Data Visualization (CSCI 627/490)

Tasks & Design

Dr. David Koop

Data

- What is this data?

R011	42ND STREET & 8TH AVENUE	00228985	00008471	00000441	00001455	00000134	00033341	00071255
R170	14TH STREET-UNION SQUARE	00224603	00011051	00000827	00003026	00000660	00089367	00199841
R046	42ND STREET & GRAND CENTRAL	00207758	00007908	00000323	00001183	00003001	00040759	00096613

- **Semantics**: real-world meaning of the data
- **Type**: structural or mathematical interpretation
- Both often require **metadata**
  - Sometimes we can infer some of this information
  - Line between data and metadata isn't always clear

Data Terminology

- Item (also Nodes): an entity
- Link: relationship between two items
- Attribute: property of an item
- Position: location in space
- Grid: how data is sampled

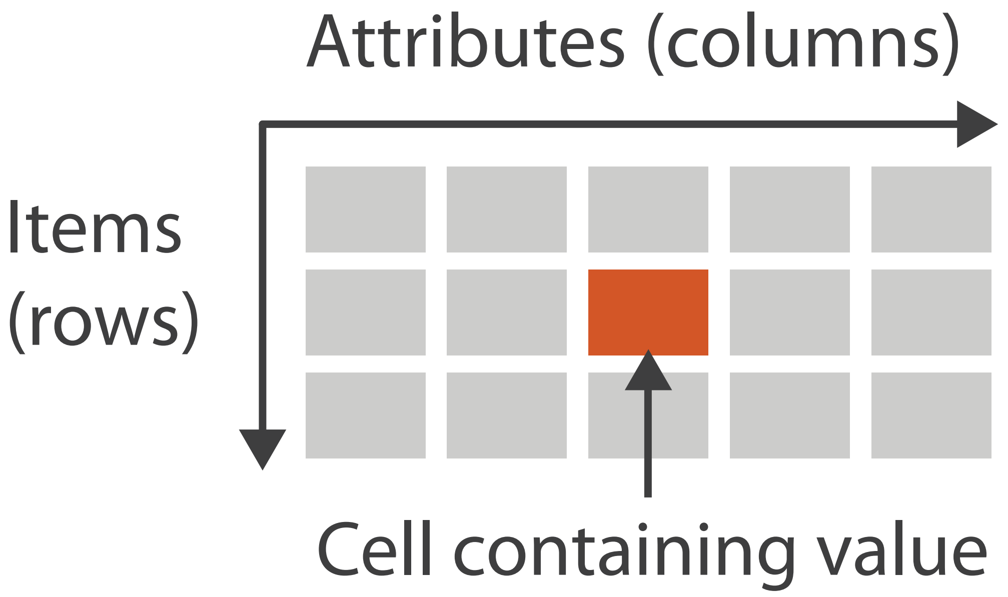
attribute

item

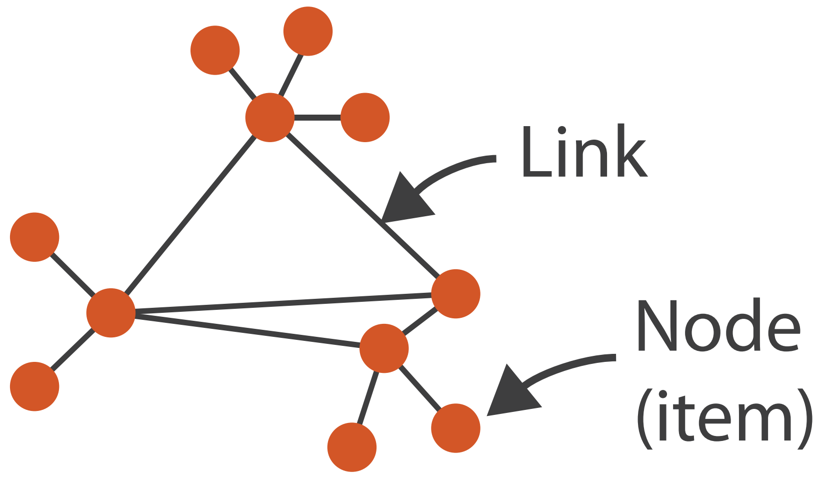
B	C	S	T	
Order Date	Order Priority	Product Container	Product Base Margin	Ship Da
10/14/06	5-Low	Large Box	0.8	1
2/21/08	4-Not Specified	Small Pack	0.55	
7/16/07	2-High	Small Pack	0.79	
7/16/07	2-High	Jumbo Box	[illegible]	
7/16/07	2-High	Medium Box	[illegible]	
7/16/07	2-High	Medium Box	[illegible]	
10/23/07	4-Not Specified	Wrap Bag	0.52	1
10/23/07	4-Not Specified	Small Box	0.58	1
11/3/07	1-Urgent	Small Box	0.55	
3/18/07	1-Urgent	Small Pack	0.49	
[illegible]	5-Low	Wrap Bag	0.56	
[illegible]	4-Not Specified	Small Pack	0.44	
[illegible]	4-Not Specified	Wrap Bag	0.6	
12/18/06	5-Low	Small Box	0.59	1
12/18/06	5-Low	Wrap Bag	0.82	1
4/17/05	2-High	Small Box	0.55	
1/29/06	3-Medium	Small Box	0.38	
11/19/08	5-Low	Small Box	0.37	1
5/8/08	2-High	Small Box	0.37	
5/8/08	2-High	Medium Box	0.38	
5/8/08	2-High	Small Box	0.6	
6/11/06	3-Medium	Medium Box	0.6	
6/11/06	3-Medium	Jumbo Box	0.69	
5/1/08	4-Not Specified	Large Box	0.82	
10/21/07	4-Not Specified	Small Pack	0.64	1
9/12/07	2-High	Small Box	0.55	
8/8/06	1-Urgent	Medium Box	0.57	
4/5/08	3-Medium	Wrap Bag	0.42	

Dataset Types

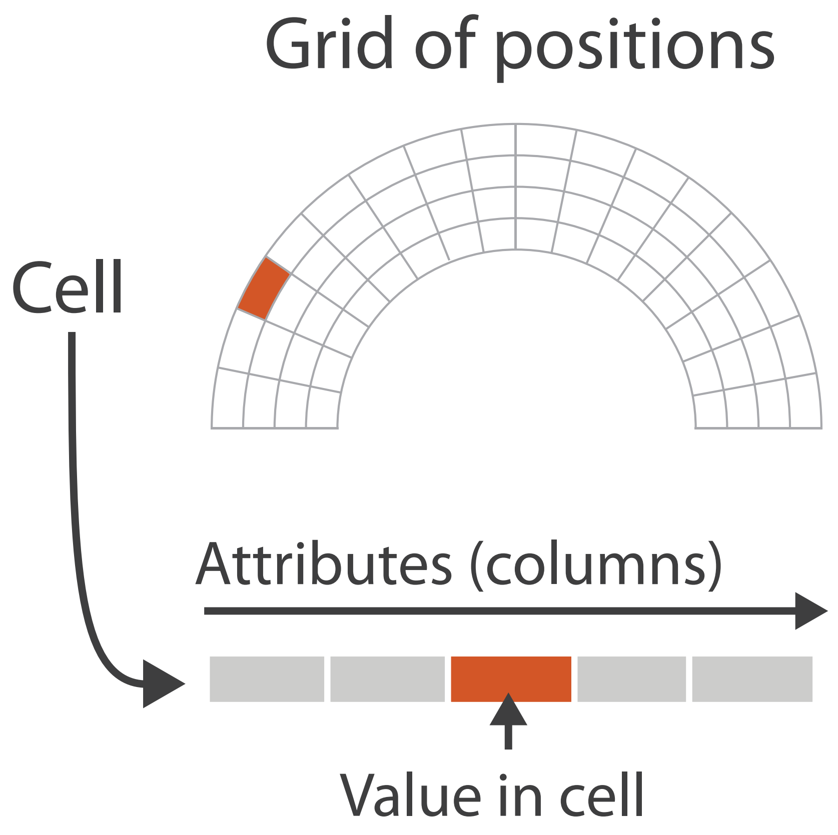
- ➔ Tables



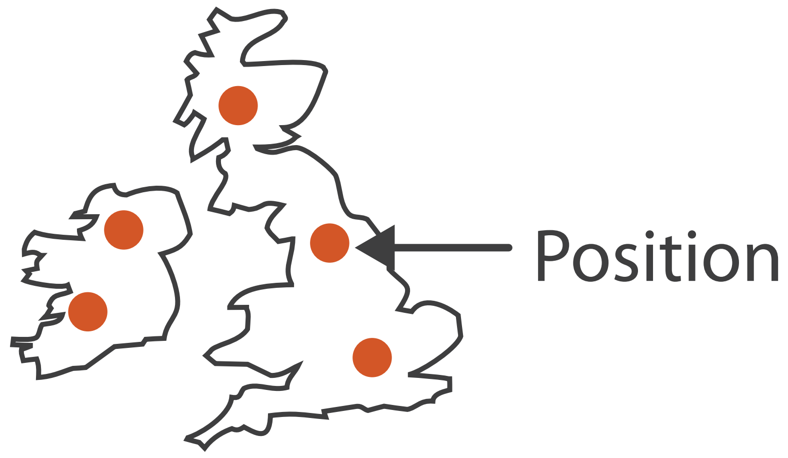
- ➔ Networks



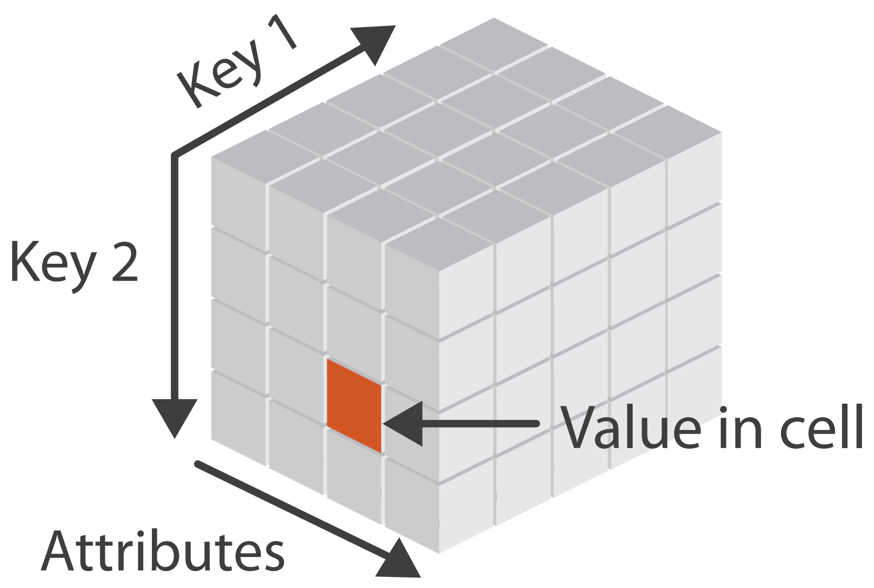
- ➔ Fields (Continuous)



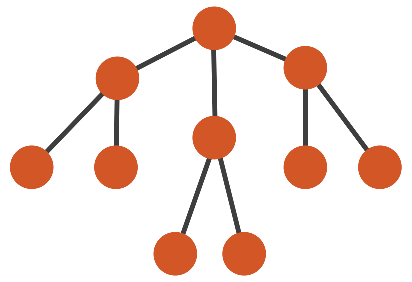
- ➔ Geometry (Spatial)



- ➔ *Multidimensional Table*

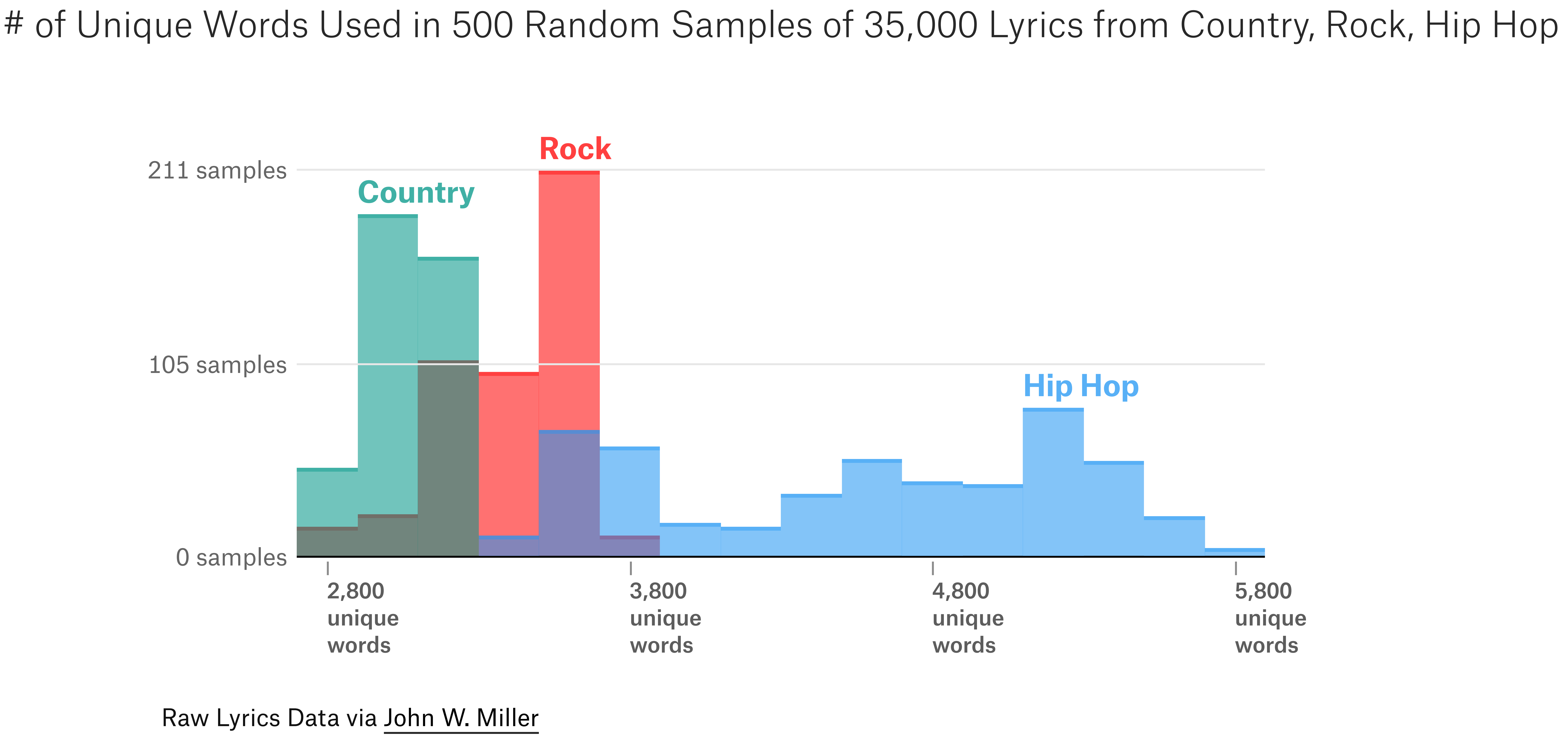


- ➔ *Trees*



[Munzner (ill. Maguire), 2014]

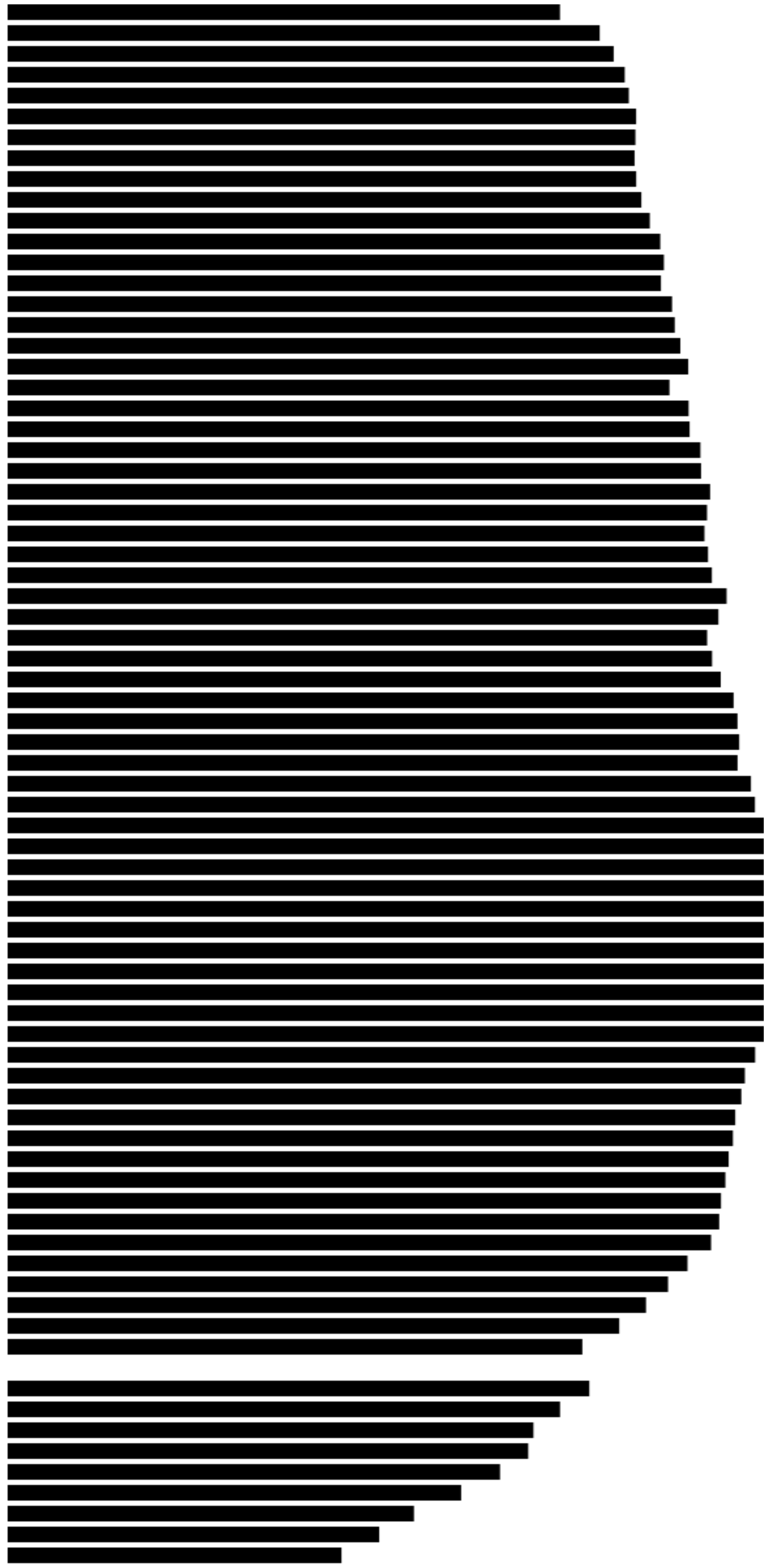
Sets & Lists



[M. Daniels, 2019]

