Looking to the future of accessible data interfaces

HIGHSOFT

Frank Elavsky, PhD Student
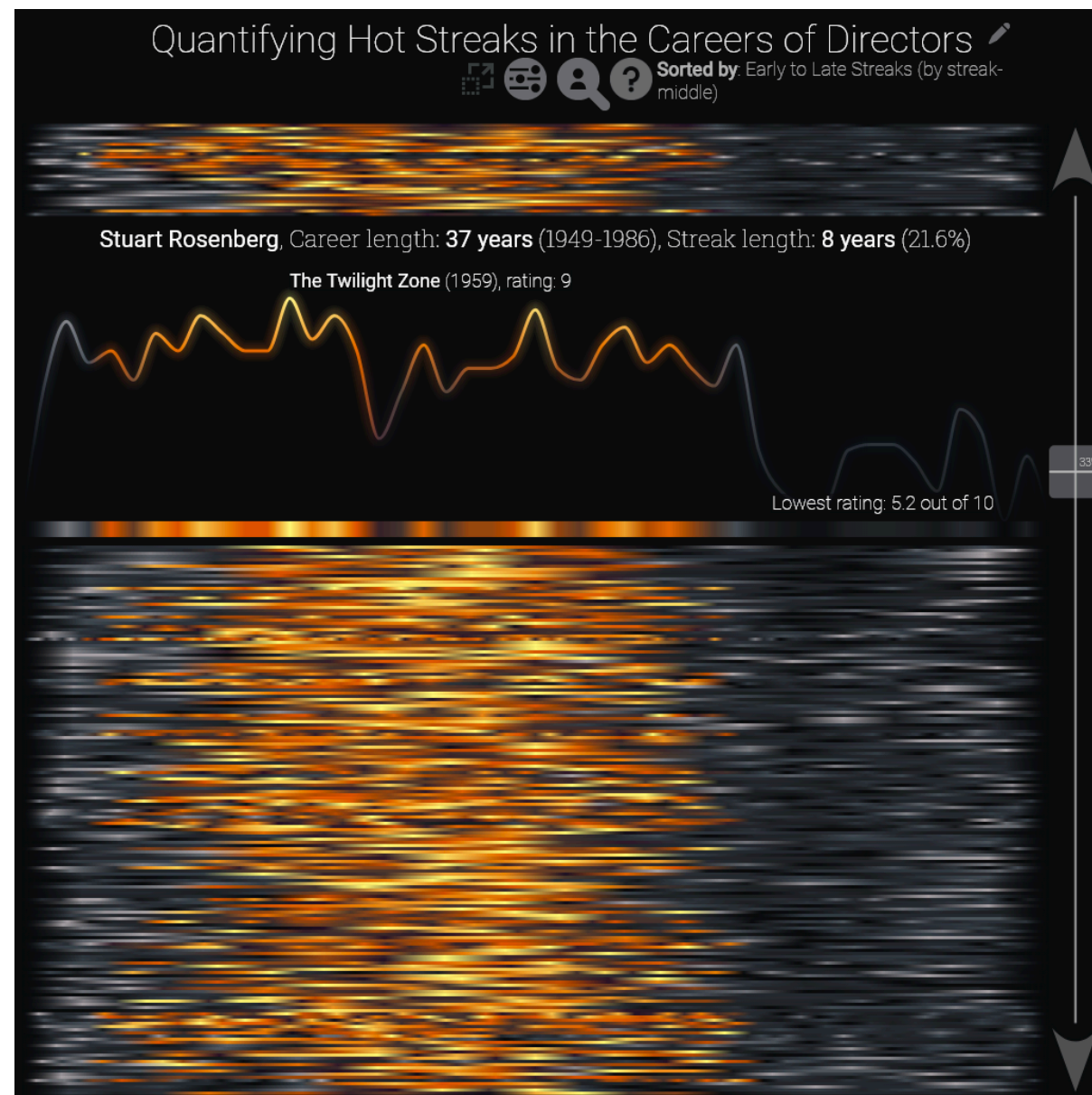
hcii.cmu.edu, axle-lab.com, dig.cmu.edu

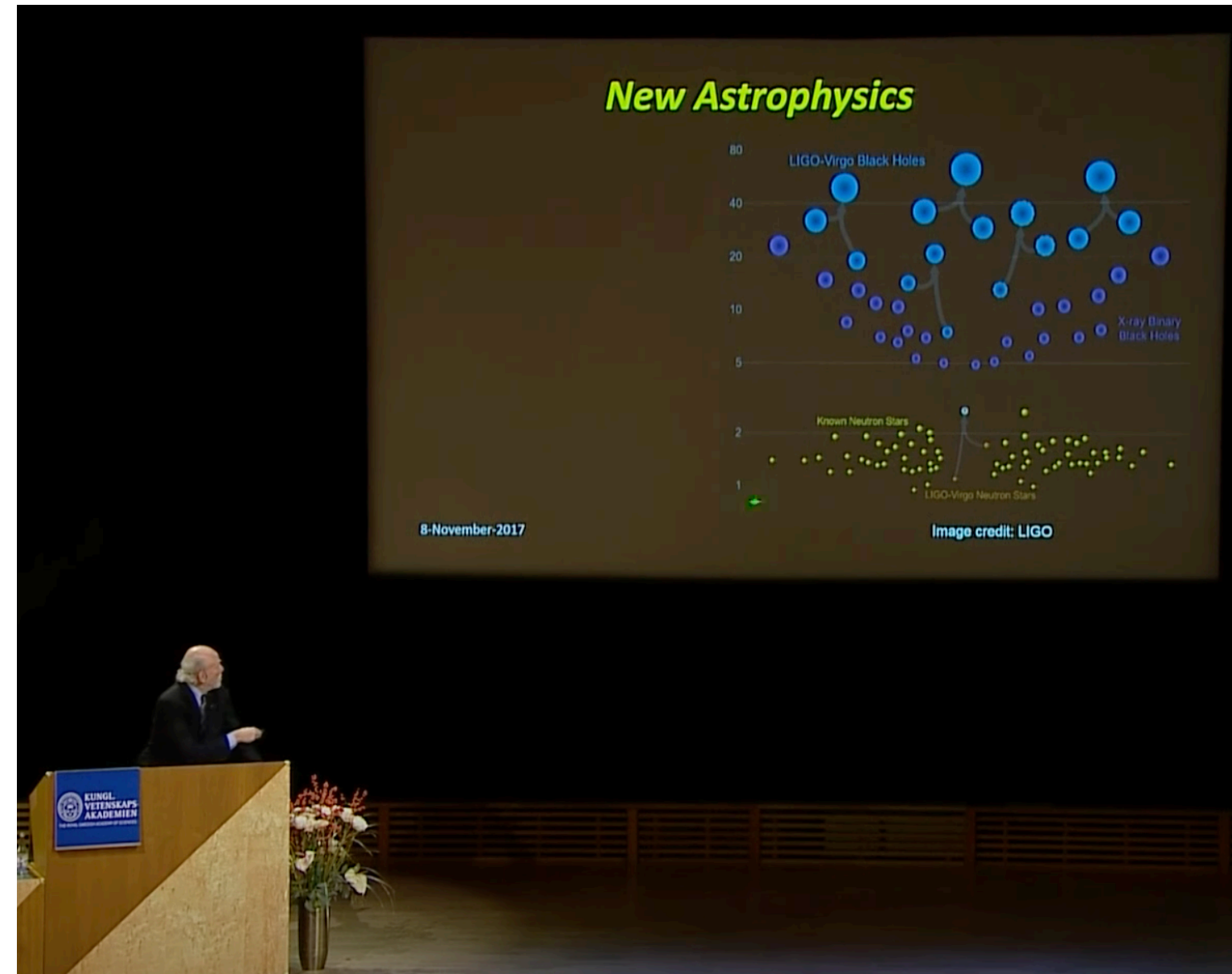Human-Computer Interaction Institute

My pre-phd work in visualization
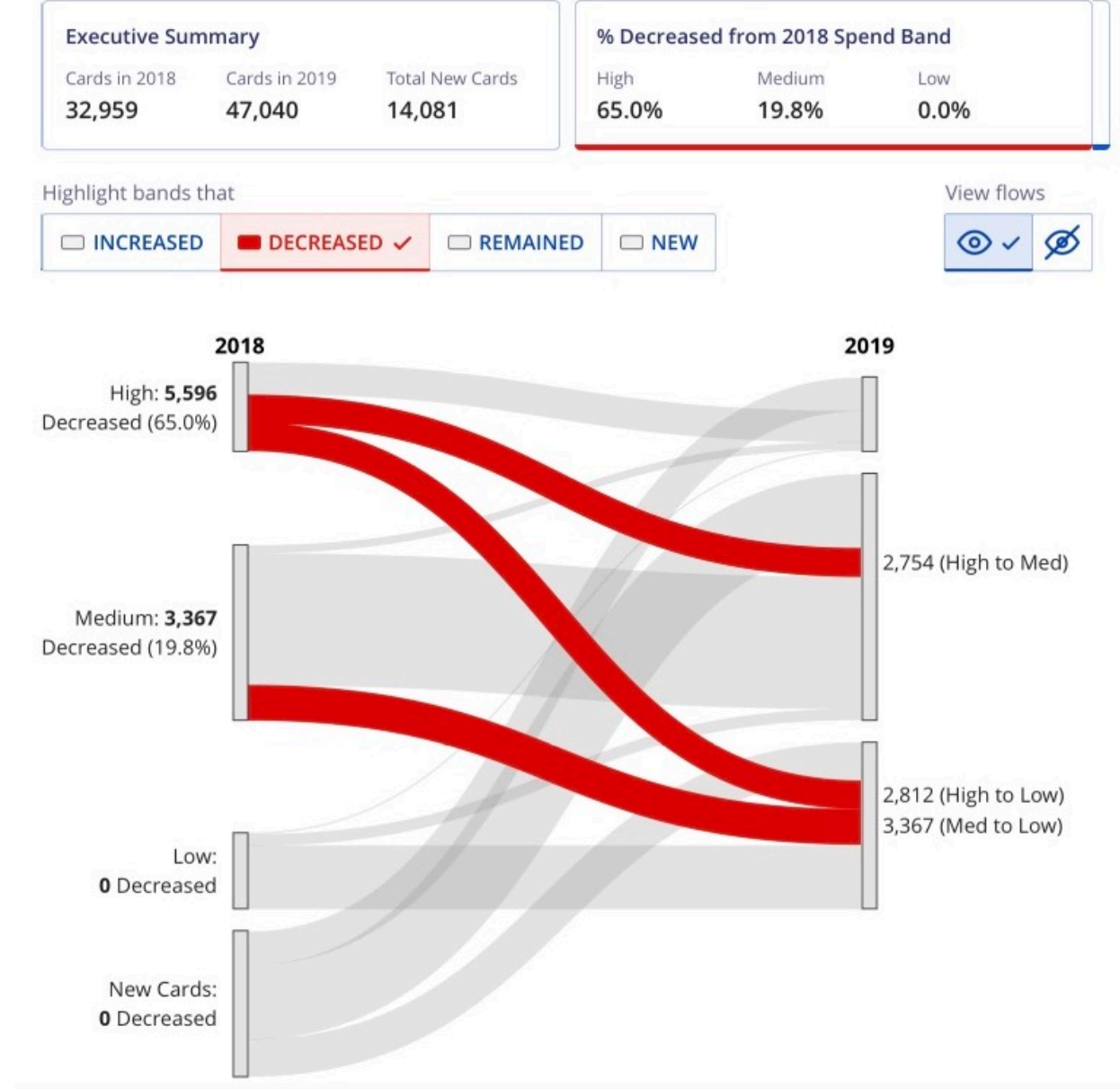## Industry and research engineering

Dense model visualizations
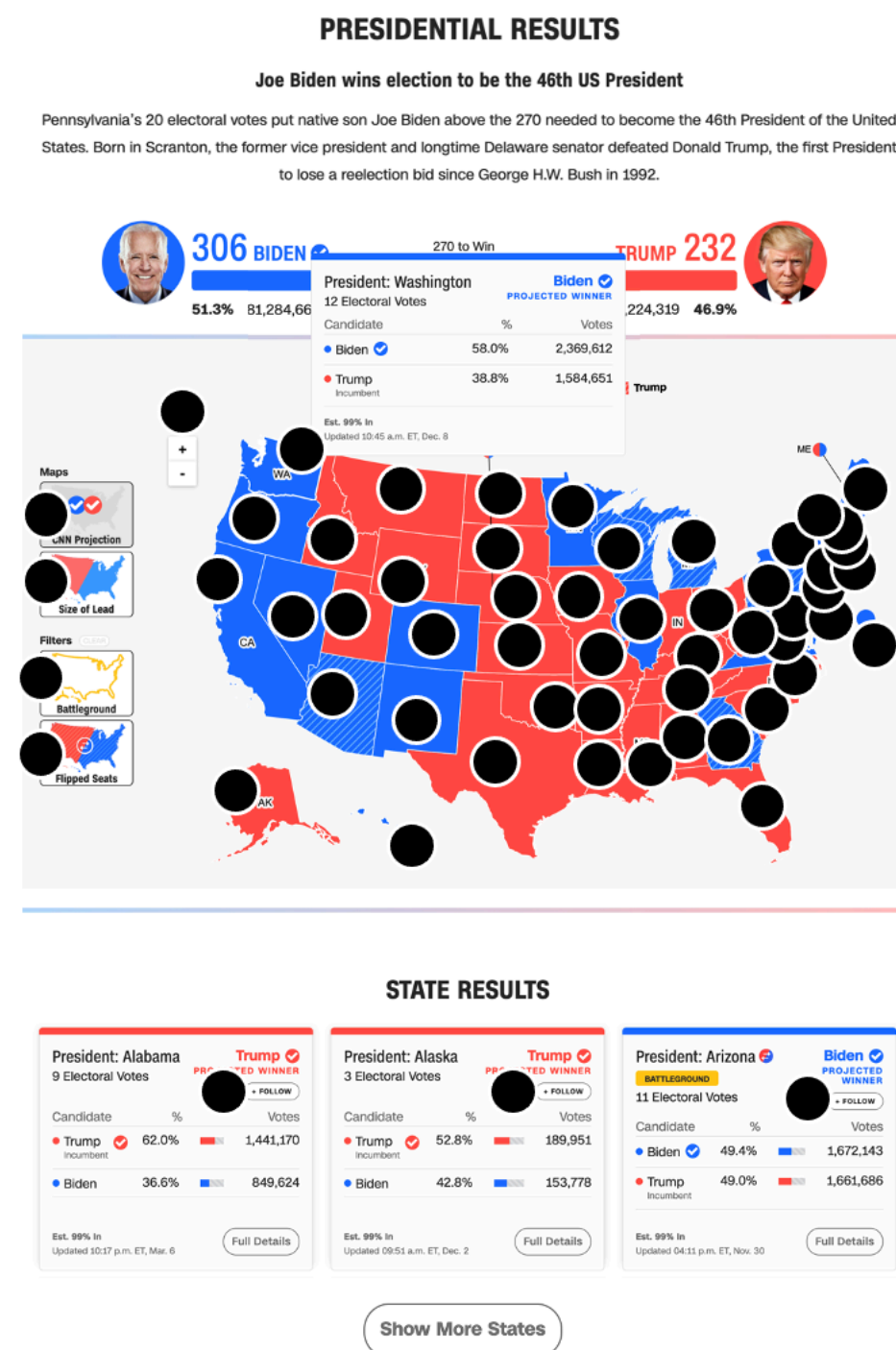

Domain-specific visualizations
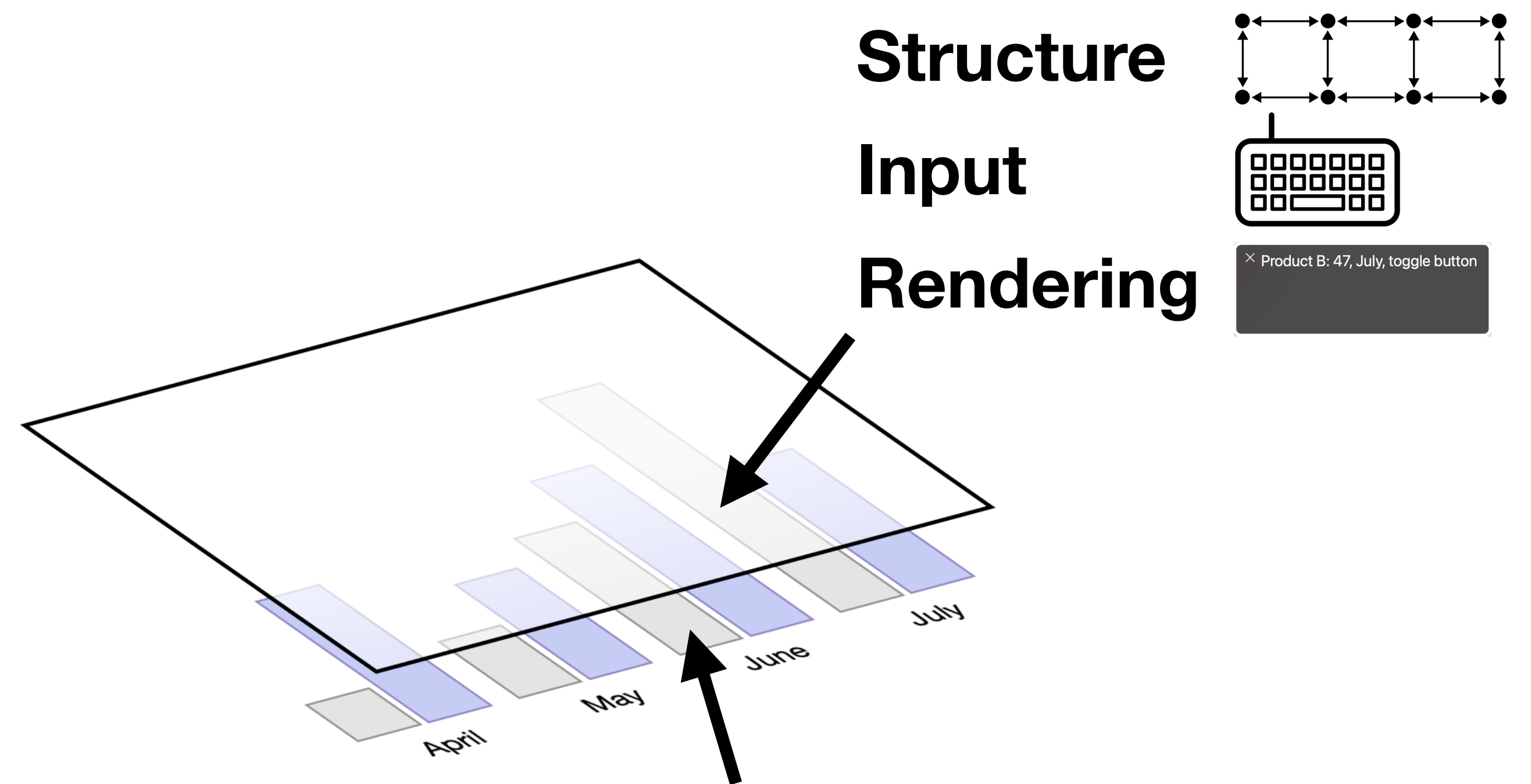

Data visualization library

What and how of visualization accessibility
(My recent research)

Chartability:
What are accessibility barriers?

