Surfacing Visualization Mirages

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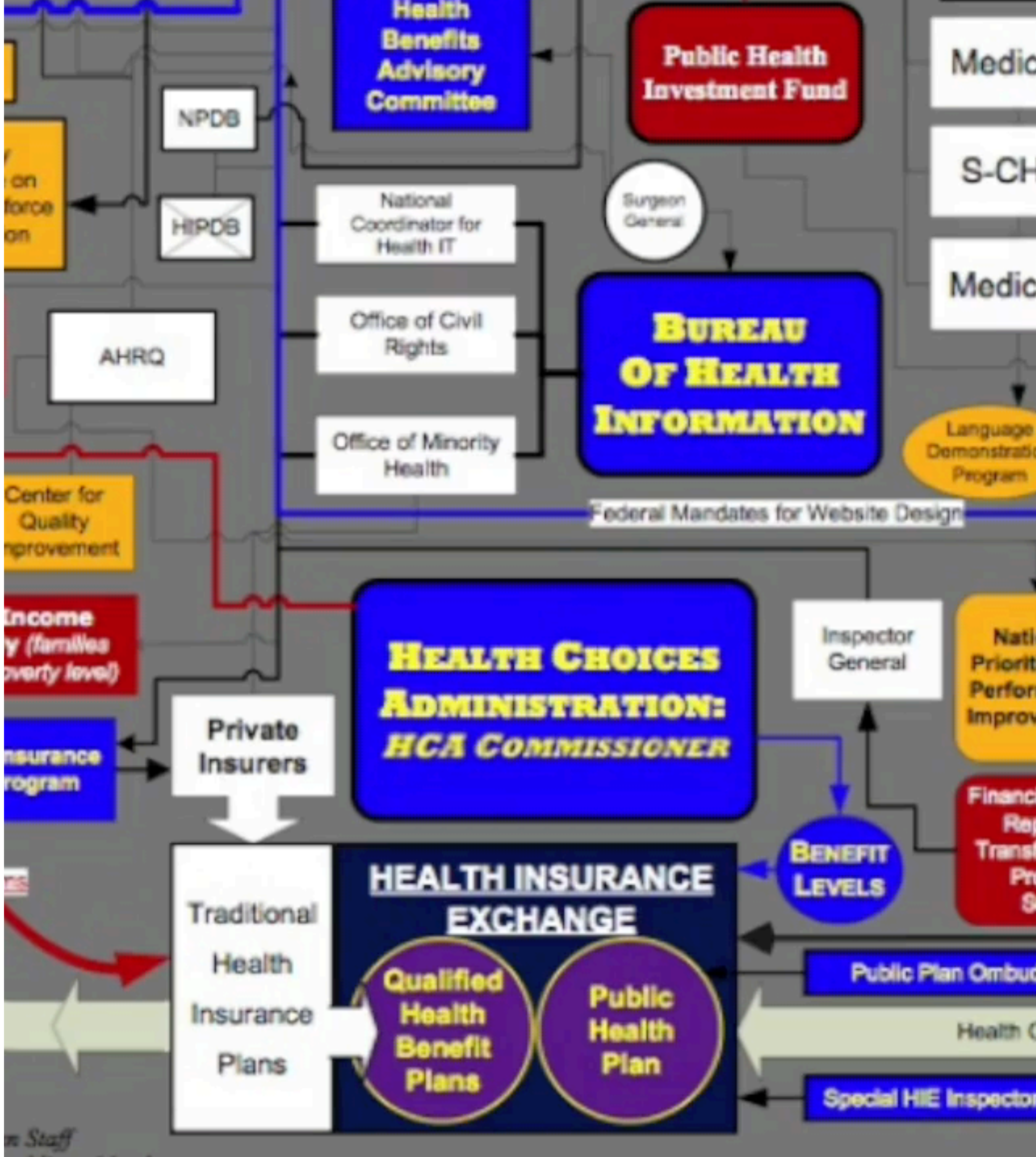
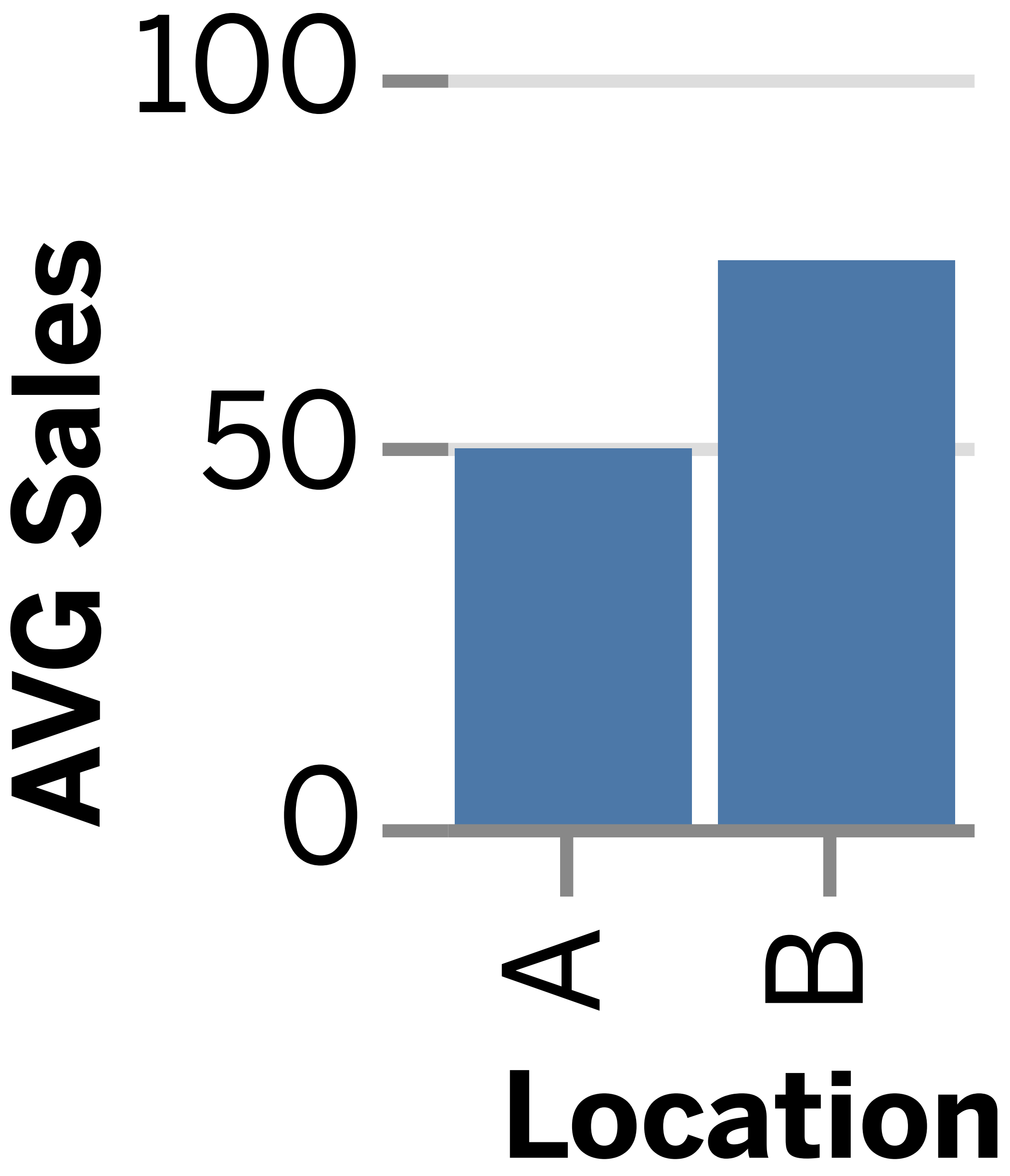
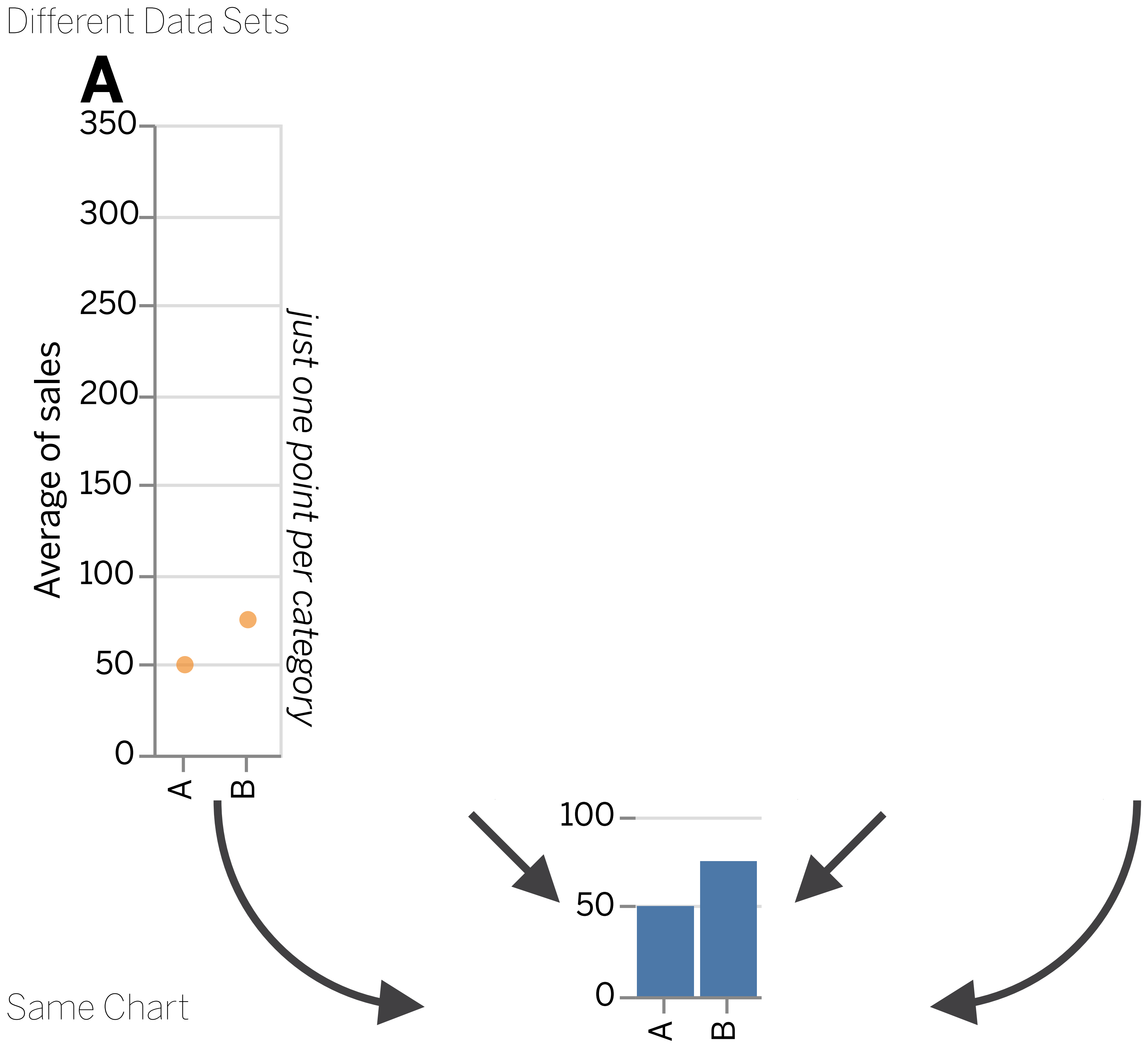


What can be said about this chart?

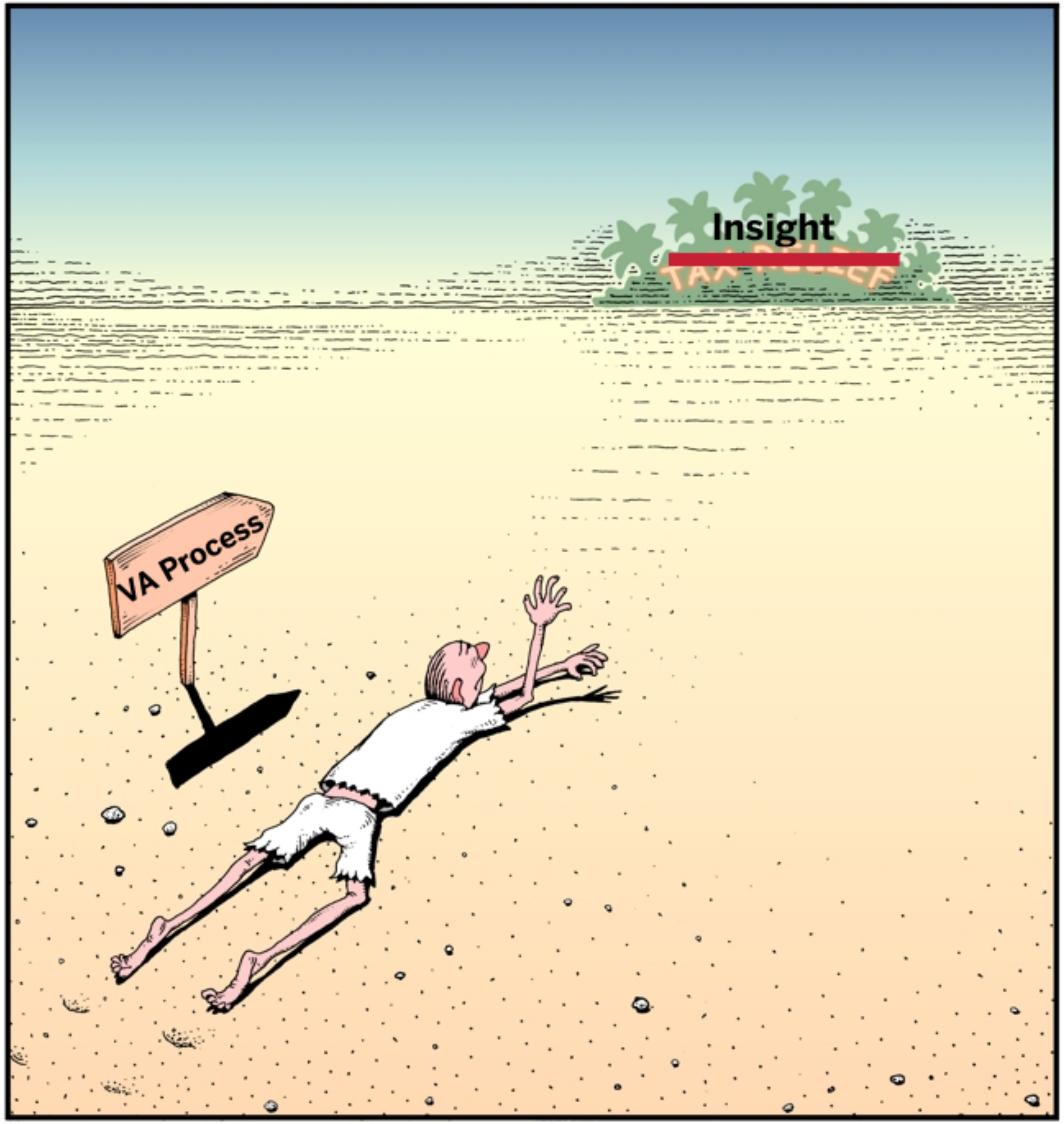


Aggregations can mask substantially different datasets



What is a visualization mirage?

