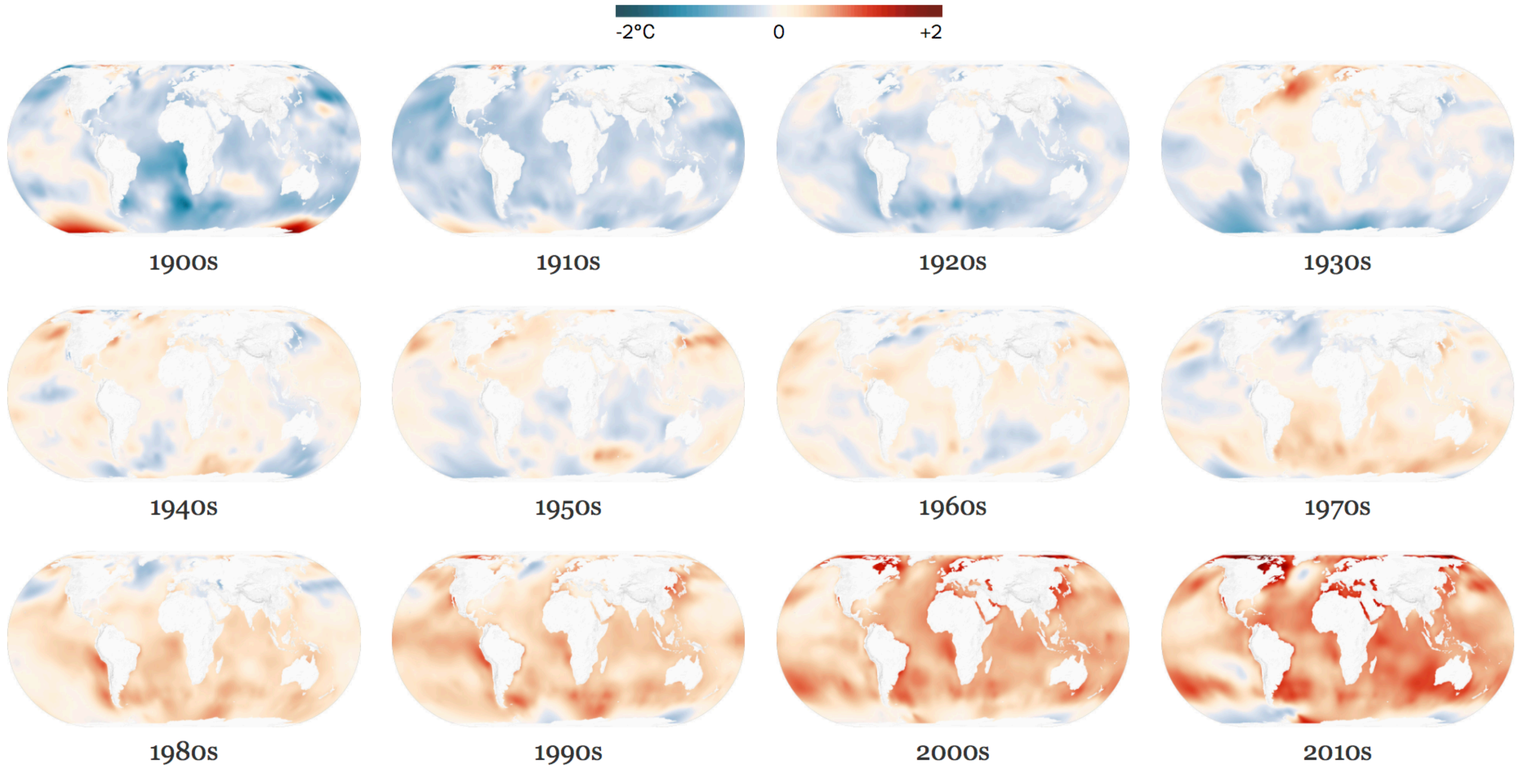
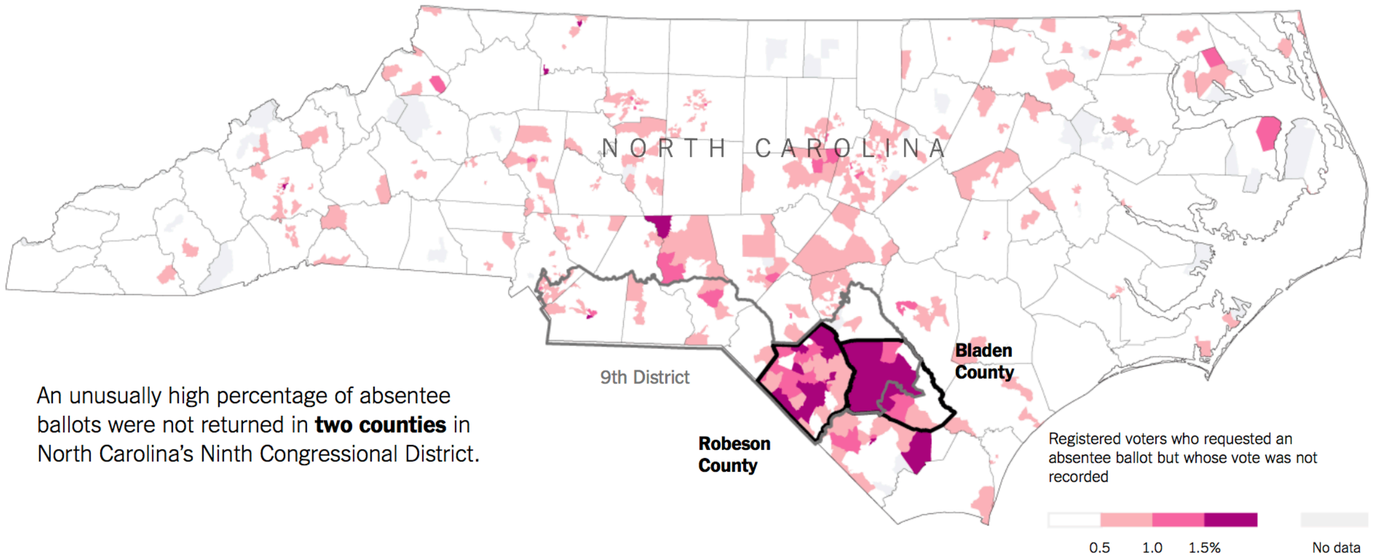
3. Spatial:
   Continuous "fields" vs discrete "positions"



https://www.nytimes.com/interactive/2016/09/12/science/earth/ocean-warming-climate-change.html



https://www.nytimes.com/2018/12/07/upshot/mapped-why-voting-anomalies-are-impossible-to-ignore-in-north-carolina.html

Attribute / Data Types

Nominal **=, ≠**	Labels or categories. E.g., Fruits: apples, bananas, cantaloupes, ...
Ordinal =, ≠, **<, >**	Ordered. E.g., Quality of eggs: Grade AA, A, B
Quantitative (Interval) =, ≠, <, >, **−**	Interval (zero can be arbitrarily located). E.g., Dates: Jan 19, 2018; Location: (Lat 42.36, -71.09) Only differences can be calculated (e.g., distances or spans).
Quantitative (Ratio) =, ≠, <, >, −, **%**	Ratio (fixed zero / meaningful baseline). E.g., Physical measurement: length, mass, temperature Counts and amounts. Can measure ratios or proportions.

Data Models

Physical Model
32.5, 54.0, -17.3, ...
Floating point numbers

Attribute Type
Burned vs. Not-Burned (N)
Hot, Warm, Cold (O)
Temperature Value (Q)

Conceptual Model
Temperature (°C)

Activity: U.S. Census

What are the types of these attributes?
(N, O, Q-interval, or Q-ratio)

People Count: # of people in group

Year: 1850 – 2000 (every decade)

Age: 0 – 90+

Sex: Male, Female

Marital Status: Single, Married, Divorced, ...