Data Navigator:
How do we build accessible visualizations?

Structure

Input

Rendering

To any visualization toolkit

Chartability has helped me audit and train others
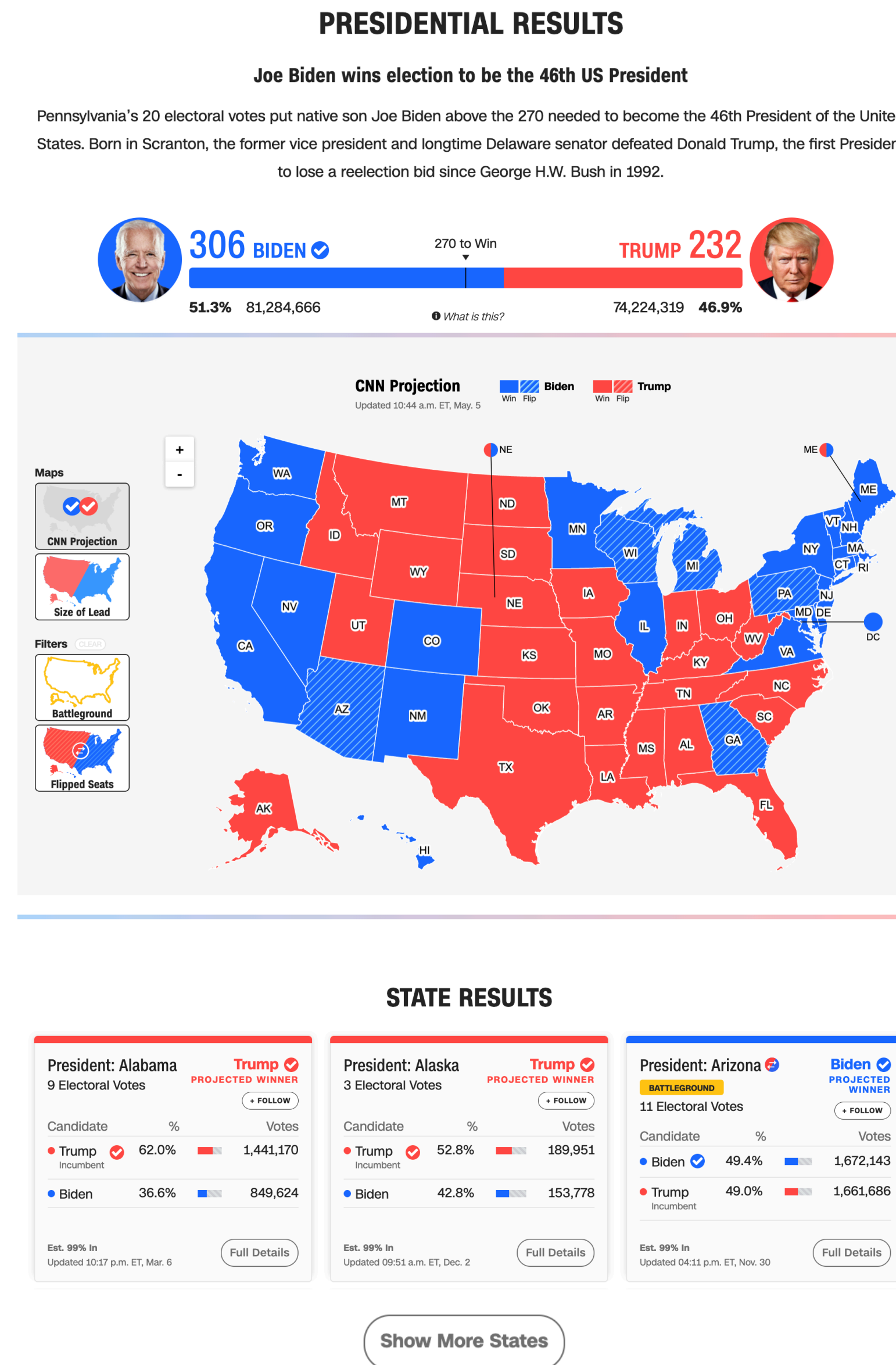
978 access failures found in ~60 minutes.

Perceivable:
6 – Low contrast
57 - Content is only visual
50 - Color alone is used
3 - Meaningful elements can be distinguished

Operable:
54 - Interaction modality only has one input type
58 - No interaction cues or instructions
5 - Low contrast on interactive elements
4 - Keyboard focus indicator missing
4 - Complex actions have no alternative
18 - Target pointer interaction is too small

Understandable:
4 - Interactive context is not clear
6 - Metrics or variables are undefined

PRESIDENTIAL RESULTS

Joe Biden wins election to be the 46th US President

Pennsylvania's 20 electoral votes put native son Joe Biden above the 270 needed to become the 46th President of the United States. Born in Scranton, the former vice president and longtime Delaware senator defeated Donald Trump, the first President to lose a reelection bid since George H.W. Bush in 1992.

306 BIDEN ✓   270 to Win   TRUMP 232
51.3% 81,284,666   ⓘ What is this?   74,224,319 46.9%

CNN Projection
Updated 10:44 a.m. ET, May. 5   Biden Win/Flip   Trump Win/Flip

STATE RESULTS

President: Alabama — Trump ✓ PROJECTED WINNER
9 Electoral Votes   + FOLLOW
Candidate   %   Votes
Trump Incumbent ✓   62.0%   1,441,170
Biden   36.6%   849,624
Est. 99% In
Updated 10:17 p.m. ET, Mar. 6   Full Details

President: Alaska — Trump ✓ PROJECTED WINNER
3 Electoral Votes   + FOLLOW
Candidate   %   Votes
Trump Incumbent ✓   52.8%   189,951
Biden   42.8%   153,778
Est. 99% In
Updated 09:51 a.m. ET, Dec. 2   Full Details

President: Arizona — Biden ✓ PROJECTED WINNER
BATTLEGROUND
11 Electoral Votes
Candidate   %   Votes
Biden ✓   49.4%   1,672,143
Trump Incumbent   49.0%   1,661,686
Est. 99% In
Updated 04:11 p.m. ET, Nov. 30   Full Details

Show More States

Robust:
275 - Does not conform to standards
82 - Semantically invalid
12 - Fragile technology support

Compromising:
54 - Information can only be reached through single process
61 - Information cannot be navigated according to narrative or structure

Assistive:
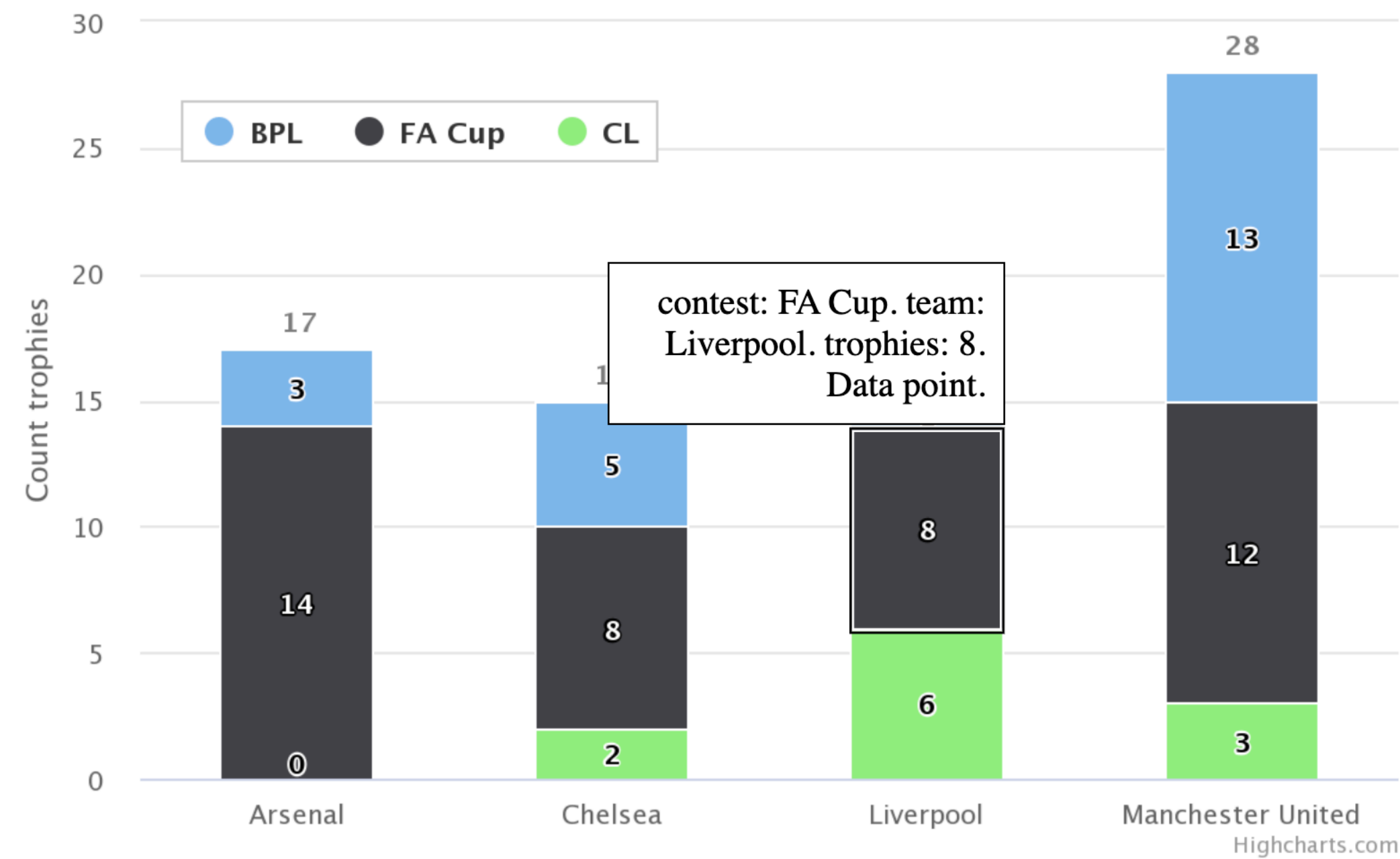101 - Navigation and interaction is tedious

Flexible:
2 - User style change not respected
121 - User text adjustments are not respected
1 - Scrolling experiences cannot be adjusted or opted out of Contrast and textures cannot be adjusted

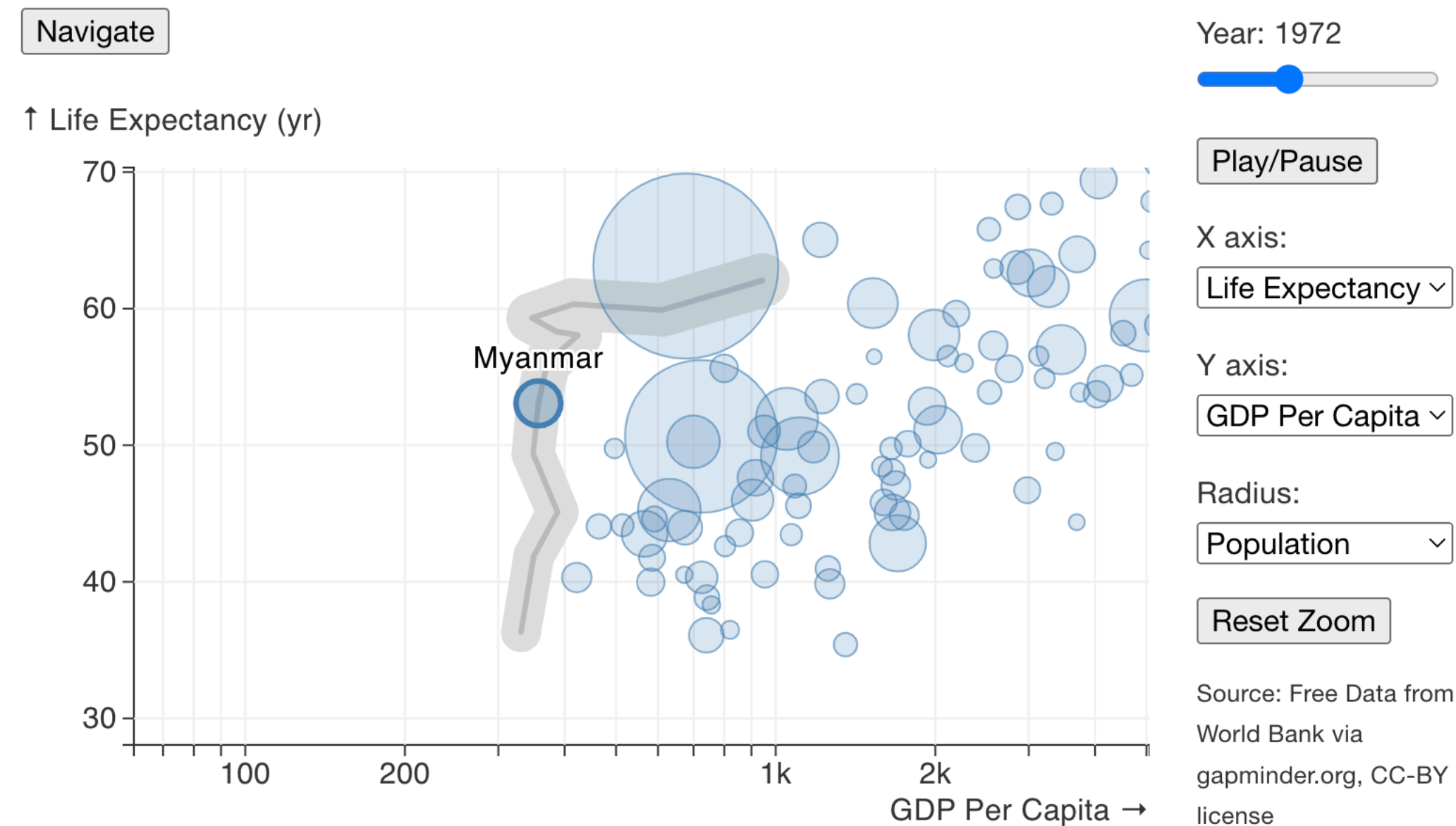# Data Navigator makes previously inaccessible formats more accessible

Interactive demo link

Data Navigator also opened up new collaborations

## Example: Accessible Gapminder Chart

Below is a responsive, screen-reader-navigable version of the chart shown on the homepage. Press Navigate to enter keyboard navigation. Or, change your "prefers reduced motion" system setting to see fade animations instead of motion.

Navigate

↑ Life Expectancy (yr)

Year: 1972

Play/Pause

X axis:
Life Expectancy ⌄

Y axis:
GDP Per Capita ⌄

Radius:
Population ⌄

Reset Zoom

Source: Free Data from World Bank via gapminder.org, CC-BY license

Myanmar 1972: GDP Per Capita is 357, Life Expectancy (yr) is 53.1, Population is 28,500,000. In 5 years, GDP Per Capita increases by 3.9% and Life Expectancy (yr) increases by 5.6%. left/right arrow to change country, up/down arrow to change year, space to summarize trend, backspace to return.