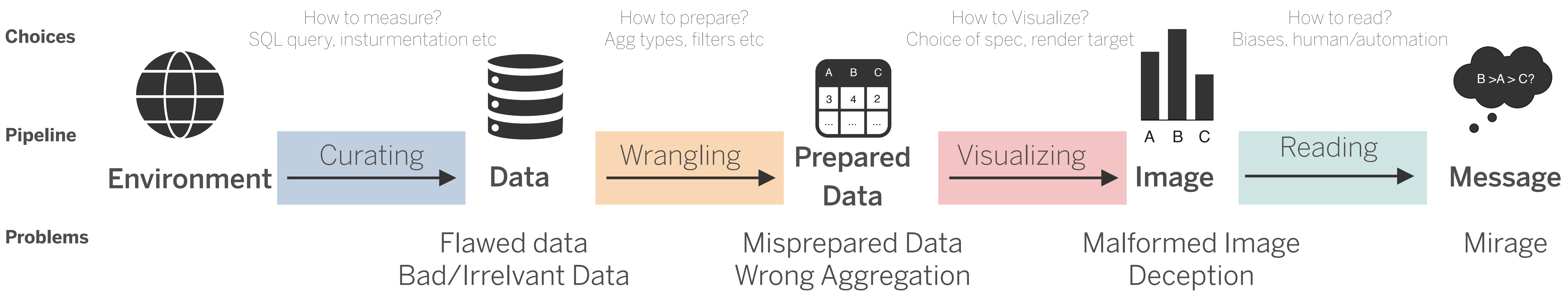
"A **visualization mirage** *is any visualization where the cursory reading of the visualization would appear to support a particular message arising from the data, but where a closer re-examination would remove or cast significant doubt on this support."*



Outliers	Many forms of analysis assume data have similar magnitudes and were generated by similar processes. Outliers, whether in the form of erroneous or unexpectedly extreme values, can greatly impact aggregation and discredit the assumptions behind many statistical tests and summaries. [61]
Overplotting	We typically expect to be able to clearly identify individual marks, and expect that one visual mark corresponds to a single value or aggregated value. Yet overlapping marks can hide internal structures in the distribution or disguise potential data quality issues. [24, 77, 81]
Availability Heuristic	Examples that are easier to recall are perceived as more typical than they actually are. In a visual analytics context, this could be reflected in analysts recalling outlying instances more easily than values that match the trend, or assuming that the data patterns they encounter most frequently (for instance, in the default or home view of their tool) are more common than they really are in the dataset as a whole. [28, 29, 35]
Inappropriate/Missing Aggregation	The size of the dataset is often far larger than what can fit in a particular chart. Aggregation at a particular level of detail is a common technique to reduce the size of the data. However, the choice of aggregation function can lead to differing conclusions based on the underlying distribution of the data. Furthermore, these statistical summaries may fail to capture important features of distribution, such as second-order statistics. Conversely, when a designer fails to apply an aggregation function (or applies one at too low a level of detail), the overplotting, access visual complexity, or reduced discoverability can likewise hide important patterns in the data. [3, 35, 76, 100, 122]

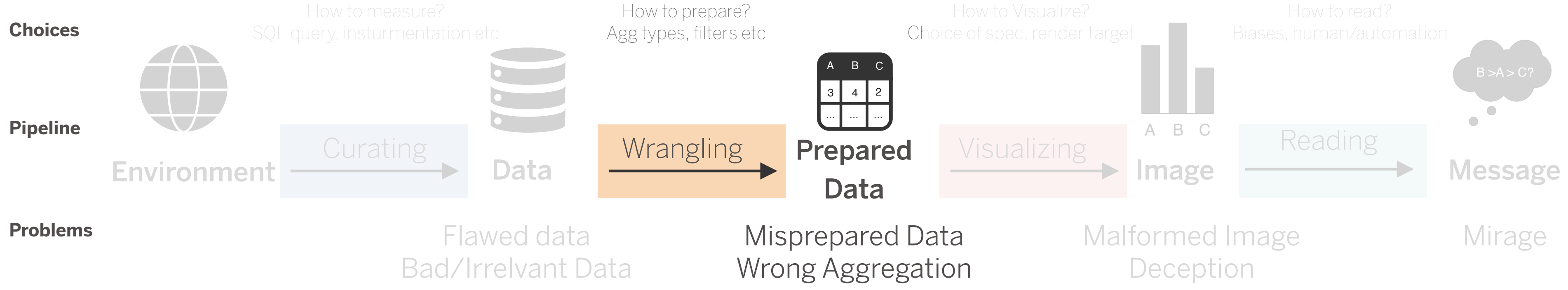
(See the appendix of our paper for this full table)

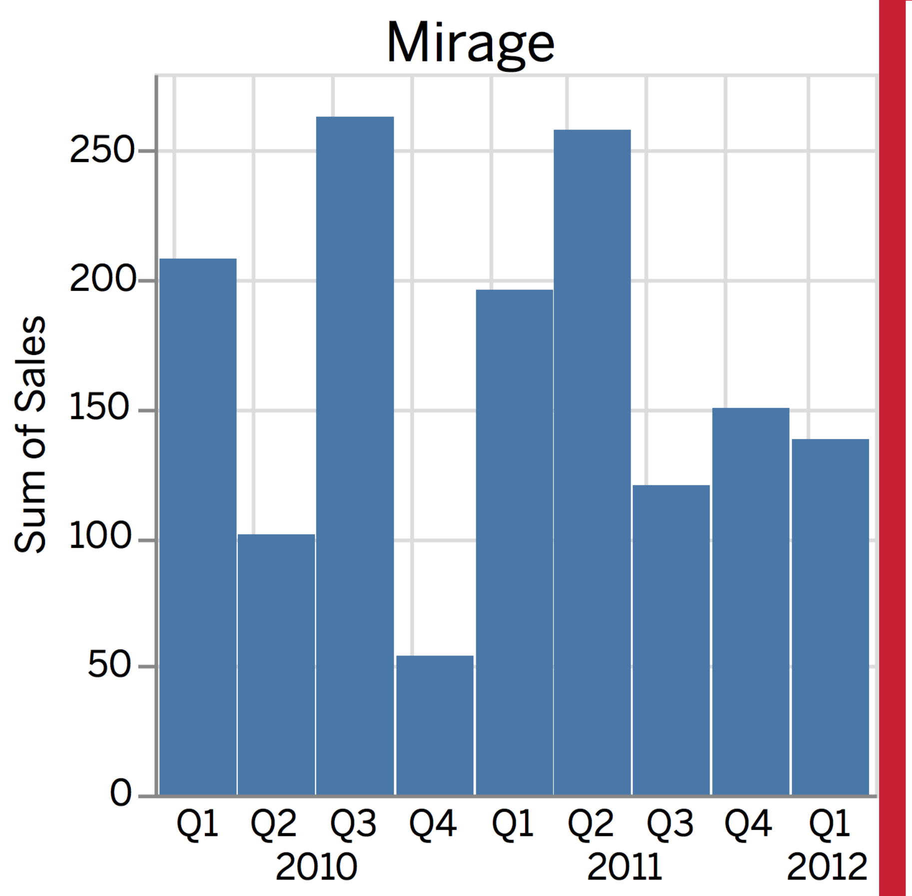
The Visual Analytics Pipeline and Agency

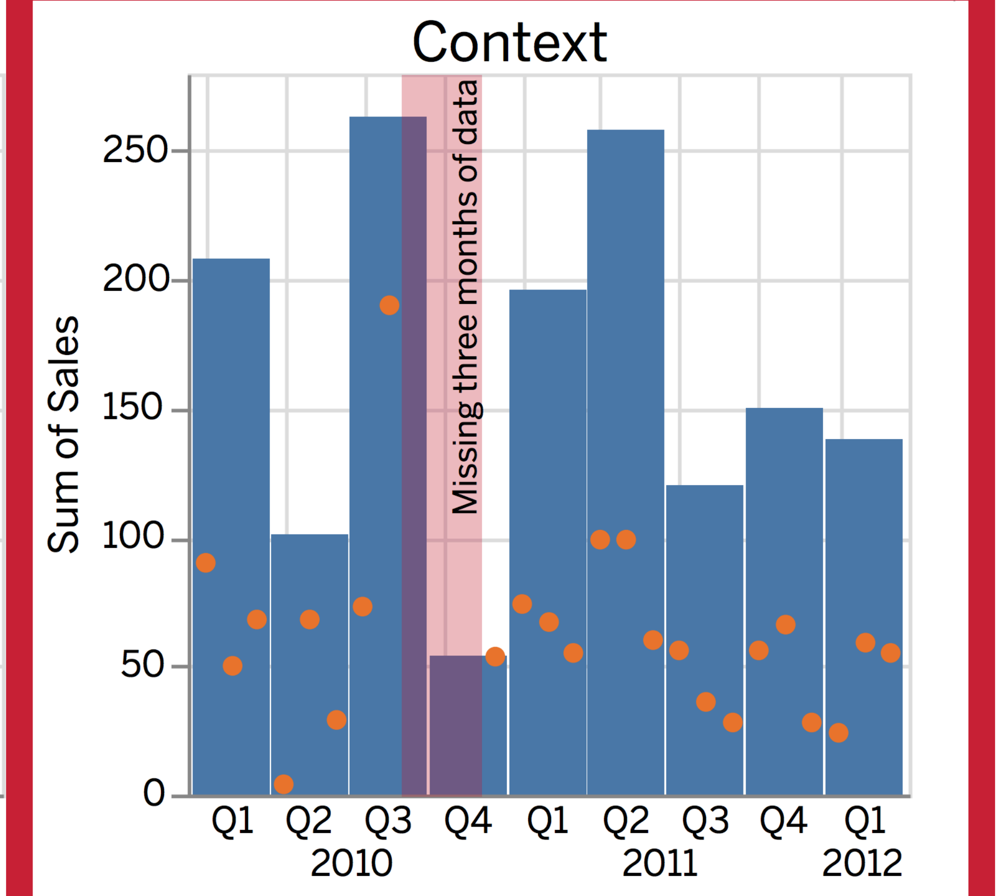


Each stage in the pipeline **offers user agency** but also presents an **opportunity for errors**

MIRAGES: Dirty Data

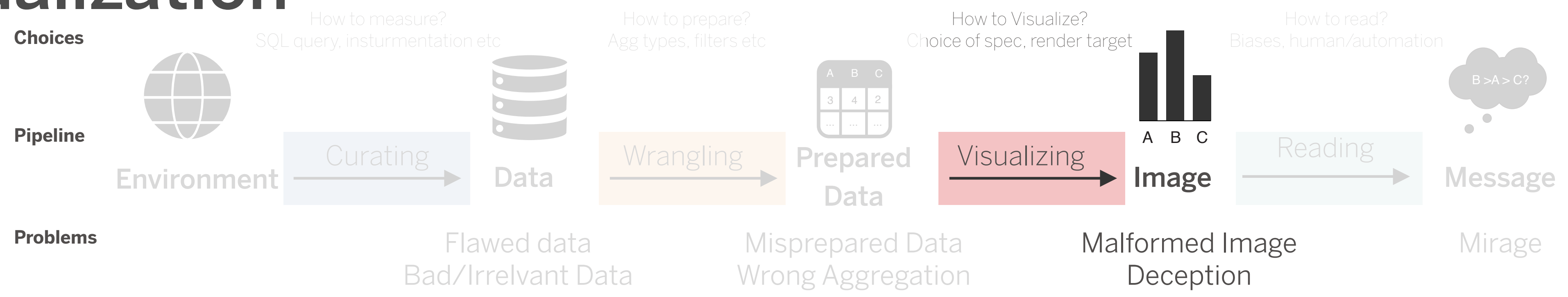


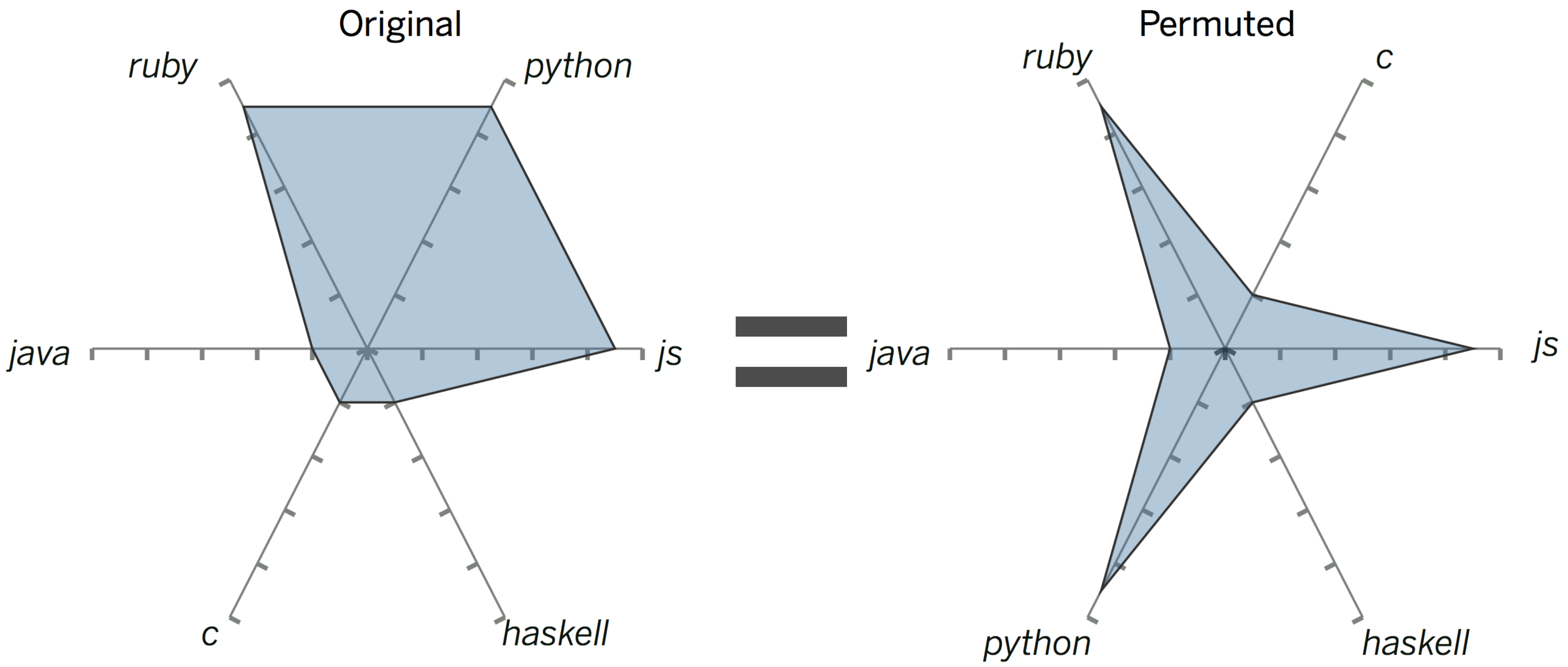




Visualizations that fall prey to **statistical and data entry** errors can cause downstream difficulties

