

Gulf of Alaska Common names No temperatures

Aleutian Islands Common names No temperatures

Scatter 1 Scatter 2

Pacific cod None

2013

Scatter 1 Scatter 2

Pacific cod None

2000

Loading...

Loading...

kg / hectare 5 10 15

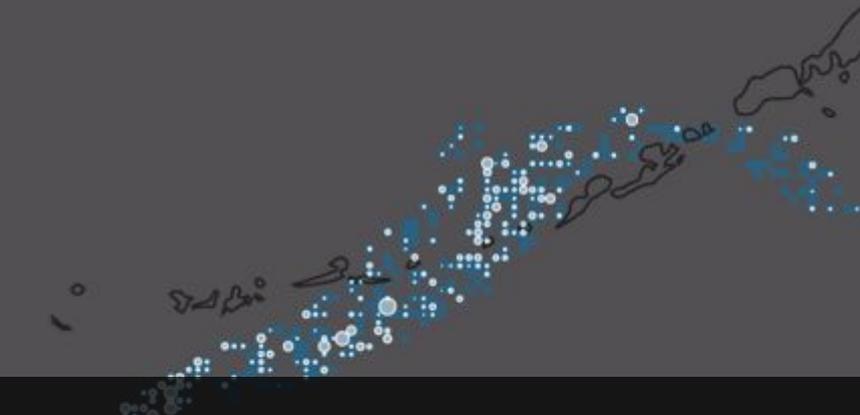
kg / hectare 5 10 15

19.77 kg/hectare overall CPUE

22.18 kg/hectare overall CPUE

Dynamic scaling enabled

Dynamic scaling enabled



Visualization, Interactivity, Co-Design
 in Exploring Humanity and the Built Environment through Data

A Samuel Pottinger
 Mar 3, 2026
 Introduction to Urban Data Analytics



Hello! I'm a data scientist, software engineer, and information designer.

Sam Pottinger

A more human-centered AI/ML

<https://gleap.org>

UC Berkeley | Data + Environment / Teaching

EVERY | Data + Synthetic Biology

IDEO | Data + Design

Plenty | Data + Indoor Agriculture

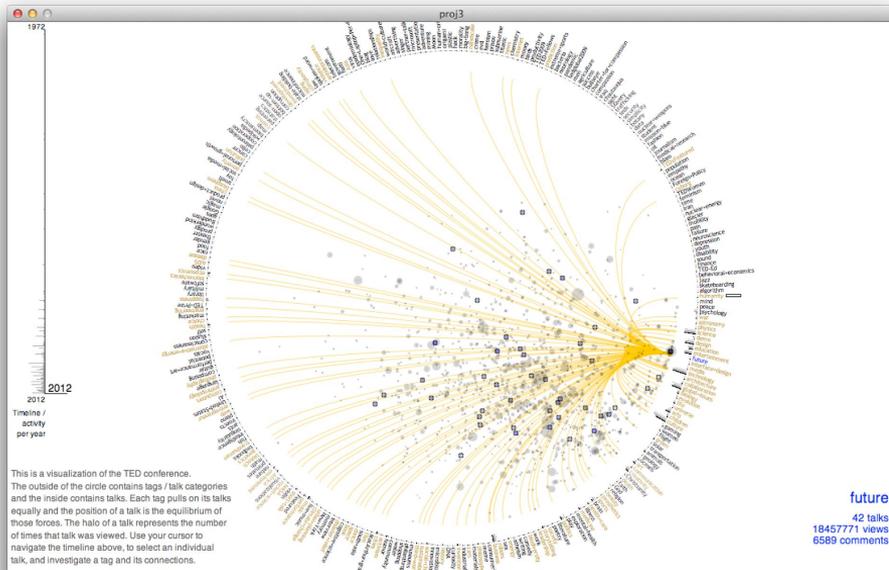
Apple | Data + Engineering

Google | Data + Visualization

LabJack | Data + Hardware

Processing | Data + Love in Java

Sketchingpy | Data + Love in Python



Today

Why engage data visualization at all?

Ingredients of data visualization.

Designing data visualizations.

Visualization and the built environment.

Year	Number of Wolves	Number of Moose
1980	50	664
1982	14	700
1984	24	811
1986	20	1025
1988	12	1653
1990	15	1216
1992	12	1600
1994	15	1800
1996	22	1200
1998	14	700
2000	29	850
2002	17	1000
2004	29	750
2006	30	385
2008	23	650
2010	19	510
2012	9	750
2014	9	1050
2016	2	1300
2018	2	1500

Premise: The human visual system is good at spotting patterns.

What year saw the most moose?

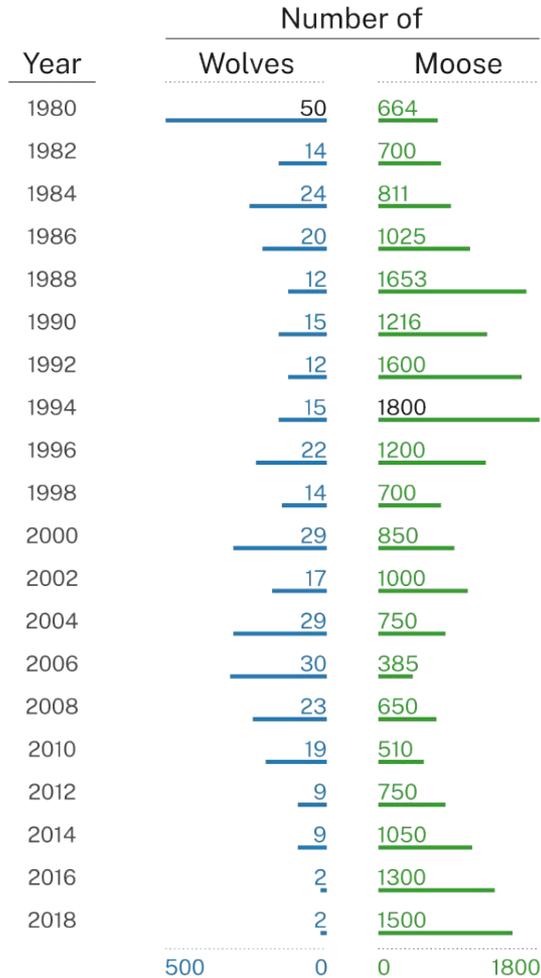
 Raise your hand when you have it.

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Premise: The human visual system is good at spotting patterns.

What year saw the most wolves?

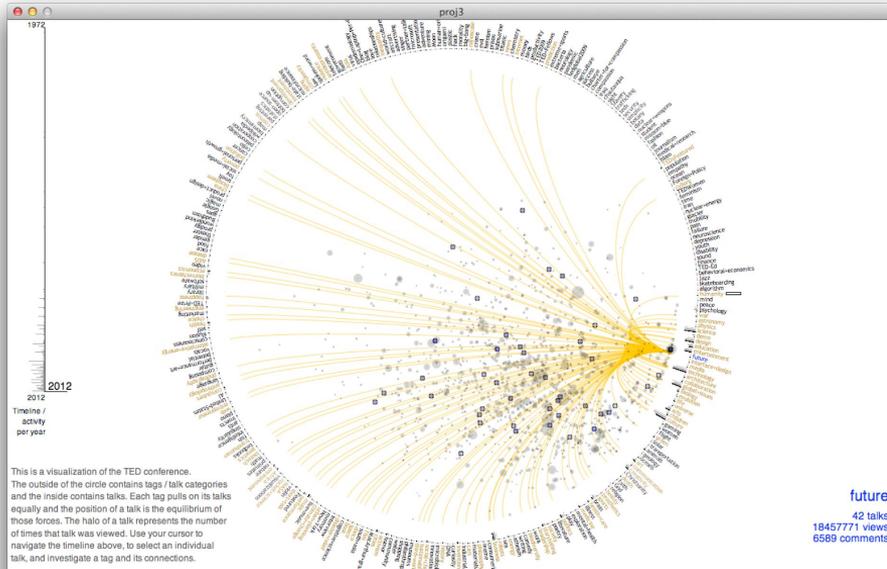
 Raise your hand when you have it.



Premise: The human visual system is good at spotting patterns.

What is the relationship between wolves and moose in Isle Royale?

 Raise your hand when you have it.



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Cleveland and McGill

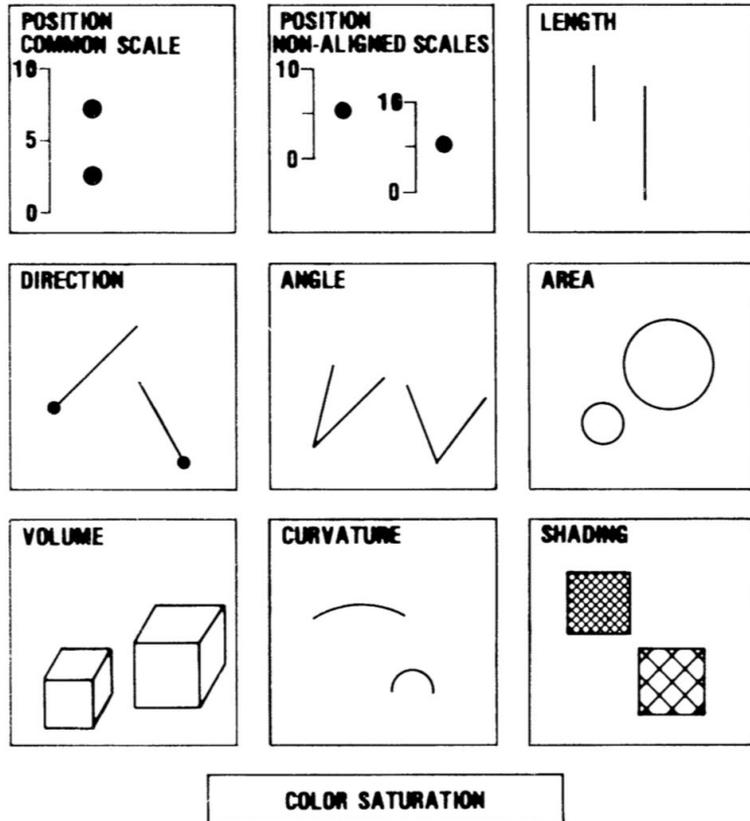


Figure 1. Elementary perceptual tasks.

Evolution gives us preattentive features.

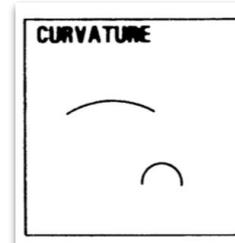
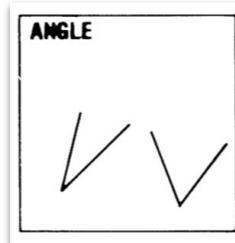
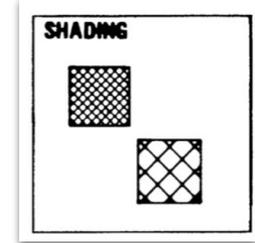
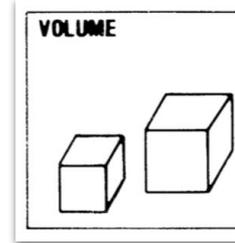
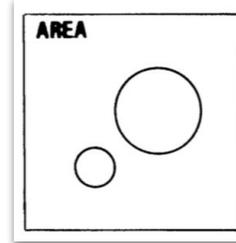
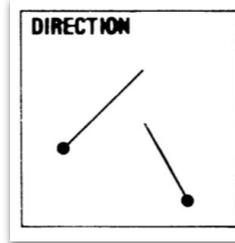
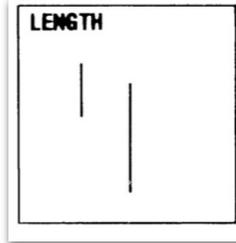
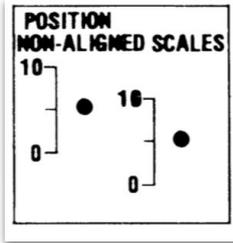
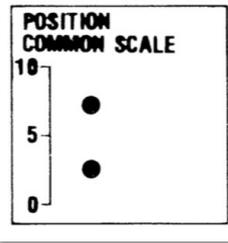
However, what is the right design of using those features?

Presenting on Cleveland and McGill in addition to some work that came after as cited.