Interactive demo link

6
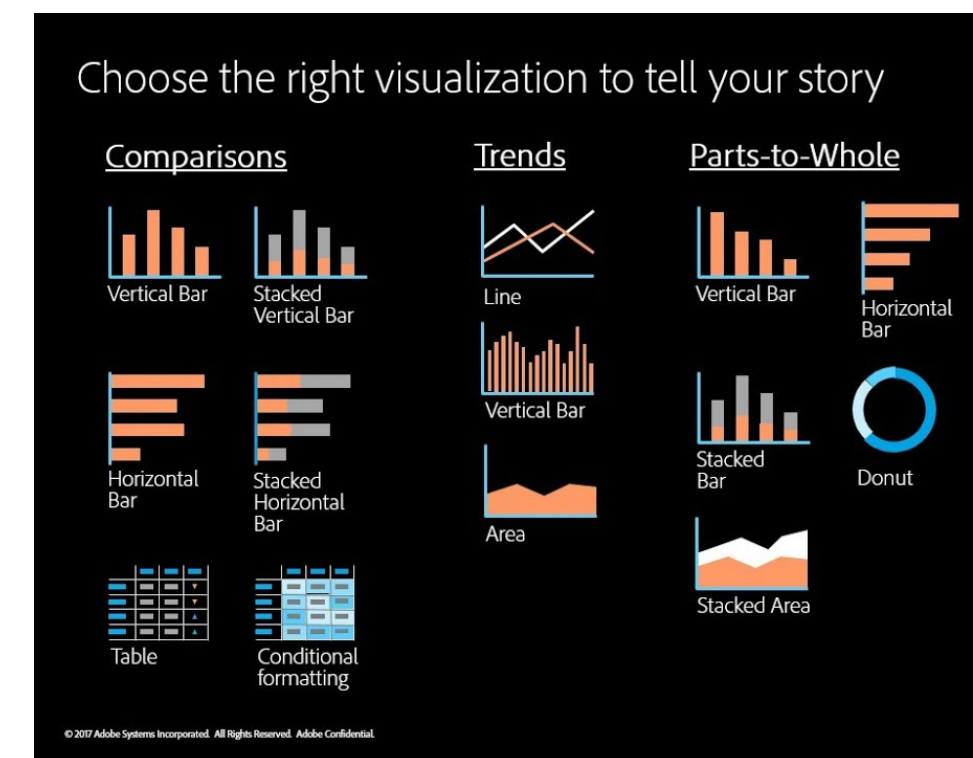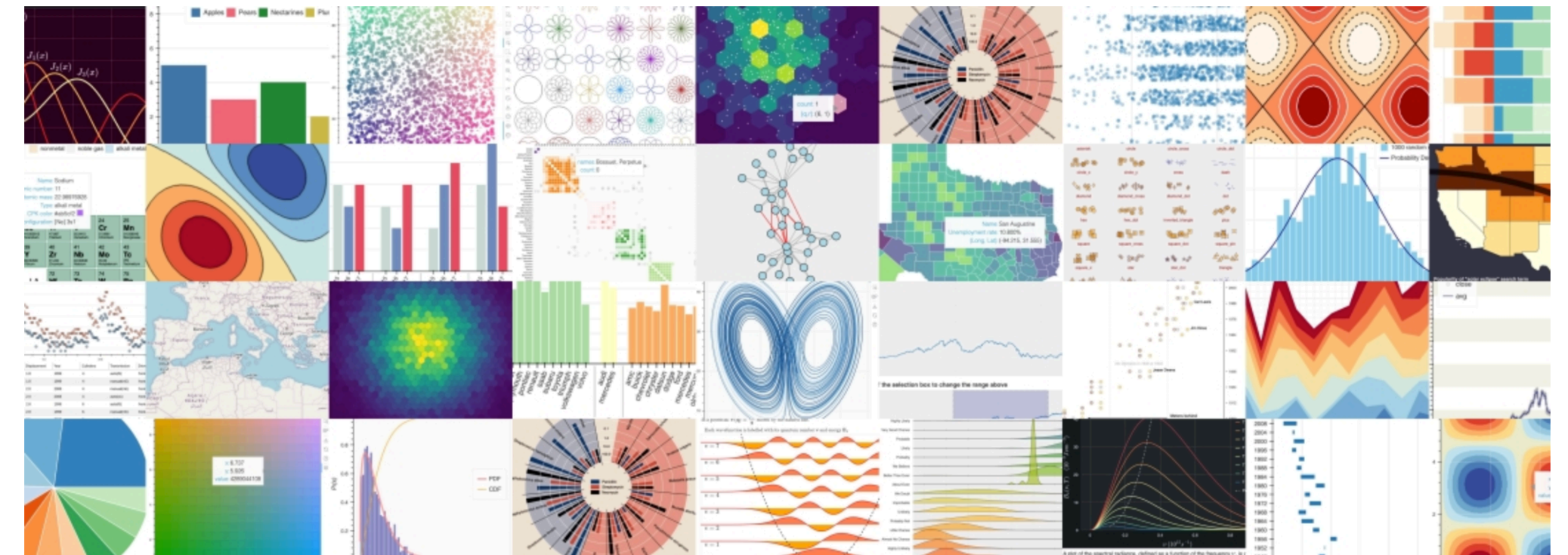
What are some "big-P" Problems in accessibility and visualization?

Problem 1: **Ability Assumptions** produce static systems

Ability Assumptions

(a)

Ability Assumptions

Burden
(b)
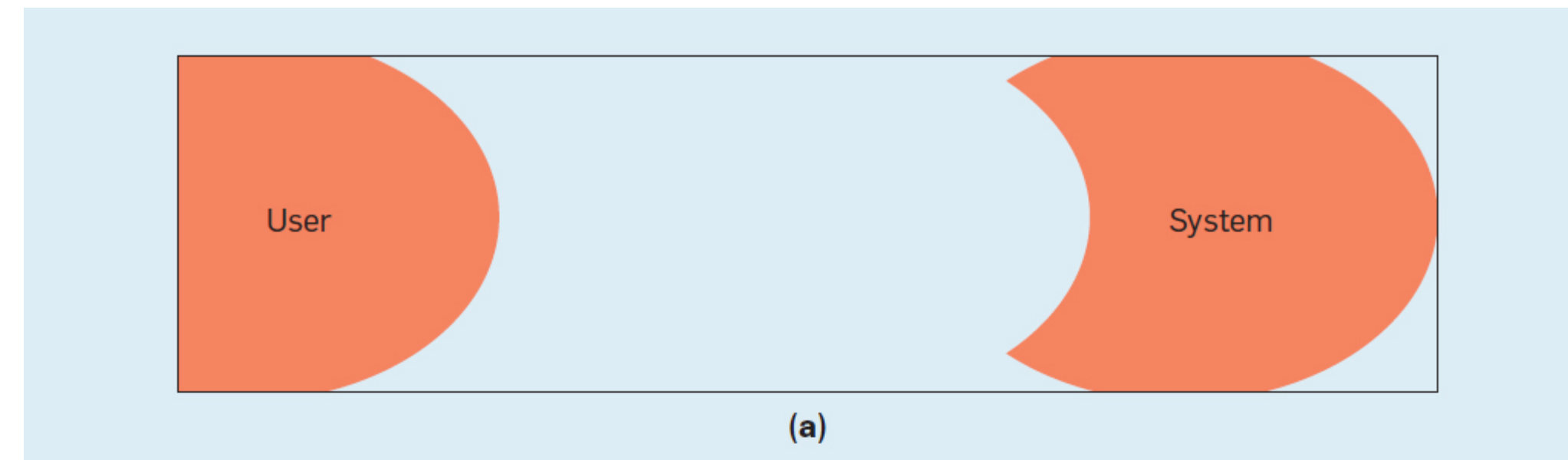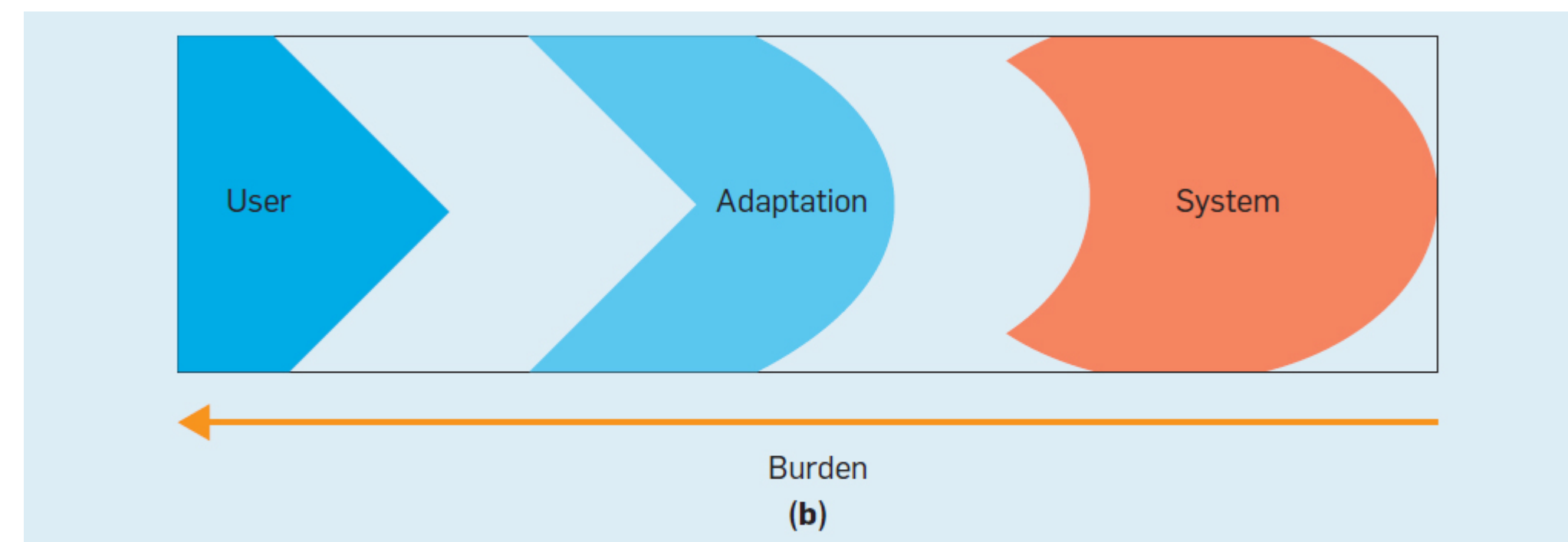
Ability Assumptions
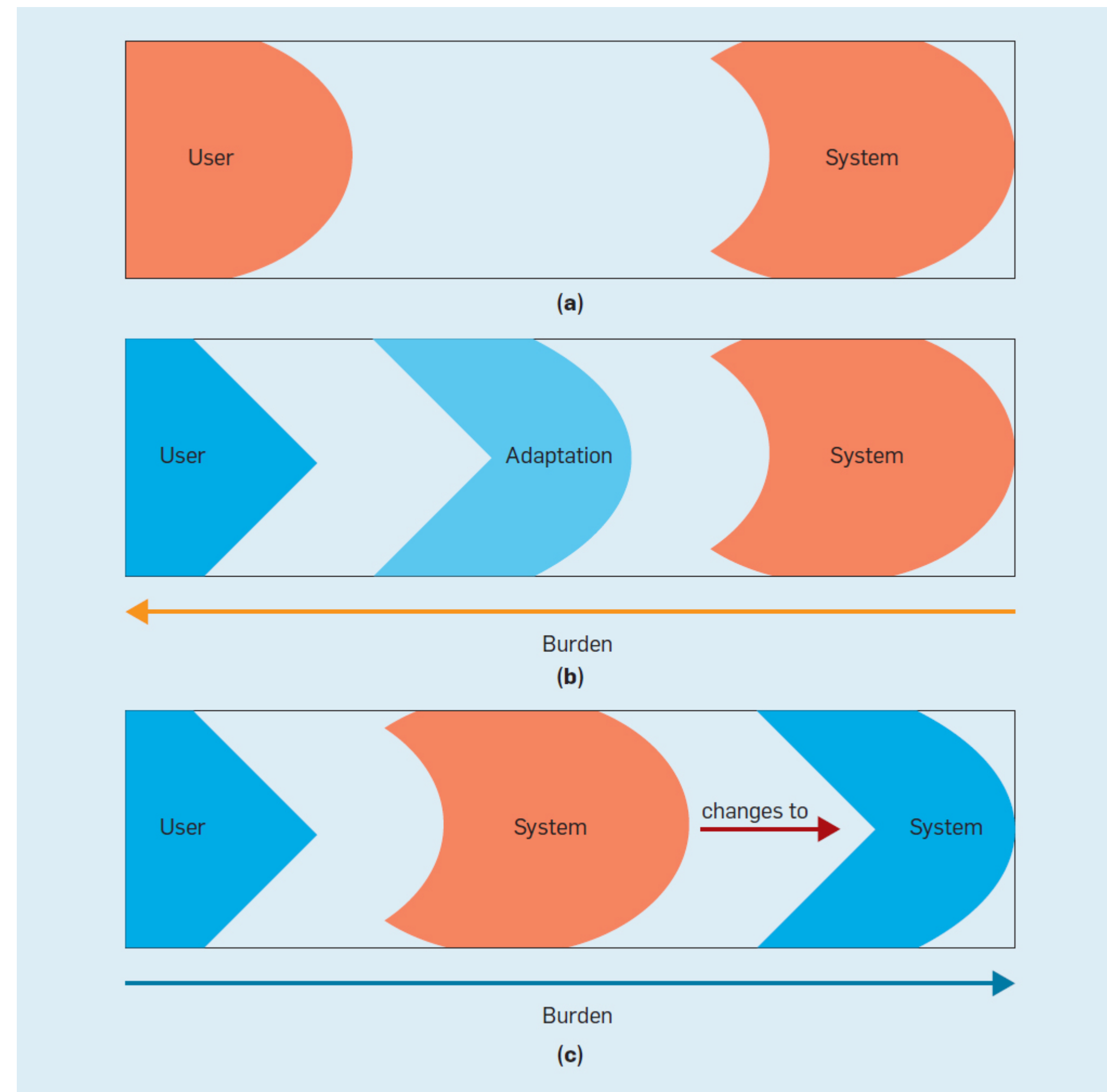
Problem 2: **Centering research** and development on screen readers (not blind people) limits what we can do

Accessible data *representation*
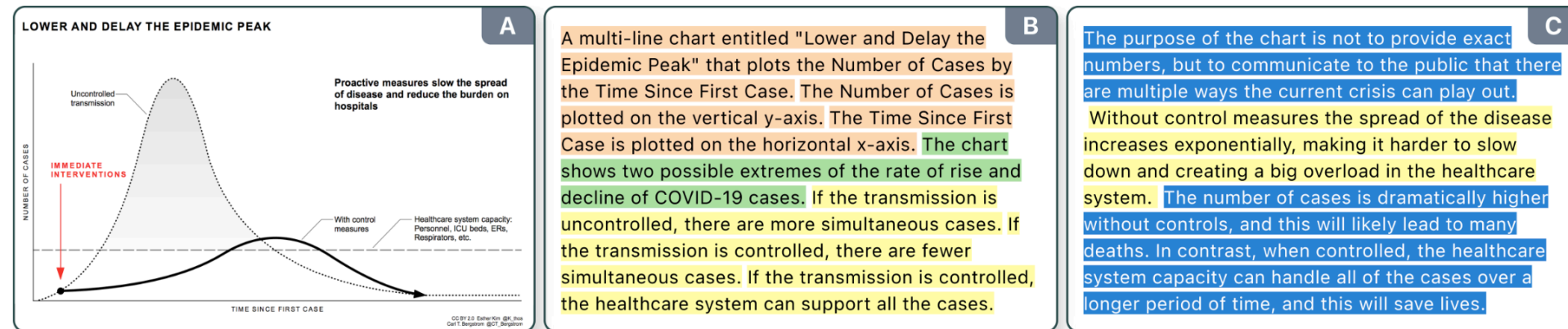
Accessible data *representation*
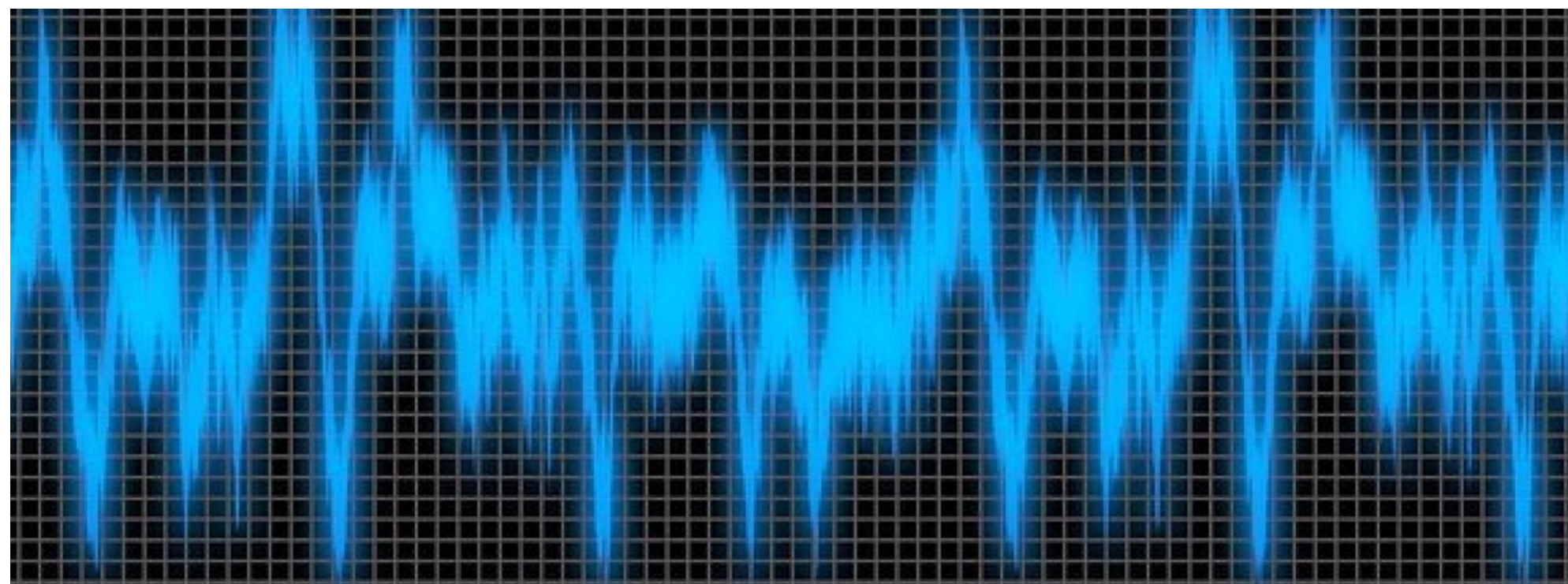
Descriptions

Long Description

Visualizations like "Flatten the Curve" (A) efficiently communicate critical public health information, while simultaneously excluding people with disabilities [11, 28]. To promote accessible visualization via natural language descriptions (B, C), we introduce a four-level model of semantic content. Our model categorizes and color codes sentences according to the semantic content they convey.