	A	B	C	D	E
1	year	age	marst	sex	people
2	1850	0	0	1	1483789
3	1850	0	0	2	1450376
4	1850	5	0	1	1411067
5	1850	5	0	2	1359668
6	1850	10	0	1	1260099
7	1850	10	0	2	1216114
8	1850	15	0	1	1077133
9	1850	15	0	2	1110619
10	1850	20	0	1	1017281
11	1850	20	0	2	1003841
12	1850	25	0	1	862547
13	1850	25	0	2	799482
14	1850	30	0	1	730638
15	1850	30	0	2	639636
16	1850	35	0	1	588487
17	1850	35	0	2	505012
18	1850	40	0	1	475911
19	1850	40	0	2	428185
20					211
21	1850	45	0	2	341254
22	1850	50	0	1	321348

Think on your own for 1 minute

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What are the types of these attributes?

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1	year	age	marst	sex	people
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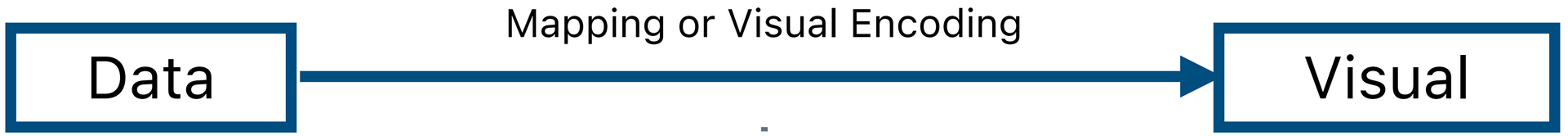
9	1850	15	0	2	1110619
10	1850	20	0	1	1017281
11	1850	20	0	2	1003841
12	1850	25	0	1	862547
13	1850	25	0	2	799482
14	1850	30	0	1	730638
15	1850	30	0	2	639636
16	1850	35	0	1	588487
17	1850	35	0	2	505012
18	1850	40			11
19	1850	40			85
20	1850	45			11
21	1850	45	0	2	341254

tryclassbuzz.com: **census**



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Data models give us a way of talking about what the facts are.

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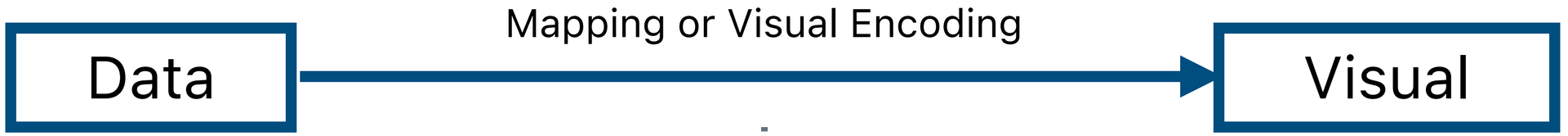

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Effectiveness

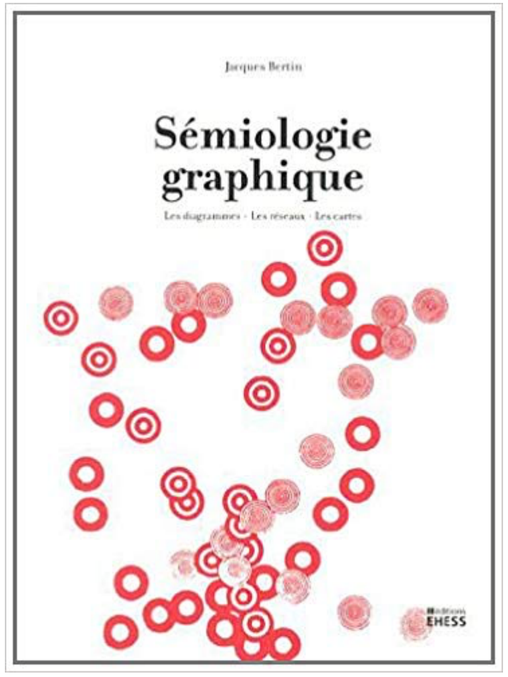
A visualization is more *effective* than another if the information it conveys *is more readily perceived* than the information in the other visualization

Image models give us a way of talking about what is more readily perceived.

Mackinlay, Jock. "Automating the design of graphical presentations of relational information." *Acm Transactions On Graphics (Tog)* 5.2 (1986): 110-141.

Image Models

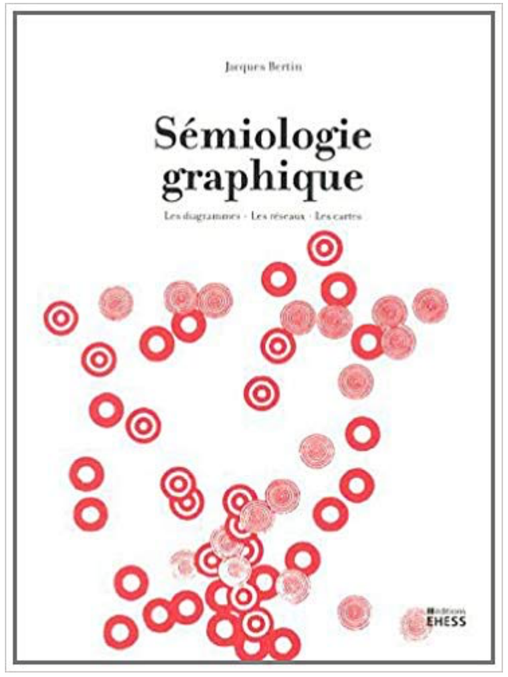
The Semiology of Graphics (1967)



Jacques Bertin (1918 – 2010)
French cartographer

The Semiology of Graphics (1967)

Study of signs and how cultures use them.



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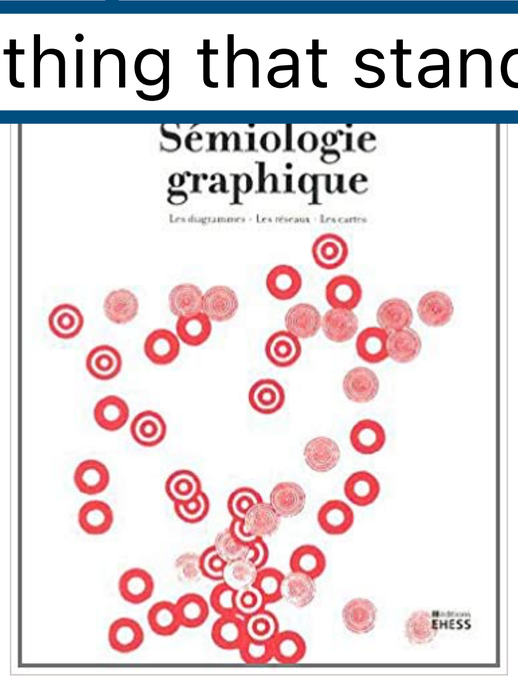
The Semiology of Graphics (1967)

Study of signs and how cultures use them.

Anything that stands for something other than itself.

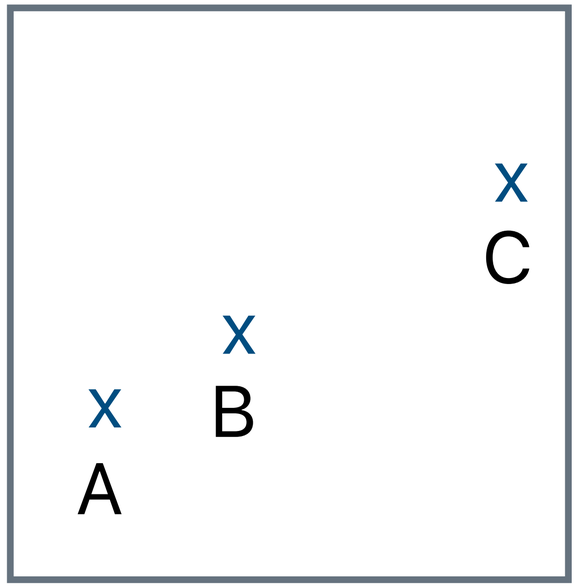


"Metal painted red"?

or

"Hit the brakes!"