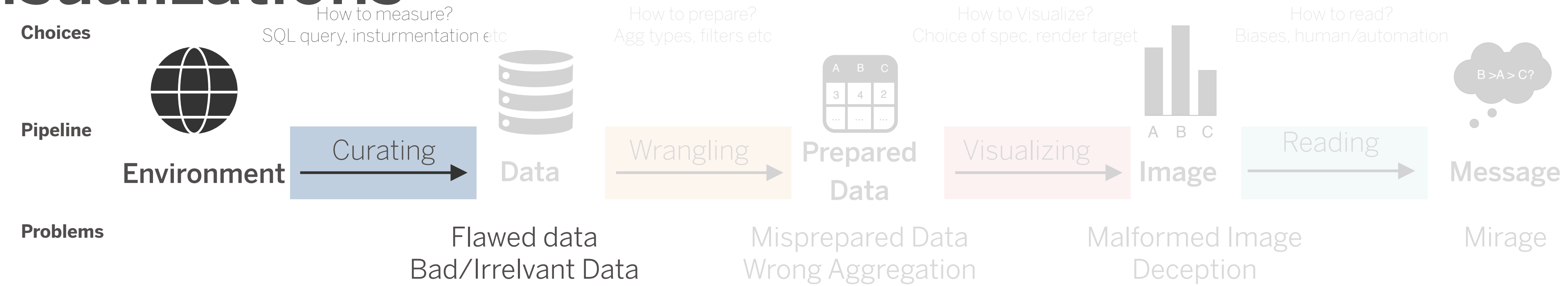
MIRAGES: Volatile Visualization





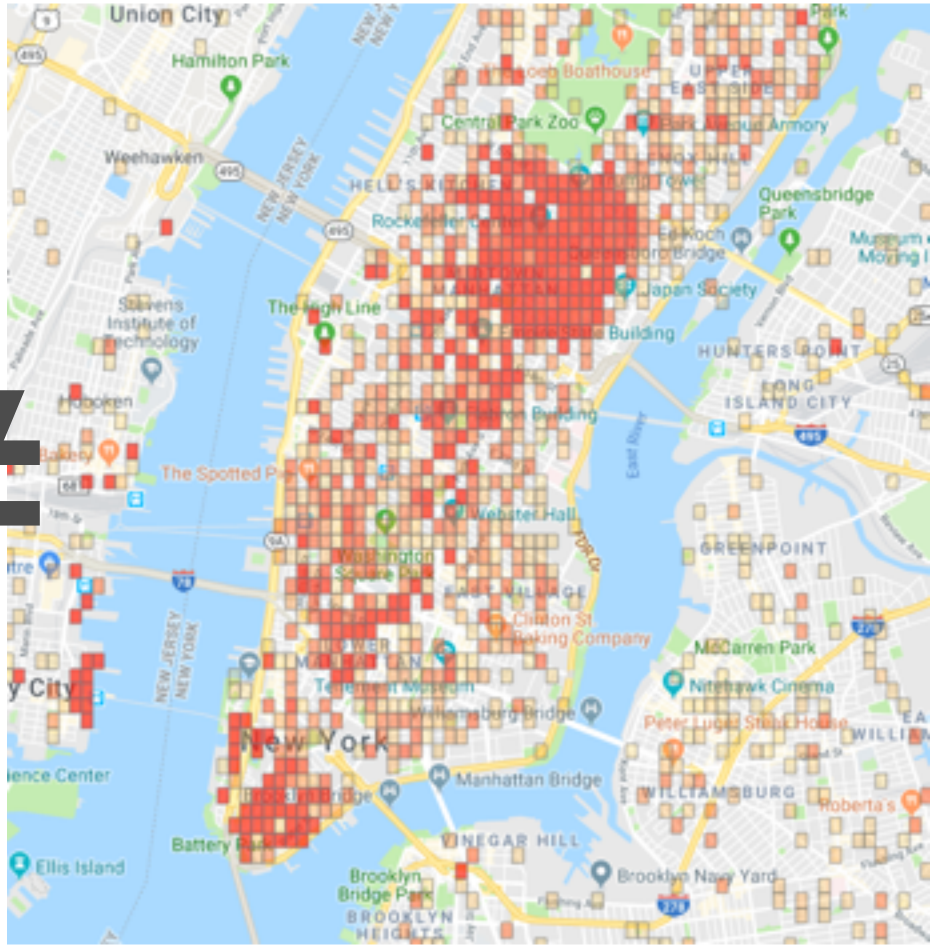
Visualizations that don't reflect **significant changes** to their data in a **significant way**

MIRAGES: Uncritical Visualizations



Crime by Trulia

≠



White collar crime

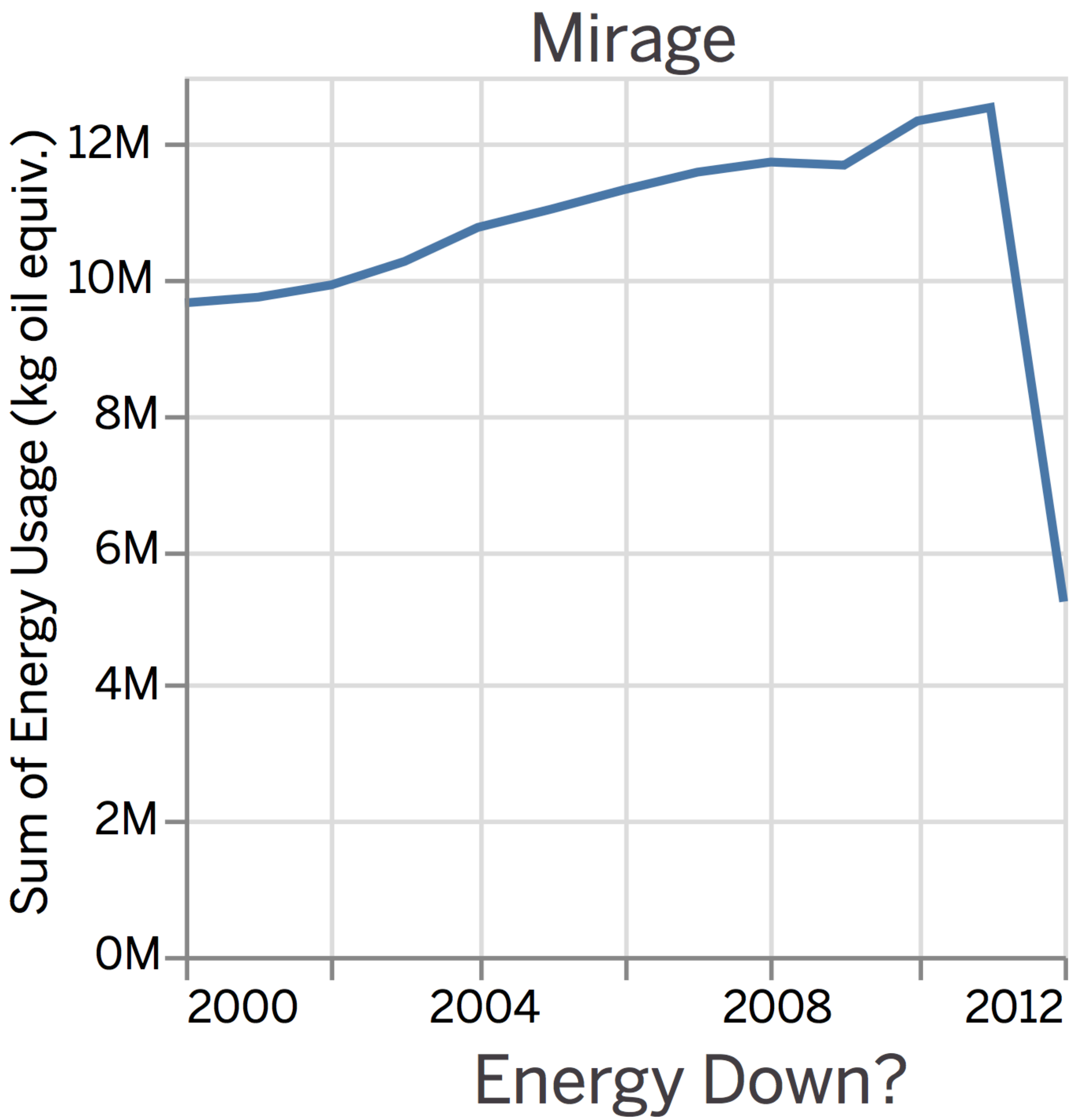
Visualizations constructed in an **uncritical or unreflective** way, in such a way that bias and subjectivity are obscured

Do mirages really happen in practice?

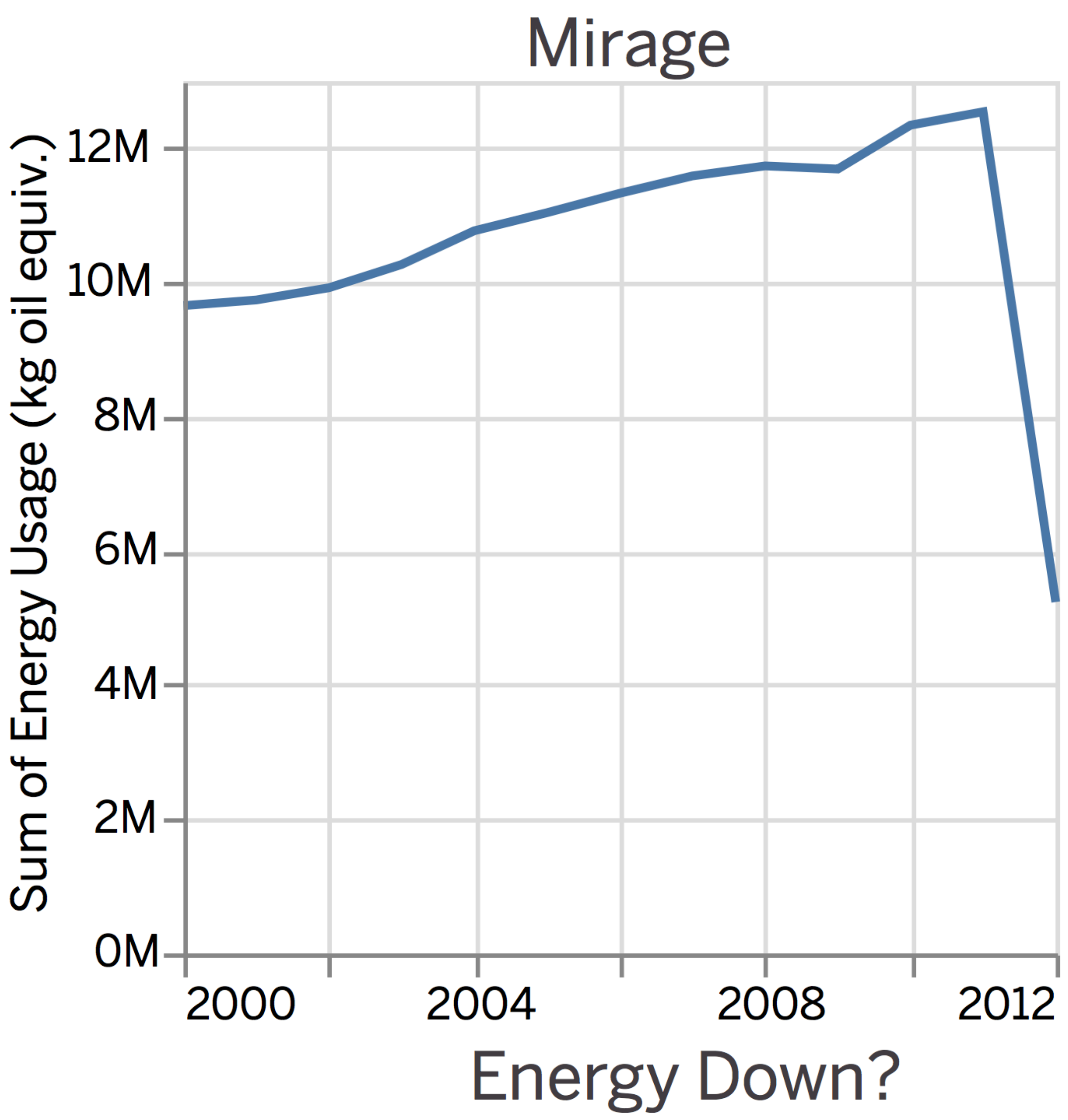
Example:

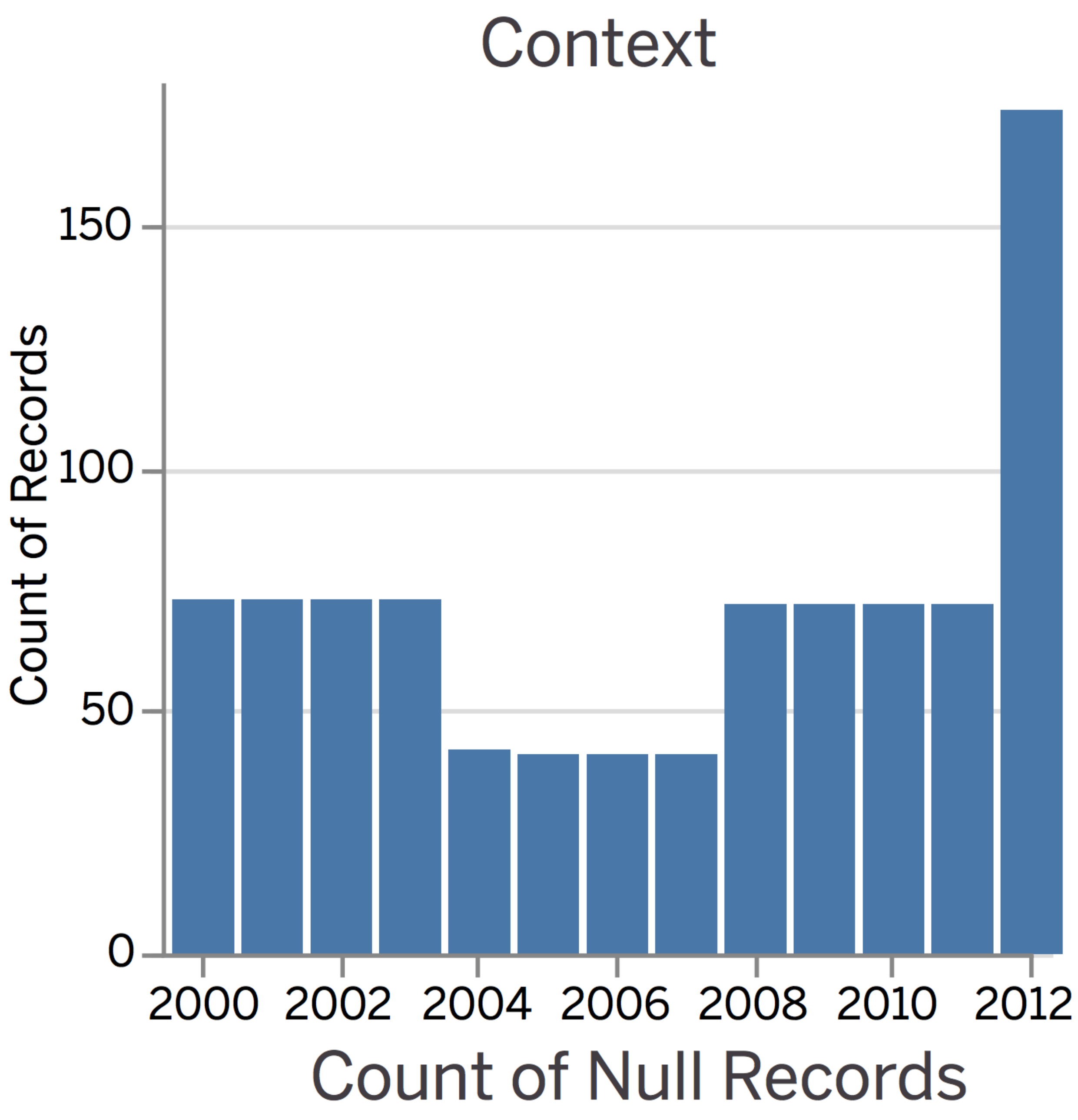
What is the trend of global energy usage over time?

Do these things really happen?