Assignment 2

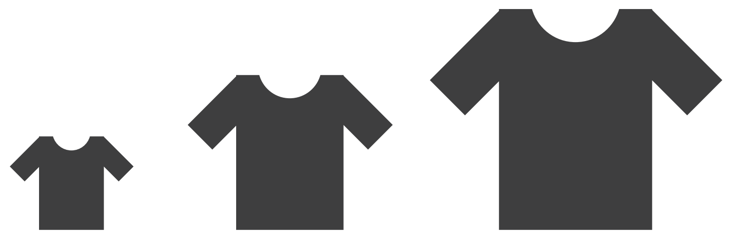
- Process Data
- Create Bar Charts using SVGs and JavaScript
- Add Interaction



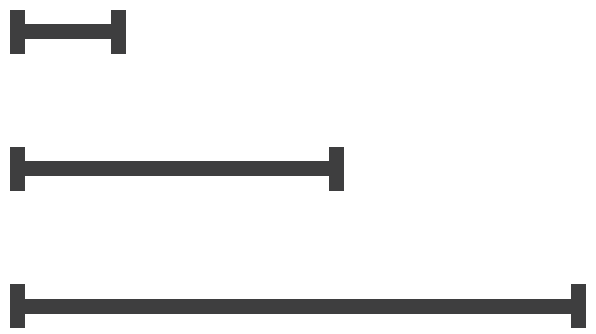
Attribute Types

- ➔ Categorical

- ➔ Ordered
  - ➔ *Ordinal*



  - ➔ *Quantitative*



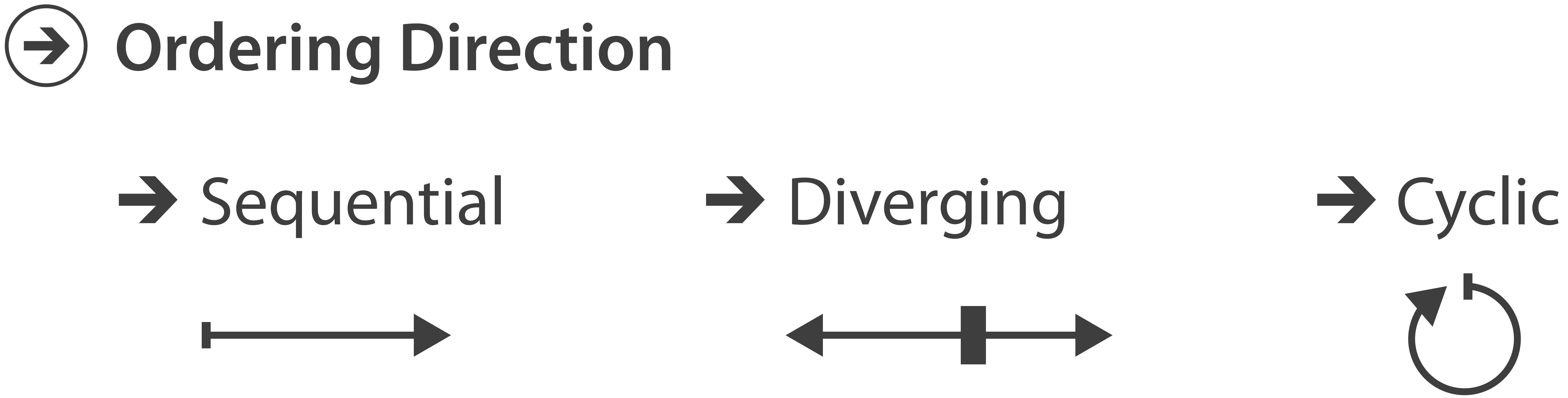
[Munzner (ill. Maguire), 2014]

Categorial, Ordinal, and Quantitative

A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	0.72	7/17/07
32	7/16/07	2-High	Medium Box	0.6	7/18/07
32	7/16/07	2-High	Medium Box	0.65	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	1/20/05	5-Low	Wrap Bag	0.56	1/20/05
69	6/4/05	4-Not Specified	Small Pack	0.44	6/6/05
69	6/4/05	4-Not Spec[illegible]	[illegible]	0.6	6/6/05
70	12/18/06	5-Low	[illegible]	0.59	12/23/06
70	12/18/06	5-Low	[illegible]	0.82	12/23/06
96	4/17/05	2-High	[illegible]	0.55	4/19/05
97	1/29/06	3-Medium	[illegible]	0.38	1/30/06
129	11/19/08	5-Low	[illegible]	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

quantitative
ordinal
categorical

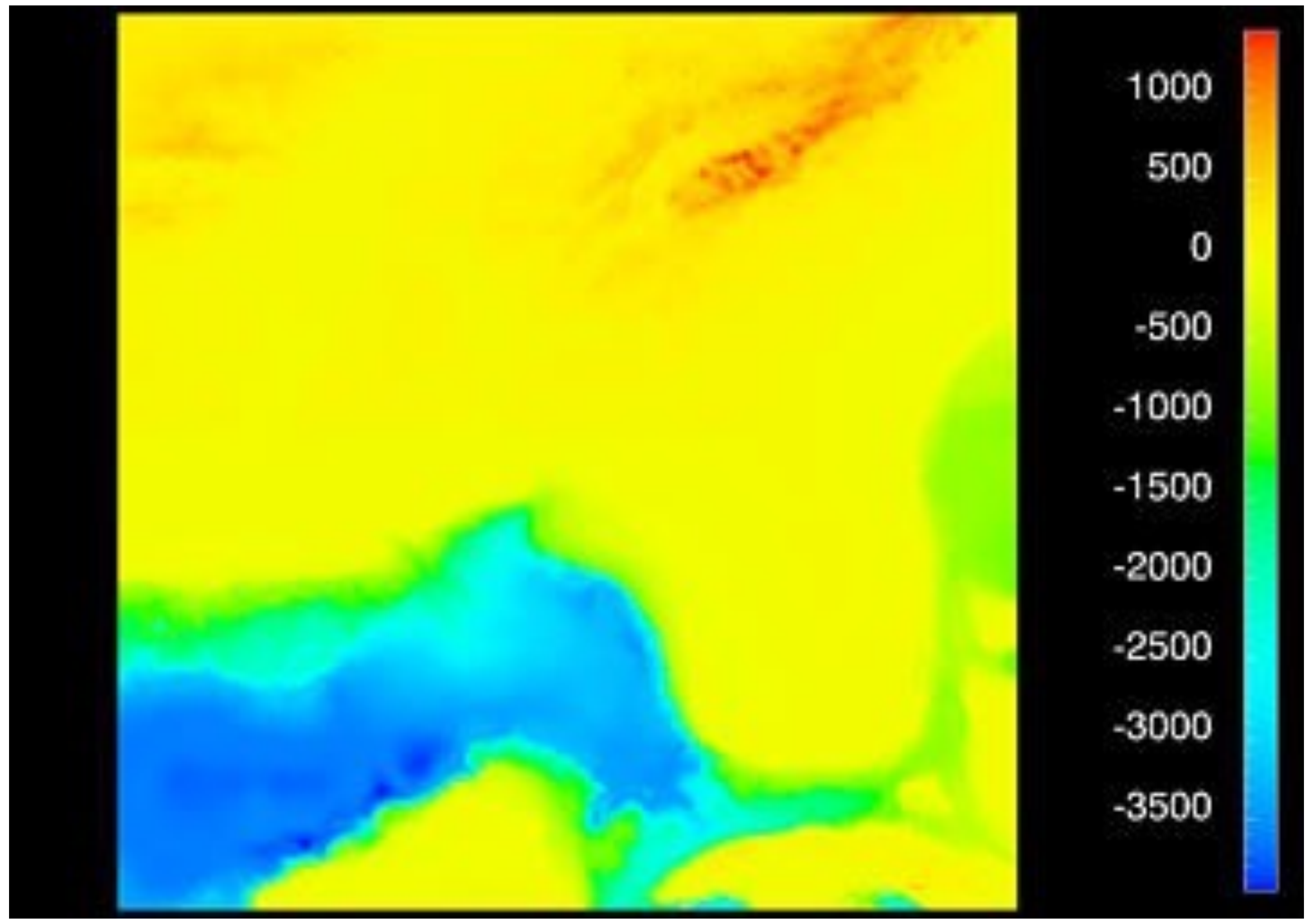
Ordering Direction

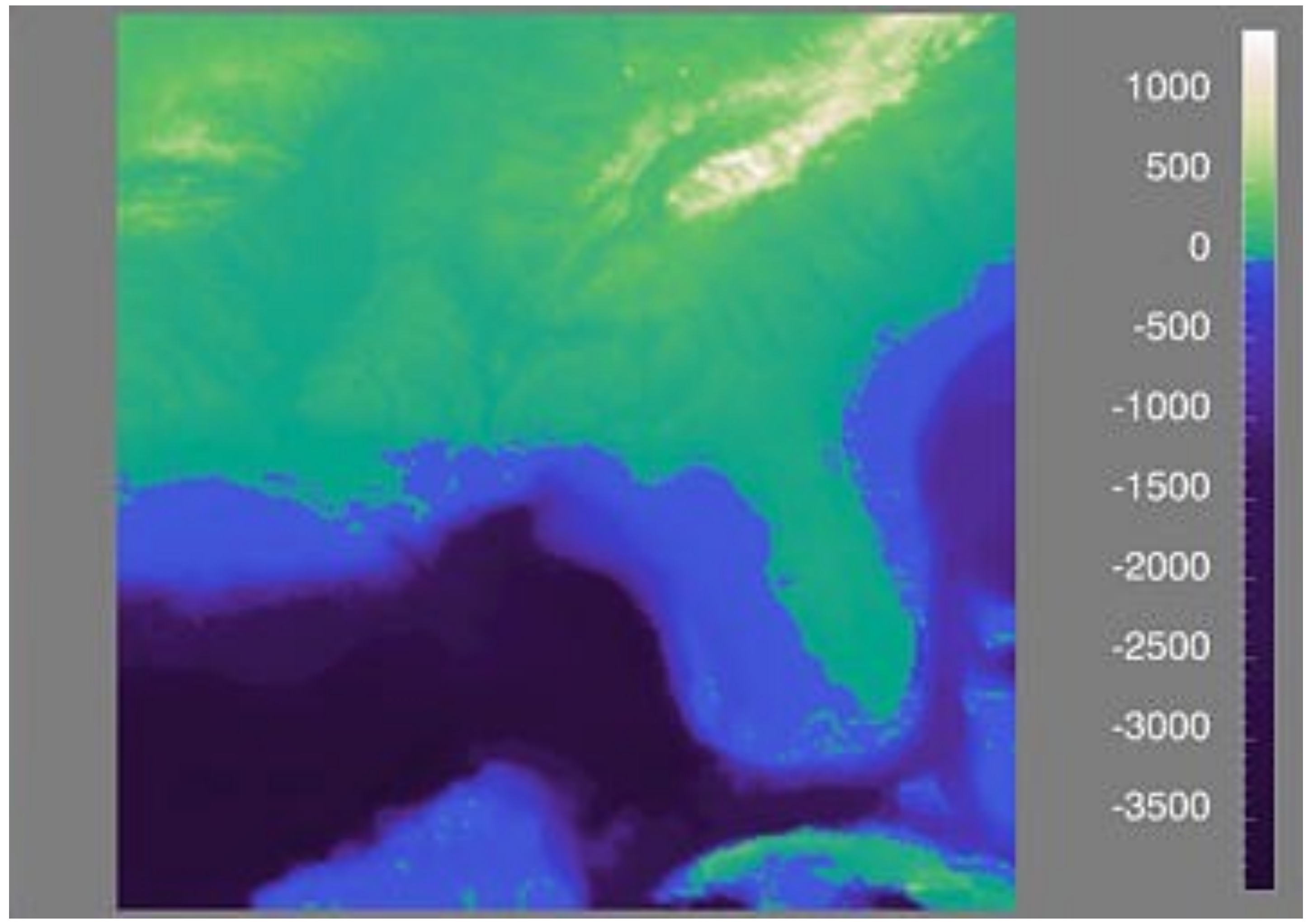


[Munzner (ill. Maguire), 2014]

Sequential and Diverging Data

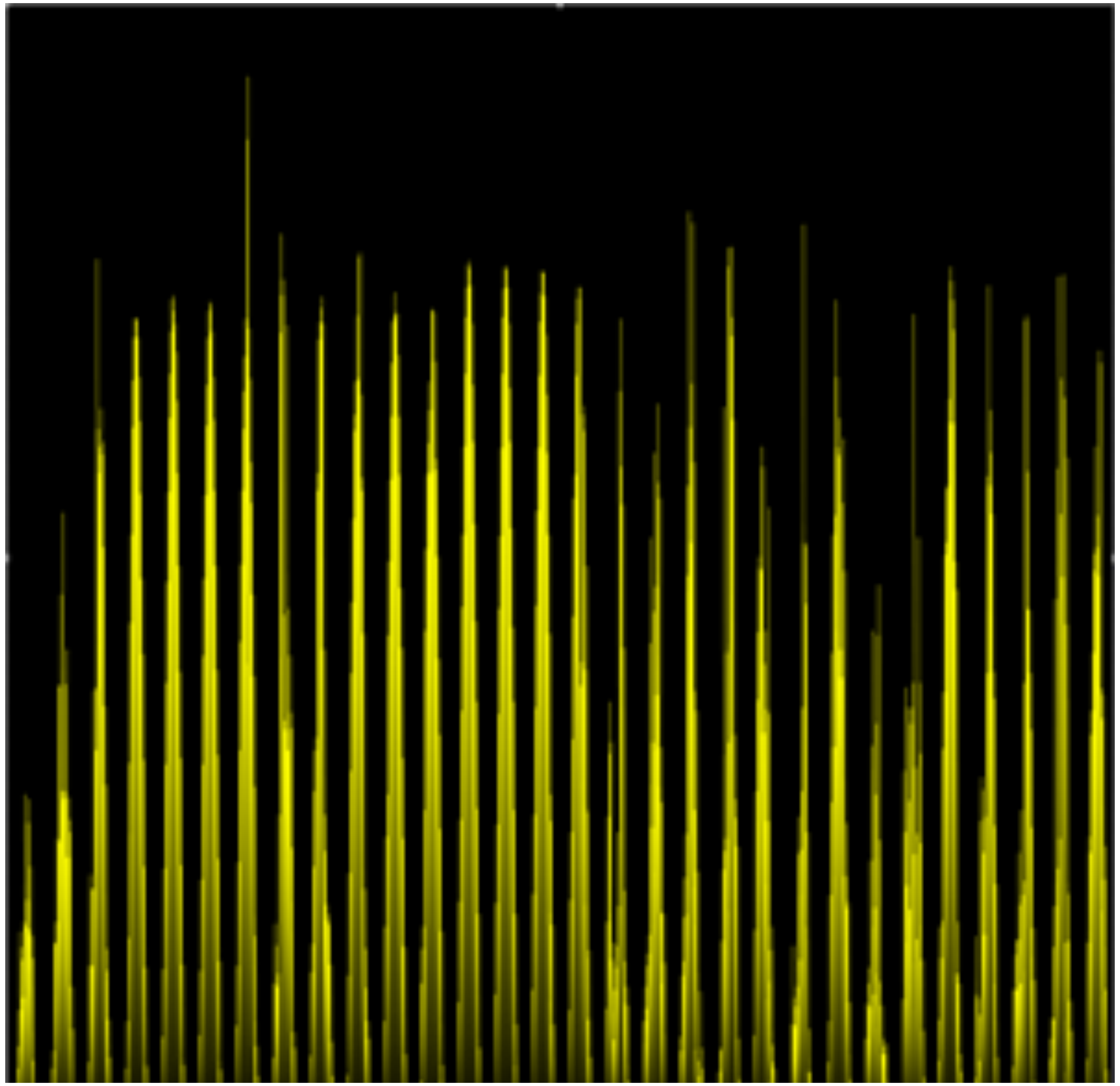
- Sequential: homogenous range from a minimum to a maximum
  - Examples: Land elevations, ocean depths
- Diverging: can be deconstructed into two sequences pointing in opposite directions
  - Has a **zero point** (not necessary 0)
  - Example: Map of both land elevation and ocean depth