Jacques Bertin (1918 – 2010)
French cartographer



What do these signs signify?

1. A, B, C are distinguishable.
2. B is between A and C.
3. BC is twice as long as AB.

"Resemblance, order, and proportion are the three signfields in graphics."

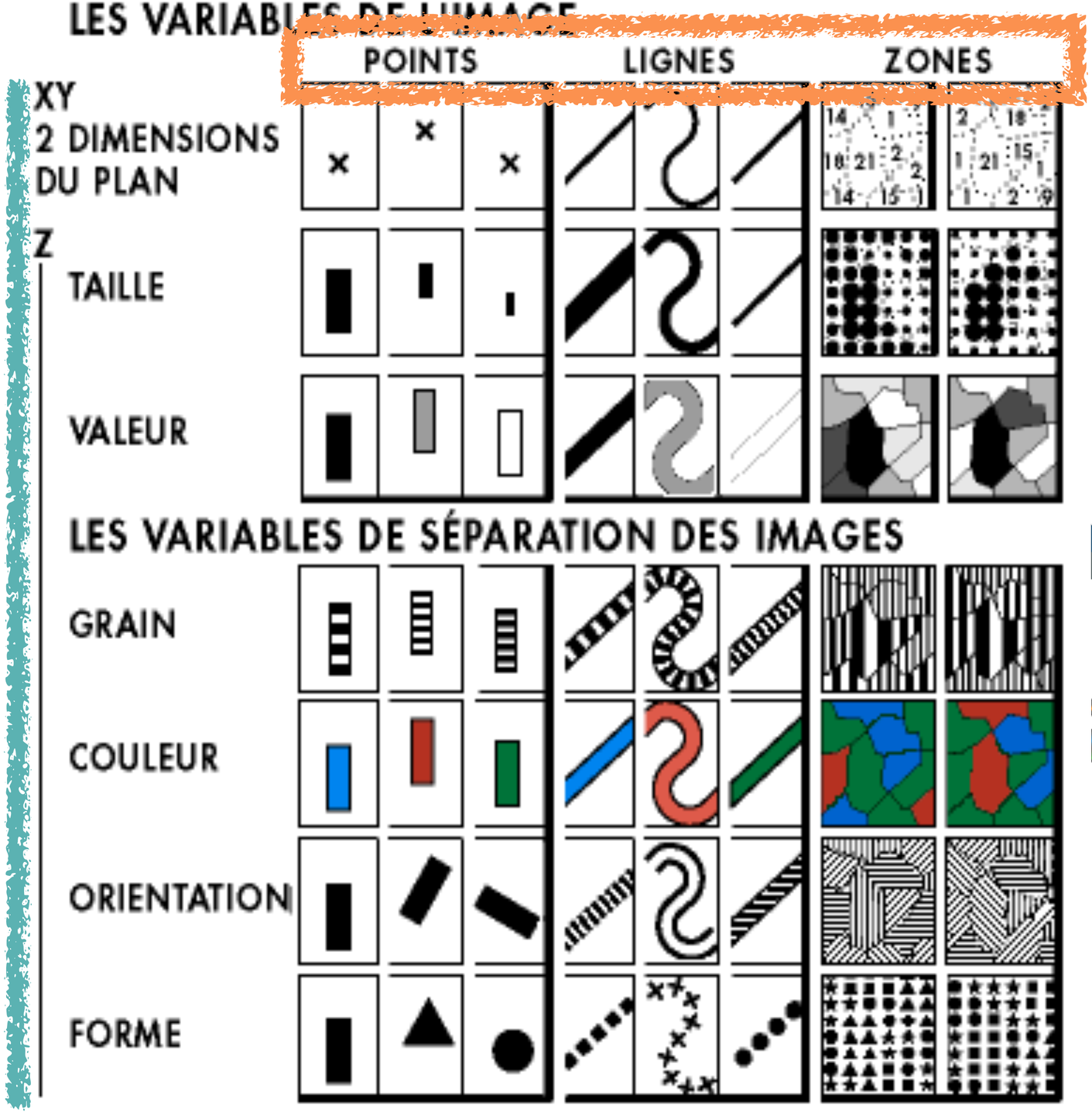
–Bertin

Visual Variables

Also called visual *channels*.

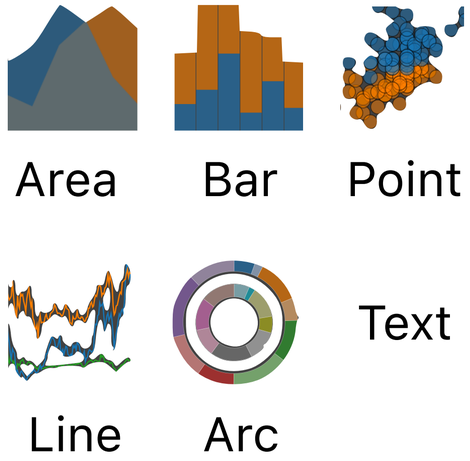
Used to encode data values as characteristics of marks.

** From 1967, so Bertin only accounted for visualizations that were printable on white paper.*



Marks

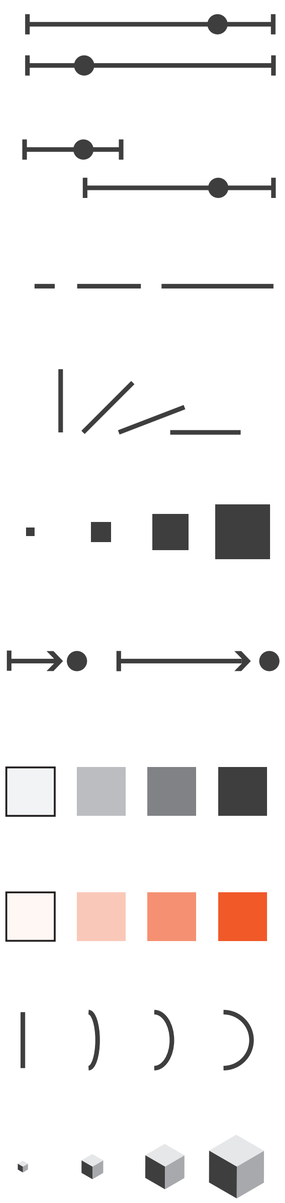
Basic graphical elements that represent data items.



Channels: Expressiveness Types and Effectiveness Ranks

Magnitude Channels: Ordered Attributes

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)



Most

Effectiveness

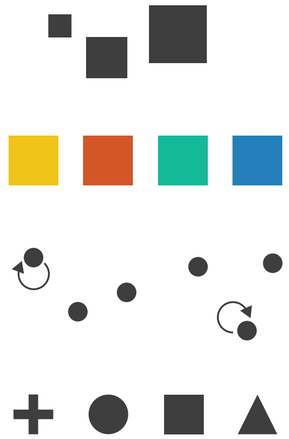
Least

Same

Same

Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape



Tamara Munzner, *Visualization Analysis and Design* (2014).