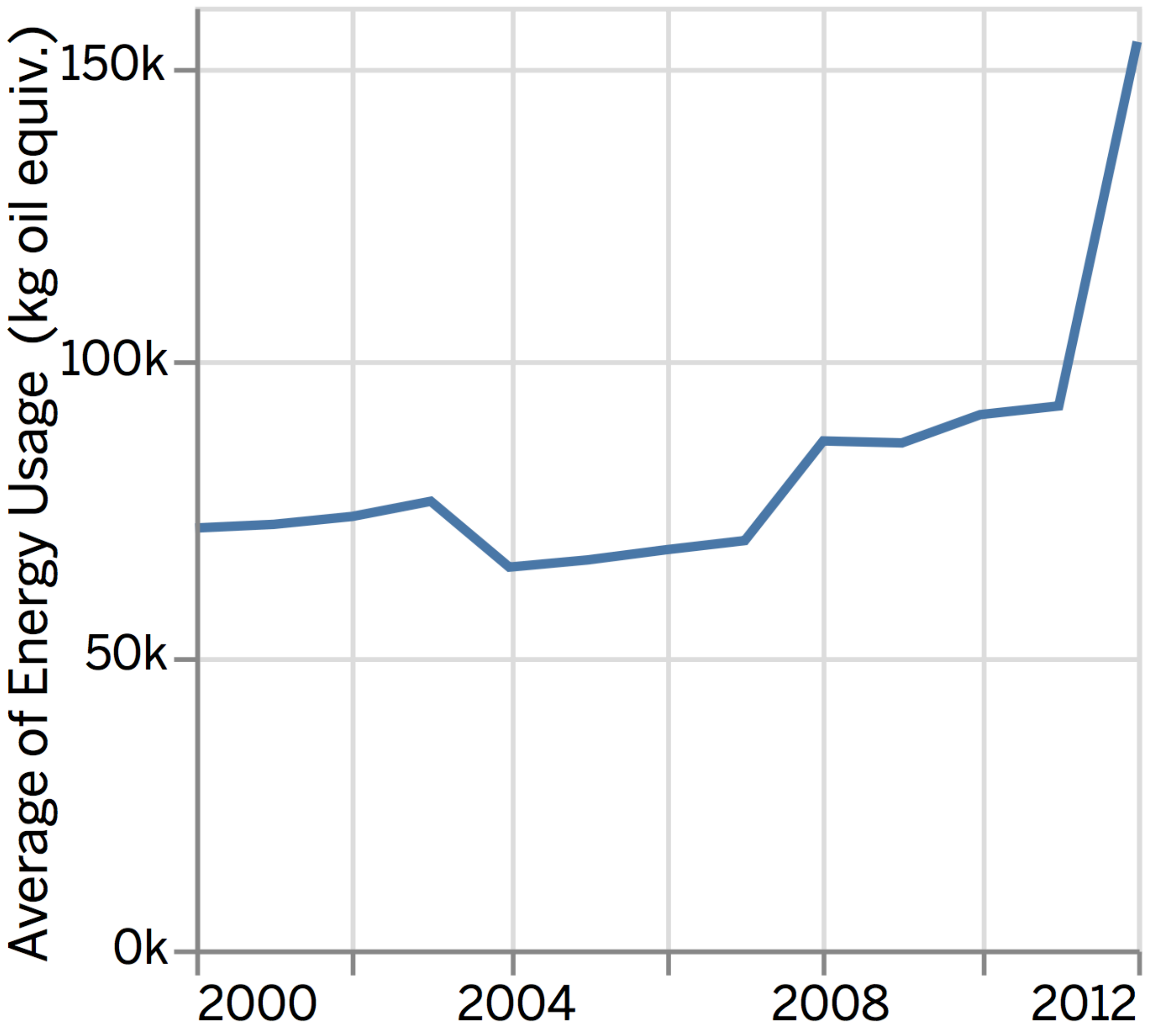


Do these things really happen?



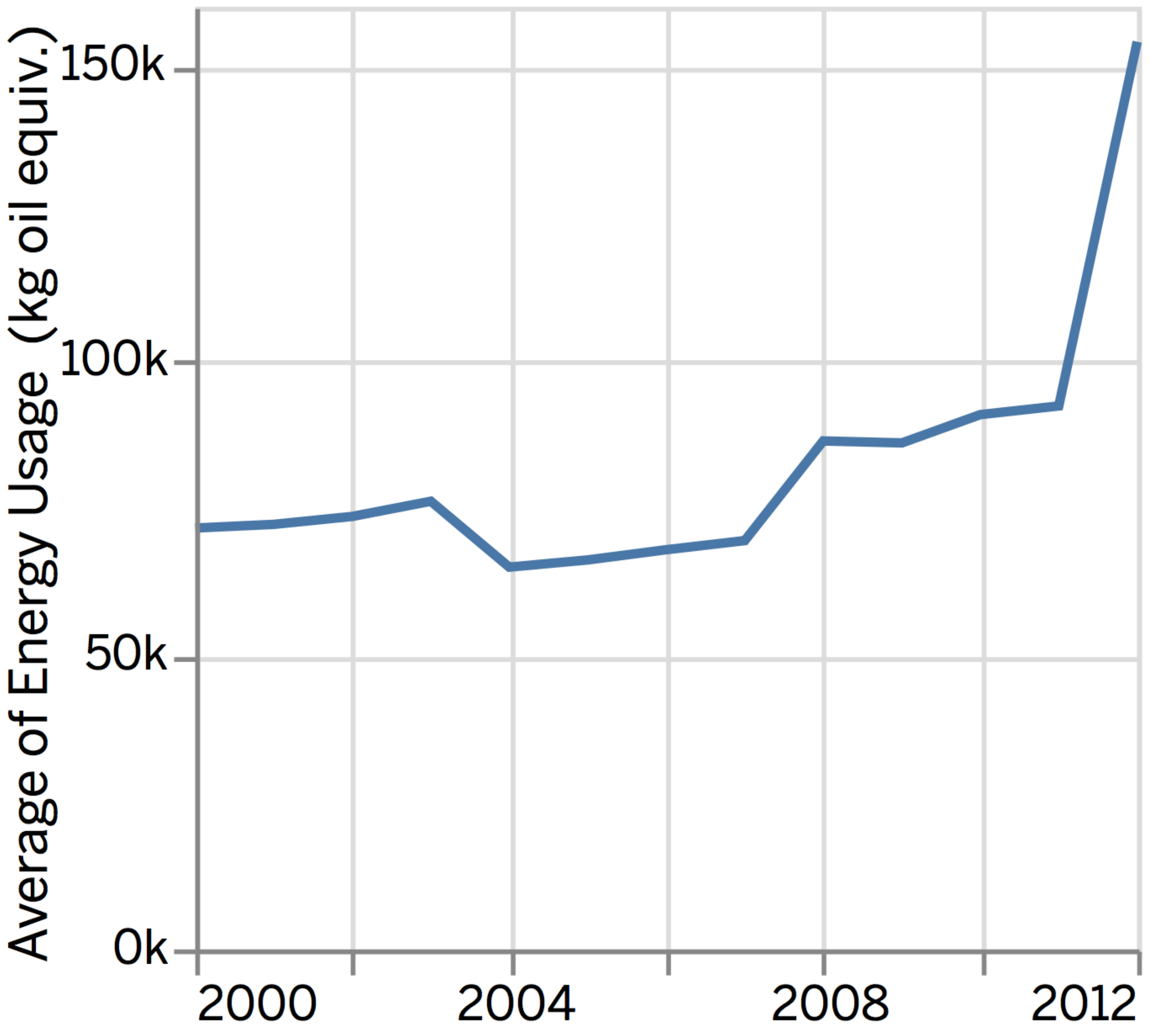


Do these things really happen?

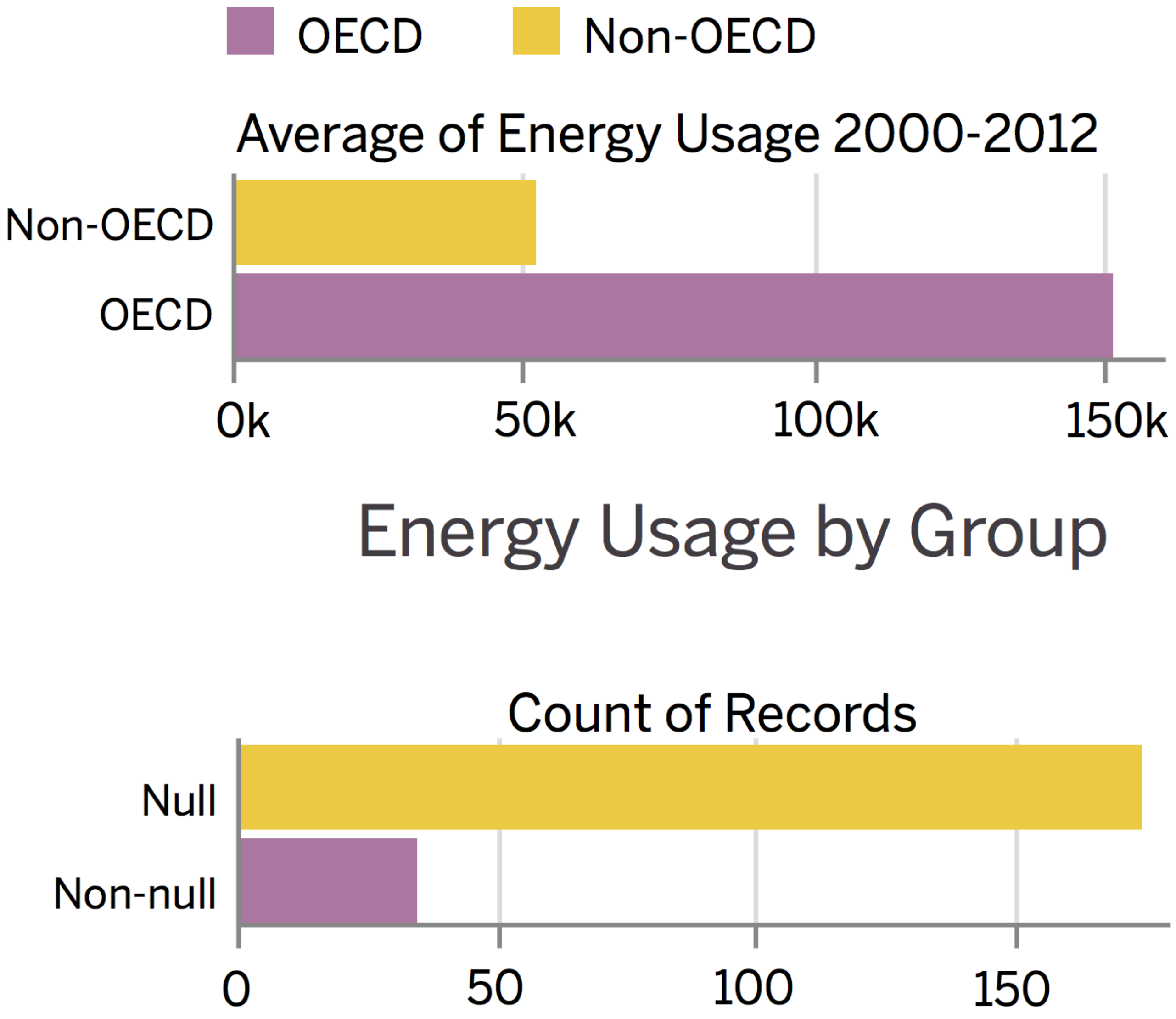


Energy Up?

Do these things really happen?

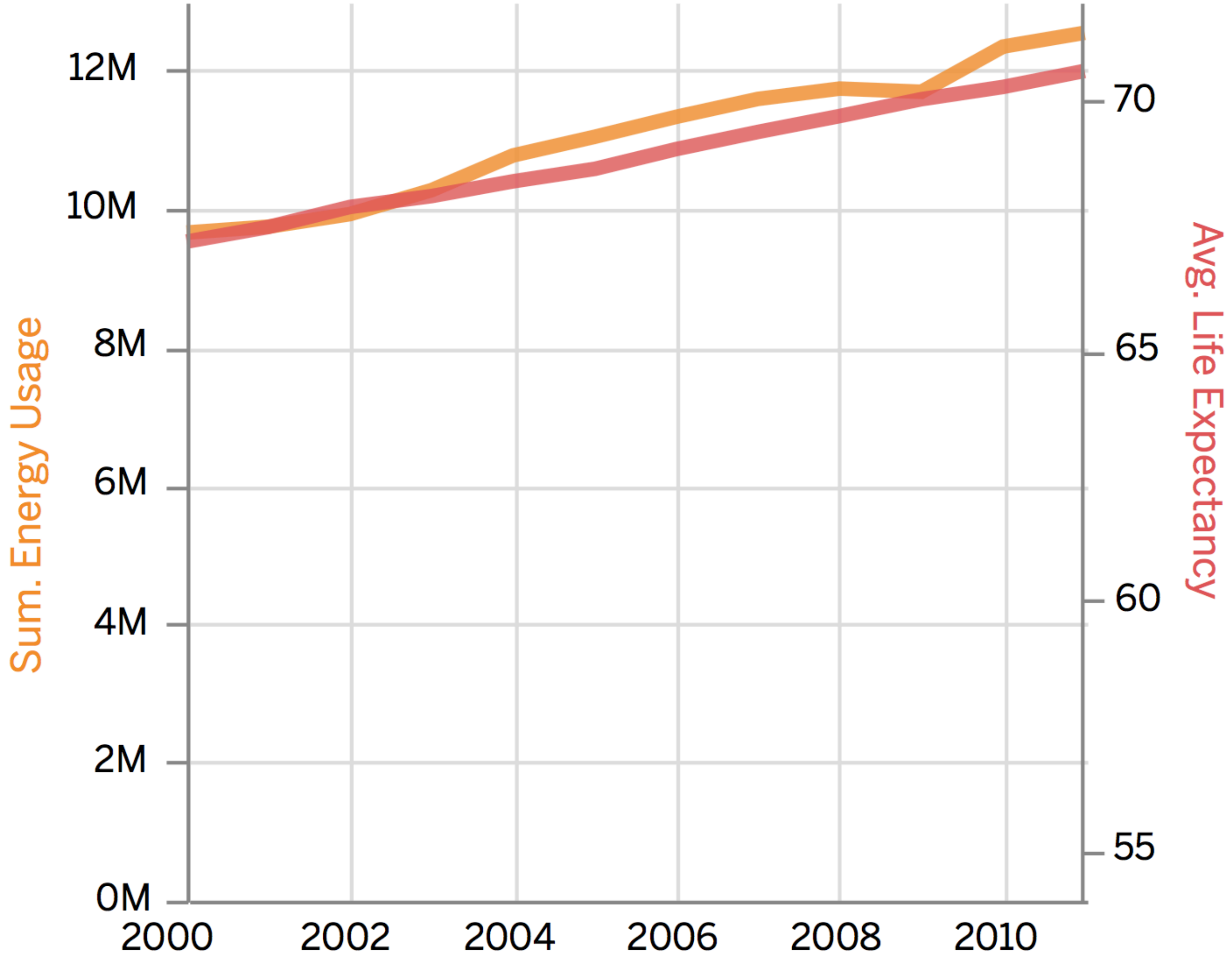


Energy Up?