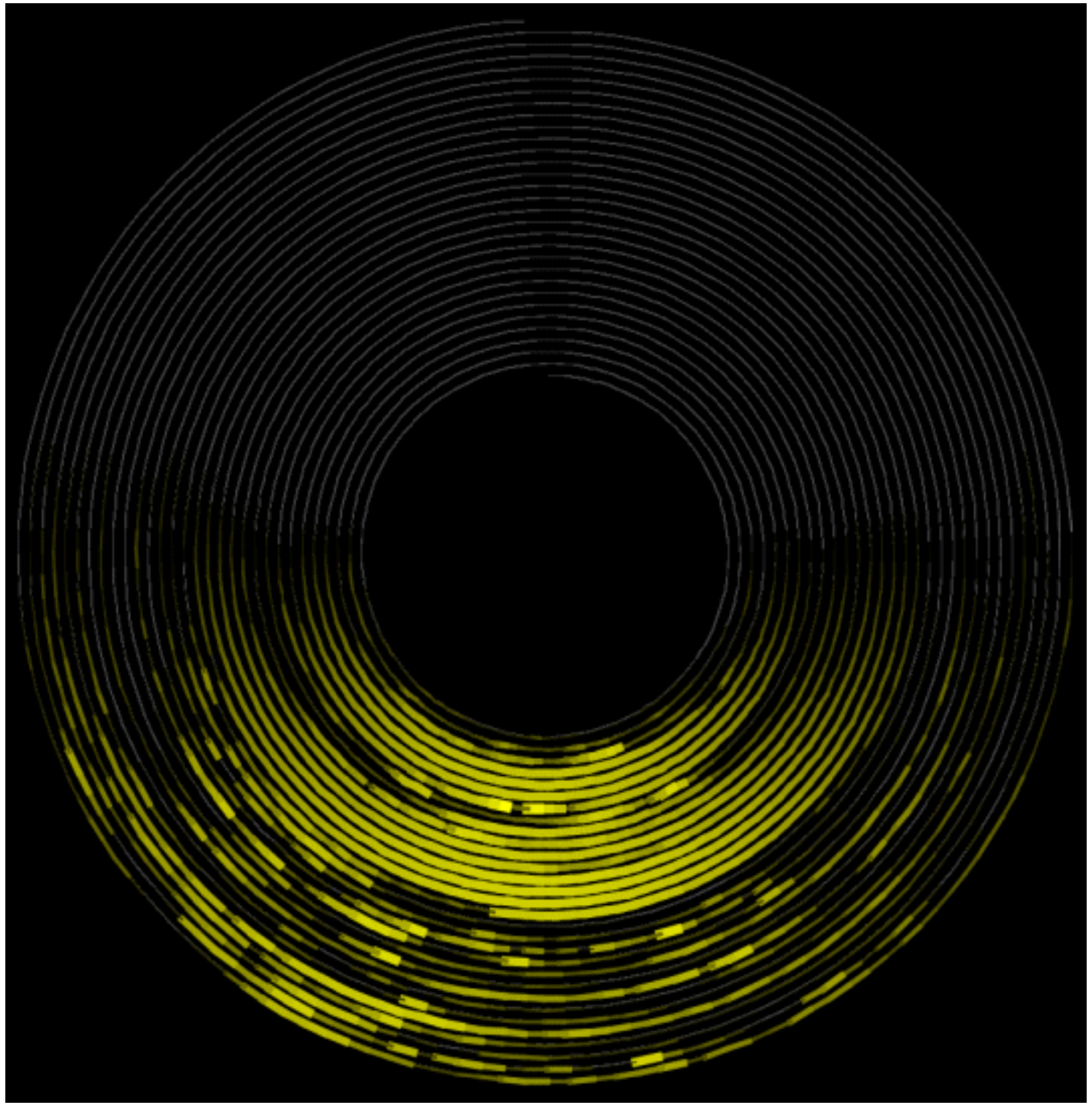




[Rogowitz & Treinish, 1998]

Cyclic Data





[Sunlight intensity, Weber et al., 2001]

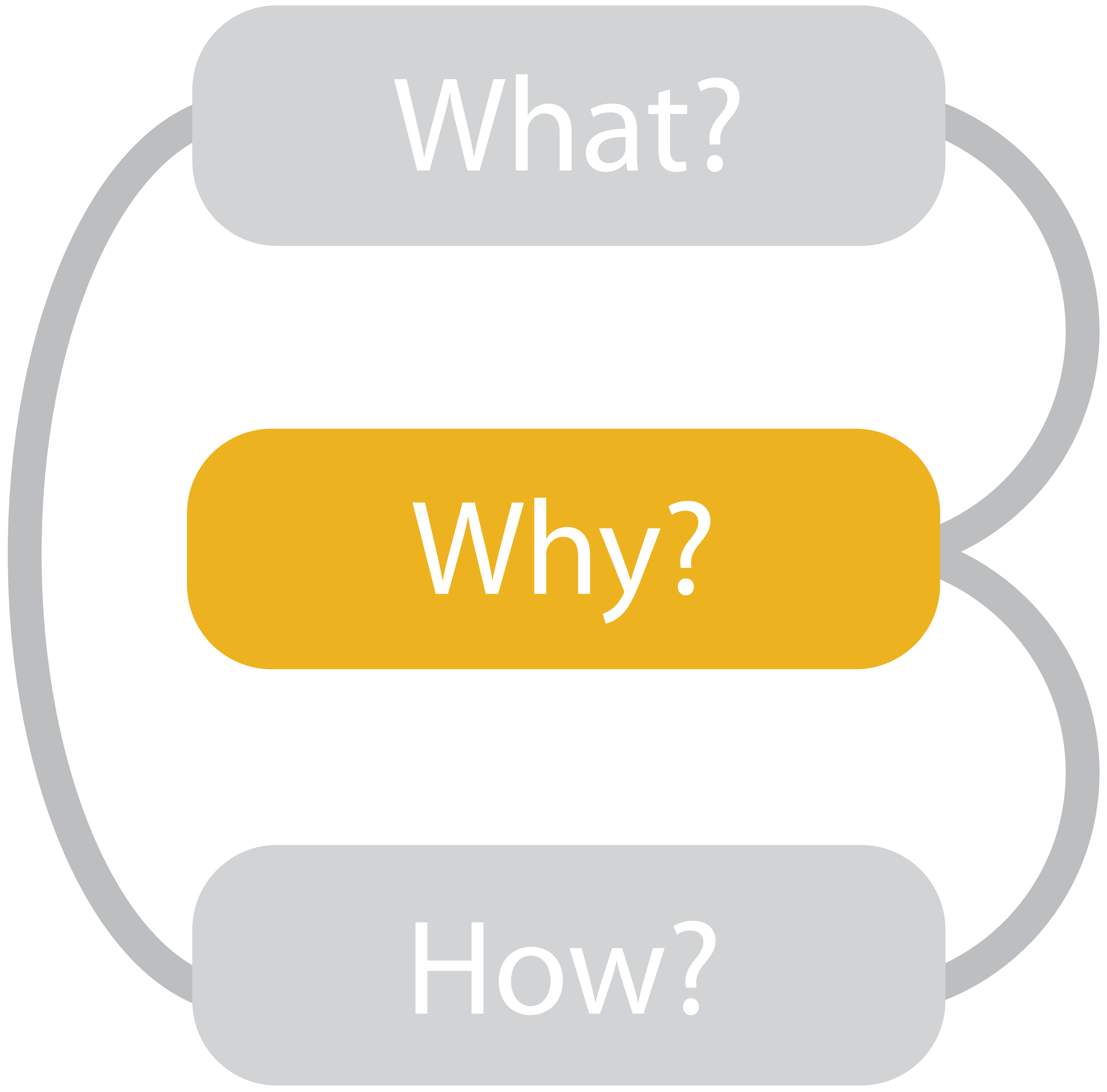
“Computer-based visualization systems provide visual representations of datasets designed to help people carry out **tasks** more effectively.”

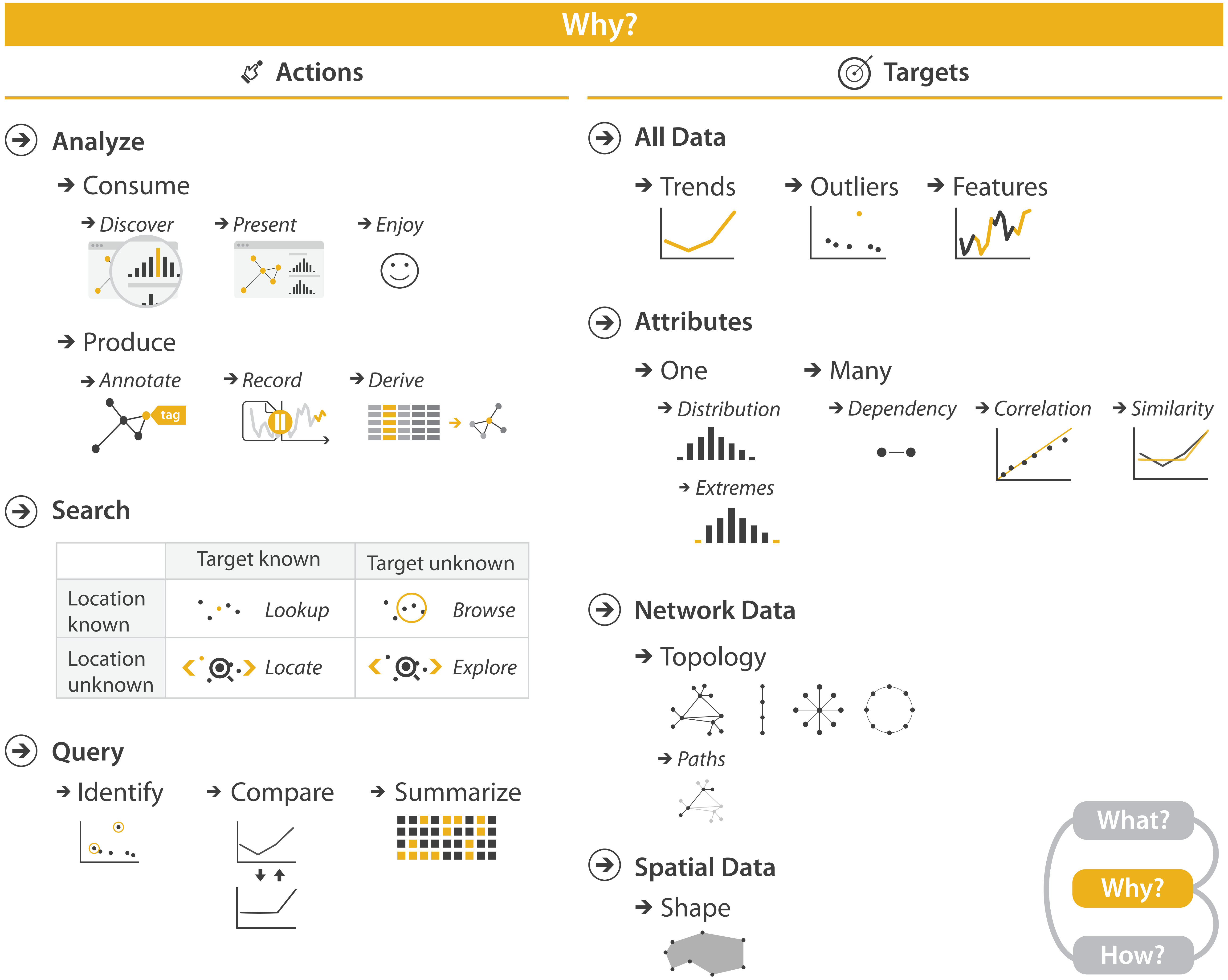
— T. Munzner

Tasks

- Why? Understand data, but what do I want to do with it?
- Levels: High (Produce/Consume), Mid (Search), Low (Queries)
- Another key concern: Who?
  - Designer <-> User (A spectrum)
  - Complex <-> Easy to Use
  - General <-> Context-Specific
  - Flexible <-> Constrained
  - Varied Data <-> Specific Data

Tasks





[Munzner (ill. Maguire), 2014]

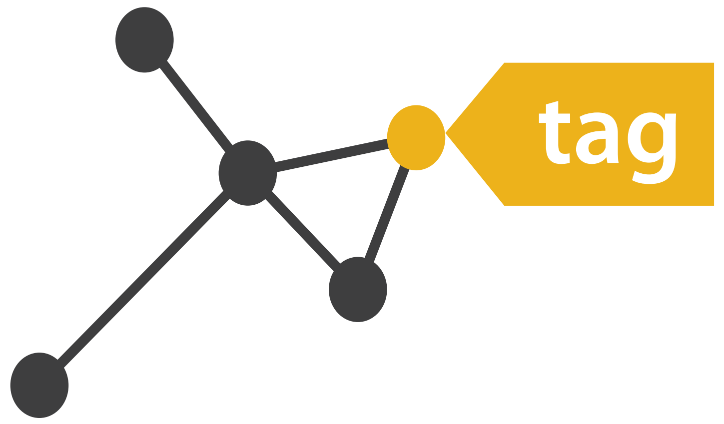
Actions: Analyze

- Consume
  - *Discover*

  - *Present*

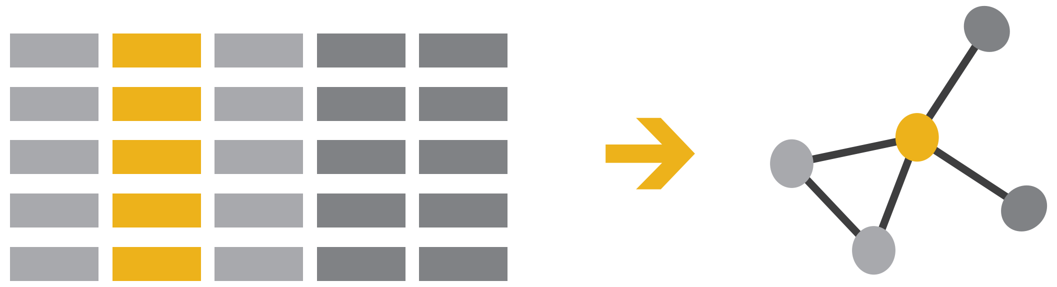
  - *Enjoy*

- Produce
  - *Annotate*



  - *Record*

  - *Derive*



[Munzner (ill. Maguire), 2014]

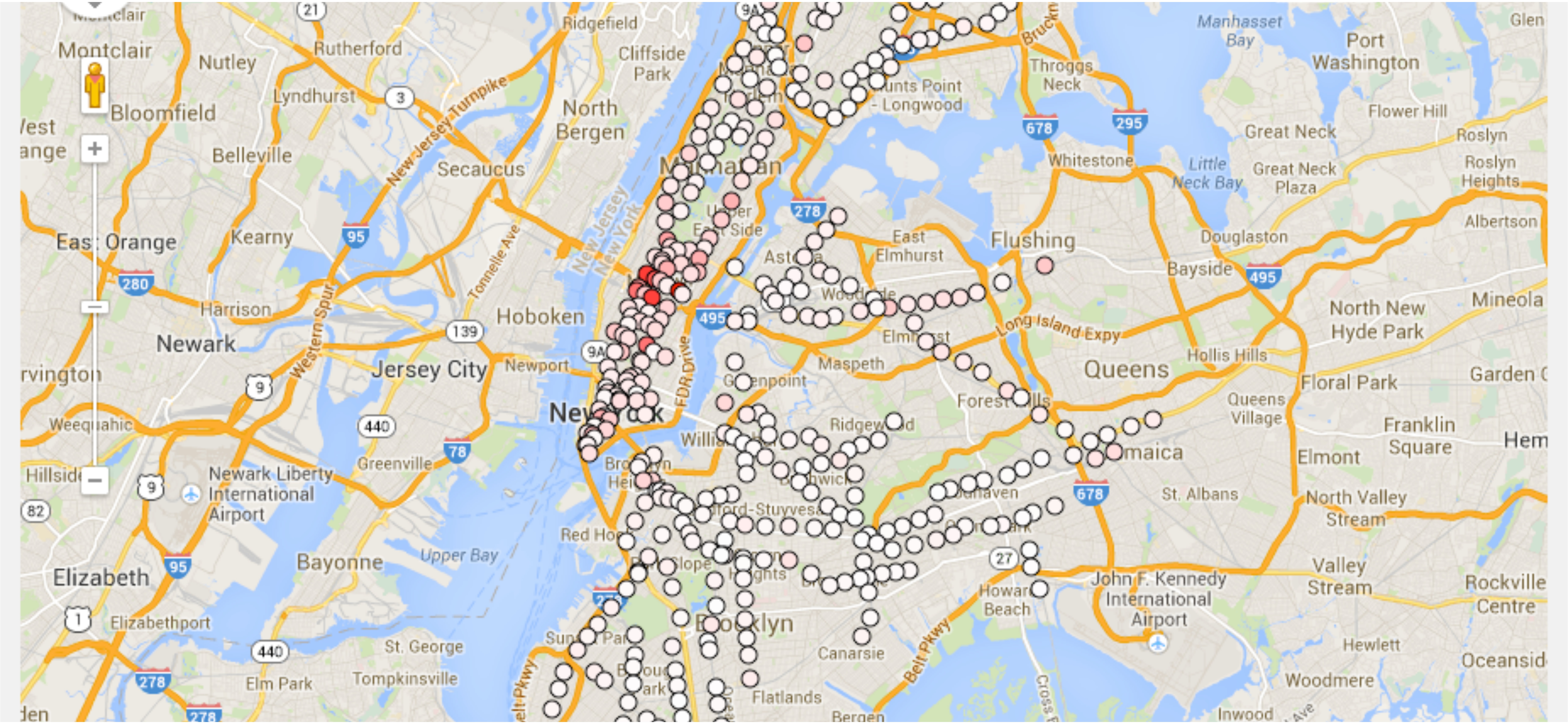
Visualization for Consumption

- Discover new knowledge
  - Generate new hypothesis or verify existing one
  - Designer doesn’t know what users need to see
  - "why doesn't dictate how"
- Present known information
  - Presenter already knows what the data says
  - Wants to communicate this to an audience
  - May be static but not limited to that
- Enjoy
  - Similar to discover, but without concrete goals
  - May be enjoyed differently than the original purpose

