

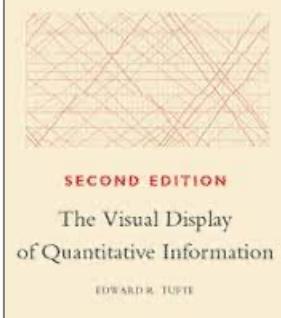
# Addressing Complexity

Effective Visualisation Design – Part 3

02/11/2023

# Principles of Graphical Excellence

From: E. Tufte.  
The Visual  
Display of  
Quantitative  
Information  
(1983)



Graphical displays should:

- ◆ show the data
- ◆ induce viewer to think about substance rather than the methodology
- ◆ serve reasonably **clear purpose**: description, exploration, tabulation or decoration.
  
- ◆ avoid distorting data
  
- ◆ present many numbers in a small space
- ◆ make large data sets coherent
- ◆ reveal the data at several levels of detail

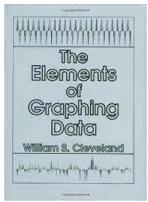
Address a  
clear Objective

Avoid  
Distortion

Handle  
Complexity

# Visualization Principles [Cleveland 85]

From William S. Cleveland, *The Elements of Graphing Data* (1985)



## Clear vision

- ◆ Make the data stand out. **Avoid superfluidity.**
- ◆ Use **visually prominent** graphical elements to **show the data**.
- ◆ **Do not clutter** the data region.
- ◆ Use a reference line when there is an important value that must be seen across the entire graph, but **do not** let the line **interfere** with the data.
- ◆ Do not allow data labels in the data region to interfere with the quantitative data or to clutter the graph.
- ◆ Avoid putting notes, keys, and markers in the data region. Put keys and markers outside the data region and put notes in the legend or in the text.
- ◆ Overlapping plotting symbols must be **visually distinguishable**.
- ◆ Superposed data sets must be readily **visually discriminated**.
- ◆ **Visual clarity must be preserved** under reduction and reproduction.

## General strategy

- ◆ A large amount of quantitative information can be packed into a small region.
- ◆ Graphing data should be an interactive, experimental process.
- ◆ Graph data two or more times when it is needed.
- ◆ Many useful graphs require careful, detailed study.

## Scales

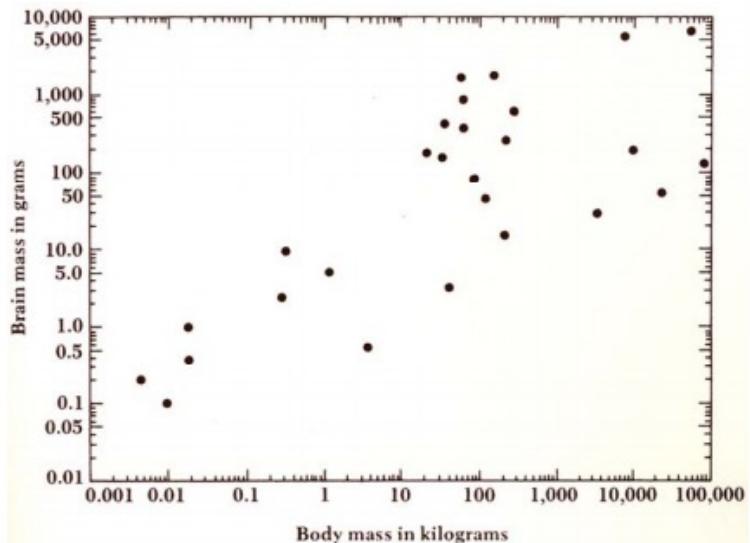
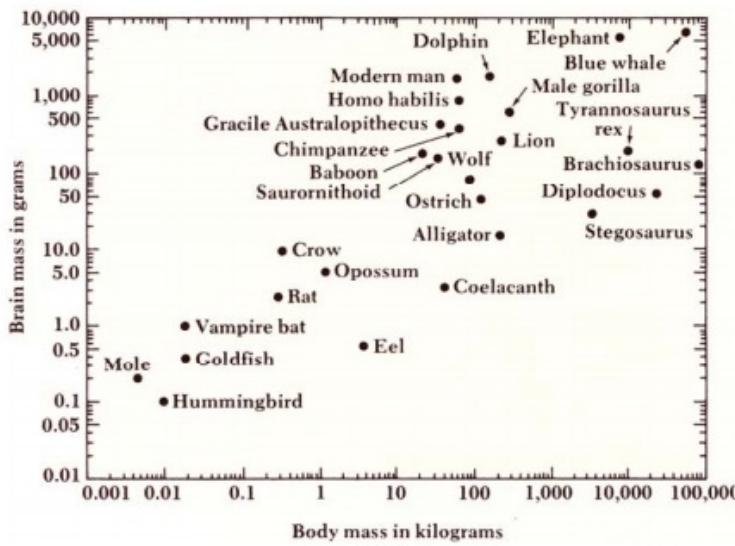
- ◆ Choose range of tick marks to include the range of data.
- ◆ Subject to the constraints that scales have, choose the scales so that the data fill up as much of the region as possible.
- ◆ It is sometimes helpful to use the pair of scale lines for a variable to show two different scales.
- ◆ Choose appropriate scales when graphs are compared.
- ◆ Do not insist that zero always be included on a scale showing magnitude.
- ◆ Use a logarithmic scale when it is important to understand percent change or multiplicative factors.
- ◆ Showing data on a logarithmic scale can improve resolution.

## Clear understanding

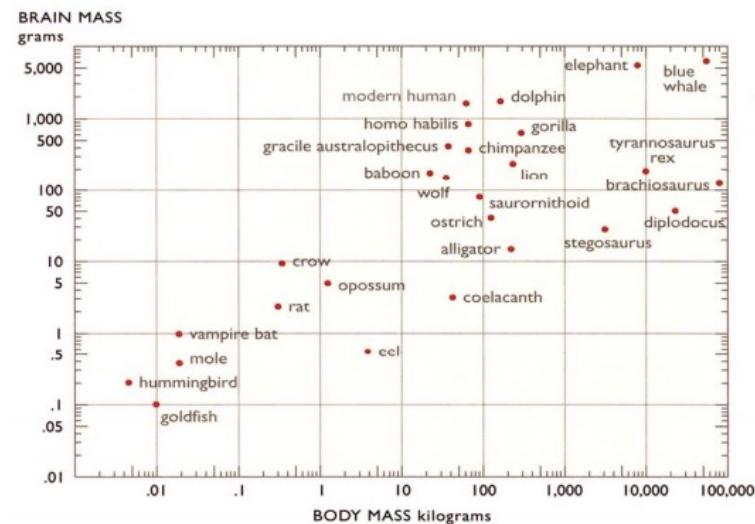
- ◆ Put major conclusions into graphical form. Make legends comprehensive and informative.
- ◆ Error bars should be clearly explained.
- ◆ Proofread graphs.
- ◆ Strive for clarity.

# Visual Clarity

Do not clutter the data region. Do not allow data labels, reference lines interfere with the quantitative data. Avoid cluttering the data region with keys, markers, notes etc.



Overlapping plotting symbols must be visually distinguishable. Superposed data sets must be readily visually-discriminable.



From William S. Cleveland, *The Elements of Graphing Data* (1985). Rightmost figure is suggested improvement by Tufte.

# Visual Complexity

## Avoid Information Overload

- ◆ Extraneous content obscures the message and complicates extraction of knowledge
- ◆ Reader has finite brainpower to dedicate to the problem [Iliinski & Steele 2011]

### TOTAL BRAINPOWER AVAILABLE

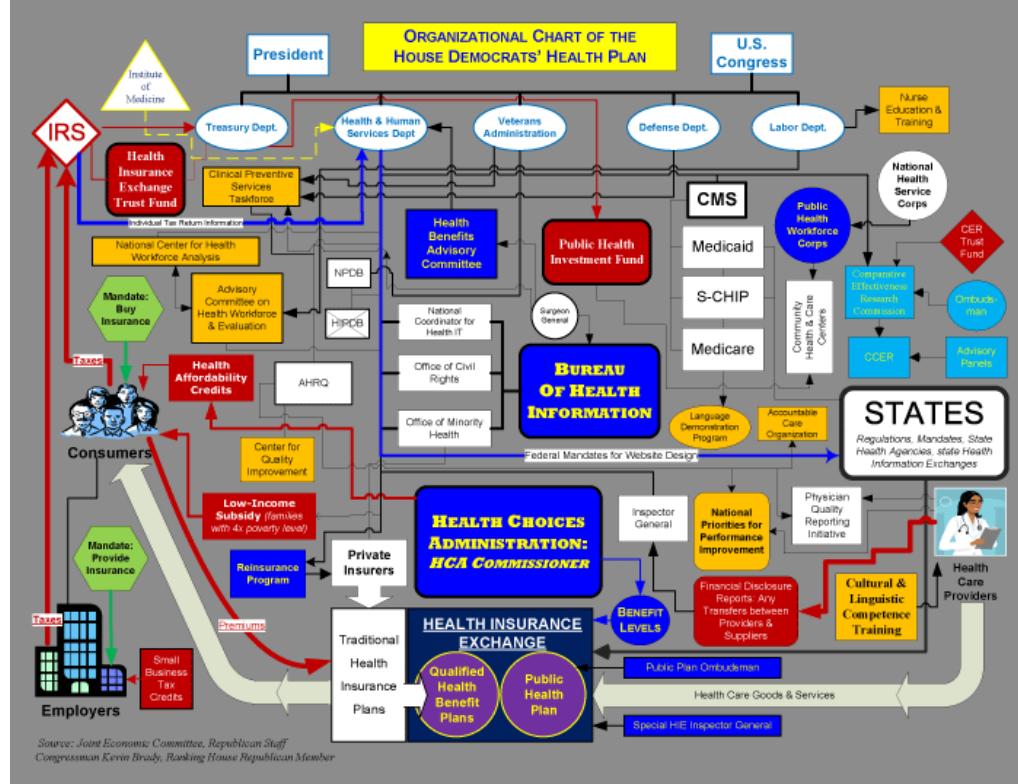


- ◆ Need to facilitate understanding by minimizing amount of Extraneous search/decoding needed

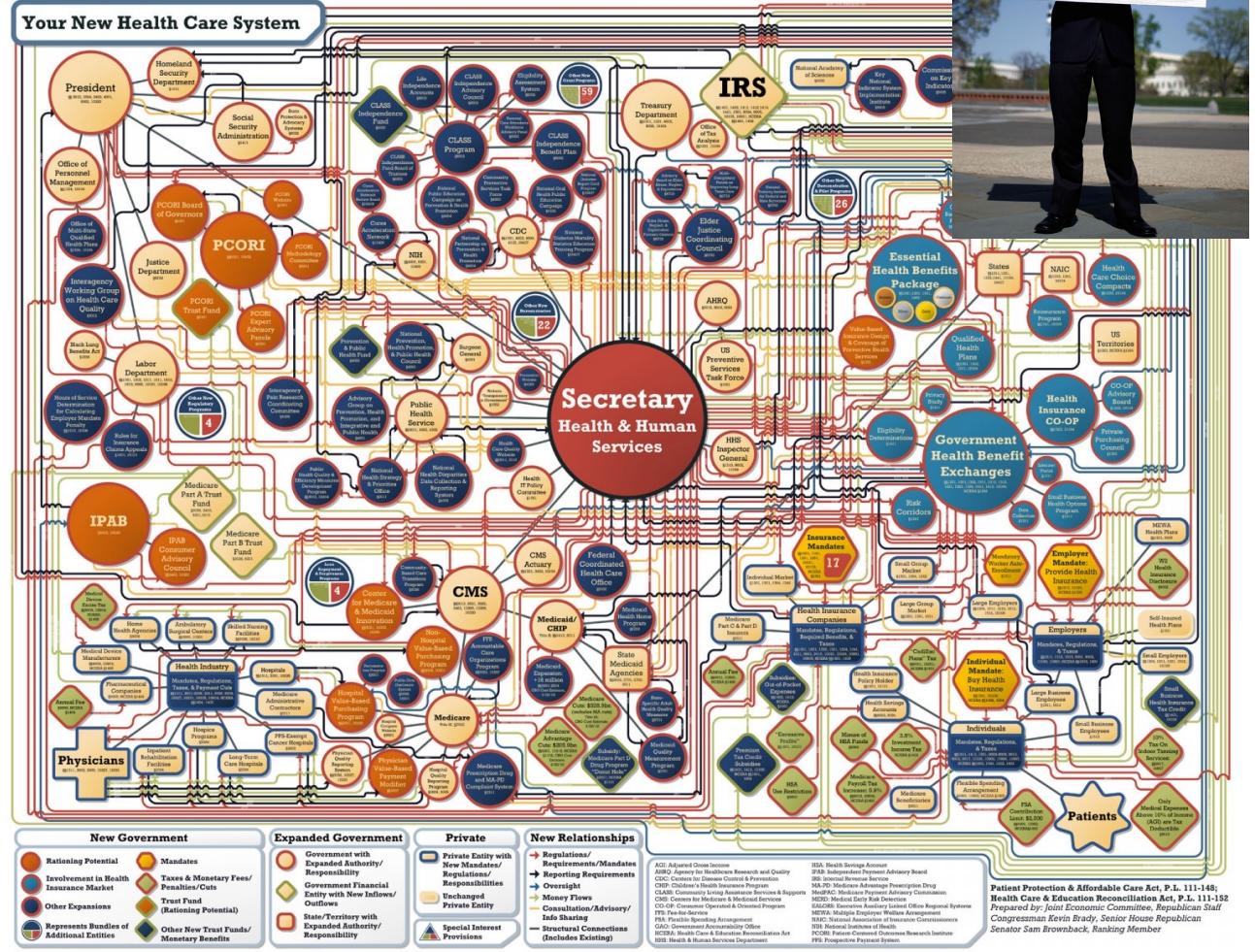
Image based on Iliinski and Steele 2011

# Keep it Simple (KISS)

Simplicity should be a key goal in design. Unnecessary complexity should be avoided.