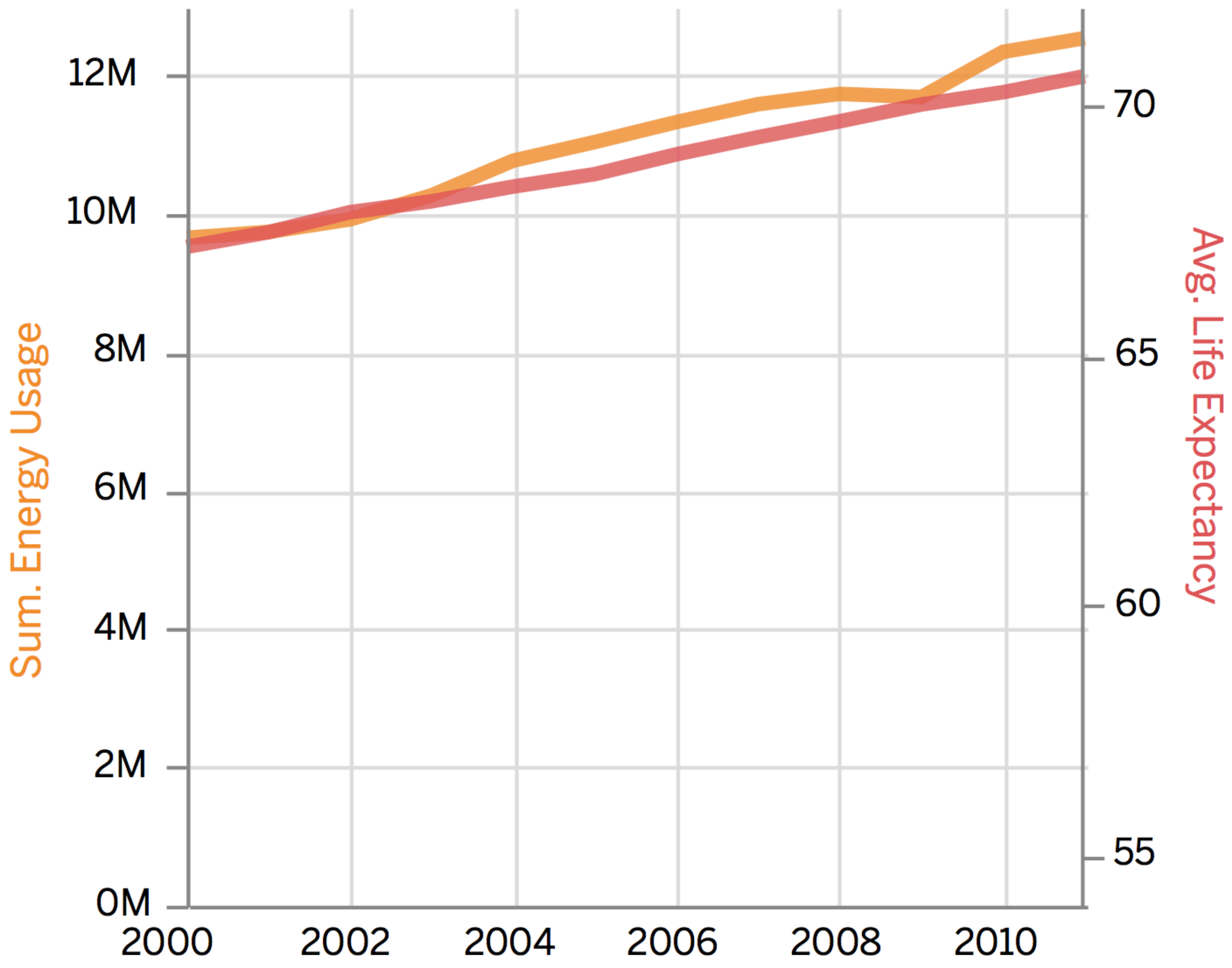
Nulls in 2012

Do these things really happen?

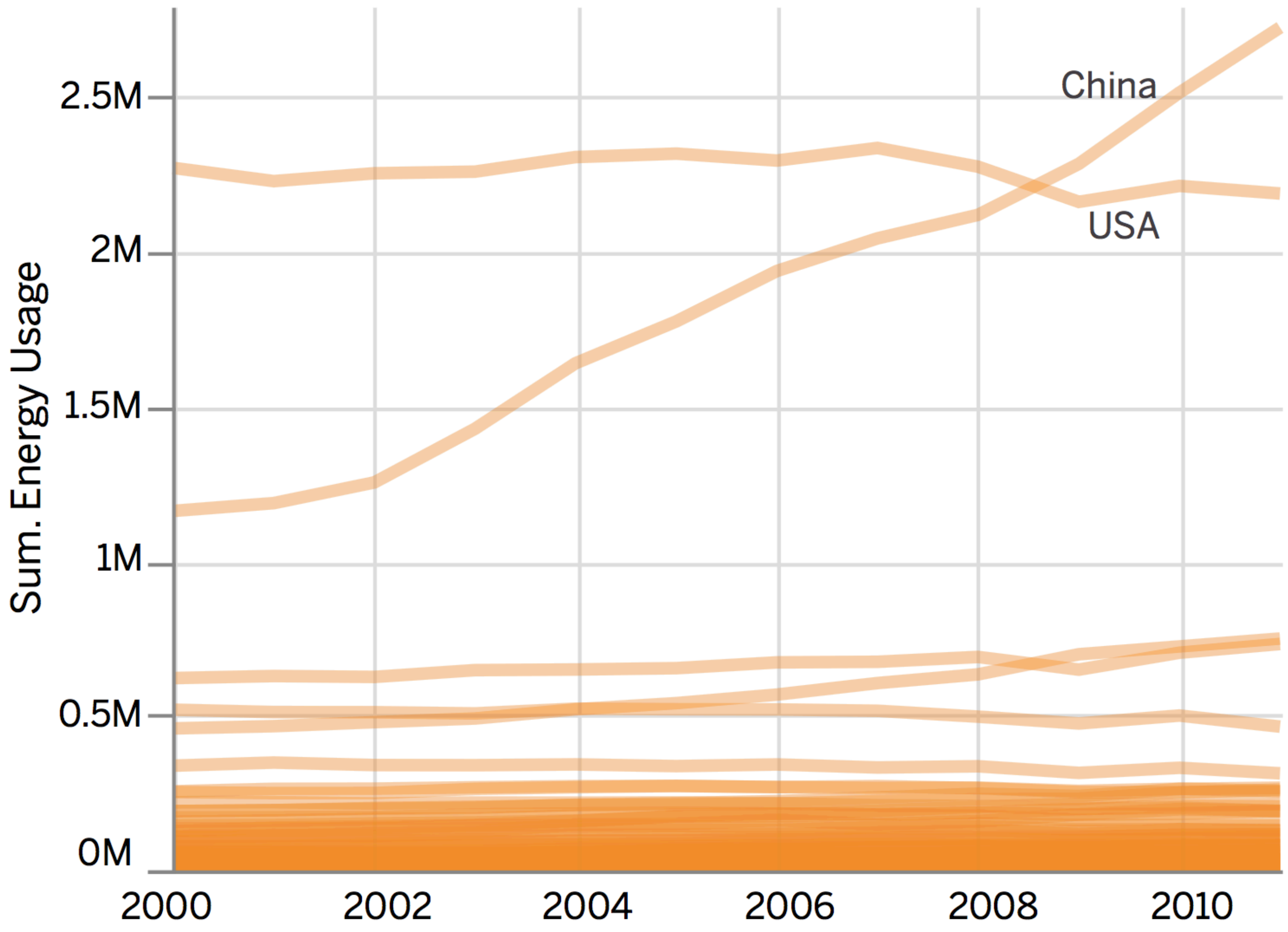


Energy Usage vs Life Expectancy

Do these things really happen?



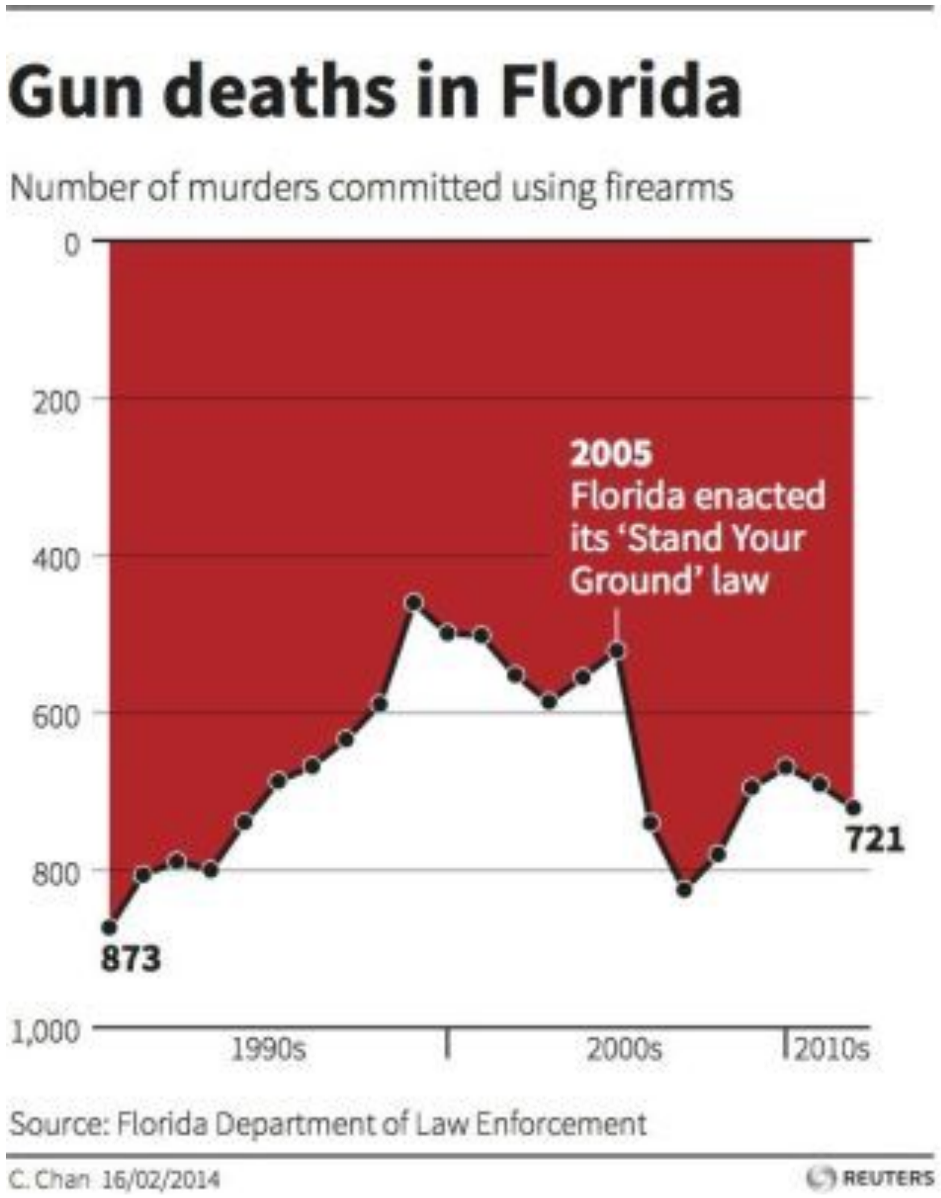
Energy Usage vs Life Expectancy



Energy Usage by Country

Visualization Literacy Won't Save You

- Despite a push for literacy, people can still be deceived
- Visualizations are rhetorical devices, that are easy to trust too deeply
- Sometimes you are tired, and you miss something "obvious"

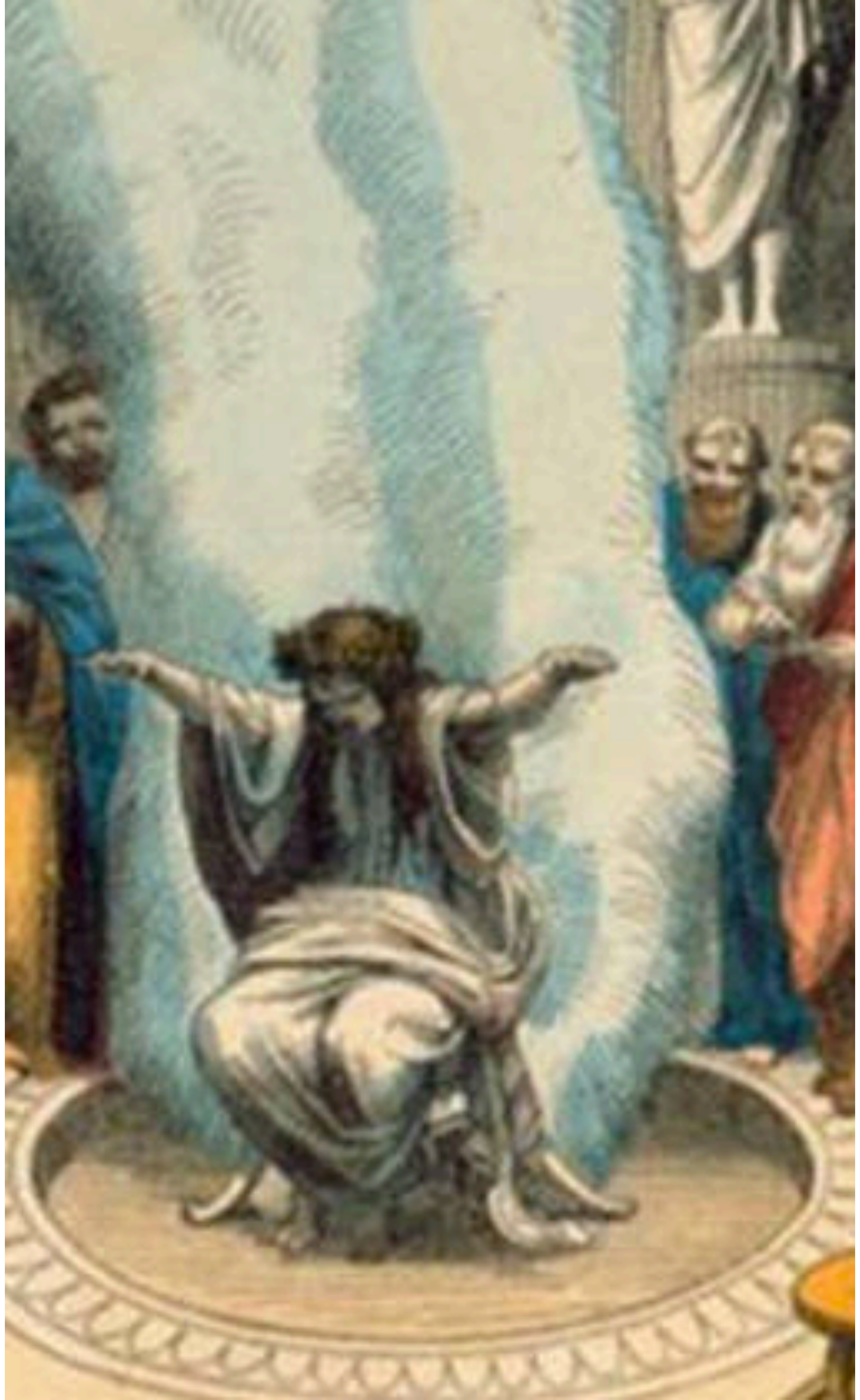


Alerting users to mirages is essential to dispelling them

Metamorphic Testing

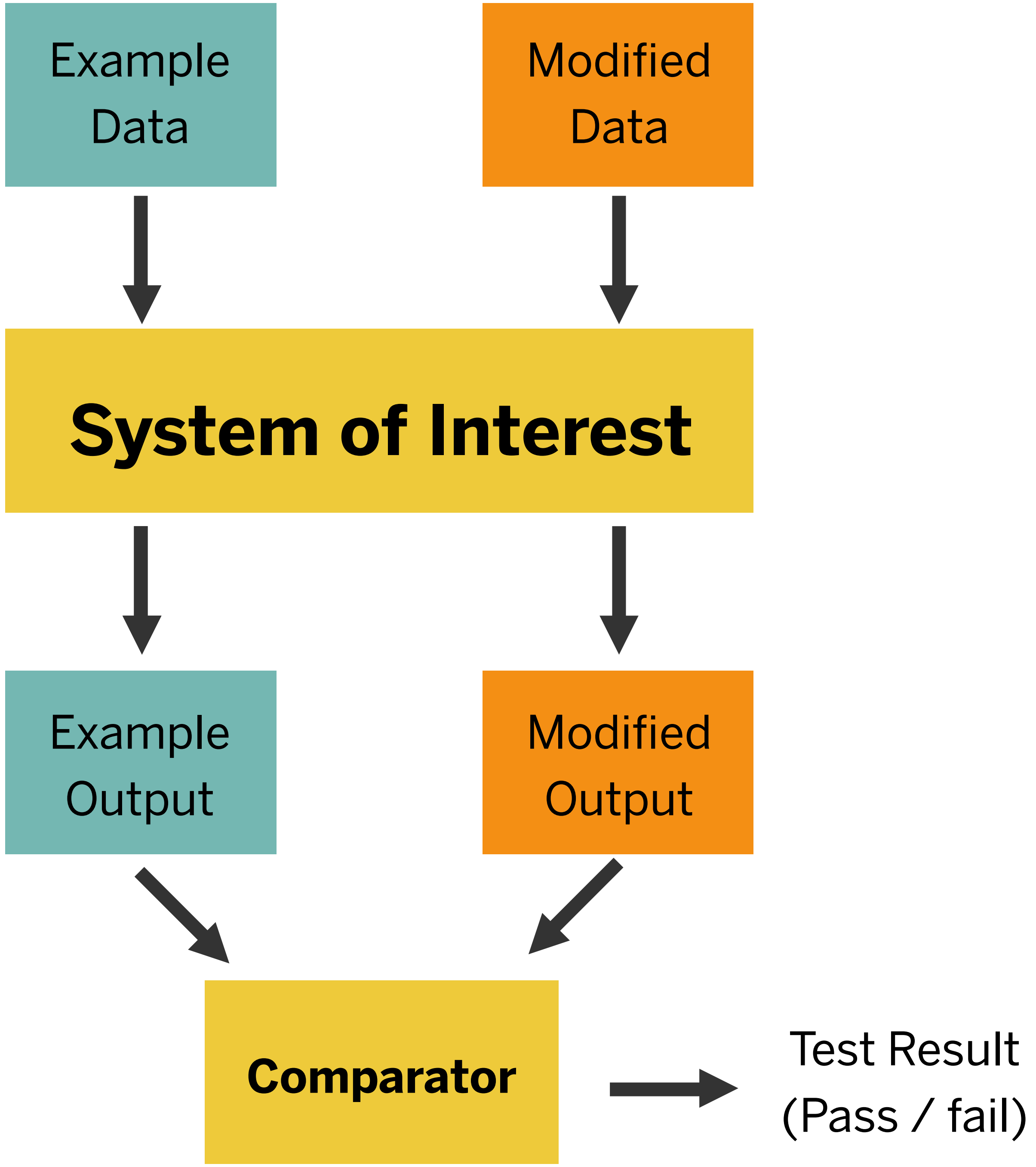
Test oracles are not always available

Sometimes it's easier to make assertions about the behavior of outputs **across changes** to the input