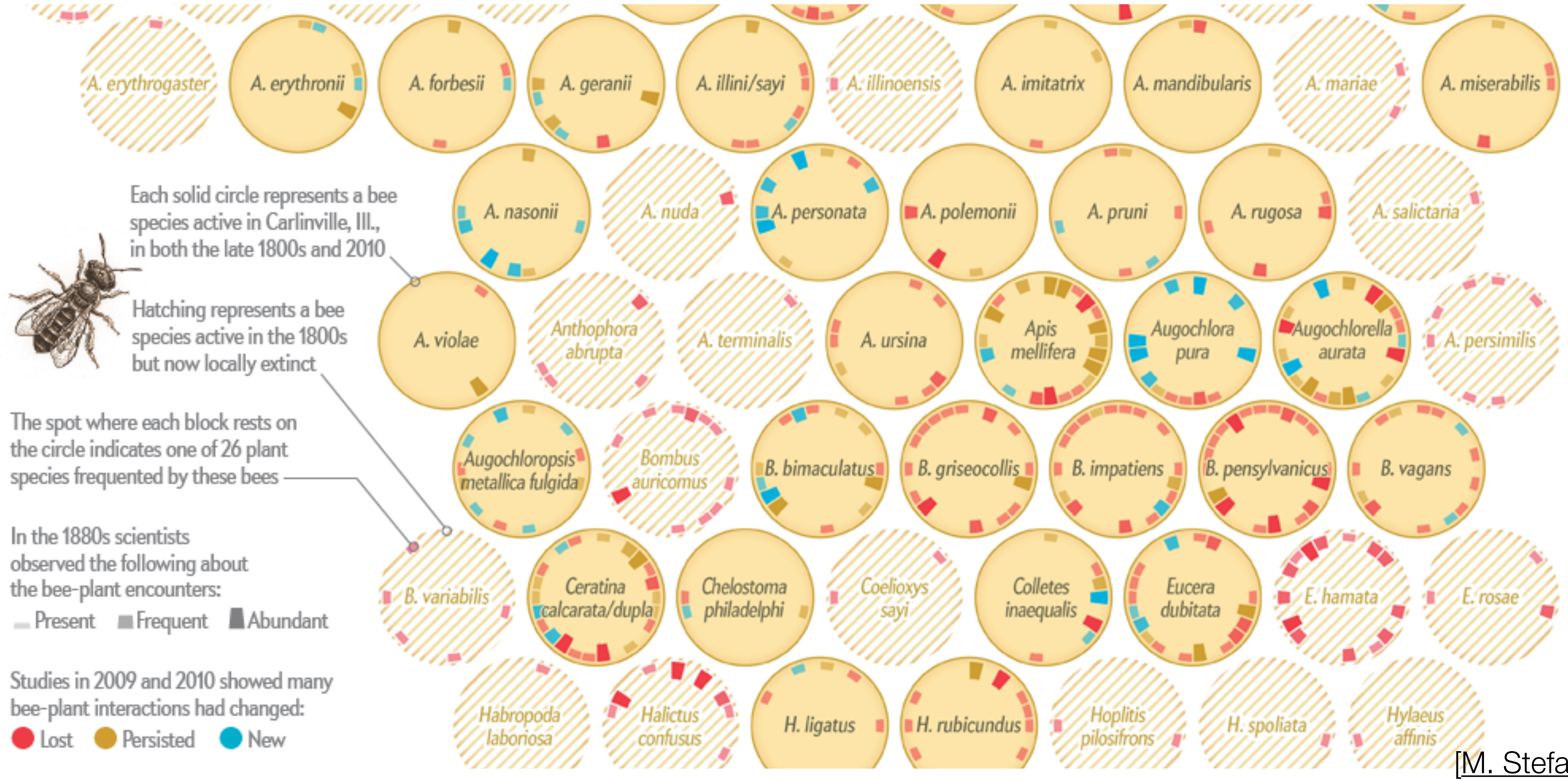
Asking good **questions** is very important

Answers often lead to **more** questions

Explore MTA Fare Data

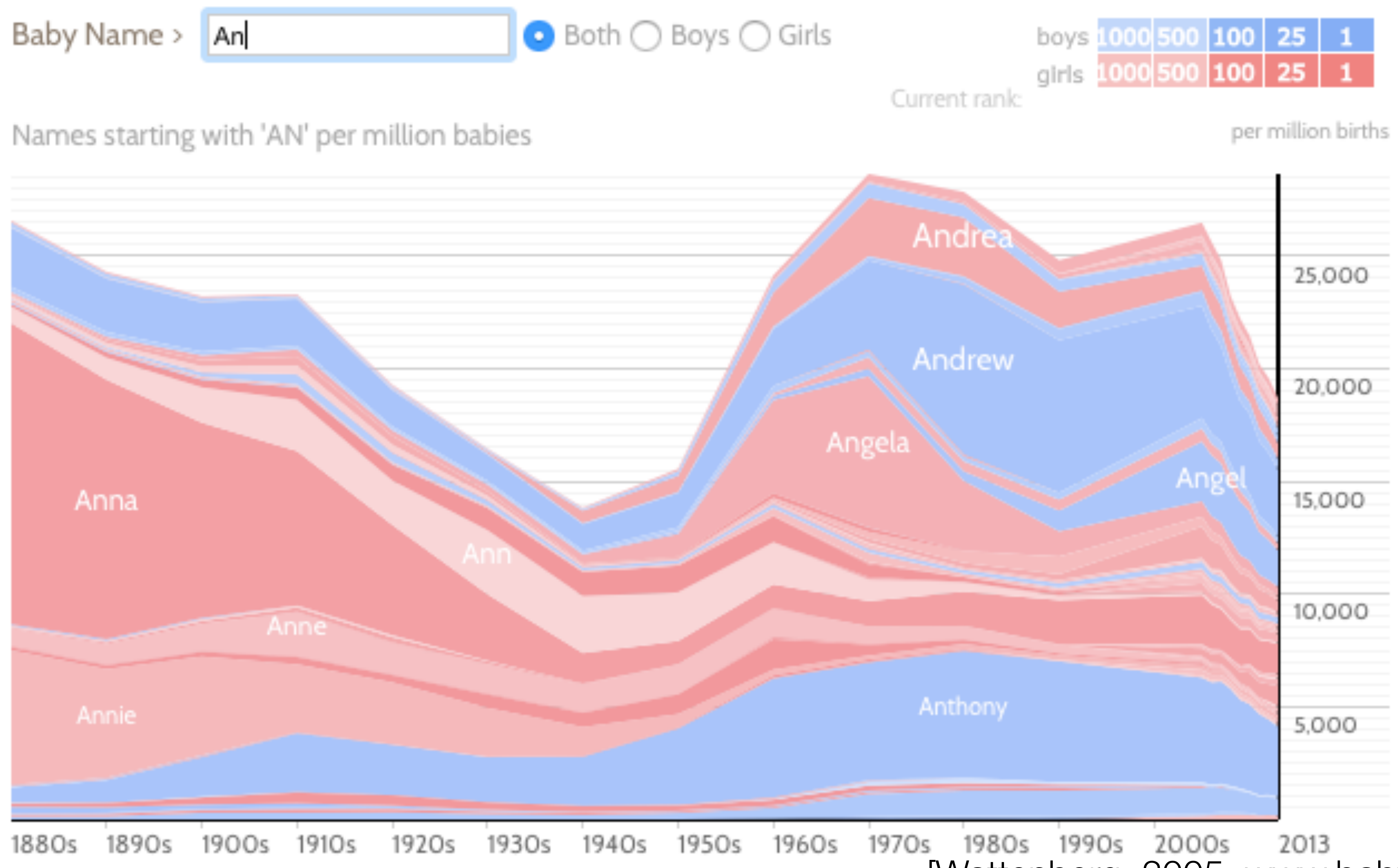


Present Known Information



[M. Stefaner, 2013]

Enjoy Visualizations of Names



[Wattenberg, 2005, www.babynamewizard.com]

"[W]e scientists now understand how important emotion is to everyday life, how valuable. Sure, utility and usability are important, but without fun and pleasure, joy and excitement, and yes, anxiety and anger, fear and rage, our lives would be incomplete."

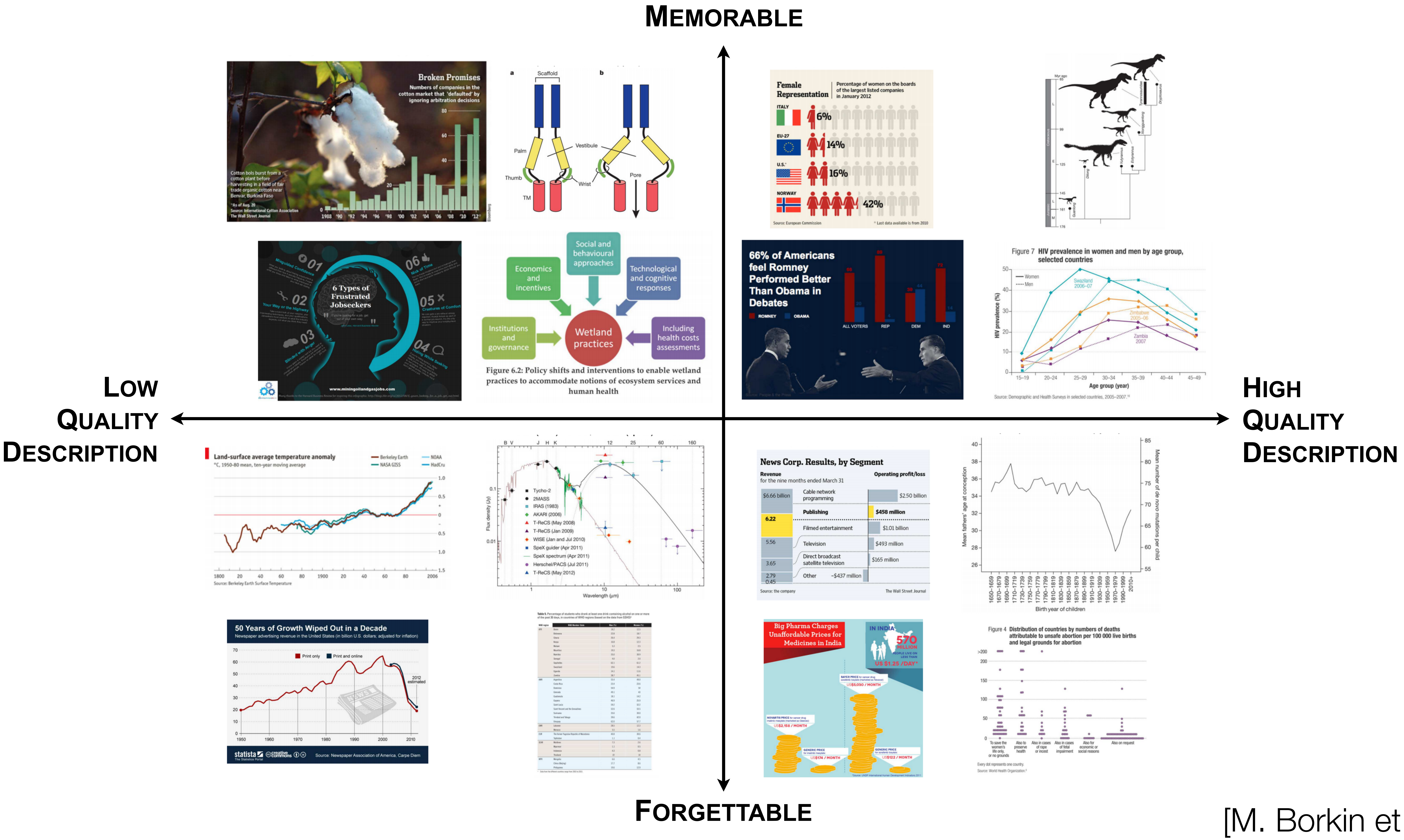
—D. Norman (Emotional Design)

Measuring User Experience in Visualization

- Memorability: Capability of maintaining and retrieving information [J. Brown et al., 1977]
- Engagement: Emotional, cognitive and behavioral connection that exists, at any point in time and possibly over time, between a user and a resource. [S. Attfield et al., 2011]
- Enjoyment: Feeling that causes a person to experience pleasure. Pleasure is recognized with occurrent happiness and excitement, which can be explained in terms of belief, desire, and thought. [W. A. Davis, 1982]

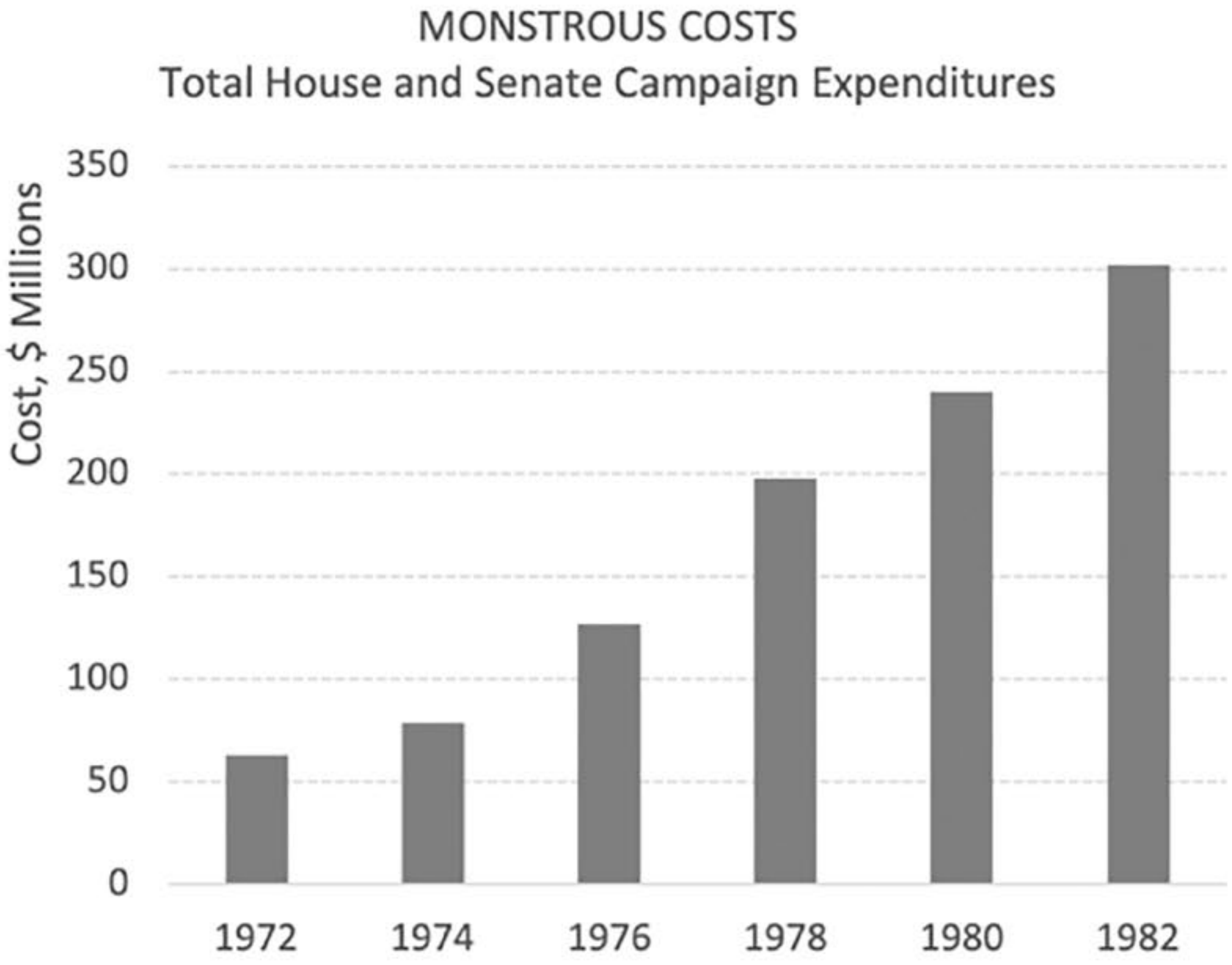
[B. Saket et al., BELIV 2016]

Memorability



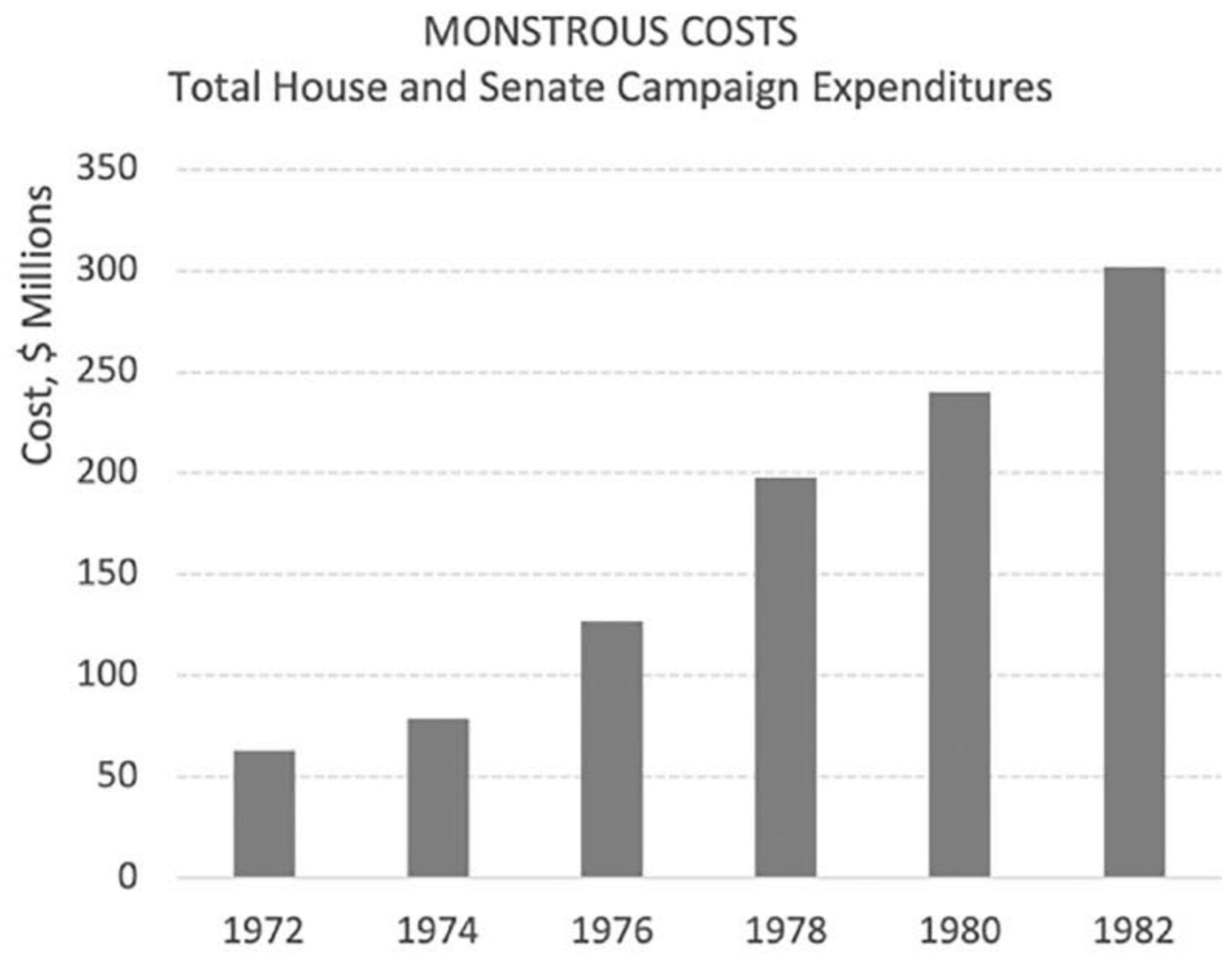
[M. Borkin et al., InfoVis 2015]

