

2024

frank.computer

Visualization and accessibility: The state of the art, 2024



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Human-
Computer
Interaction
Institute



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

**Technology will not solve all of
our problems**

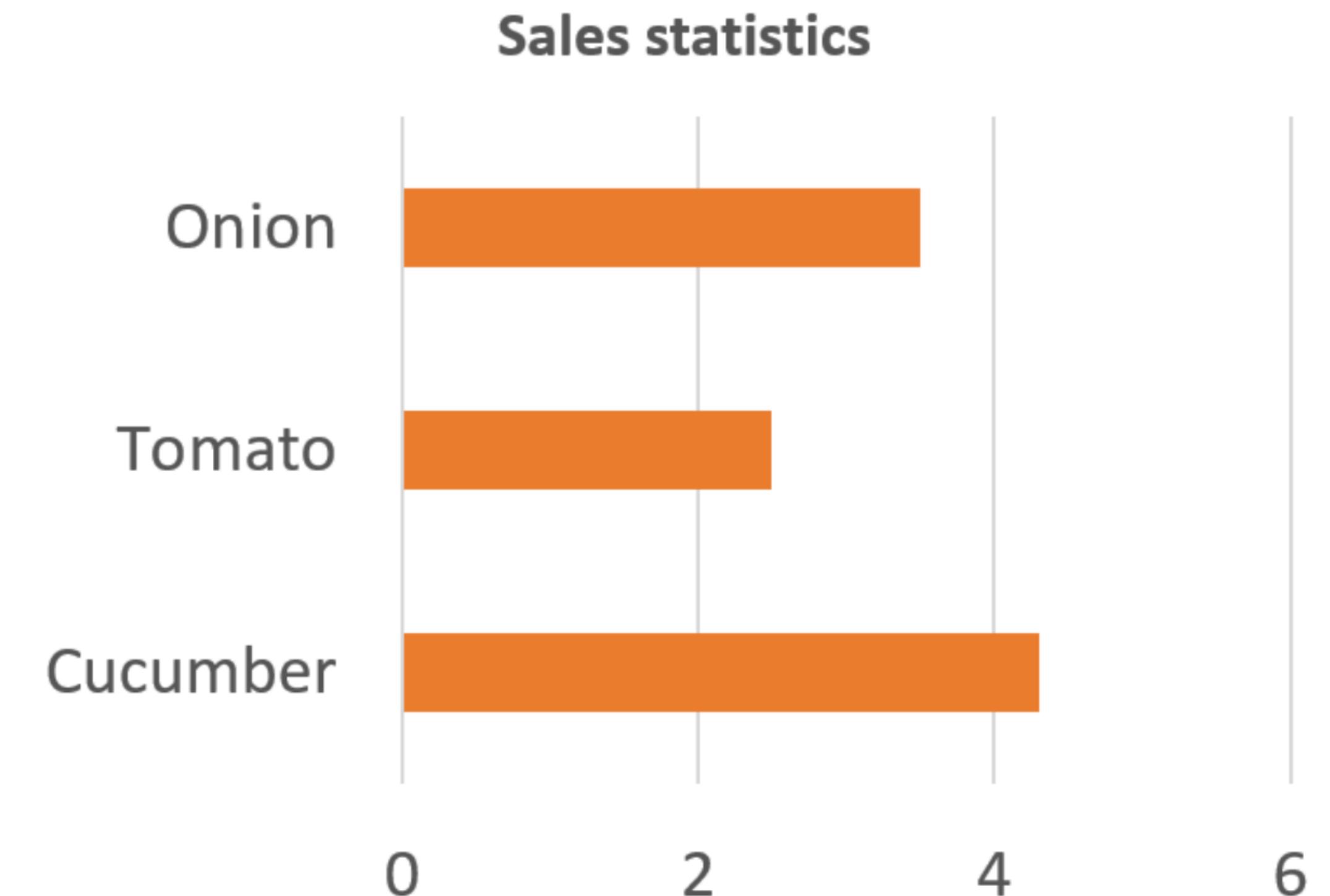
**Despite this, there *is* a place for
better technology.**

**3 main areas:
Describing things, using other
senses, and improving tools**

Section 1: Describing data visualizations

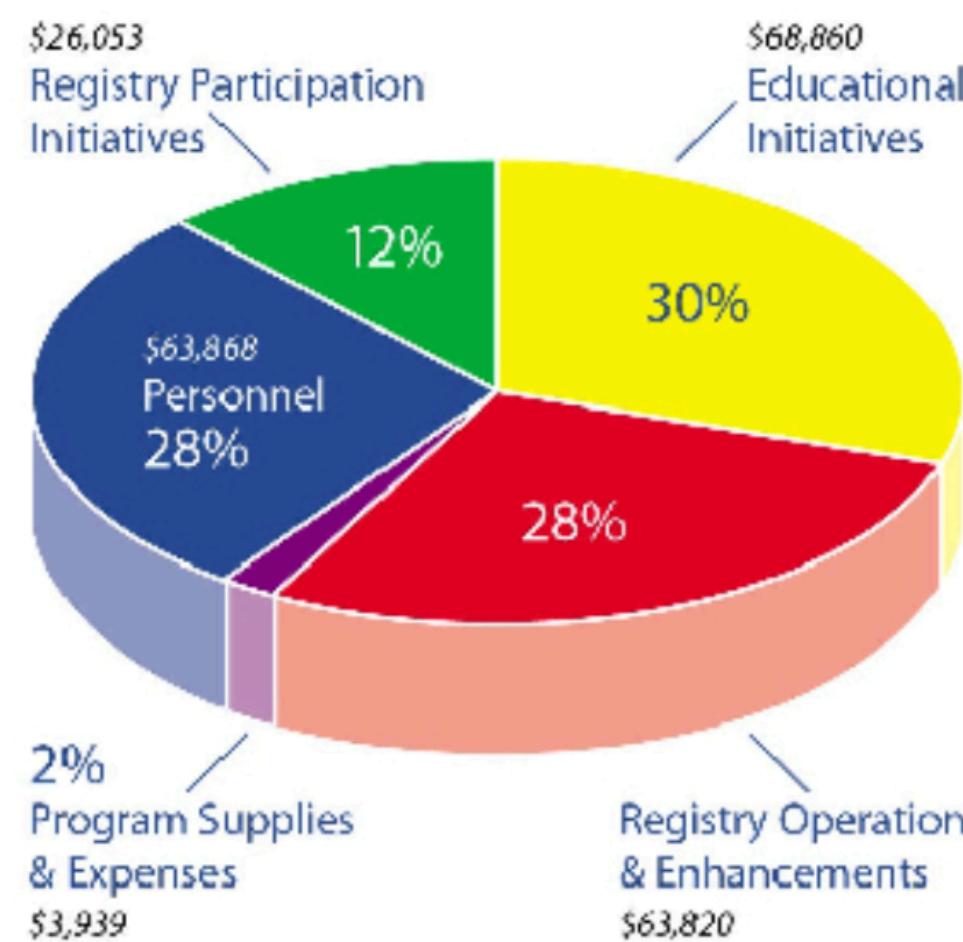
Many projects have attempted *automatic* description

Unichart, Chart-to-text, FigJAM, “automatic chart understanding,” + more



The chart compares sales stats among different products. Three bars are there. The bars are horizontal. Cucumber is the label of the first bar from the bottom. Tomato is the label of the second bar from the bottom. Cucumber sold the most units. The item Tomato sold less units than Onion.

3. Pie Graphs



© NCAM 2009

Guidelines:

- Pie graphs should be converted into accessible tables.
- It is not necessary to describe the visual attributes of the charts, e.g., red wedge, blue lines, etc., unless there is an explicit need such as an exam question referring to these attributes.
- It is helpful to list the numbers from smallest to largest, regardless of how they are presented in the image.