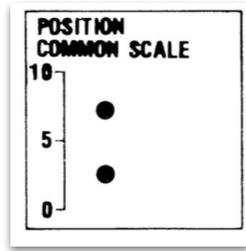
Fairly robust hierarchy

Higher Accuracy

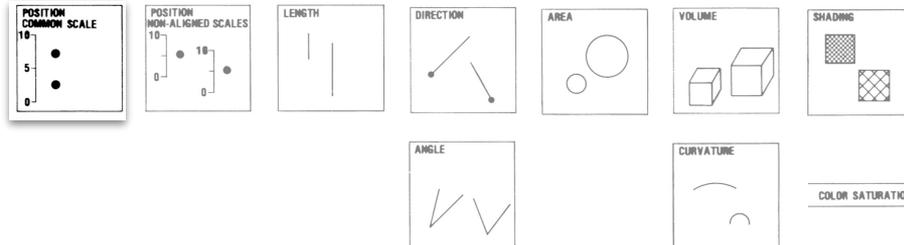
Lower or Inconsistent



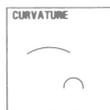
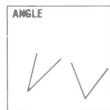
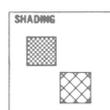
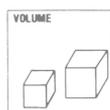
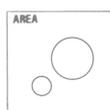
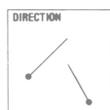
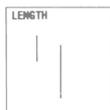
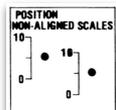
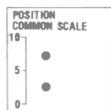
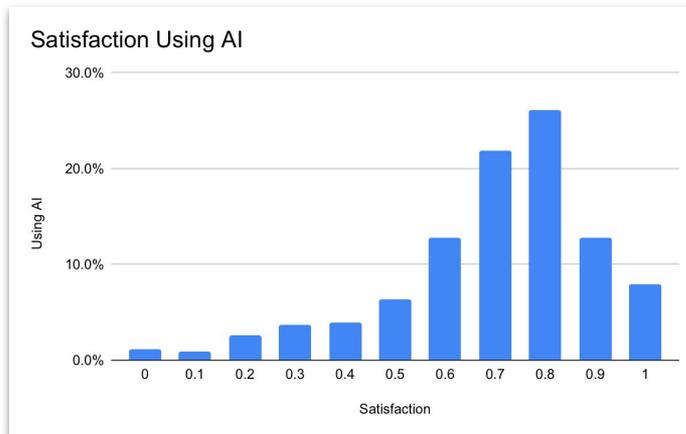
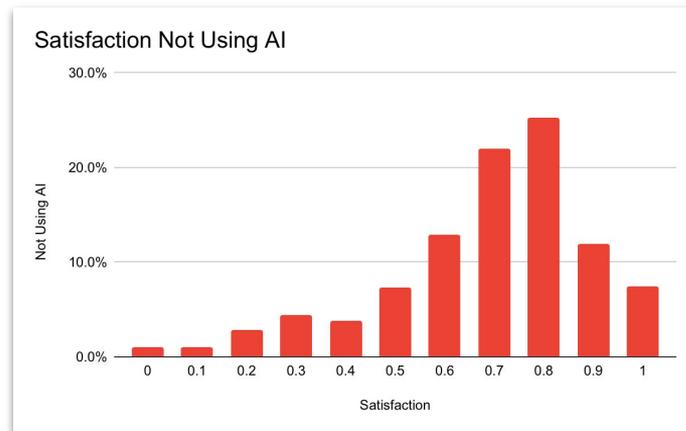
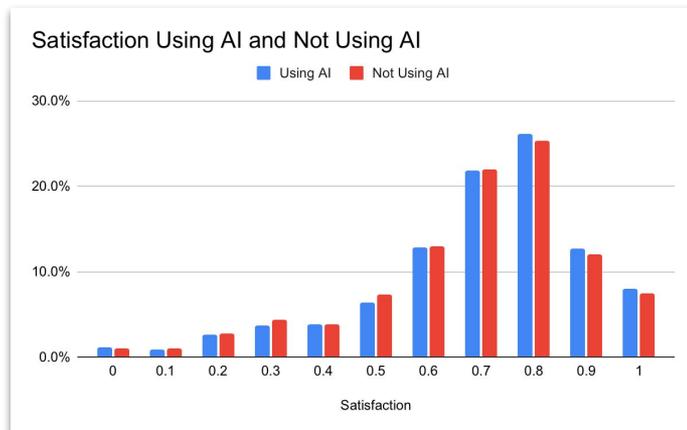
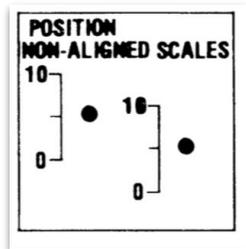
Fairly robust hierarchy



The highest accuracy encoding device is potentially not surprising as it underpins common patterns like scatter plots.

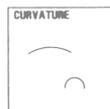
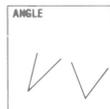
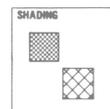
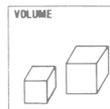
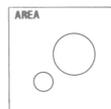
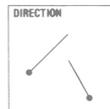
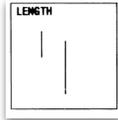
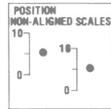
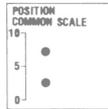
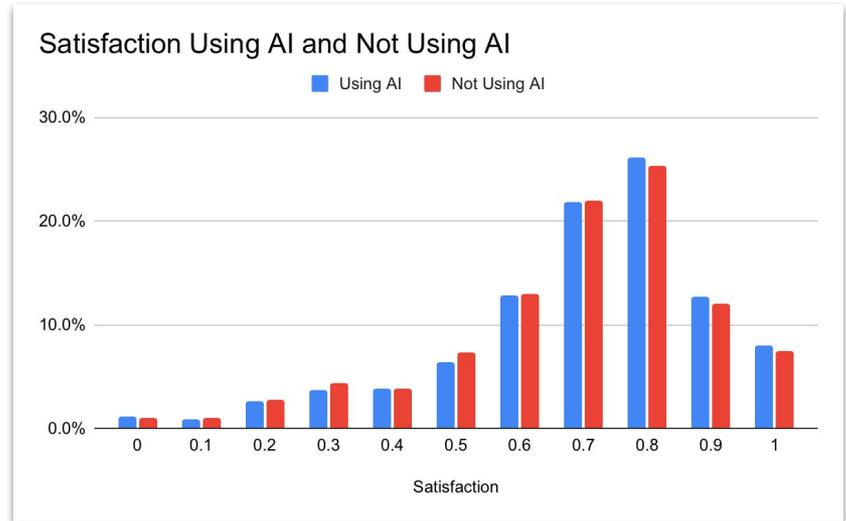
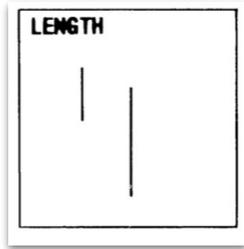


Fairly robust hierarchy

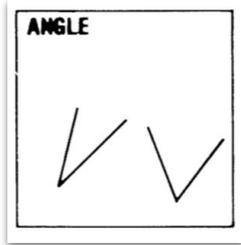
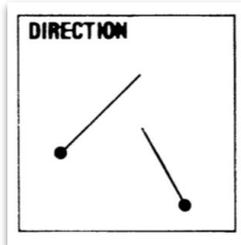


COLOR SATURATION

Fairly robust hierarchy

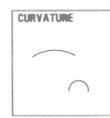
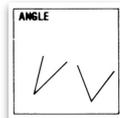
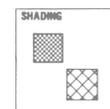
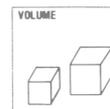
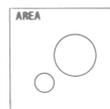
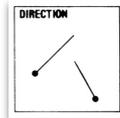
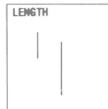
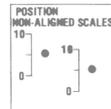
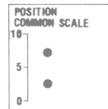


Fairly robust hierarchy

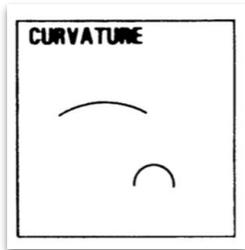
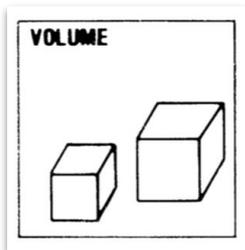
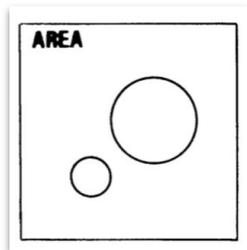


I am placing length higher than direction (slope) and angle because of consistency. There's evidence that we do better with angle closer to cardinal directions.

This is why pie charts may perform relatively poorly. Length typically has an easy fix: align against a common axis.



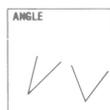
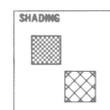
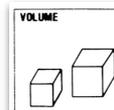
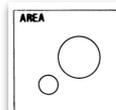
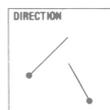
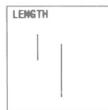
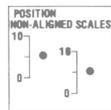
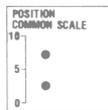
Fairly robust hierarchy



Volume generally goes poorly. This may be partially due to 3D representation within 2D media.

In general, area is good for less important “contextualizing” metrics.

Area has an issue: area vs radius.



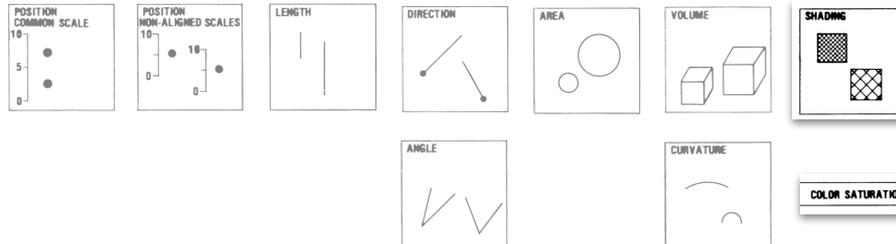
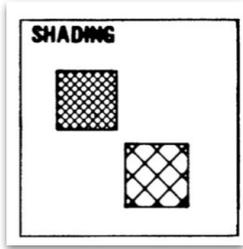
Fairly robust hierarchy

Color is fairly unreliable. It is often better for branding or complementing a message through emotion and aesthetic than it is for conveying quantitative information.

It may still serve a purpose for a limited number of qualitative groups.

Lightness generally better than hue.

Accessibility issues: readability and color-blindness.



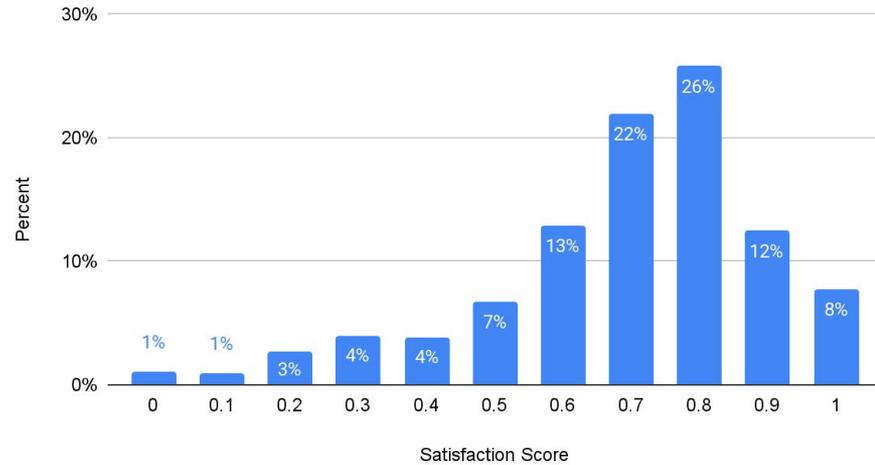
Group Activity



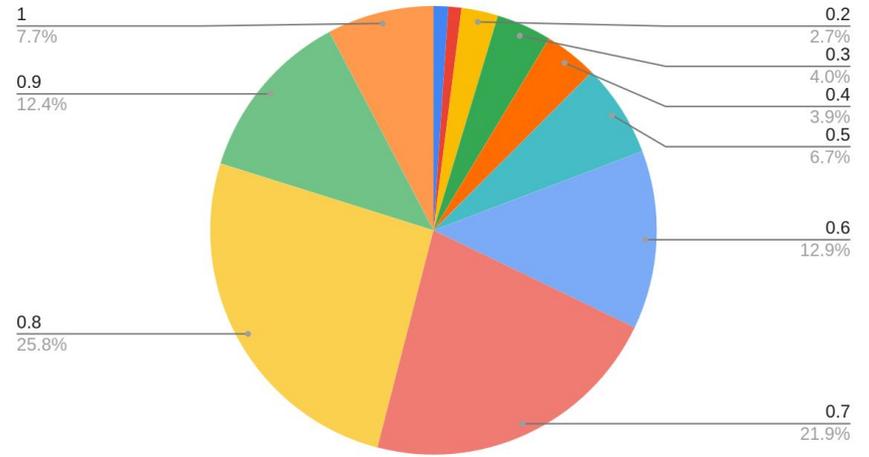
Which graphic is more likely to be read accurately?