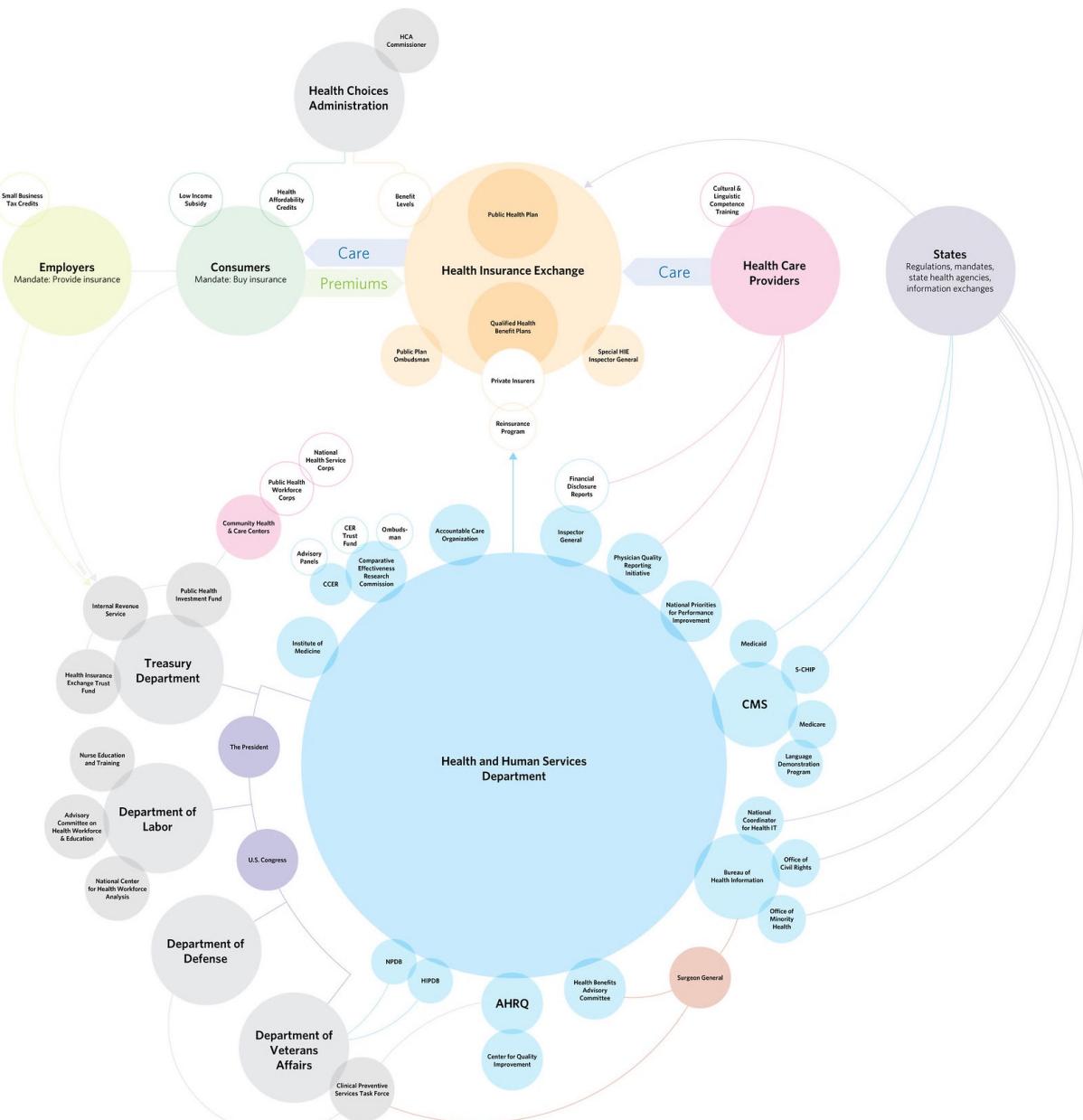
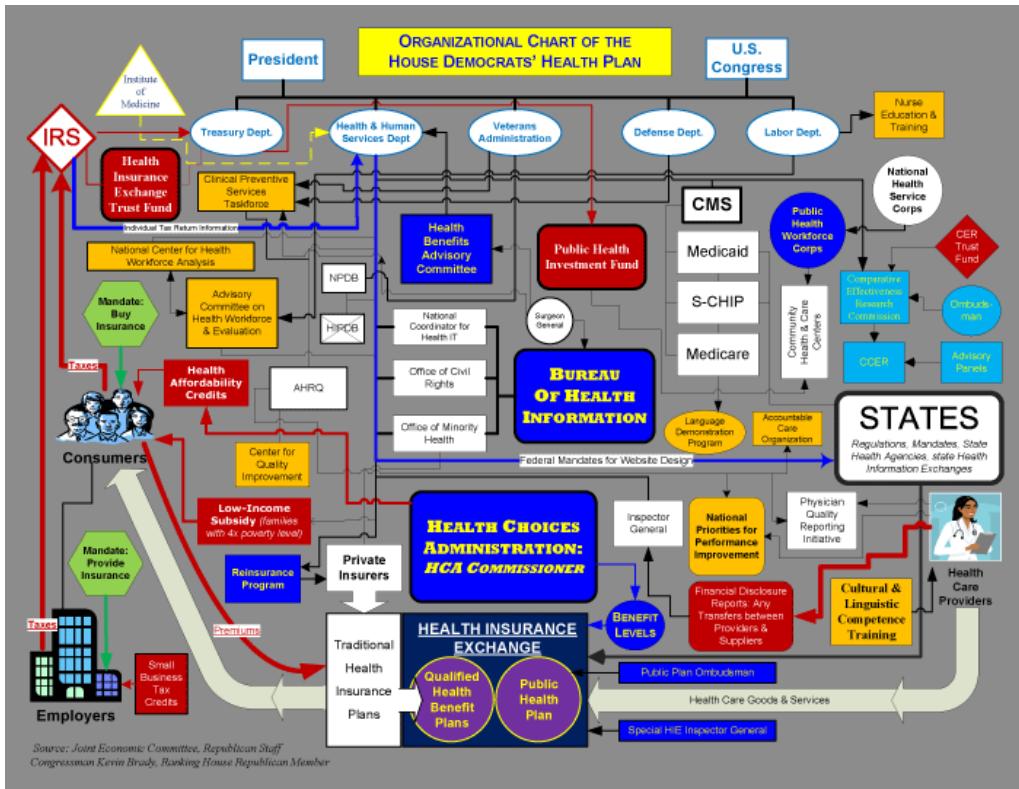


Counterexamples?: visualizations of the a healthcare system



# Keep it Simple (KISS)

Simplicity should be a key goal in design. Unnecessary complexity should be avoided.



Alternative visualizations of the same data: right Robert Palmer

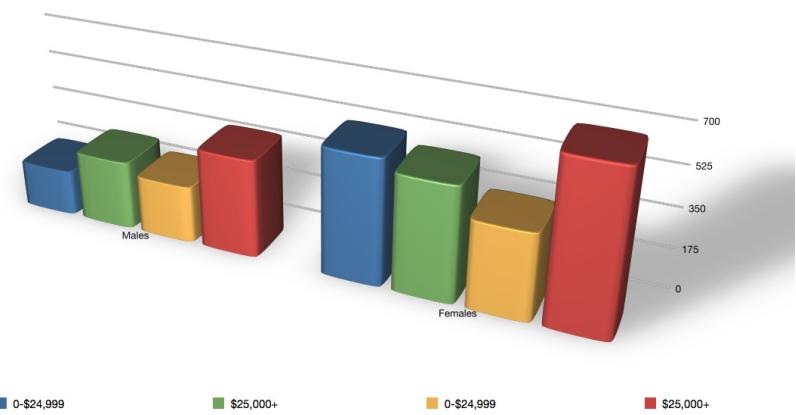
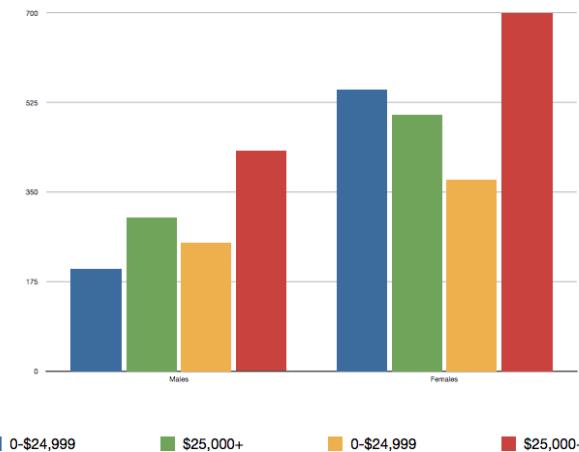
# Graphical Excellence [TUFTE]

- ◆ Above all else show the data

*Data to Ink Ratio*

$$= \frac{\text{ink used specifically to depict data}}{\text{total ink used on graphic}}$$

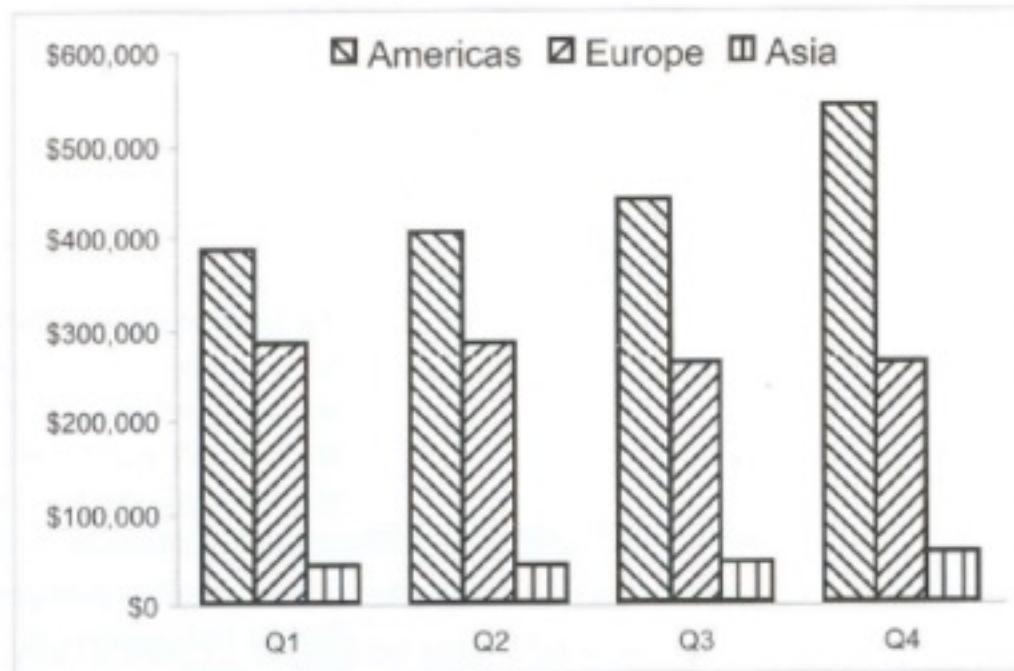
- ◆ Maximize the data-ink ratio, within reason.
- ◆ Erase non-data ink, within reason
- ◆ Erase redundant data ink, within reason