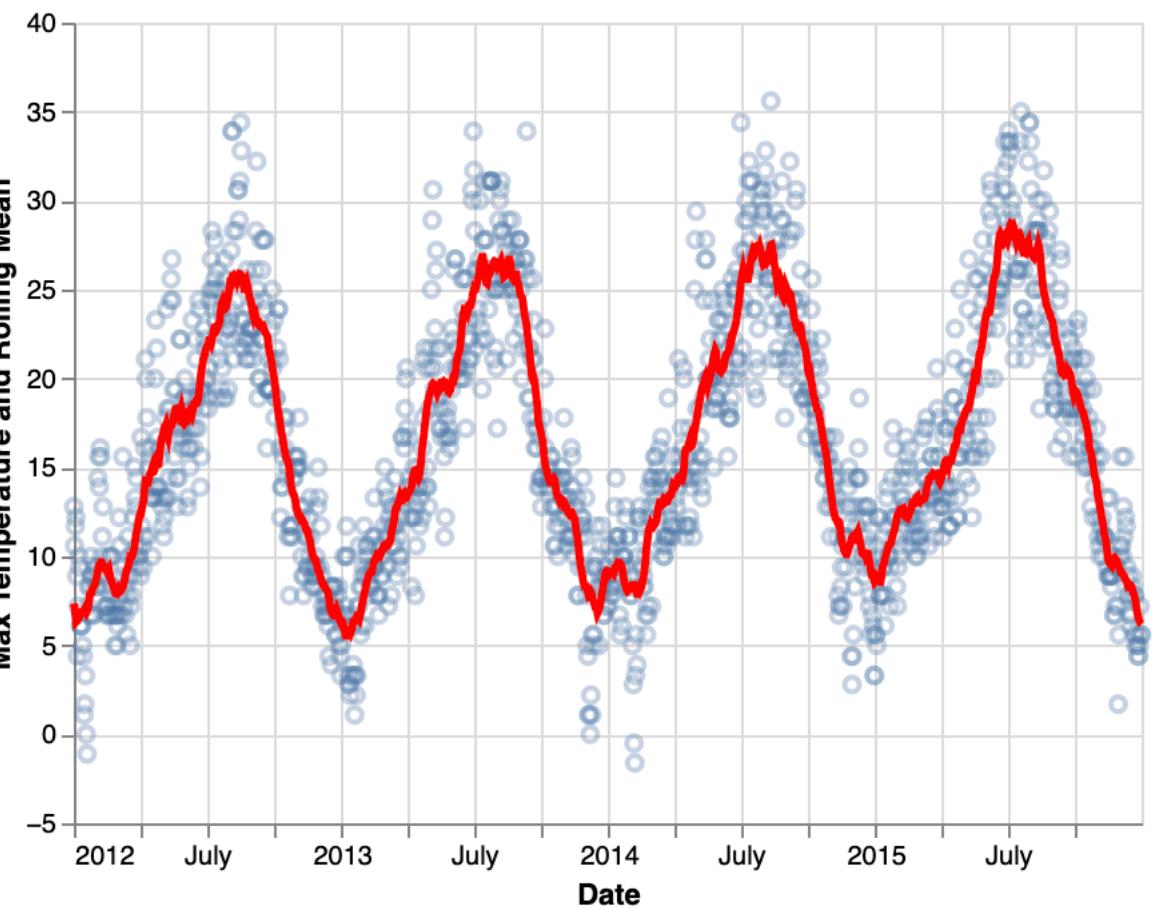
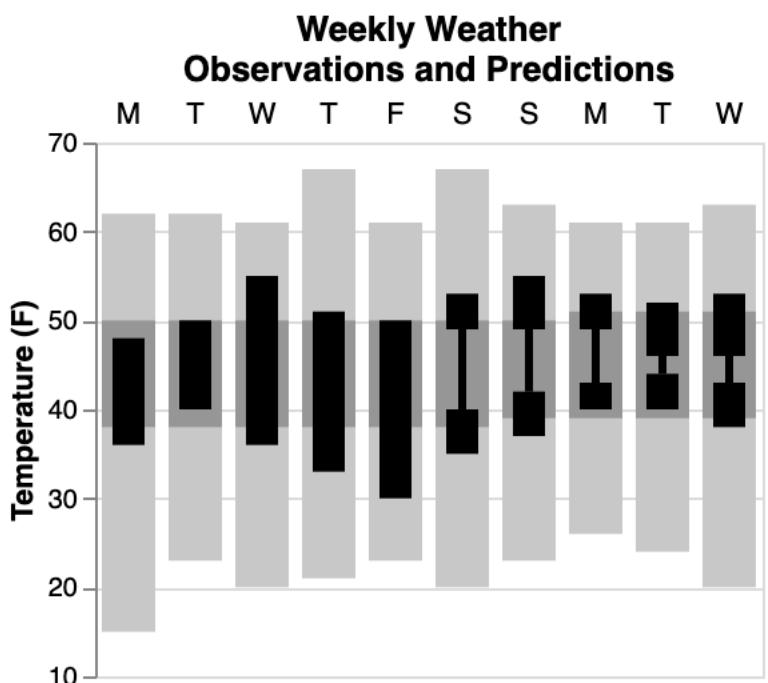
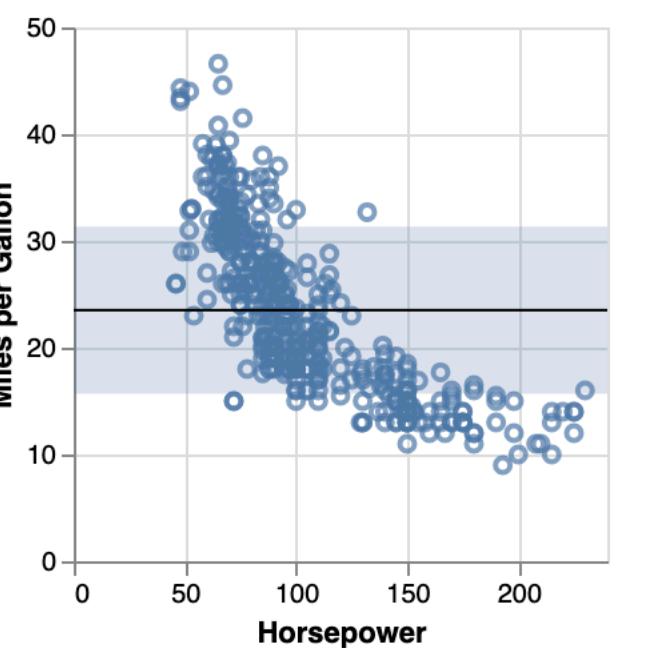
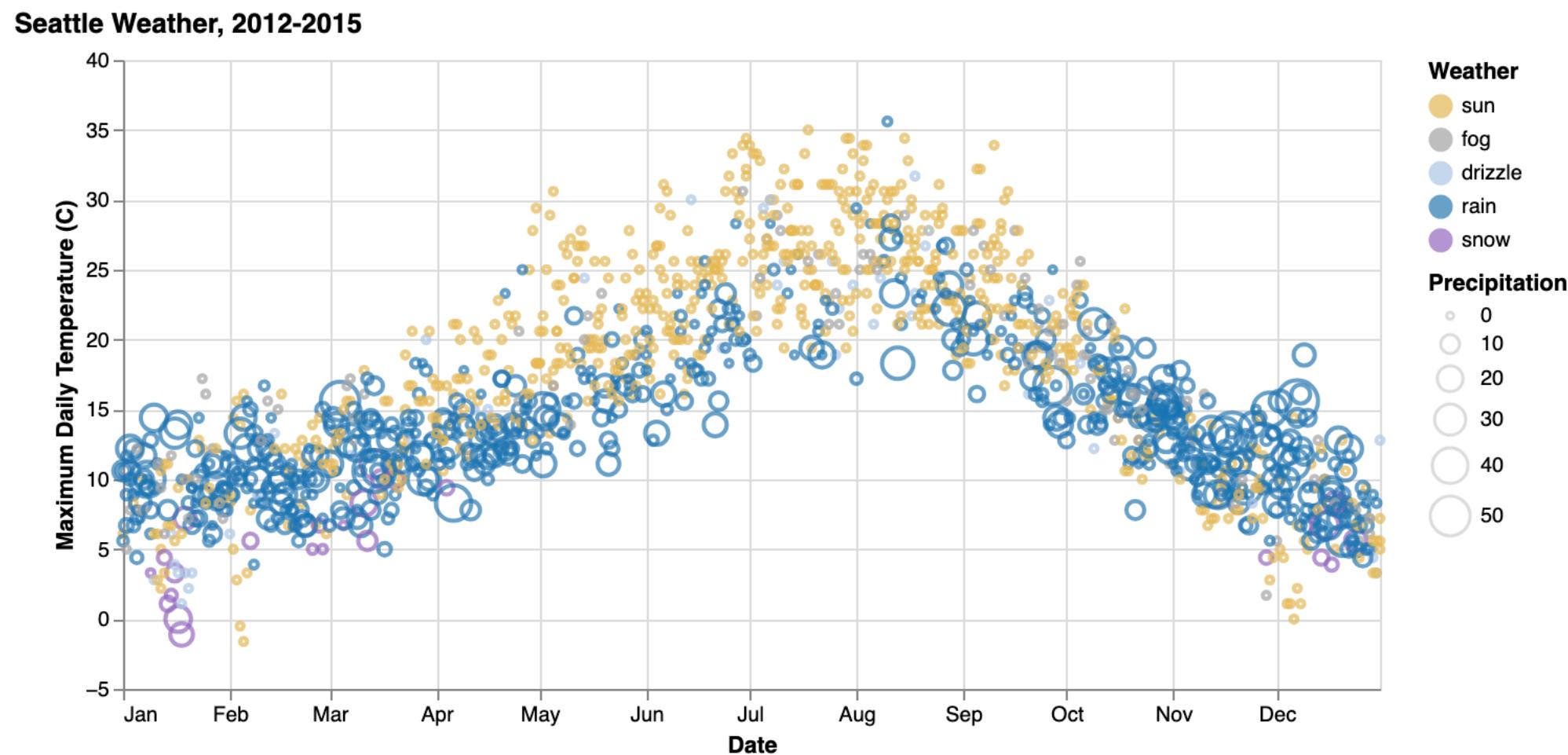
Description:

This figure is a pie graph that can be shown in the following table.

Program Expenses

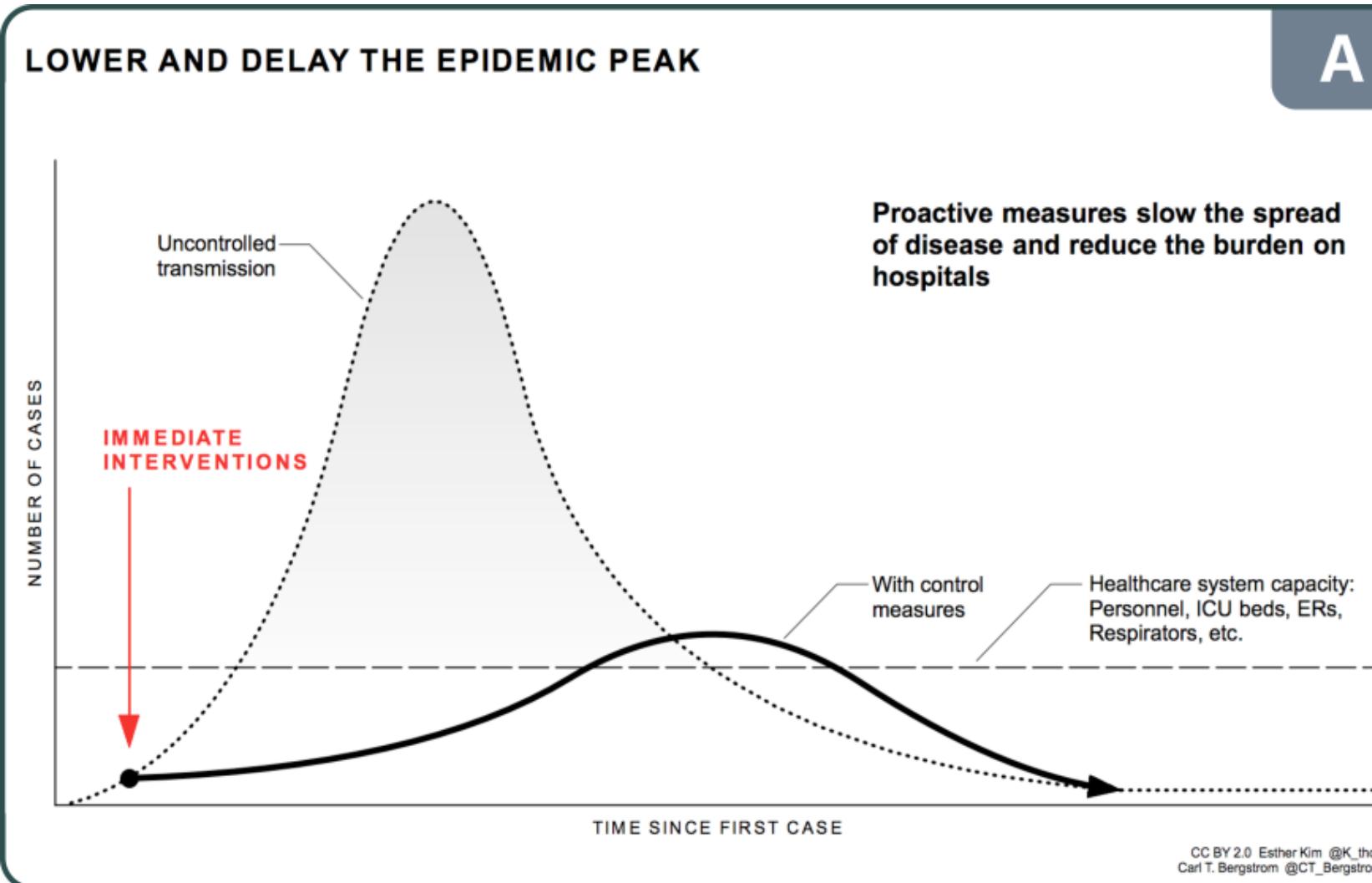
Expense	Percent of Total	Dollar Amount
Program Supplies and Expenses	2%	\$3,939
Registry Participation Initiatives	12%	\$26,052
Registry Operation and Enhancements	%28	\$63,820
Personnel	28%	\$63,868
Educational Initiatives	30%	\$68,860