Which one is more likely to be successful?

Satisfaction Score Frequency

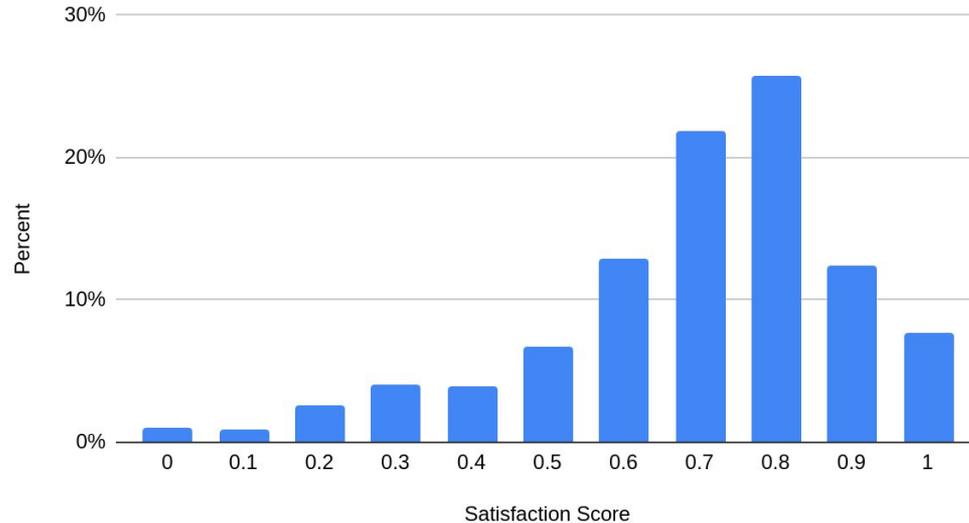


Satisfaction Score Frequency



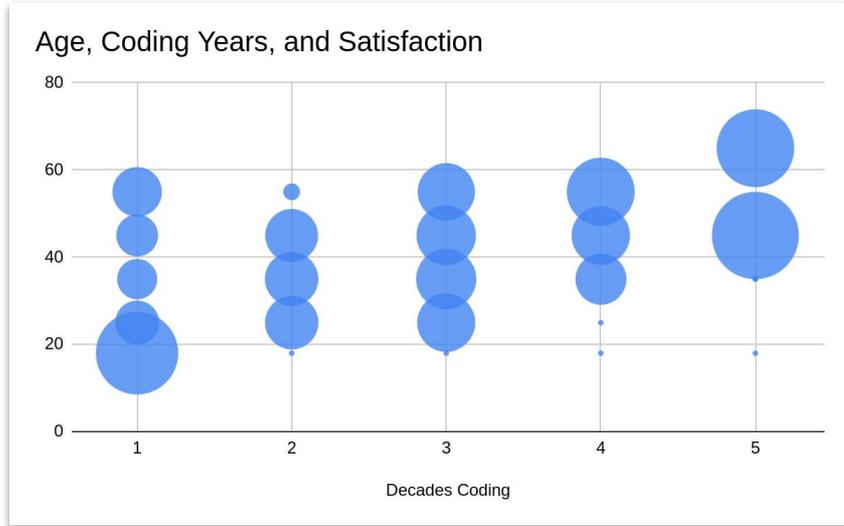
Which one is more likely to be successful?

Satisfaction Score Frequency



Satisfaction Score	Percent
0	
0.1	
0.2	
0.3	
0.4	
0.5	
0.6	
0.7	
0.8	
0.9	
1	

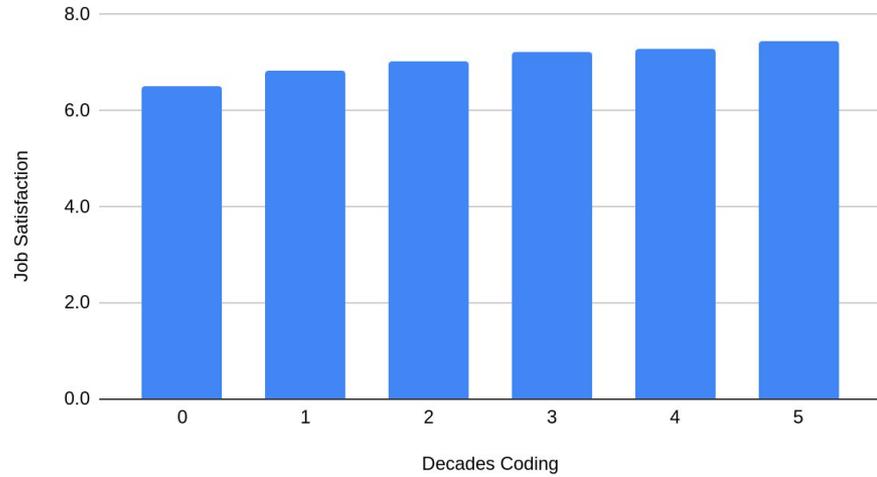
Which one is more likely to be successful?



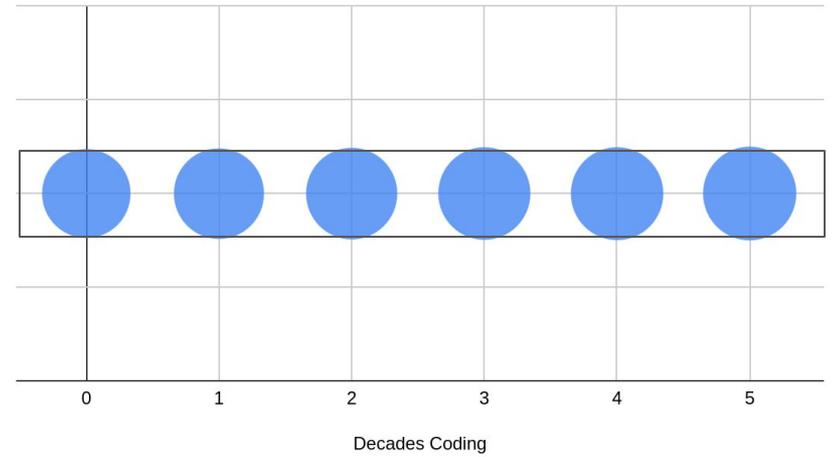
		Decades Coding				
		1	2	3	4	5
Age Group	65					✓
	55	✓	✓	✓	✓	
	45	✓	✓	✓	✓	✓
	35	✓	✓	✓	✓	
	25	✓	✓	✓		
	18	✓				

Which one is more likely to be successful?

Job Satisfaction vs. Decades Coding



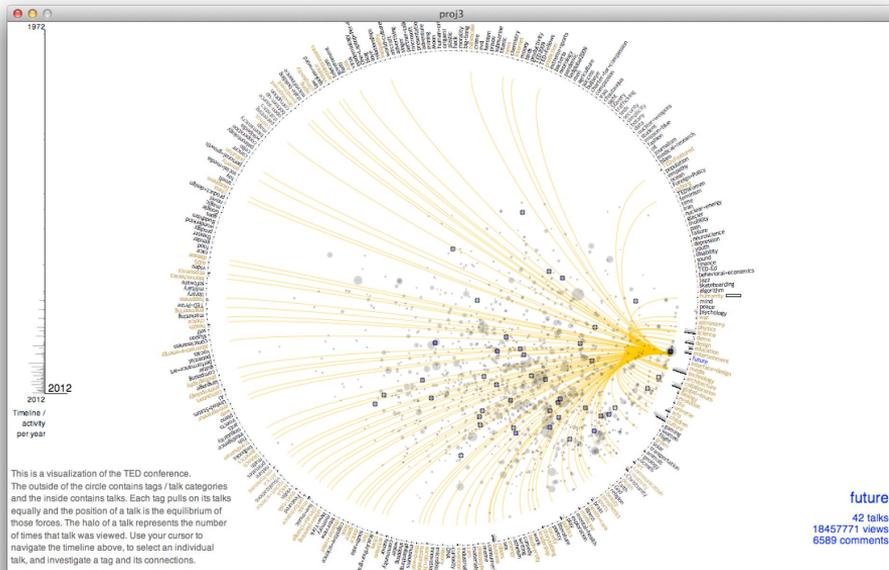
Job Satisfaction vs. Decades Coding



Pause here

If you got here, you did great!

Please wait and we will reconvene as
a group!



Today

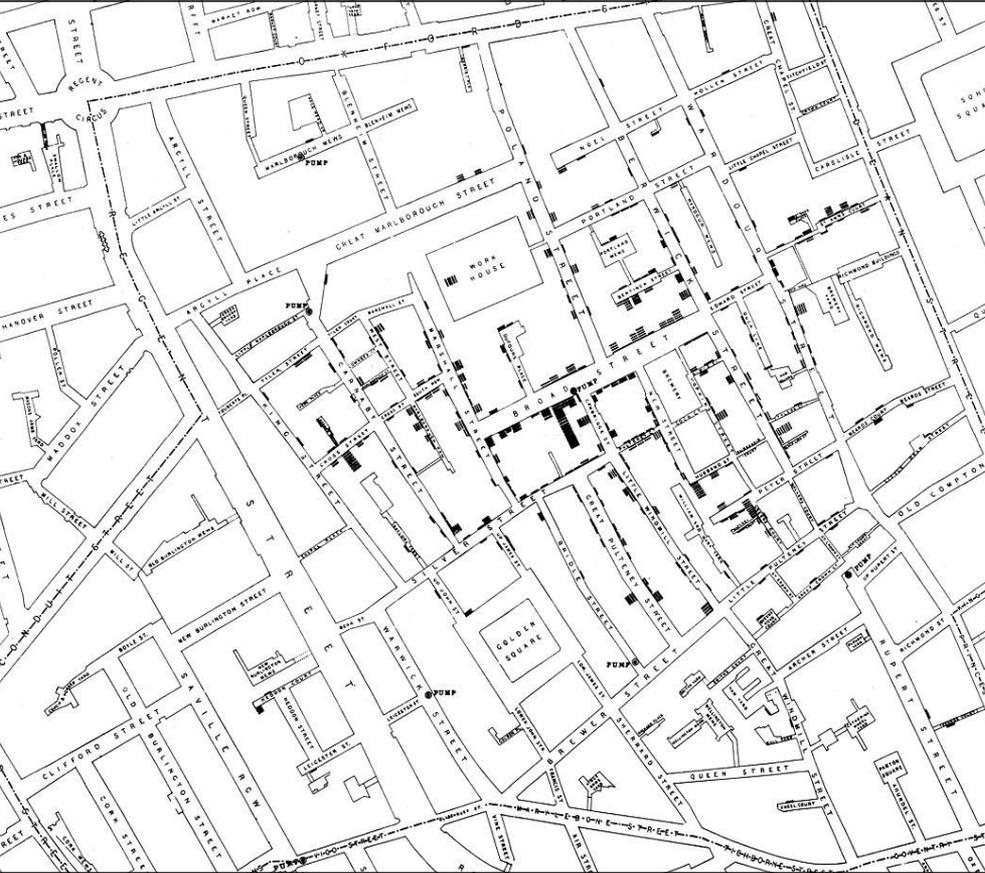
Why engage data visualization at all?

Ingredients of data visualization.

Designing data visualizations.

Visualization and the built environment.

How can data become visible?



Data -> Graphic

4 Perspectives

| As representation

As task

As message

As dialogue

Why and how different groups do data visualization. How you can think about it in your work.