Channels: Expressiveness Types and Effectiveness Ranks

Magnitude Channels: Ordered Attributes

Position on common scale

Position on unaligned scale

Color saturation

Curvature

Volume (3D size)

Most

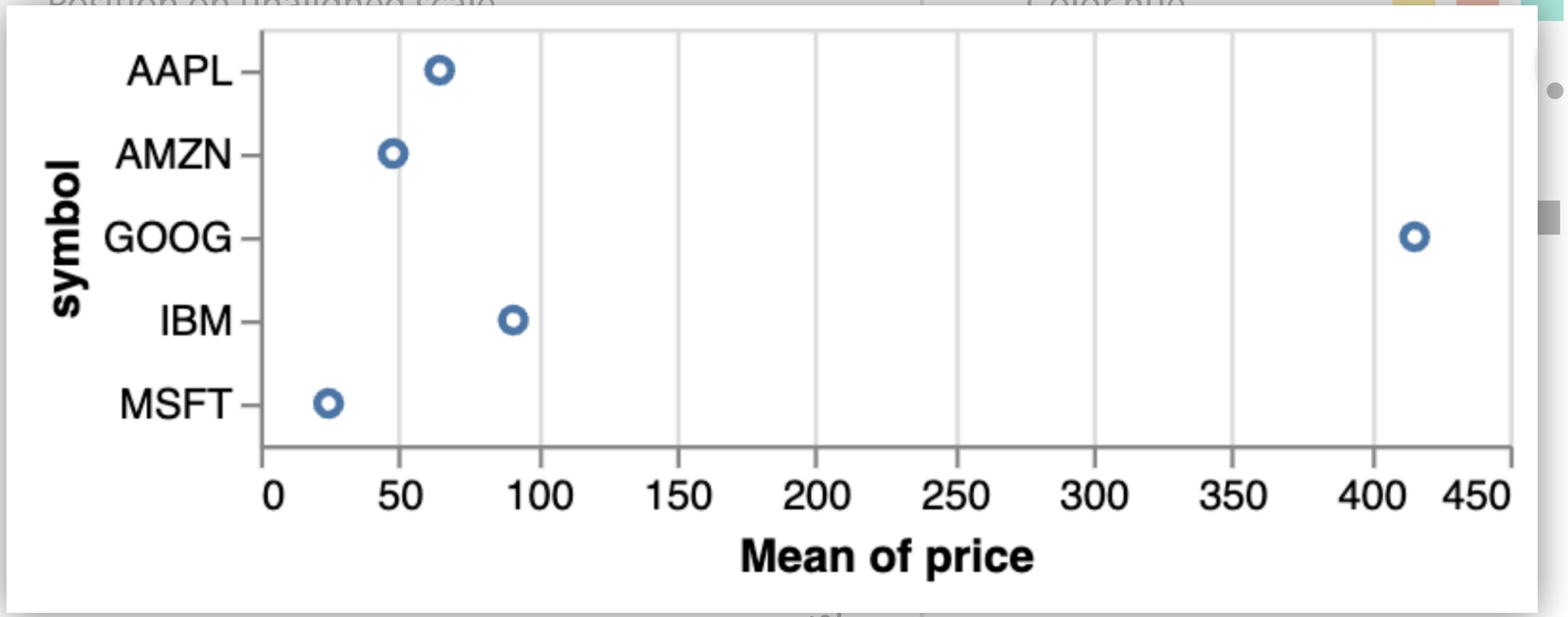
Same

Least

Identity Channels: Categorical Attributes

Spatial region

Color hue



Perceive dot positions on common x-axis scale

Tamara Munzner, *Visualization Analysis and Design* (2014).

Channels: Expressiveness Types and Effectiveness Ranks

Magnitude Channels: Ordered Attributes

Position on common scale

Position on unaligned scale

Length (1D size)