**What about
modern, complex
visualizations?
And *scientific*
audiences?
We needed more guidance.**



We started to break charts down into parts

First, Lundgard et al's *Semantic Levels*



A

A multi-line chart entitled "Lower and Delay the Epidemic Peak" that plots the Number of Cases by the Time Since First Case. The Number of Cases is plotted on the vertical y-axis. The Time Since First Case is plotted on the horizontal x-axis. The chart shows two possible extremes of the rate of rise and decline of COVID-19 cases. If the transmission is uncontrolled, there are more simultaneous cases. If the transmission is controlled, there are fewer simultaneous cases. If the transmission is controlled, the healthcare system can support all the cases.

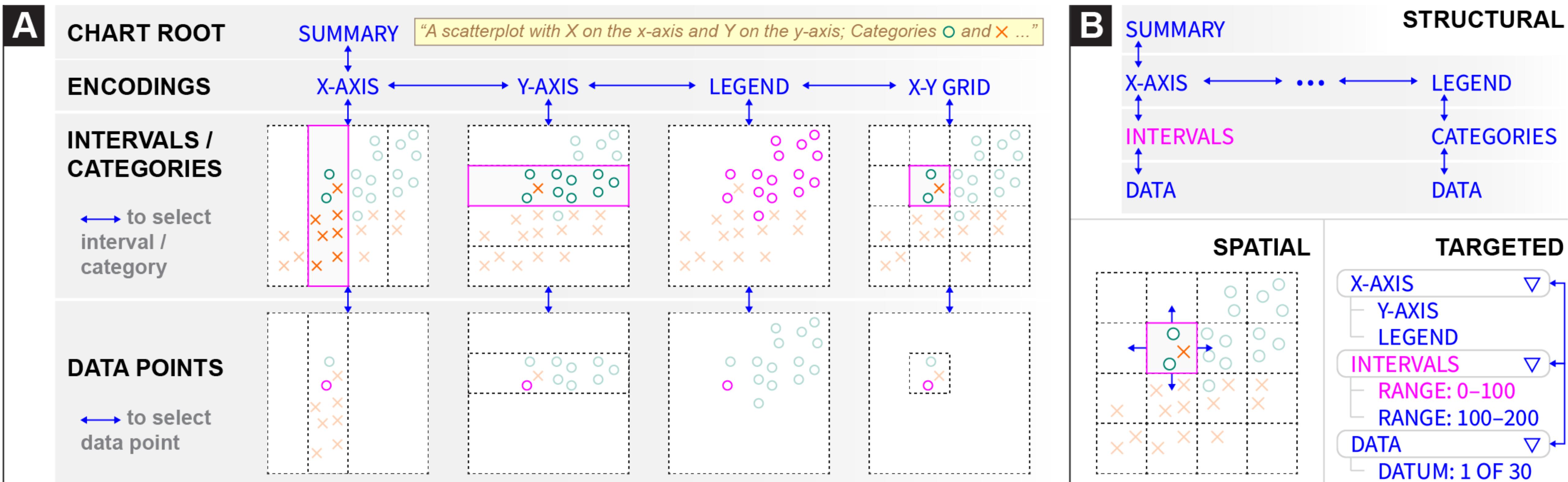
B

The purpose of the chart is not to provide exact numbers, but to communicate to the public that there are multiple ways the current crisis can play out. Without control measures the spread of the disease increases exponentially, making it harder to slow down and creating a big overload in the healthcare system. The number of cases is dramatically higher without controls, and this will likely lead to many deaths. In contrast, when controlled, the healthcare system capacity can handle all of the cases over a longer period of time, and this will save lives.

C

Then we explored rich navigational experiences

Thanks to Zong et al's *Rich Screen Reader Experiences*

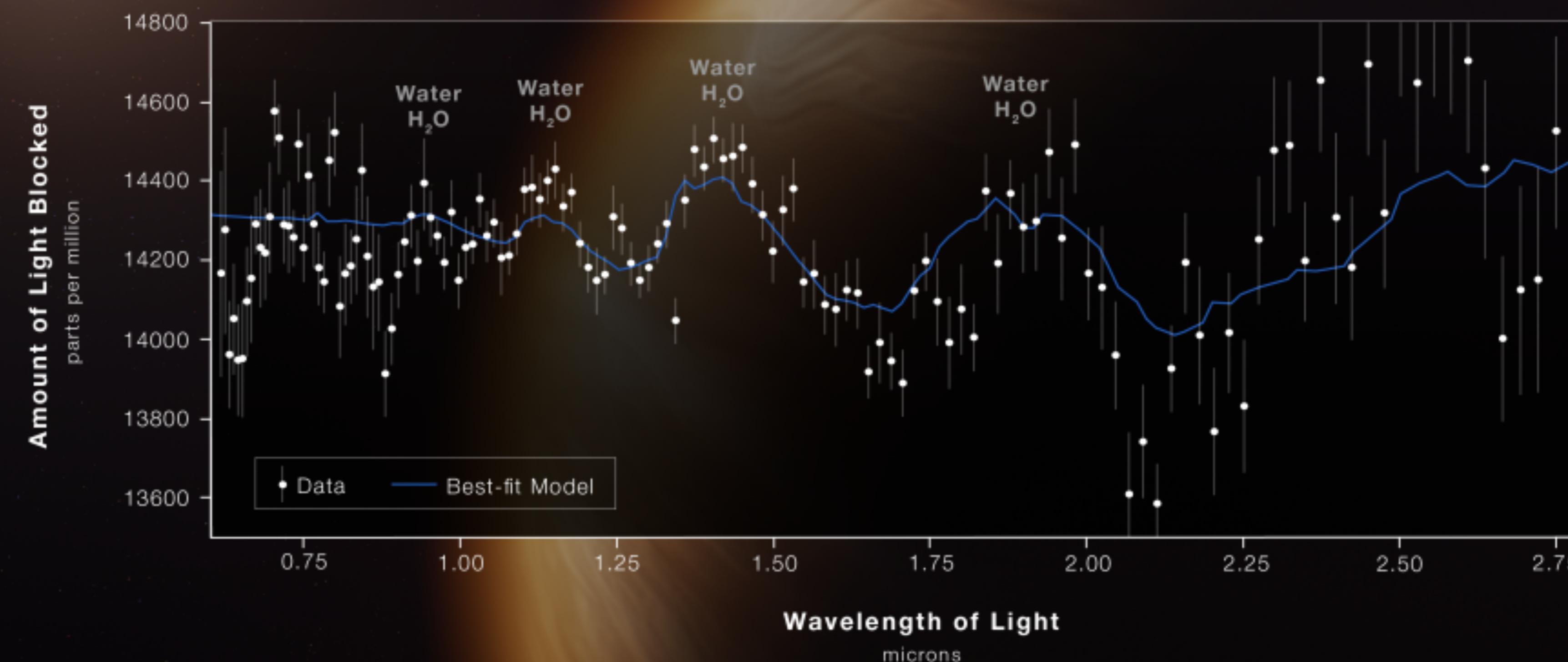


Then came NASA



HOT GAS GIANT EXOPLANET WASP-96 b ATMOSPHERE COMPOSITION

NIRISS | Single-Object Slitless Spectroscopy



Exoplanet WASP-96 b (NIRISS Transmission Spectrum)

Extended Description

Graphic titled "Hot Gas Giant Exoplanet WASP-96 b Atmosphere Composition, NIRISS Single-Object Slitless Spectroscopy."

The graphic shows a transmission spectrum in the form of a graph of the Amount of Light Blocked by the planet's atmosphere in parts per million on the vertical *y*-axis versus Wavelength of Light in microns on the horizontal *x*-axis.

Graph

Axes

The *y*-axis ranges from 13,500 parts per million (less light blocked) at the bottom to 14,800 parts per million (more light blocked) at the top, with labeled tick marks are labeled every 200 parts per million, starting at 13,600.

The *x*-axis ranges from 0.6 microns on the left to 2.8 microns on the right, with labeled tick marks every 0.25 microns, starting at 0.75 microns.

Key

The graph includes a key showing that the solid white circles centered on gray vertical lines represent data points, and a blue solid line represents a best-fit model.