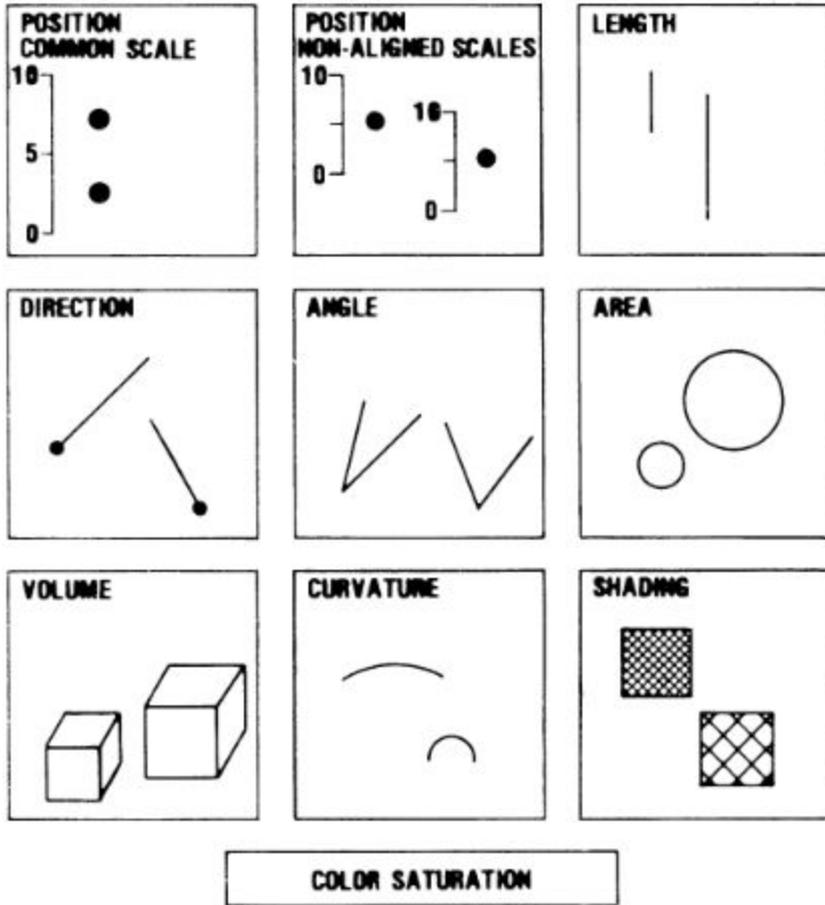


Figure 1. Elementary perceptual tasks.

Example: This first way of thinking about data visualization focuses on encoding.

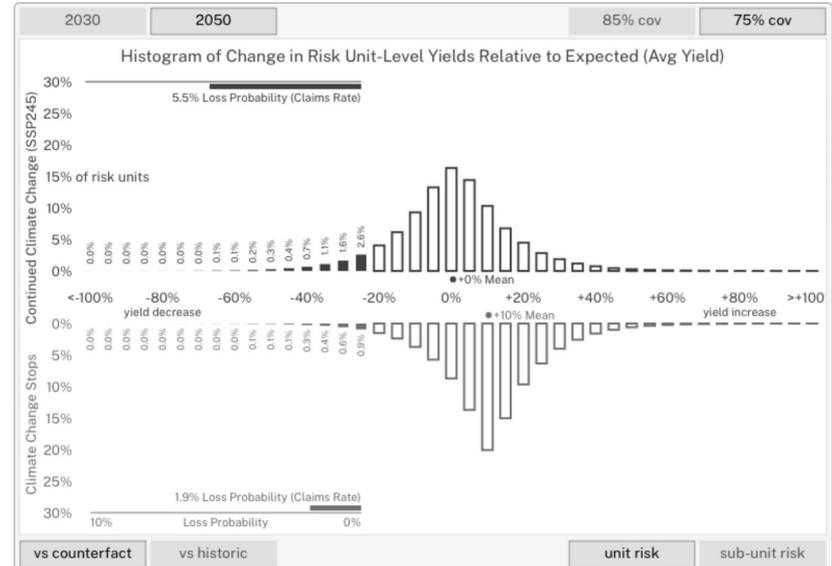
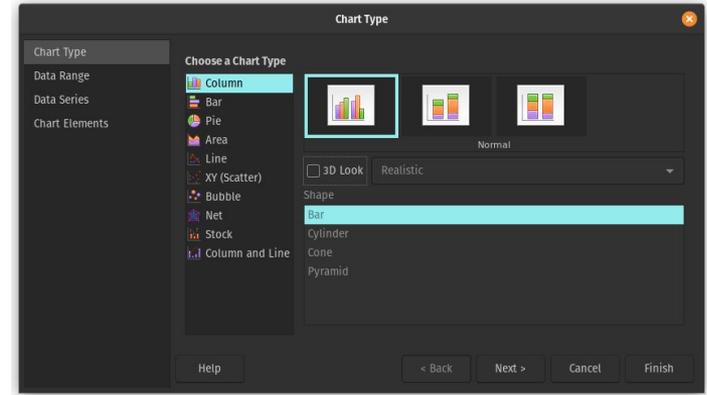
How do we “map” attributes of data to visual attributes?

What visual encodings are better than others?

How do we make visualizations accessible?

Offers: Flexibility beyond the chart wizard but principles to guide us.

Gives us the basic building blocks for how humans process visual information but lets us use that understanding in many different ways.



How can users ask questions of data?

4 Perspectives

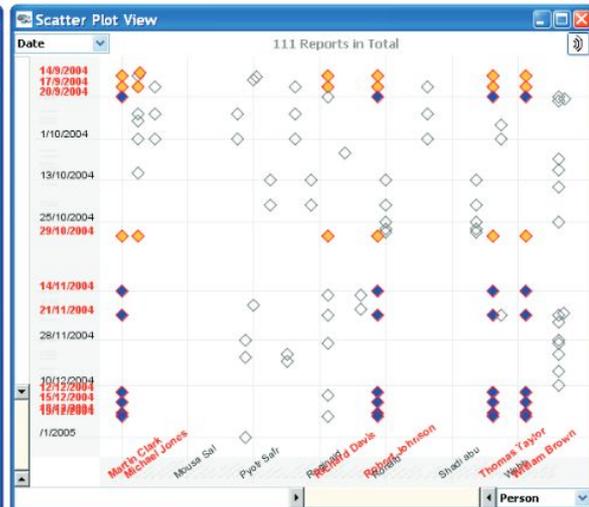
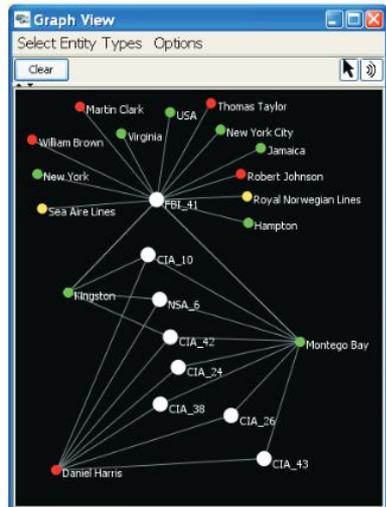
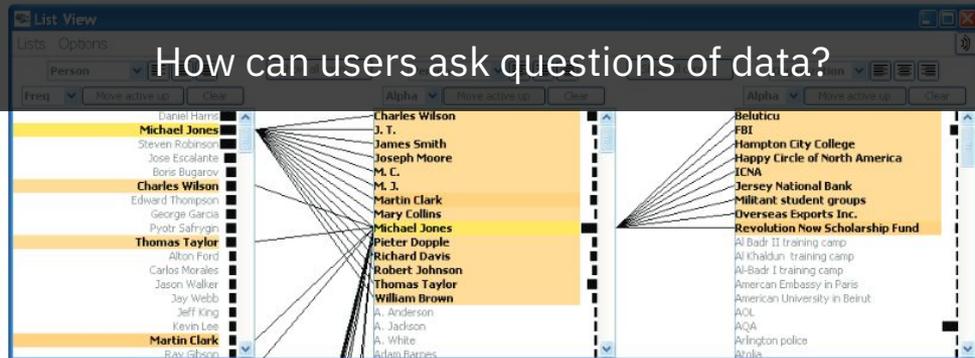
As representation

| As task

As message

As dialogue

Why and how different groups do data visualization. How you can think about it in your work.



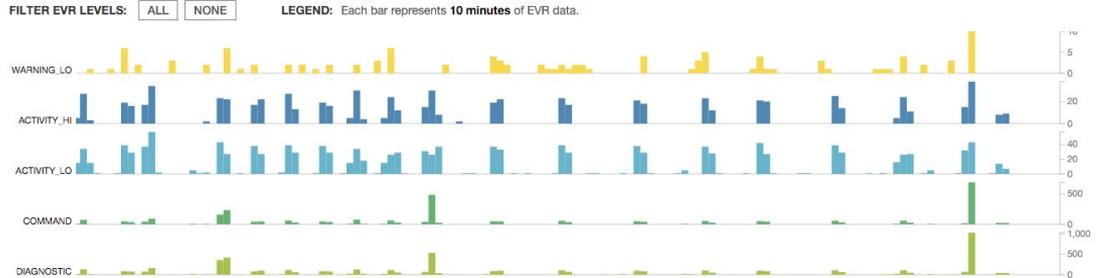
Premise: Visualizations
are part of a broader user
journey.

A structured way to think about the user
in the context of data visualization.

SET A SCET TIME RANGE (FROM END): **LAST 24 HOURS** LAST 48 HOURS LAST WEEK CUSTOM

START: 2016-012T21:13:58.459 END: 2016-013T21:13:58

▼ EVR COUNTS *Click on a bar or brush the graph to select a time range for EVRs, displayed in the table below.*



▼ EVR TABLE *Click on a row to save an EVR to your EVR collection below.*

FILTER EVRS:

Level	Name	Task	Message	SCET ▼
ACTIVITY_LO	DWN_EVR_MANAGE_PACKET_BUFFER_GATE	dwn	Pktbuf (PB_RECORDERD_DP) enabled status updated to CLOSED.	2016-013T19:57:15.034
DIAGNOSTIC	CMD_EVR_SEQ_CMD_DISPATCH	seqeng	Dispatching sequenced command: engine number=2, seconds=505987127, subseconds=917504.	2016-013T19:57:15.034
DIAGNOSTIC	CMD_EVR_SEQ_CMD_DISPATCHED	seqeng	Successfully dispatched sequenced command: seconds=505987127, subseconds=917504.	2016-013T19:57:15.034
COMMAND	SEQ_EVR_CMD_COMPLETED_SUCCESS	seqeng	Successfully completed sequenced command DMD DOWN dispatched from sequence engine number 2, command number 4142016-013T19:57:15.034	2016-013T19:57:15.034
COMMAND	SEQ_EVR_CMD_DISPATCH	seqeng	Dispatching sequenced command DMD DOWN from sequence engine number 2, from sequence file BKG_COMM_2016_013.se2016-013T19:57:15.033	2016-013T19:56:55.956
COMMAND	SEQ_EVR_CMD_COMPLETED_SUCCESS	seqeng	Successfully completed sequenced command CORRECT TIME PACKET dispatched from sequence engine number 2, command 2016-013T19:56:55.956	2016-013T19:56:55.956
ACTIVITY_HI	DWN_EVR_GENERATING_TC_PACKET	dwn	The time correlation packet was created: vcid=0, vfc=1155444, packet_time=1e28c024:e8500000, frame_time=1e28c022:f1f2c2016-013T19:56:55.956	2016-013T19:56:53.993
DIAGNOSTIC	DWN_EVR_TC_TIME_ARRIVED	dwn	The time correlation (TC) time arrived: expected=TRUE, time=1e28c022:f1f2c000.	2016-013T19:56:51.962
DIAGNOSTIC	DWN_EVR_TC_SENDING_FRAME	dwn	The time correlation (TC) reference frame was sent: vcid=0, vfc=1155444.	2016-013T19:56:51.962
DIAGNOSTIC	CMD_EVR_SEQ_CMD_DISPATCHED	seqeng	Successfully dispatched sequenced command 0xC9D3: seconds=505987103, subseconds=917504.	2016-013T19:56:51.034
DIAGNOSTIC	CMD_EVR_SEQ_CMD_DISPATCH	seqeng	Dispatching sequenced command 0xC9D3: engine number=2, seconds=505987103, subseconds=917504.	2016-013T19:56:51.034
COMMAND	SEQ_EVR_CMD_DISPATCH	seqeng	Dispatching sequenced command CORRECT TIME PACKET from sequence engine number 2, from sequence file BKG_COMM_2016-013T19:56:51.033	2016-013T19:56:23.685
COMMAND	SEQ_EVR_CMD_COMPLETED_SUCCESS	seqeng	Successfully completed sequenced command XBAND POWER dispatched from sequence engine number 2, command number 2016-013T19:56:23.685	2016-013T19:56:23.685

Example: Rachel Binx at NASA.

Looking at “event records” sent from spacecraft to NASA.

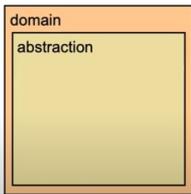
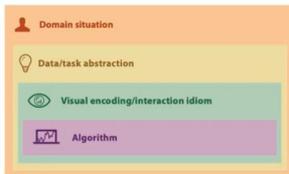
Interviewed a bunch of users to figure out how they worked with these data previously (log files).

Binx talks about how people had never seen their data before visually and the periodicity of events was revelatory for example.

Boils down into “tasks” the user executes and build user experiences to support those tasks.

From domain to abstraction

- domain characterization: details of application domain
 - group of users, target domain, their questions & data
 - varies wildly by domain
 - must be specific enough to get traction
 - domain questions/problems
 - break down into simpler abstract tasks
- abstraction: data & task
 - map *what* and *why* into generalized terms
 - identify tasks that users wish to perform, or already do
 - find data types that will support those tasks
 - possibly transform /derive if need be



Task Abstraction (Ch 3), Visualization Analysis & Design, 2021



Tamara Munzner

31.3K subscribers

Subscribe



Share



14K views 2 years ago

Task Abstraction Lecture, 2021.