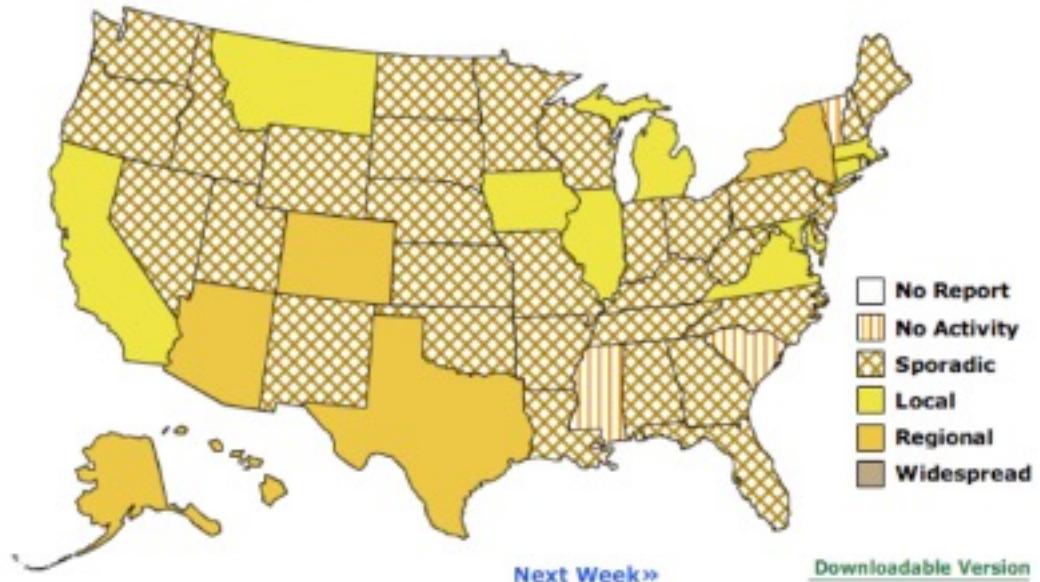
Bottom: Unneeded ink

# Low Data-Ink Ratio

Texture-based encodings have some advantages  
e.g. CVD-safe, suit multi-variate/multi-dimensional.  
But must beware of increase in mental load



Weekly Influenza Activity Estimates Reported by State and Territorial Epidemiologists\*  
Week Ending December 29, 2007- Week 52



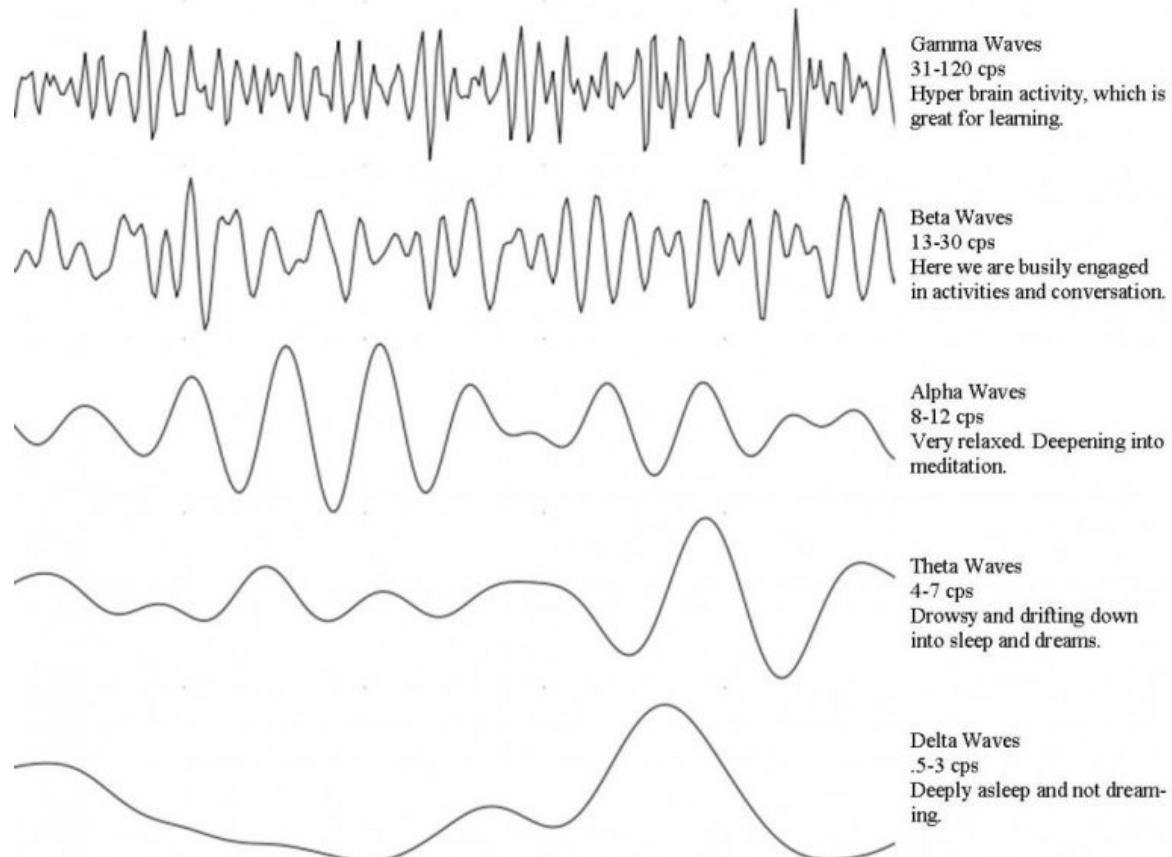
\*This map indicates geographic spread and does not measure the severity of influenza activity.

[Next Week»](#)

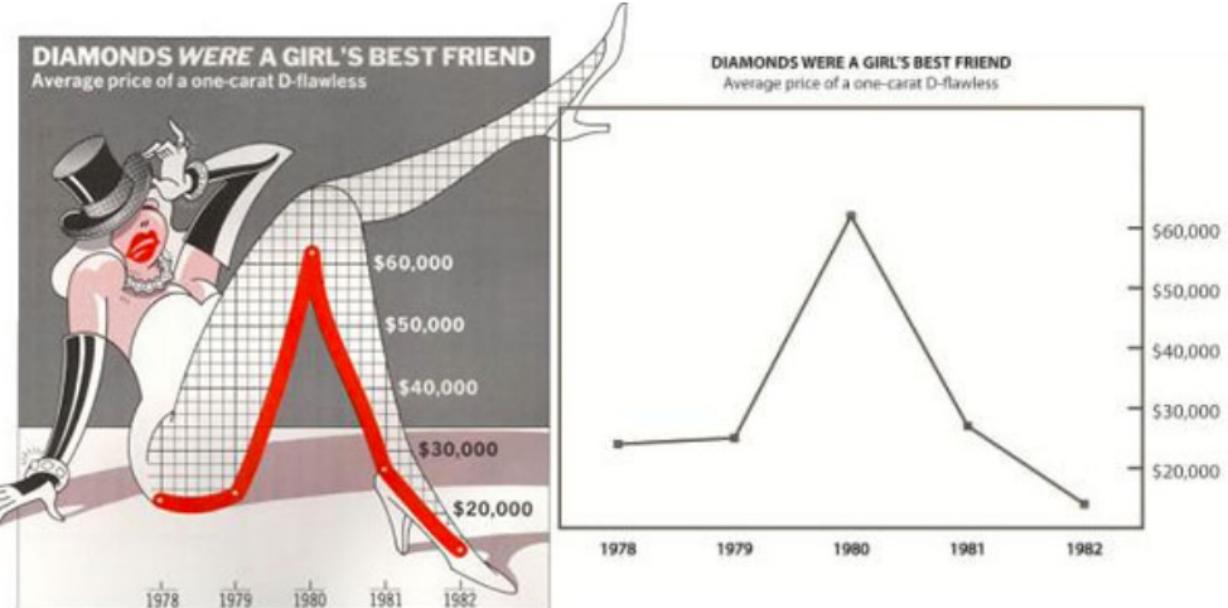
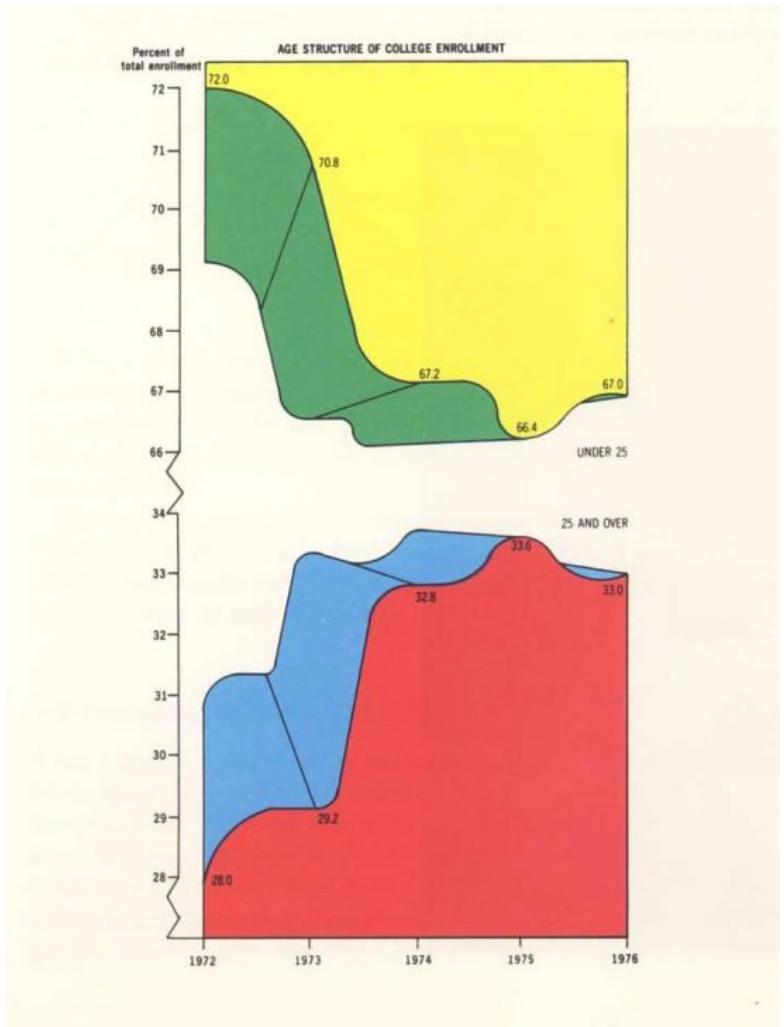
[Downloadable Version](#)

# High Data-Link Ratio

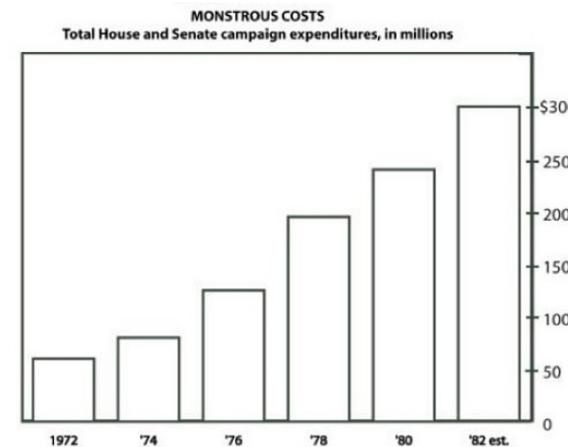
Brain Waves Graph



# Superfluous Ink



[Bateman et al. 2010]

