

# Visualization for Data Science

## Discourse with Data II

### Interaction



320

# Adminstrivia

- No lab this week
  - I heard you ooooo!!!
    - No DS 3, either split the weight between DS1/2 OR move to project OR final.
    - Work on your Project deliverable during this time.
- Office hours tomorrow online
- Technical
  - We've spent roughly half of the class time on tooling, this will shift. There will be some tutorials, but we expect most of your programming learning to come outside of class.
- Theory
  - We will start spending more time on the WHY of info. Viz so expect to sometimes being required to have assigned readings before class.

# The Human-Information Interaction Epistemic Cycle

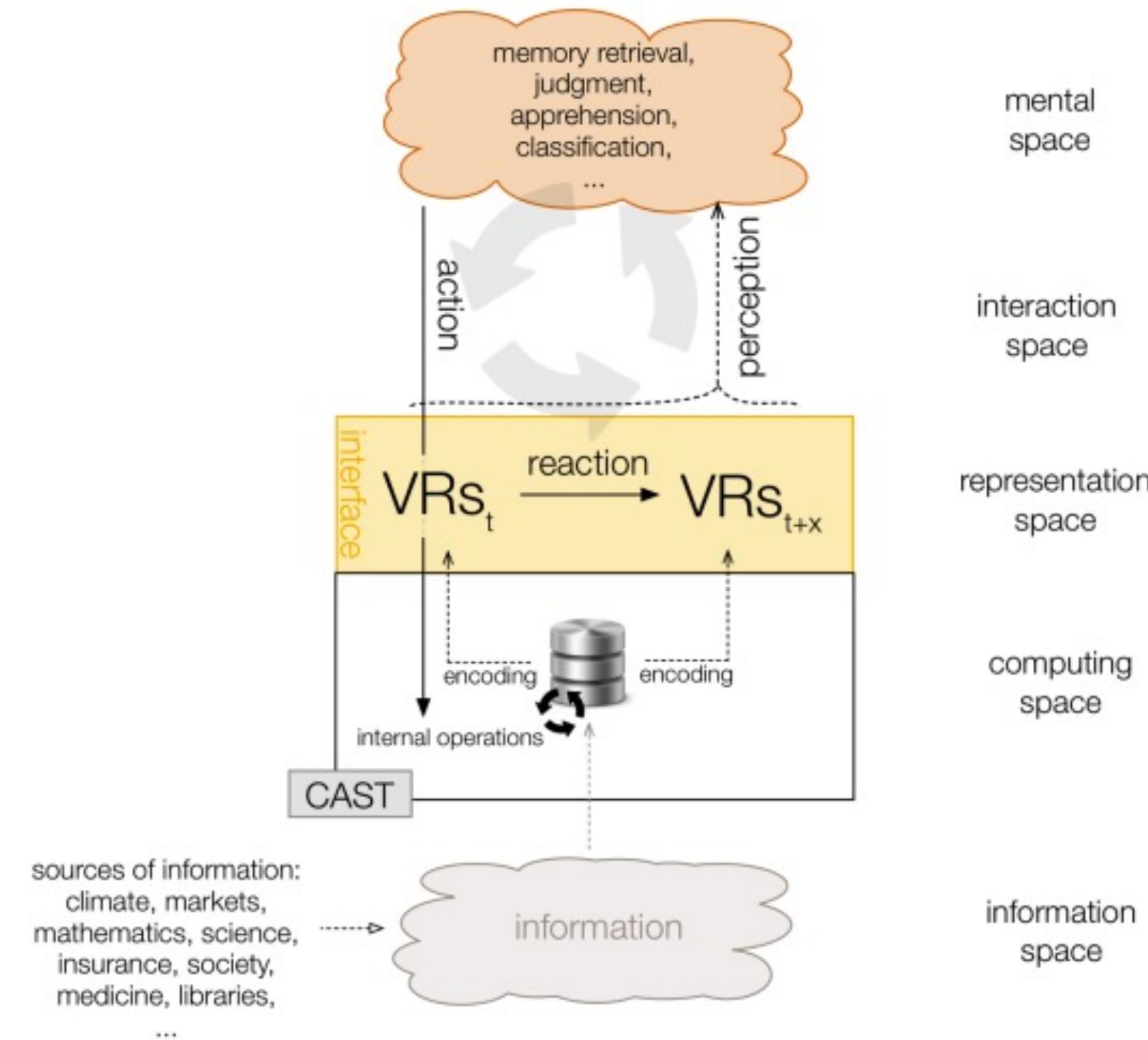
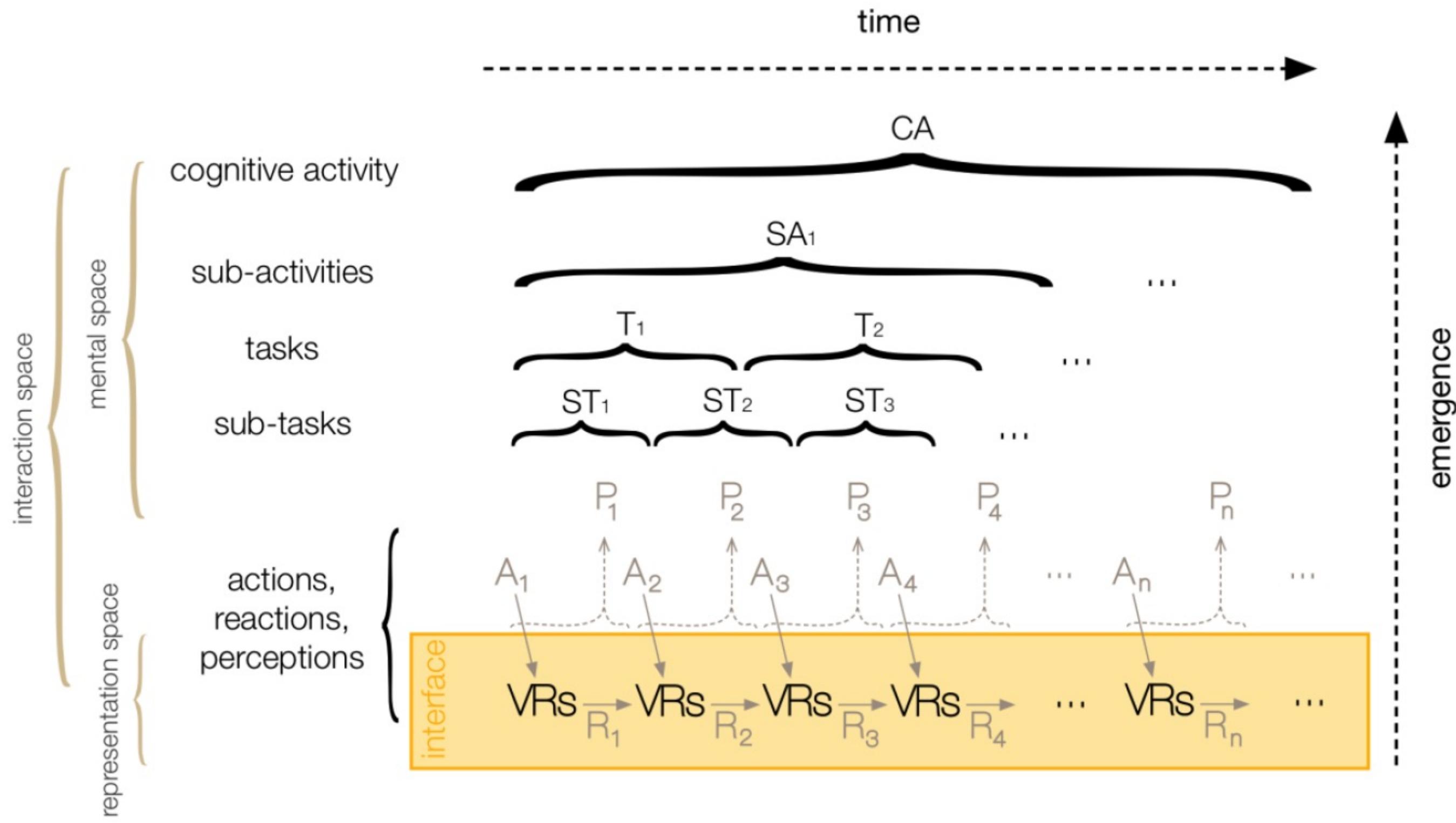


Figure 3: The Human-Information Interaction Epistemic Cycle

# The Hierarchical Structure of a Complex Cognitive Activity



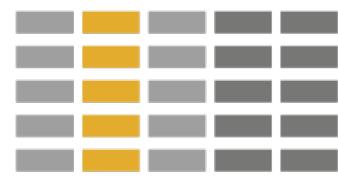
# Approaches to Supporting the Discourse with Large Datasets

- Faceting – juxtapose, partition, superimpose
- Interaction – manipulate the external view
- Reduce
  - embed additional data into smaller glyphs
  - reduce amount of attributes visualized (e.g. maps reduces from 3D to 2D)



# How to handle complexity

→ *Derive*



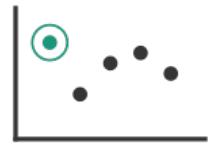
## Manipulate

→ **Change**



- derive new data to show within view
- change view over time
- facet across multiple views
- reduce items/attributes within single view

→ **Select**



→ **Navigate**

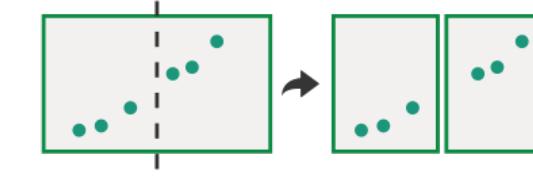


## Facet

→ **Juxtapose**



→ **Partition**



→ **Superimpose**

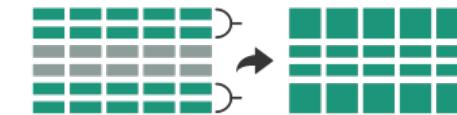


## Reduce

→ **Filter**



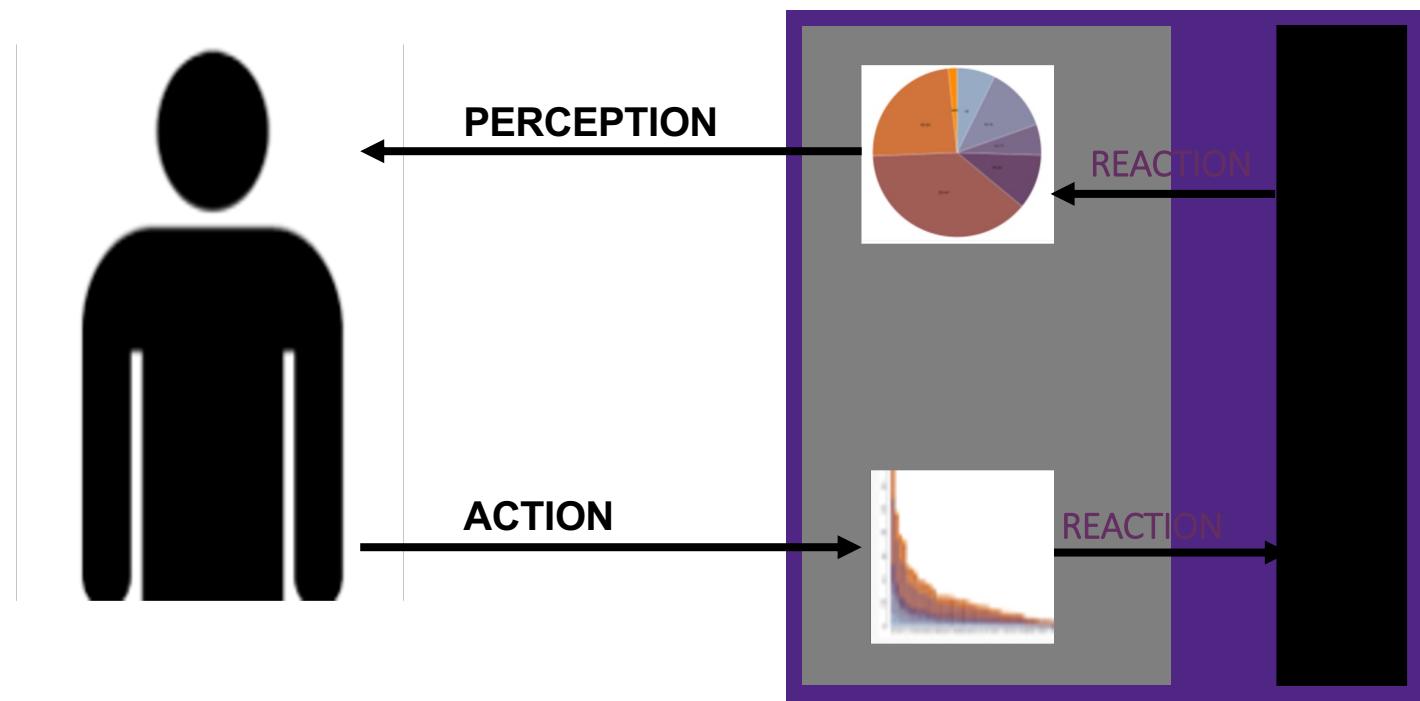
→ **Aggregate**



→ **Embed**



# Interaction



# Interaction

## Why Interaction?

Interactions allows us to

- control flow of data,
- be active participants in the analysis of data,
- adjust features of the tool to suit the user's needs,
- visualization of large amounts of data,
- extend/amplifies users' sensemaking abilities,
- increase engagement (vis becomes personal to user),
- improve the discourse with information,

# Learning Outcomes

- Describe how interaction can be used for changing data representation, transformation, and communication.
- Describe various interaction techniques and select the technique most appropriate for a given problem.
- Discuss the role of interaction in visualizations and its strength and limitations in data science
- Evaluate the effectiveness of an interaction technique based on the human-computer interaction (HCI) principle of affordances.
- Identify situations where coordinated views would be effective.
- Critique existing visualizations and suggest improvements and refinements.

# Manipulate

## → Change over Time



## → Navigate

→ *Zoom  
Geometric*



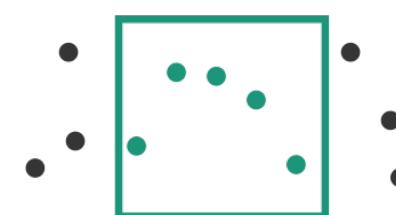
## → Select



→ *Pan/Translate*



→ *Constrained*



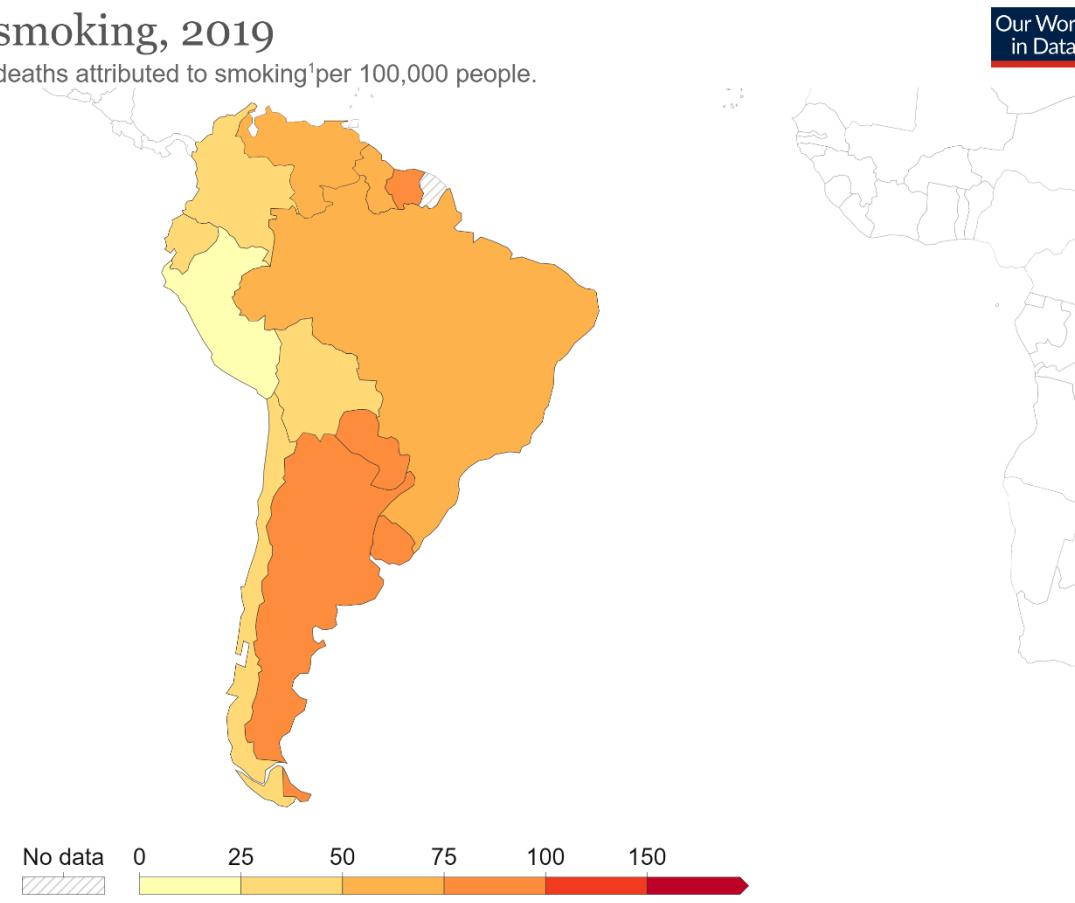
# Change over time

- change any of these choices
  - encoding itself: same data, different viz. technique, e.g. first rep as a bar then as a map
  - parameters
  - arrange: rearrange, reorder, alignment
  - aggregation level, what is filtered...
  - interaction entails change
- powerful & flexible

# Idiom: Change Encodings

Death rate from smoking, 2019

Estimated annual number of deaths attributed to smoking<sup>1</sup> per 100,000 people.