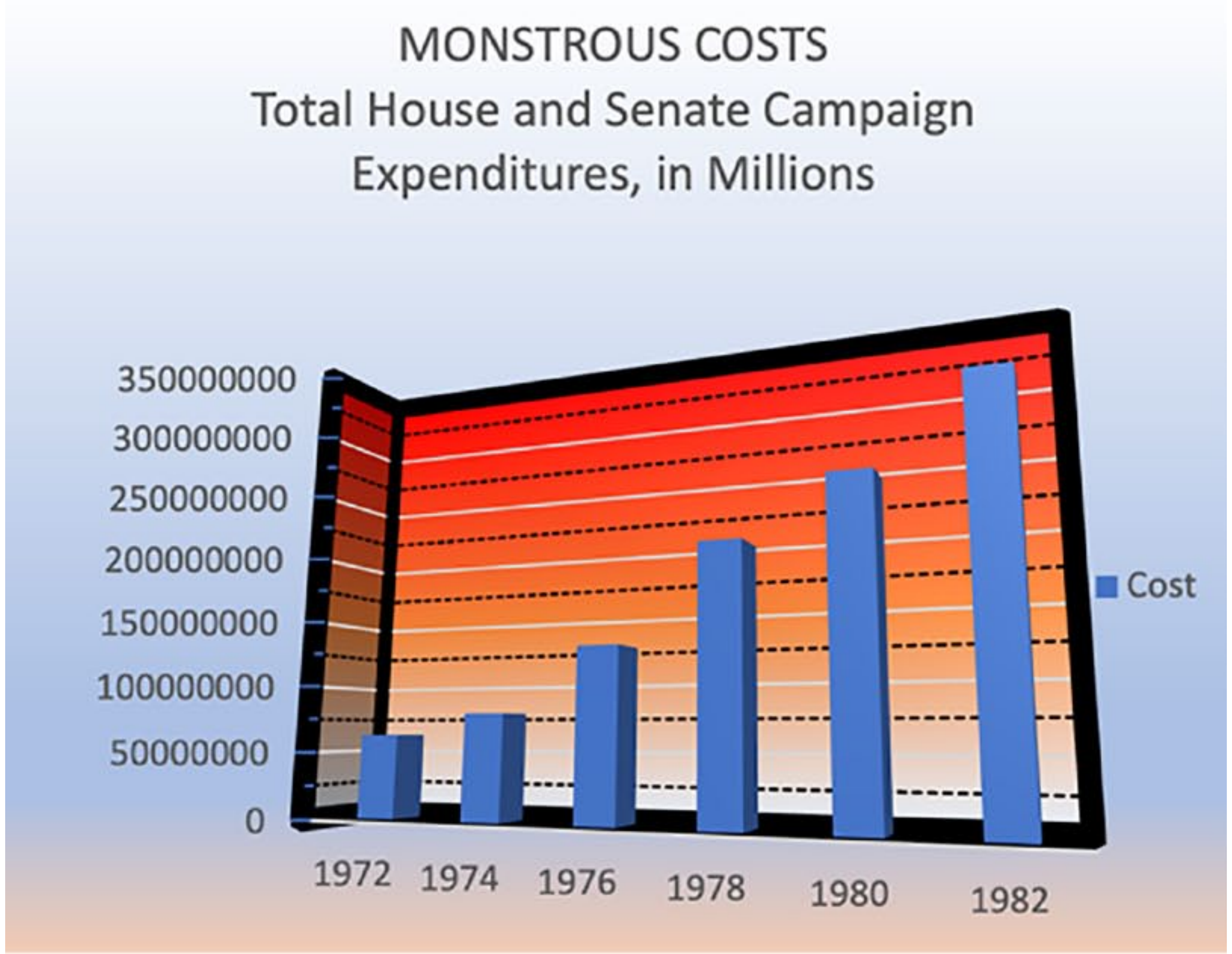
Memorability & Clutter



[S. Franconeri et al., 2021]

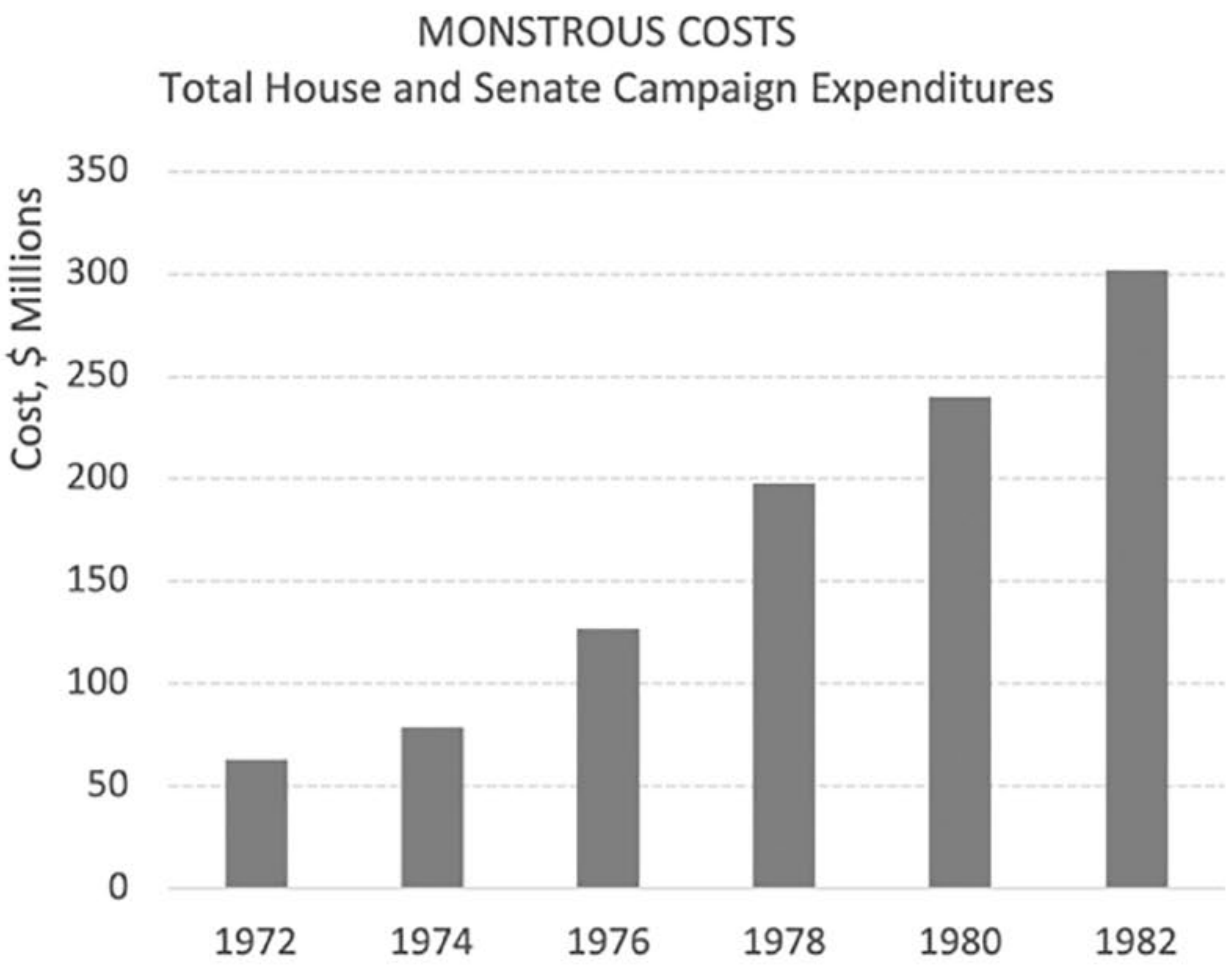
Memorability & Clutter

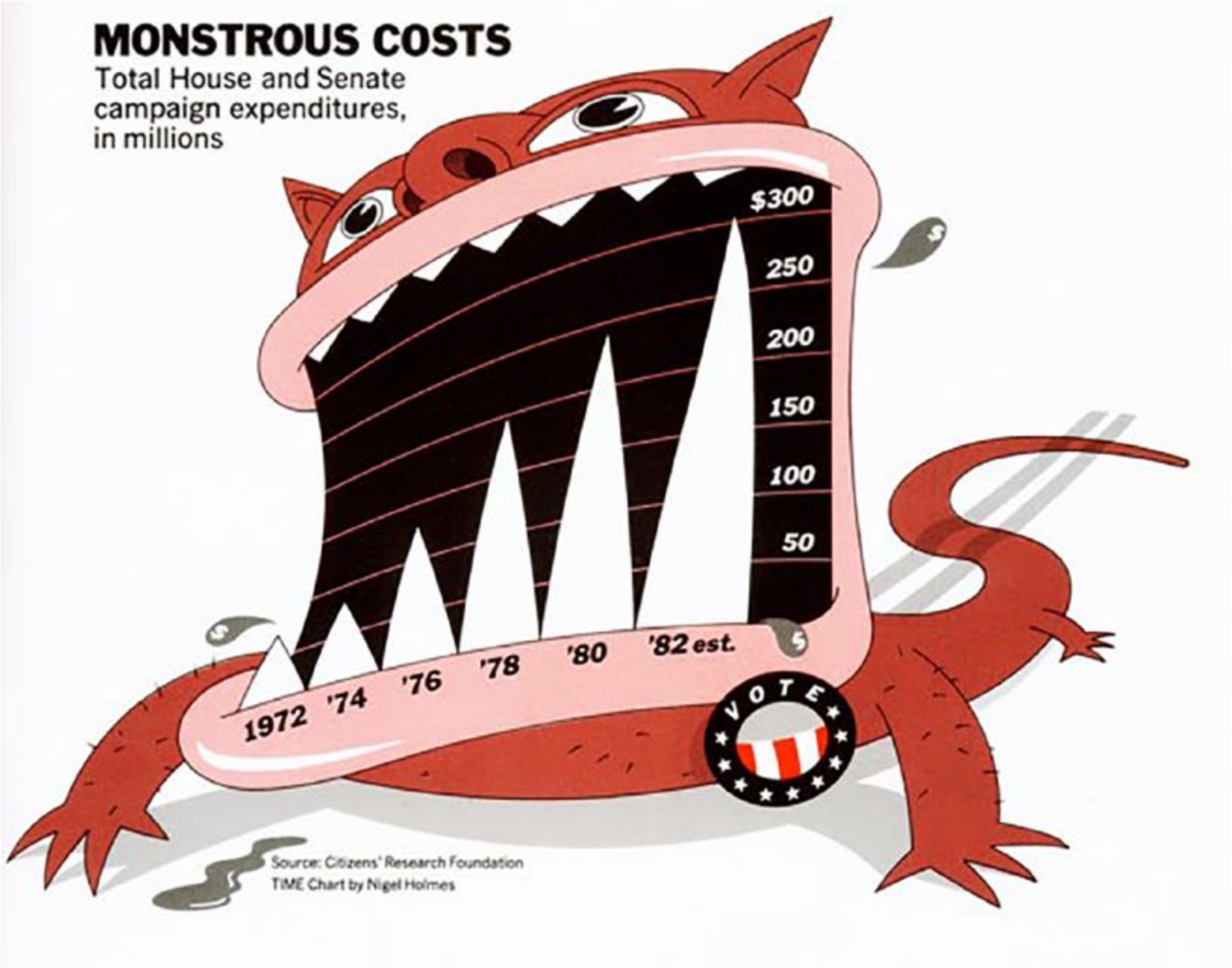




[S. Franconeri et al., 2021]

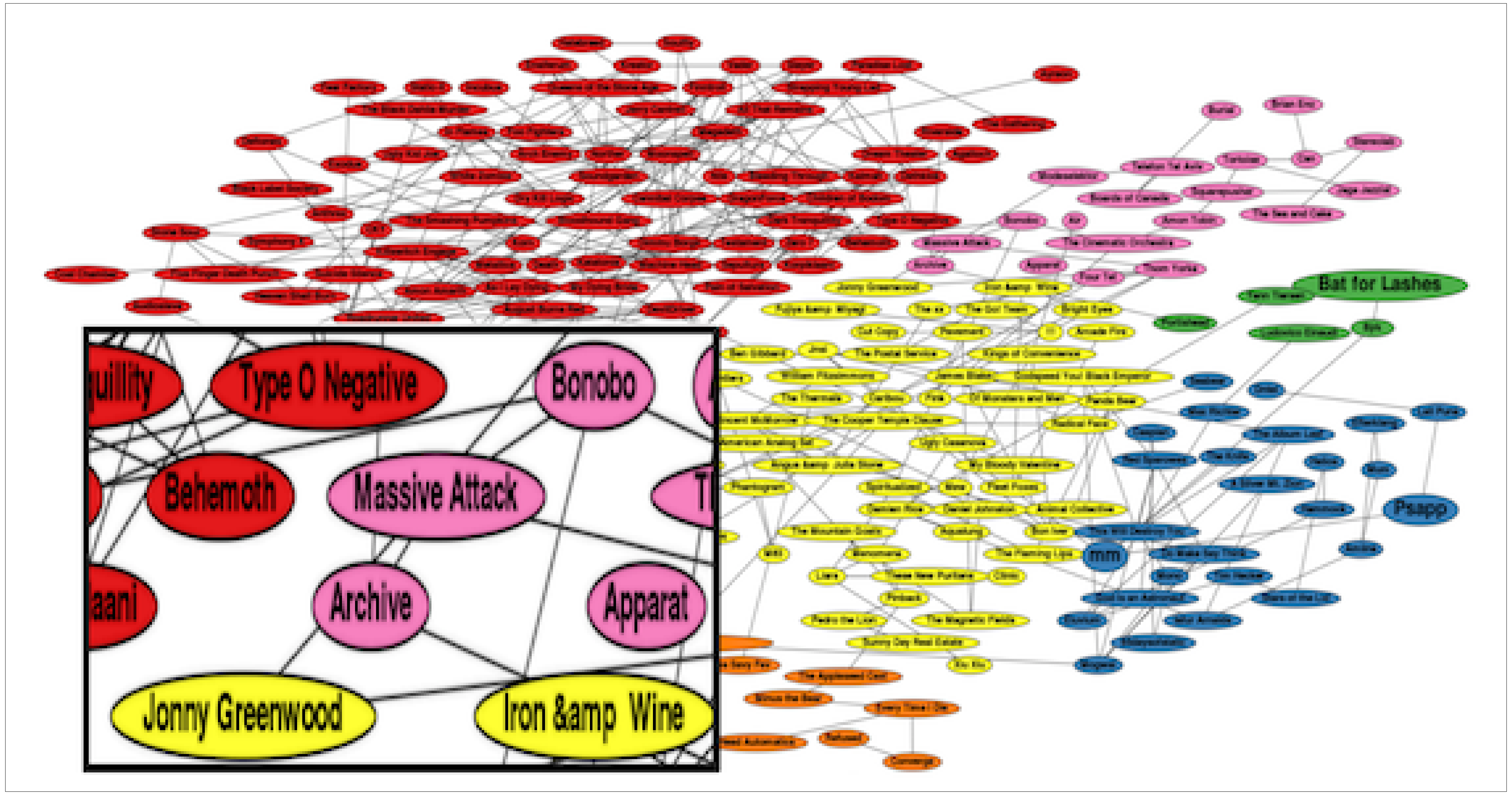
Memorability & Clutter





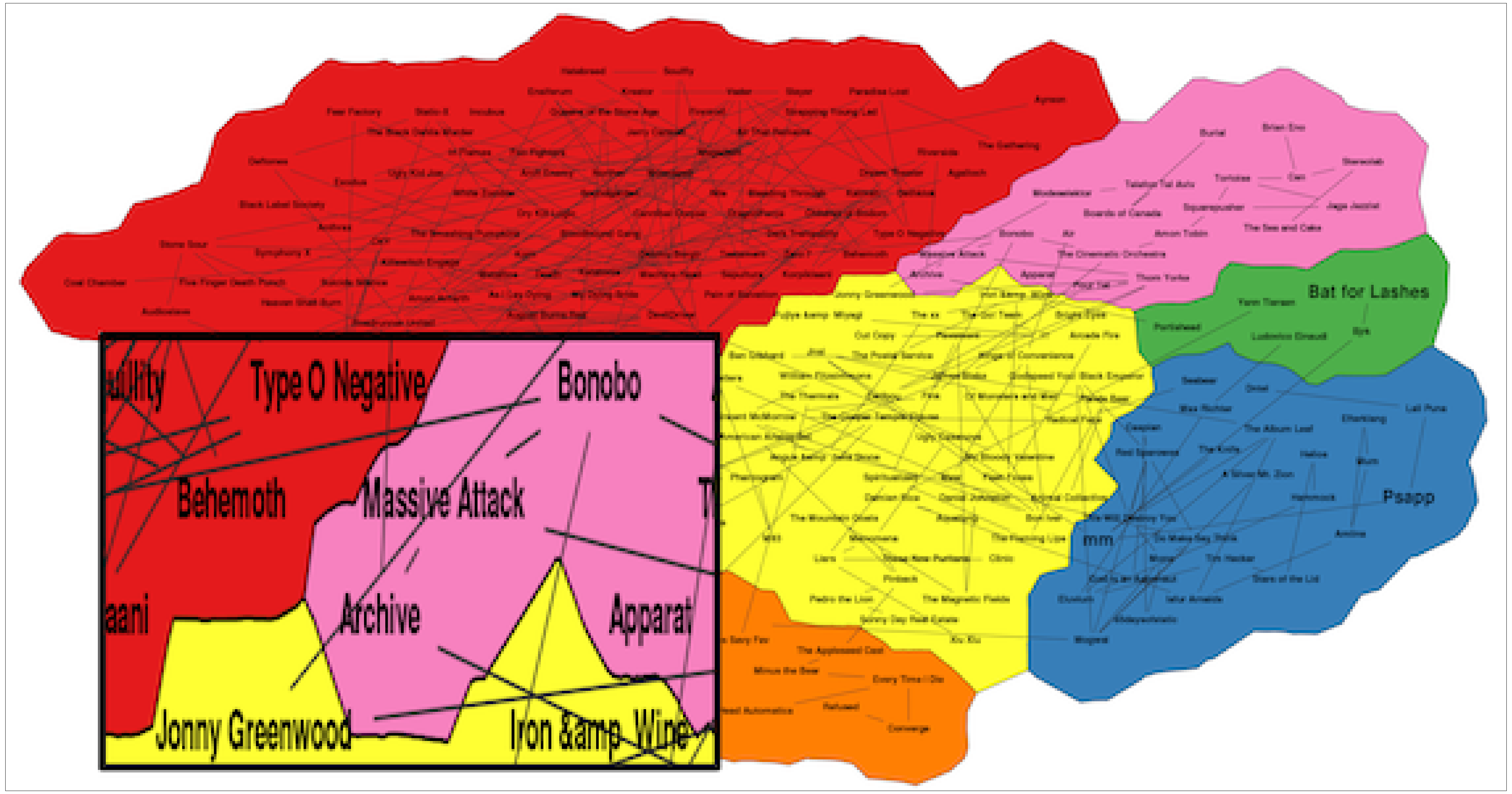
[N. Holmes, 2014] and [S. Franconeri et al., 2021]