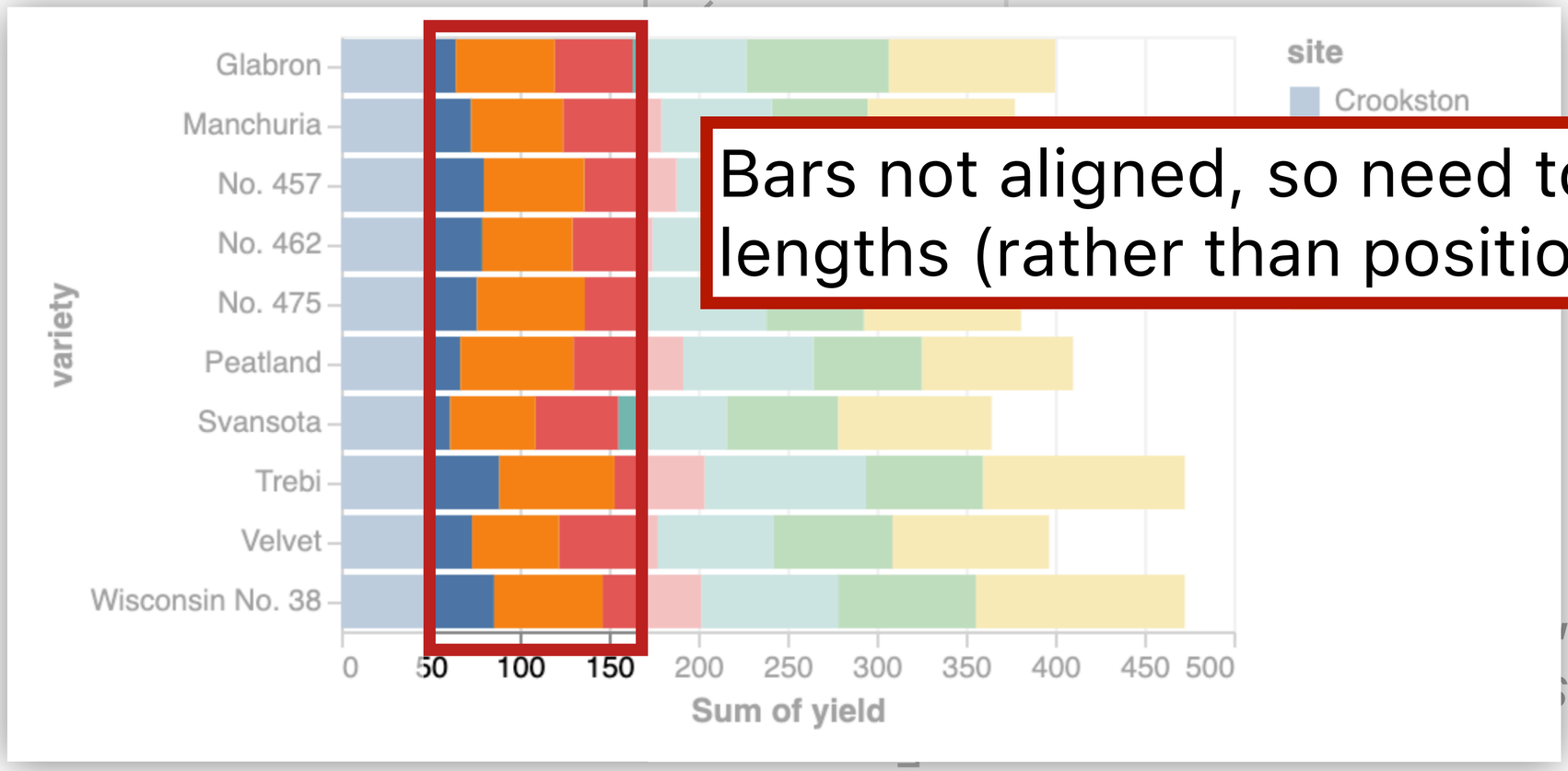
Most

Identity Channels: Categorical Attributes

Spatial region

Color hue

Motion

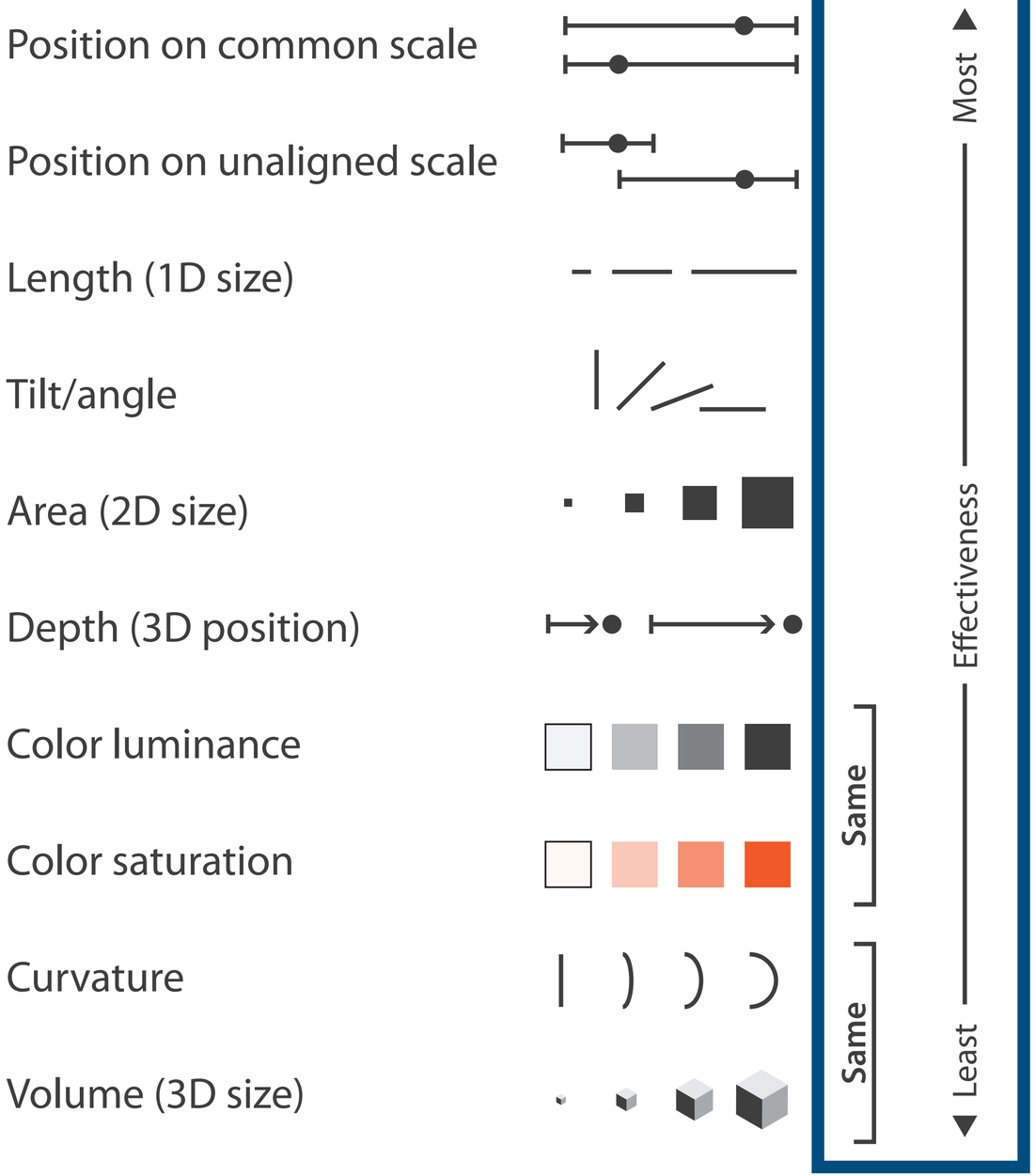


Bars not aligned, so need to compare lengths (rather than position)

Visualization (2014).

Channels: Expressiveness Types and Effectiveness Ranks

Magnitude Channels: Ordered Attributes



Identity Channels: Categorical Attributes

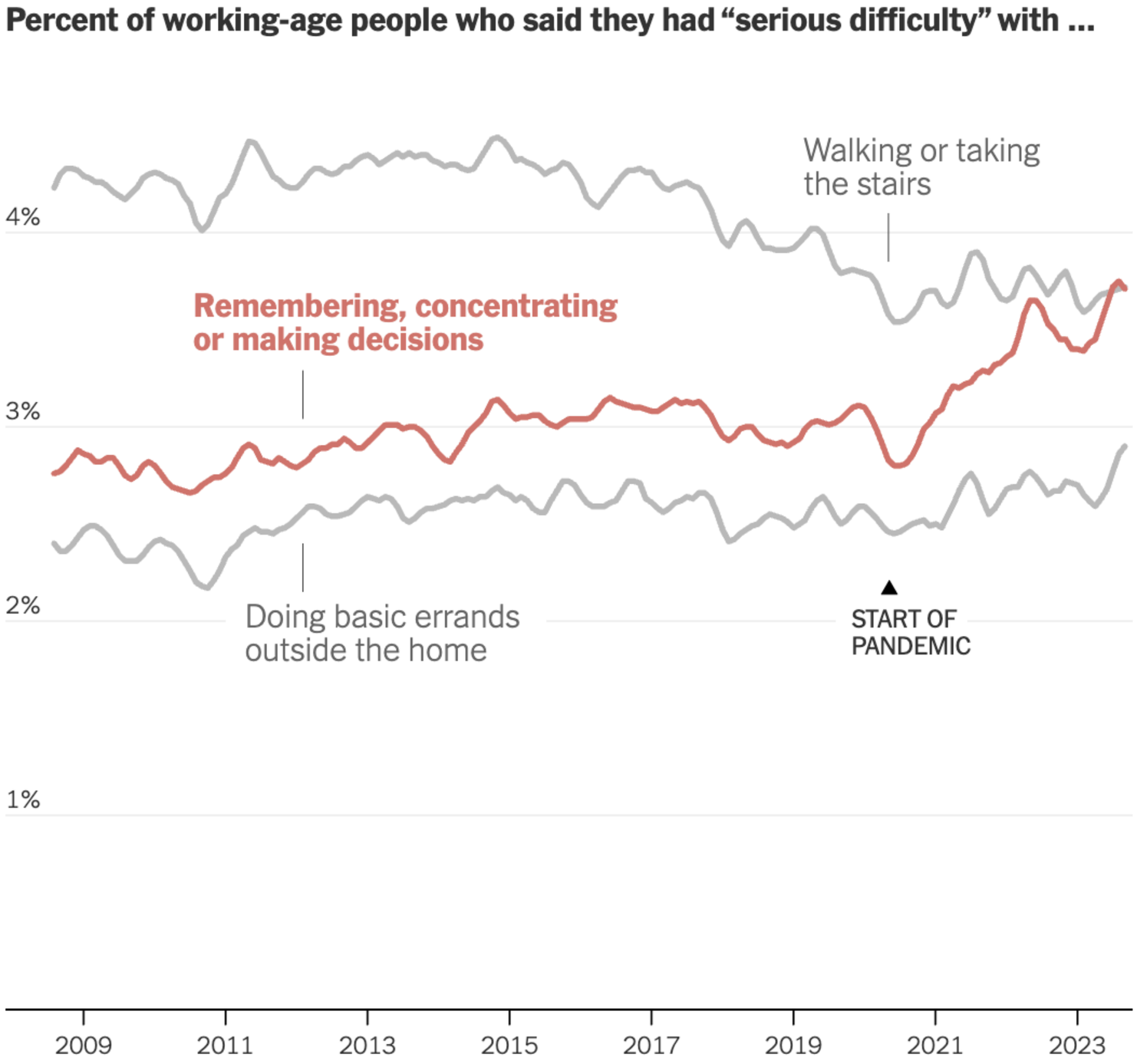
Most effective to least effective

Top of scale = easiest for people to make accurate comparisons

Tamara Munzner, *Visualization Analysis and Design* (2014).

Name that ~~chart!~~

Visual Encoding!