Source: IHME, Global Burden of Disease (2019)

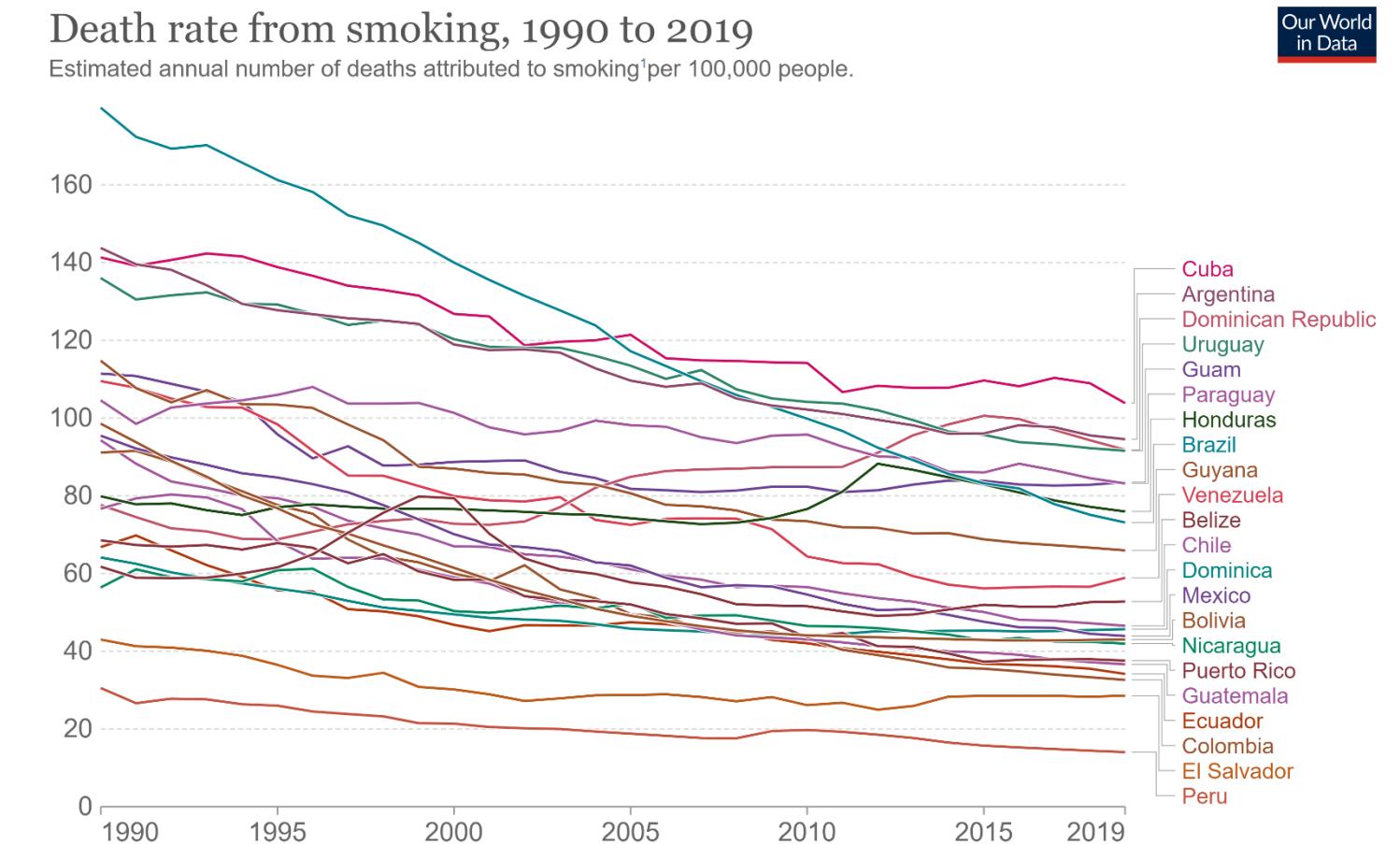
Note: To allow comparisons between countries and over time this metric is age-standardized.

1. **Smoking:** Tobacco smoking is the practice of burning tobacco and ingesting the smoke that is produced. Smoking is a risk factor for many diseases including heart attacks, strokes and cancer. It is the leading risk factor for death in men, globally.

Our World  
in Data

Death rate from smoking, 1990 to 2019

Estimated annual number of deaths attributed to smoking<sup>1</sup> per 100,000 people.



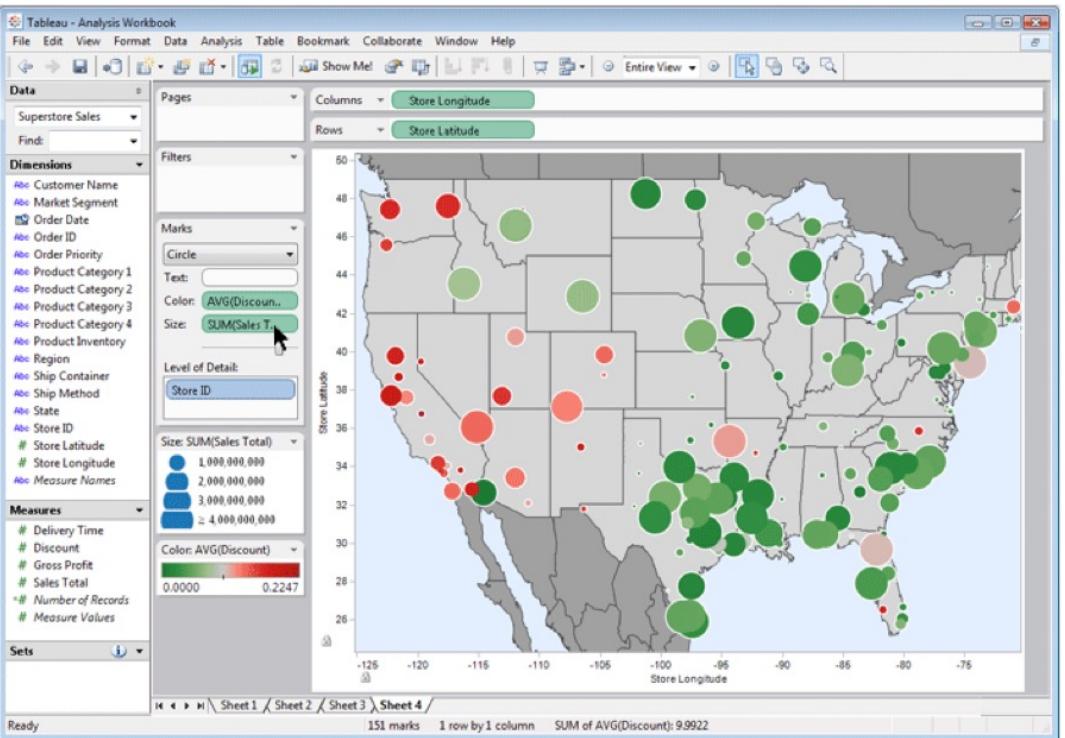
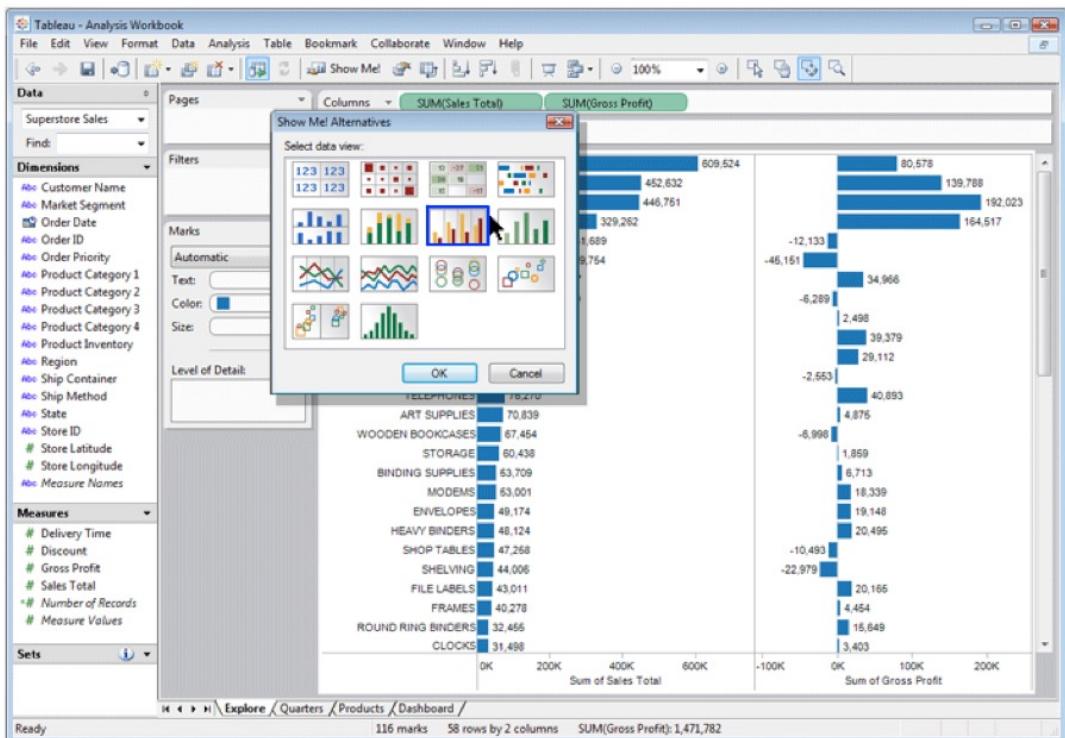
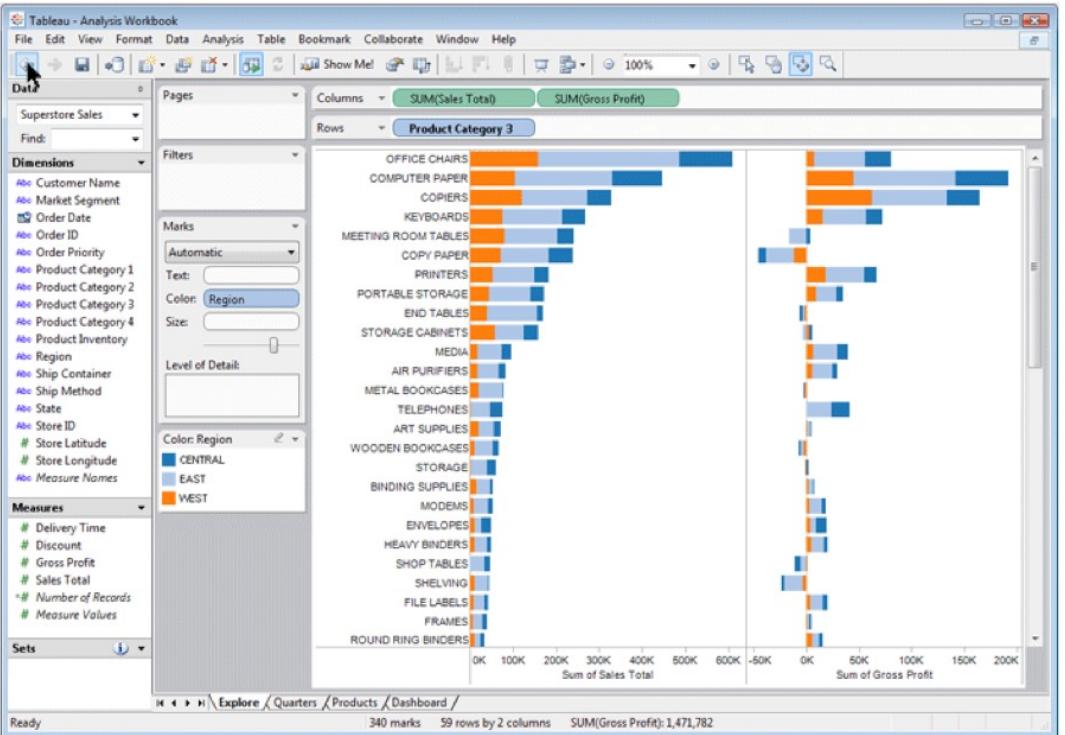
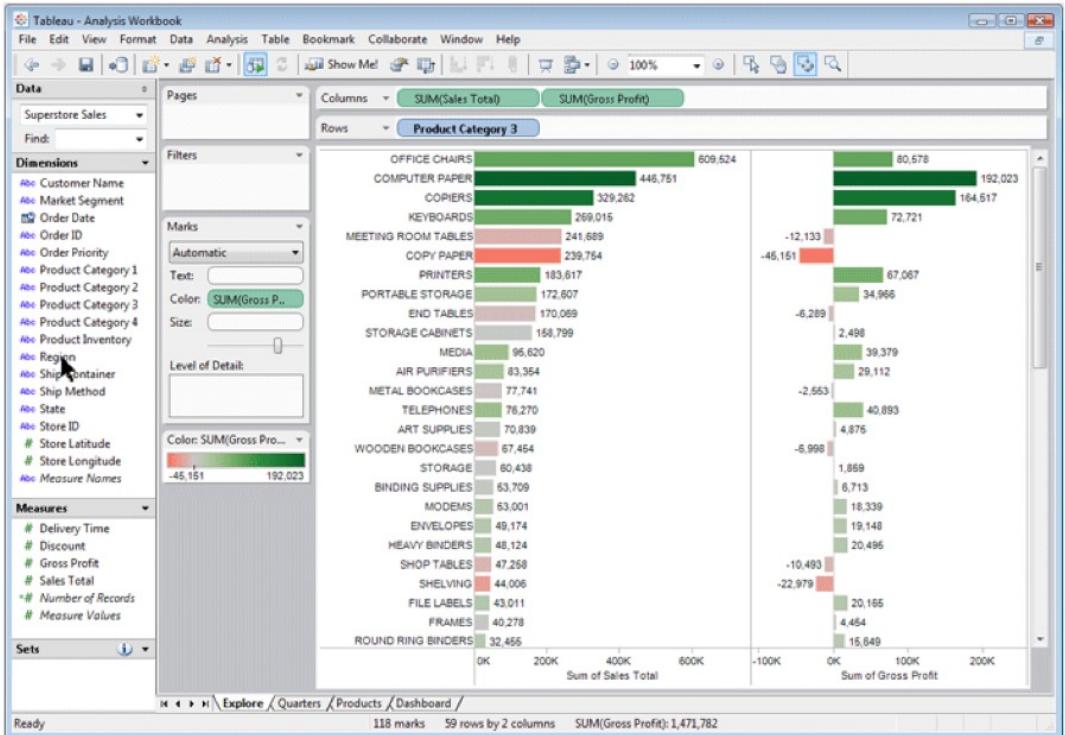
Source: IHME, Global Burden of Disease (2019)