Image source

Accessible data *representation*

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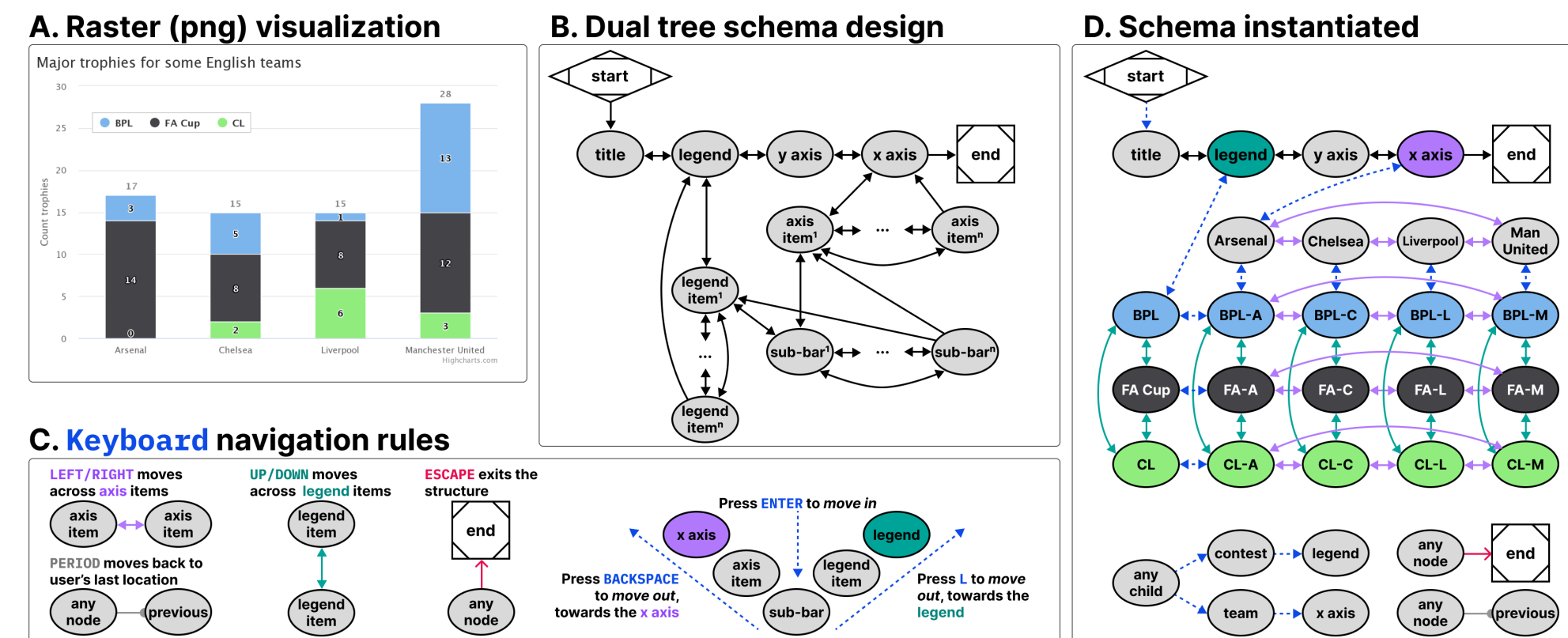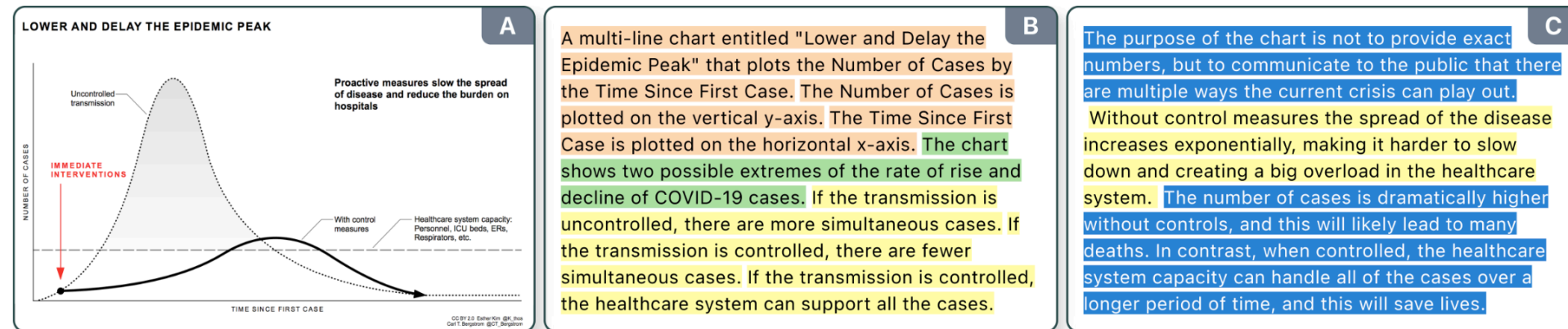
Image source

Structure

Image source

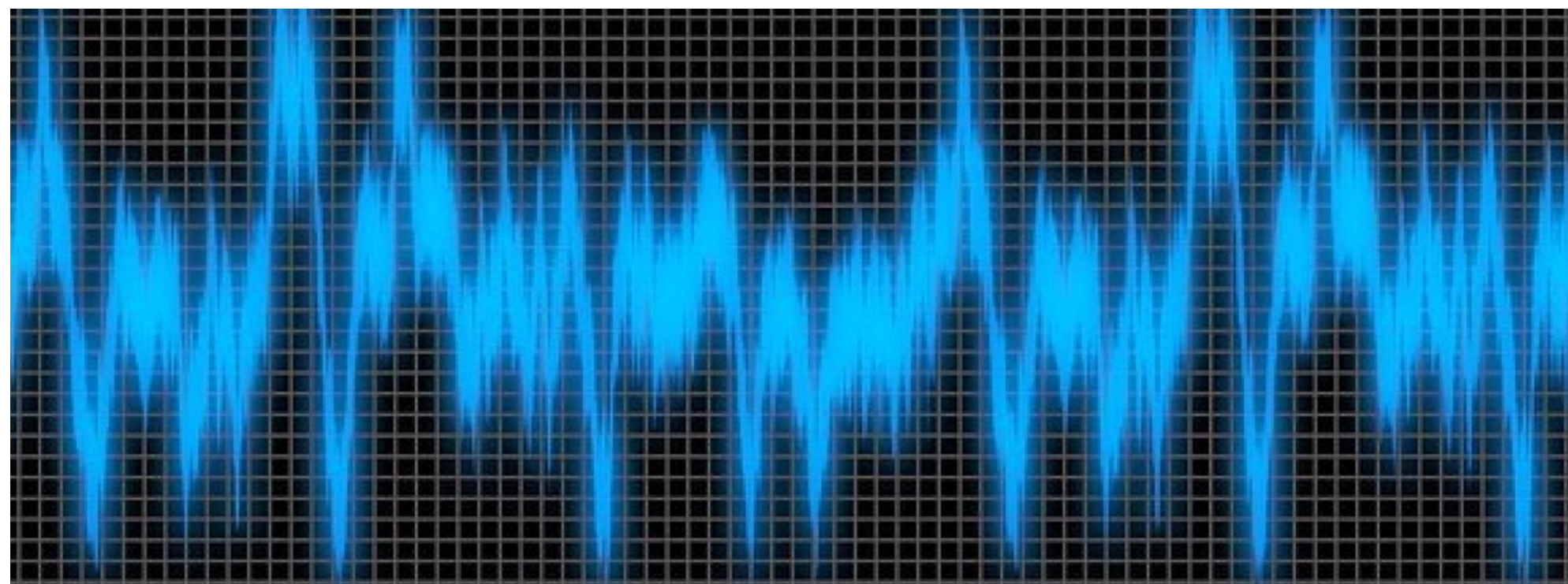# Accessible data *representation*

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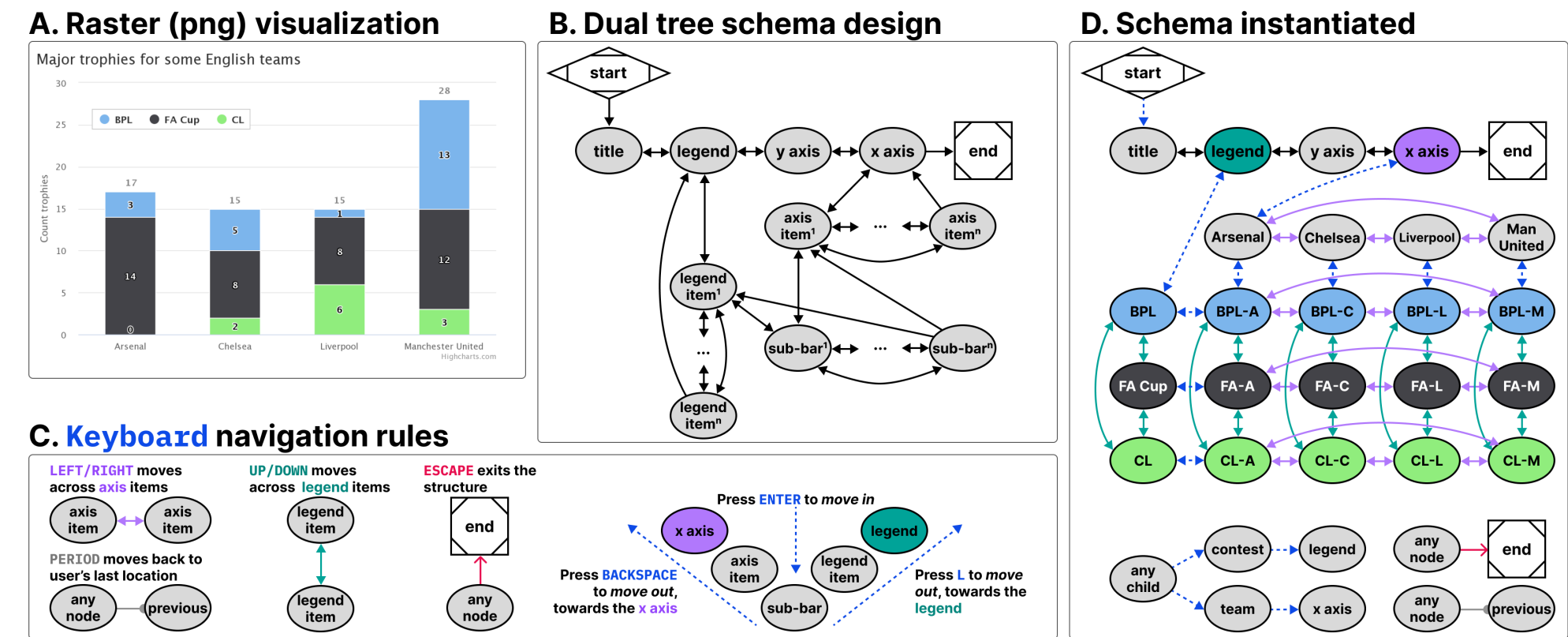
Image source

Structure

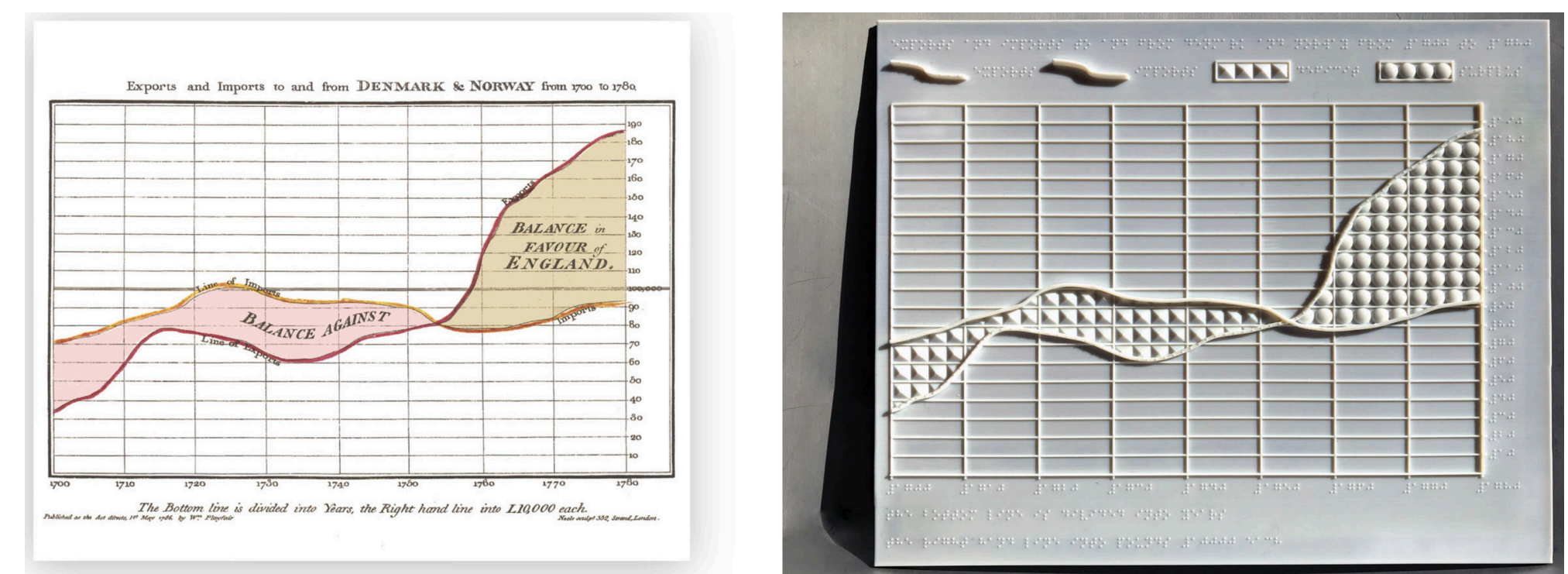Image source

Sonifications

Image source

Accessible data *representation*

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Image source

Structure

Image source

Sonifications

Image source

Tactiles

Image source

17

But what about *interactivity?*

Output has been our focus, primarily. But what about *input?*

But screen readers processes 1 input at a time

67 Nav points, ~32s

Movement between tasks becomes cognitively expensive

67 Nav points, ~32s

Auditory processing struggles with *dual-task* paradigms*

So what about cross-filtering?