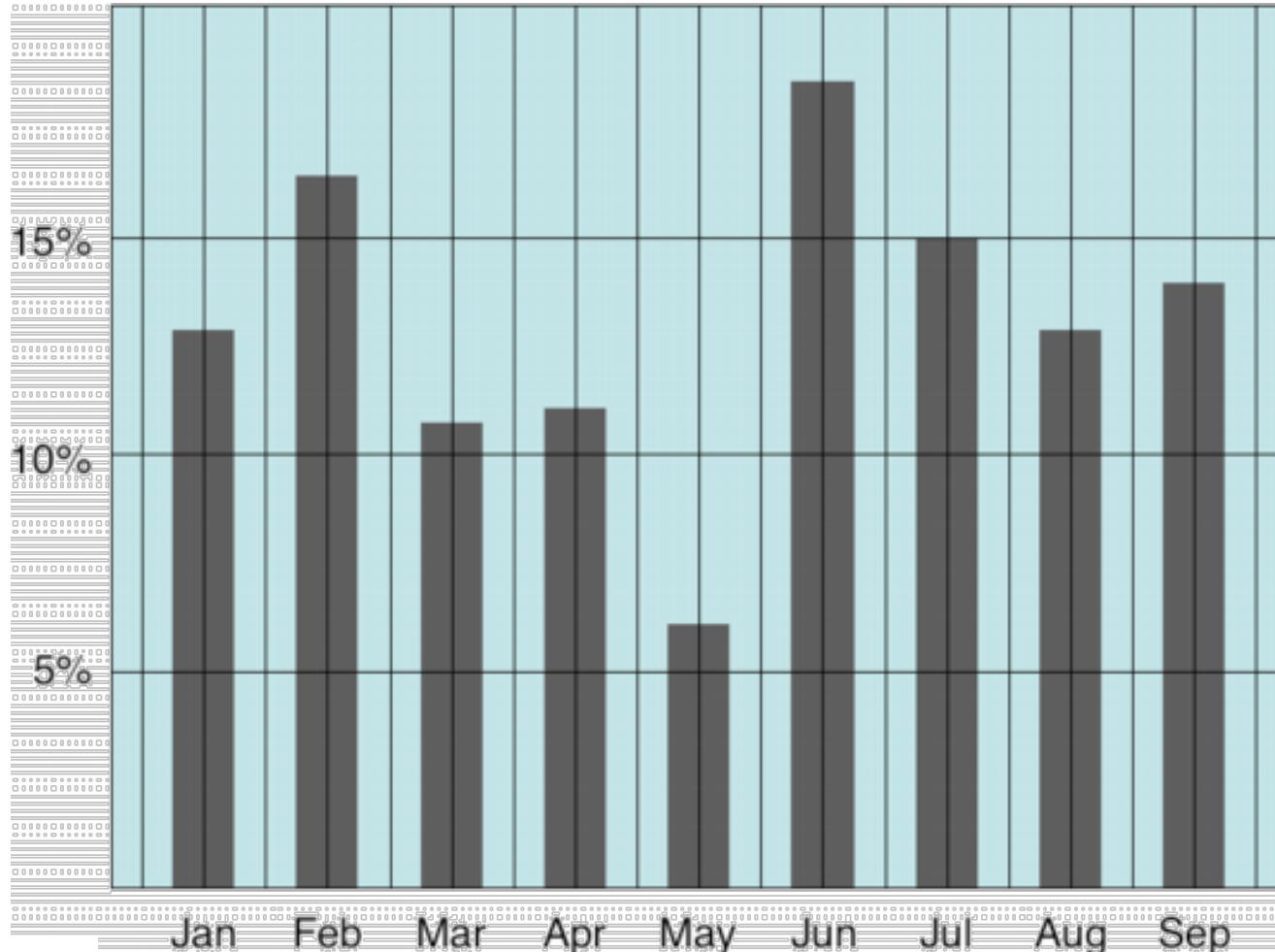


[Bateman et al. 2010]

<https://eagereyes.org/criticism/chart-junk-considered-useful-after-all>

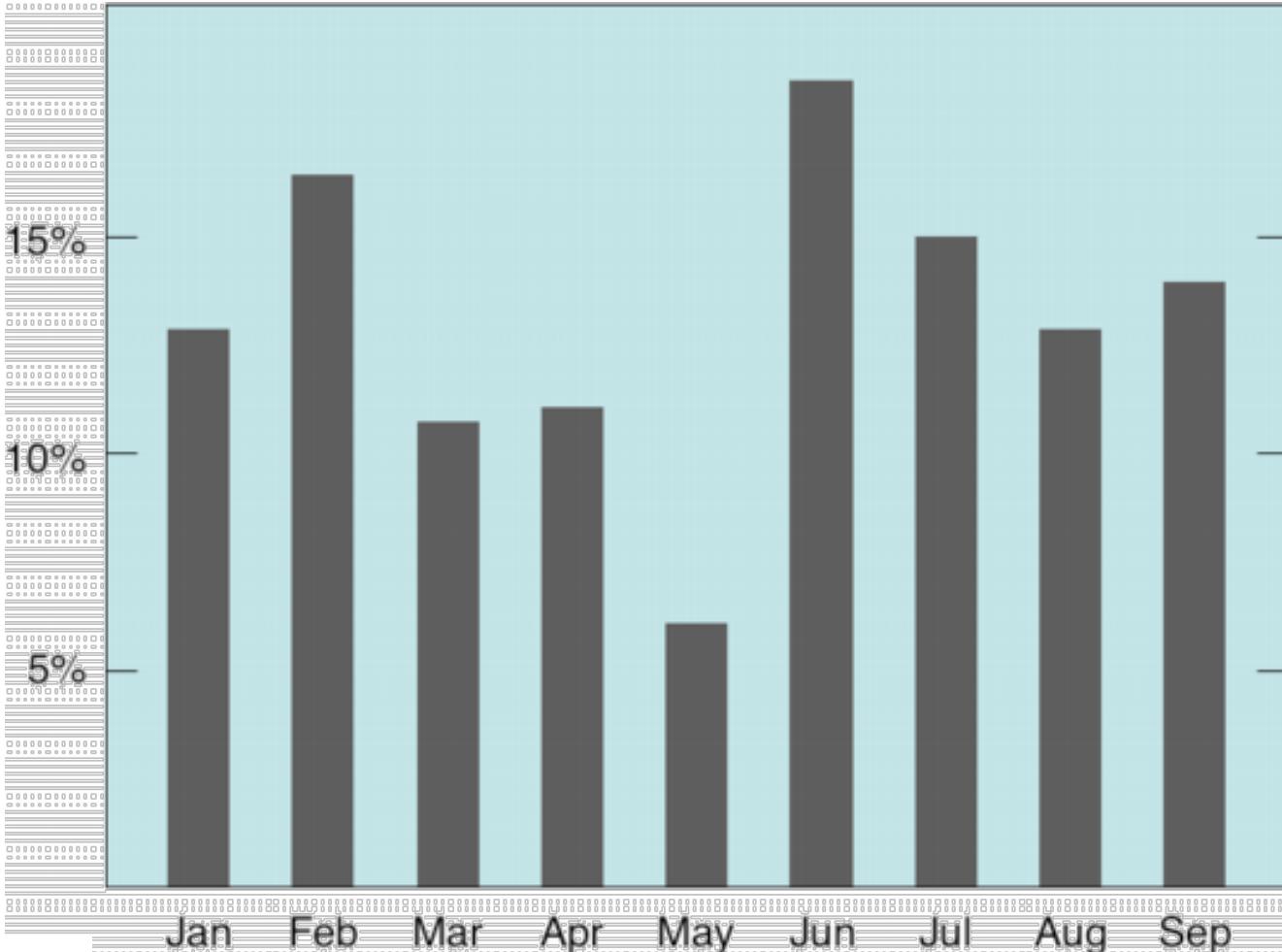
# Avoid Chart Junk

Extraneous visual elements that distract from the message



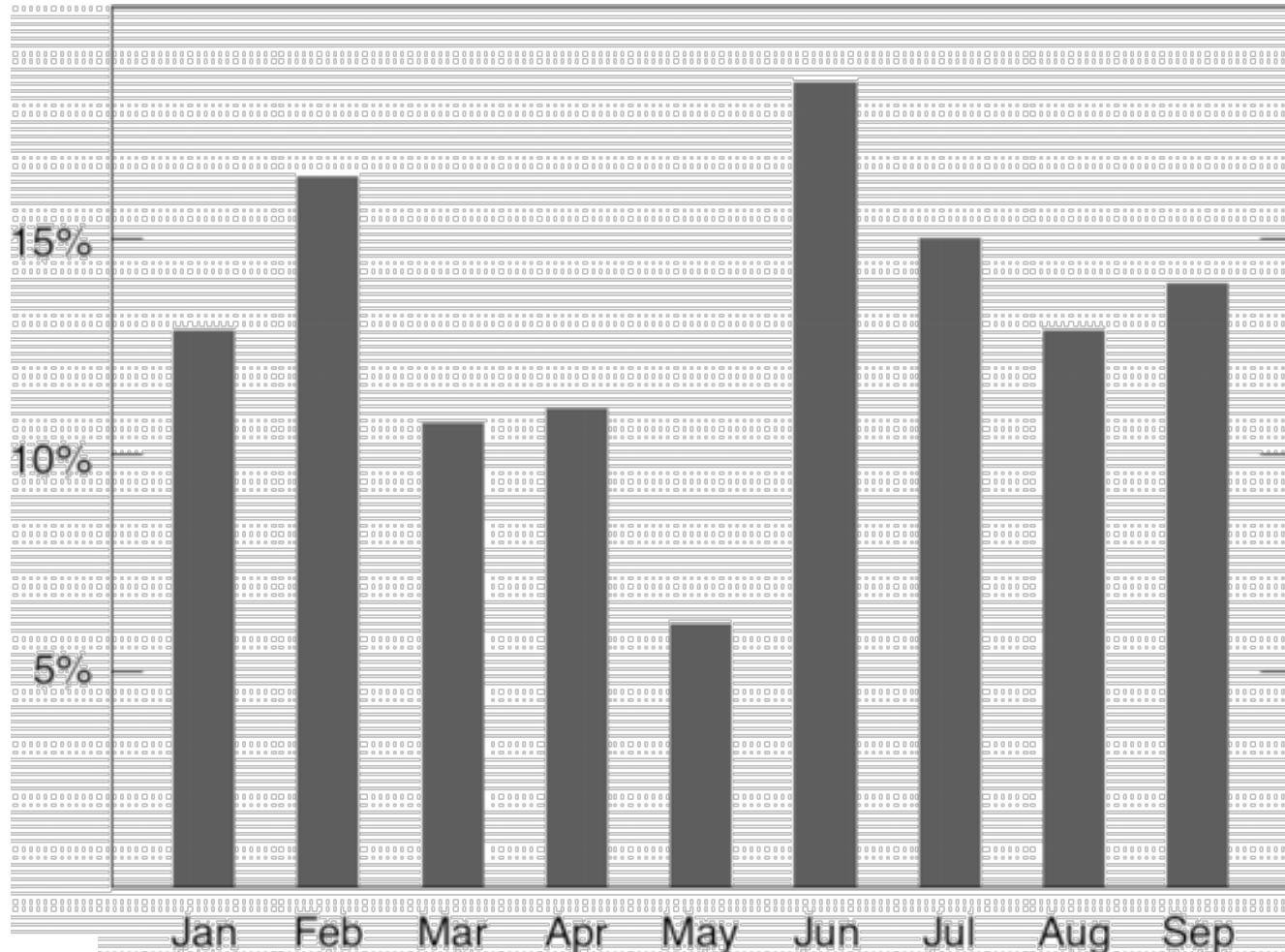
Example by Tim Brey [[URL](#)]

# Avoid Chart Junk



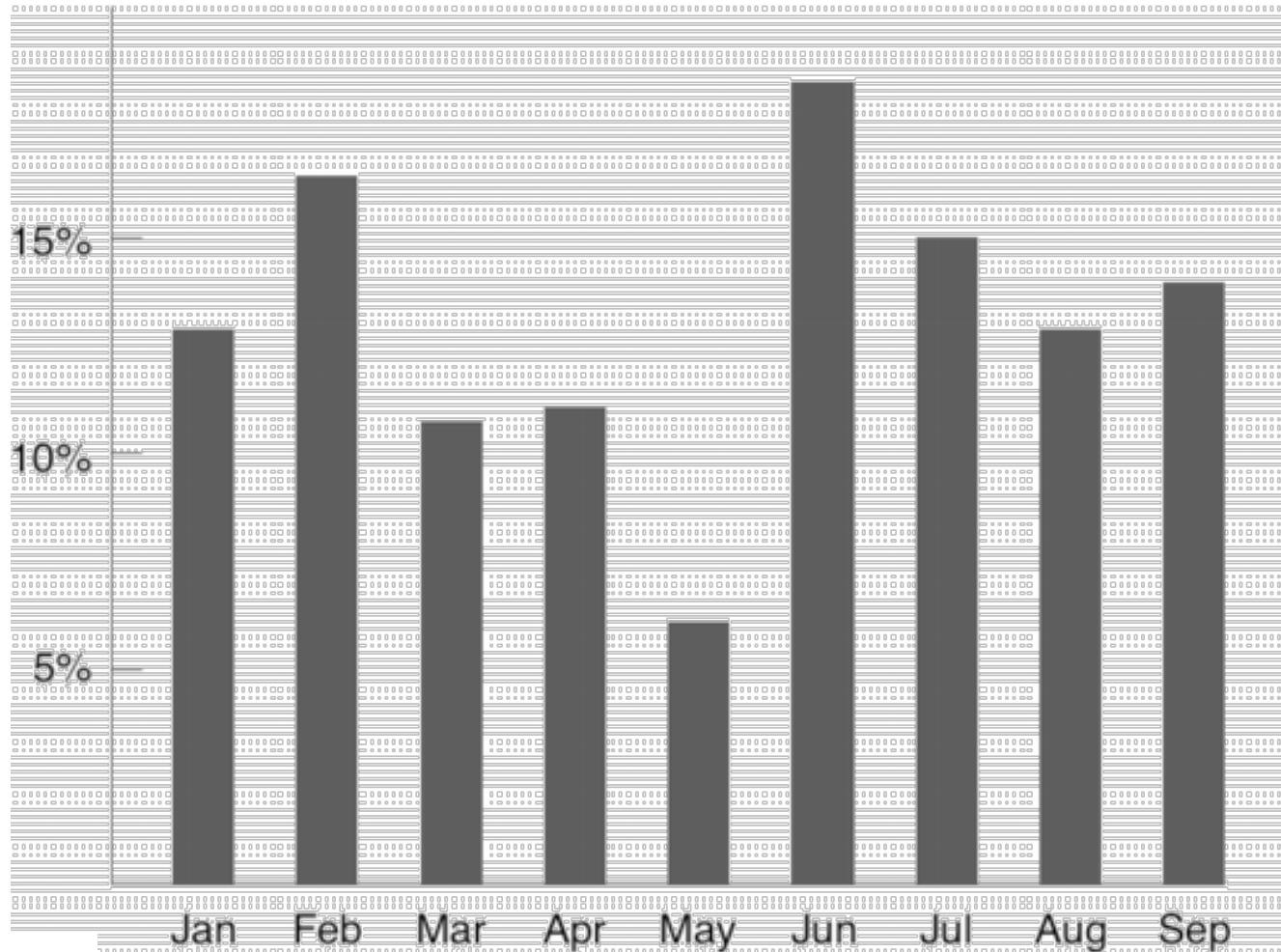
Example by Tim Brey [[URL](#)]