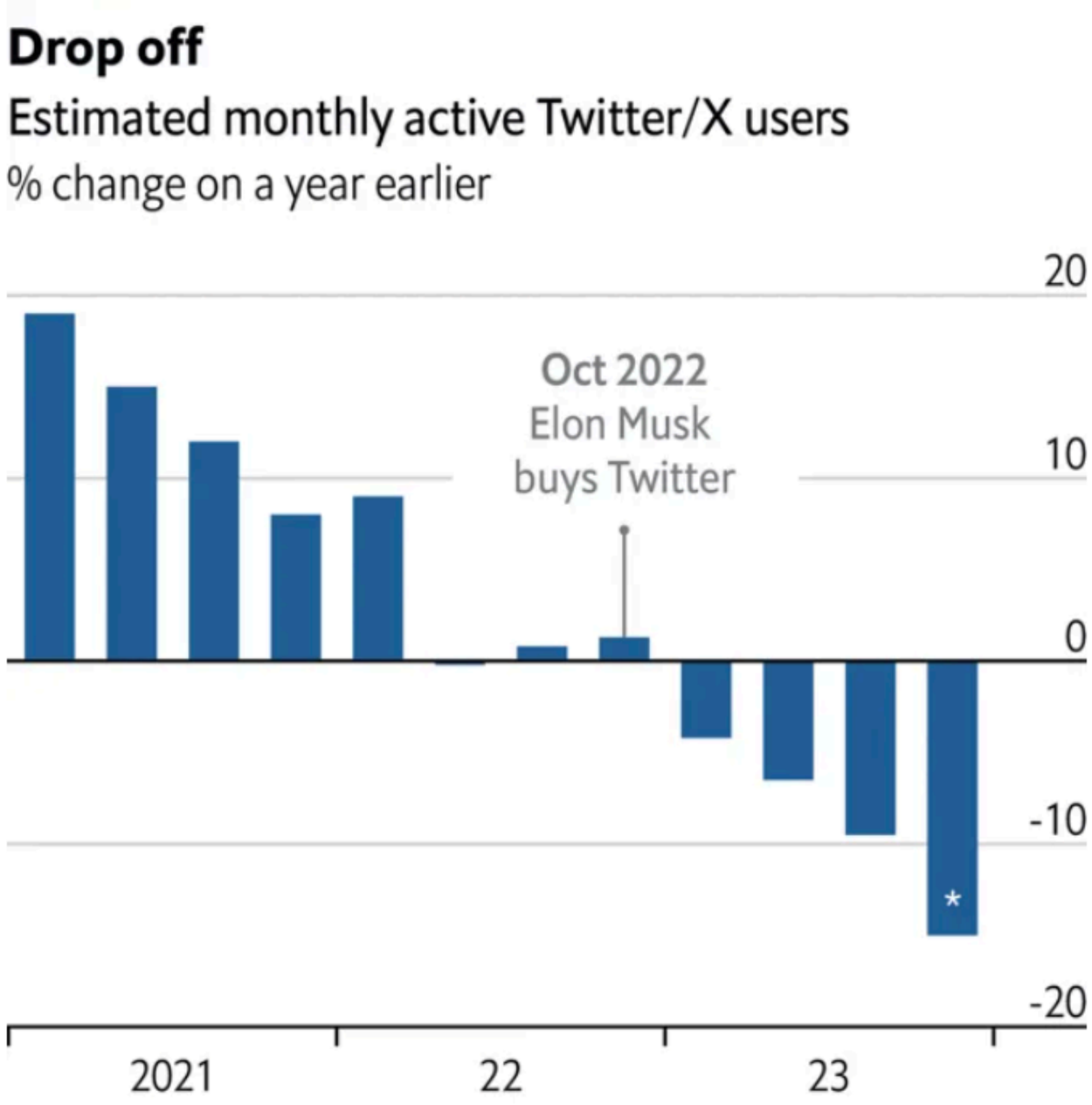


Mark: `line`

X-axis: `date` (Q-interval)
Y-axis: `percent` (Q-ratio)

What about color?

https://www.nytimes.com/2024/01/10/upshot/covid-pandemic-wave.html



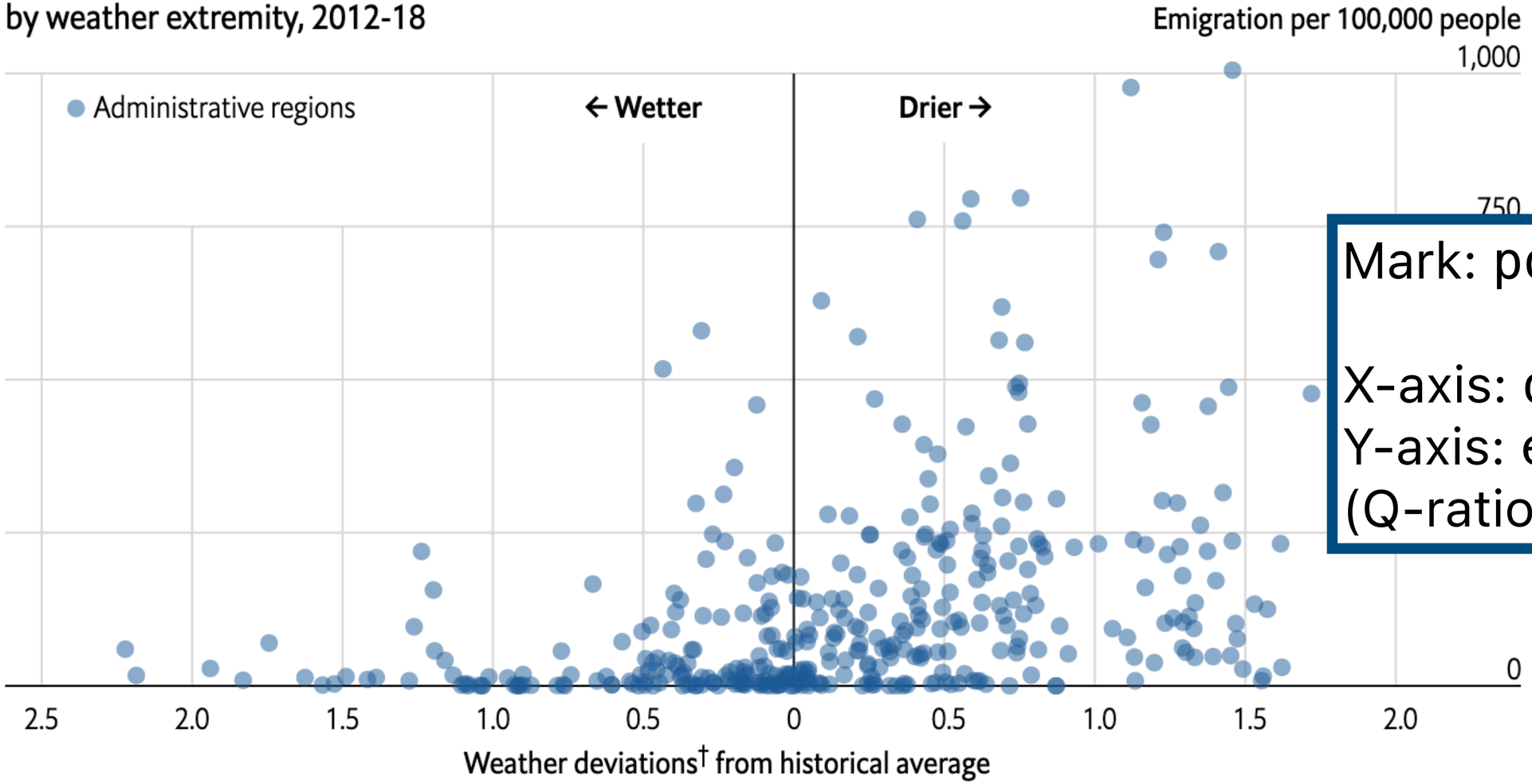
Mark: `bar`

X-axis: `date` (Q-interval)
Y-axis: `percent` (Q-ratio)

https://www.economist.com/graphic-detail/2023/12/20/has-twitter-now-x-become-more-right-wing

Spotting a trend

Emigration from the Northern Triangle* to United States, by weather extremity, 2012-18