Data and Model

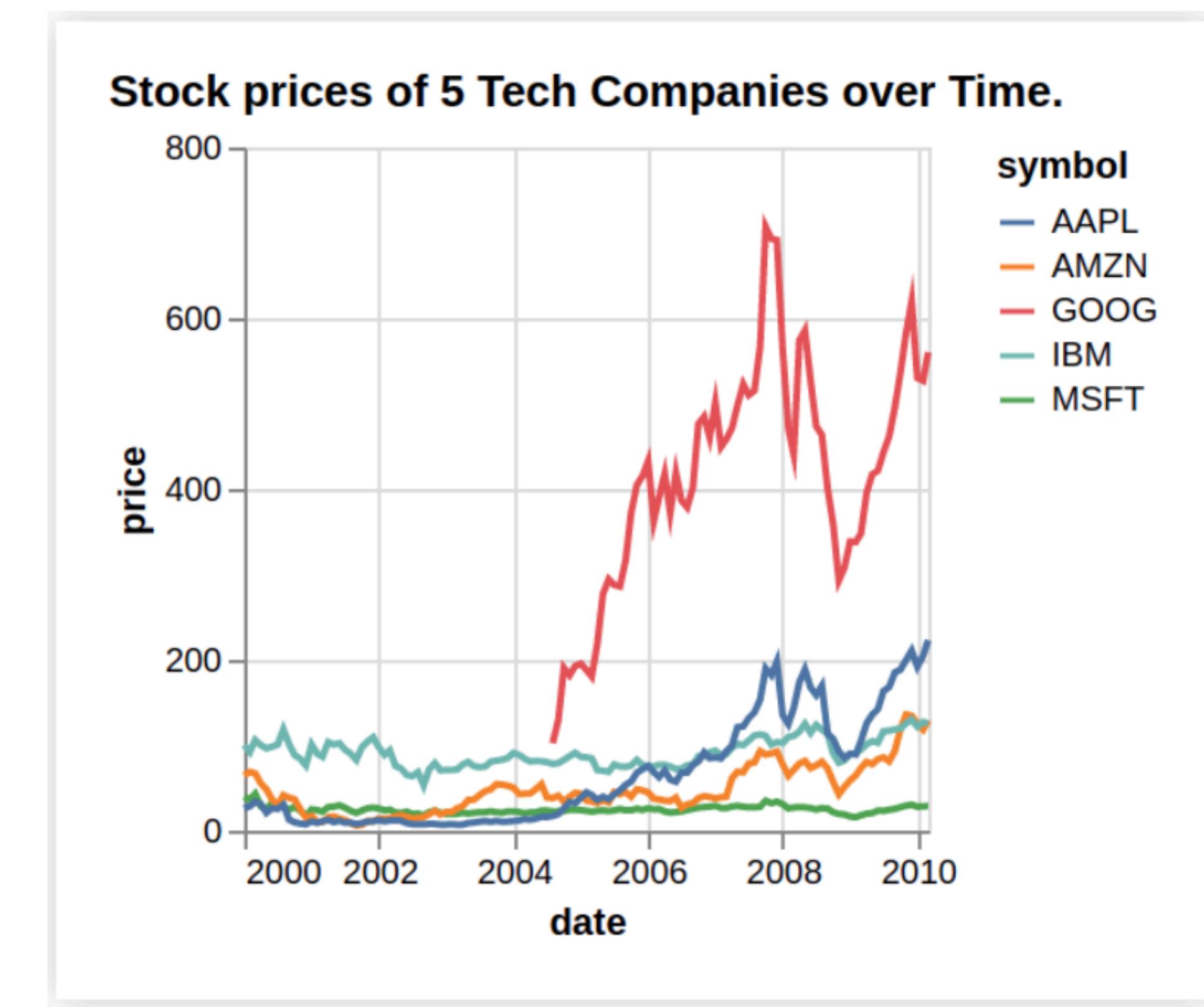
The graph consists of 141 data points, each with a gray error bar. The points range in value from 13,589 to 14,883 parts per million. The data points are not connected. They follow a jagged trend from left to right, with a number of broad peaks and valleys. The lengths of the error bars vary from a minimum of plus or minus 43 to a maximum of plus or minus 314. The error bars are smallest between about 1 and 1.3 microns, generally increasing in length toward the left from 1 to 0.6 microns, and toward the right from about 1.3 to 2.8 microns.

A solid blue line with several prominent peaks and valleys represents the best-fit model. The model begins at the far left with a very slight downward slope toward the right with a small peak around 0.95 microns, and another peak at about 1.15 microns. The line then becomes more sinuous, forming a taller, broader peak centered at about 1.4 microns and a slightly shorter broad peak at 1.9 microns. Starting around 2.15 microns, the line trends back upward with a wavy slope of about 30 degrees.

The blue best-fit model line generally follows the trend of the data. It intersects some data points, but does not match the data perfectly. The match between the model and data is clearest between about 0.9 and 1.65 microns.

What if text experiences were interactive and conversational?

VoxLens, VizAbility, “Blind question answering,” and more!



Question: *When the difference between the Apple and Google stocks was the highest?*

Answer: **2008**

Figure 1: An example of a natural language question about a line chart that shows stock prices of some tech companies over time.

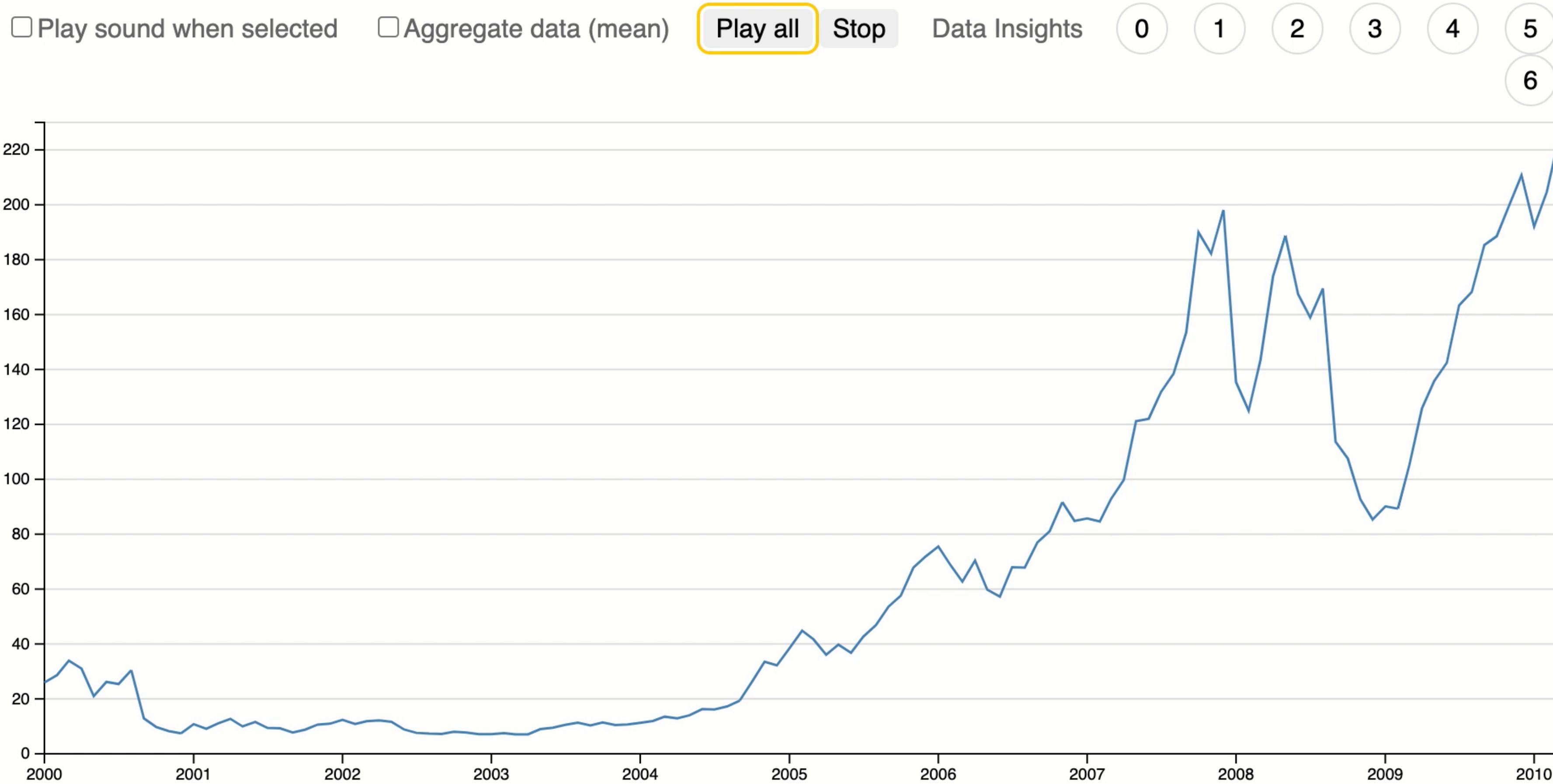
Section 2: Non-visual data representation

**If language can do everything, why
visualize at all in the first place?**

Sonification

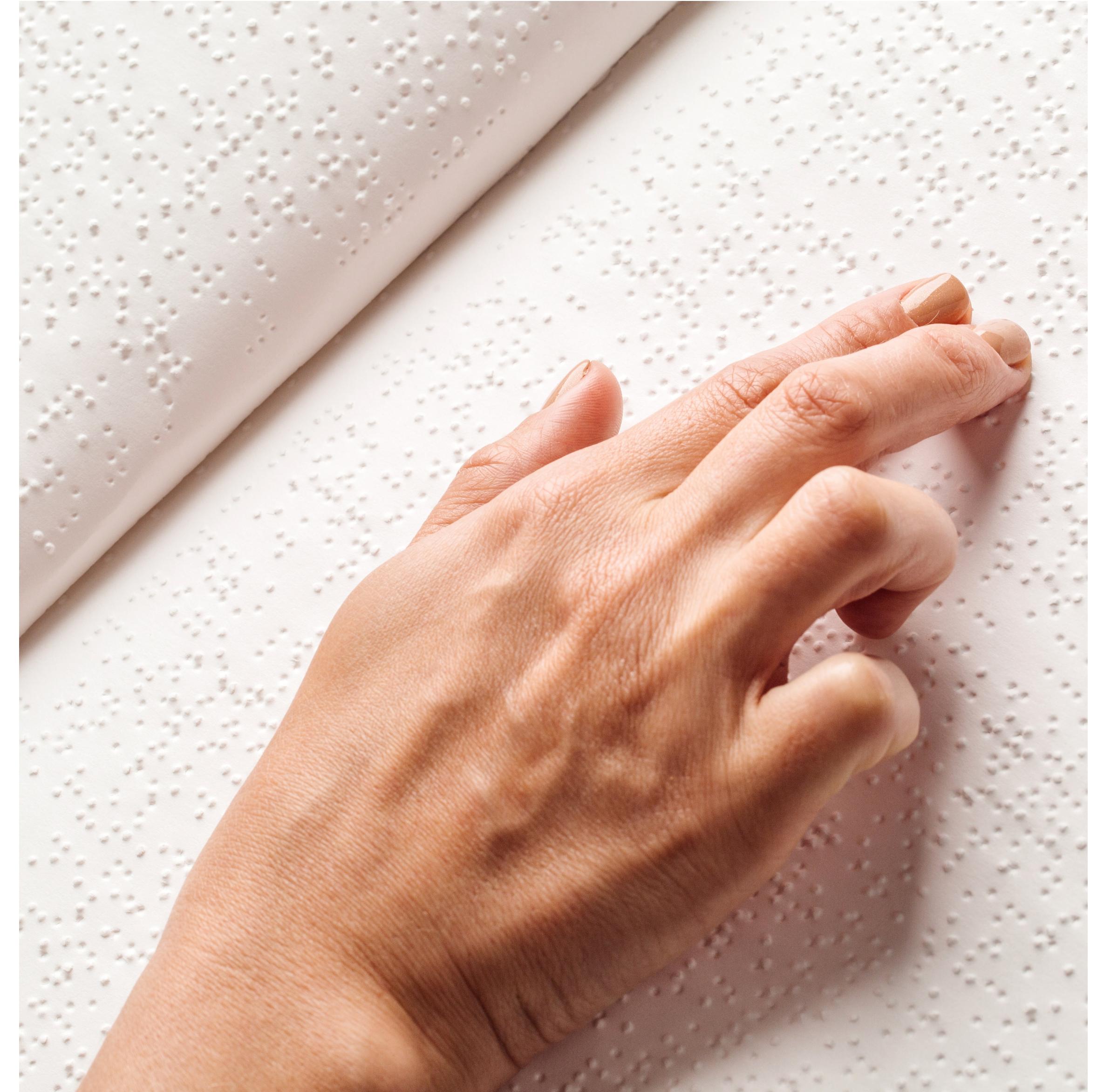
Data Insights for Apple's Stock Price Change from 2000 to 2010