Interactive link

So what about cross-filtering?
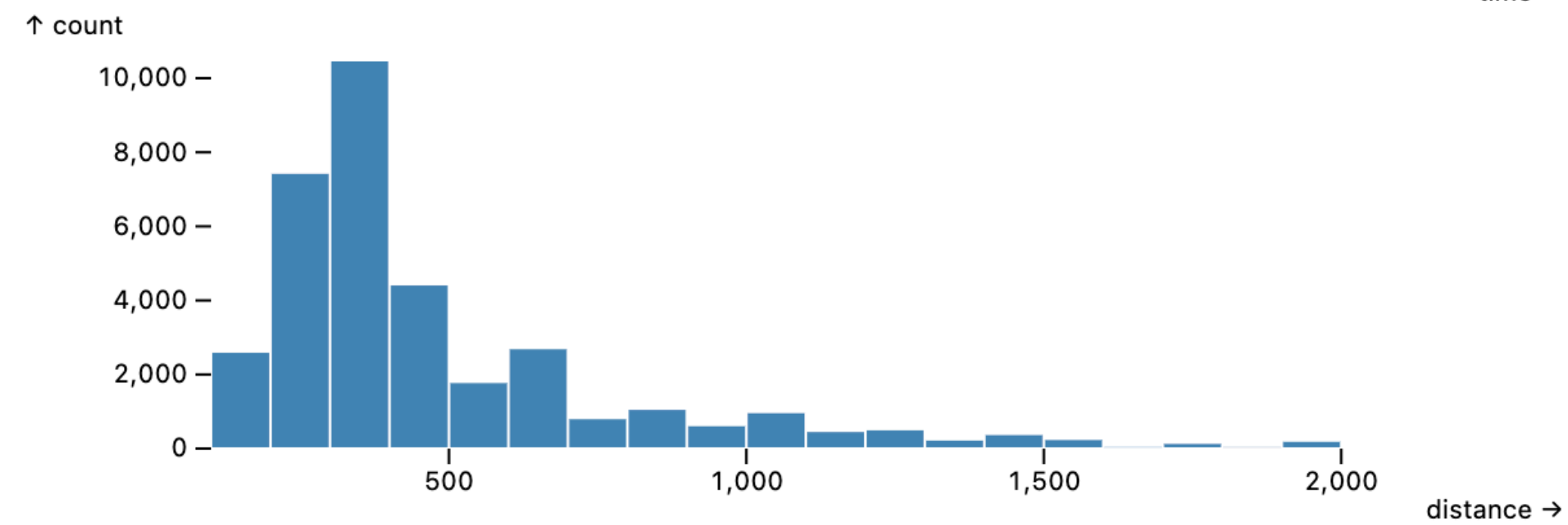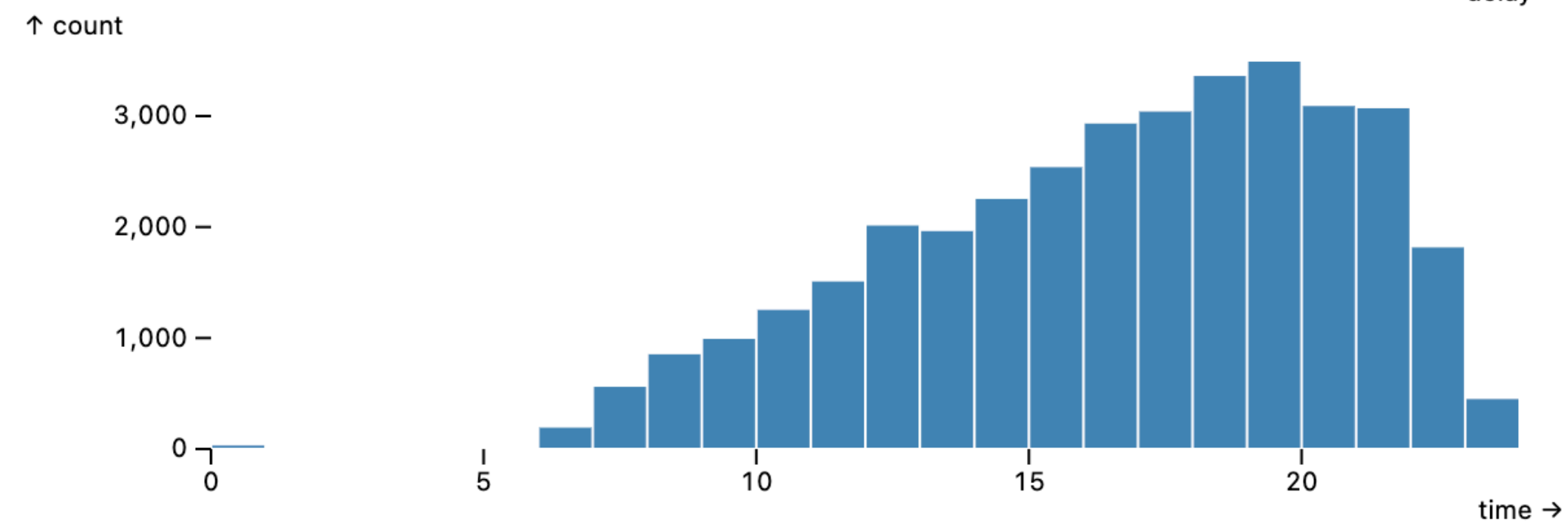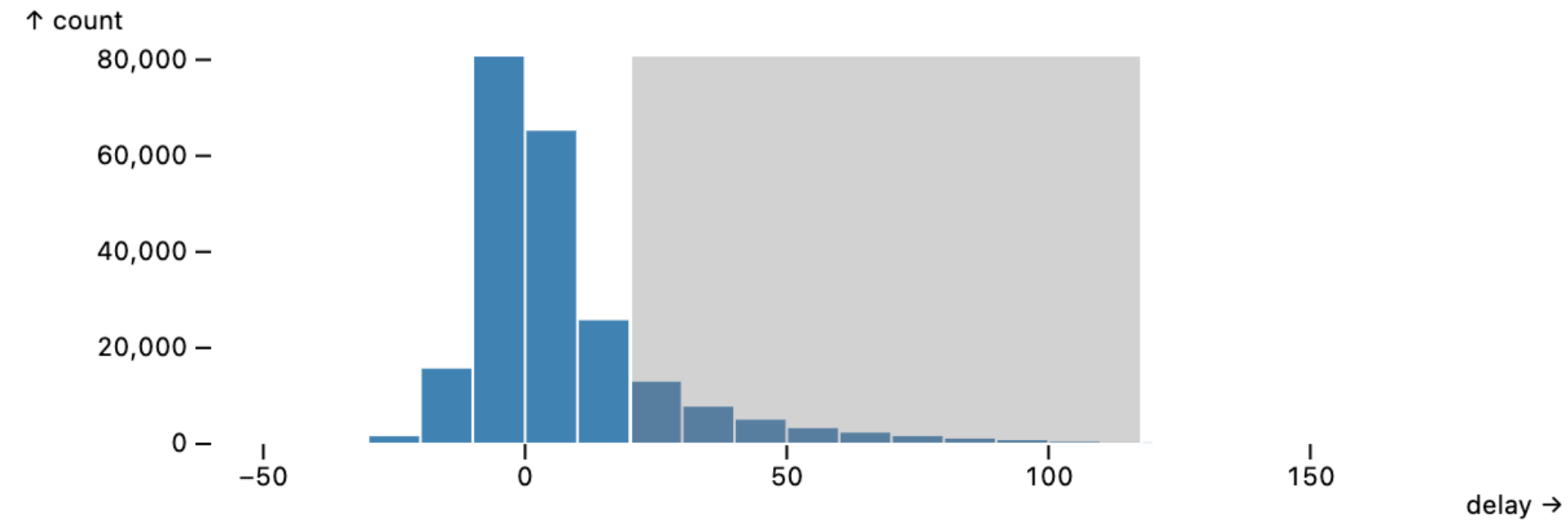
Interaction in one space…
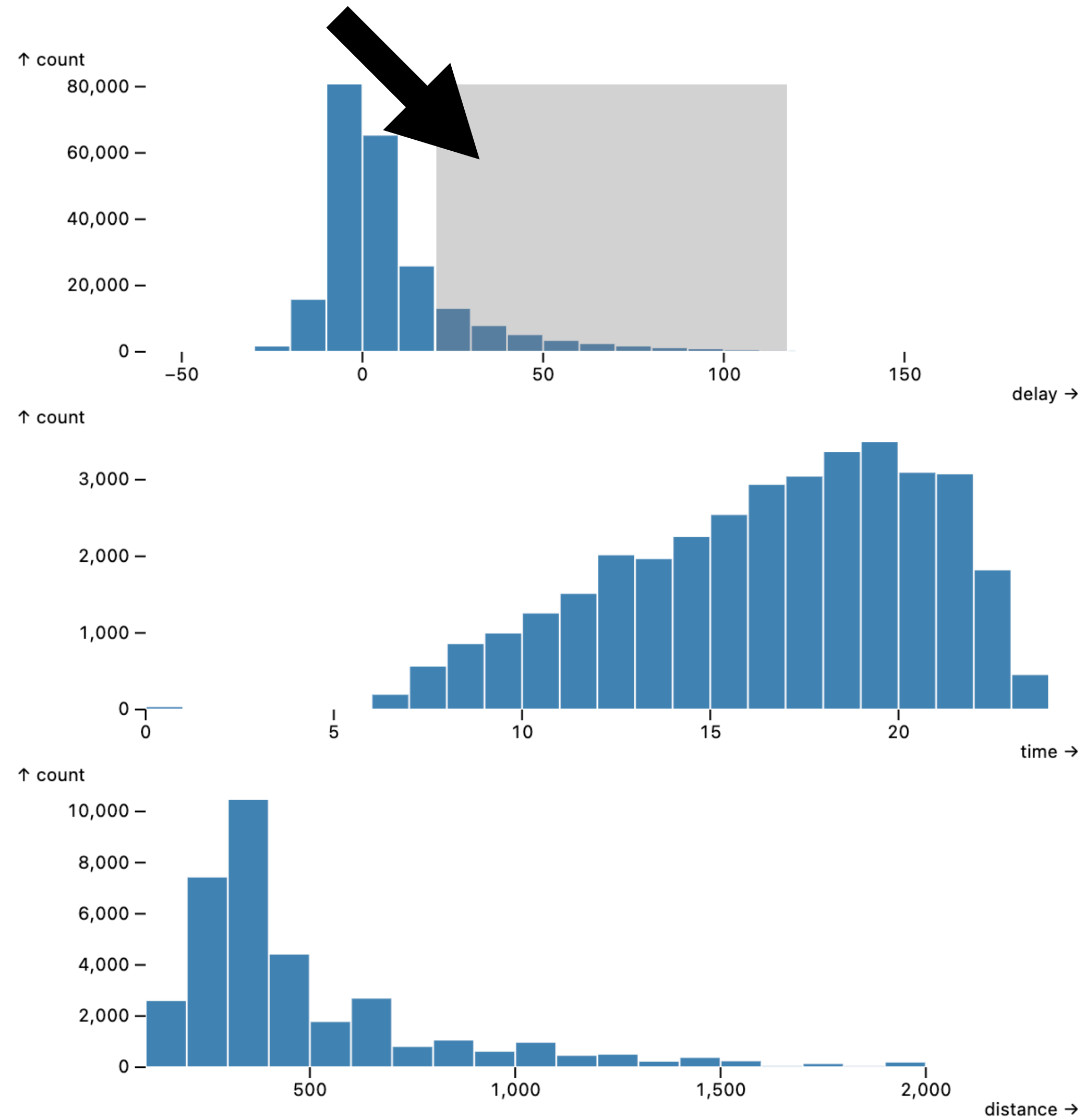
Produces simultaneous, coordinated change in another.
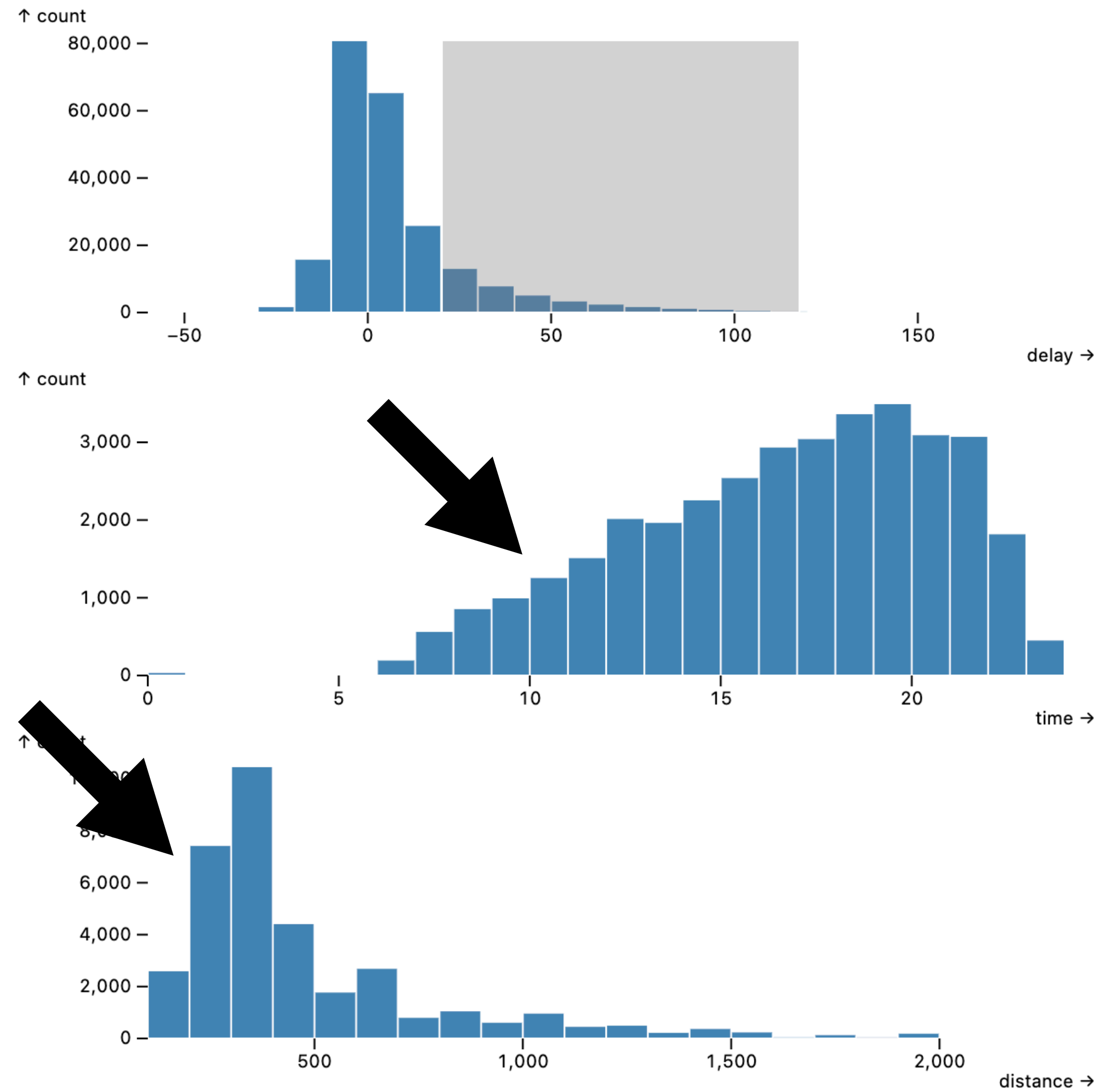
For blind users, descriptions, structural navigation, and sonifications will likely *not* solve this challenge.

Preliminary research question:

How do blind people interact with *multiple* tactile media simultaneously?

Observing: Embossed braille in a research context

Image source

Observation 1: Spatial memory storage

My friend didn't remember the details of a math equation exactly, but he knew *where* that equation was located in his stack of braille pages and *where* on the page the equation was.
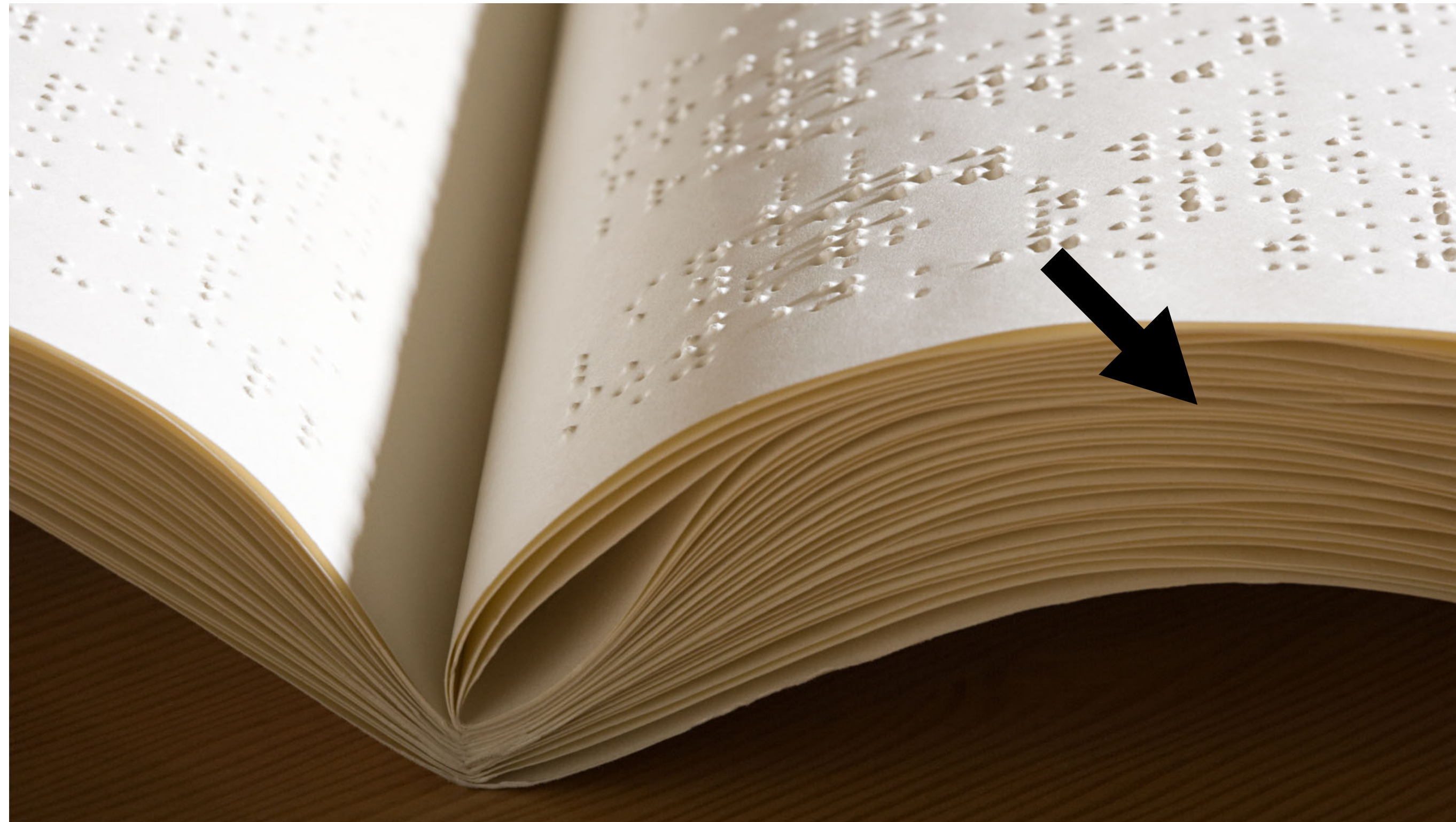
Image source

Observation 2: Coordinating perception and comparison

He then compared 2 equations at once. The details of each weren't important. He was *feeling* for differences simultaneously.