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Our World  
in Data

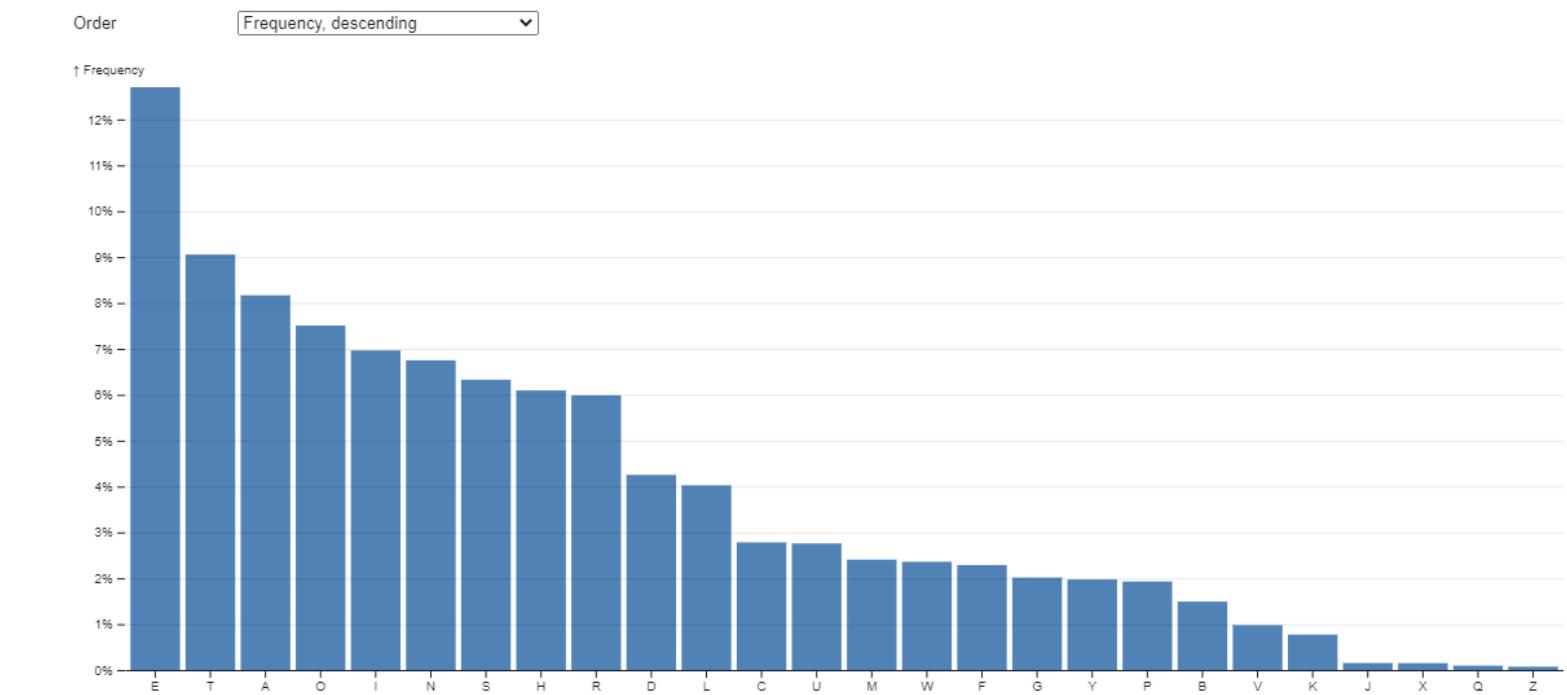
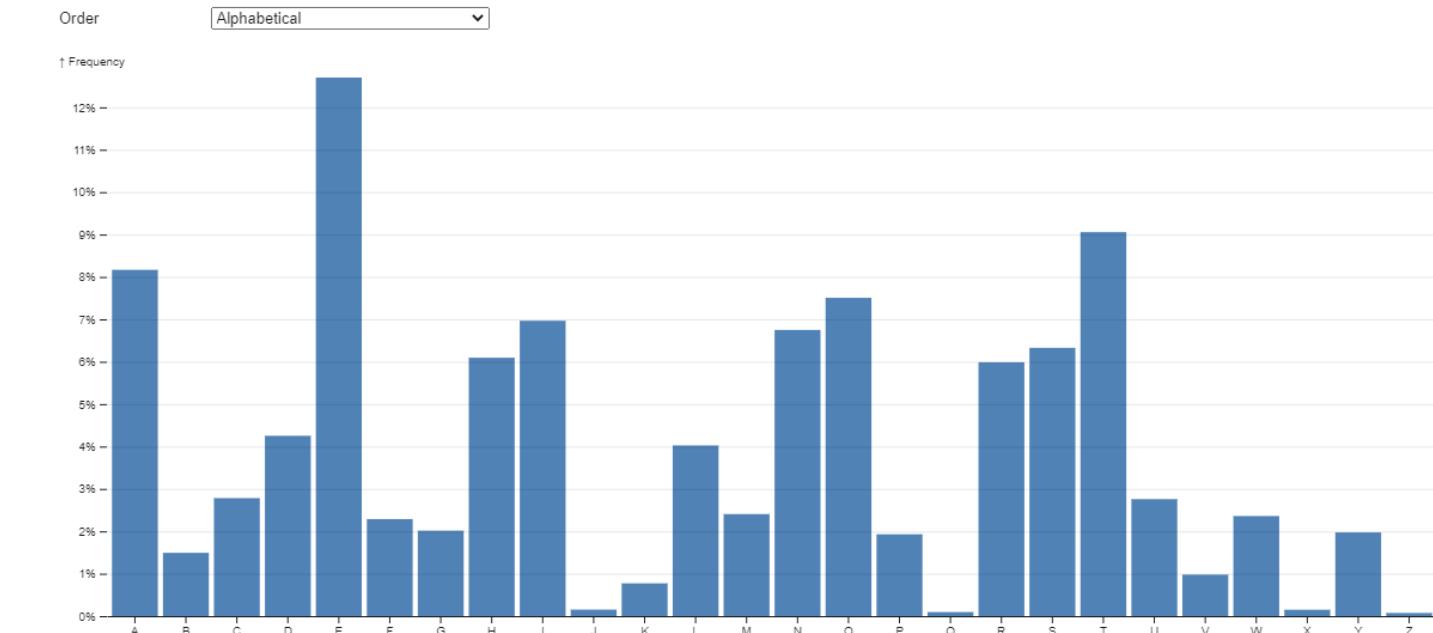
# Idiom: Change Encodings



# Idiom: Change order/arrangement

*made with D3*

- what: simple table
- how: data-driven reordering
- why: find extreme values, trends

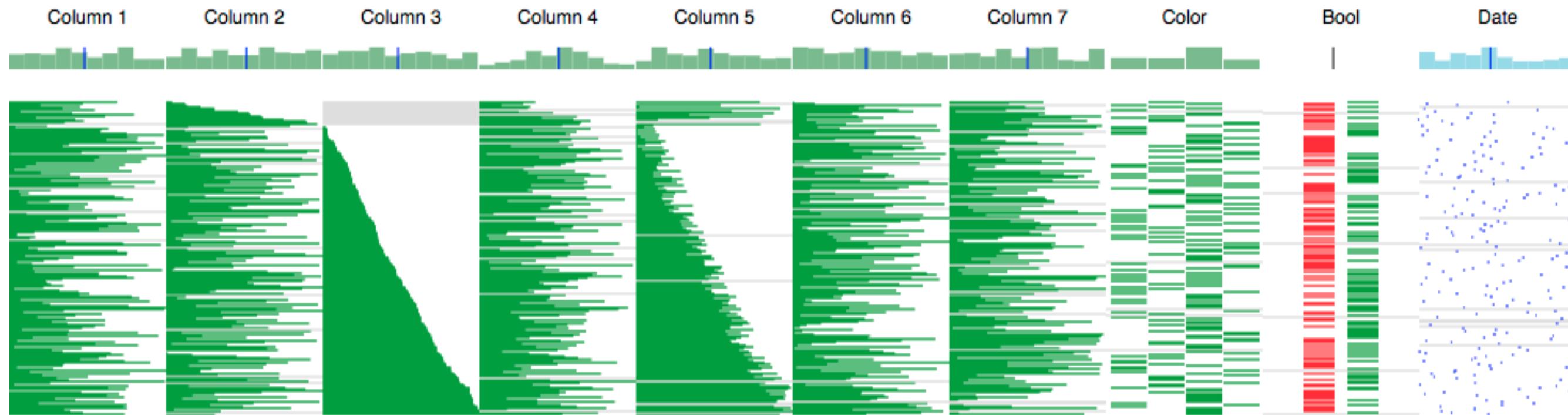


# Idiom: Change order/arrangement

# System: DataStripes

- what: table with many attributes
- how: data-driven reordering by selecting column
- why: find correlations between attributes

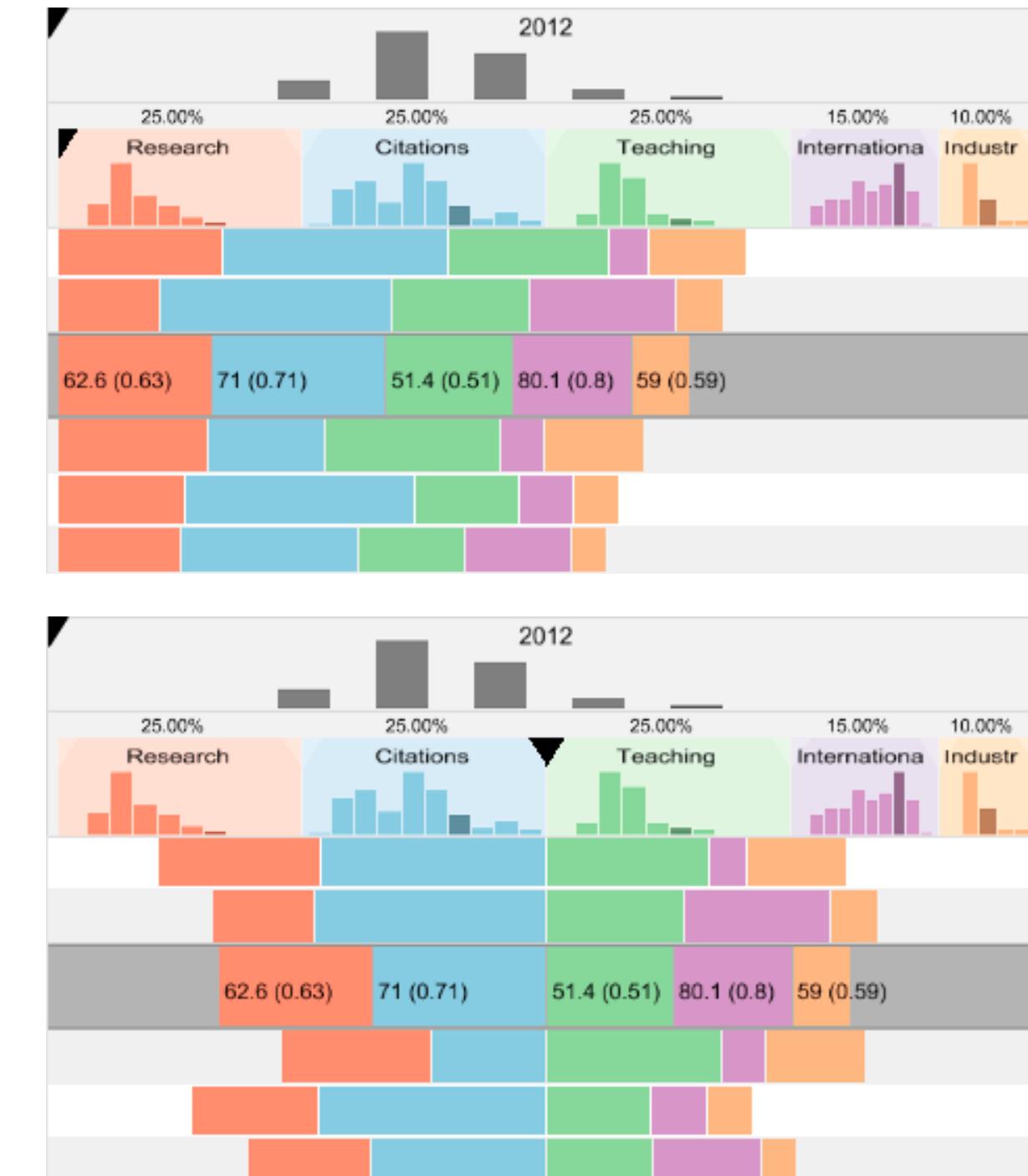
*made with D3*



# Idiom: Change alignment

# System: LineUp

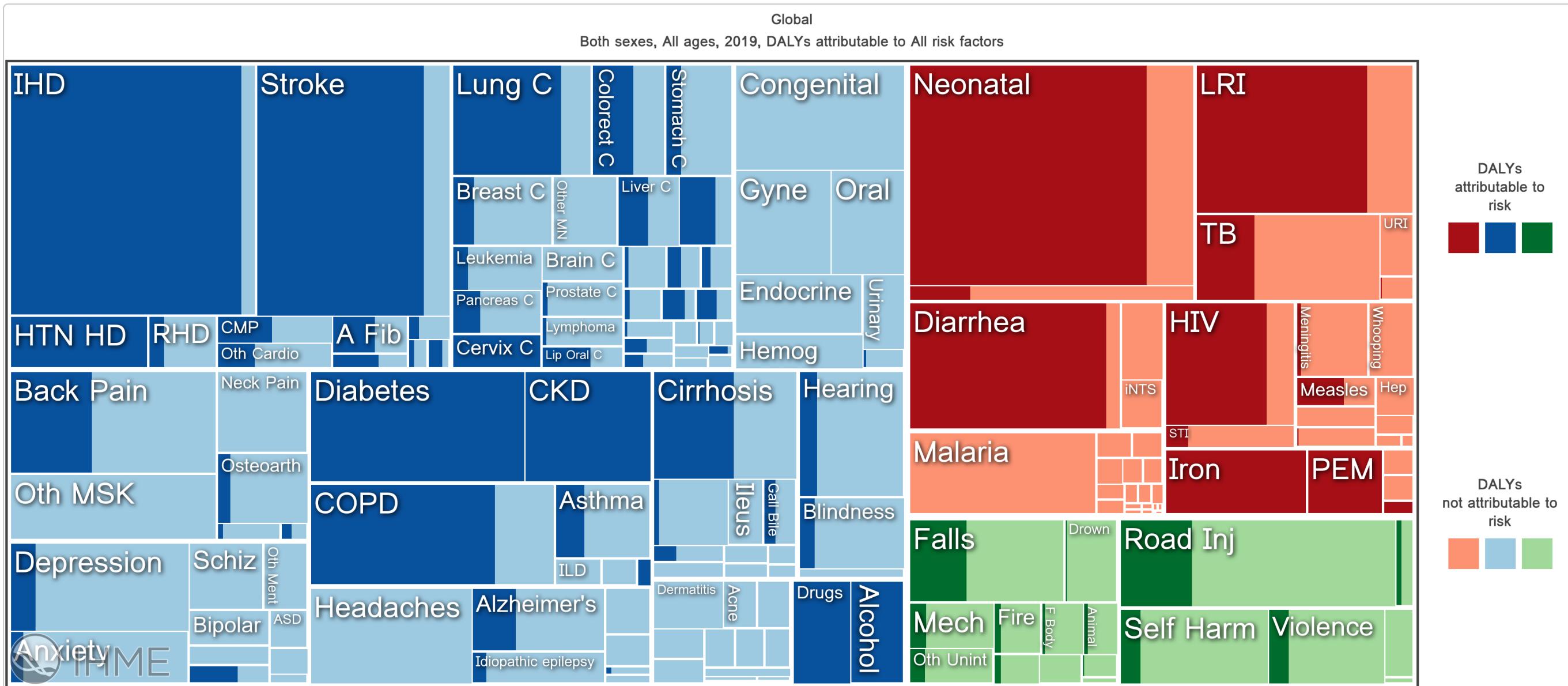
- stacked bars
  - easy to compare
    - first segment
    - total bar
- align to different segment
  - supports flexible comparison



[LineUp: Visual Analysis of Multi-Attribute Rankings. Gratzl, Lex, Gehlenborg, Pfister, and Streit. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2013) 19:12 (2013), 2277–2286.]