Memorability: Maps instead of Networks



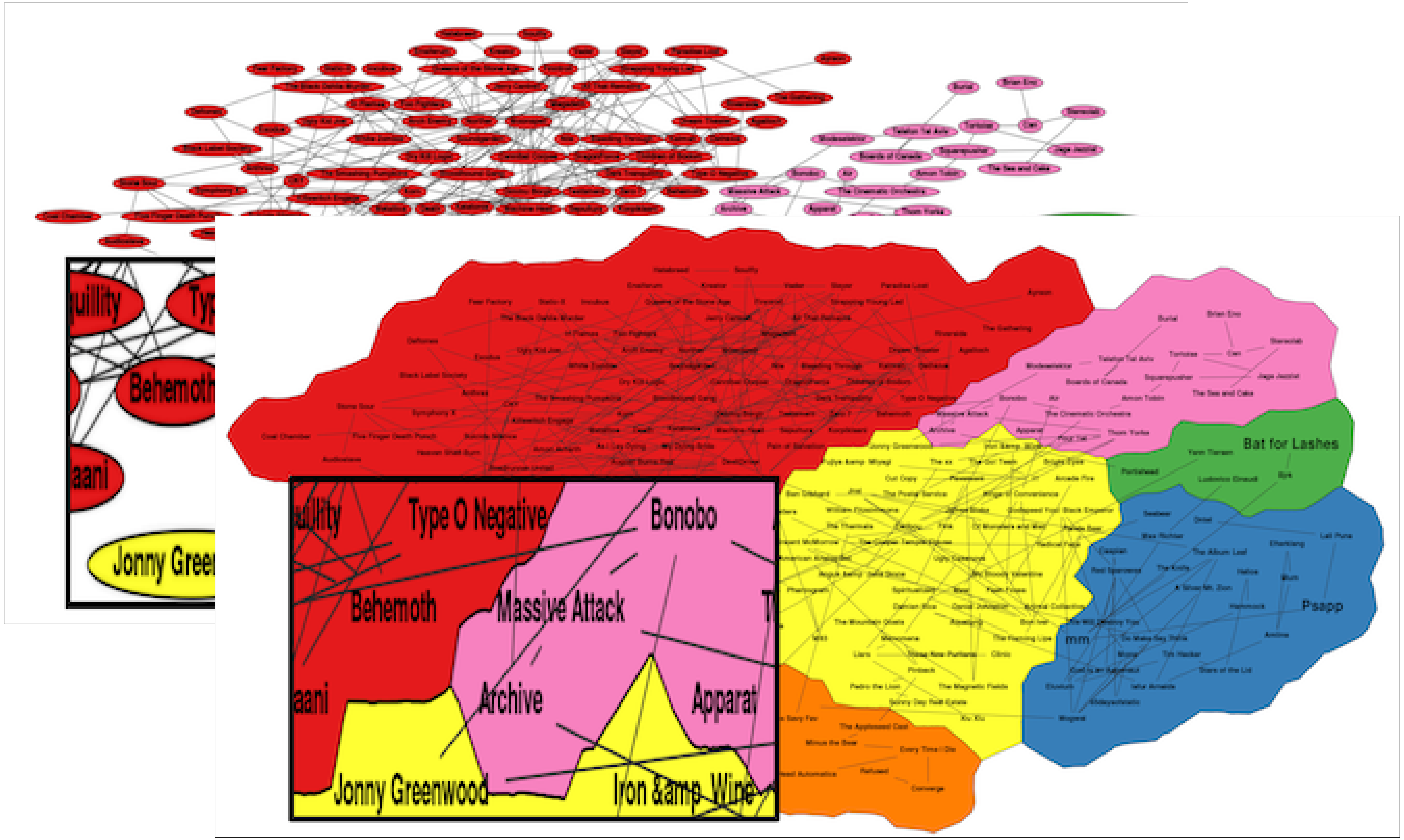
[B. Saket et al., 2015]

Memorability: Maps instead of Networks



[B. Saket et al., 2015]

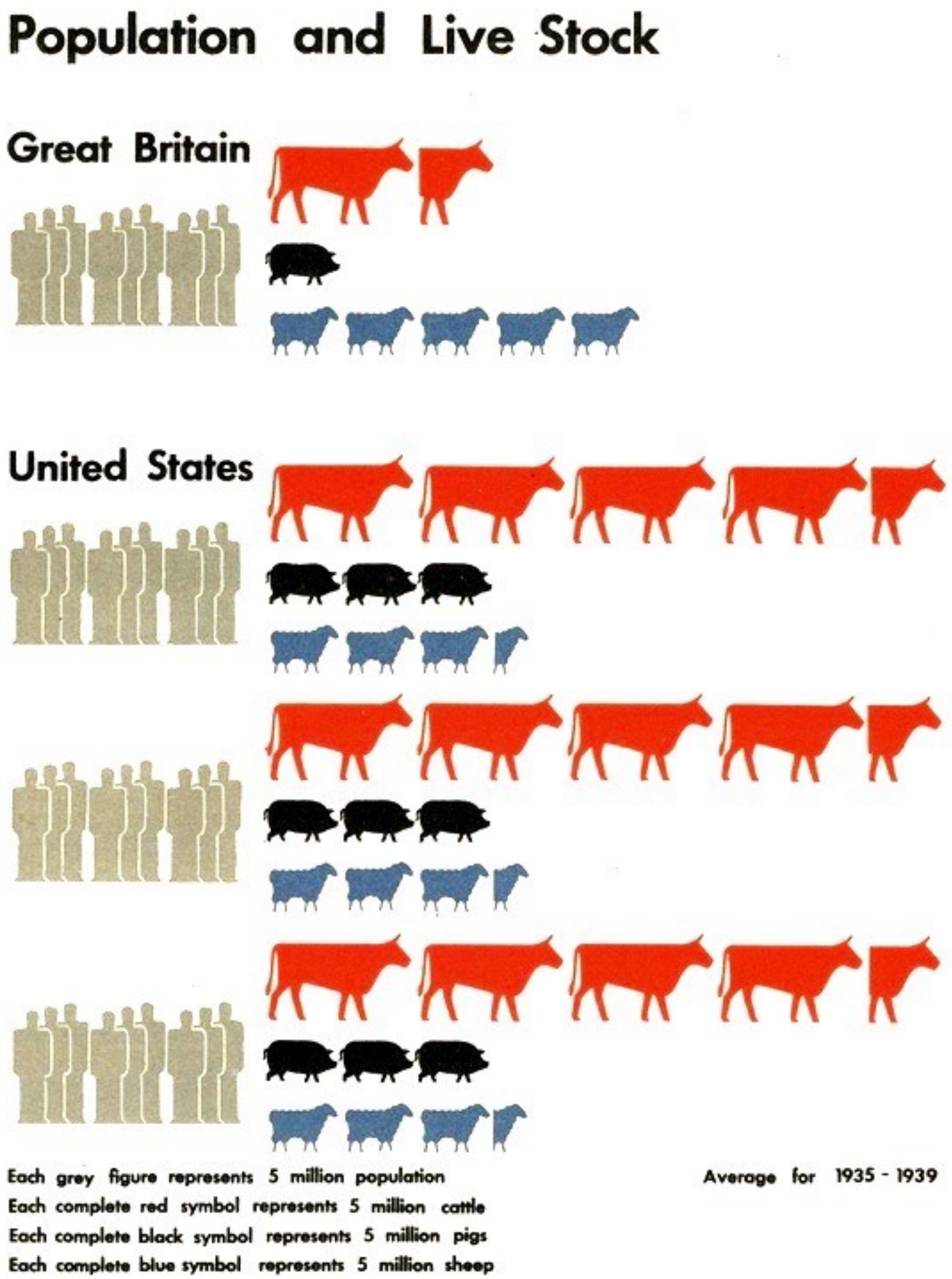
Memorability: Maps instead of Networks



[B. Saket et al., 2015]

ISOTYPE Visualizations

- Study [Haroz et al., 2015]
  - Want quick understanding and ease of remembering
  - Does ISOTYPE help?
- Results:
  - Stacked icons allow both length and quantity encoding
  - Icons are more memorable
  - Images that aren't used to show data are distracting



[Image by O. and M. Neurath, Study by S. Haroz et al., 2015]

Memorability

- Capability of maintaining and retrieving information [J. Brown et al., 1977]
- How to measure?
  - test users
- How long?
  - short-term, intermediate, or long-term?
- What types of visualizations?
  - bar/line/pie, networks, graphs, etc.

[B. Saket et al., BELIV 2016]

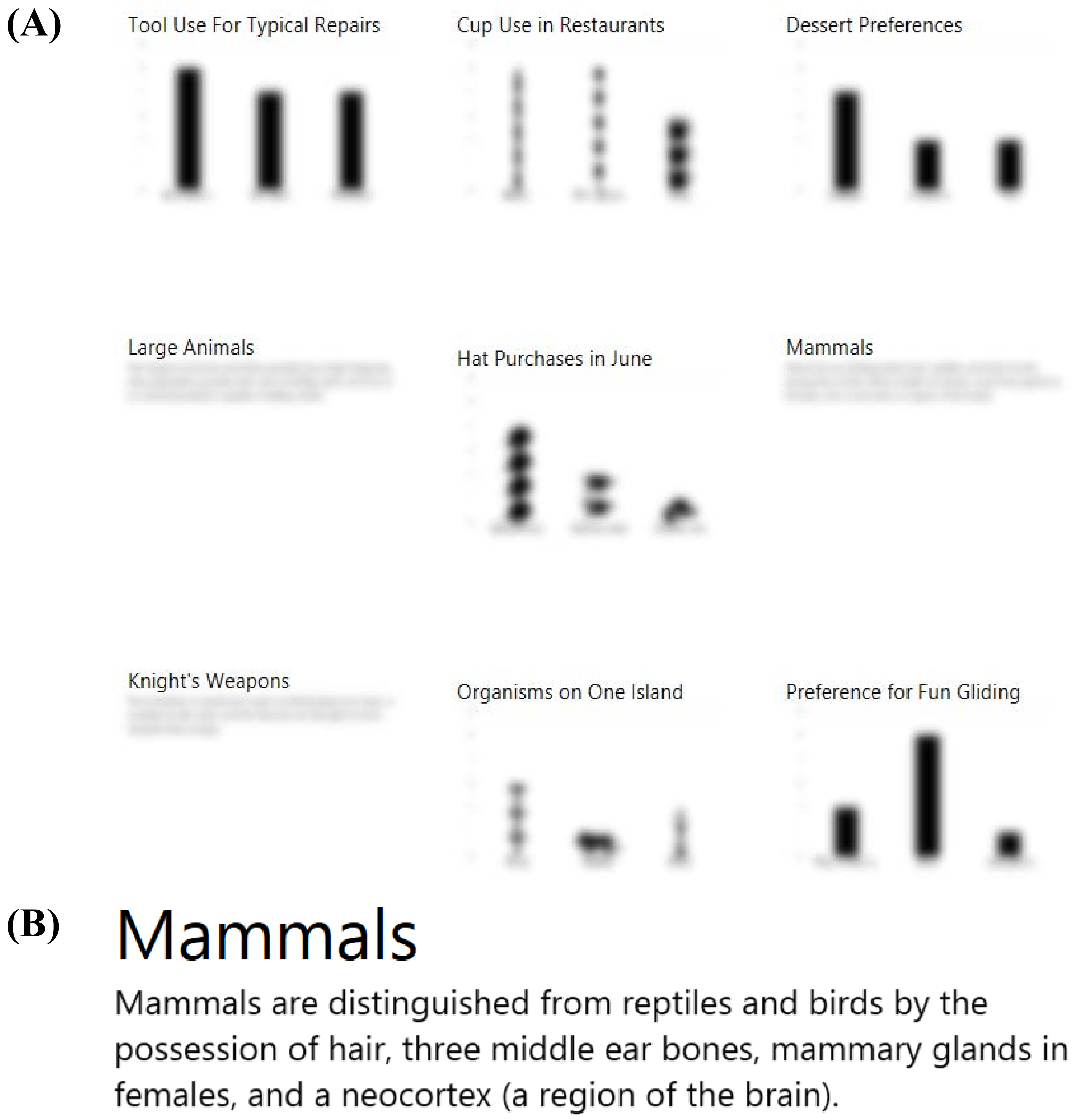
Engagement

- "Emotional, cognitive and behavioral connection that exists, at any point in time and possibly over time, between a user and a resource." [S. Attfield et al., 2011]
- How to measure? total time spent looking at a chart

[B. Saket et al., BELIV 2016]