# Avoid Chart Junk



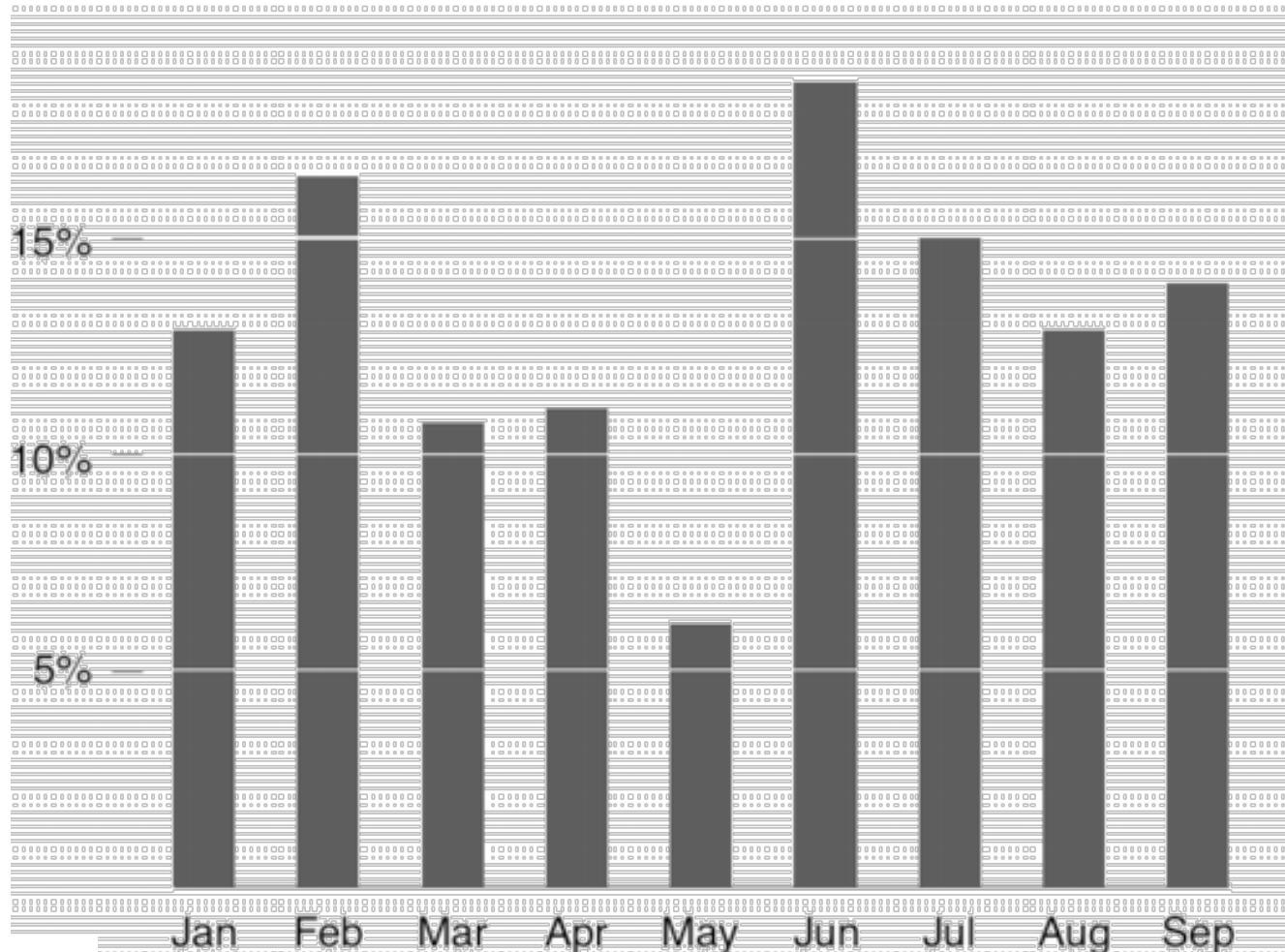
Example by Tim Brey [[URL](#)]

# Avoid Chart Junk



Example by Tim Brey [[URL](#)]

# Avoid Chart Junk



Example by Tim Brey [[URL](#)]

# Revise and edit

“Perfection is achieved not when there is nothing more to add but when there is nothing left to take away”

– Antoine de Saint Exupery [Translated from French]

Remove to improve

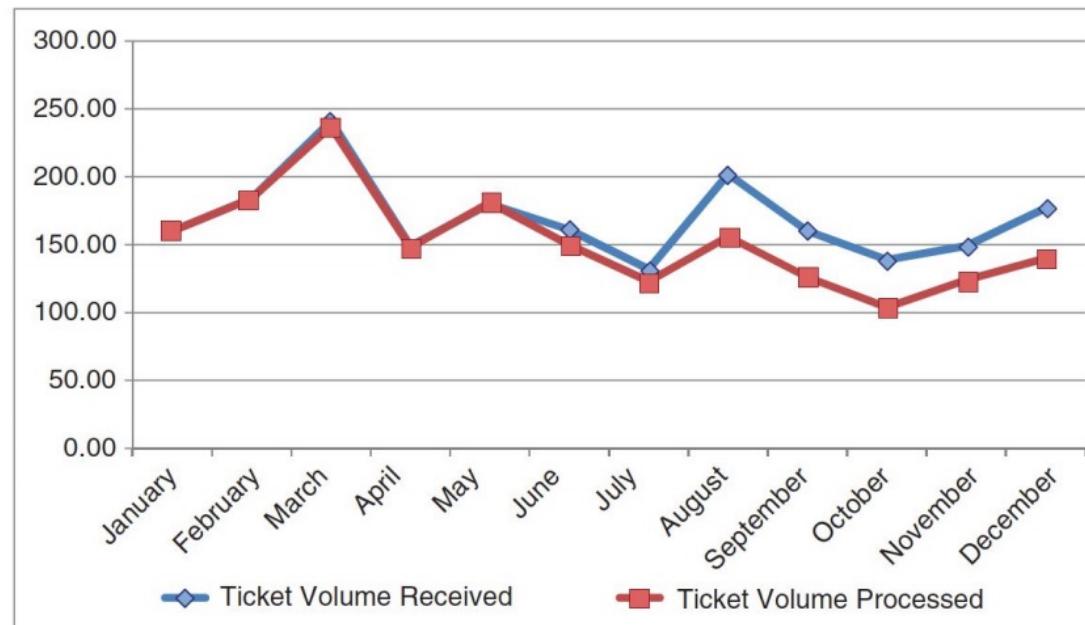


FIGURE 3.17 Original graph



# Attention vs Distraction

Conversely to previous cases: We can draw attention productively: e.g. to aid Visual Search

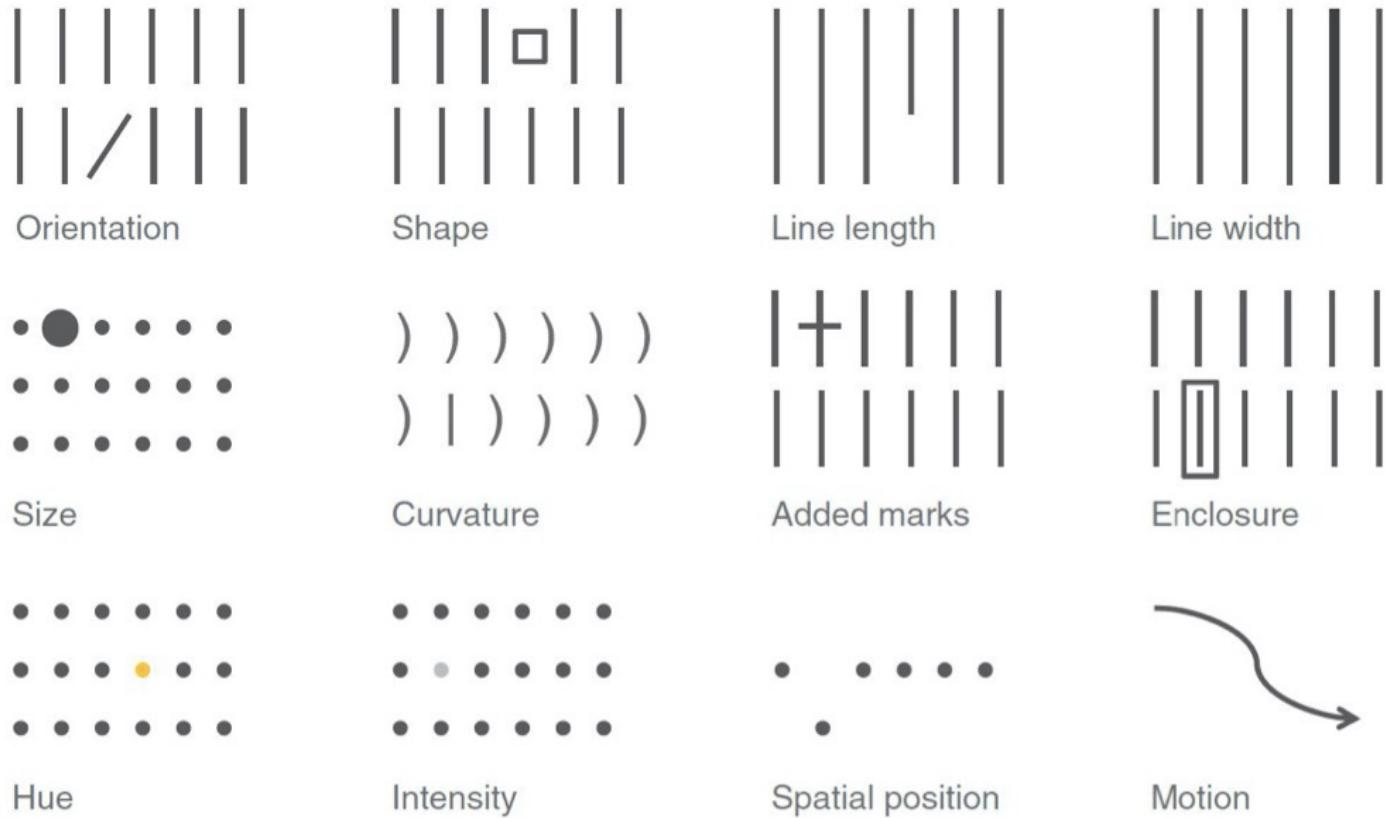
756395068473  
658663037576  
860372658602  
846589107830

# Attention vs Distraction

Conversely to previous cases: We can draw attention productively: e.g. to aid Visual Search