This is a replication of the "interface" of [Chart Reader by Thompson et al. \(2023, CHI '23\)](#) (c.f., Figure 4)



Embossed paper

**Still one of the best
technologies out there!**

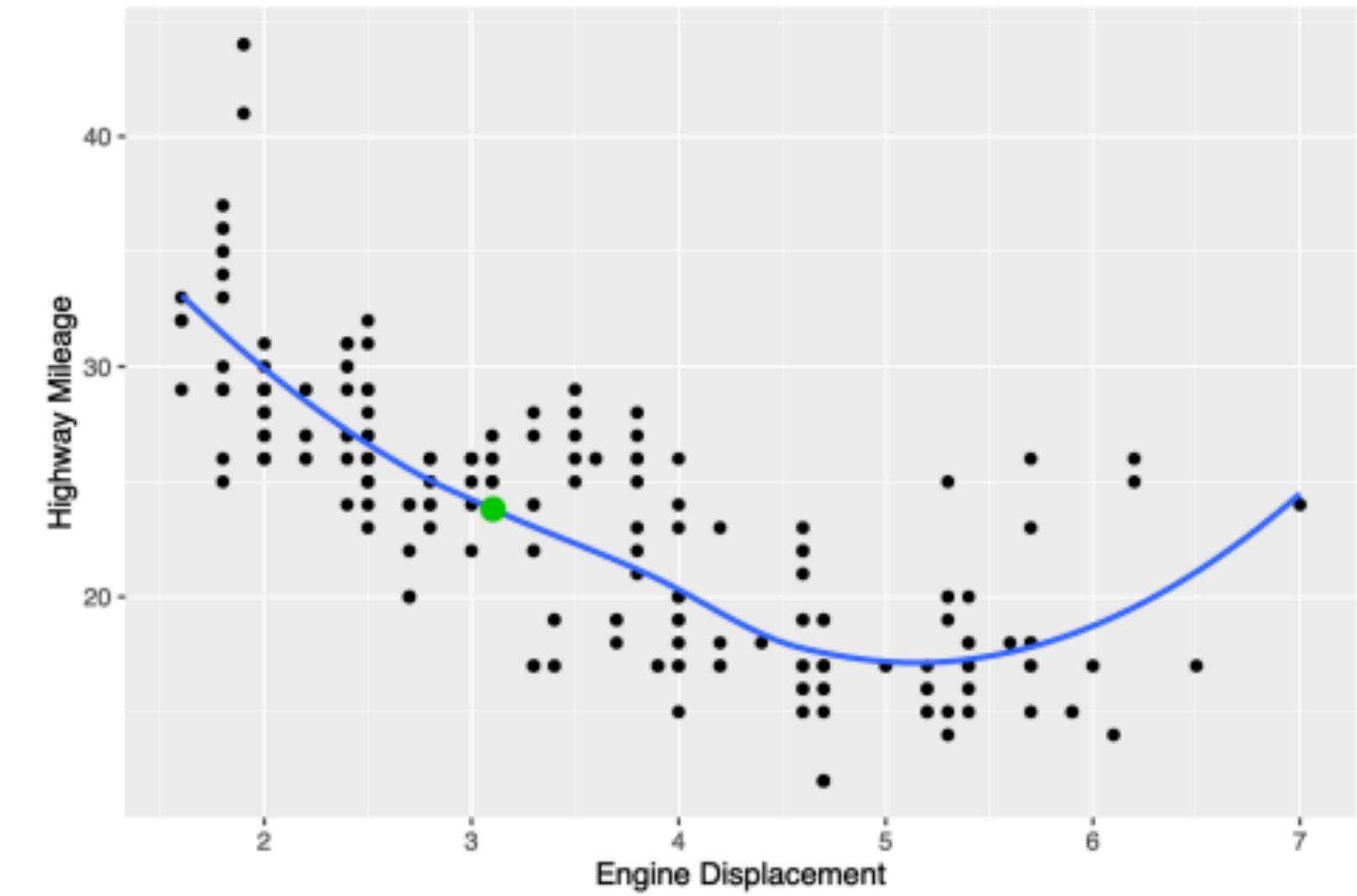


Refreshable tactile displays



Micro-tactiles (MAIDR, SparkBraille, etc)

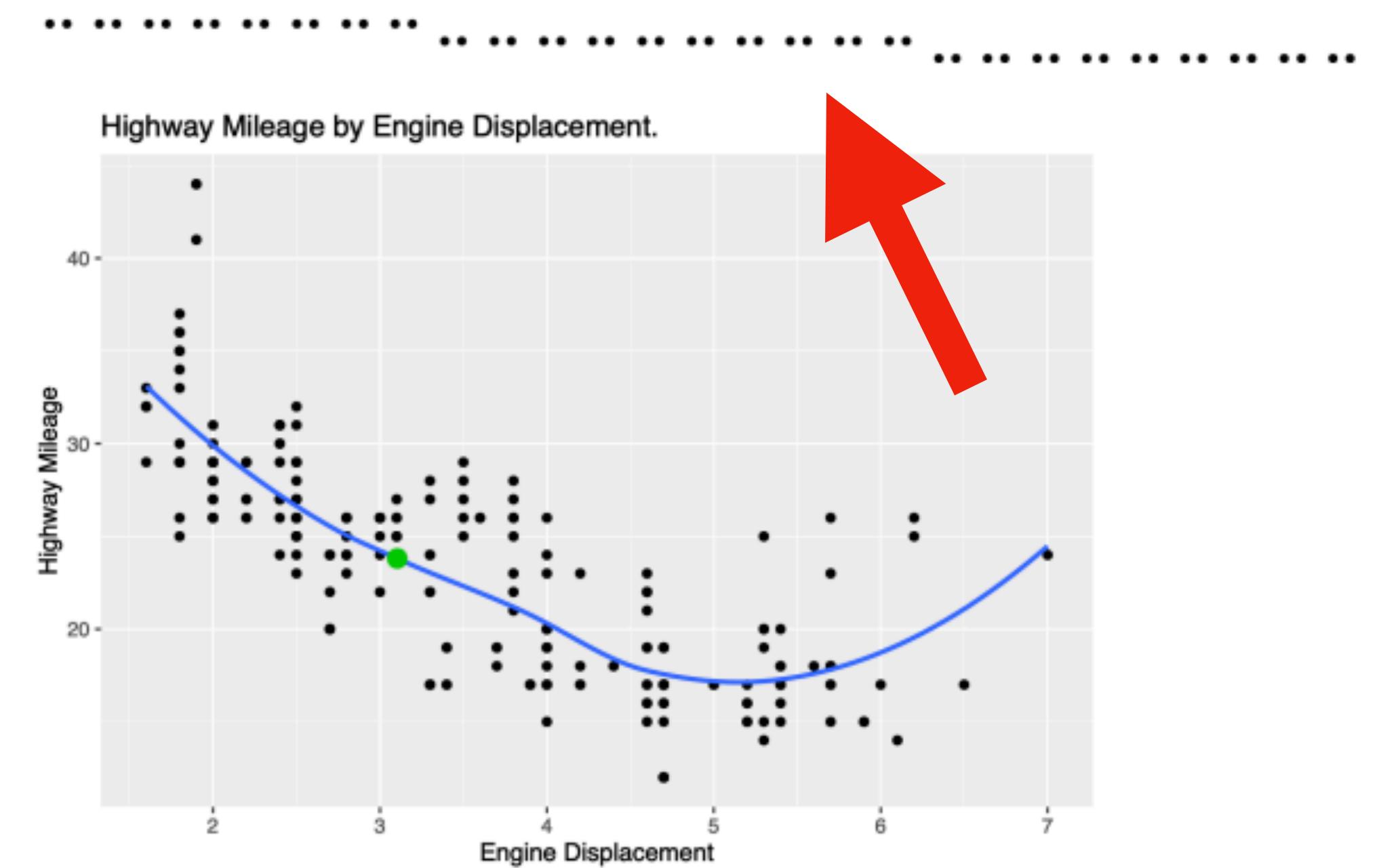
Highway Mileage by Engine Displacement.