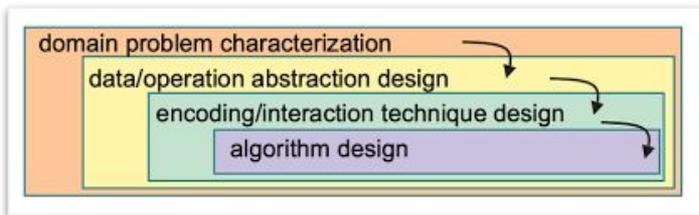
Task Abstraction (Ch 3), Visualization Analysis & Design by Tamara Munzner, CRC/Routledge 2014.

More info including editable slides and free CC-BY diagram figures on book page: <https://www.cs.ubc.ca> ...more

Offers: Structured evidence-based understanding of the user to support them in their tasks.

Orients around domains, tasks, questions, and data.

Fits within a broader modern user experience design dialogue.







Hello! Are you here?

What does it mean to be here?

How can I help you be here?

Please let me know after checking in.

Note: there will be a brief mention of
gun violence I will offer a heads up.



11,356

PEOPLE KILLED

724 | 6%
Children under 18

AGE D

10,632 | 94%
All Other Victims

Premise: Forms given to data enable authors to convey a message to a reader.

How does the reader feel when going through a visualization?

Where is efficiency helpful but where does it conflict with the message of the piece?

How might we defy reader expectations or have them confront prior held beliefs?

guns.perisopic.com

SEX

RACE

AGE GROUP

REGION

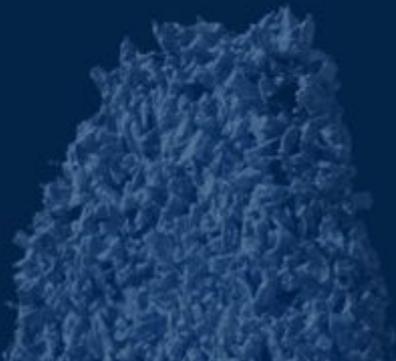
GUN TYPE

VICTIM C

A Treaty To End Plastic Pollution. Forever.

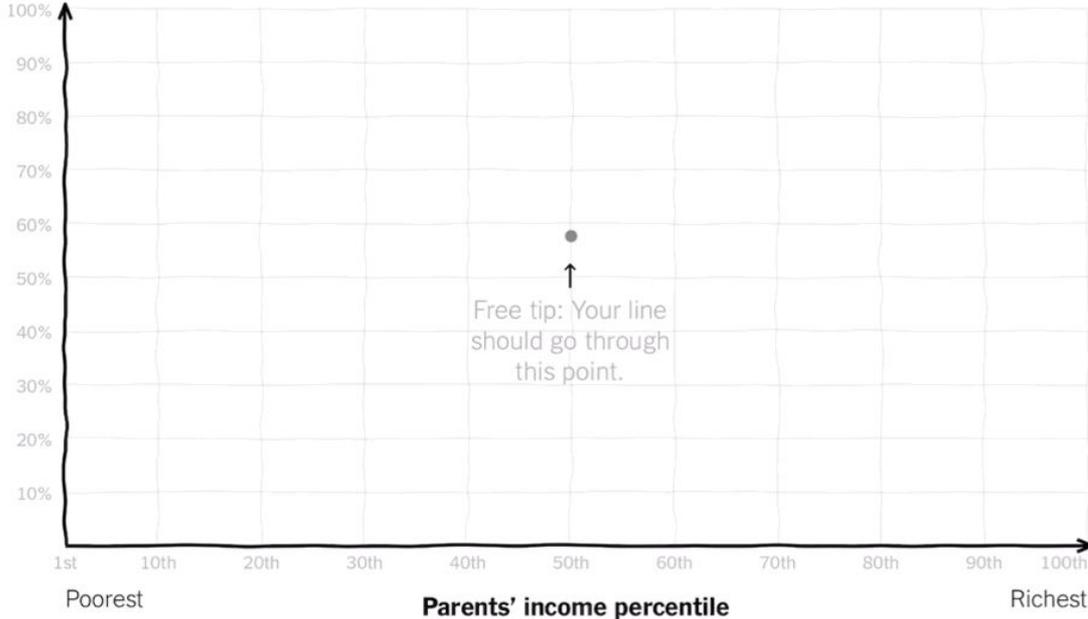
World leaders must take steps to drastically limit the
impact of plastics on the environment and human
health

CHOOSE OUR FUTURE



Draw your line on the chart below

Percent of children who attended college



I'm done

Start over

Offers: A way to convey messages with logos and pathos.

How to invoke emotional response.

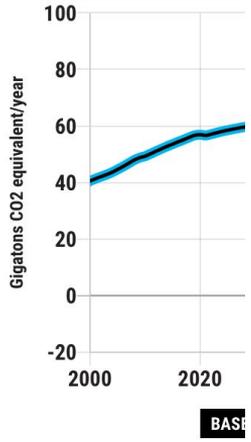
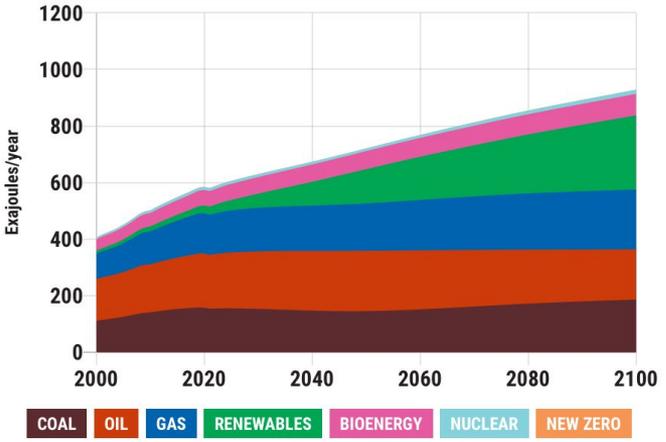
How to challenge reader assumptions.

How to understand the process by which messages and meaning are interpreted.

How can data help us think?

Global Sources of Primary Energy

Greenhouse Gas Ne



4 Perspectives

As representation

As task

As message

| As dialogue

Why and how different groups do data visualization. How you can think about it in your work.

Energy Supply

Coal status quo

Oil status quo

Natural Gas status quo

Bioenergy status quo

Renewables status quo

Nuclear status quo

New Zero-Carbon status quo

Carbon Price status quo

Transport

Energy Efficiency status quo

Buildings and Industr

Energy Efficiency status quo

Growth

Population status quo

Econom

Data <- Tool -> Collaborator

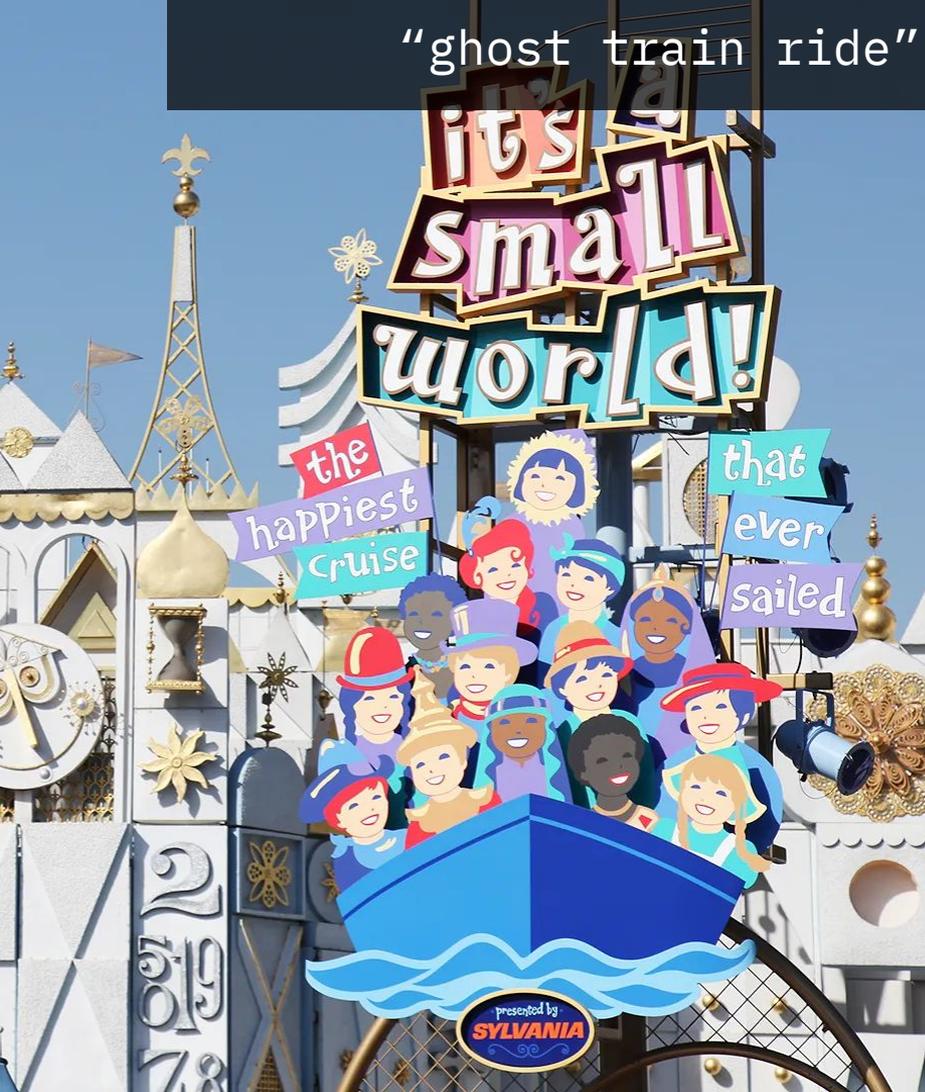
Premise: Data as humane dynamic media.

The designer creates media for thought, elevating the reader to an author of tools and co-creator of meaning.



```
function drawScene (canvas) {  
  ctx = canvas.getContext("2d");  
  extendCanvasContext(ctx);  
  
  canvasWidth = parseInt(canvas.getAttribute("width"));  
  canvasHeight = parseInt(canvas.getAttribute("height"));  
  
  drawSky();  
  drawMountains();  
  drawTree();  
}  
  
//-----  
//  
// sky  
//  
  
function drawSky () {  
  ctx.save();  
  
  var gradient = ctx.createLinearGradient(0,0,0,canvasHeight);  
  gradient.addColorStop(0, "#b4c0fe");  
  gradient.addColorStop(1, "#d3f8ff");  
  
  ctx.fillStyle = gradient;  
  ctx.fillRect(0,0,canvasWidth,canvasHeight);  
  
  ctx.restore();  
  
  ctx.fillStyle = "#ecf88a";  
  ctx.fillCircle(300, 99, 67);  
}  
  
//-----  
//
```

"ghost train ride" vs "open world"



Mismanaged Waste ⓘ

71.7

Million Metric Tons



Incinerated Waste ⓘ

129.3

Million Metric Tons



Landfill Waste ⓘ

118.4

Million Metric Tons



Gross GHG ⓘ

2755.7

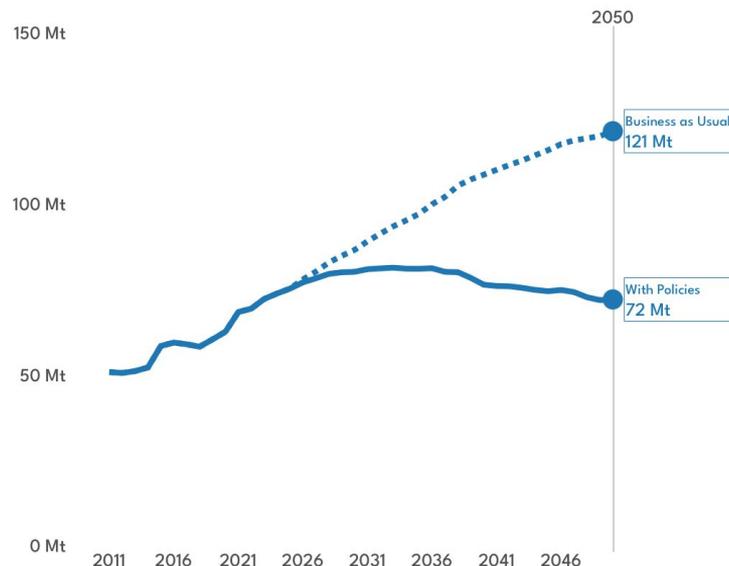
Million Metric Tons



Policies

 High > Reduction in Single Use Packaging ⓘ 90 > % Reduced Additives ⓘ Ban Polystyrene Packaging ⓘ Ban Waste Trade ⓘ Cap to 2020 Virgin Production ⓘ 40 > % Min Recycle Collection Rate ⓘ 80 > % Packaging Reuse / Life Extension ⓘ 40 > % Min Recycled Content ⓘ High > Packaging Consumption Tax ⓘ 100 > Billion USD for Plastic Recycling ⓘ 50 > Billion USD for Waste Infrastructure ⓘ Custom ⓘ

Global Annual Rate of Mismanaged Waste as Million Metric Tons ☰

[With Policies](#)[Business as Usual](#)

Example:
Finding a solution to the plastics crisis.