Prototype 2: the *cross-feelter*, 2 motorized faders

Casing

2 parallel motorized sliding faders

USB to computer

Schematic

Arduino

To computer

Motorized fader

Motorized fader
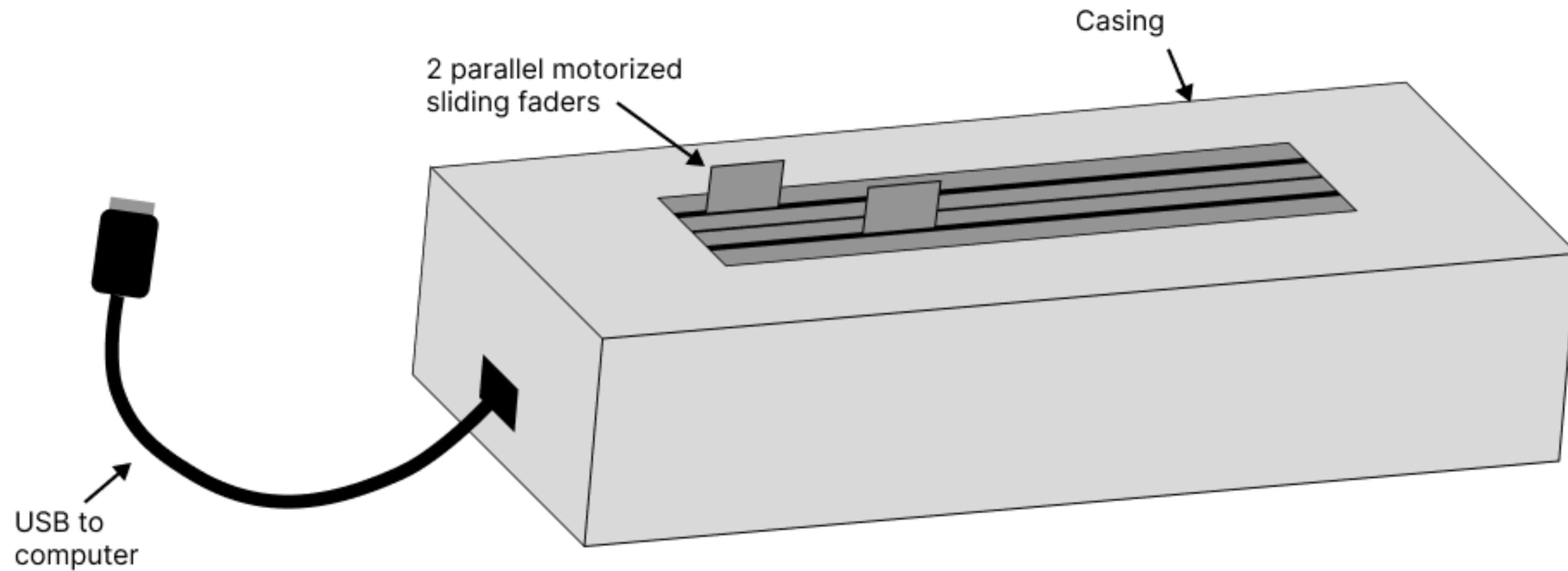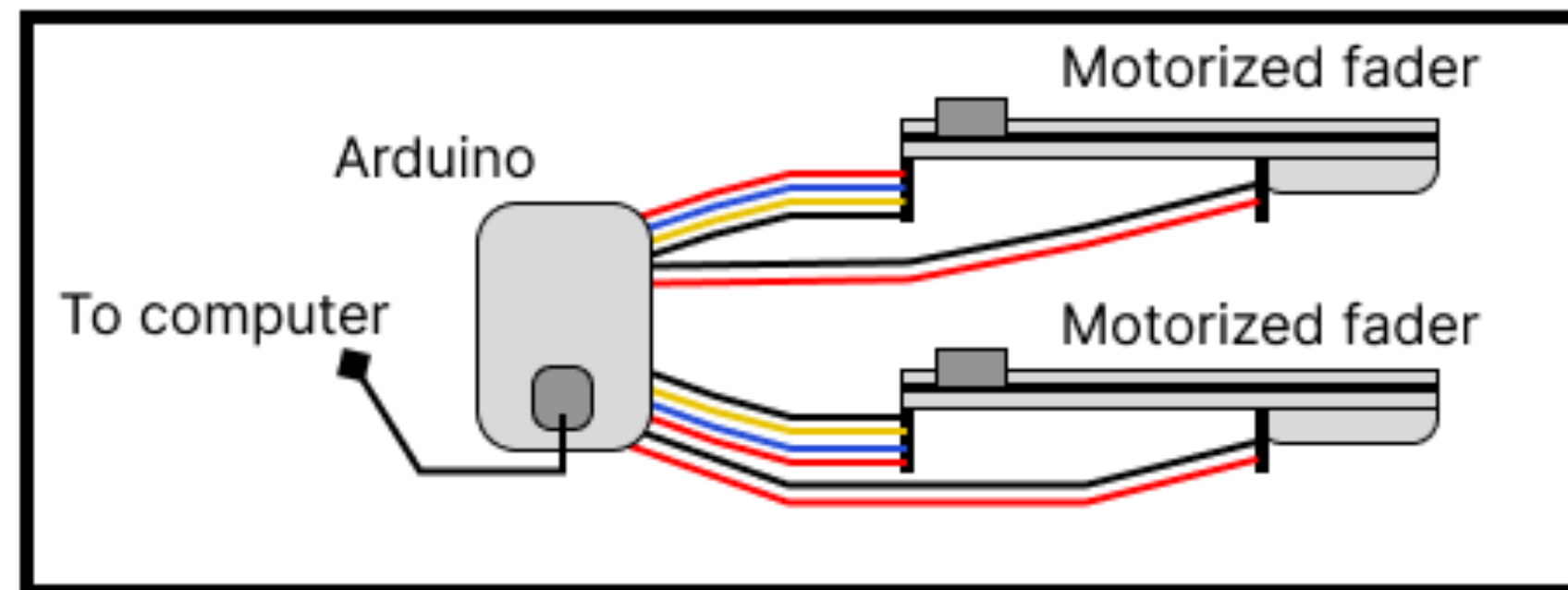
One slider can work with video

1. Video plays with progress slider moving

2. Slider follows, can be felt
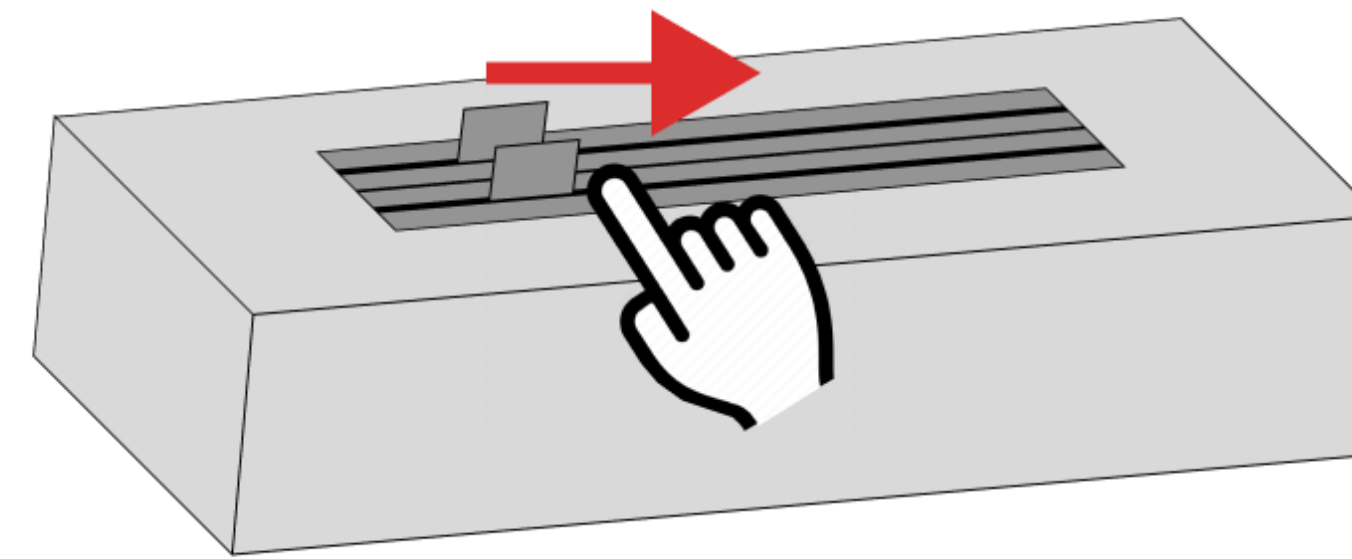
3. User can move slider
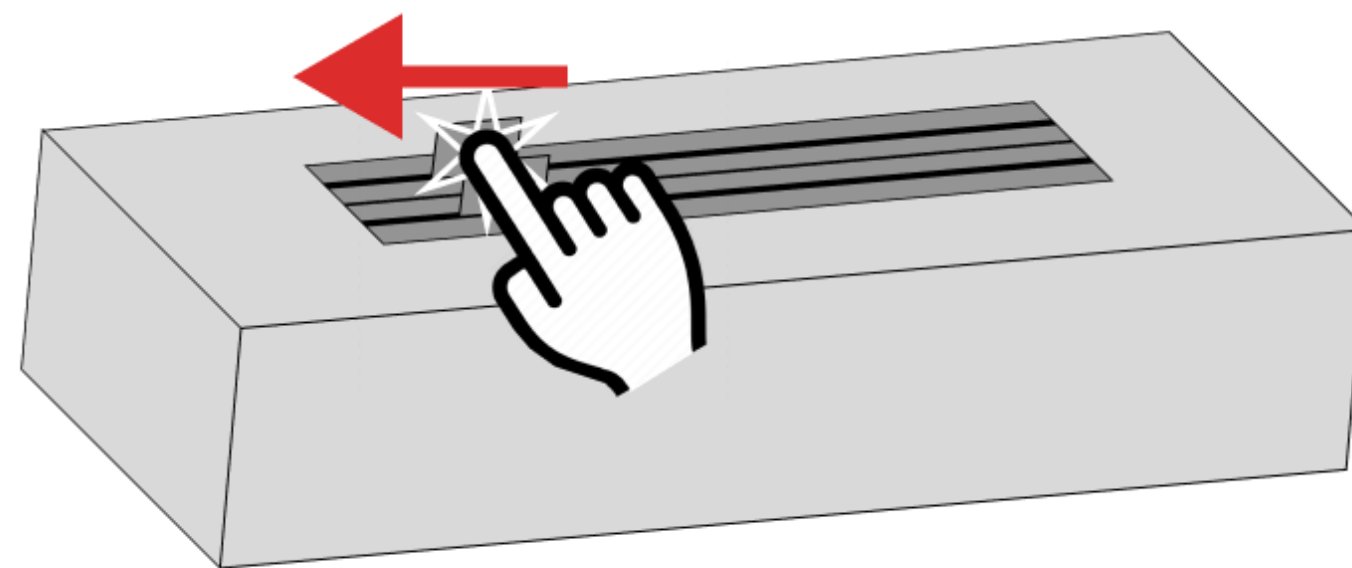
4. Video slider will move with slider change

While 2 sliders works for cross-filtering

1. User moves a slider
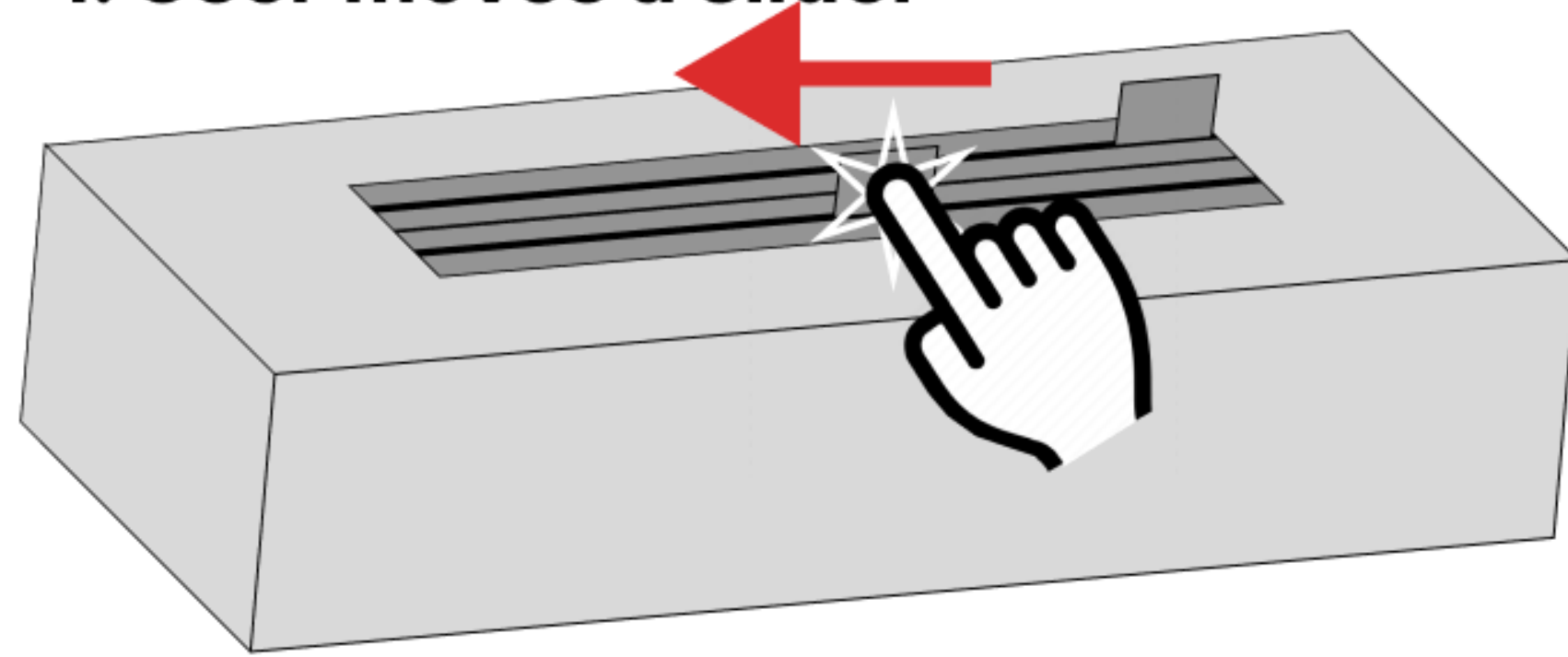
2. Corresponding filter edge moves with
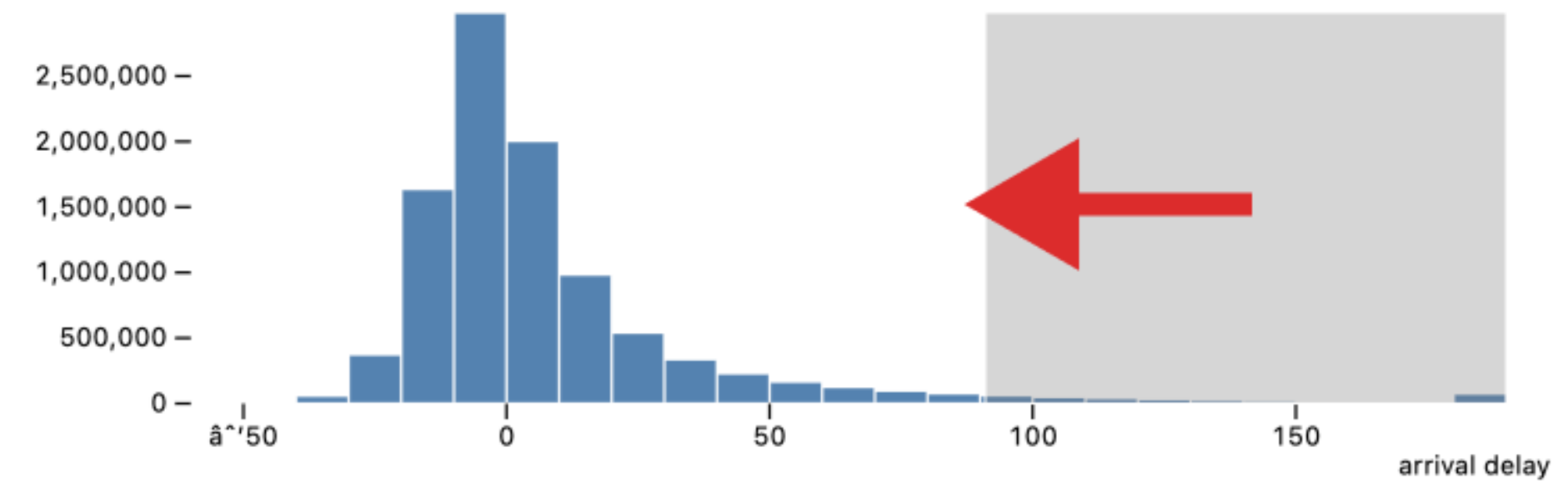
3. Secondary visualization updates
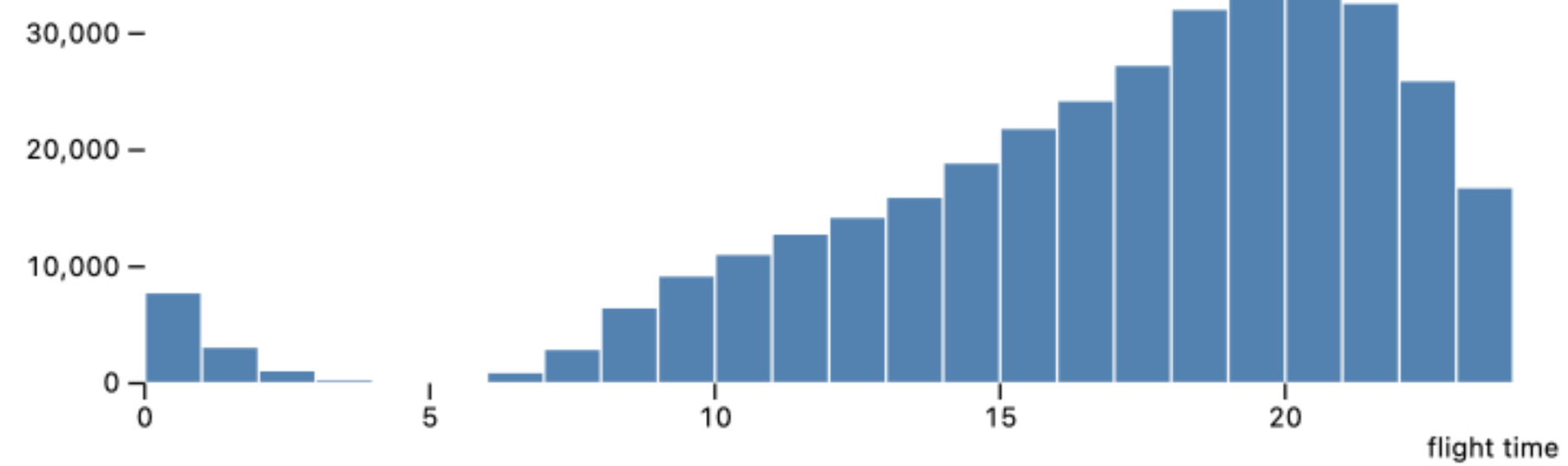
A tactile display can render the input *or* output chart