Engine Displacement 3.1038, Highway Mileage 23.8055

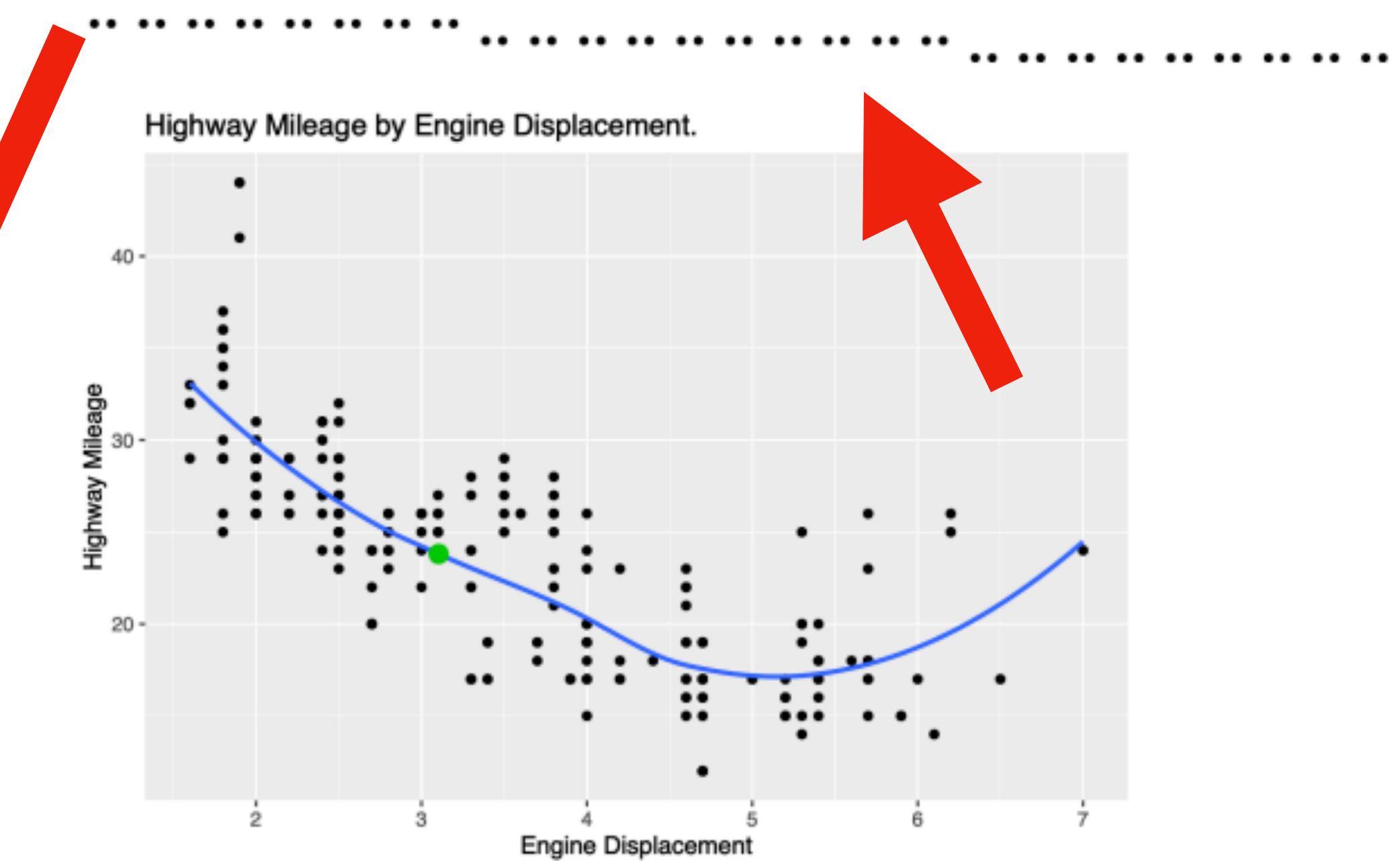
(d) Scatter plot

Micro-tactiles (MAIDR, SparkBraille, etc)



(d) Scatter plot

Micro-tactiles (MAIDR, SparkBraille, etc)



(d) Scatter plot

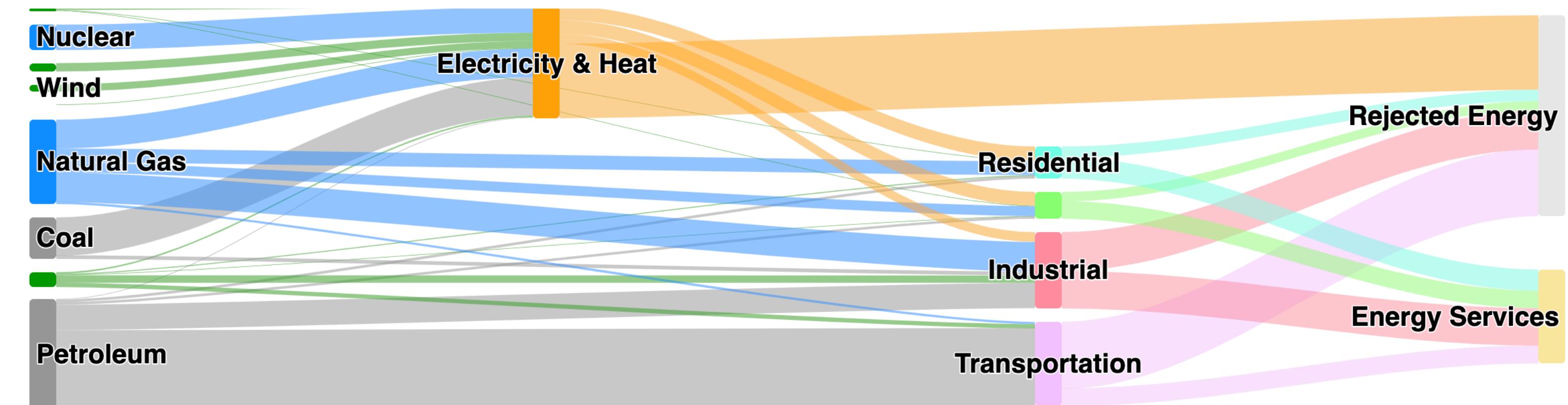
Section 3: Tools for building accessible visualizations

**Having cutting-edge prototypes is nice,
but people still need to be able to
replicate them in practice!**

Highsoft's Highcharts

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.

Highcharts.com

Energy Sources

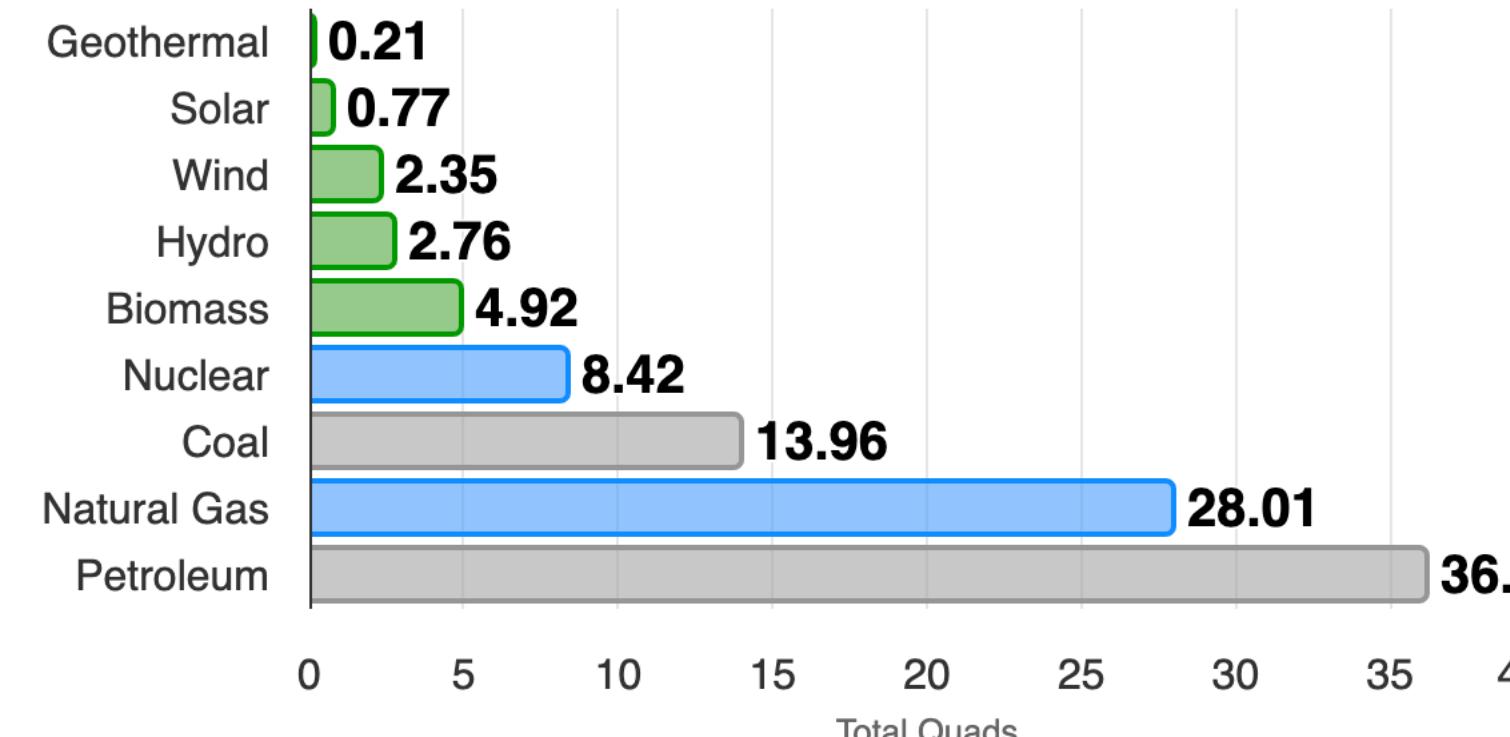
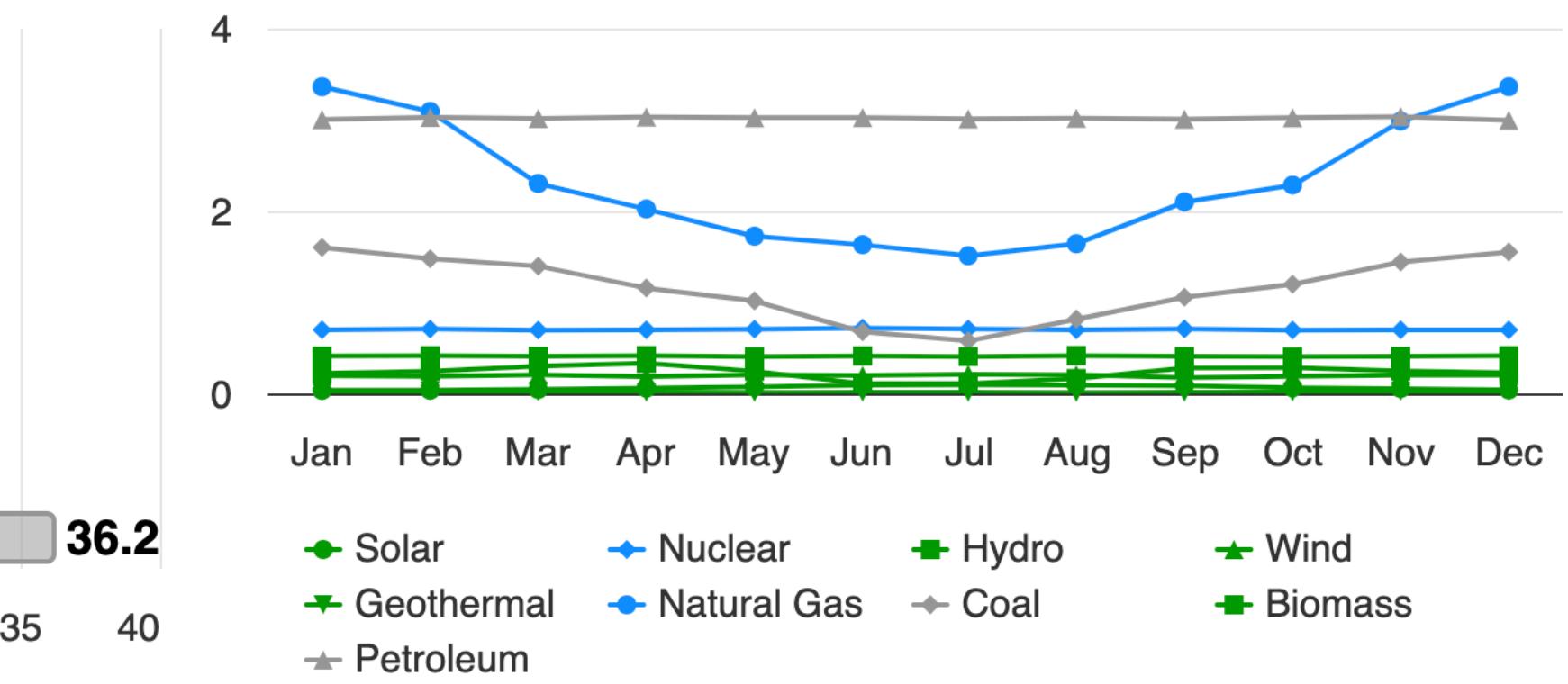