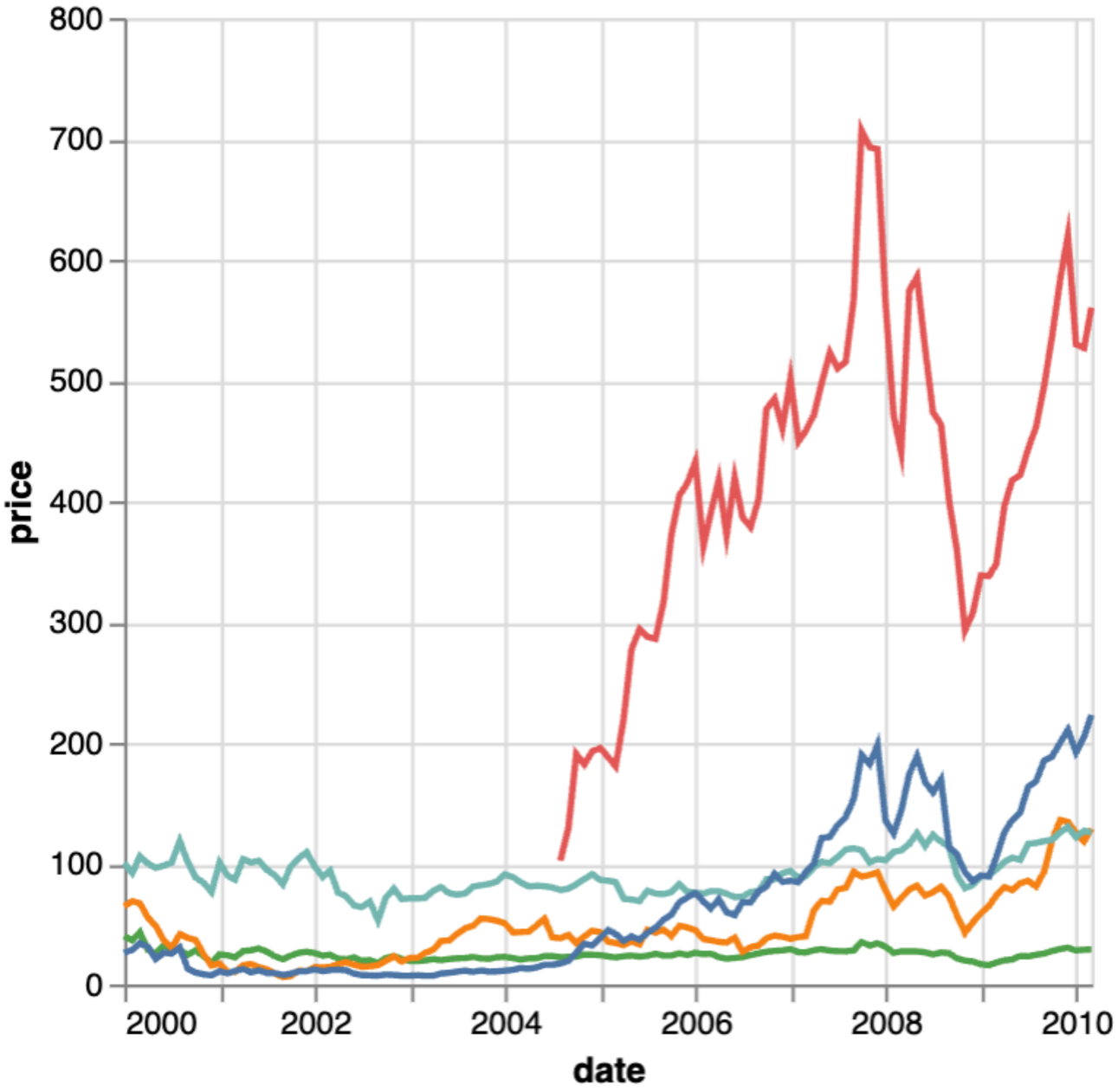
Mark: `point`

X-axis: `dev` (Q-ratio)
Y-axis: `emigration` (Q-ratio)

*El Salvador, Guatemala and Honduras †Using the Standardised Precipitation-Evapotranspiration Index three-month average

Source: "Dry growing seasons predicted Central American migration to the US from 2012 to 2018", by A. Linke et al., 2023

https://www.economist.com/graphic-detail/2023/11/17/why-central-americans-migrate-to-the-united-states-when-they-do https://www.nature.com/articles/s41598-023-43668-9

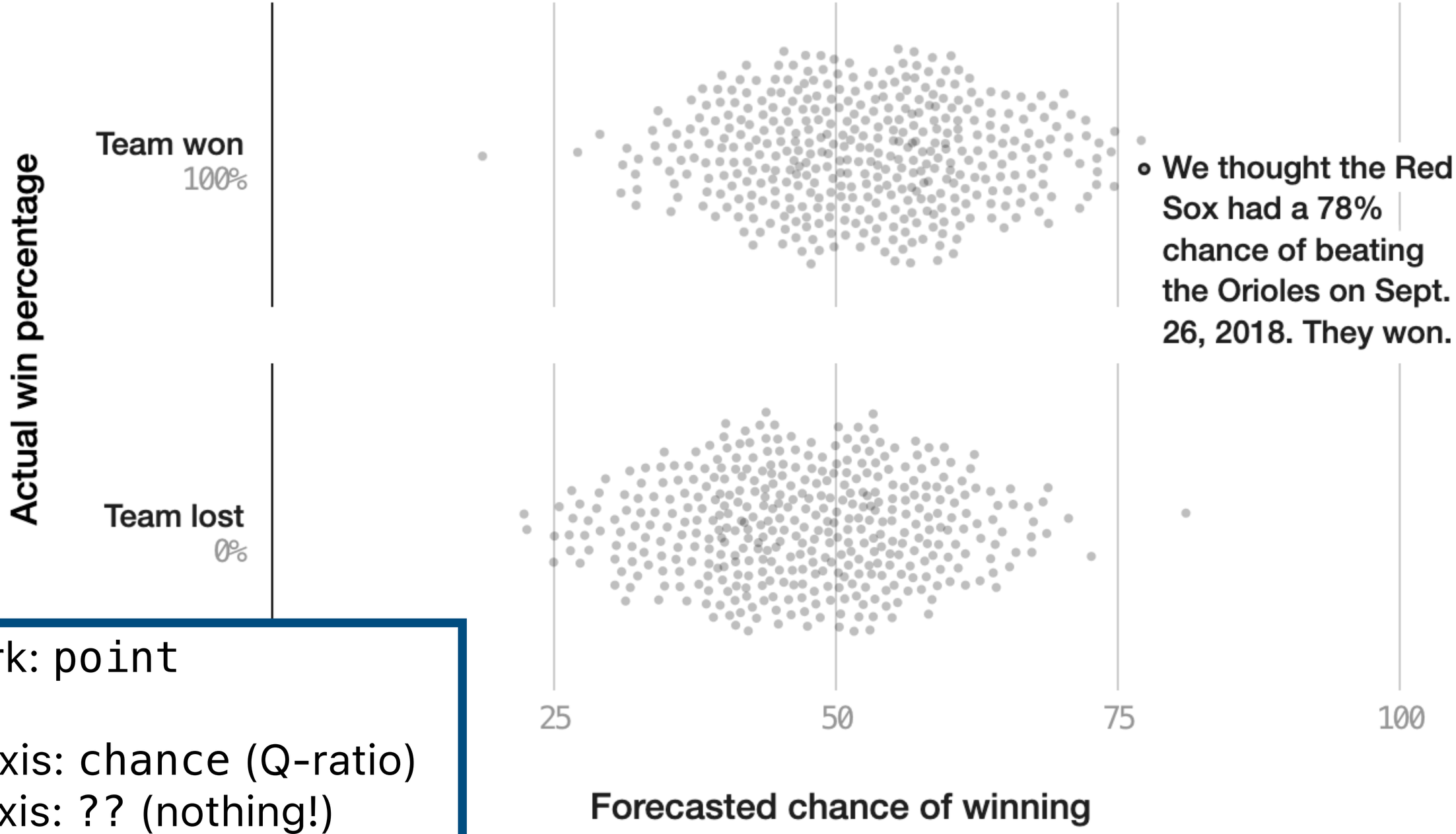


Mark: `line`

X-axis: `date` (Q-interval)
Y-axis: `price` (Q-ratio)
Color: `symbol` (N)

Notice the parallel with plotly express syntax!