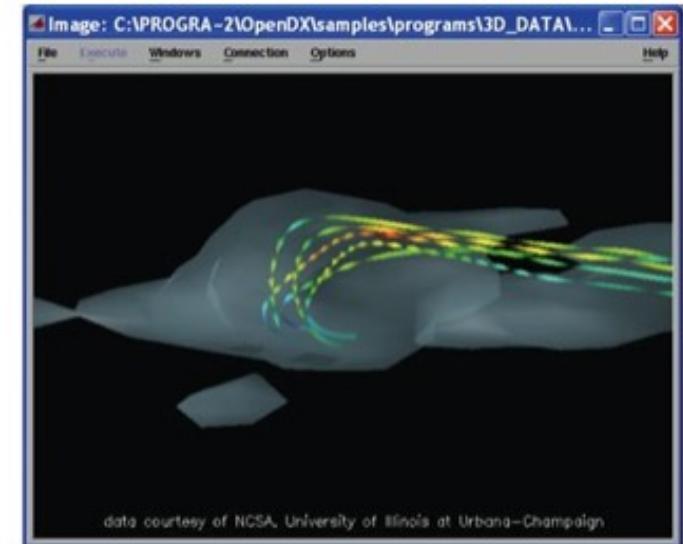
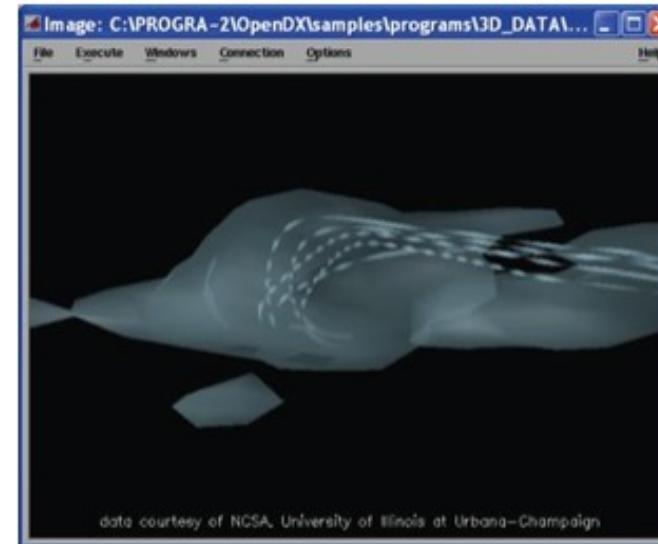
756**3**9506847**3**  
65866**3**037576  
860**3**72658602  
8465891078**3**0

# Pre-attentive Attributes

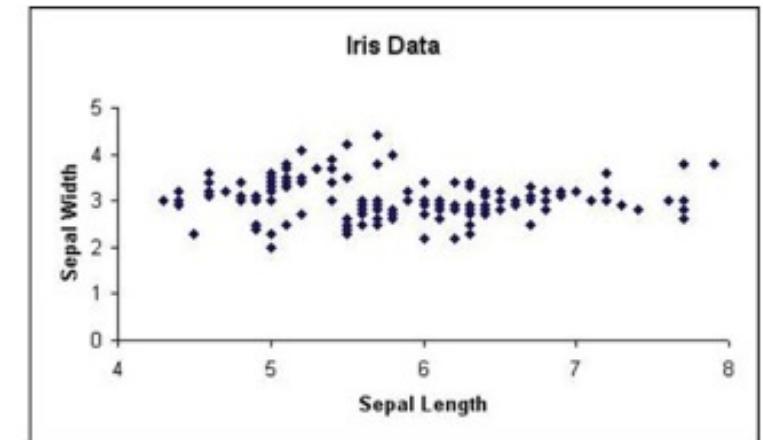
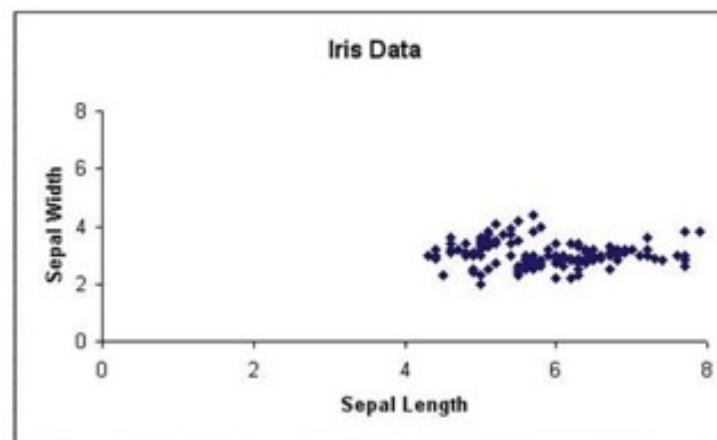


# Visualization Aesthetics [Ward 14]

**Focus:** draw attention to the parts that are important

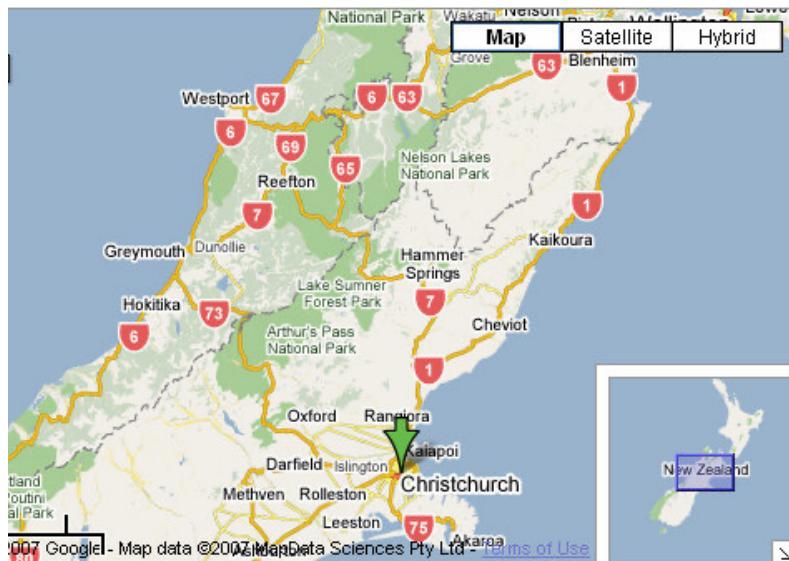


**Balance:** maximise use of screen space, with most important components center stage.

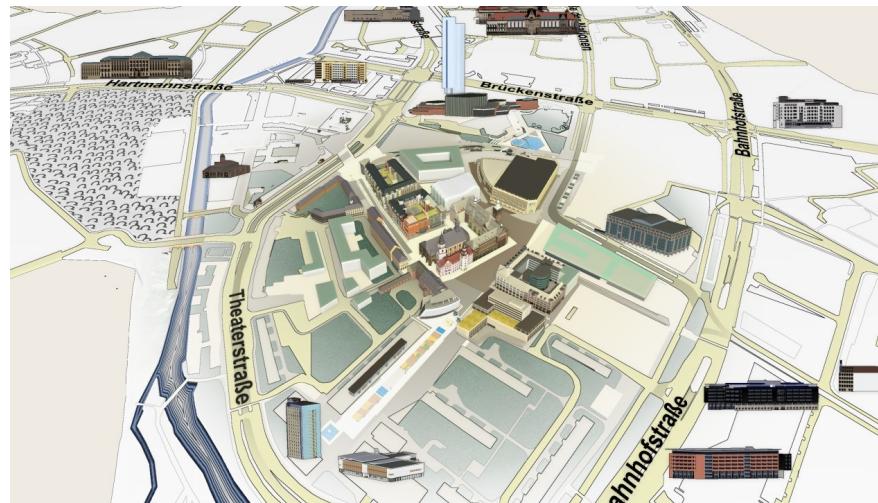


# Focus and Context

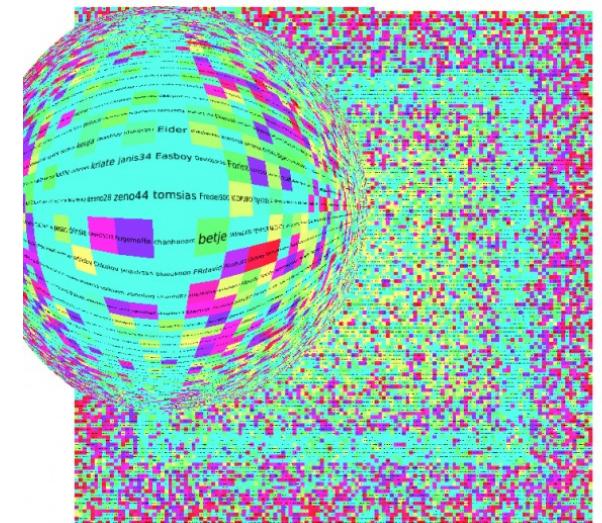
Embed detailed information about a selected subset of the data (the focus) within a single view that also contains overview information (the context)



Superimposition



Elision



Distortion

NOTE: These comprise some degree of “distortion” (see previous lecture) so care needs to be taken that user doesn’t misread the data. However, these idioms are a form “information scent”, in interactive visualizations where changes are transient/temporary.

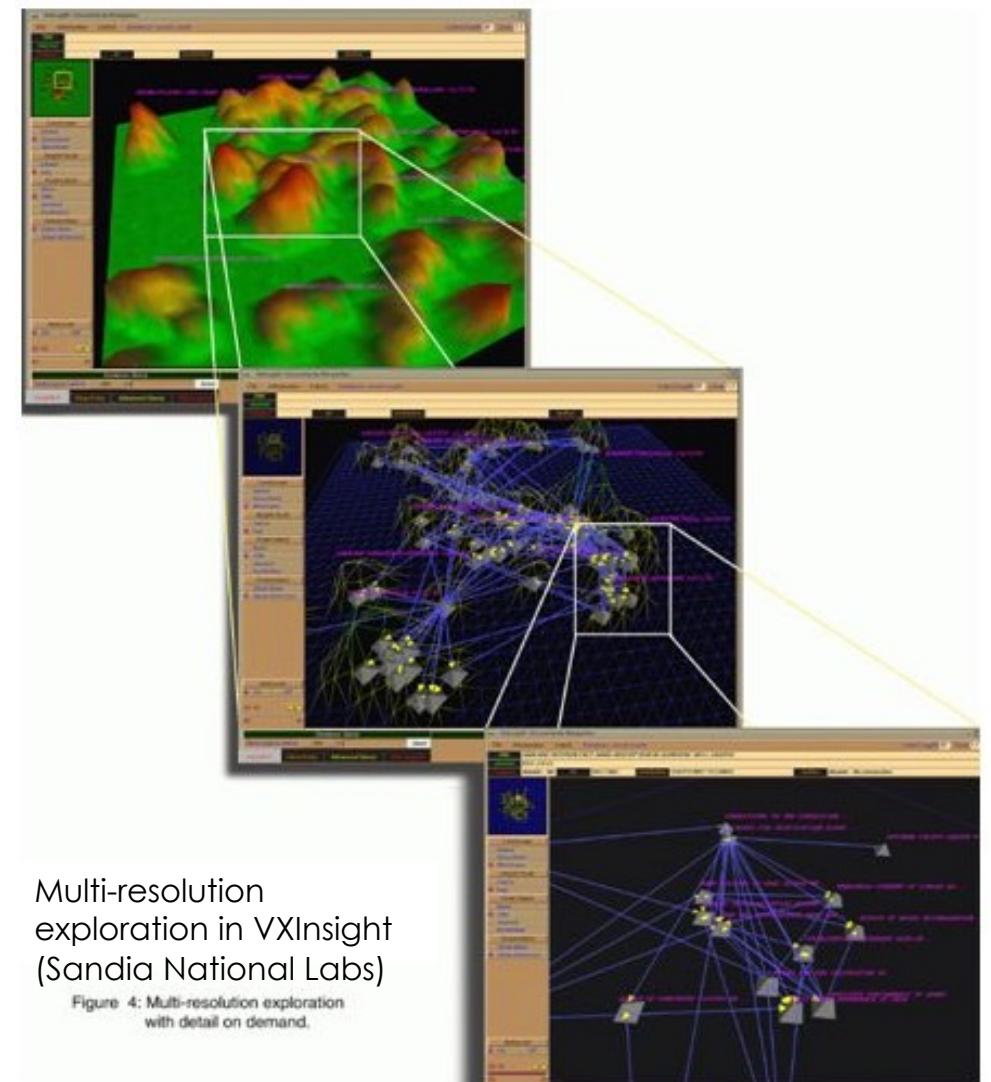
# Overview + details on demand

Proposed strategy when dealing with large dataset

- ◆ Overview first, Zoom and filter, Details on Demand [Shneiderman 1996]
- ◆ Search, Show context, Expand on Demand [van Ham & Perer 2009]

Balance between need for high-level summary and low-level detail

- ◆ **Overview:** provides broad awareness of entire information space; show full dataset without navigations; requires summarization or reduction
- ◆ **Adaptive detail-view:** allows drill-down in areas of interest detail-view