A layered experience in which the user can simulate different policies.

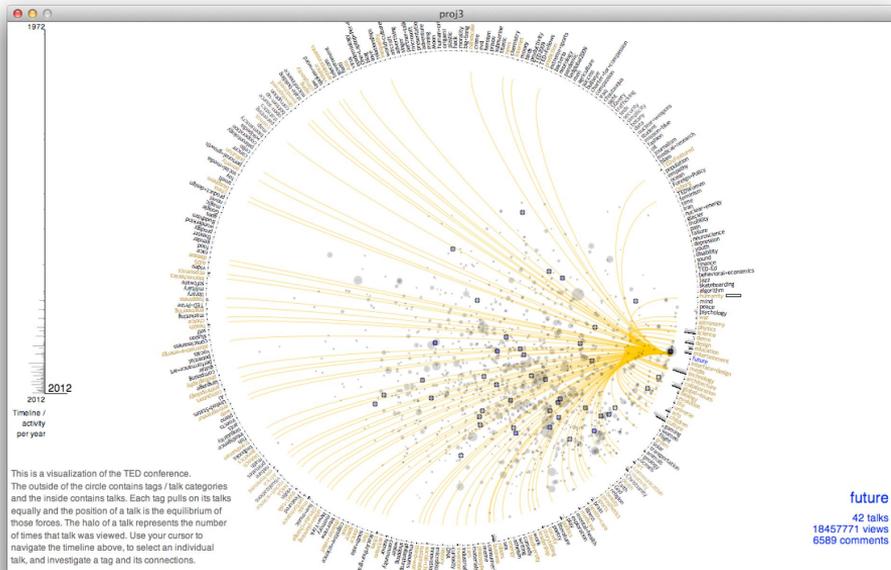
An invitation to build outside the original designer's intention.



[https://
global-plastics-tool
.org](https://global-plastics-tool.org)

Let's zoom out: What does good data visualization mean?

Perspective	Good	Measurement
Representation	Expedient	Controlled experiment
Task	Efficient	Think-aloud
Message	Expressive	Exposure / reflection
Dialogue	Explorable	Diary studies



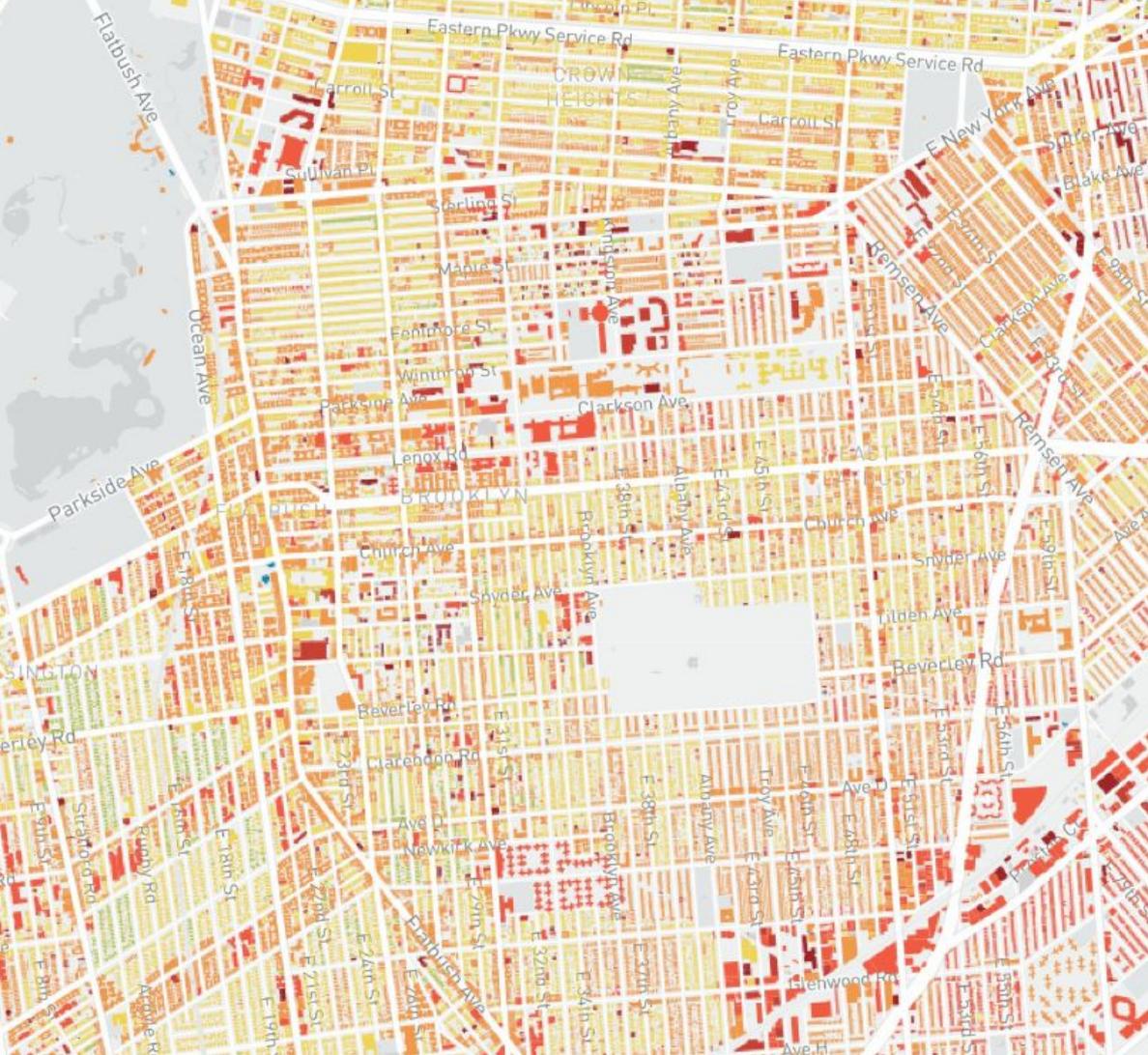
Today

Why engage data visualization at all?

Ingredients of data visualization.

Designing data visualizations.

Visualization and the built environment.



Let's start with a map.

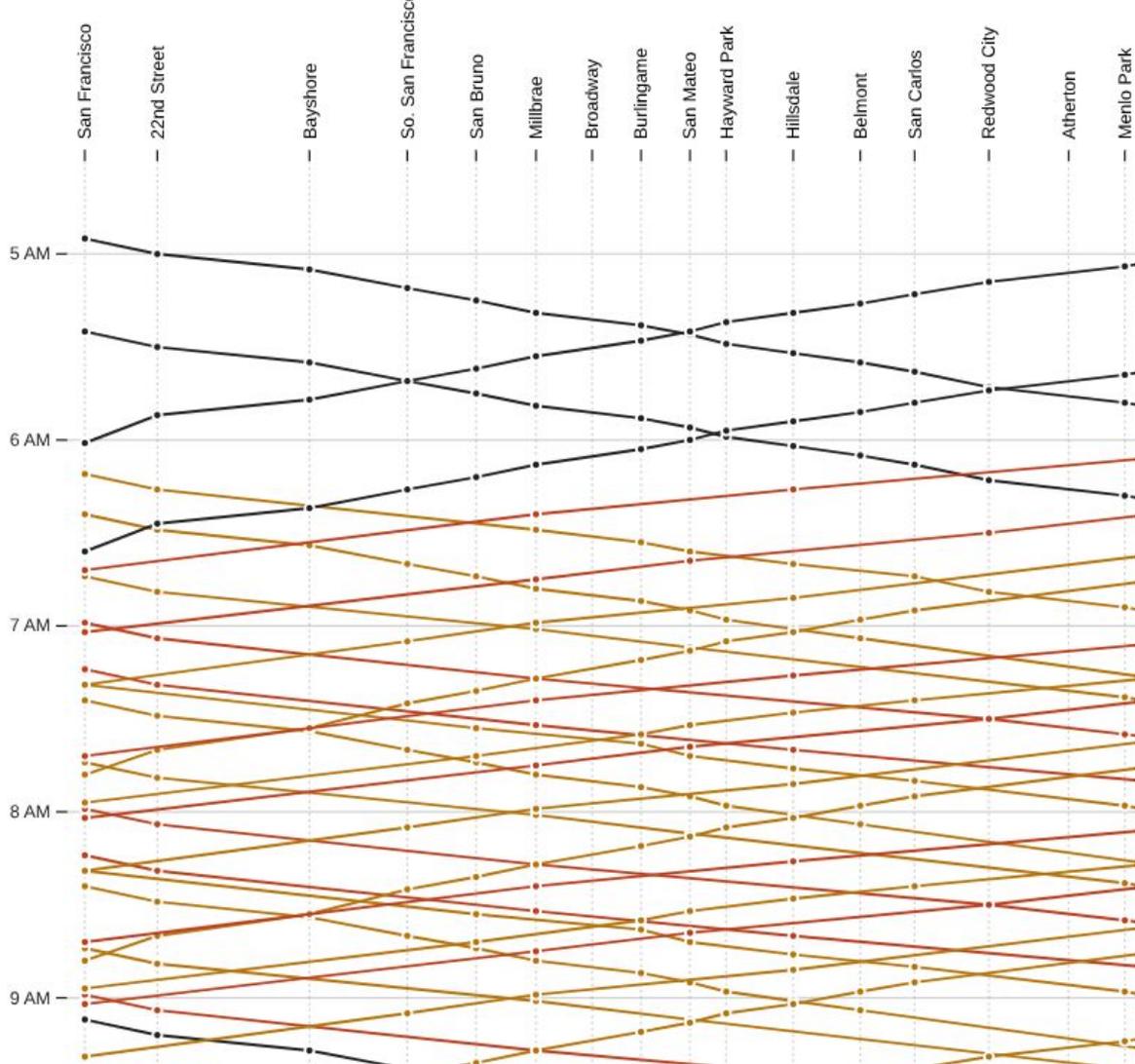
Maps are a common way of thinking about the built environment.

What are the encodings here?

What is good about a map?
What might be a drawback?



<https://www.bklynr.com/block-by-block-brooklyns-past-and-present/>



Let's try something else.

What if we don't use a map?

What is made visible here?

What is hidden?

How is geography experienced differently?

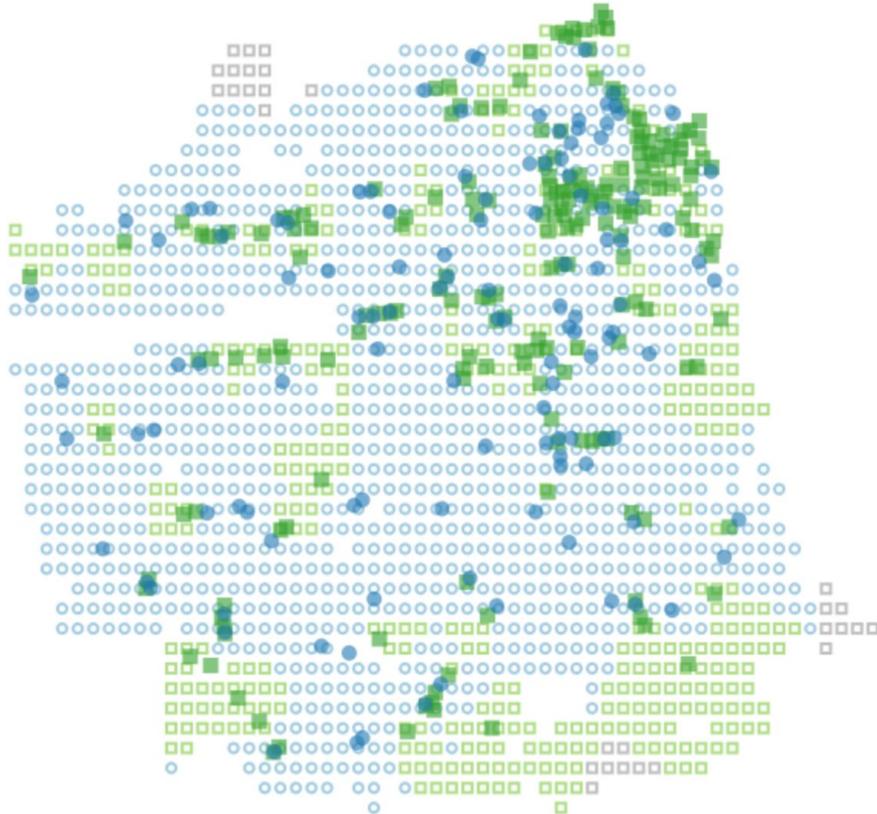


<https://observablehq.com/@d3/mareys-trains>



Progress:

Keep going! You have spent 0% of your budget (0% on rezoning and construction subsidy, 0% on transit improvement and subsidy). Goal: 80% choose supermarket. You can also [reset your design and try again](#).