Metamorphic Testing

- Find an example of normal behavior
- Mess up the inputs in someway
- Compare the old and new outputs

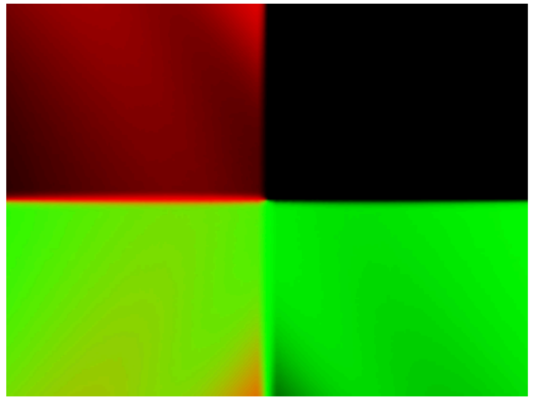


Metamorphic Testing

Original output

Injected Code

Modified Output



Automated Testing of Graphics Shader Compilers
Donaldson etal **OOPSLA17**.

Algebraic Vis Design

"A good visualization, will accurately reflect significant changes in the data with ***COMPREHENSIBLE*** *& significant changes to the visualization"*

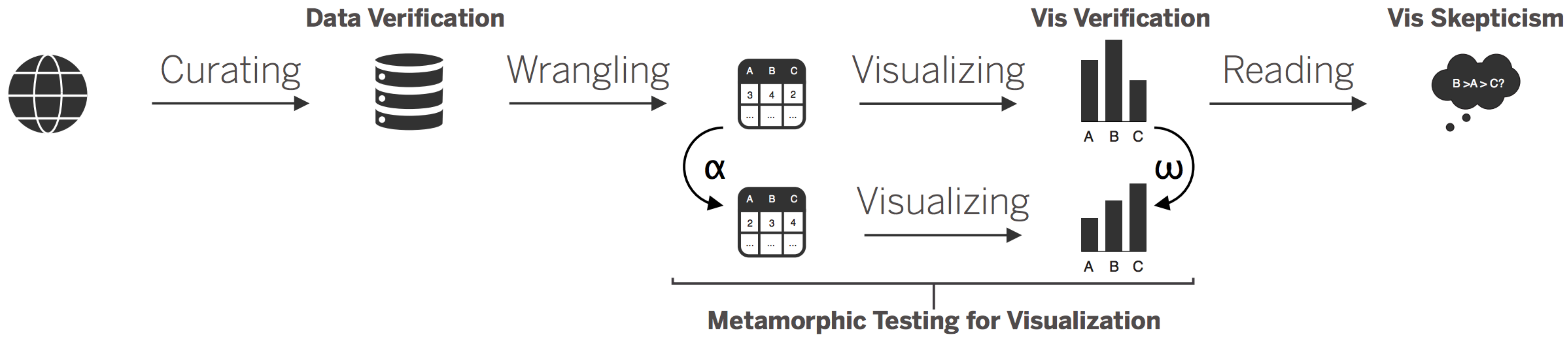
$$\begin{tikzcd} D_1 \arrow[r, "r_1"] \arrow[d, "\alpha"'] & R_1 \arrow[r, "v"] & V_1 \arrow[d, "\omega"] \\ D_2 \arrow[r, "r_2"] & R_2 \arrow[r, "v"] & V_2 \end{tikzcd}$$

Metamorphic Testing

$$\forall x : p(f_I(x)) = f_O(p(x))$$

These framings turn out to be isomorphic!

Metamorphic Testing for Visualization



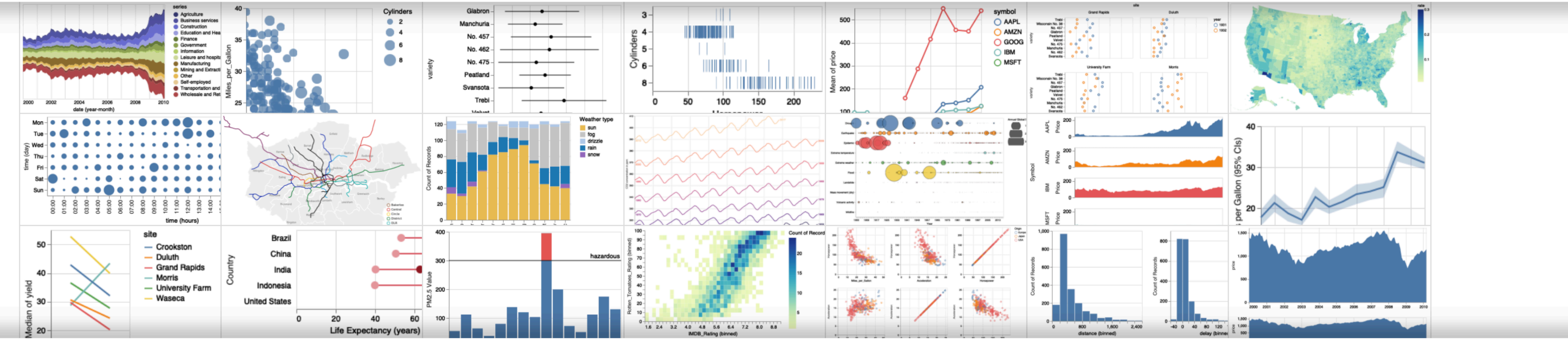
$$MTV :: (Eq, \alpha, \omega) \Rightarrow (spec, data) \Rightarrow Boolean$$

$$MTV(Eq, \alpha, \omega)x = Eq(v(\alpha(x)), \omega(v(x)))$$

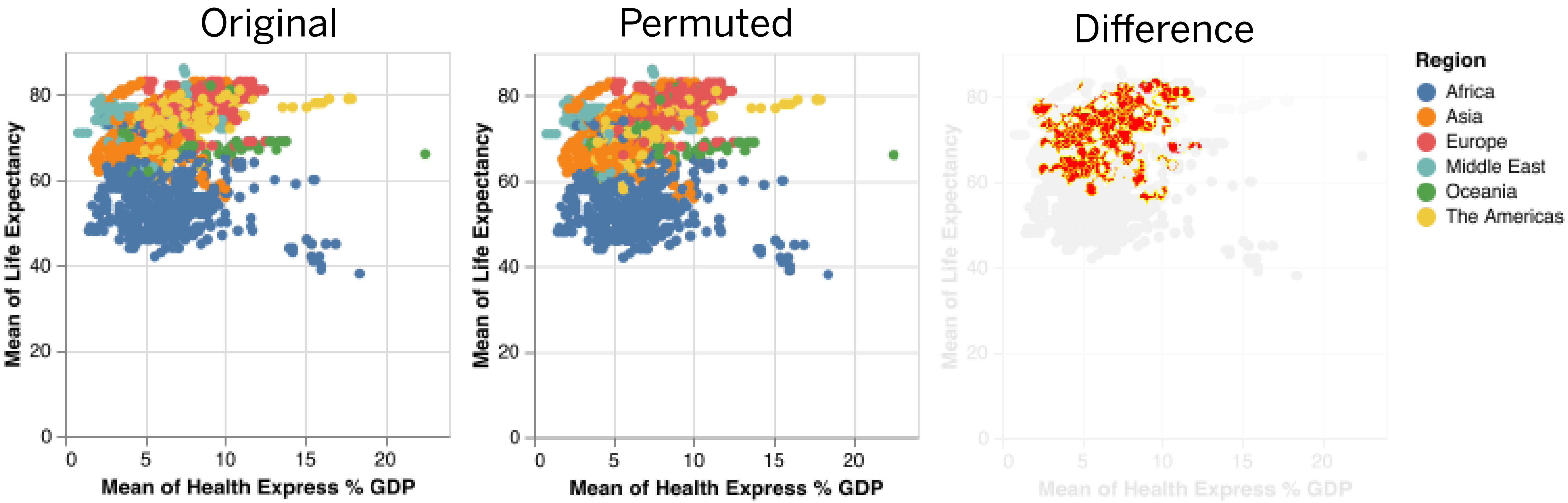
Metamorphic Testing for Visualization

We build a proof-of-concept test based on vega-lite

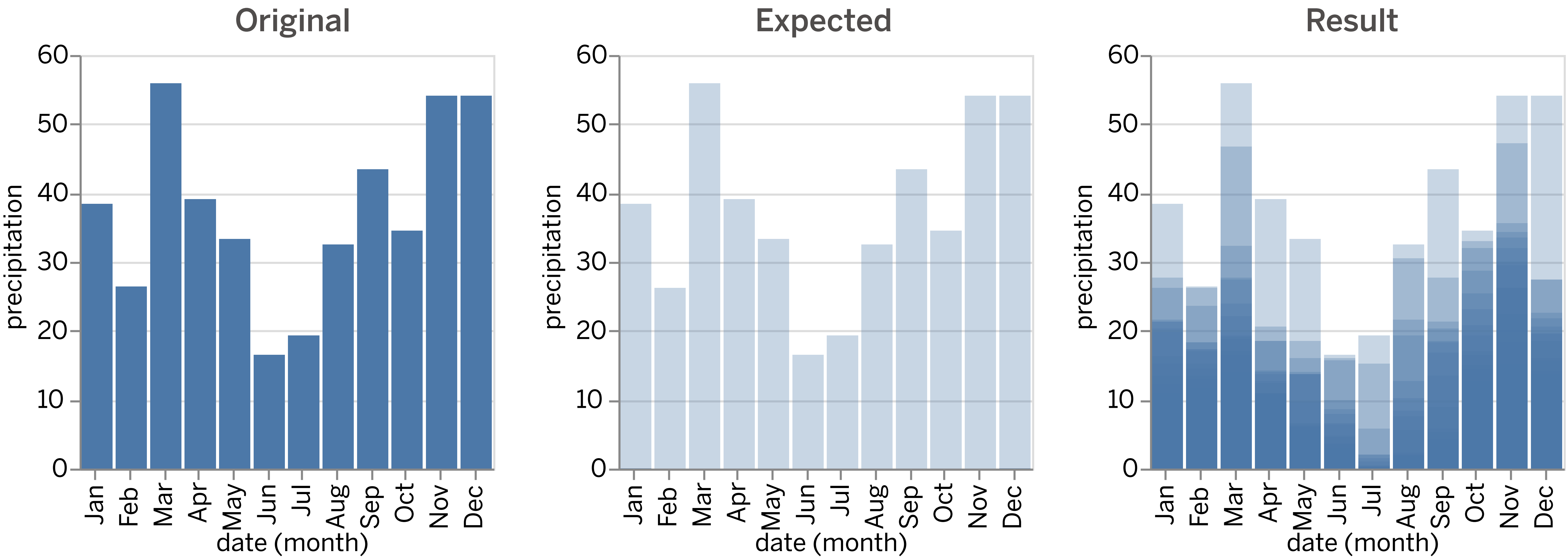
Vega-Lite – A Grammar of Interactive Graphics