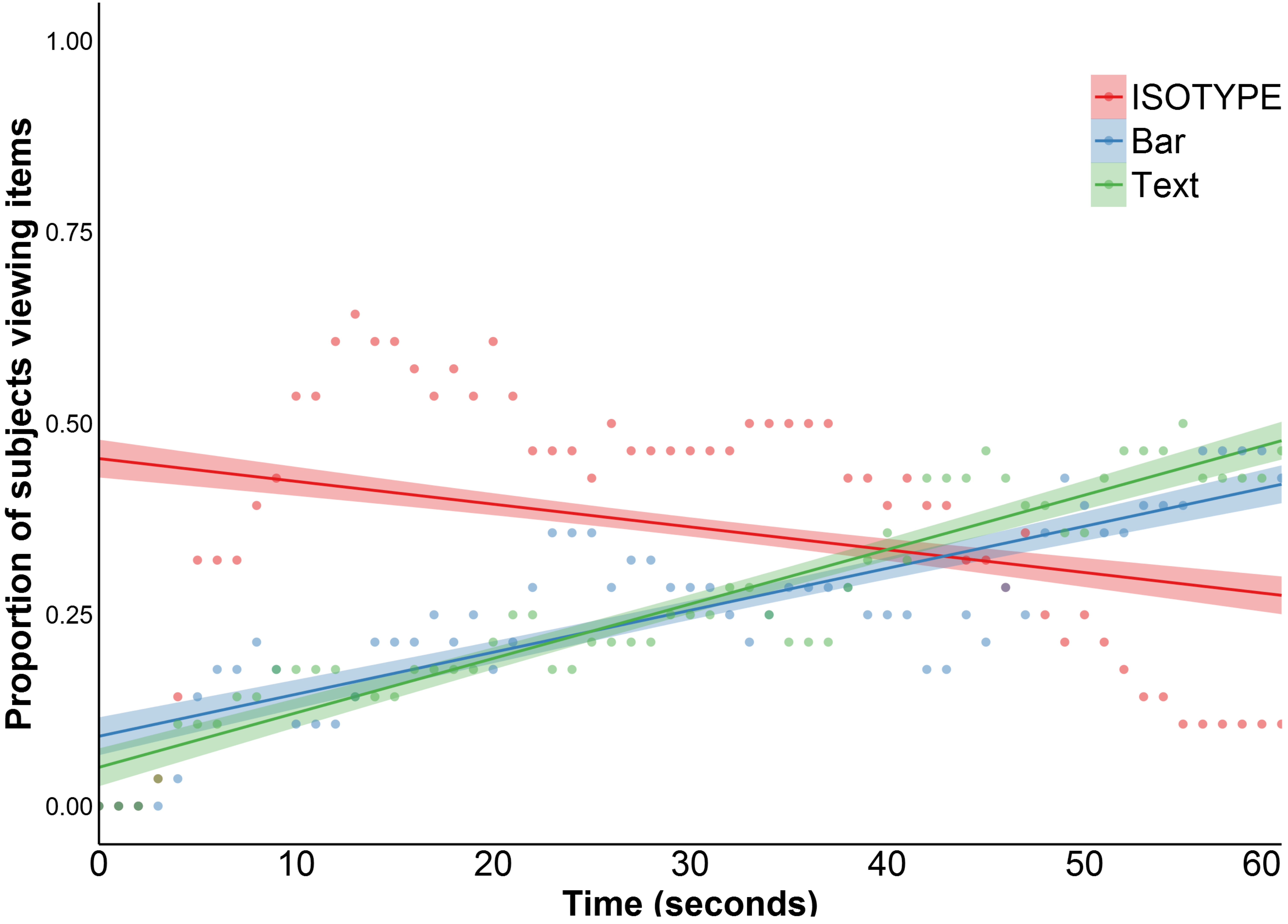
Measuring Engagement

Grid is blurred, click for detail



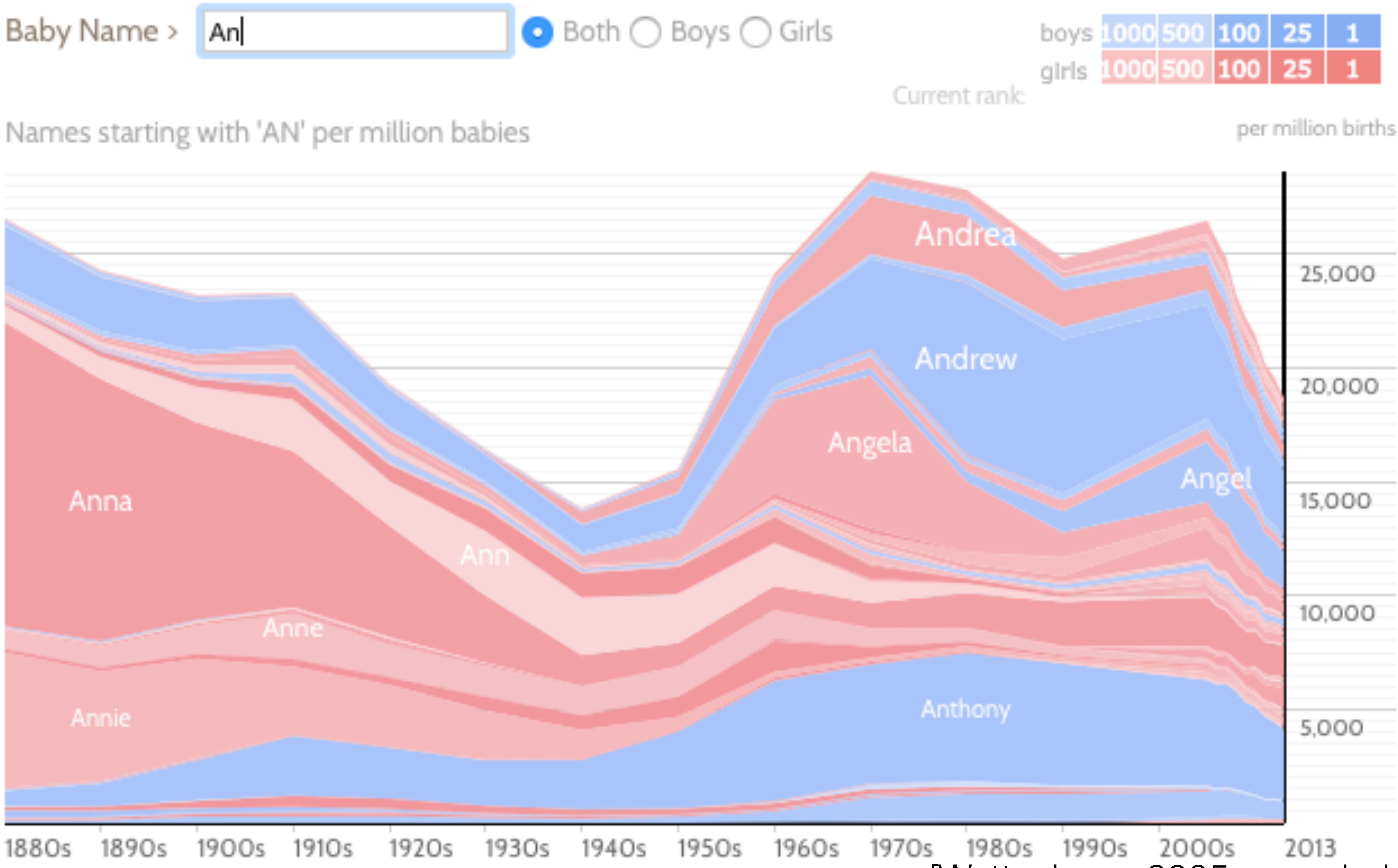
[S. Haroz et al., 2015]

Measuring Engagement



[S. Haroz et al., 2015]

Enjoyment: Name Voyager



[Wattenberg, 2005, www.babynamewizard.com]

Measuring Enjoyment

- Difference from engagement (e.g. may be for a job)
- Self-reporting (e.g. comparison between different charts
- Measure why someone enjoys a visualization:
  - Challenge
  - Focus
  - Clarity
  - Feedback
  - Control
  - Immersion

[B. Saket et al., 2016]

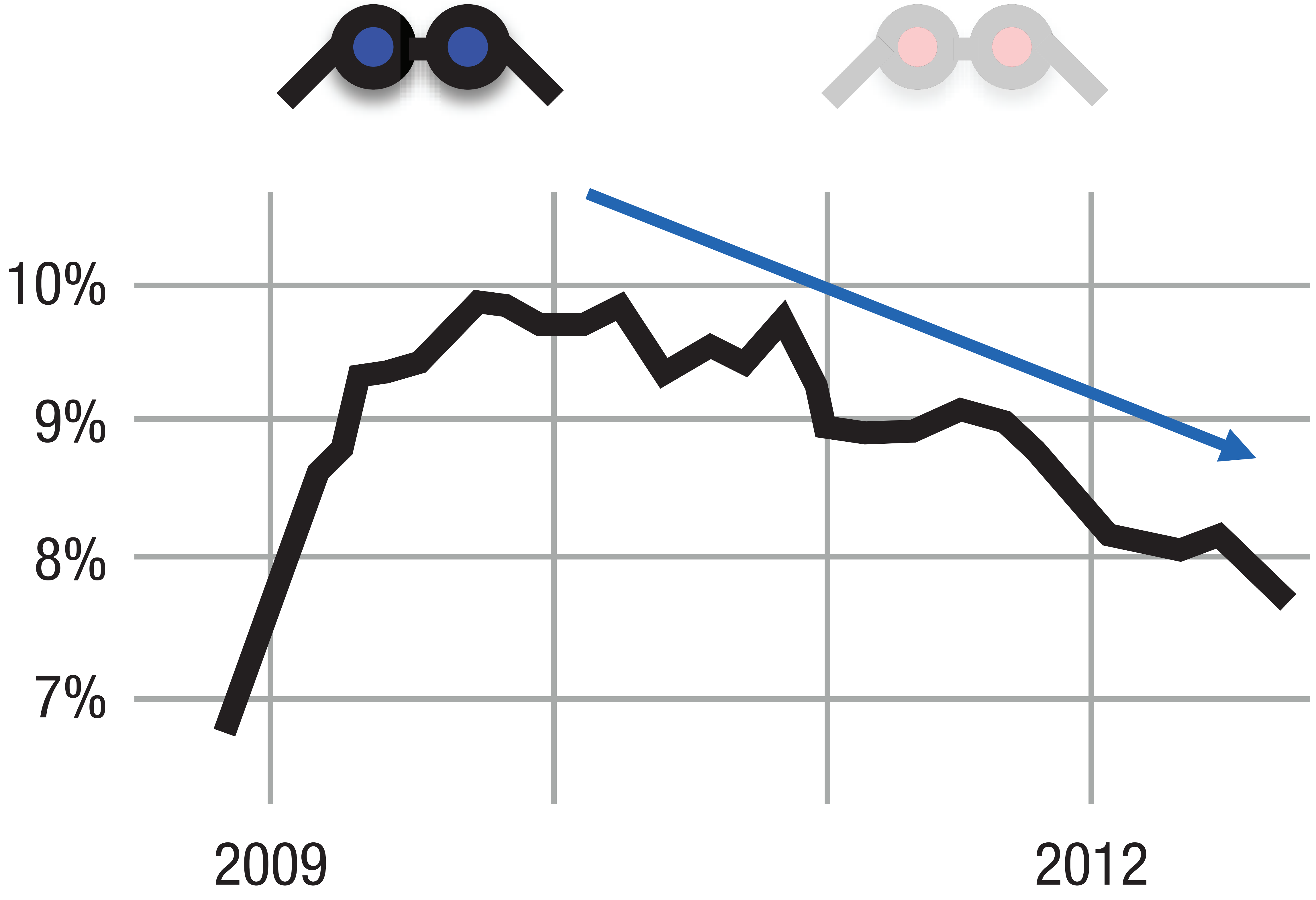
"Visualizations don't need to be designed for memorability – they need to be designed for comprehension. For most visualizations, the comprehension that they provide need only last until the decision that it informs is made. Usually, that is only a matter of seconds."

— S. Few

Reaction

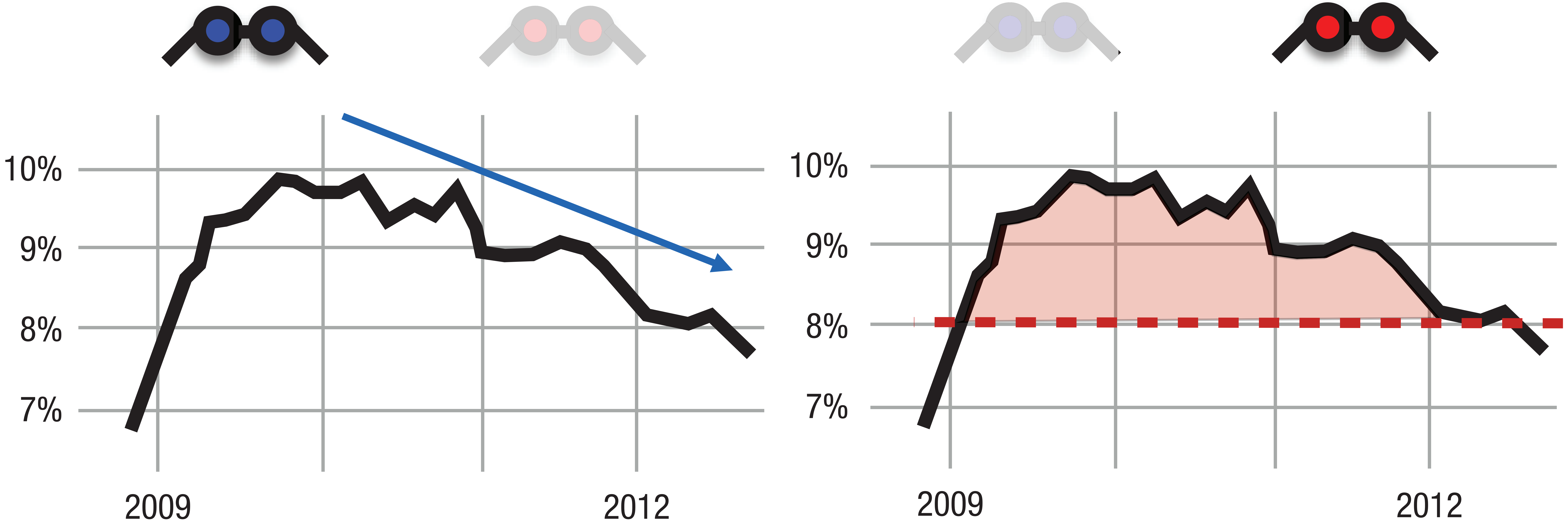
- B. Jones (paraphrased): People make decisions using visualizations but this isn't instantaneous like robots or algorithms; they often chew on a decision for a while
- R. Kosara: there are cases where people benefit from remembering a visualization (e.g. health-related visualization)
- Are there tradeoffs between the characteristics?

Present to Persuade



[S. Franconeri et al., 2019]

Present to Persuade



[S. Franconeri et al., 2019]

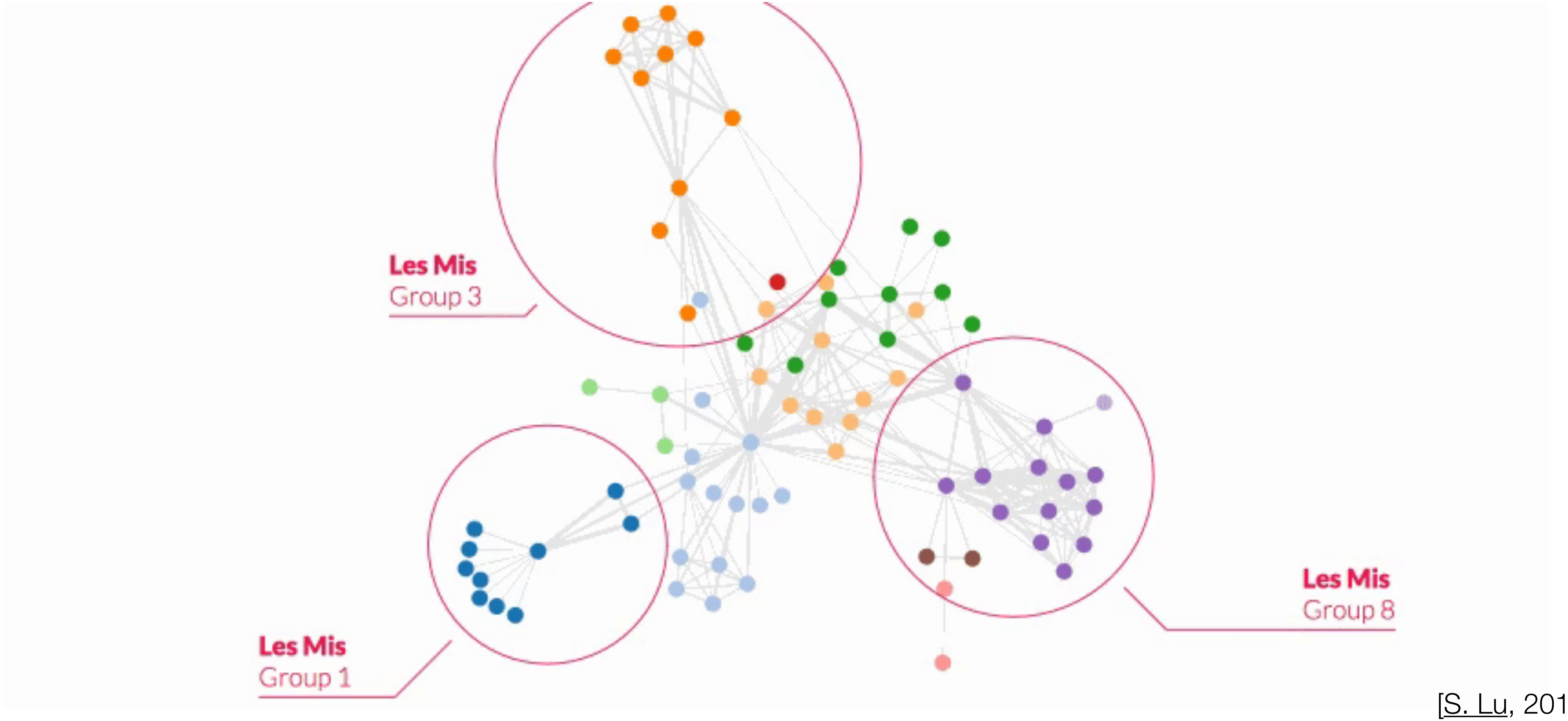
Influencing Messages in Visualizations

- Perception is influenced by existing biases (e.g. unemployment numbers)
- Perception is influenced by visualization's title [Kong et al., 2019]
- Perception can be biased by social influence [Hullman et al., 2011]
- See A. Cairo's books

Visualization for Production

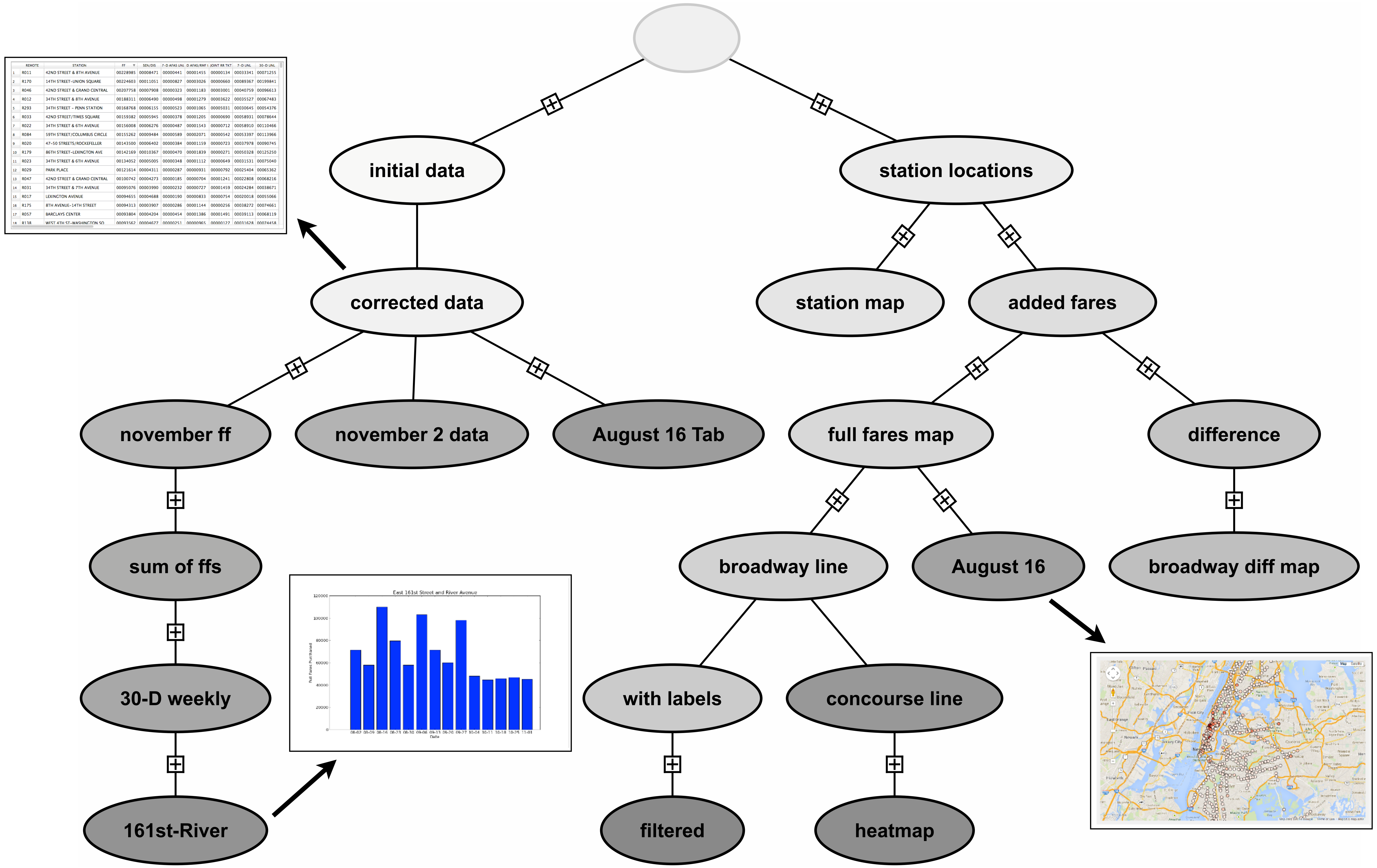
- Generate new material
- Annotate
- Record
- Derive (Transform)