1. User moves a slider
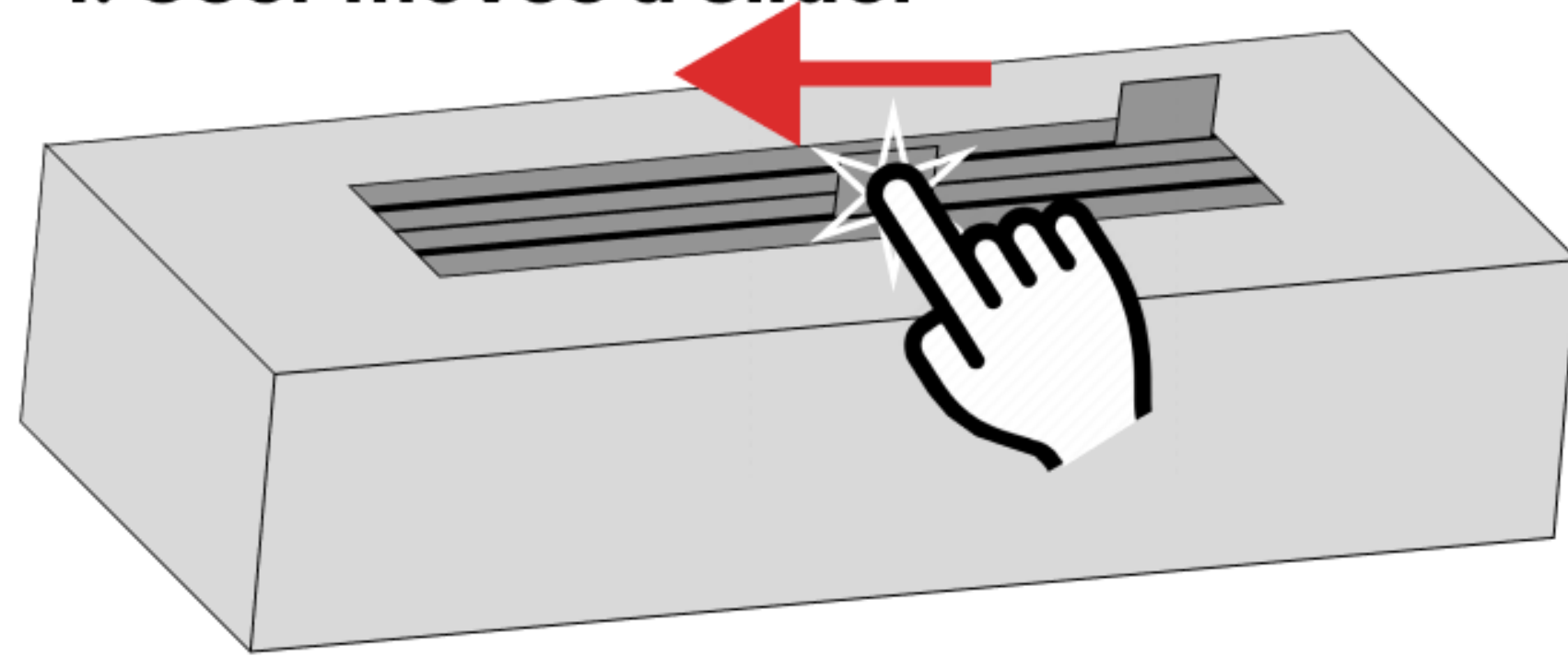
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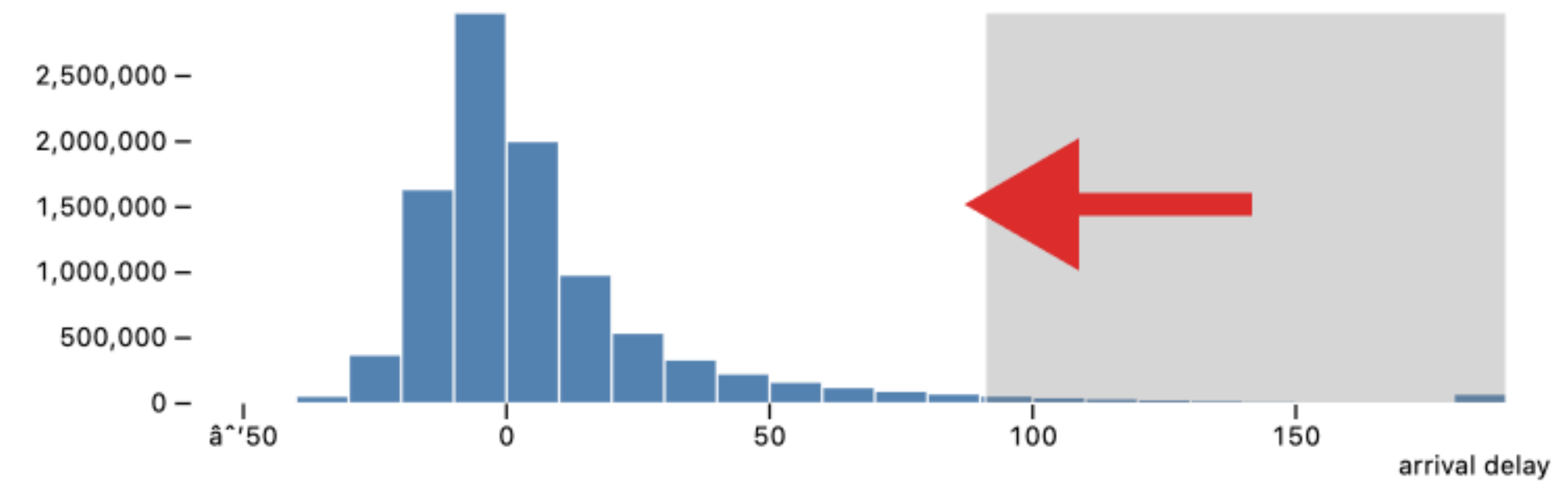
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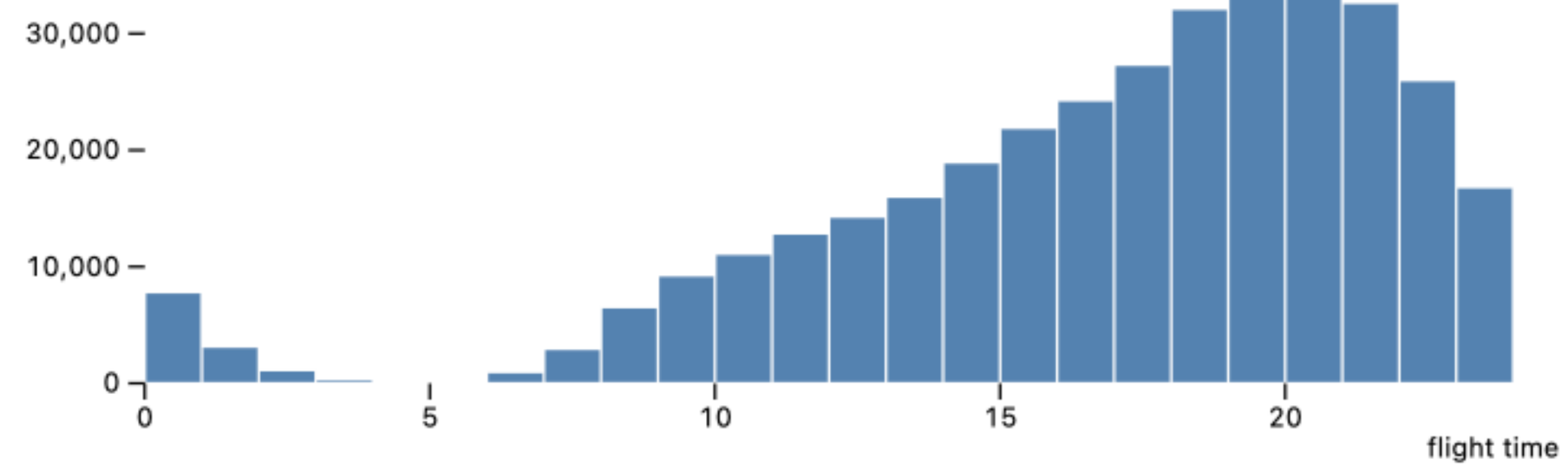
4. Tactile display renders

Cross-coordination! A tactile, dual-task paradigm.

User can interact with a space separate from their current focus!
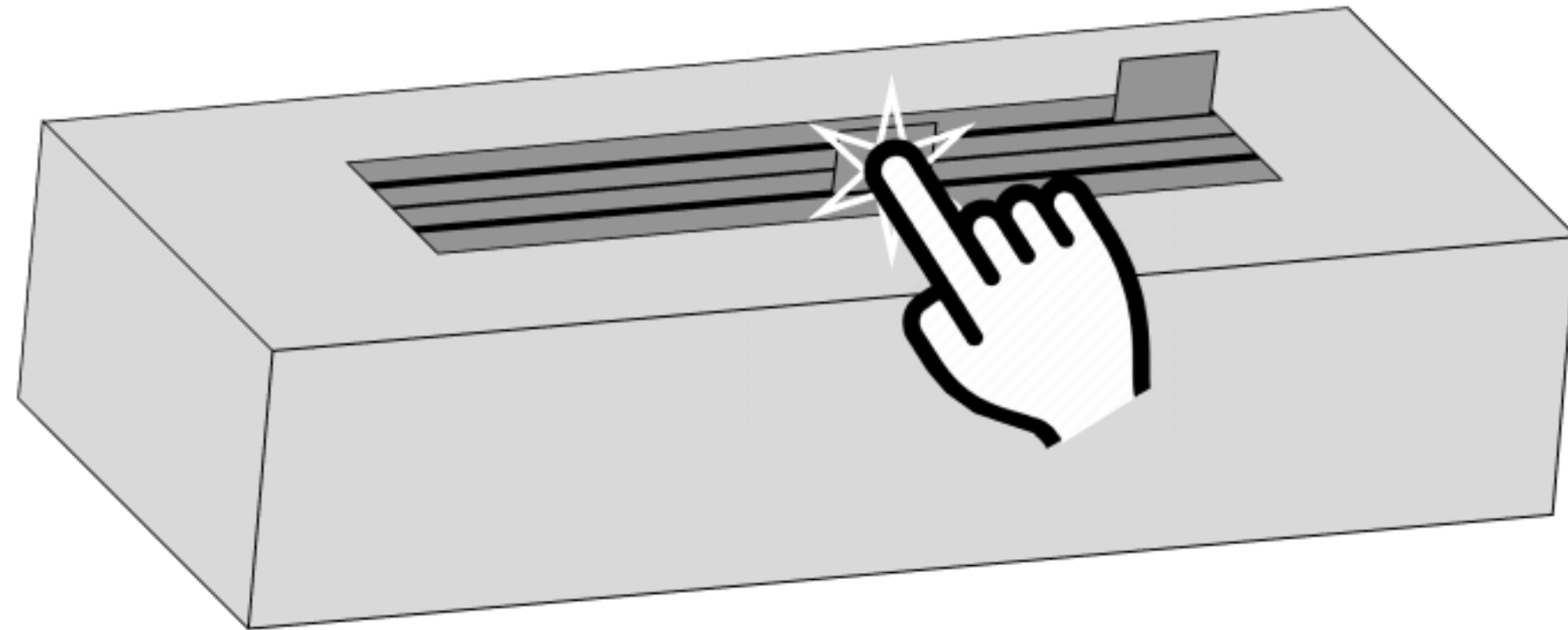
Problem 3: **Access Friction** is when accessibility for someone produces a barrier for others

What about this is accessible? Why?

Estimated US Energy Consumption in 2017

Source: Lawrence Livermore National Laboratory
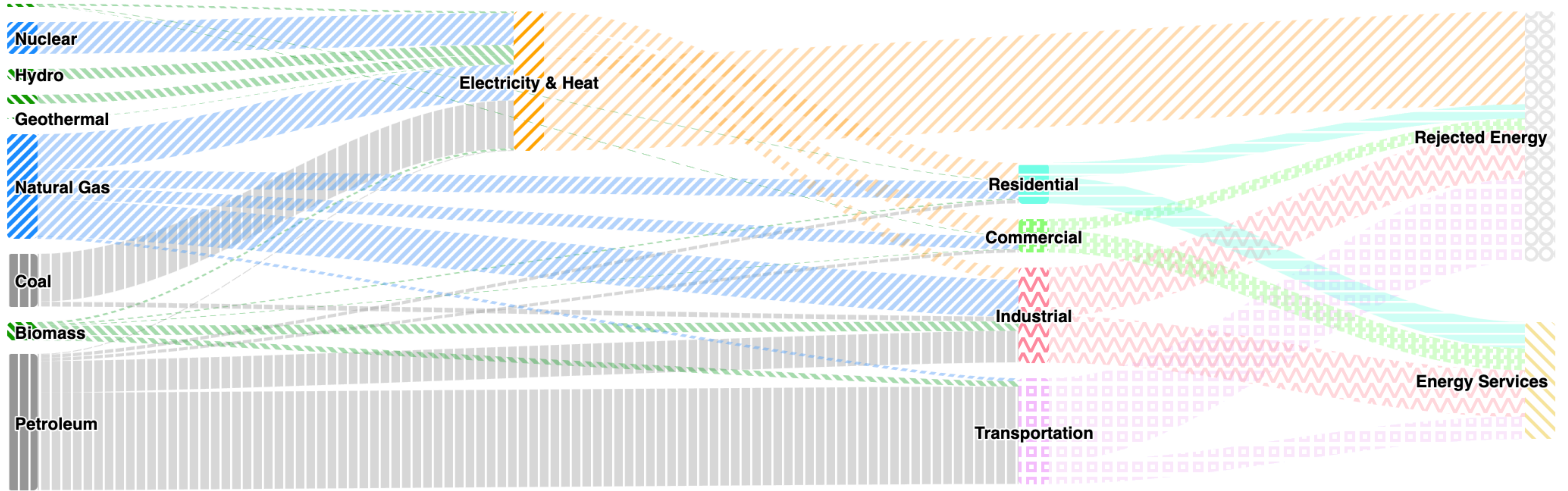
Sankey charts are used to visualize data flow and volume between nodes. The wider lines indicate larger volumes.

What about this might be a barrier? Why?

Estimated US Energy Consumption in 2017

Source: Lawrence Livermore National Laboratory

Nuclear

Hydro

Geothermal

Electricity & Heat

Rejected Energy

Natural Gas

Residential

Commercial

Coal

Industrial

Biomass

Energy Services

Petroleum

Transportation

Highcharts.com

Sankey charts are used to visualize data flow and volume between nodes. The wider lines indicate larger volumes.

What about this now might be a barrier?

Estimated US Energy Consumption in 2017

Source: Lawrence Livermore National Laboratory

Nuclear
Hydro
Geothermal
Natural Gas
Coal
Biomass
Petroleum

Electricity & Heat

Residential
Commercial
Industrial
Transportation

Rejected Energy
Energy Services

Highcharts.com

Sankey charts are used to visualize data flow and volume between nodes. The wider lines indicate larger volumes.

So some folks use tools to hack what they want
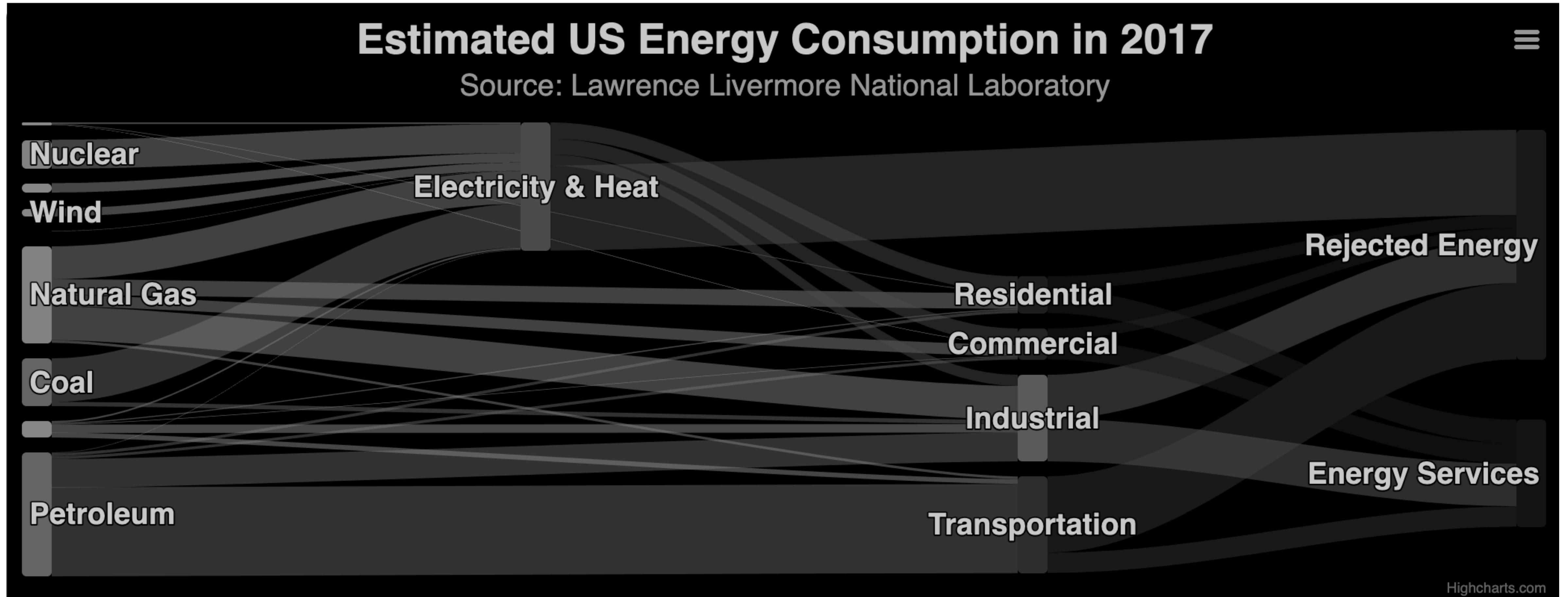
Estimated US Energy Consumption in 2017
Source: Lawrence Livermore National Laboratory

Nuclear
Wind
Natural Gas
Coal
Petroleum

Electricity & Heat
Residential
Commercial
Industrial
Transportation

Rejected Energy
Energy Services

Highcharts.com

Sankey charts are used to visualize data flow and volume between nodes. The wider lines indicate larger volumes.

What if we *let* users hack the design?