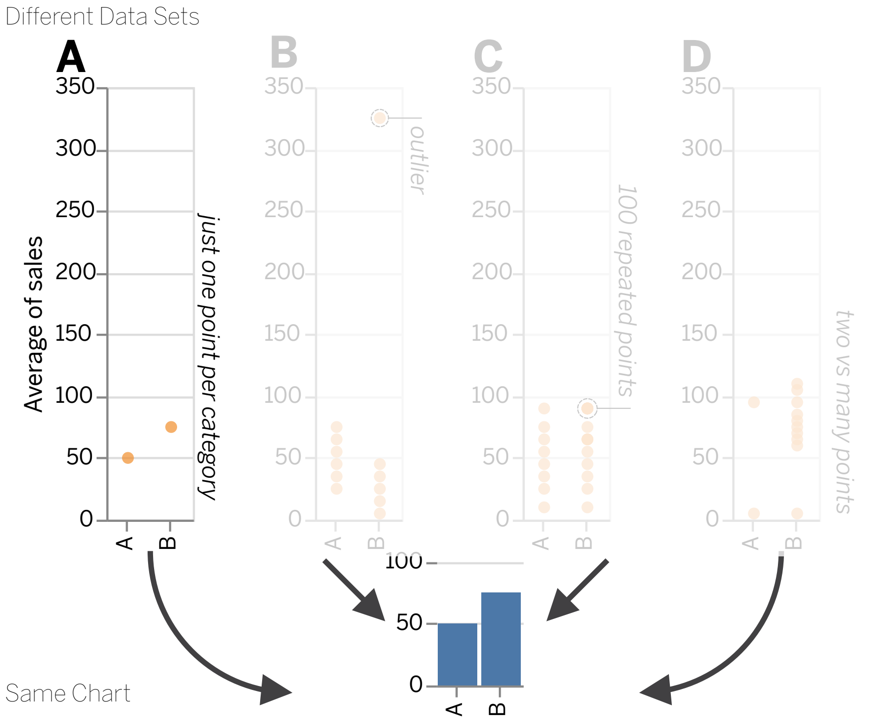
Proof of Concept: **SHUFFLE**

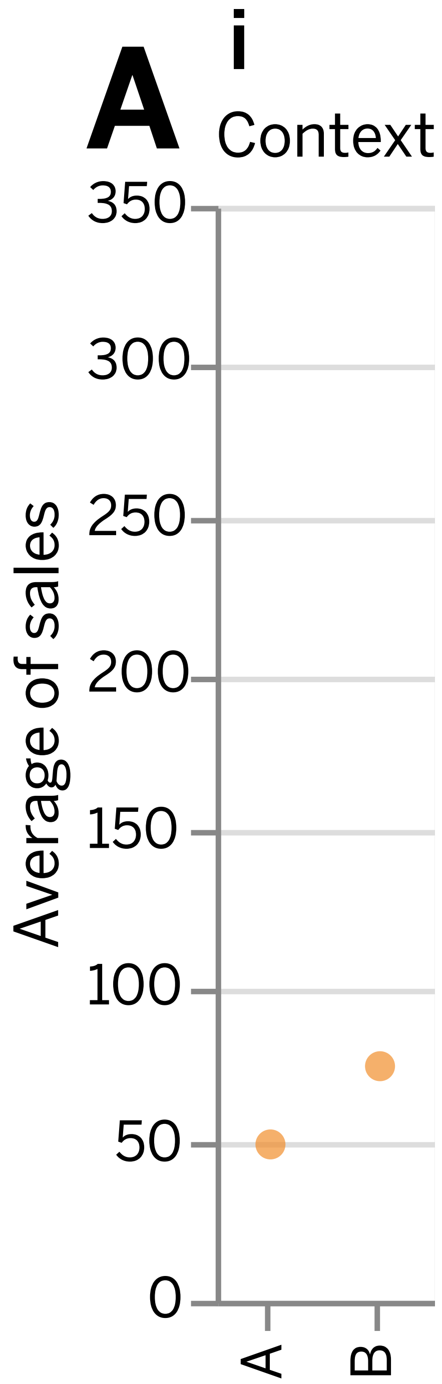


Proof of Concept: CHANGE OPACITY

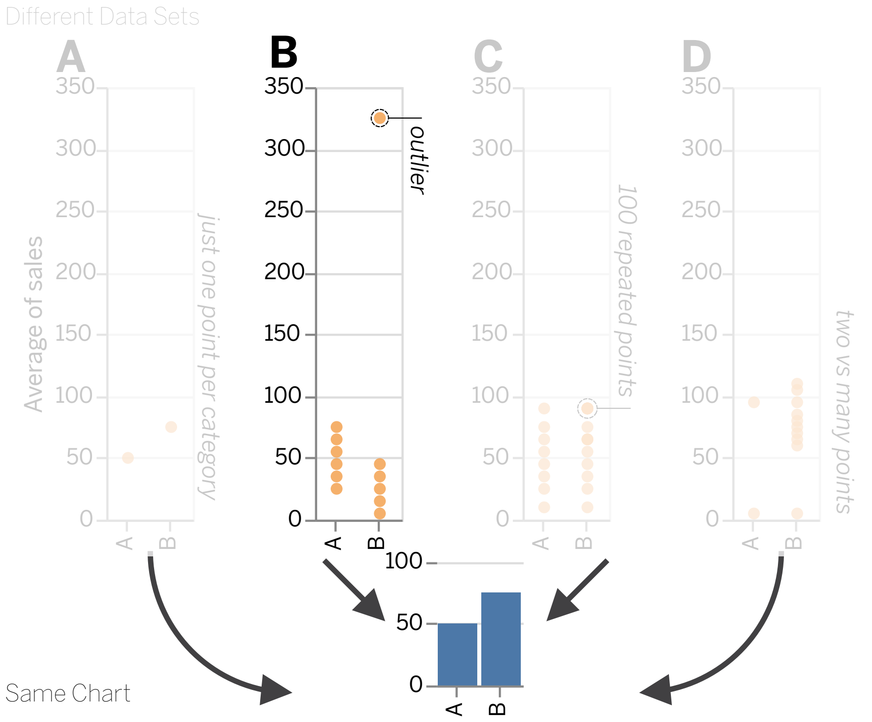


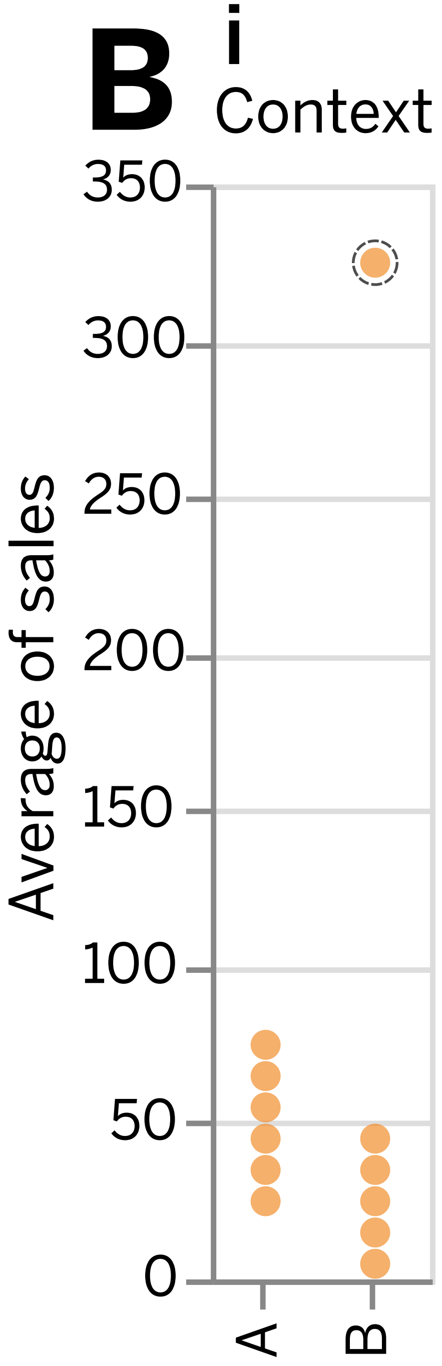
Proof of Concept: **BOOTSTRAP WITHIN AGGREGATE MARKS**





Proof of Concept: **BOOTSTRAP WITHIN AGGREGATE MARKS**





Limitations

We find that this approach can detect a wide variety of visualization errors

Not all visualization mirages can be tested for analytically.

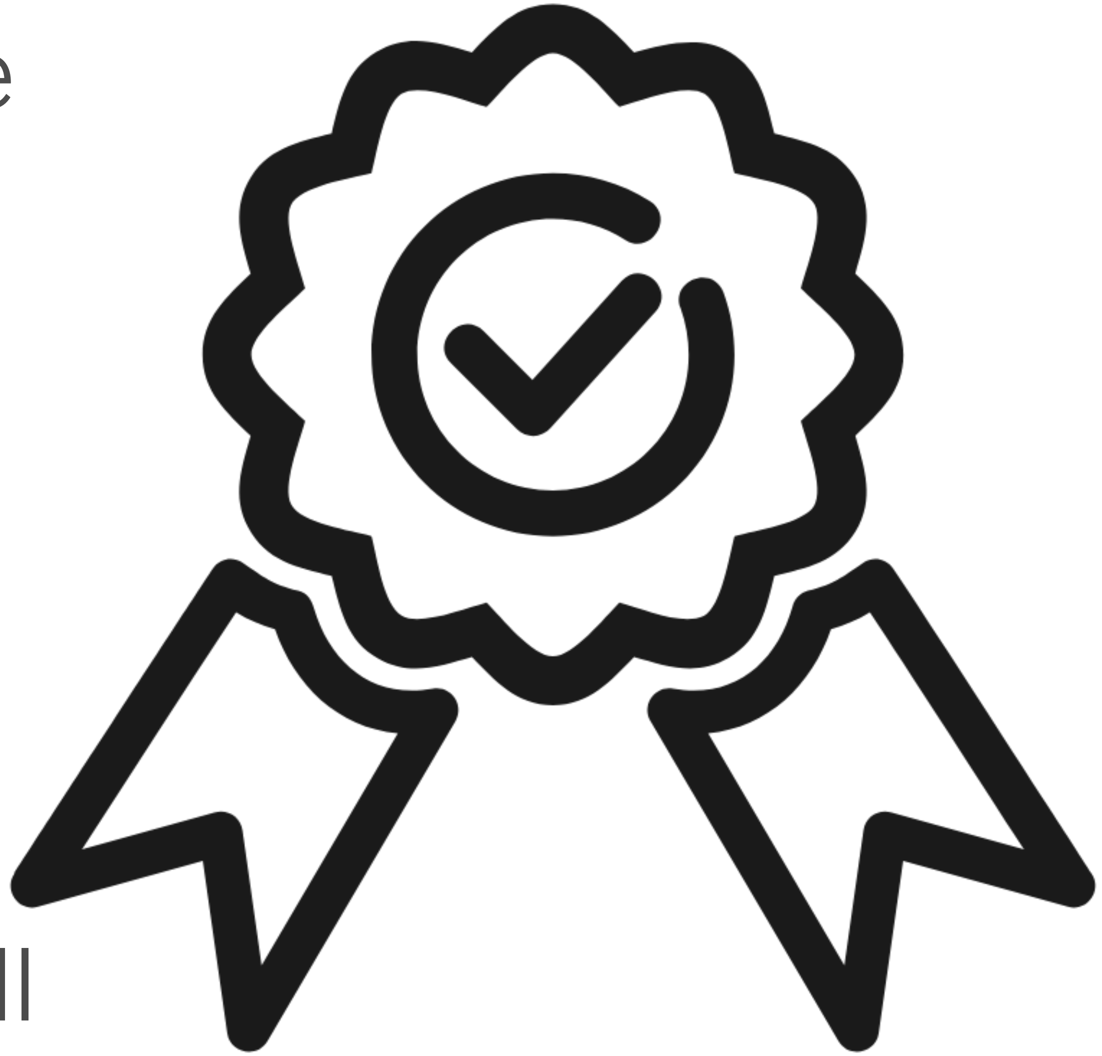
(e.g. how do you automatically test for inequality)

Visualization Validation

Visual analytics systems should do more to protect their readers from noisy insights and themselves

MT4V & Mirages are the first steps towards a **visual analytic validation**

The right interface for this problem is still unknown, but linting for visualization looks promising



Thanks!

Happy to take any questions

Find out more at

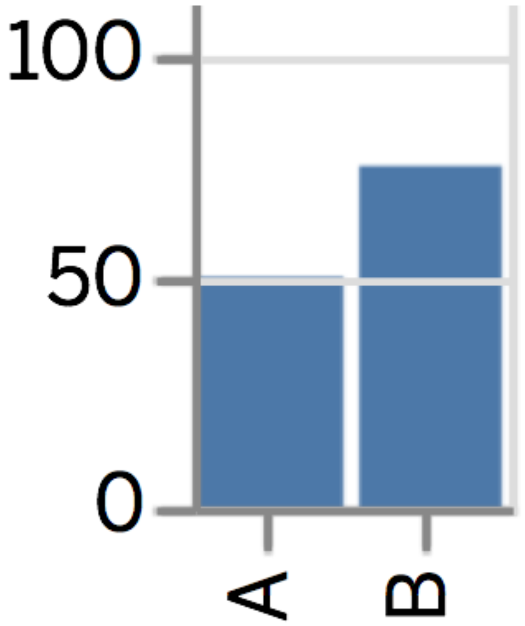
tinyurl.com/mirage-vis

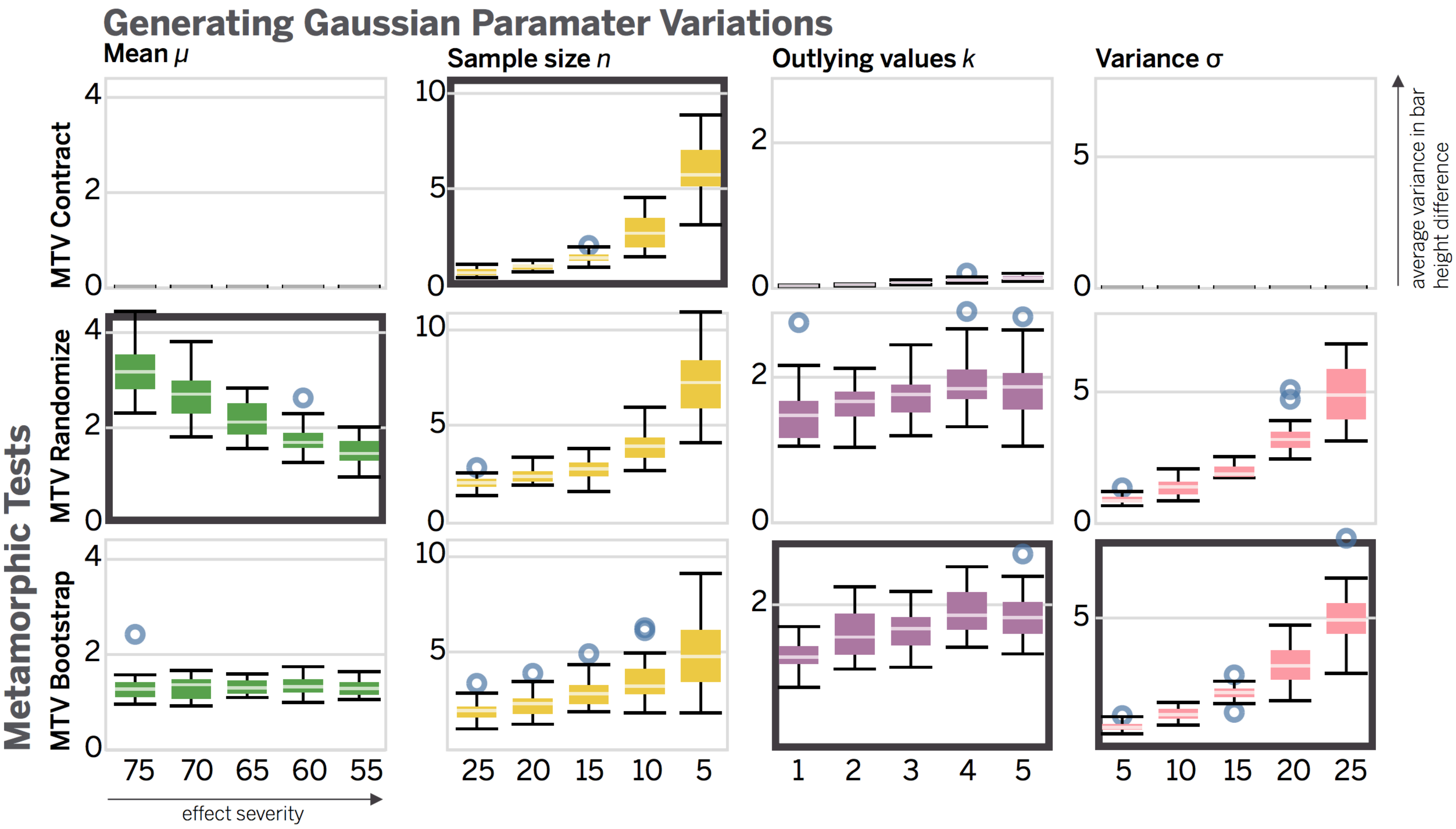
Ask me internet questions!