# Idiom: Change Data and/or Parameters

- widgets and controls
  - sliders, buttons, radio buttons, checkboxes, dropdowns/comboboxes

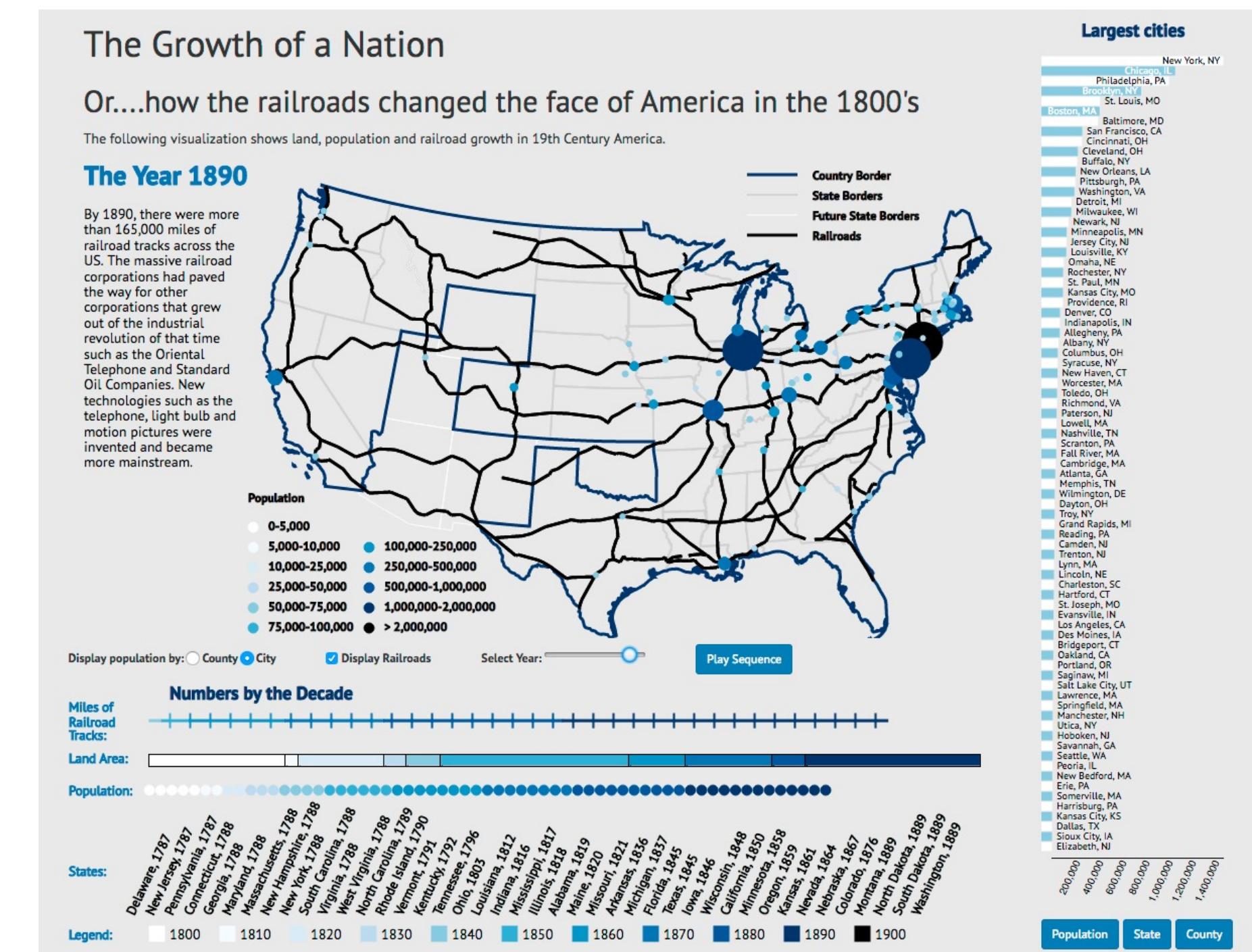


<https://vizhub.healthdata.org/gbd-compare/>

# Idiom: Change Data and/or Parameters

made with D3

- pros
  - clear affordances, self-documenting (with labels)
- cons
  - uses screen space
- design choices
  - separated vs interleaved
    - controls & canvas

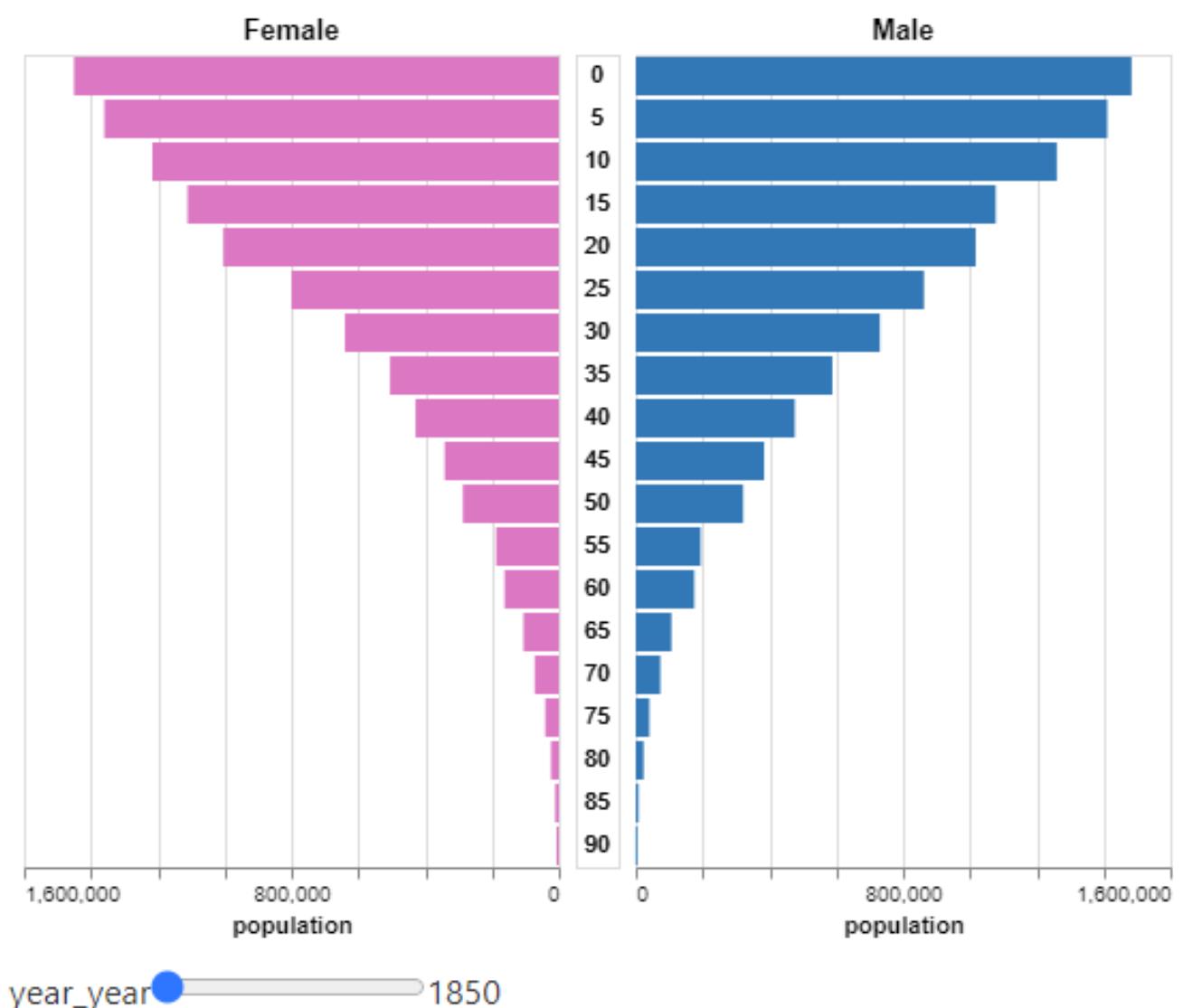


<http://laurenwood.github.io/>

# Idiom: Change Data and/or Parameters

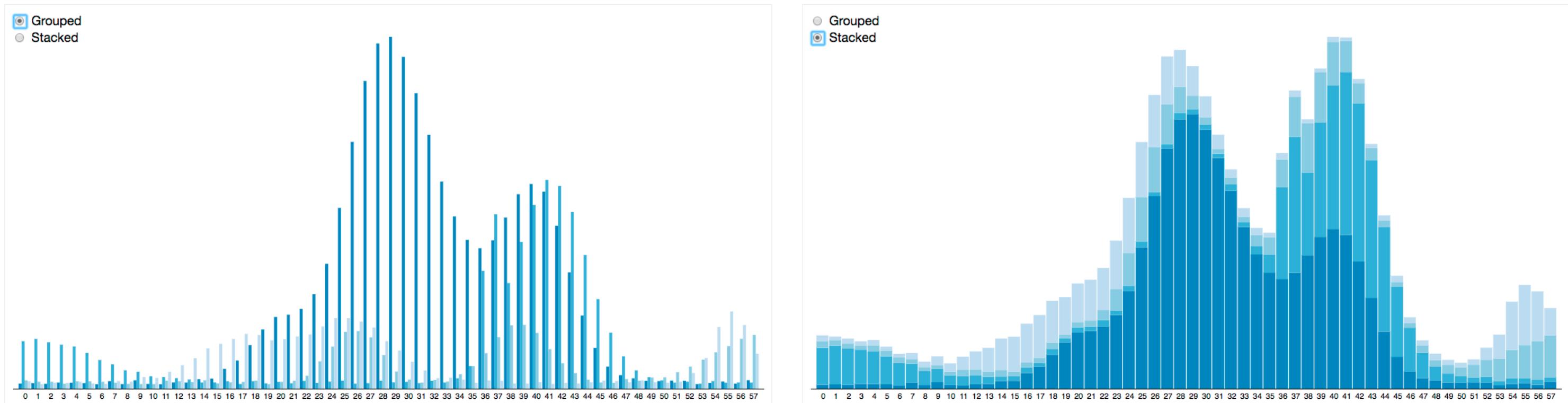
## US Population Pyramid Over Time

A population pyramid shows the distribution of age groups within a population. It uses a slider widget that is bound to the year to visualize the age distribution over time.



# Idiom: Animated transitions - visual encoding change

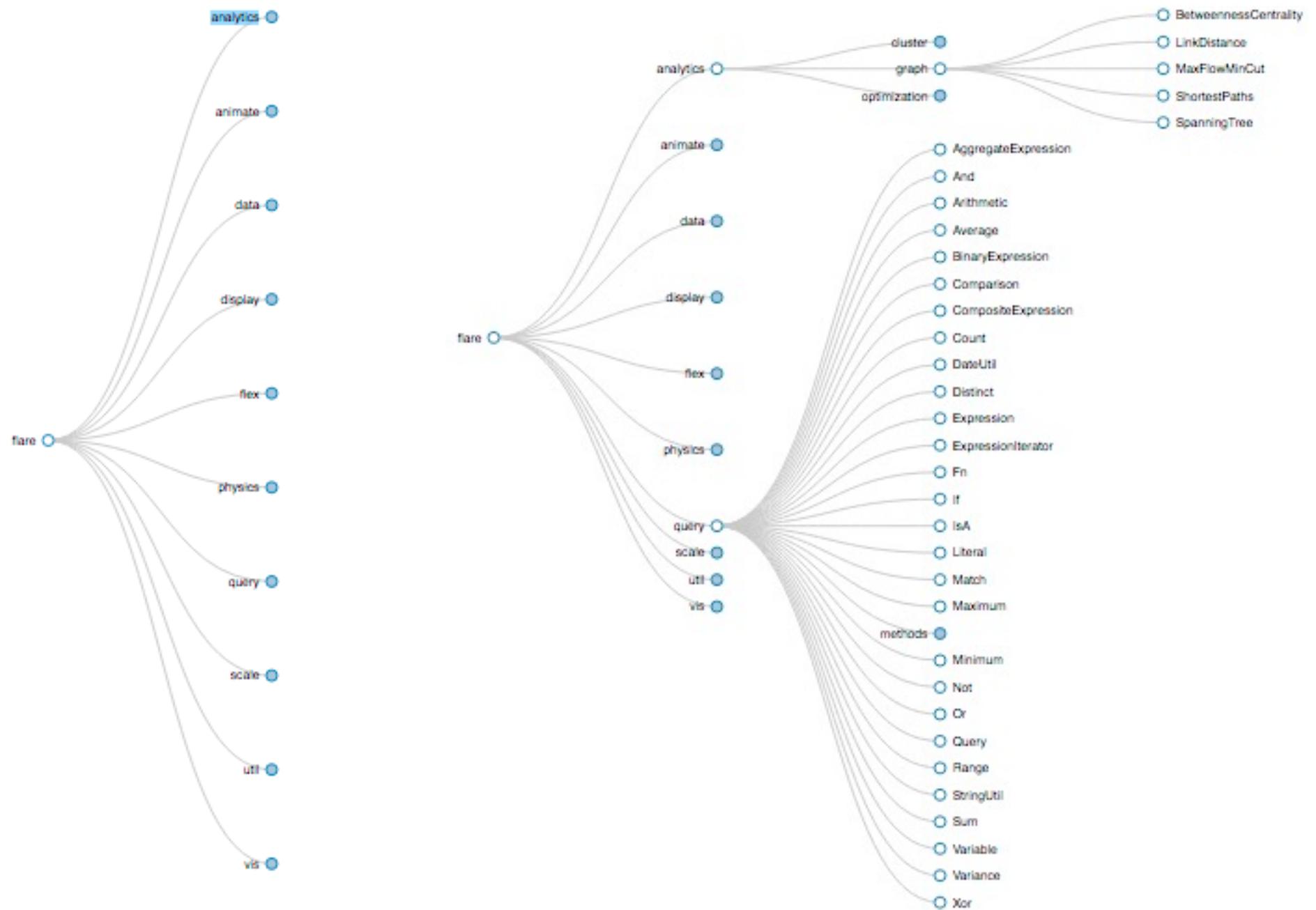
- smooth transition from one state to another
  - alternative to jump cuts, supports item tracking
    - best case for animation
  - staging to reduce cognitive load



<https://observablehq.com/@d3/stacked-to-grouped-bars>

# Idiom: Animated transition - tree detail

- animated transition
  - network drilldown/rollup

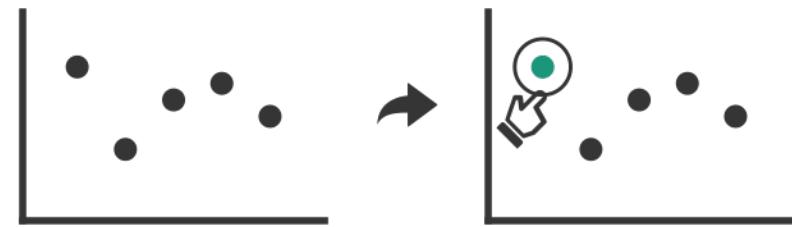


# Manipulate

## → Change over Time



## → Select



# Interaction technology

- what do you design for?
  - mouse & keyboard on desktop?
    - large screens, hover, multiple clicks
  - touch interaction on mobile?
    - small screens, no hover, just tap
  - gestures from video / sensors?
    - ergonomic reality vs movie bombast
  - eye tracking?



Data visualization and the news - Gregor Aisch (37 min)  
[vimeo.com/182590214](https://vimeo.com/182590214)



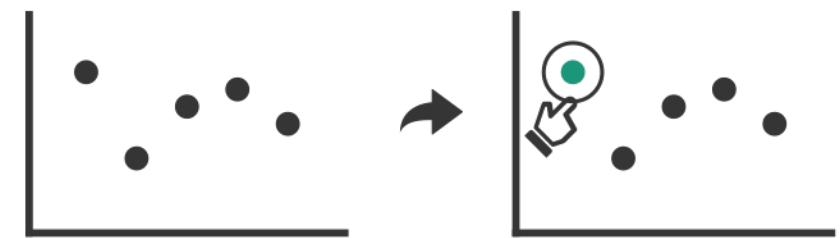
I Hate Tom Cruise - Alex Kauffmann (5 min)

[www.youtube.com/watch?v=QXLfT9sFcbc](https://www.youtube.com/watch?v=QXLfT9sFcbc)

# Selection

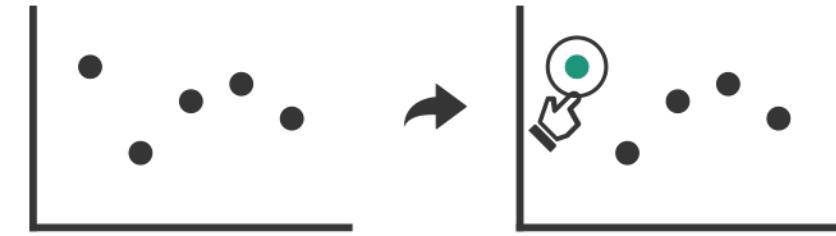
- selection: basic operation for most interaction
- design choices
  - how many selection types?
    - interaction modalities
      - click/tap (heavyweight) vs hover (lightweight but not available on most touchscreens)
      - multiple click types (shift-click, option-click, ...)
      - proximity beyond click/hover (touching vs nearby vs distant)
    - application semantics
      - adding to selection set vs replacing selection
      - can selection be null?
        - ex: toggle so nothing selected if click on background
        - primary vs secondary (ex: source/target nodes in network)
        - group membership (add/delete items, name group, ...)