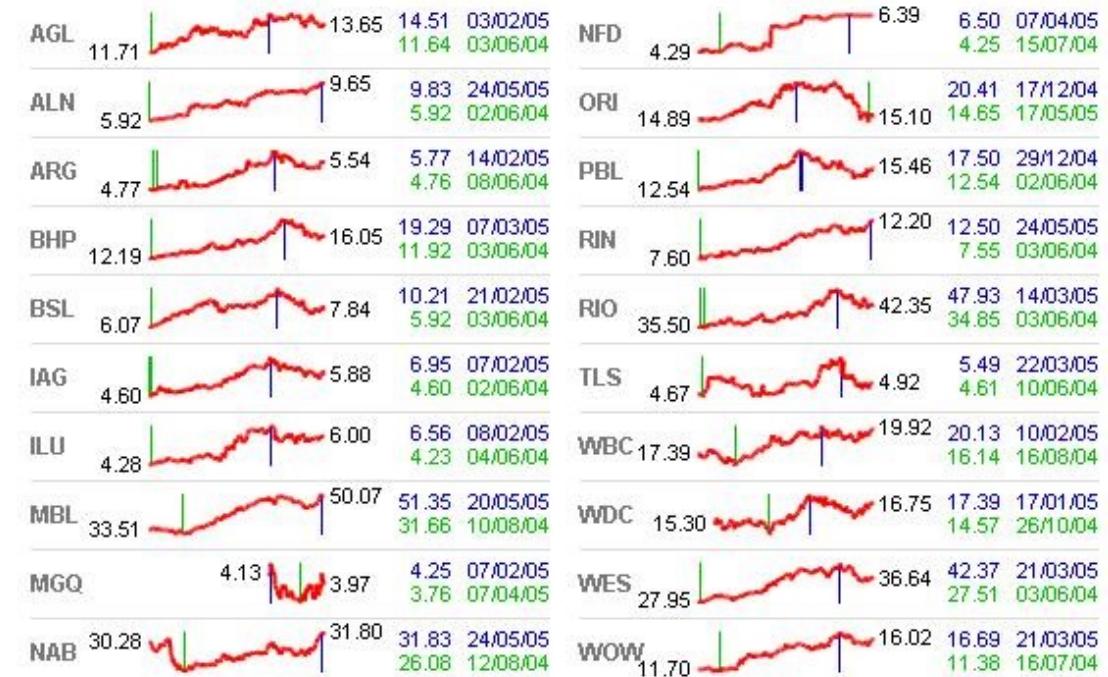
# Maximize Data Density

*Data density*

$$= \frac{\text{number of entries in data matrix}}{\text{area of data graphic}}$$

[Tufte 83]

- ◆ As the volume of data increases, data measures must shrink.
- ◆ Maximize data density and the size of the data matrix ....within reason.
  - ❖ put as much as necessary to communicate your point but don't overwhelm

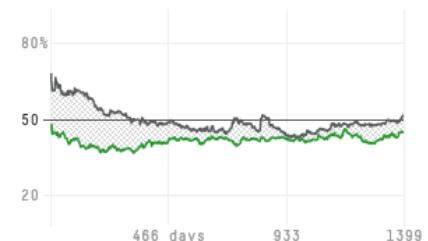


# Small Multiples

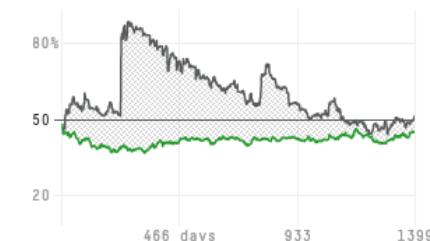
High-quality information graphics portray many numbers per square inch.

Small multiple, comparative images work especially well for this.

Barack Obama 2009-17



George W. Bush 2001-09



Bill Clinton 1993-2001



George H.W. Bush 1989-93



Ronald Reagan 1981-89



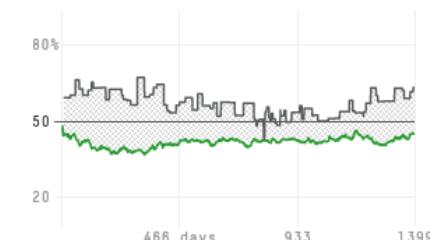
Jimmy Carter 1977-81



Gerald Ford 1974-77



Richard Nixon 1969-74



Lyndon B. Johnson 1963-69

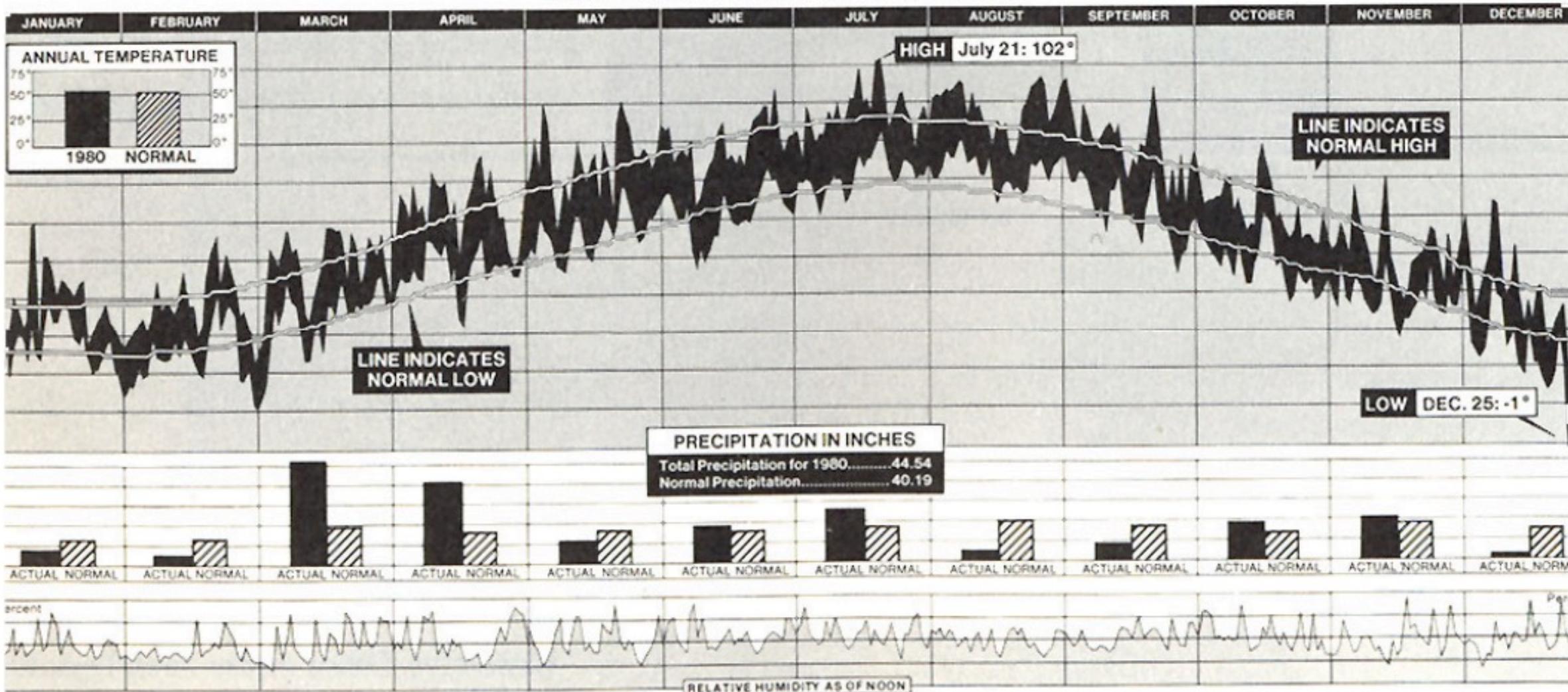


How Trump compares with past presidents.

Approval ratings © FiveThirtyEight

# Heterogeneous Parallelism

Isomorphism and visual juxtapositions reveal connections



New York Weather History 1980 (from Tufte 1983) / Data Density : 181 Numbers/sq Inch

# Complexity in Exploratory Visualization

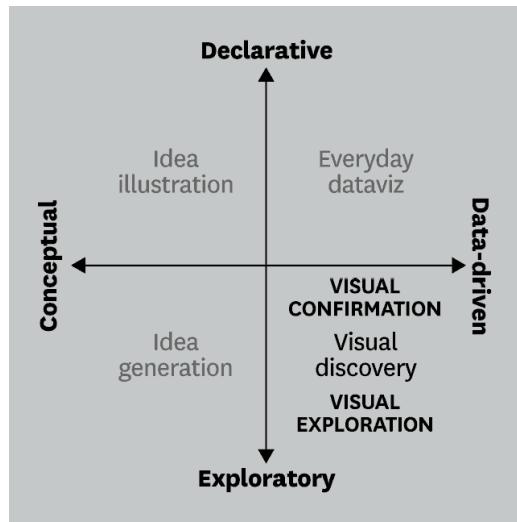


Image © omnisci.com

- ◆ Open-ended : don't know what we're looking for, typically quite complex (multiple data sets, dynamic/real-time)
- ◆ Tend to plot more inclusively
- ◆ Benefits from interactivity, continual iteration
- ◆ More about function than aesthetics



Berinato (2016). Visualizations that really Work. Harvard business review.  
<https://hbr.org/2016/06/visualizations-that-really-work>

# Dashboard Design

- ◆ Avoid trying to support every single user. Define the exact purpose and do not overload without reason.
- ◆ Pre-plan (storyboarding). Iterate design based on user feedback
- ◆ Use appropriate idioms/encodings: don't vary components for the sake of it
- ◆ Try to leverage established conventions or limit number of new mappings (e.g. use consistent color maps/scales where possible)
- ◆ Don't show too much granular detail on first view: show higher level or most important data first and let users drill down
- ◆ Avoid displaying too many alerts. Limit number of colors where possible

More on this later

Some further light reading on this:

<https://www.idashboards.com/blog/2018/09/05/the-ultimate-guide-to-storyboarding/>

<https://www.octoboard.com/blog/top-8-mistakes-creating-data-dashboard/>

<https://visualbi.com/blogs/business-intelligence/dashboards/10-common-mistakes-avoid-creating-effective-dashboards/>

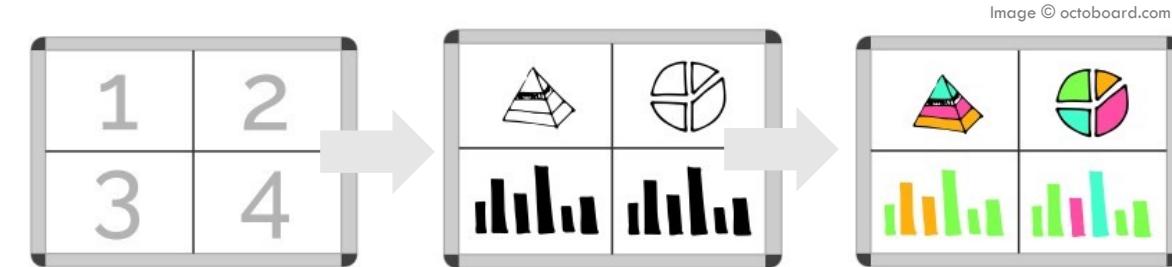


Image © octoboard.com



Image © www.idashboards.com

# Static vs Dynamic Approach



literal  
animation  
show facets with time

abstract  
parallelism  
show facets with space



## Eyes beat memory [Munzner 14] External cognition vs. internal memory mapping

- ◆ easy to compare by moving eyes between side-by-side views
- ◆ harder to compare visible item to memory of what you saw

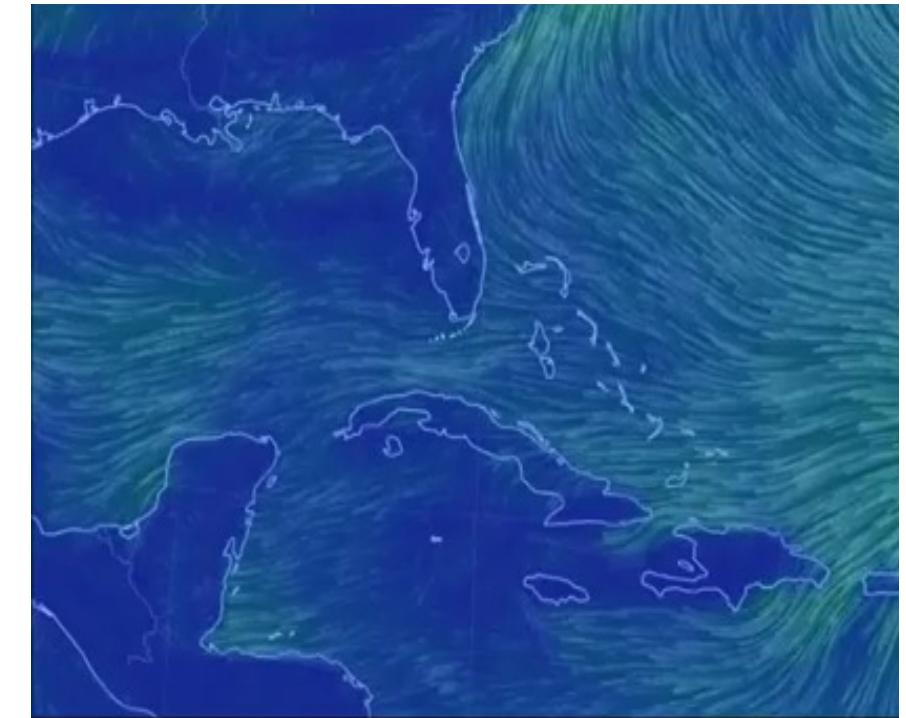
## Implications for animation

- ◆ good for choreographed storytelling
- ◆ good for transitions between two states
- ◆ poor for many states with changes everywhere : consider small multiples instead

# Visual Complexity During Animation/Interaction

Even more important in Dynamic Visualizations

- ◆ Extraneous content obscures the message and complicates extraction of knowledge
- ◆ Reader has finite brainpower to dedicate to the problem



- ◆ Need to facilitate understanding by minimizing amount of Extraneous search/decoding needed

# Change Blindness



If attention is directed elsewhere,  
even drastic changes not noticeable

Every few seconds the image will  
flash. Can you say what else is  
changing in the picture?)