Chart showing stacked columns for comparing quantities. Stacked charts are often used to visualize data that accumulates to a sum.

Monthly Energy Consumption



Line chart for comparing change in data across categories. Line charts are often used to visualize change in data over time, showing important trends. Sonification will play all values selected in legend.

Play chart sonification

Erie, a sonification grammar (I cannot get over how amazing this grammar is)

Audio Narrative for Apple's Stock Price Change from 2000 to 2010

This is a replication and extension of the "sonification design" of [Audio Narrative by Siu et al. \(2022, CHI '22\)](#).

Customization

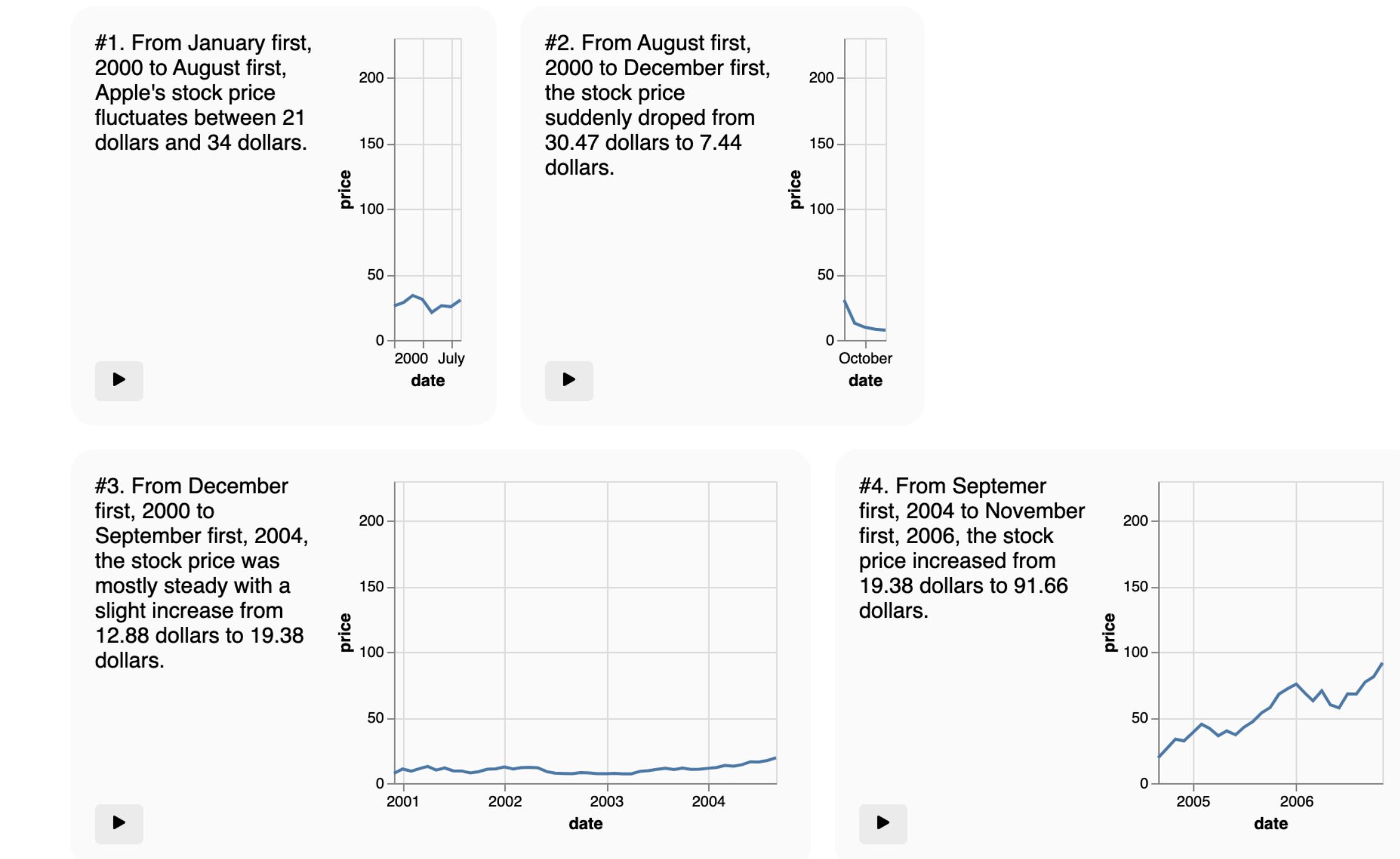
Encoding From (Stock price: 0) To (Stock price: 230)

Pitch 200 1600

Sonification

[Play scales](#) [Play audio narrative](#) [Stop audio narrative](#)

Visualization



Umwelt: de-centering visualization in authoring

Editor

Data Fields Visual Audio

Fields

Select fields: symbol
 date
 price

Key: symbol
date

symbol

Type nominal ▾
Encodings: Add encoding
color ▾ Go to visual tab
Remove encoding

date

Type temporal ▾
Encodings: Add encoding
x ▾ Go to visual tab
Remove encoding

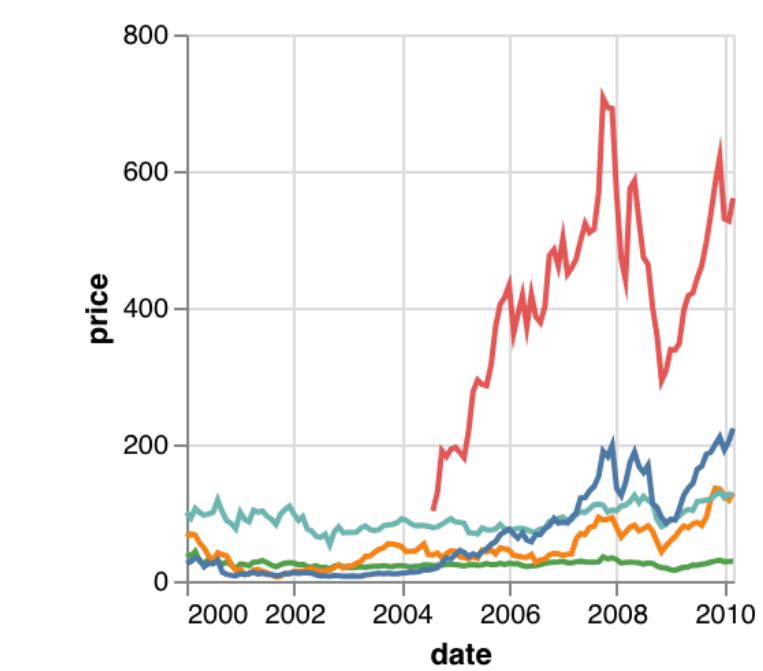
► Additional options

price

Type quantitative ▾
Encodings: Add encoding
pitch ▾ Go to audio tab
Remove encoding
y ▾ Go to visual tab
Remove encoding

► Additional options

Viewer



UMWELT

symbol MSFT ▾
date
pitch: price
Playback rate 1 ▾
Playback order MSFT to AAPL by date ▾ Play