Summ

74% c

24% c

2% m

0%

Buildi

Left cl

- Su
- Fa
- Re
- Re

Trans

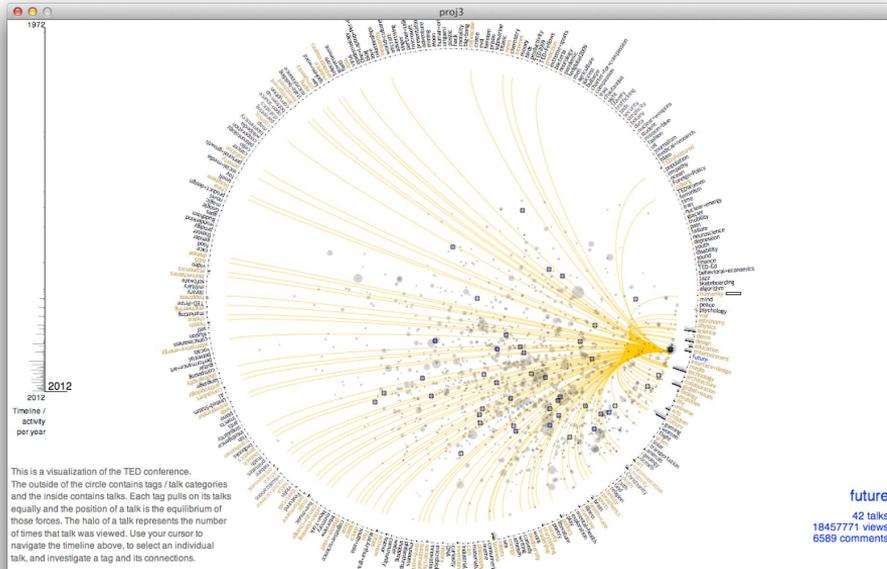
Invest travel

You are designing geography.

What is an interface and how does it prescribe framing or invite it?



foodsimsf.com



Today

Why engage data visualization at all?

Ingredients of data visualization.

Designing data visualizations.

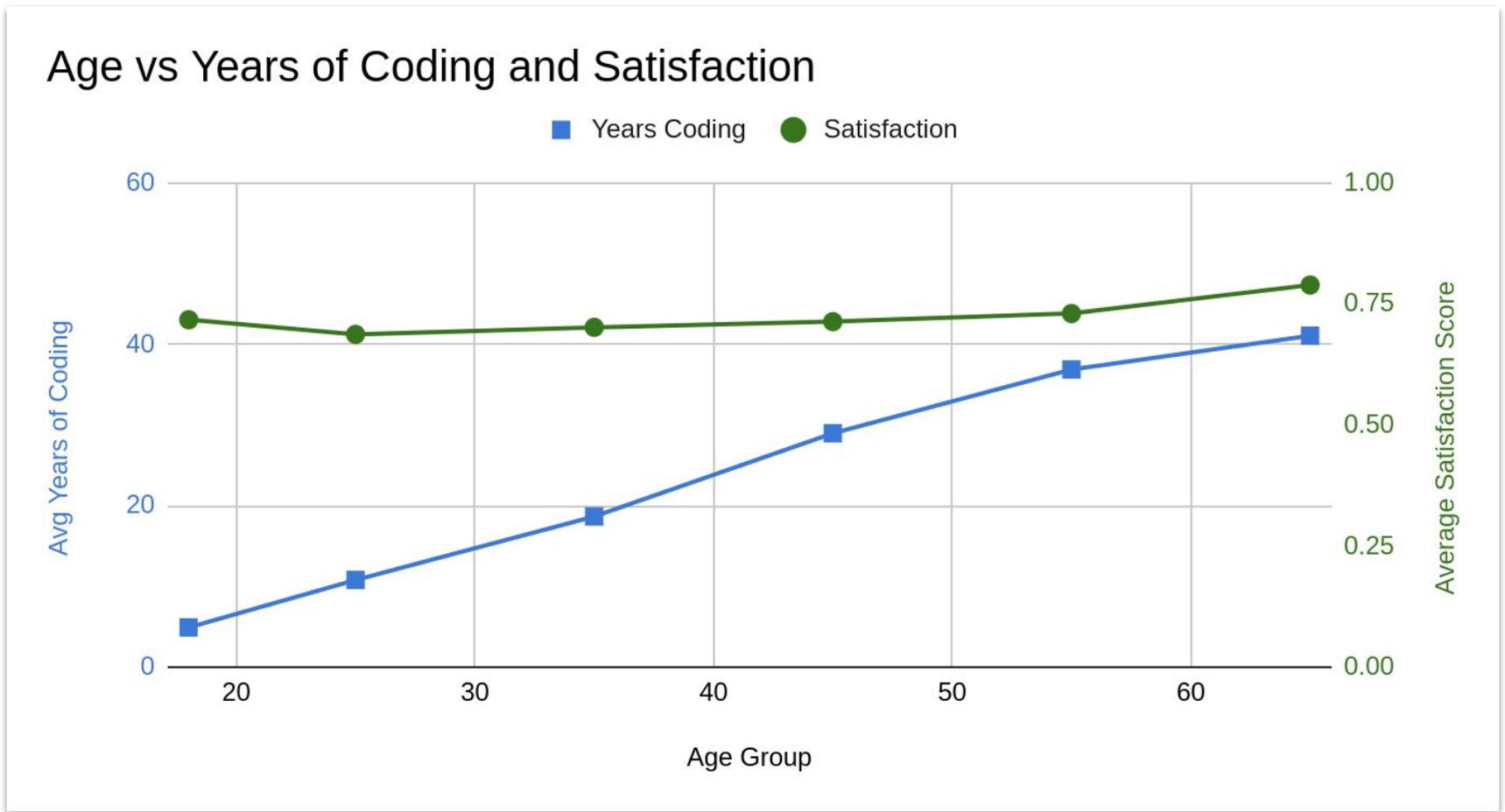
Visualization and the built environment.

Keep it going: Check-in before we go to future.



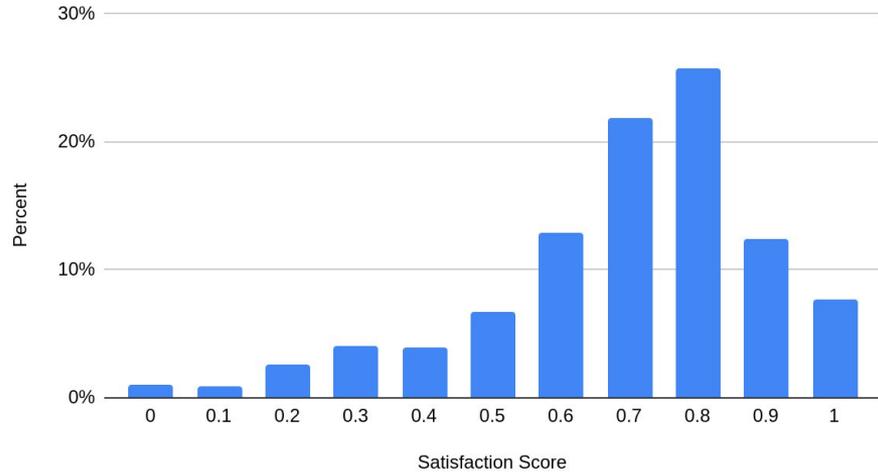
What's something you
learned today?

A few tricks: **Dual Axes**

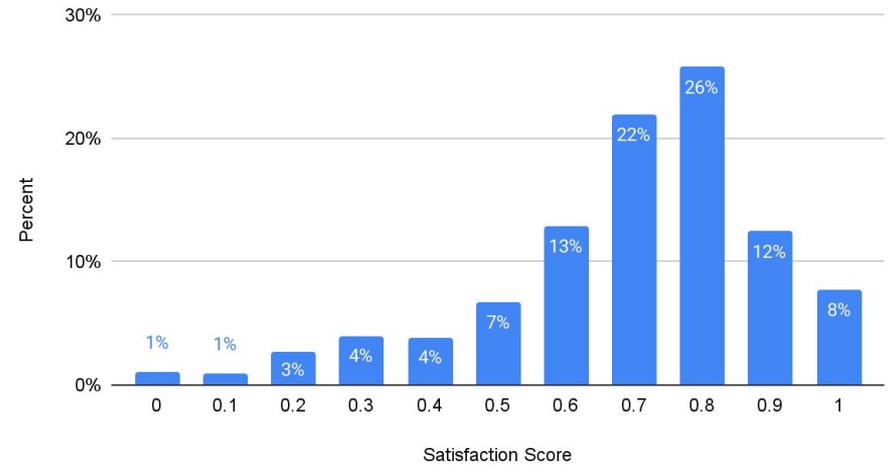


A few tricks: **Direct Labeling**

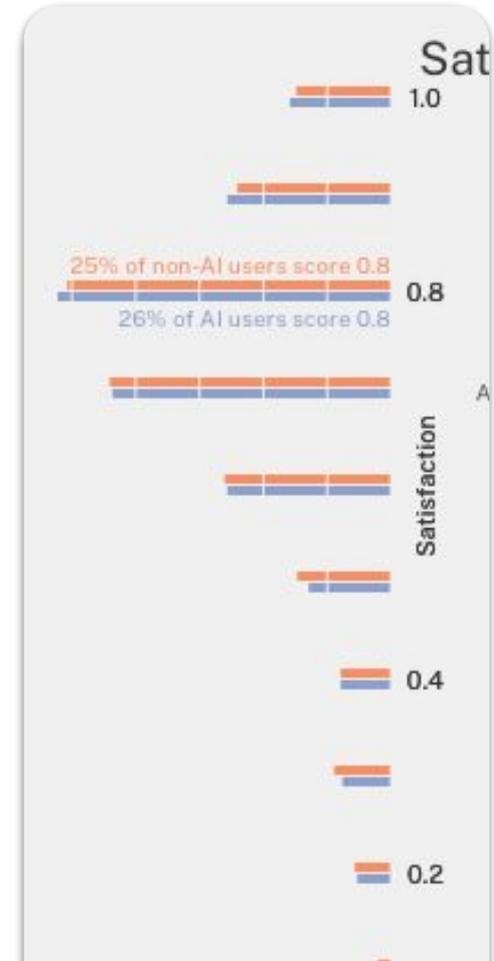
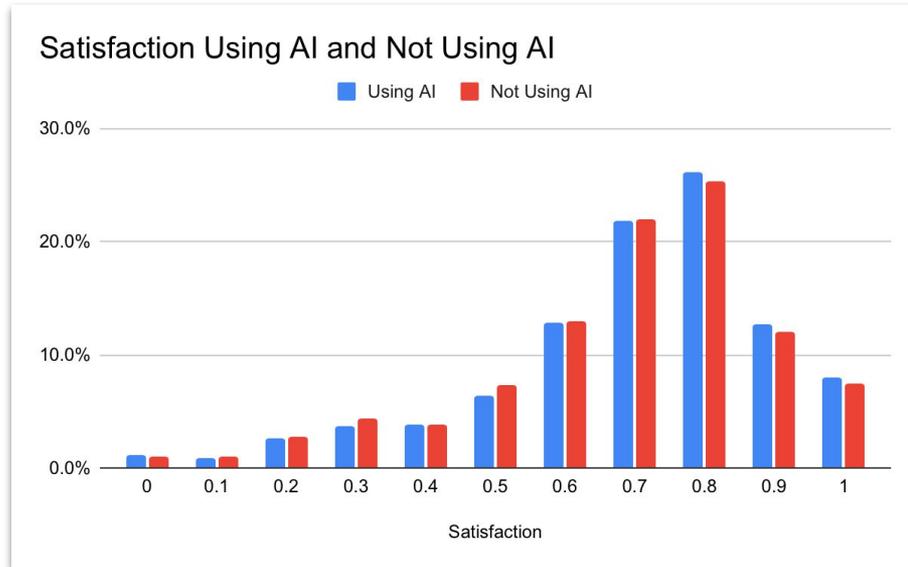
Satisfaction Score Frequency

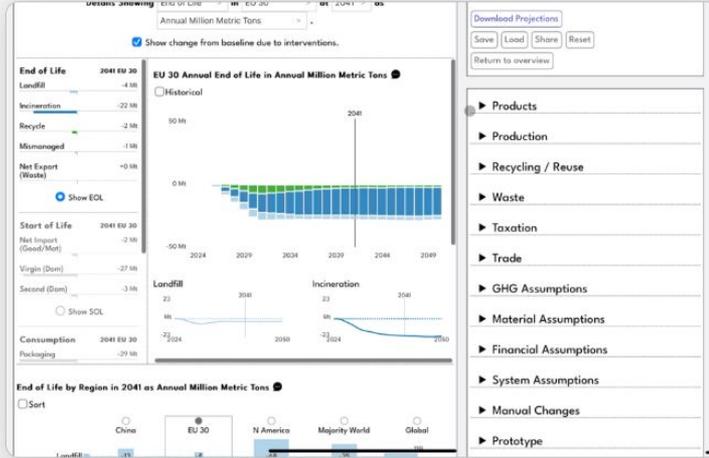


Satisfaction Score Frequency



A few tricks: **Keeping channels clear**





Keep going:
Resources online.