→ **Select**



# Highlighting

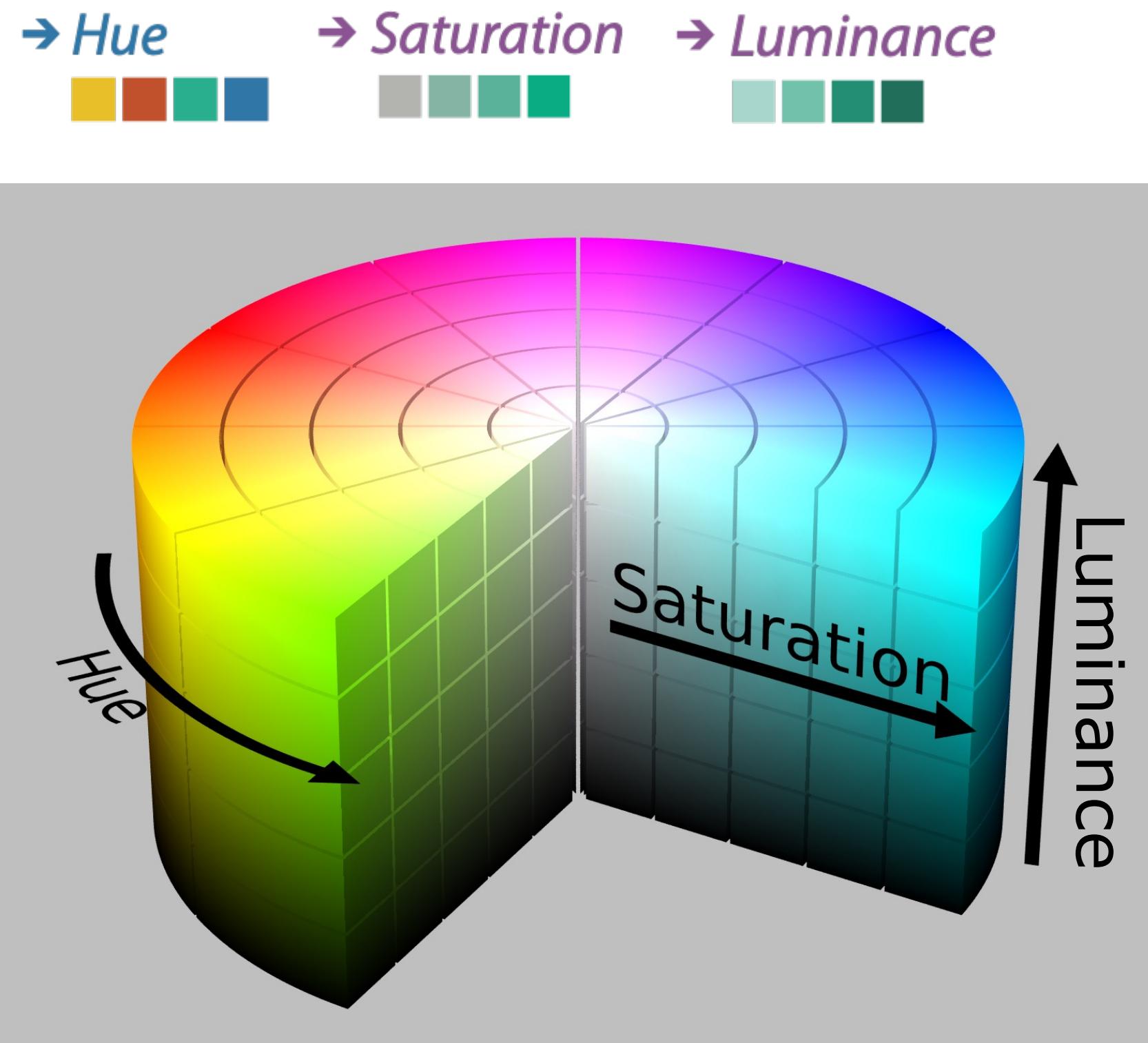
- highlight: change visual encoding for selection targets
  - visual feedback closely tied to but separable from selection (interaction)
- design choices: typical visual channels
  - change item color
    - but hides existing color coding
  - add outline mark
  - change size (ex: increase outline mark linewidth)
  - change shape (ex: from solid to dashed line for link mark)
- unusual channels: motion
  - motion: usually avoid for single view
    - with multiple views, could justify to draw attention to other views



# Revisiting Color

Transparency – extent to which object blocks light

- Fully opaque – blocks light 100%
- Fully transparent – see through
- Cannot be used independently of the other color channels (fully integral)
- Typically used in conjunction with Hue
- Not advisable for use with luminance and saturation because of the strong interaction



# Examples: Interactive Legend

- Selection

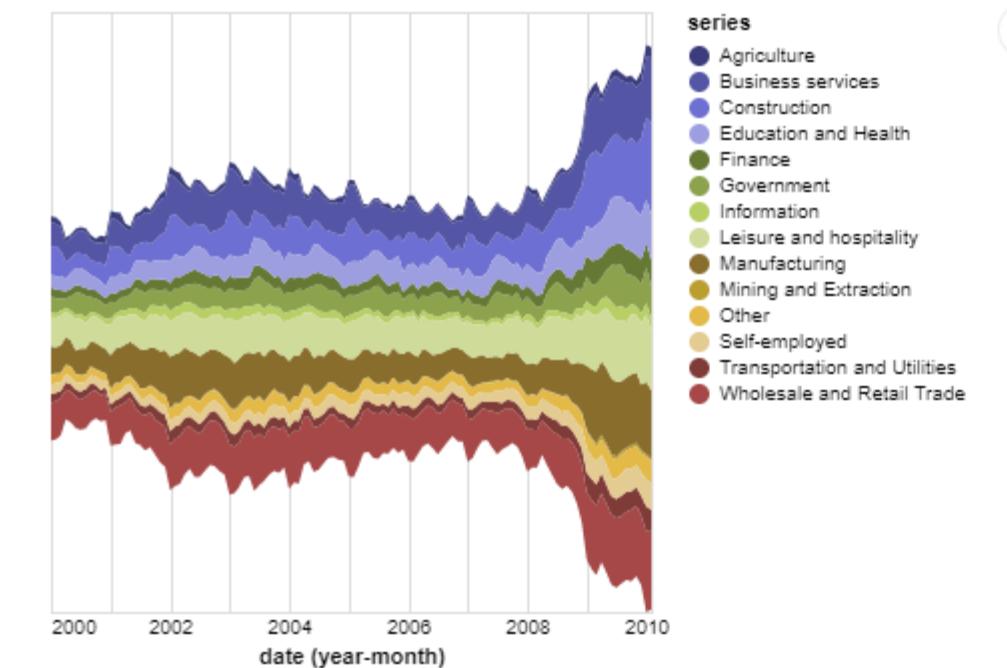
- Type: On click
- Semantics: Single and multiple

- Highlight

- Color: Transparency

## Interactive Legend

The following shows how to create a chart with an interactive legend, by binding the selection to `"legend"`. Such a binding only works with `selection_point` when projected over a single field or encoding.

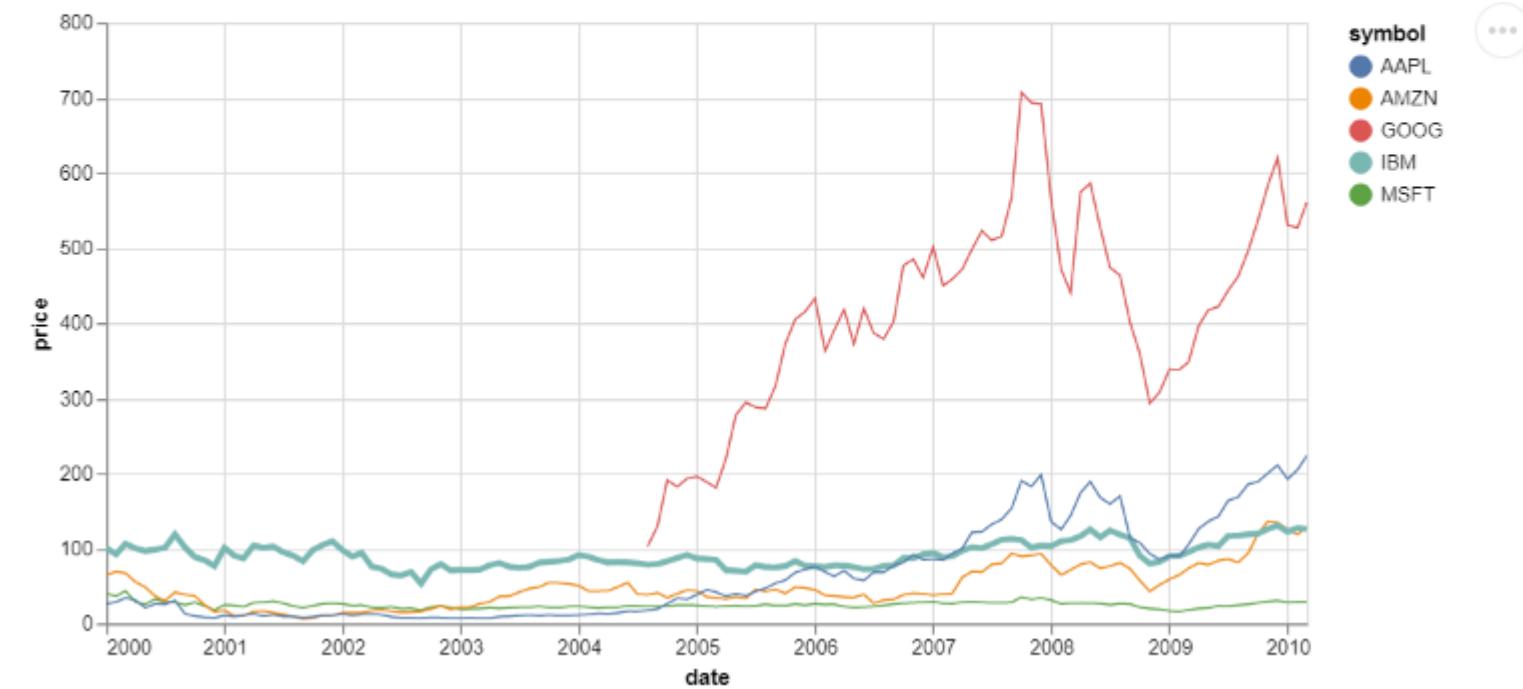


# Examples: Multi-Line Highlight

- Selection
  - Type: On Hover
  - Semantics: Single
- Highlight
  - Stroke-width

## Multi-Line Highlight

This multi-line chart uses an invisible Voronoi tessellation to handle mouseover to identify the nearest point and then highlight the line on which the point falls. It is adapted from the Vega-Lite example found at <https://bl.ocks.org/amitkaps/fe4238e716db53930b2f1a70d3401701>



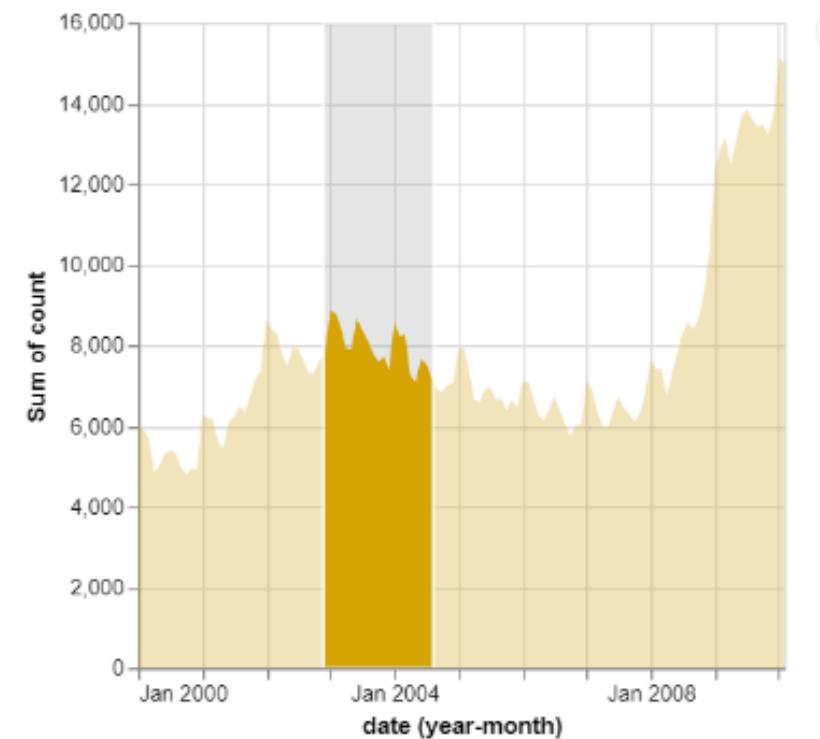
# Examples: Rectangular Brush

- Selection
  - Constrained on y channel
  - Type: ???
  - Type: ???
  - Type: ???
  - Semantics: ????
- Highlight
  - ???

## Using Selection Interval with mark\_area

Because area is considered one object, just using the plain selector will select the entire area instead of just one part of it.

This example shows how to use two areas, one on top of the other, and a *transform\_filter* to fake out this effect.



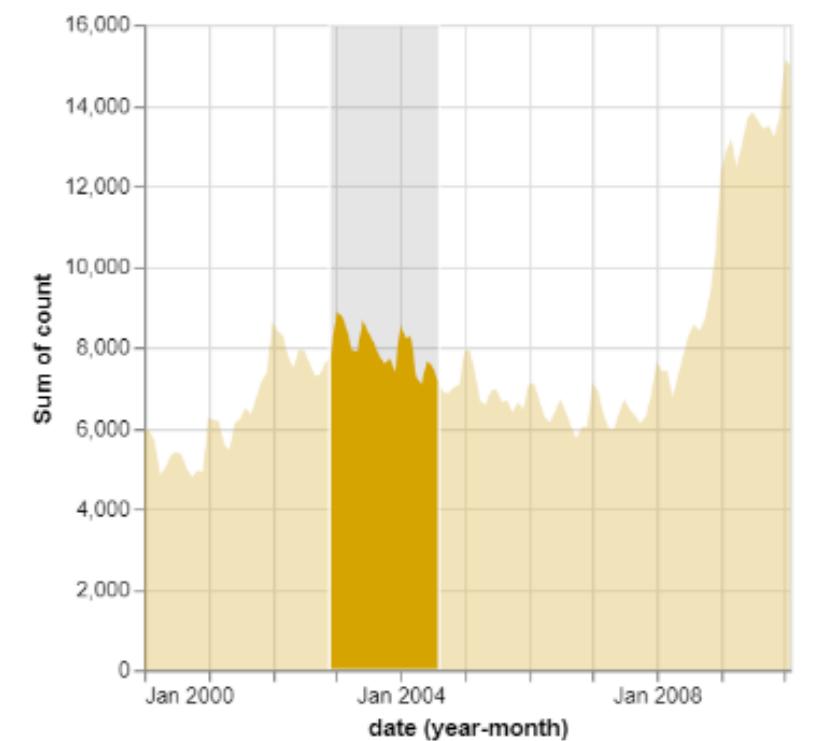
# Examples: Rectangular Brush

- Selection
  - Constrained on y channel
  - Type: On shift-click
  - Type: On mouse scroll
  - Type: On click
  - Semantics: Null, Group
- Highlight
  - Color: Transparency

## Using Selection Interval with mark\_area

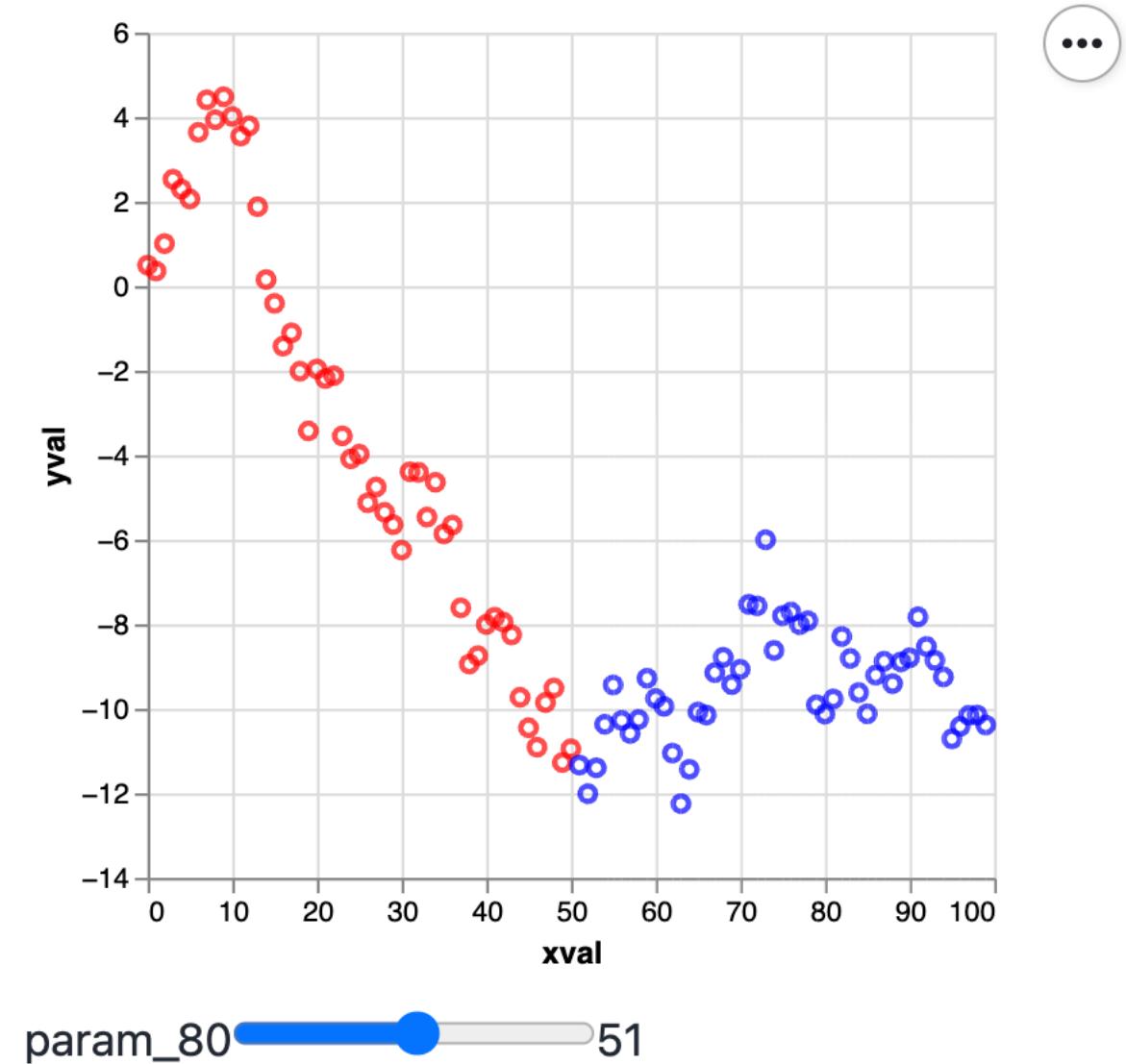
Because area is considered one object, just using the plain selector will select the entire area instead of just one part of it.