Speak audio axis ticks
Audio axis speech rate 3.5 ▾

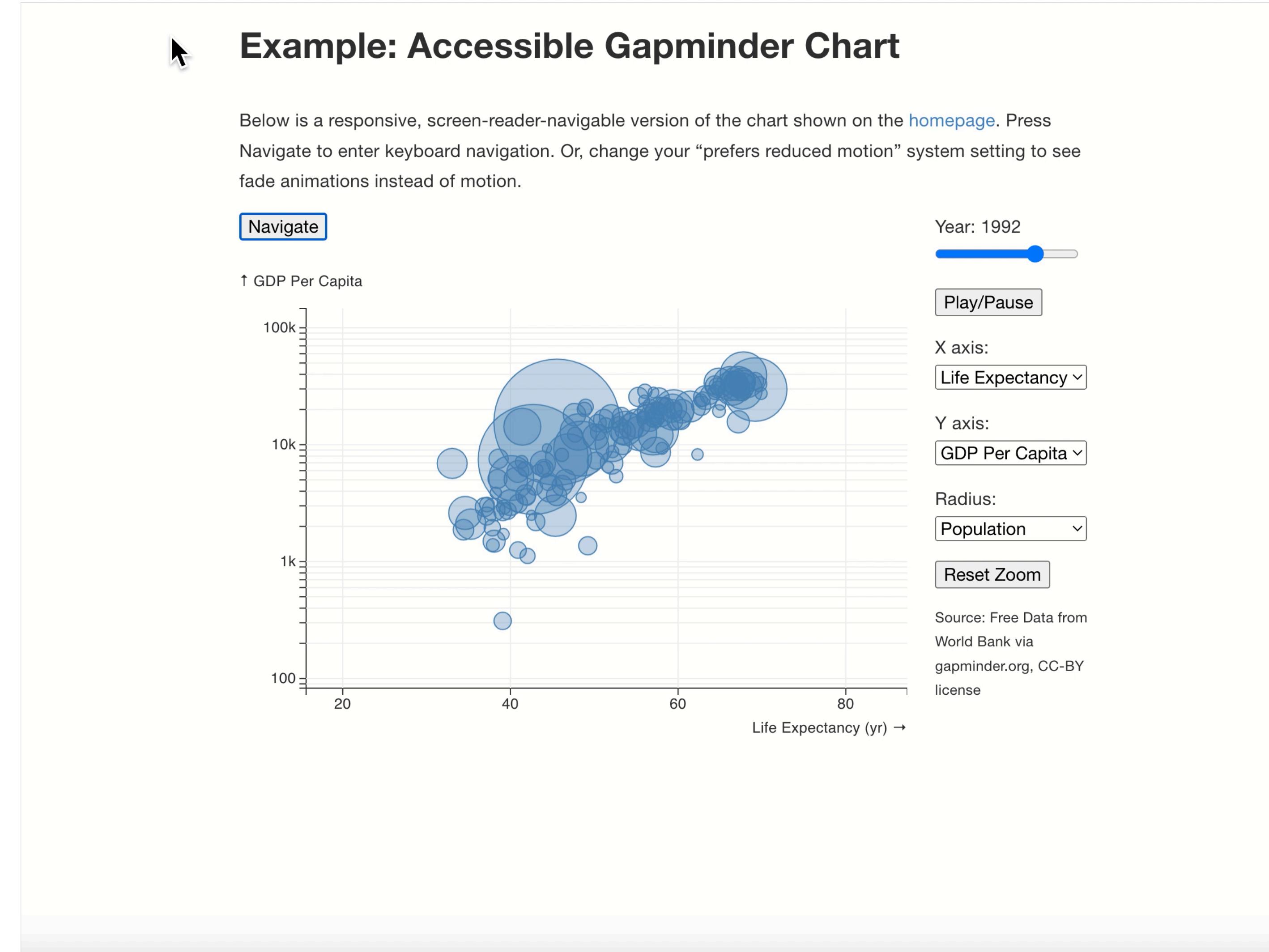
Unmuted

Keyboard shortcuts

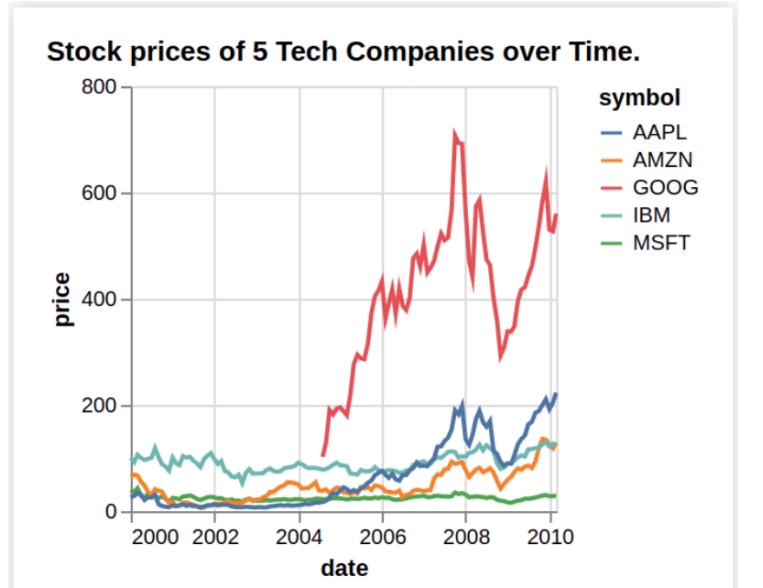
e — Jump to editor
v — Jump to viewer
o — Jump to olli text structure
a — Jump to audio controls
p — Play audio
shift + p — Jump to playback mode control

Counterpoint + Data Navigator

A high-performance visualization animation library with accessibility!



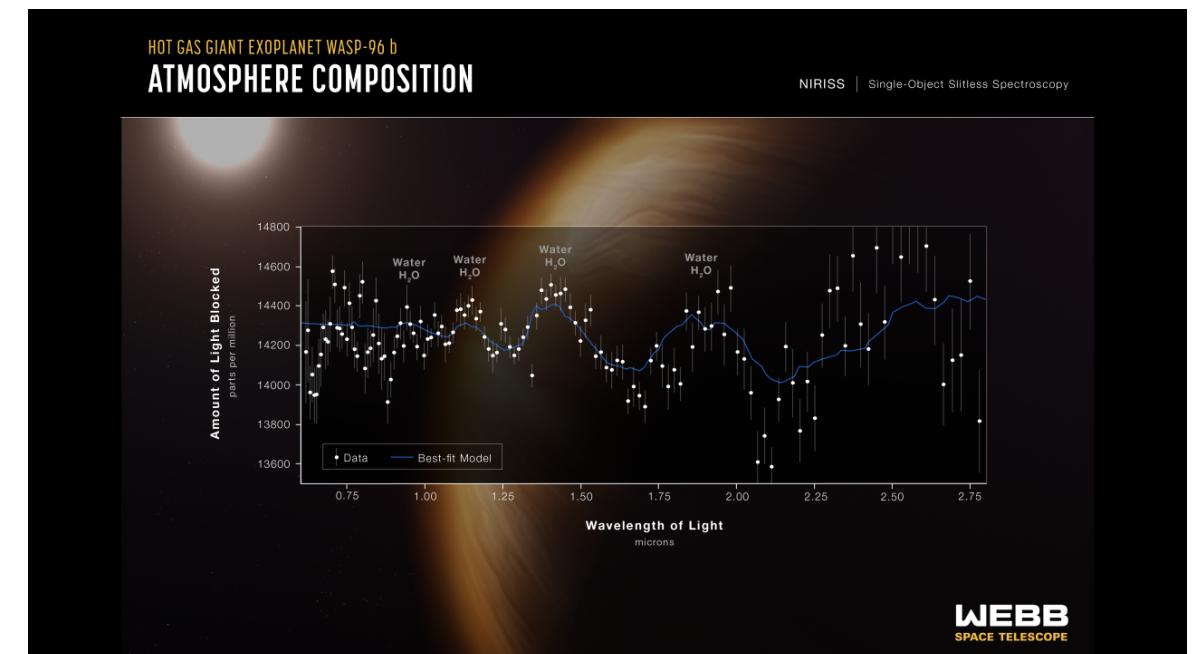
• Richer text



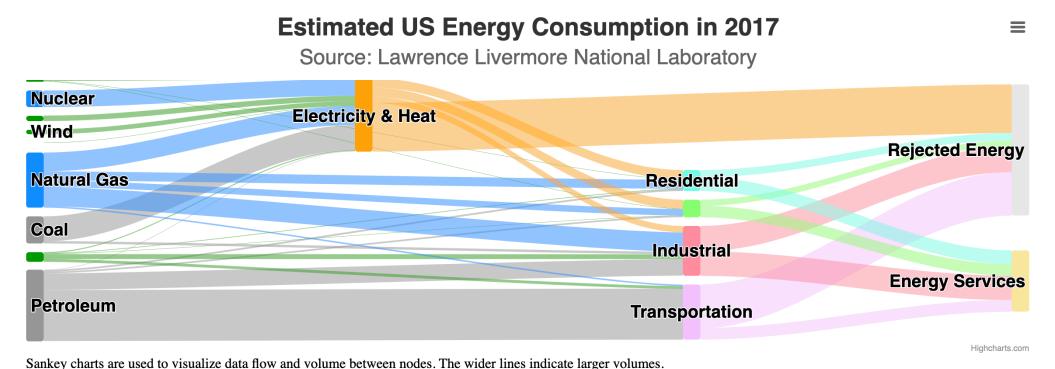
Question: *When the difference between the Apple and Google stocks was the highest?*

Answer: 2008

Figure 1: An example of a natural language question about a line chart that shows stock prices of some tech companies over time.



• More modalities



Line chart for comparing change in data across categories. Line charts are often used to visualize data that accumulates to a sum.

Play chart sonification

Data Insights for Apple's Stock Price Change from 2000 to 2010

This is a replication of the "interface" of *Chart Reader* by Thompson et al. (2023, CHI '23) (c.f., Figure 4)

Play sound when selected Aggregate data (mean) Play all Stop Data Insights 0 1 2 3 4 5 6

Editor

Data Fields Visual Audio

Fields

Select fields: symbol date price

Key: symbol date

symbol Type nominal

Encodings: Add encoding color Go to visual tab Remove encoding

date Type temporal

Encodings: Add encoding x Go to visual tab Remove encoding

price Type quantitative

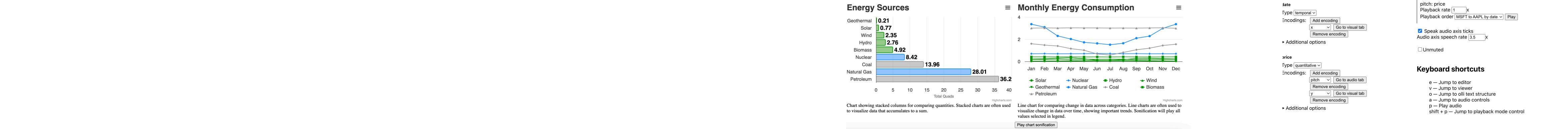
Encodings: Add encoding pitch Go to audio tab Remove encoding y Go to visual tab Remove encoding

Additional options

Keyboard shortcuts

e = Jump to editor
v = Jump to viewer
o = Jump to off text structure
a = Jump to audio controls
p = Play audio
shift + p = Jump to playback mode control

• Better tools



2024

★Slides here → frank.computer

Visualization and accessibility: The state of the art, 2024



Frank Elavsky, PhD Student



Human-
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Interaction
Institute



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