[https://
interactive
data
science
.courses](https://interactive-datascience.courses)

Interactive Data Science

👋 Hello! I'm [Sam](#). This website houses my courses, workshops, and lectures on interactive data, participatory science, democratized AI, and user-centered data visualization.

🚀 Get learning! Try [my open source online course](#) (free and self-paced) or, if you are in Berkeley, [participate in-person](#).

[Course](#) / [Why](#) / [Upcoming](#) / [Materials](#) / [Sign Up](#) / [About](#)

Gulf of Alaska Common names No temperatures

Aleutian Islands Common names No temperatures

Scatter 1 Scatter 2

Pacific cod None

2013

Scatter 1 Scatter 2

Pacific cod None

2000

Loading...

Loading...

kg / hectare 5 10 15

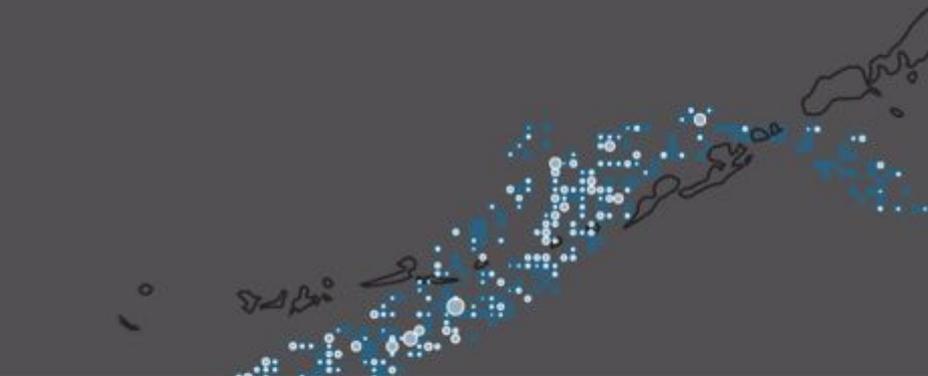
kg / hectare 5 10 15

19.77 kg/hectare overall CPUE

22.18 kg/hectare overall CPUE

Dynamic scaling enabled

Dynamic scaling enabled



Works Cited / Further Reading

- G. Aisch, A. Cox, and K. Quealy, "You Draw It: How Family Income Predicts Children's College Chances." The New York Times Company, May 28, 2015. [Online]. Available: <https://www.nytimes.com/interactive/2015/05/28/upshot/you-draw-it-how-family-income-affects-childrens-college-chances.html> [1]
- R. Binx, "Vortex." 2015. [Online]. Available: <https://rachelbinx.com/data-visualization/vortex> [2]
- R. Binx, "Designing for Realtime Spacecraft Operations." Bocoup LLC, Apr. 2016. [Online]. Available: <https://www.youtube.com/watch?v=HuYKhSHcRSQ> [3]
- Book Books Book, "We Feel Fine." YouTube, Dec. 2009. [Online]. Available: <https://www.youtube.com/watch?v=vi8WrrnWNSzU> [4]
- W. S. Cleveland and R. McGill, "Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods," *Journal of the American Statistical Association*, vol. 79, no. 387, pp. 531–554, Sep. 1984, doi: [10.1080/01621459.1984.10478080](https://doi.org/10.1080/01621459.1984.10478080). [5]
- Flipflops, "I feel... everything." Flipflops.org, Oct. 2007. [Online]. Available: <https://www.flipflops.org/category/thoughtful/page/2/> [6]
- V. Hart and N. Case, "Parable of the Polygons." Nicky Case, 2022. [Online]. Available: <https://ncase.me/polygons/> [7]
- Isle Royale National Park Michigan, "Wolf & Moose Populations." National Parks Service, Mar. 29, 2024. [Online]. Available: <https://www.nps.gov/isro/learn/nature/wolf-moose-populations.htm> [8]
- S. D. Kamvar and J. Harris, "We feel fine and searching the emotional web," in *Proceedings of the fourth ACM international conference on Web search and data mining*, Hong Kong China: ACM, Feb. 2011, pp. 117–126. doi: [10.1145/1935826.1935854](https://doi.org/10.1145/1935826.1935854). [9]
- A. KIRK, *DATA VISUALISATION: a handbook for data driven design*. S.I.: SAGE PUBLICATIONS, 2024. [10]
- A. Kirk, "Visualizing Data." Visualising Data Ltd, 2024. [Online]. Available: <https://visualisingdata.com/> [11]
- T. Munzner, "A Nested Model for Visualization Design and Validation," *IEEE Trans. Visual. Comput. Graphics*, vol. 15, no. 6, pp. 921–928, Nov. 2009, doi: [10.1109/TVCG.2009.111](https://doi.org/10.1109/TVCG.2009.111). [12]
- T. Munzner, "Visualization Analysis and Design." AK Peters Visualization Series, 2014. [Online]. Available: <https://books.apple.com/us/book/visualization-analysis-and-design/id1567434451> [13]
- T. Munzner, *Visualization analysis and design*. in A.K. Peters visualization series. Boca Raton: CRC Press, Taylor & Francis Group, CRC Press is an imprint of the Taylor & Francis Group, an informa business, 2015. [14]
- T. Munzner, "Task Abstraction (Ch 3), Visualization Analysis & Design, 2021." YouTube, 2021. [Online]. Available: <https://www.youtube.com/watch?v=pHlid-cgICY> [15]
- M. Nix, *Visual simplicity: die Darstellung großer Datenmengen*. Frankfurt am Main: entwickler.press, 2013. [16]
- Periscopic, "U.S. Gun Deaths." Periscopic, 2018. [Online]. Available: <https://guns.periscopic.com/> [17]
- A. Pottinger, "FoodSim: San Francisco." 2023. [Online]. Available: <https://foodsimsf.com/> [18]
- [19]

A. Pottinger, "Income Gaps." 2023. [Online]. Available: <https://incomegaps.com/> [19]

A. Pottinger, "Interactive Data Science." 2024. [Online]. Available: <https://interactivedatascience.courses/> [20]

A. S. Pottinger *et al.*, "Combining Game Design and Data Visualization to Inform Plastics Policy: Fostering Collaboration between Science, Decision-Makers, and Artificial Intelligence," 2023, *arXiv*. doi: [10.48550/ARXIV.2312.11359](https://doi.org/10.48550/ARXIV.2312.11359). [21]

A. S. Pottinger, L. Connor, B. Guzder-Williams, M. Weltman-Fahs, and T. Bowles, "Climate-Driven Doubling of Maize Loss Probability in U.S. Crop Insurance: Spatiotemporal Prediction and Possible Policy Responses," 2024, *arXiv*. doi: [10.48550/ARXIV.2408.02217](https://doi.org/10.48550/ARXIV.2408.02217). [22]

A. S. Pottinger and G. Zarpellon, "Pyafscgap.org: Open source multi-modal Python-basedtools for NOAA AFSC RACE GAP," *JOSS*, vol. 8, no. 86, p. 5593, Jun. 2023, doi: [10.21105/joss.05593](https://doi.org/10.21105/joss.05593). [23]

J. N. Rooney-Varga, F. Kapmeier, J. D. Sterman, A. P. Jones, M. Putko, and K. Rath, "The Climate Action Simulation," *Simulation & Gaming*, vol. 51, no. 2, pp. 114–140, Apr. 2020, doi: [10.1177/1046878119890643](https://doi.org/10.1177/1046878119890643). [24]

J. Schell, *The art of game design: a book of lenses*, Third edition. Boca Raton: CRC Press/Taylor & Francis Group, 2020. [25]

J. Snow, *On the mode of communication of cholera*. London: John Churchill, 1855. [Online]. Available: <https://archive.org/details/b28985266/page/n57/mode/2up> [26]

J. Stasko, C. Gorg, Z. Liu, and K. Singhal, "Jigsaw: Supporting Investigative Analysis through Interactive Visualization," in *2007 IEEE Symposium on Visual Analytics Science and Technology*, Sacramento, CA, USA: IEEE, Oct. 2007, pp. 131–138. doi: [10.1109/VAST.2007.4389006](https://doi.org/10.1109/VAST.2007.4389006). [27]

The Document Foundation, *LibreOffice*. (2024). The Document Foundation. [28]

ThoughtLab, The Wendy and Eric Schmidt Center for Data Science and Environment, and Benioff Ocean Science Laboratory, "A Treaty to End Plastic Pollution. Forever." University of California, 2023. [Online]. Available: <https://plasticstreaty.berkeley.edu/> [29]

B. Victor, "Inventing on Principle." CUSEC, 2012. [Online]. Available: <https://www.youtube.com/watch?v=PUv66718DII> [30]

B. Victor, "Media for Thinking the Unthinkable." MIT Media Lab, Apr. 04, 2013. [Online]. Available: <https://vimeo.com/67076984> [31]

Visual Computing BLOG, "Tamara Munzner discussed quantification in terms of a nested model of visualization design and evaluation." Transregional Collaborative Research Center. [Online]. Available: https://www.visual-computing.org/2018/10/17/computerscienceconferenceweek/201810_conferenceweek_munzner-2/ [32]

C. Ware, "Colin Ware | The Data Visualization Research Lab." University of New Hampshire. [Online]. Available: https://ccom.unh.edu/vislab/people/colin_ware/ [33]

C. Ware, *Information visualization: perception for design*, Fourth edition. Cambridge, MA: Morgan Kaufmann, 2021. [34]

Wikipedia Contributors, "Snow-cholera-map-1.jpg." Wikimedia Foundation, Inc., 2020. [Online]. Available: <https://en.wikipedia.org/wiki/File:Snow-cholera-map-1.jpg> [35]

[36]

Wikipedia Contributors, "Bret Victor." Wikimedia Foundation, Inc., Jun. 22, 2023. [Online]. Available: https://en.wikipedia.org/wiki/Bret_Victor

[36]

Wikipedia Contributors, "Star Wars: Galaxy's Edge." Wikimedia Foundation, Inc., Sep. 21, 2024. [Online]. Available: https://en.wikipedia.org/wiki/Star_Wars:_Galaxy%27s_Edge

[37]

Wikipedia Contributors, "It's a Small World." Wikimedia Foundation, Inc., Sep. 24, 2024. [Online]. Available: https://en.wikipedia.org/wiki/It%27s_a_Small_World

[38]

N. Yee, "Motivations for Play in Online Games," *CyberPsychology & Behavior*, vol. 9, no. 6, pp. 772–775, Dec. 2006, doi: [10.1089/cpb.2006.9.772](https://doi.org/10.1089/cpb.2006.9.772).

[39]

Thanks to <https://unsplash.com/photos/DHl49ovrn7Y>

Additional demos:

BKLYNR, "Block by Block, Brooklyn's Past and Present." BKLYNR, Aug. 2013. [Online]. Available:

<https://www.bklynr.com/block-by-block-brooklyns-past-and-present/>

M. Bostock, "Marey's Trains." Observable, 2021. [Online]. Available:

<https://observablehq.com/@d3/mareys-trains>

A. Pottinger, "FoodSim: San Francisco." 2023. [Online]. Available: <https://foodsimsf.com/>

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