This example shows how to use two areas, one on top of the other, and a `transform_filter` to fake out this effect.



# Examples: Slider Cutoff

- Selection
  - Type: Slider
  - Semantics: Grouped interval
- Highlight
  - Color hue



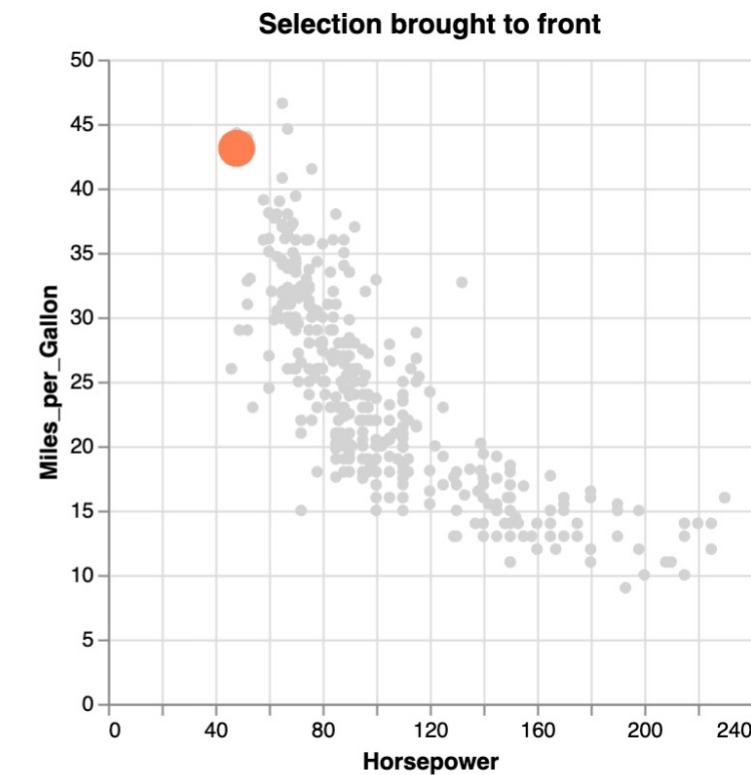
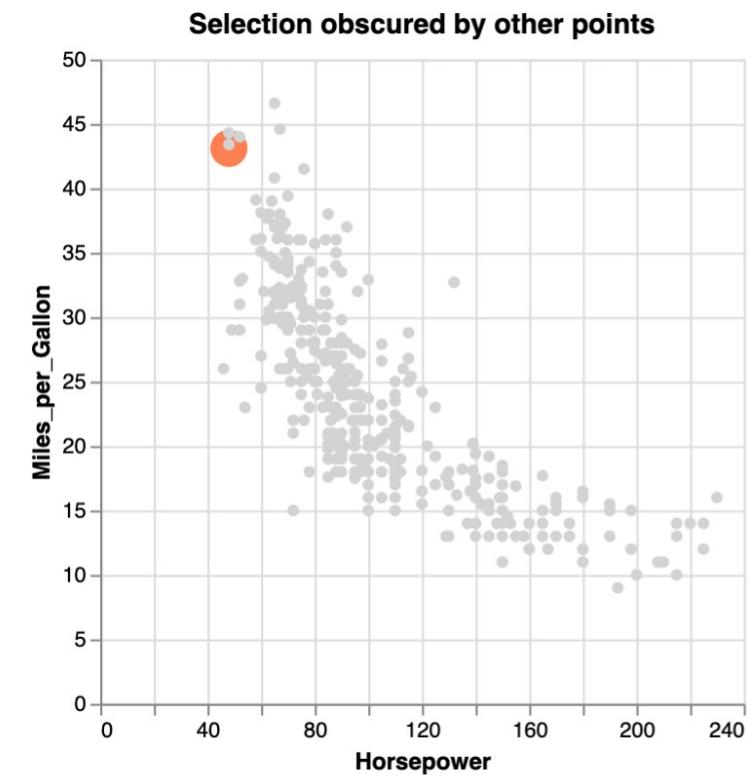
[https://altair-viz.github.io/gallery/slider\\_cutoff.html](https://altair-viz.github.io/gallery/slider_cutoff.html)

# Examples: Hover Zorder

- Selection
  - Constrained on y channel
  - Type: ???
  - Semantics: ???
- Highlight
  - ???

## Selection zorder

This example shows how to bring selected points to the front/foreground by using a condition to change the point's (z)order as it is hovered over with the pointer. This prevents that the selected points are obscured by those that are not selected.

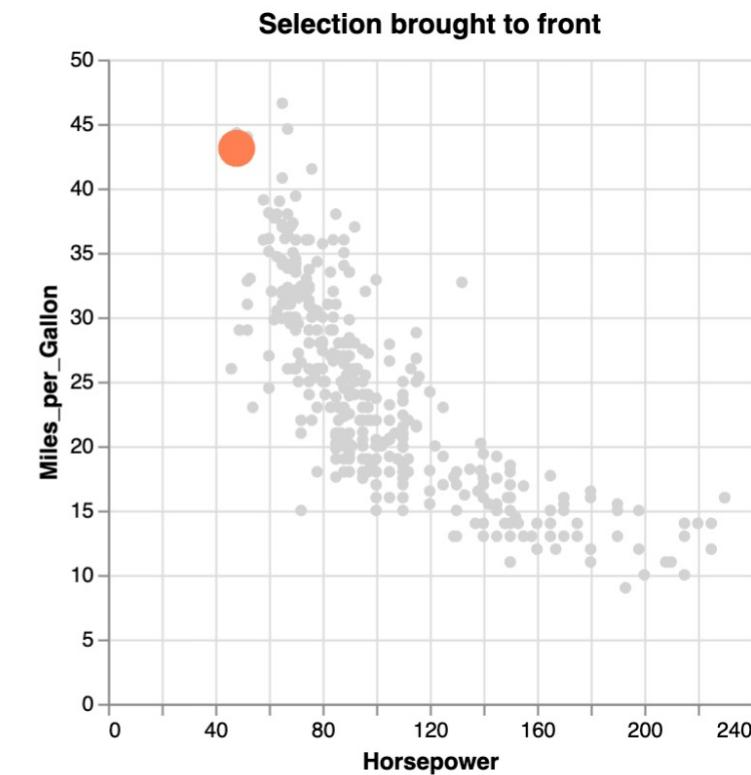
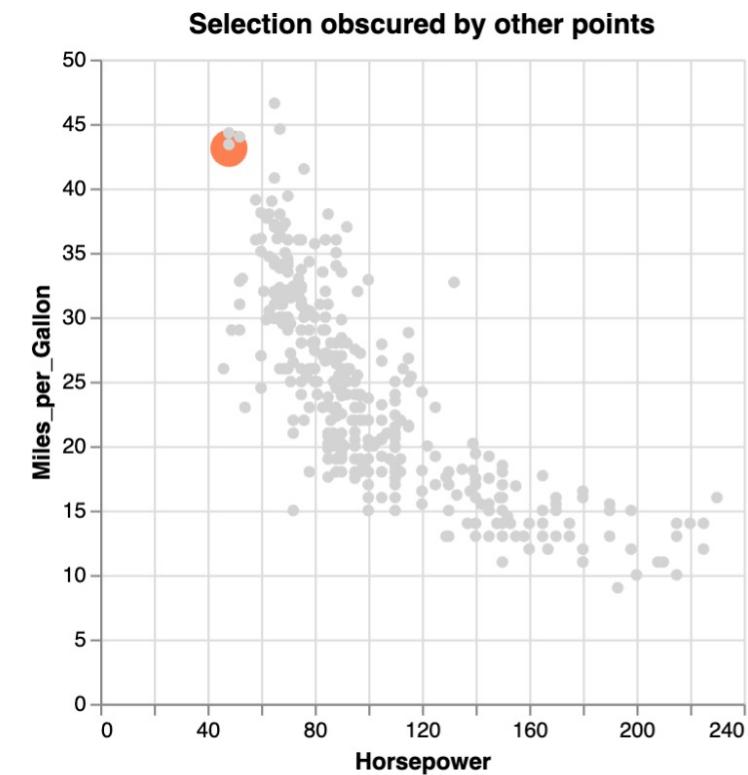


# Examples: Hover Zorder

- Selection
  - Constrained on y channel
  - Type: On hover
  - Semantics: Null, Single
- Highlight
  - Color
  - Size

## Selection zorder

This example shows how to bring selected points to the front/foreground by using a condition to change the point's (z)order as it is hovered over with the pointer. This prevents that the selected points are obscured by those that are not selected.

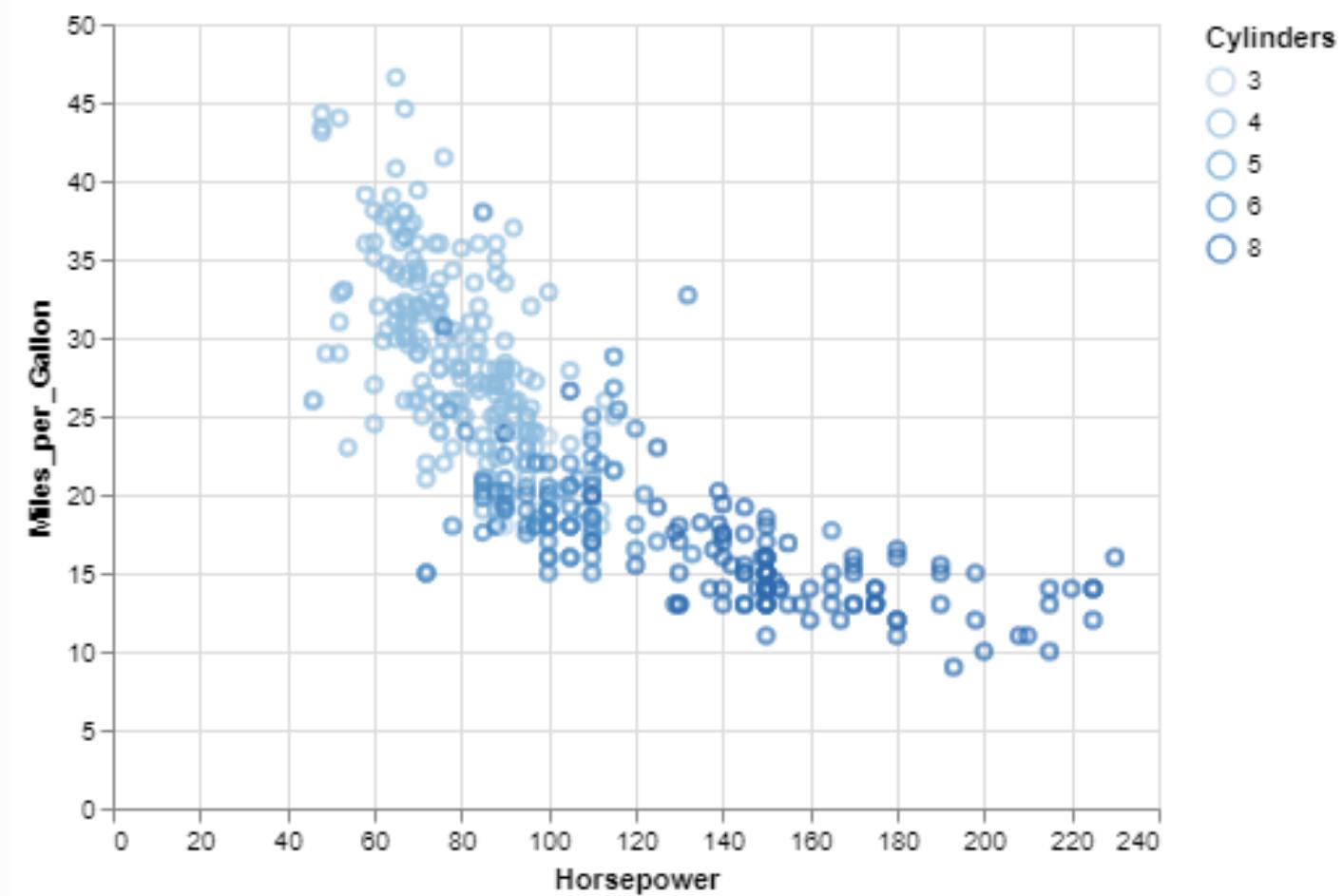


# Examples: Rectangular Brush

- Selection
  - Type: On shift-click
  - Semantics: Null, Group
- Highlight
  - Color: Transparency

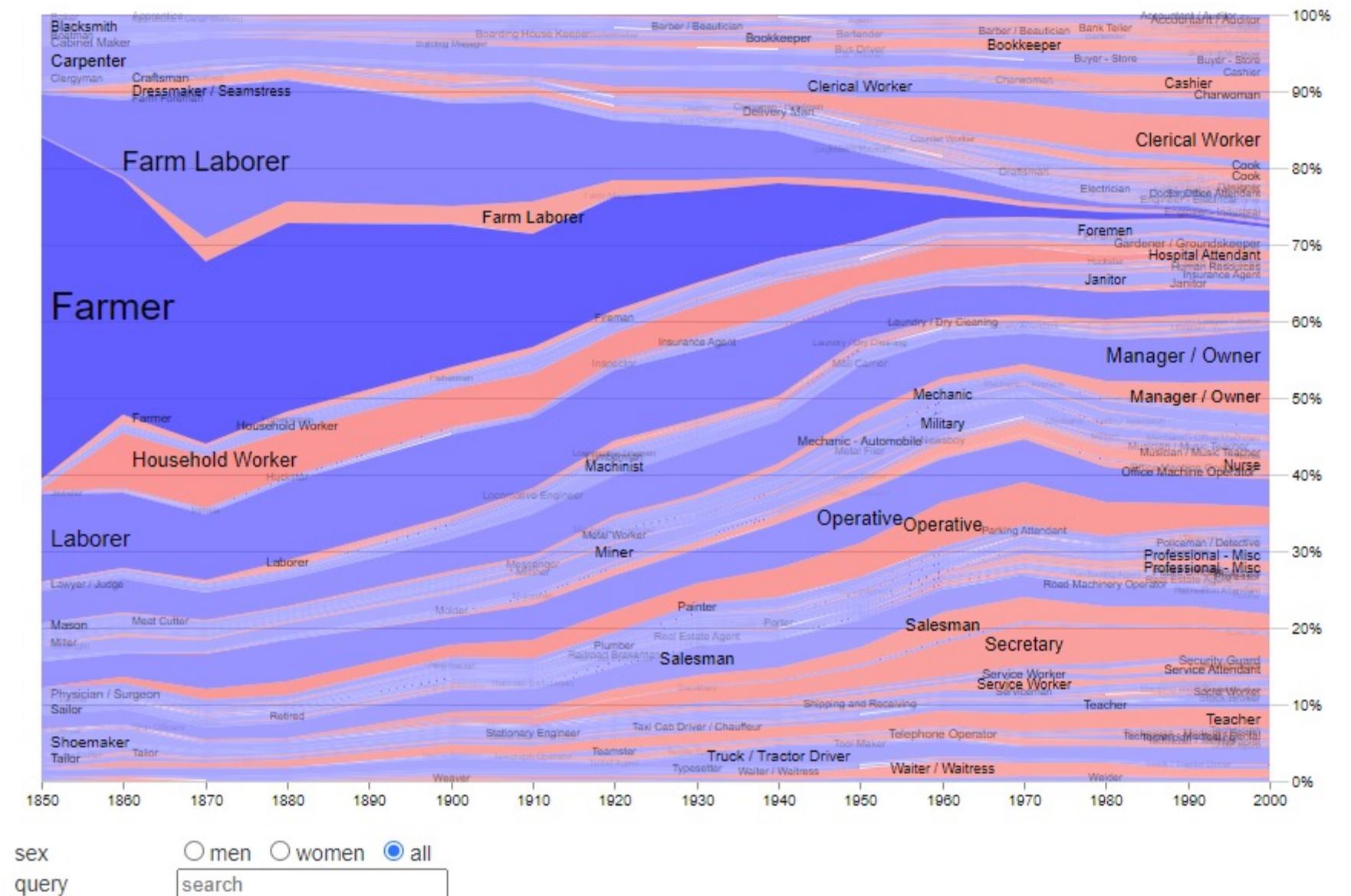
## Interactive Rectangular Brush

This example shows how to add a simple rectangular brush to a scatter plot. By clicking and dragging on the plot, you can highlight points within the range.