@_mcnutt_

Validation

We validate this statistical technique through a simulation on 600 two class Gaussian bar charts





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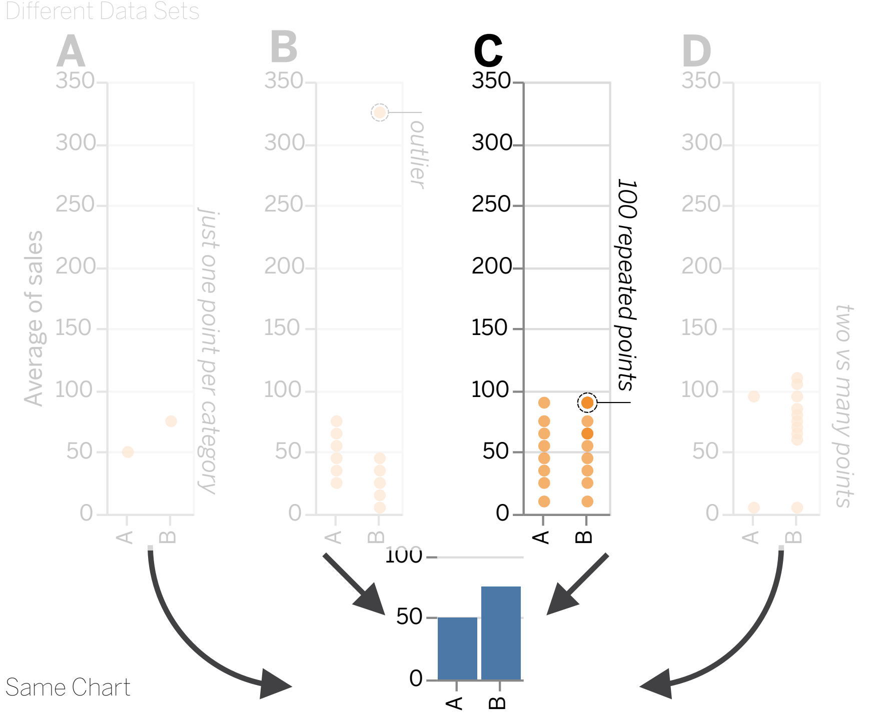

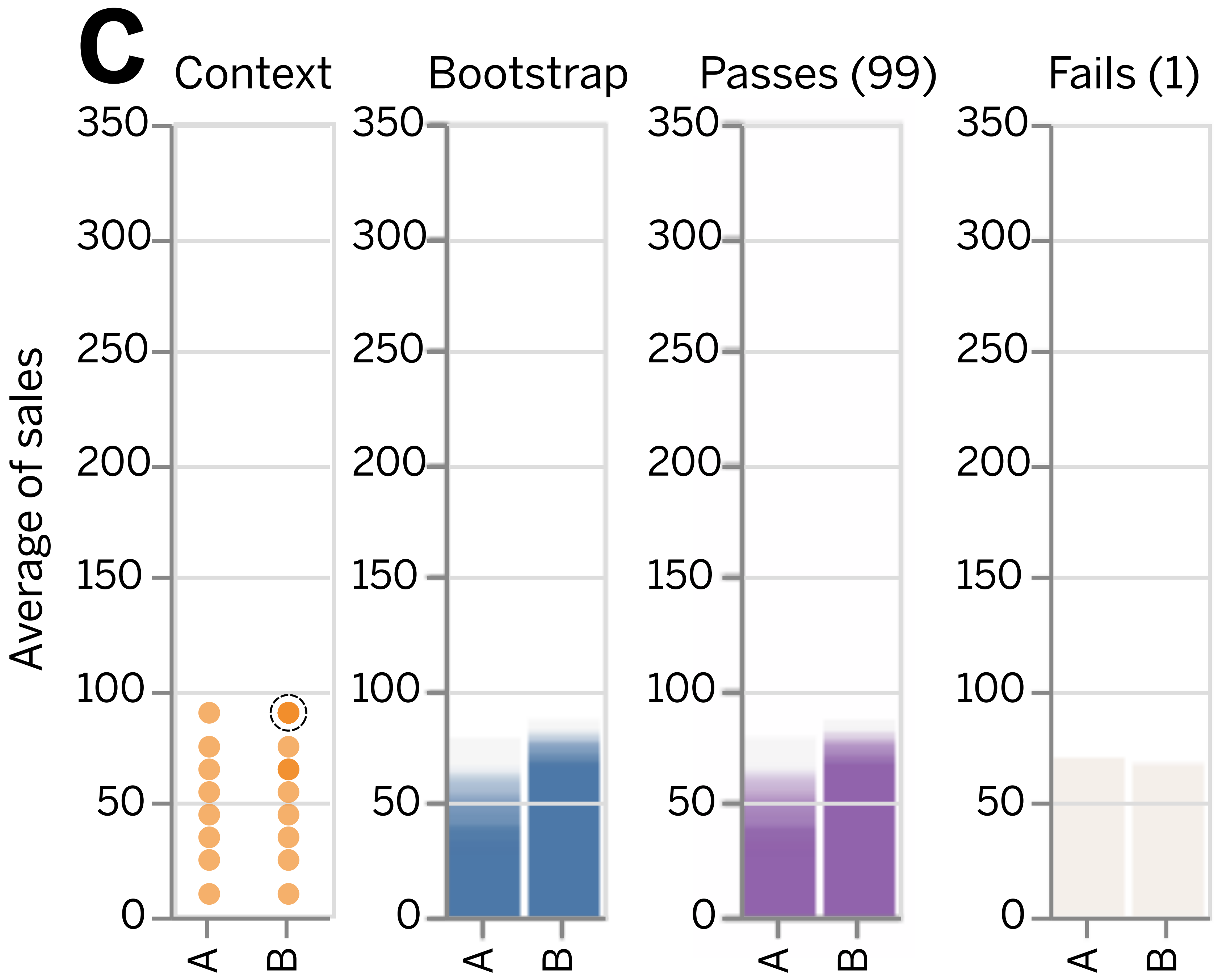

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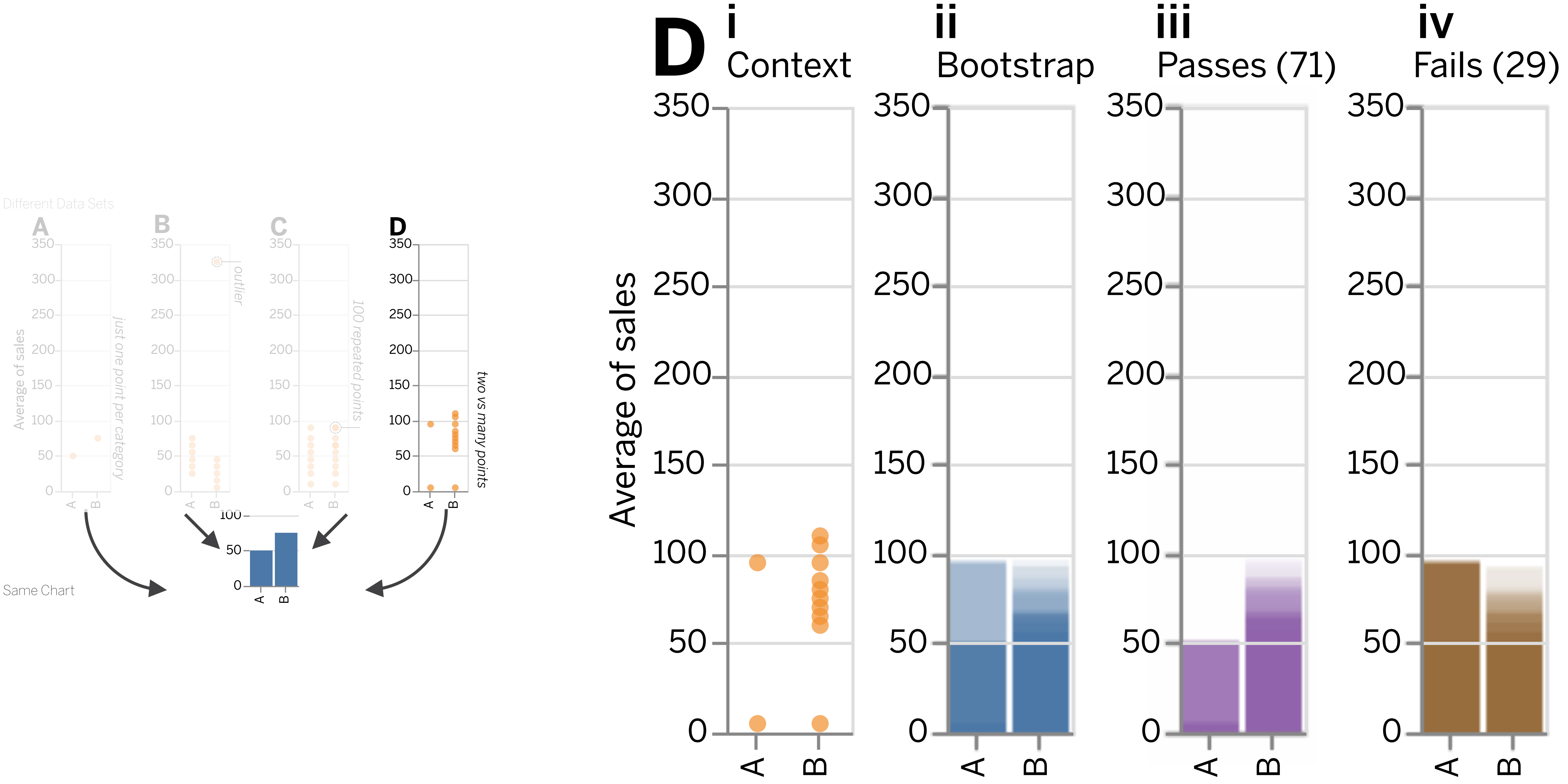
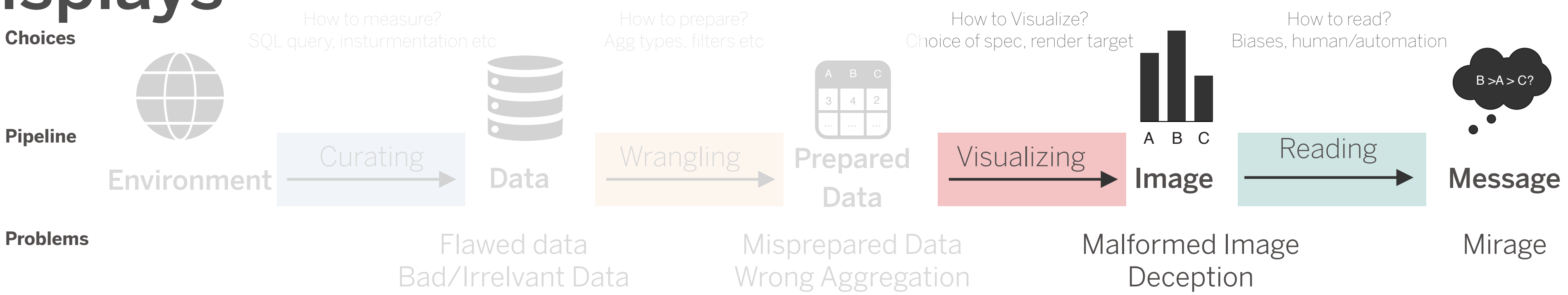
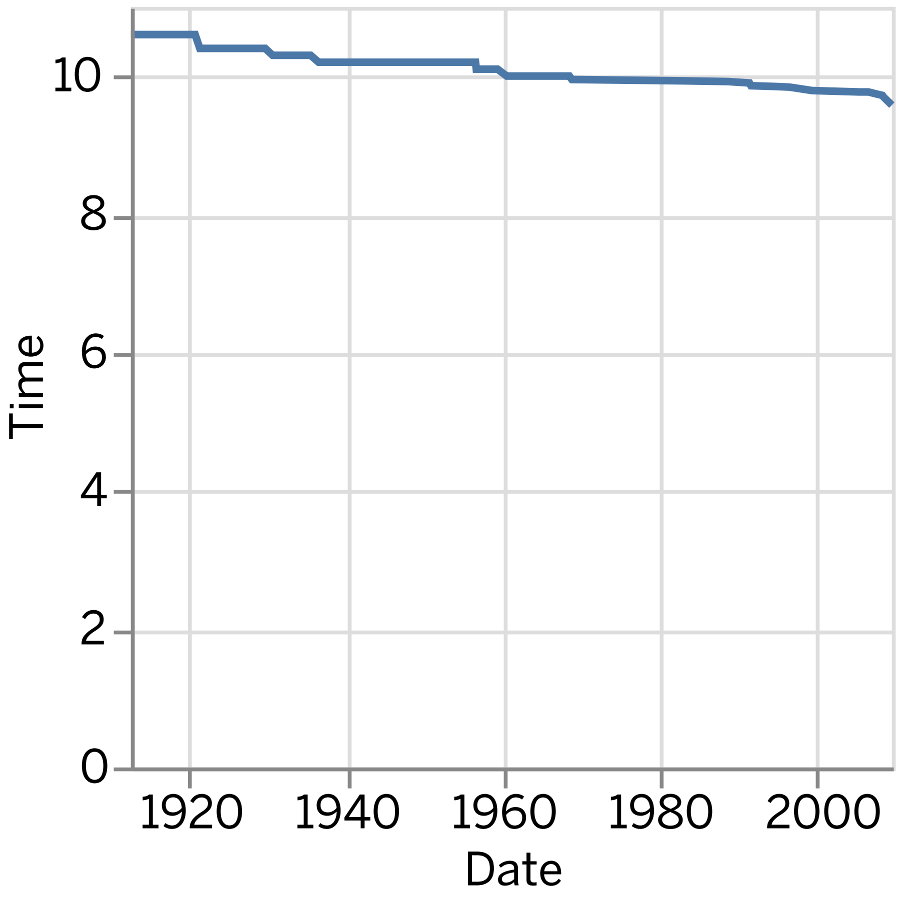
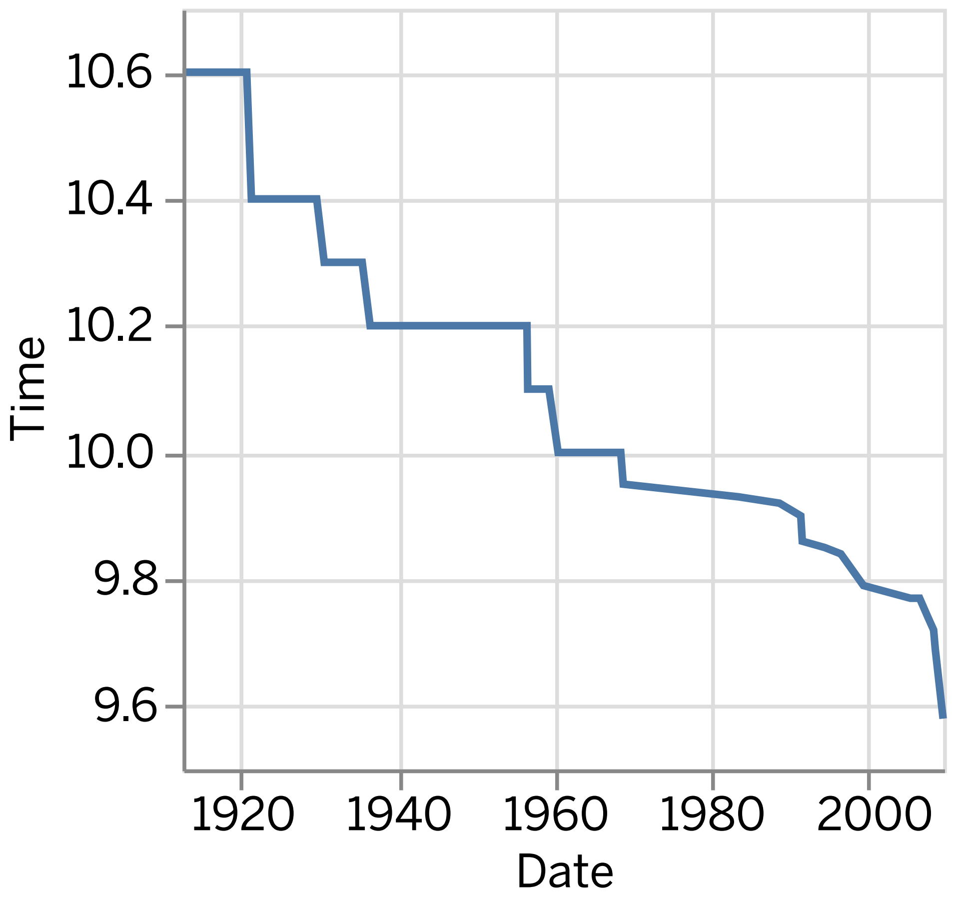


MIRAGES: Deceptive Displays







Visualizations that **mis-use visual encodings** and **abuse reader assumption** in a way that confuses interpretation