© J.K. O'Regan, R.A. Rensink & J.J. Clark

# Change Blindness



© J.K. O'Regan, R.A. Rensink & J.J. Clark

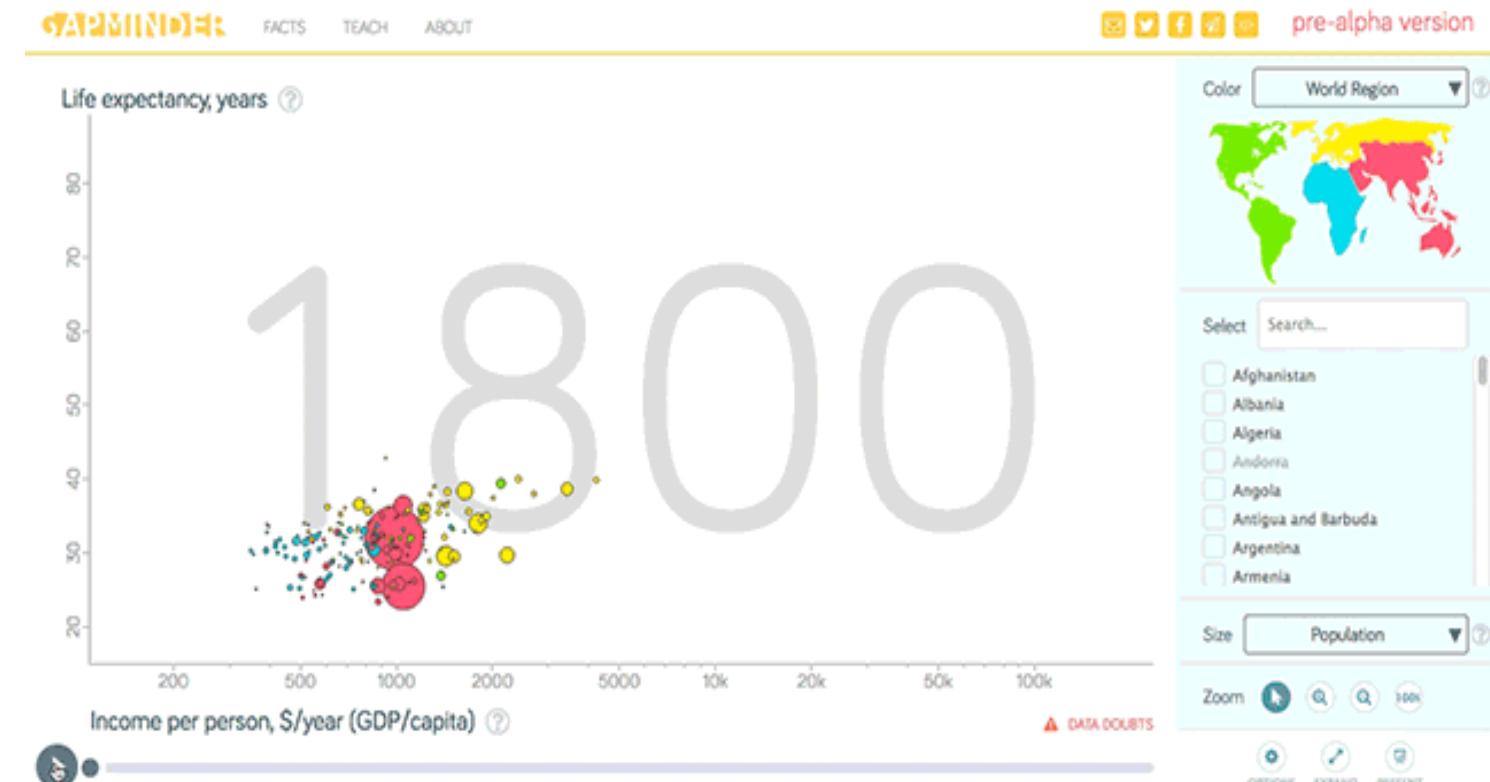
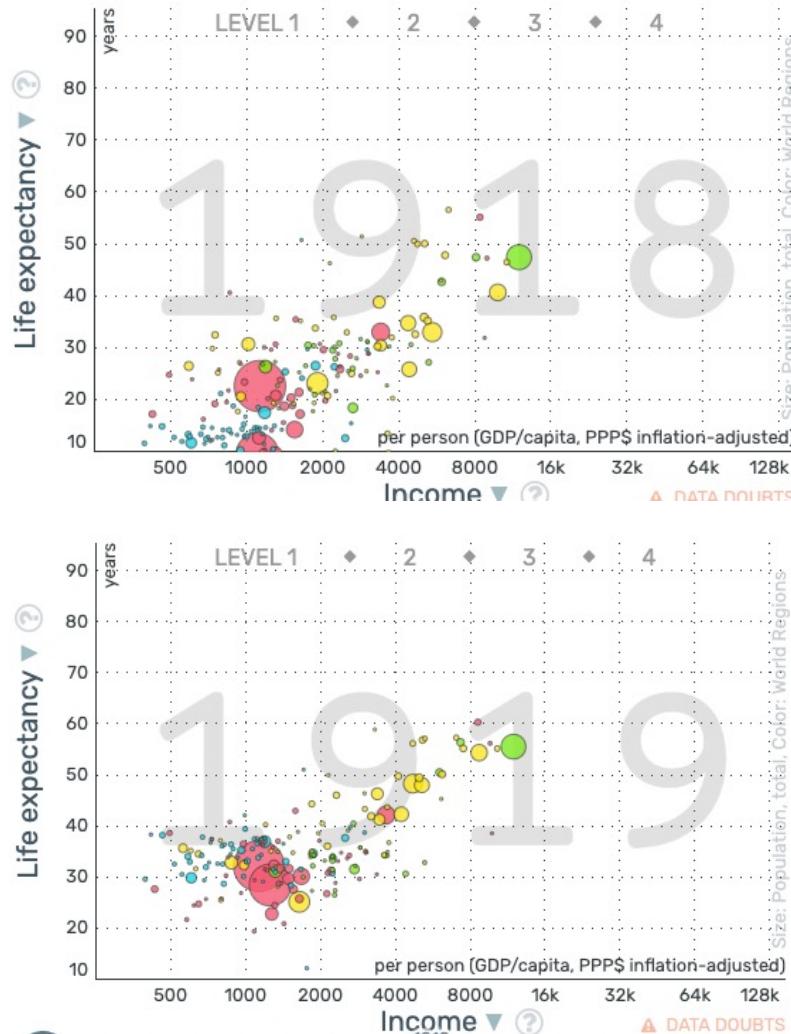
If attention is directed elsewhere,  
even drastic changes not noticeable

- ◀ Every few seconds the image will flash. Can you say what else is changing in the picture?)

More examples at:

[http://nivea.psych.univ-paris5.fr/Mudsplash/Nature\\_Supp\\_Inf/Movies/Movie\\_List.html](http://nivea.psych.univ-paris5.fr/Mudsplash/Nature_Supp_Inf/Movies/Movie_List.html)

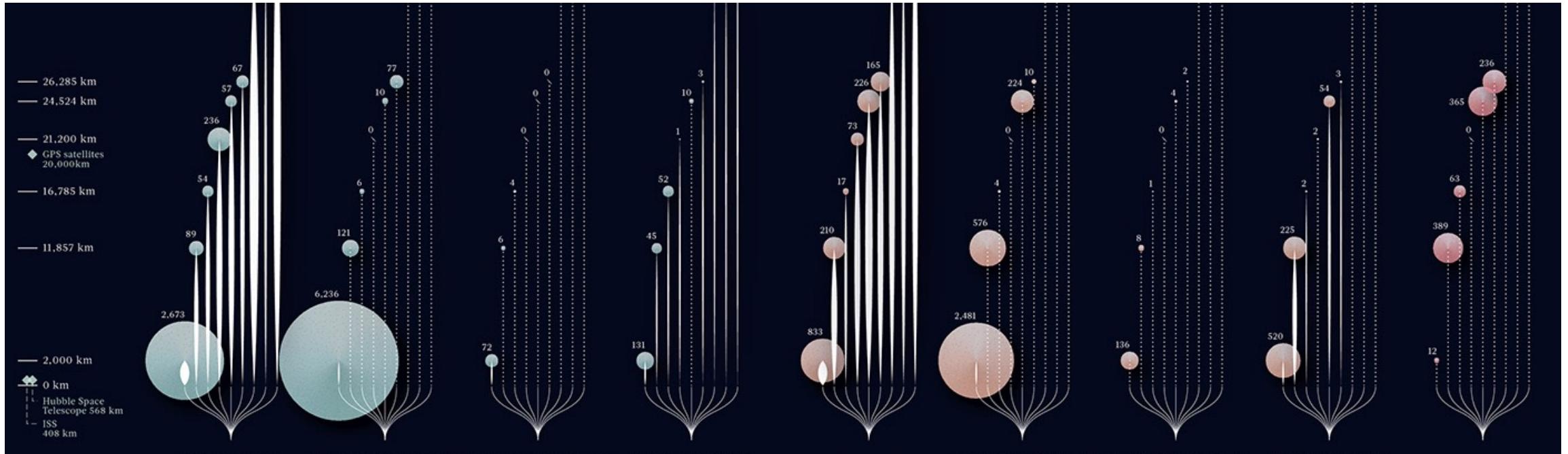
# Connections With Motion



Images © gapminder. <https://www.gapminder.org/>

# Sample Visualization Analysis

- ◆ Reminder: A3 due on 8<sup>th</sup> Nov (Extended Deadline)
- ◆ Second sample analysis provided tomorrow. But, in advance of this, try to have a look at the following visualization and think of how you'd analyse it with respect to task/data/encodings.



Space Junk (Federica Fragapane) : <https://www.behance.net/gallery/81688575/Space-Junk-BBC-Science-Focus>

# Recommended reading

“Designing Data Visualizations” by N. Iliinsky & J. Steele. O'Reilly Press. 2011.

- ◆ Free excerpt of Chapter 4 (Choose Appropriate Visual Encodings) here: <https://tinyurl.com/illinskysteel4>

The Visual Display of Quantitative Information. Edward Tufte. 1983.

- ◆ Externally hosted PDF Excerpt here: <https://tinyurl.com/uhaxq7k>
  - ◆ In particular read: Ch 1: “Graphical Excellence” and Ch 2: “Graphical Integrity”
- 

Chapter 6 “Rules of Thumb” in Visualization Analysis and Design. Munzner (2014)

Chapter 13 “Designing Effective Visualizations” in Interactive Data Visualization. Ward et al (2015)

Cole Nussbaumer Knaflic. “Storytelling with Data: A Data Visualization Guide for Business Professionals”. Wiley & Sons. 2015.

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Interesting webinar by Frederica Fragapane on the process of designing explanatory visualizations (2020):

- ◆ <https://www.youtube.com/watch?v=NlkEuAXFjyo>