# Examples: Job Voyager Example

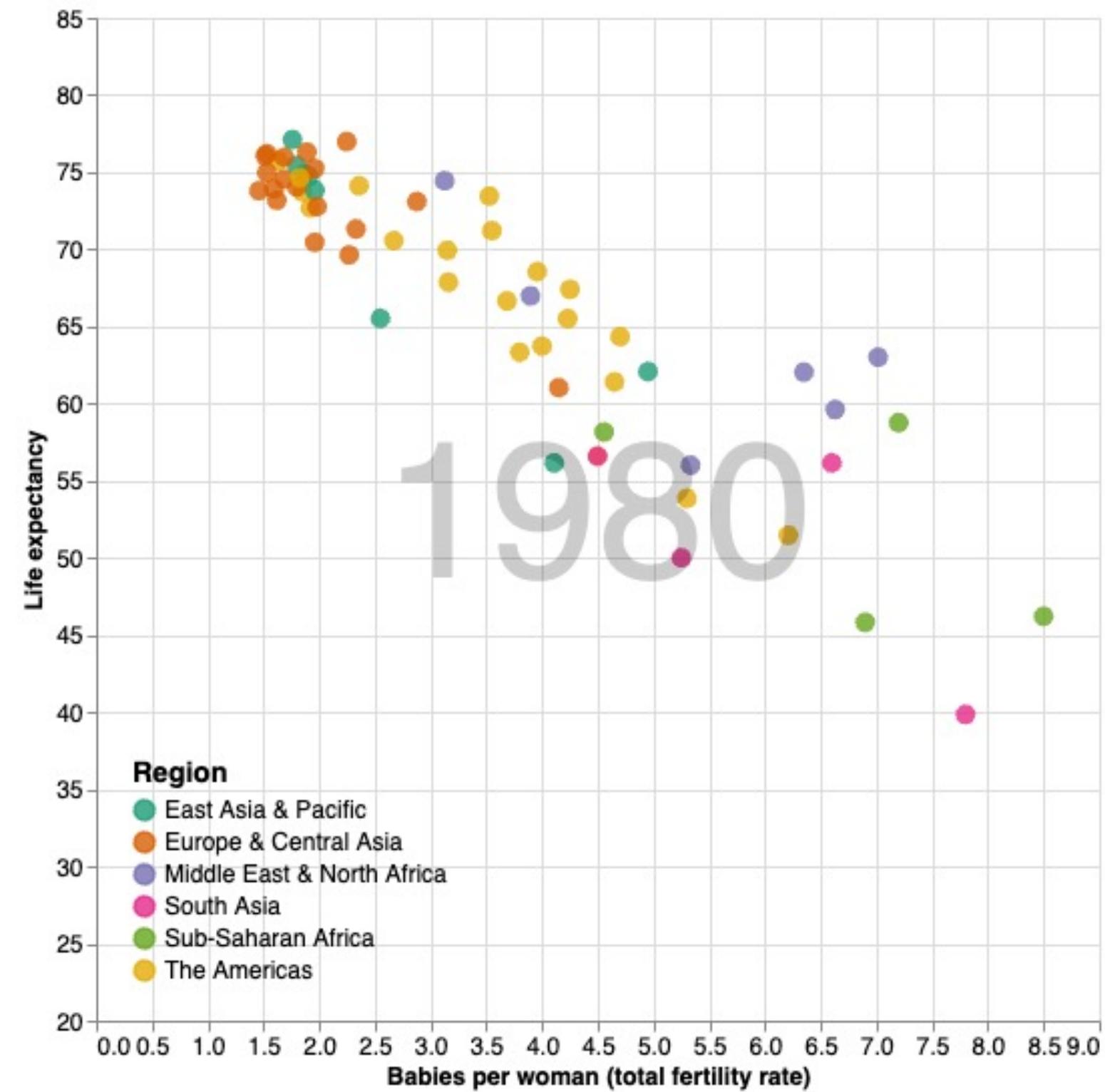
- Selection
  - On Click
  - On Type
- Highlight
  - NOPE
- Filter
  - Huh (more next Monday)



<https://vega.github.io/vega/examples/job-voyager/>

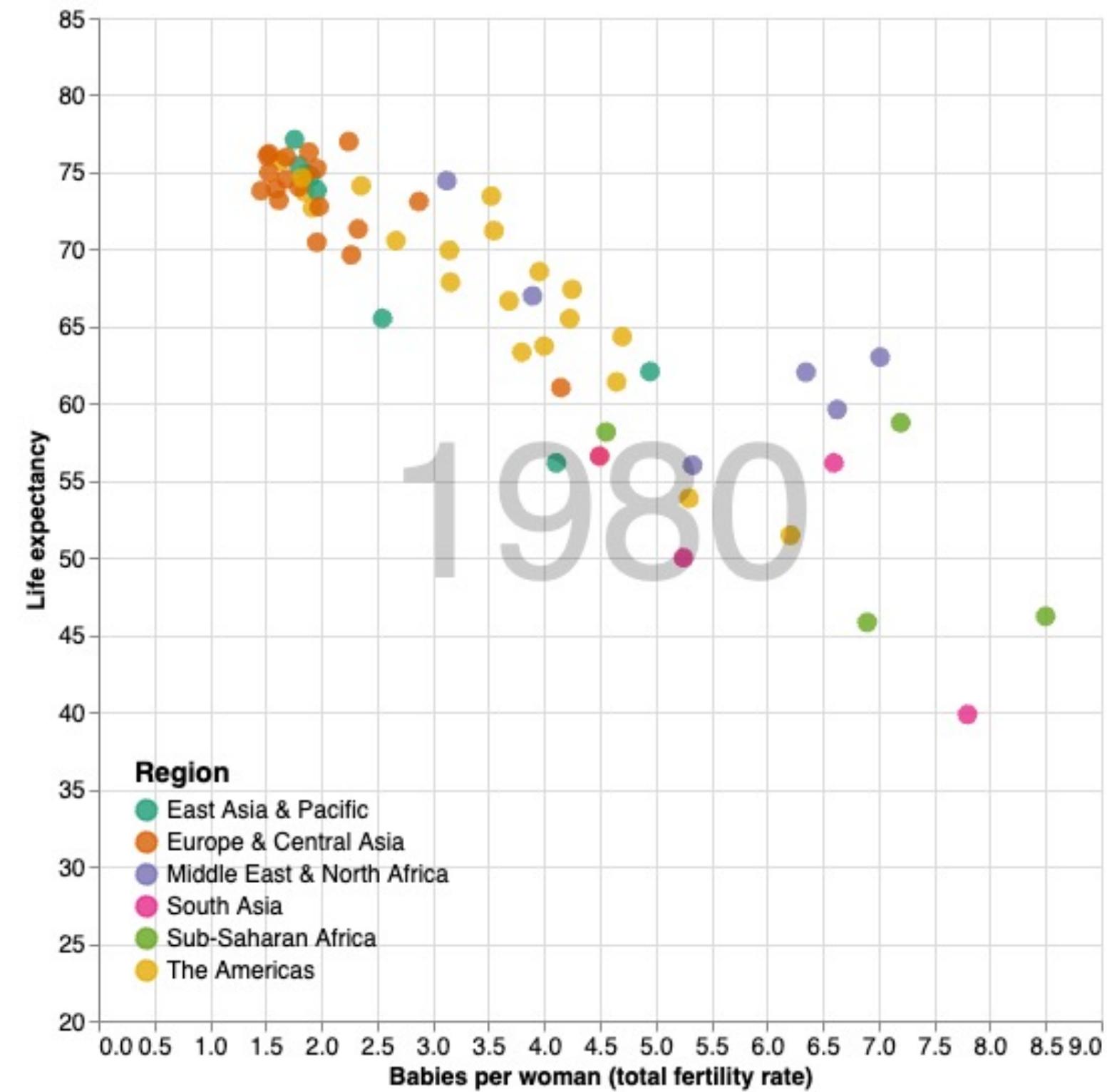
# Examples: Hover with Search

- Selection
  - Type: ???
  - Type: ???
  - Type: ???
- Highlight
  - ???
  - ???
- ???
- ???



# Examples: Hover with Search

- Selection
  - Type: On hover
  - Type: Slider
  - Type: Search Box
- Highlight
  - Color
  - Drill on Demand (huh)
- Filter (huh)
- Embed (double huh)



## Examples: Steriods

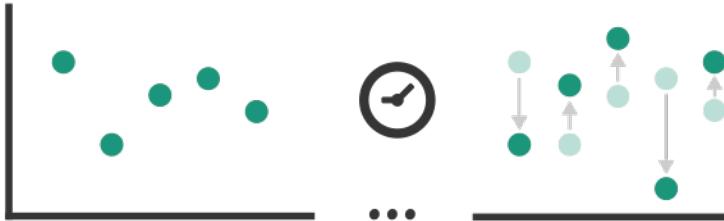
Visit [https://altair-viz.github.io/gallery/multiple\\_interactions.html](https://altair-viz.github.io/gallery/multiple_interactions.html)

Deconstruct the interactions (ha ha ha, not the viz, the interaction)

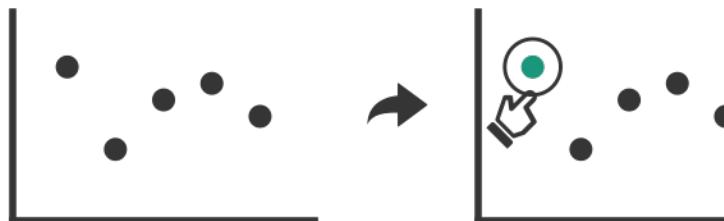
There are multiple ones.

# Manipulate

→ Change over Time



→ Select



→ Navigate

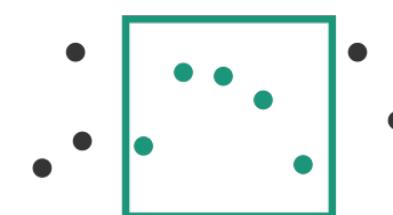
→ Zoom  
*Geometric*



→ Pan/Translate



→ Constrained

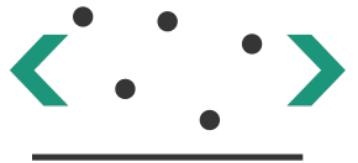


# Navigate: Changing viewpoint/visibility

→ **Navigate**

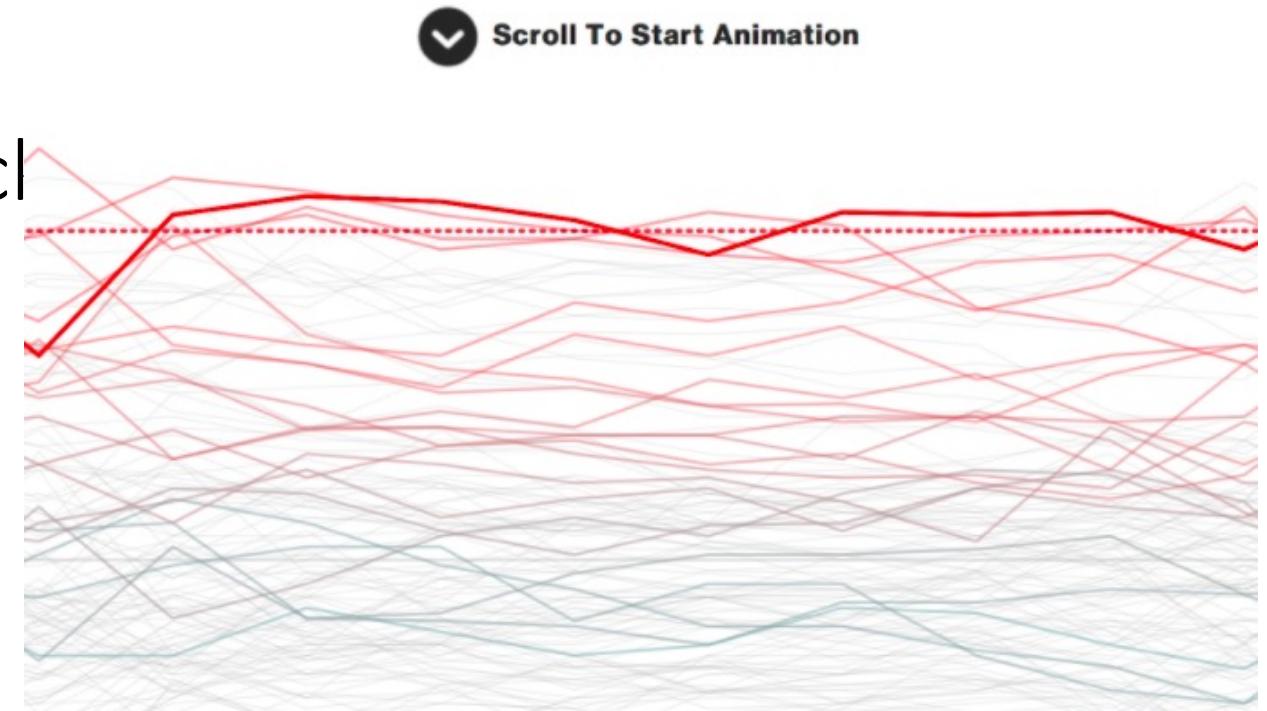
- change viewpoint
  - changes which items are visible within view
- camera metaphor
  - pan/translate/scroll
    - move up/down/sideways

→ *Pan/Translate*



# Idiom: Scrollytelling

- how: navigate page by scrolling (panning down)
- pros:
  - familiar & intuitive, from standard web browsing
  - linear (only up & down) vs possible overload of click
- cons:
  - full-screen mode may lack affordances
  - scrolljacking, no direct access
  - unexpected behaviour
  - continuous control for discrete steps



<https://eagereyes.org/blog/2016/the-scrollytelling-scouge>

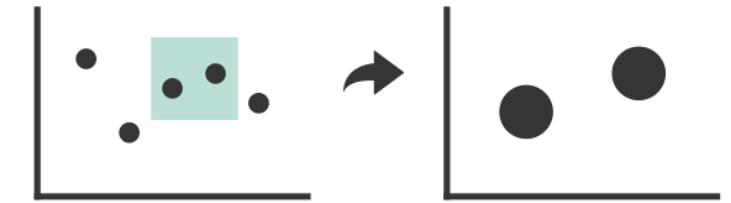
<https://www.nytimes.com/interactive/2022/05/13/us/covid-deaths-us-one-million.html>