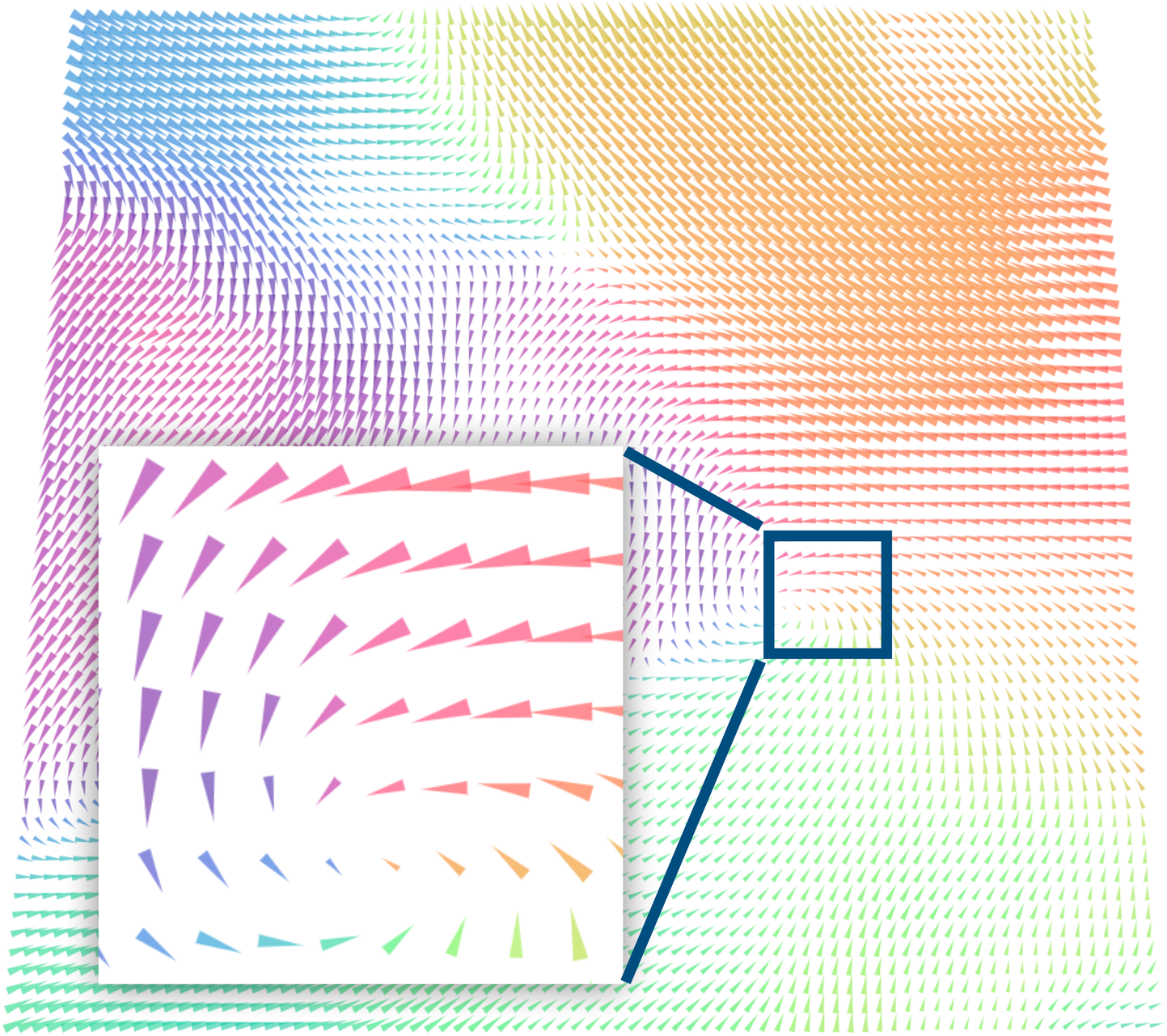
```
px.line(
    stocks_df,
    x='date',
    y='price',
    color='symbol',
)
```



Mark: `point`

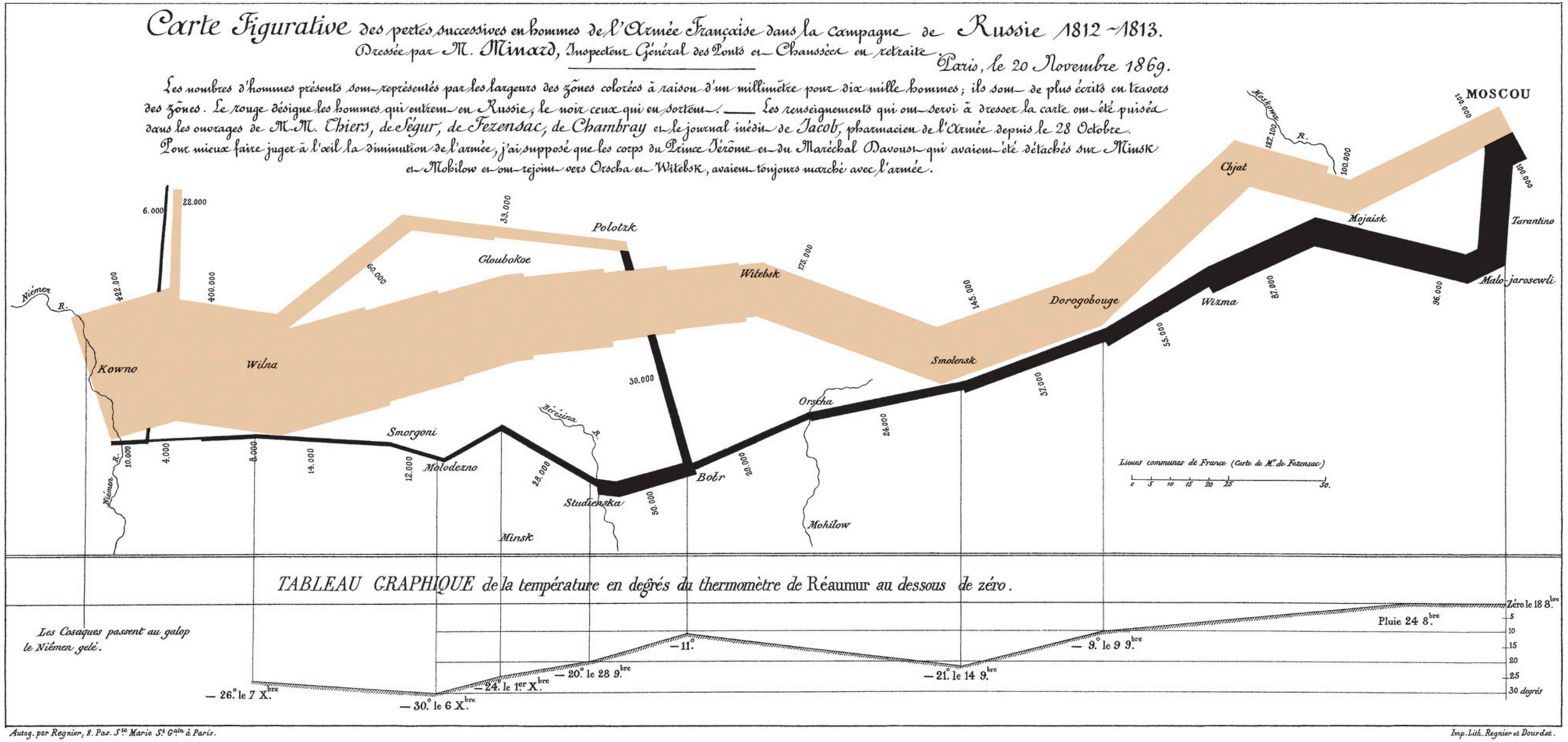
X-axis: `chance` (Q-ratio)
Y-axis: ?? (nothing!)

https://projects.fivethirtyeight.com/checking-our-work/



tryclassbuzz.com:
wind

https://vega.github.io/vega-lite/examples/point_angle_windvector.html



tryclassbuzz.com:
minard

[Charles Minard, 1869]

Next time: Visual Encoding & Design