Preferences

Hide unavailable options ✅

▼ **Comprehension**
default ⦿   moderate ○   robust ○

   Alt text appearance
   default ⦿   show high level ○   show all ○

   ▶ **Description verbosity**
   default ○   disable ⦿   minimal ○   verbose ○

▼ **Text**
default ○   minimalist ⦿   moderate ○   maximalist ○

   ▼ **Font Size**
   default ○   small ⦿   medium ○   large ○

      Title
      default ○   small ○   small+ ⦿   medium ○   medium+ ○   large ○
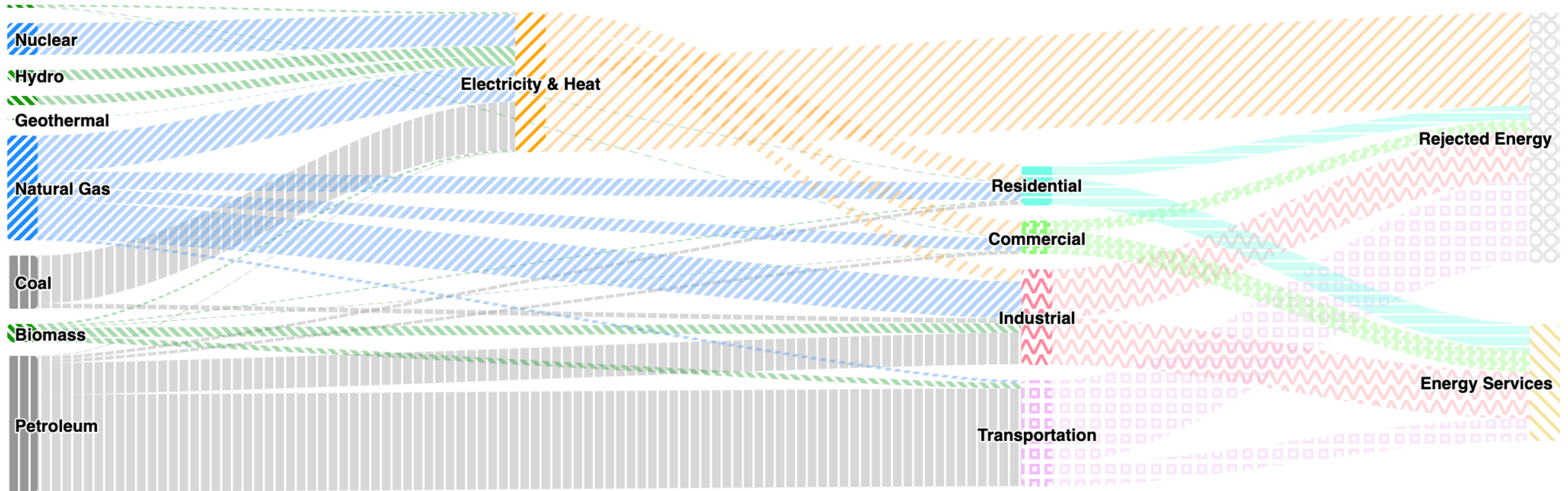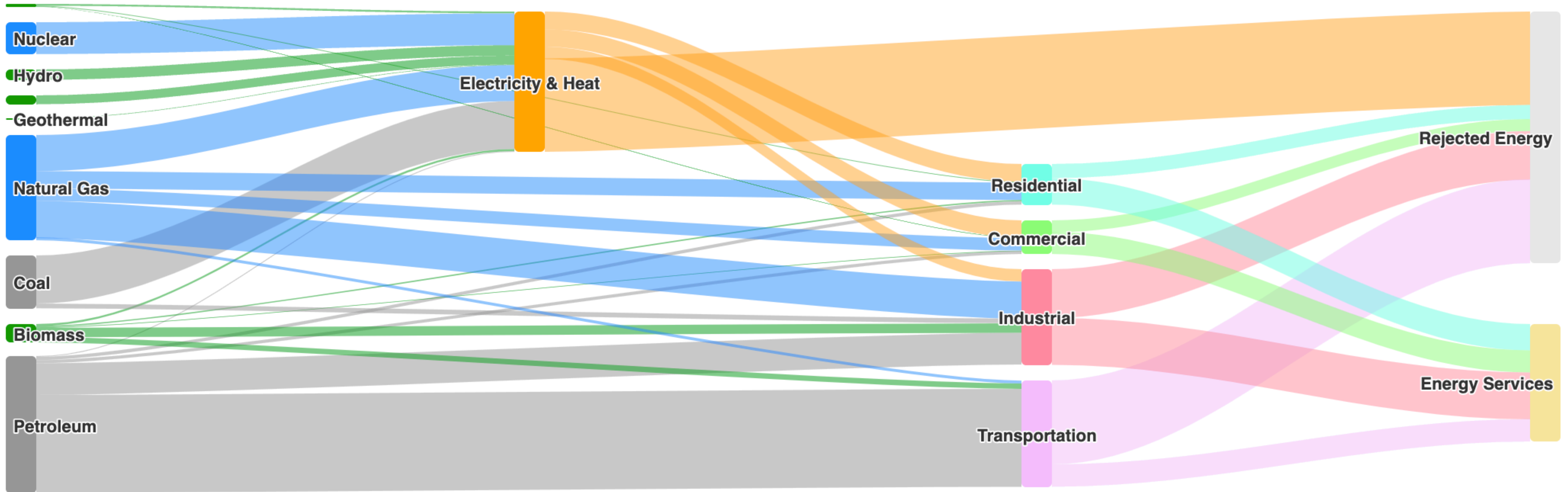
      Subtitle
      default ○   small ⦿   small+ ○   medium ○   medium+ ○   large ○

      Series Labels
      default ○   small ○   small+ ⦿   medium ○   medium+ ○   large ○

Estimated US Energy Consumption in 2017
Source: Lawrence Livermore National Laboratory

Energy Sources

	Total Quads
Geothermal	0.21
Solar	0.77
Wind	2.35
Hydro	2.76
Biomass	4.92
Nuclear	8.42
Coal	13.96
Natural Gas	28.01
Petroleum	36.2

Highcharts.com

Monthly Energy Consumption

Solar   Nuclear   Hydro   Wind   Geothermal
Natural Gas   Coal   Biomass   Petroleum

Highcharts.com

[Interactive demo link]

41
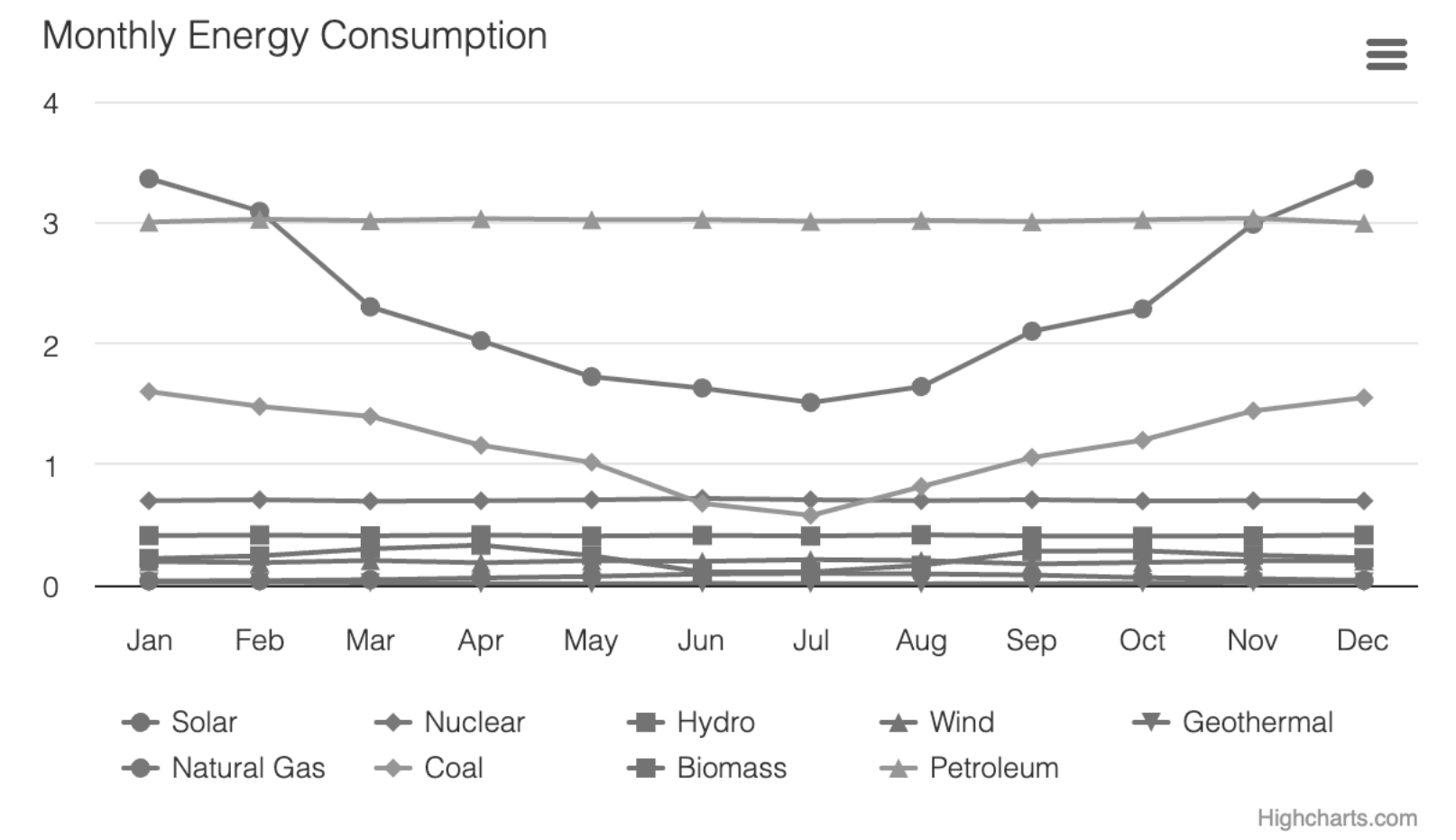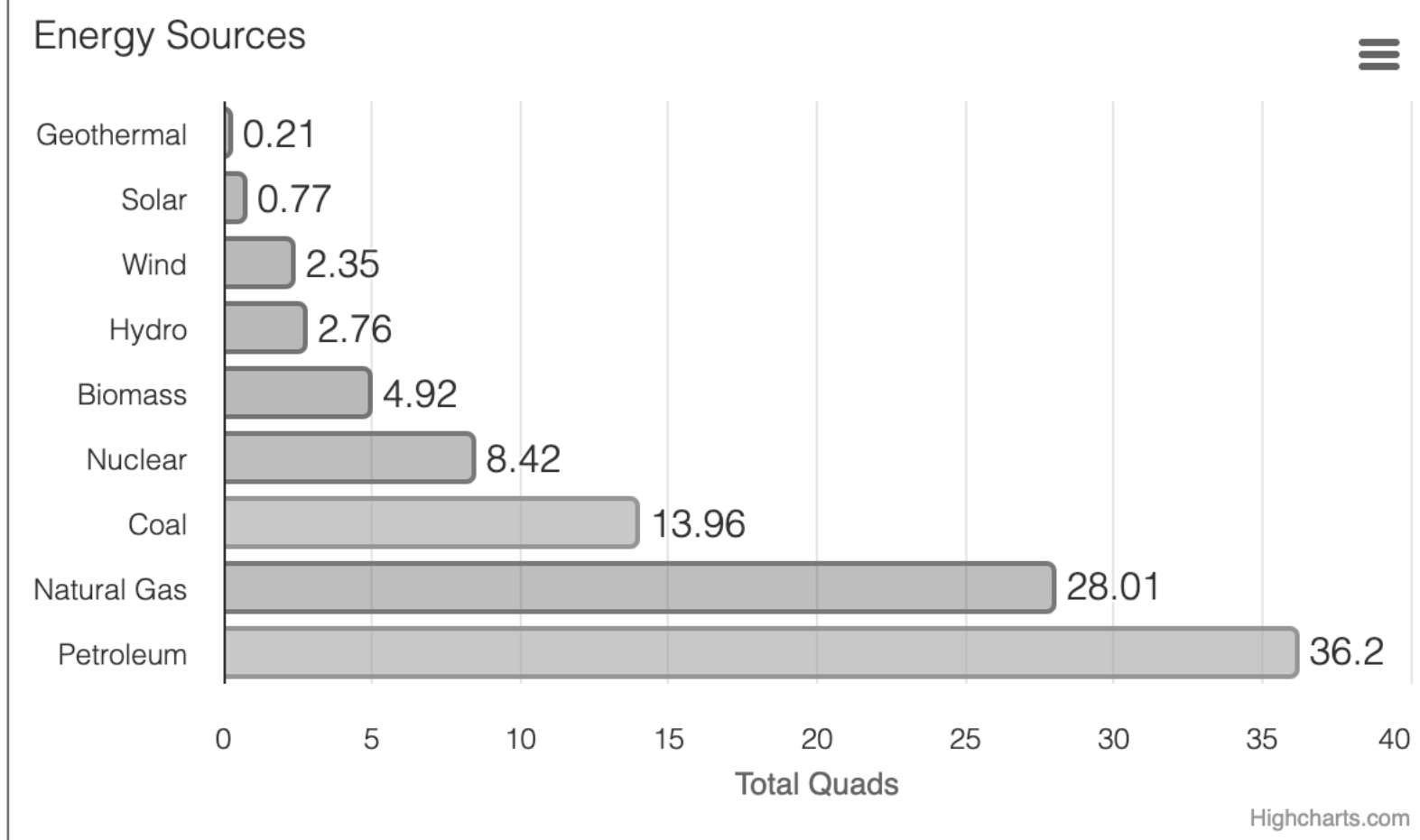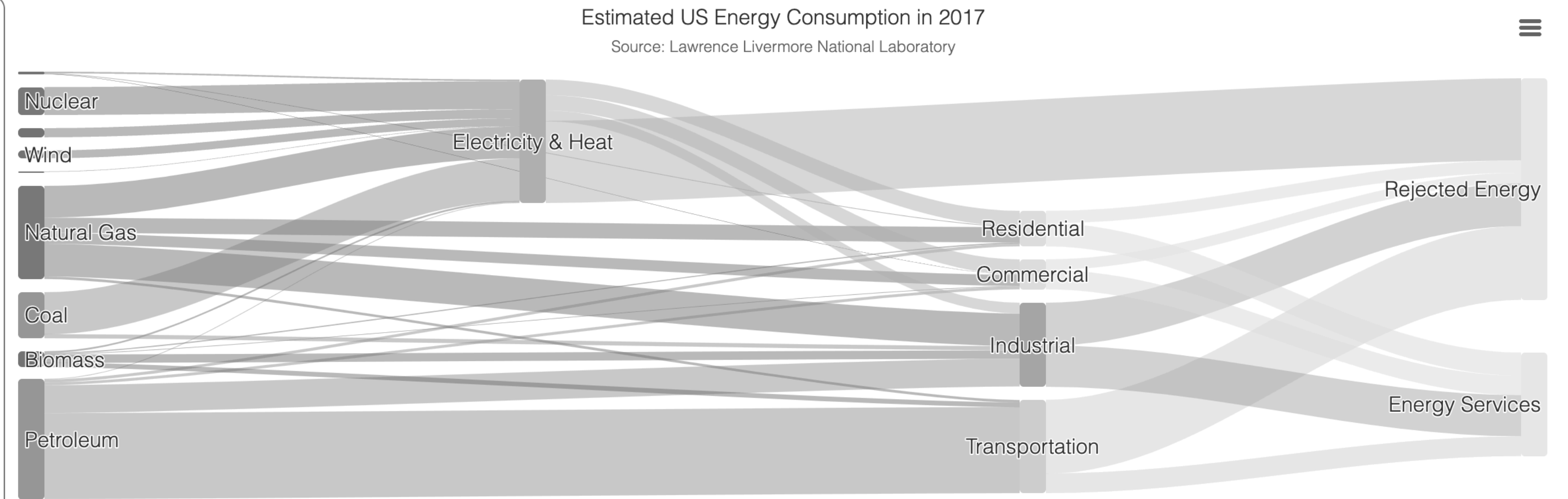
Designers do their best but it isn't always enough

https://dl.acm.org/doi/10.1145/1952383.1952384

Systems cannot always be adaptive/smart

https://dl.acm.org/doi/abs/10.1145/3373625.3416990
https://link.springer.com/article/10.1007/s42979-022-01239-1

We believe that users should have control over systems in these circumstances.

Summer plan:

1. Build a bunch of visualizations that are pretty accessible by default

2. Come up with areas we think users will still want control

3. Ask developers what they think of the core idea, from a dev perspective

    1. Challenges for devs and for users

    2. Opportunities

    3. Most important preferences to give users control of

4. Build a prototype that enables user customization of a dashboard

5. Show the prototype to users with a spectrum of different disabilities

    1. Challenges with the prototype

    2. Opportunities for the core idea

    3. Additional ideas

We organized personalization options (as "preferences") into categories

Comprehension

Text visuals

Color and contrast

Element size

Motion + Interactivity

We created subcategories that fit a given preference category

Comprehension → Showing alt text

→ Description verbosity

Text visuals

→ Explanation verbosity

Color and contrast

Element size → Cues and labels

Motion + Interactivity

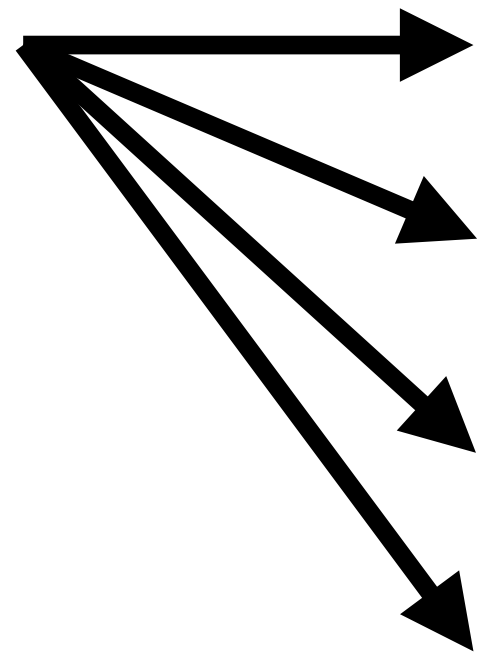# And then we created finer-levels of control

Comprehension

Text visuals

Color and contrast

Element size

Motion + Interactivity

Showing alt text

Description verbosity

Explanation verbosity

Cues and labels

Chart

Region alt

Interactions

Animations

Sonification

Why not "low vision," "blindness," or "ADHD" categories of disability?

Cognitive → Autism

Visual

Auditory

Motor

ADHD → Reduce complexity

IDD

Epilepsy

Minimize colors

Shorten textual explanations

Provide interaction cues

Enable action logging

People don't think of themselves as disabled, but often value accessibility

There is a reason behind this omission, and that reason is **internalized ableism**. People don't think of themselves as disabled, so they don't think the accessibility preference area applies to them.

"Wow, I had no idea this existed!" and, "This is going to be life changing!"

From Eric Bailey's recent and amazing blog post on customization and accessibility

We came up with over 200 items for possible customization

(Demo time)

Interactive demo link

★**Slides here** ⟶

Looking to the future of accessible data interfaces

HIGHSOFT

Frank Elavsky, PhD Student

hcii.cmu.edu, axle-lab.com, dig.cmu.edu