# Navigate: Changing viewpoint/visibility

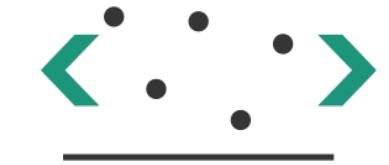
→ **Navigate**

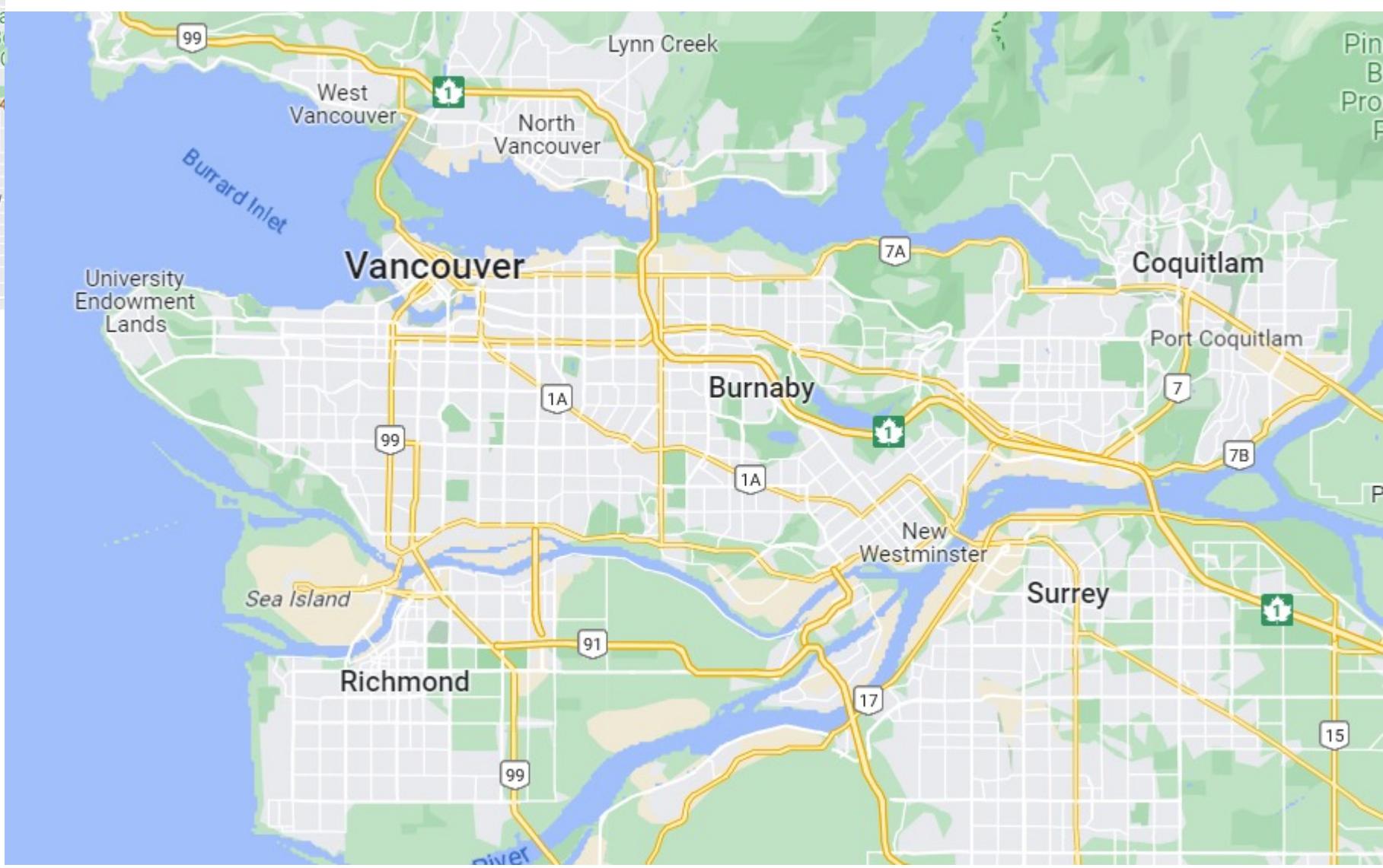
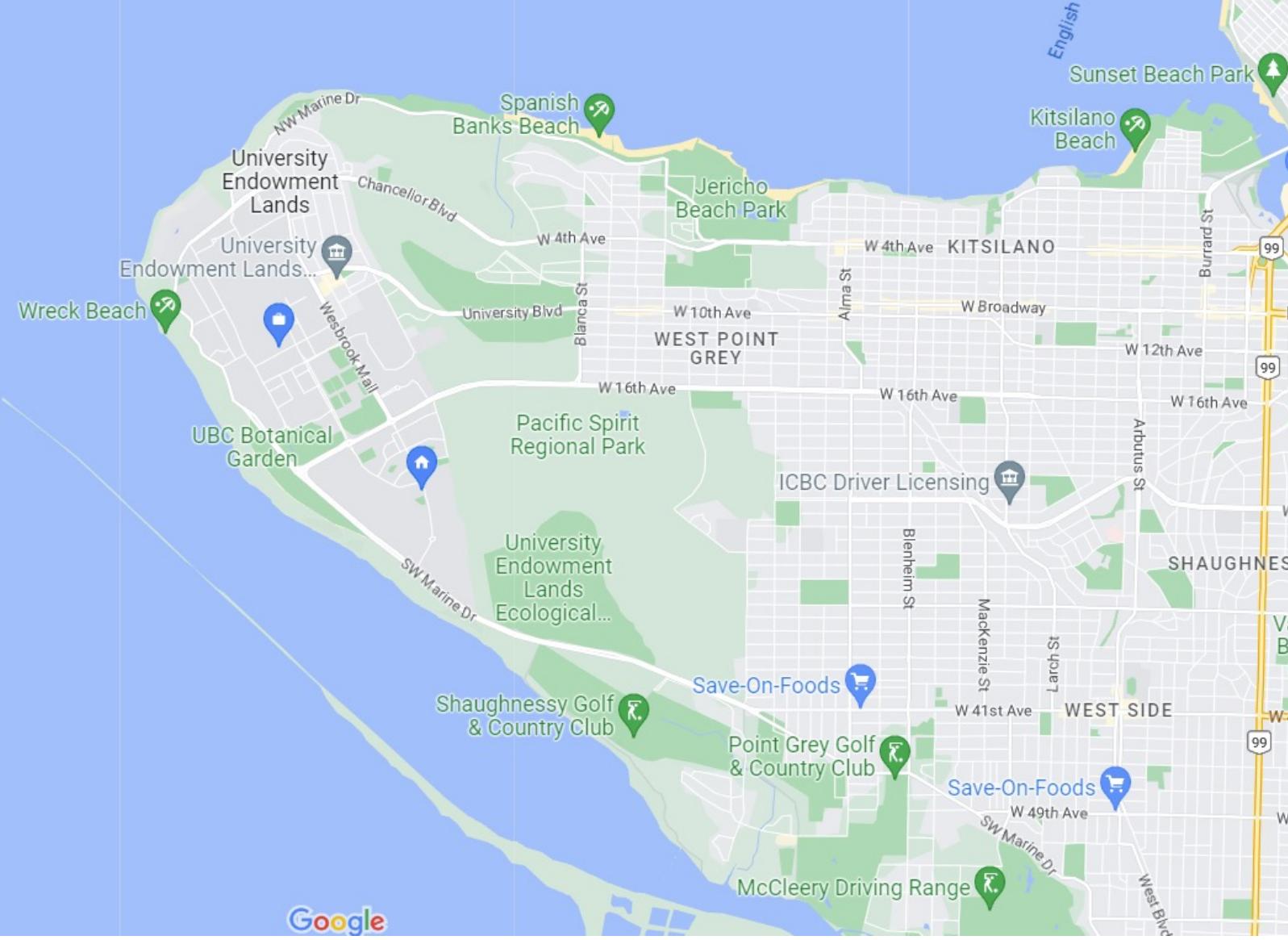
- change viewpoint
  - changes which items are visible within view
- camera metaphor
  - pan/translate/scroll
    - move up/down/sideways
  - rotate/spin
    - typically in 3D
  - zoom in/out
    - enlarge/shrink world == move camera closer/further
    - geometric zoom: standard, like moving physical object

→ *Zoom  
Geometric*



→ *Pan/Translate*





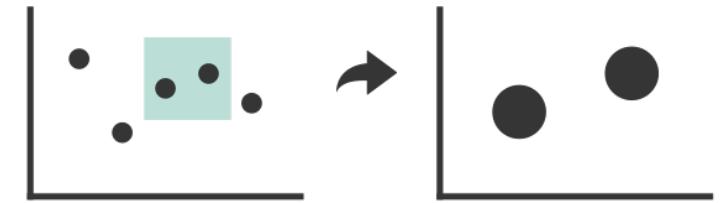
# Navigate: Unconstrained vs constrained

- unconstrained navigation
  - easy to implement for designer
  - hard to control for user
    - easy to overshoot/undershoot
- constrained navigation
  - typically uses animated transitions
  - trajectory automatically computed based on selection
    - just click; selection ends up framed nicely in final viewport

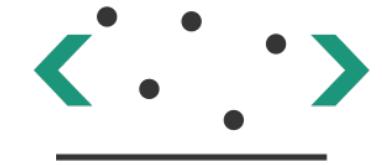
→ **Navigate**

→ Item Reduction

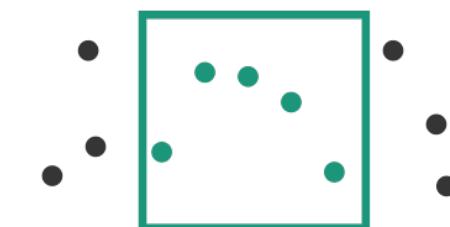
→ Zoom  
*Geometric* or *Semantic*



→ Pan/Translate



→ Constrained



# Idiom: Animated transition + constrained navigation

- example: geographic map
  - simple zoom, only viewport changes, shapes preserved

Zoom to Bounding Box



<https://observablehq.com/@d3/zoom-to-bounding-box>

# Interaction Taxonomies

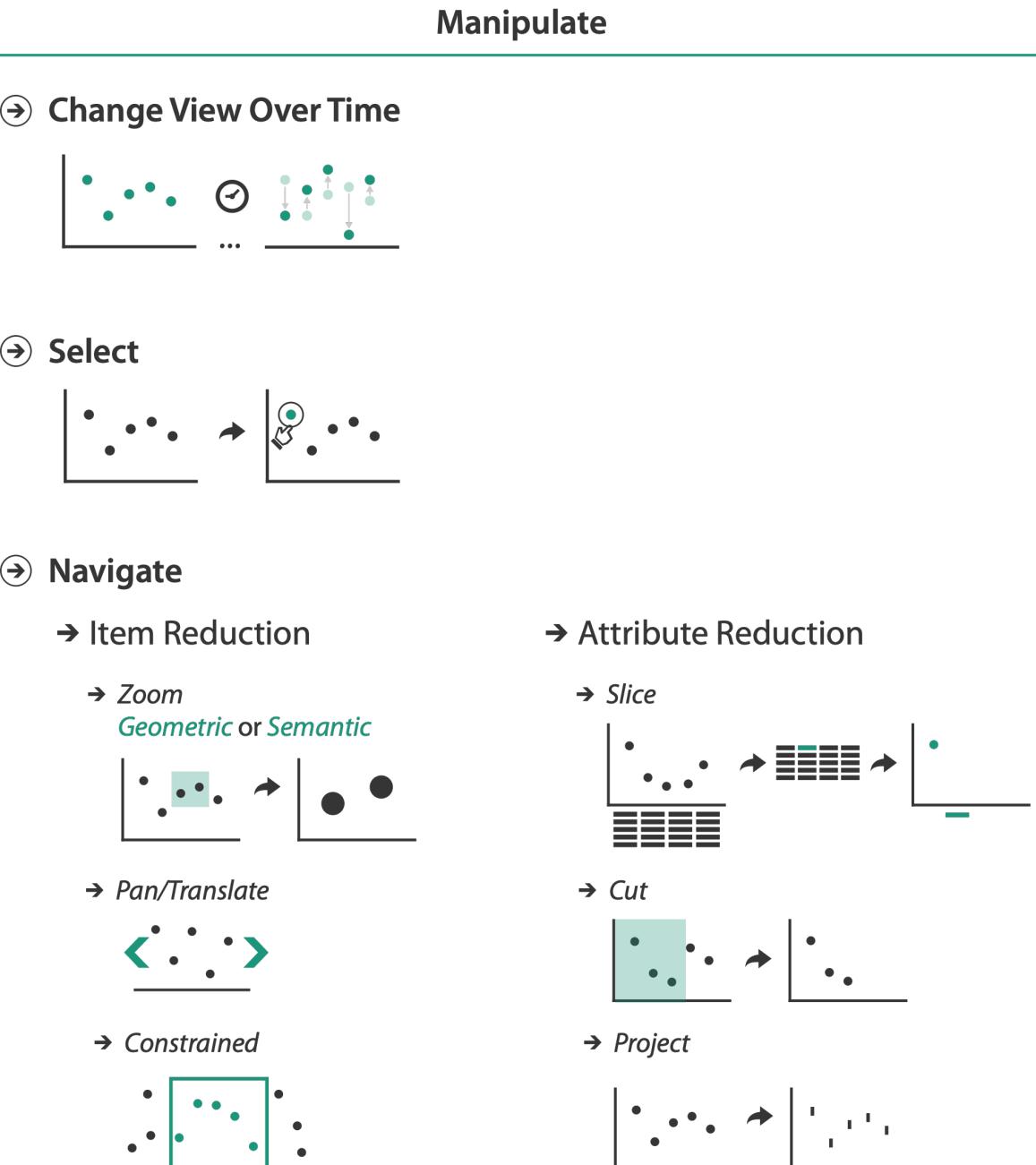


Table 1. Infovis Taxonomies Relevant to Interaction Techniques

Publications	Taxonomic units
<i>Taxonomies of low-level interaction techniques</i>	
Shneiderman (1996) [37]	Overview, zoom, filter, details-on-demand, relate, history, and extract
Buja, Cook, and Swayne (1996) [9]	Focusing (choice of [projection, aspect ratio, zoom, pan], choice of [variable, order, scale, scale-aspect ratio, animation, and 3-D rotation]), linking (brushing as conditioning / sectioning / database query), and arranging views (scatter plot matrix and conditional plot)
Chuah and Roth (1996) [13]	Basic visualization interaction (BVI) operations: graphical operations (encode data, set graphical value, manipulate objects), set operations (create set, delete set, summarize set, other), and data operations (add, delete, derived attributes, other)
Dix and Ellis (1998) [15]	Highlighting and focus, accessing extra information – drill down and hyperlinks, overview and context, same representation / changing parameters, same data / changing representation, linking representation – temporal fusion
Keim (2002) [24]	Dynamic projections, interactive filtering, interactive zooming, interactive distortion, interactive linking and brushing
Wilkinson (2005) [54]	Filtering (categorical/continuous/multiple/fast filtering), navigating (zooming/panning/lens), manipulating (node dragging/categorical reordering), brushing and linking (brush shapes/brush logic/fast brushing), animating (frame animation), rotating, transforming (specification/assembly/display/tap/2 taps/3 taps)
<i>Taxonomical dimensions of interaction techniques</i>	
Tweedie (1997) [47]	Interaction types (manual, mechanized, instructable, steerable, and automatic) and directness (direct and indirect manipulation)
Spence (2007) [38]	Interaction modes (continuous, stepped, passive, and composite interaction)
<i>A taxonomy of interaction operations</i>	
Ward and Yang (2004) [50]	interaction operators (navigation, selection, distortion), interaction spaces (screen-space, data value-spaces, data structure-space, attribute-space, object-space, and visualization structure-space), and interaction parameters (focus, extents, transformation, and blender)
<i>Taxonomies of user tasks</i>	
Zhou and Feiner (1998) [56]	Relational visual tasks (associate, background, categorize, cluster, compare, correlate, distinguish, emphasize, generalize, identify, locate, rank, reveal, switch) and direct visual organizing and encoding tasks (encode)
Amar, Eagan, and Stasko (2005) [4]	Retrieve value, filter, compute derived value, find extremum, sort, determine range, characterize distribution, find anomalies, cluster, and correlate

[https://faculty.cc.gatech.edu/~john.stasko/papers/infovis\\_07-interaction.pdf](https://faculty.cc.gatech.edu/~john.stasko/papers/infovis_07-interaction.pdf)

Action
Annotating
Arranging
Assigning
Blending
Cloning
Comparing
Drilling
Filtering
Measuring
Navigating
Scoping
Searching
Selecting
Sharing
Transforming
Translating

Unipolar

<https://aisel.aisnet.org/thci/vol5/iss2/1/>

# Interaction benefits

- major advantage of computer-based vs paper-based visualization
- flexible, powerful, intuitive
  - exploratory data analysis: change as you go during analysis process
  - fluid task switching: different visual encodings support different tasks
- animated transitions provide excellent support
  - empirical evidence that animated transitions help people stay oriented
- be active participants in the analysis of data,
- adjust features of the tool to suit the user's needs,
- visualization of large amounts of data,
- extend/amplifies users' sensemaking abilities,
- increase engagement (vis becomes personal to user),

# Interaction limitations

- Requires human time and attention
- Increases perceptual and exploration costs
- Limited performance gains
  - studies find no increase in performance (Mosca et al., 2021)
  - users may not interact as planned by designer
    - NYTimes logs show ~90% don't interact beyond scrollytelling - Aisch, 2016
- interaction has a time cost
  - sometimes minor, sometimes significant
  - degenerates to human-powered search in worst case
- remembering previous state imposes cognitive load
- controls may take screen real estate
  - or invisible functionality may be difficult to discover (lack of affordances)

# Get Stepping

- That was a lot. On Wednesday we will focus on implementation.
- TUTORIAL 9 is you on your own ooooo
  - Read through [https://altair-viz.github.io/user\\_guide/interactions/index.html](https://altair-viz.github.io/user_guide/interactions/index.html) and its subpages (Parameters, Conditions & Filters; Bindings & Widgets; Expressions)
  - Take 3 altair vizzes and re-implement the interaction using your own data. Here are some suggestions.
    - [https://altair-viz.github.io/gallery/interactive\\_legend.html](https://altair-viz.github.io/gallery/interactive_legend.html) apply this to a bar chart as opposed to area chart.
    - [https://altair-viz.github.io/gallery/interactive\\_bar\\_select\\_highlight.html](https://altair-viz.github.io/gallery/interactive_bar_select_highlight.html) keep as bar chart, but make the highlight more noticeable
    - [https://altair-viz.github.io/gallery/selection\\_histogram.html](https://altair-viz.github.io/gallery/selection_histogram.html) use your own dataset, just make sure you understand what is going on, try to change the brush so it is constrained to only the x axis.