Annotation: Circle Annotations

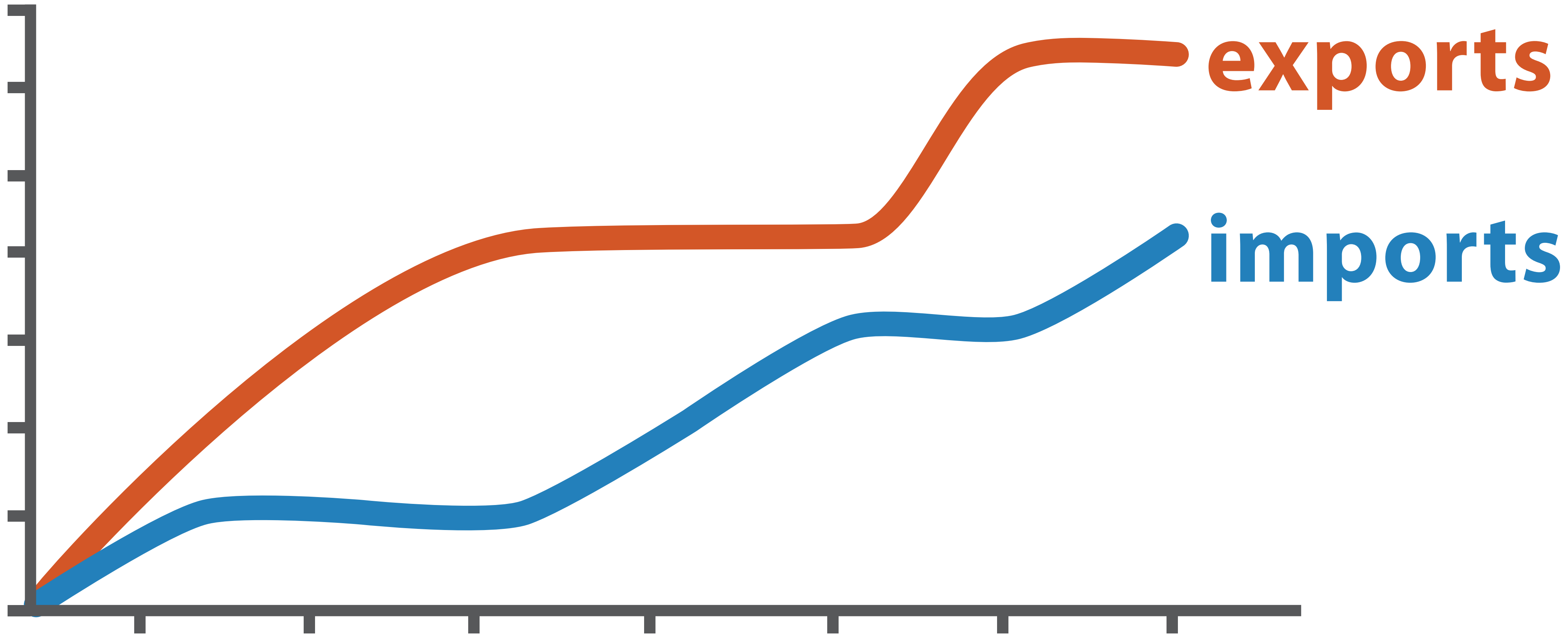


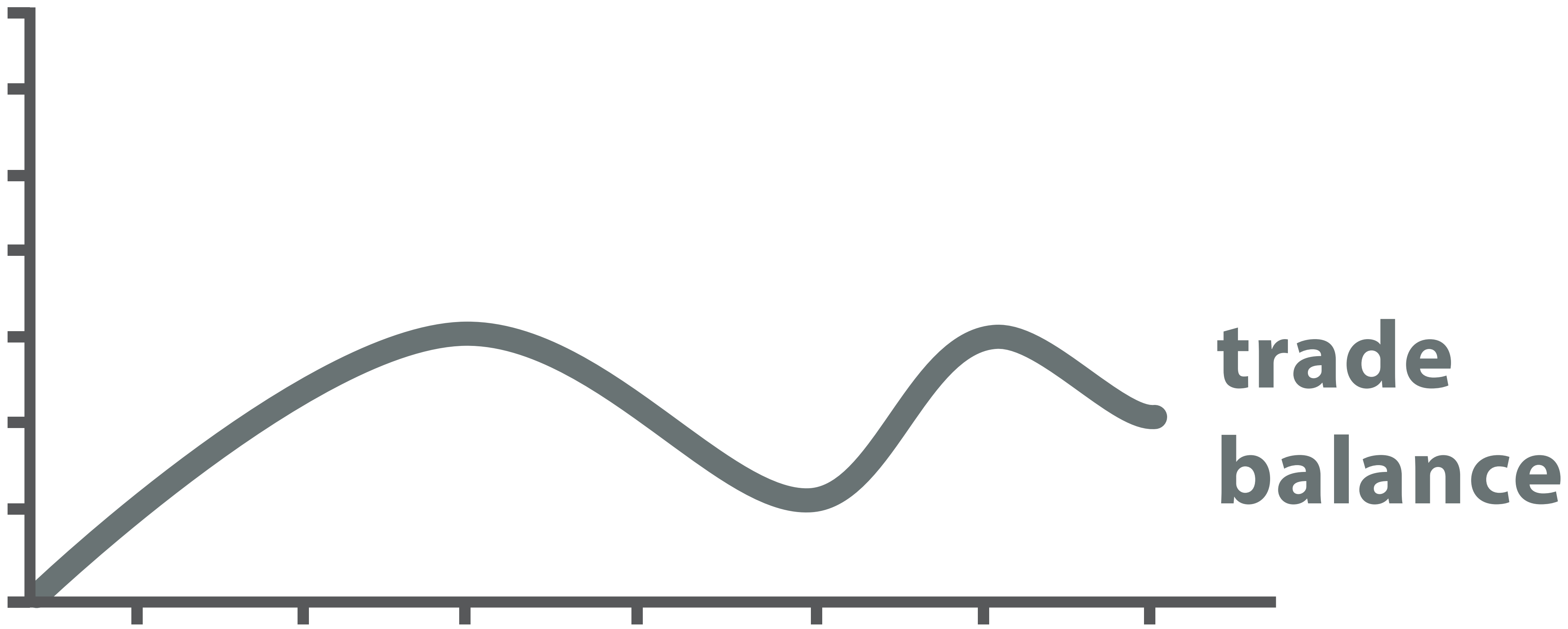
[S. Lu, 2017]

Record: Provenance of MTA Data Exploration



Derived Data





trade balance = *exports* − *imports*

Original Data

Derived Data

[Munzner (ill. Maguire), 2014]

Visualization for Production

- Generate new material
- Annotate:
  - Add more to a visualization
  - Usually associated with text, but can be graphical
- Record:
  - Persist visualizations for historical record
  - Provenance (graphical histories): how did I get here?
- Derive (Transform):
  - Create new data
  - Create derived attributes (e.g. mathematical operations, aggregation)

Actions: Search

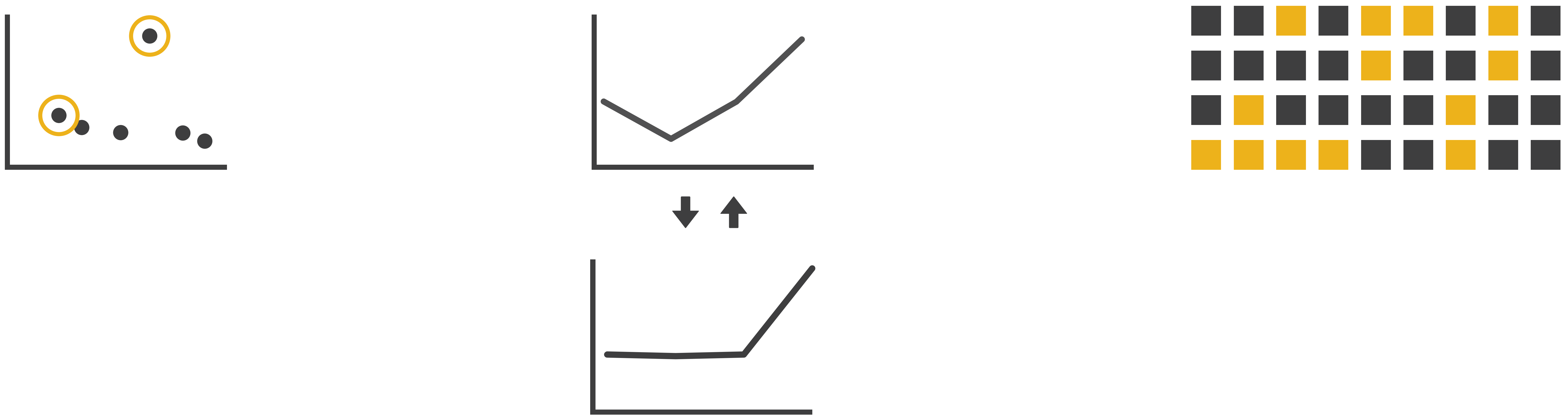
- What does a user know?
  - Lookup: check bearings
  - Locate: find on a map
  - Browse: what's nearby
  - Explore: where to go
    - Patterns

	Target known	Target unknown
Location known	*Lookup*	*Browse*
Location unknown	*Locate*	*Explore*

[Munzner (ill. Maguire), 2014]

Query

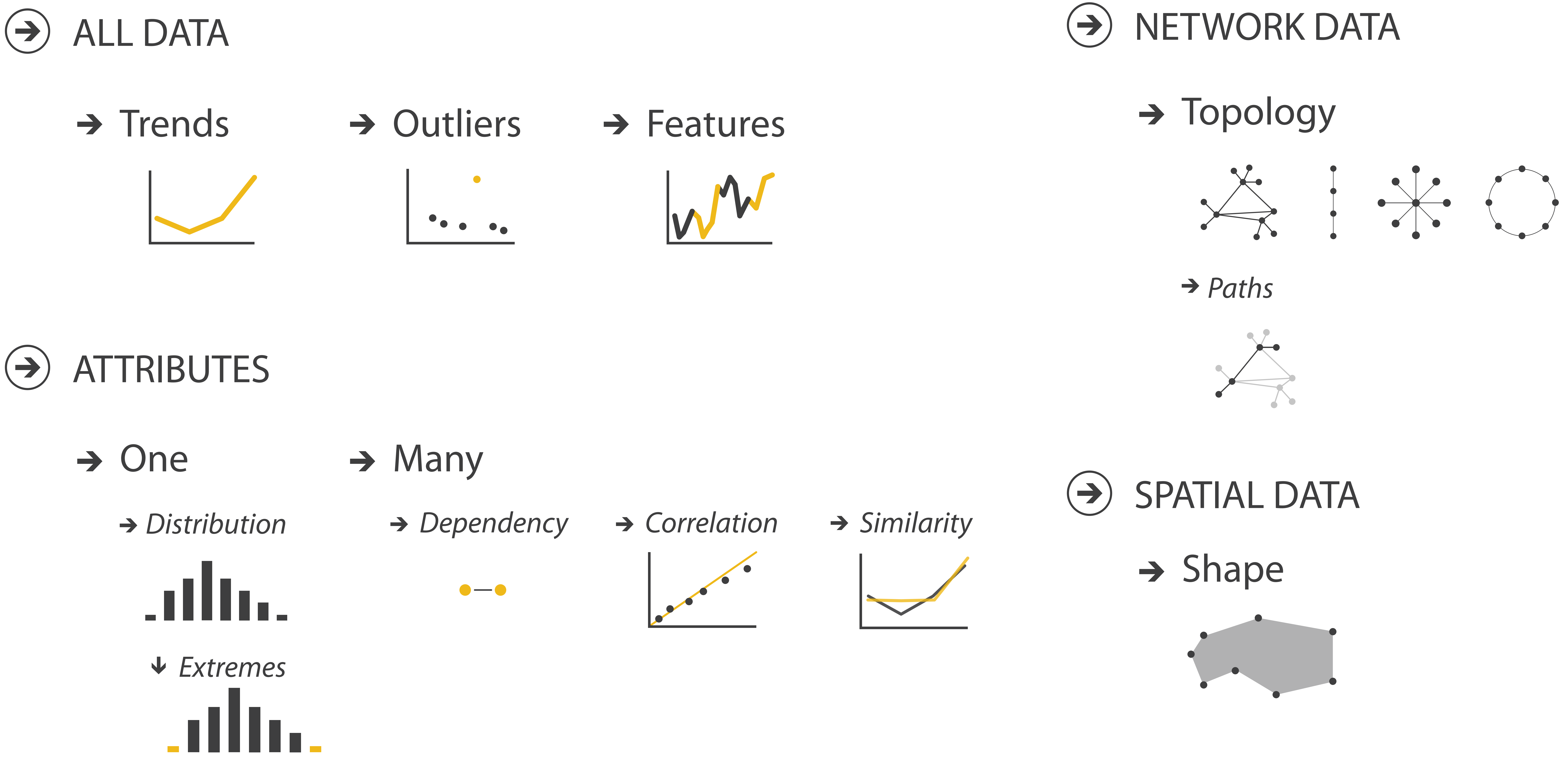
➔ Identify ➔ Compare ➔ Summarize



- Number of targets: One, Some (Often 2), or All
- Identify: characteristics or references
- Compare: similarities and differences
- Summarize: overview of everything

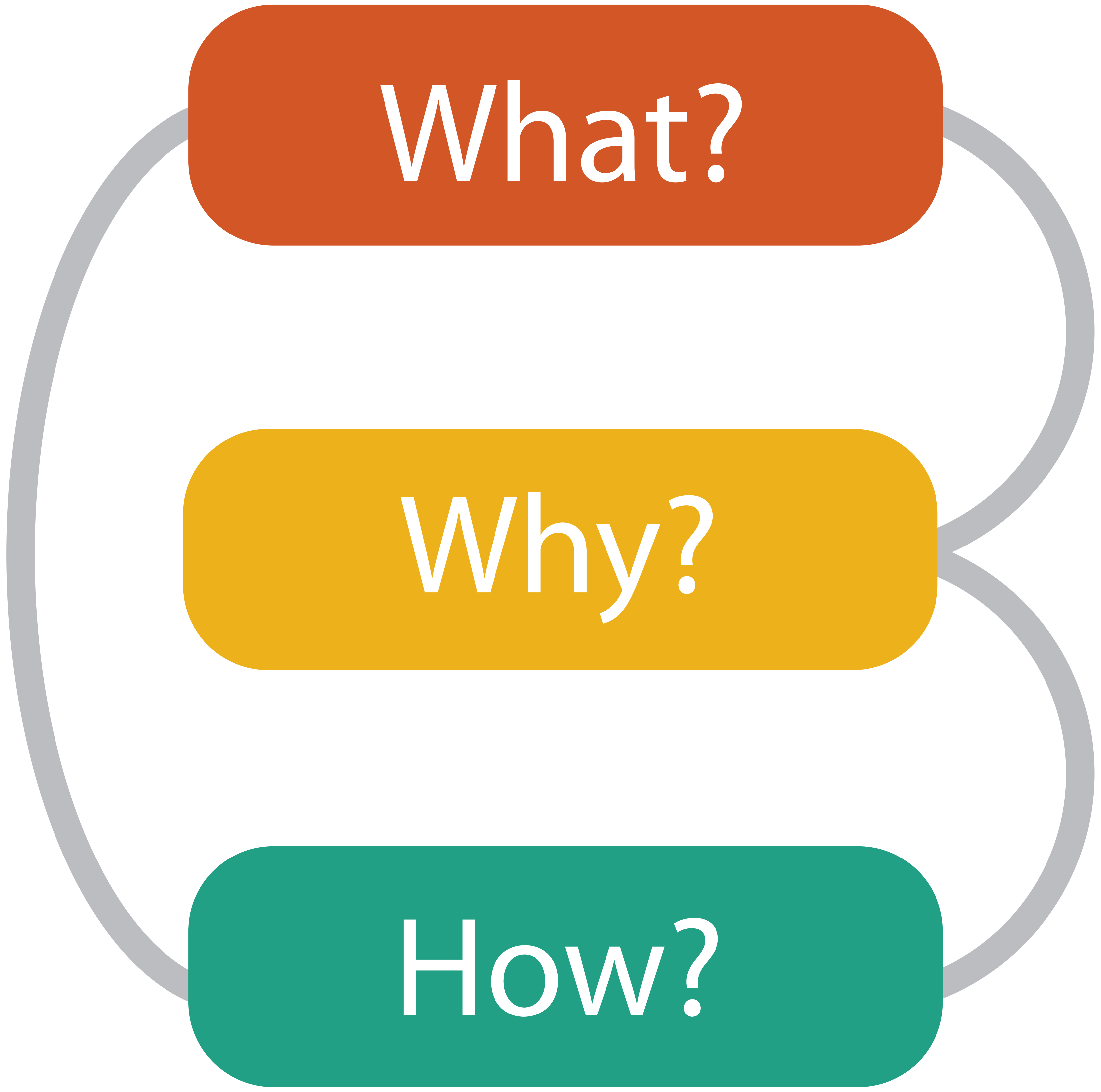
[Munzner (ill. Maguire), 2014]

Targets



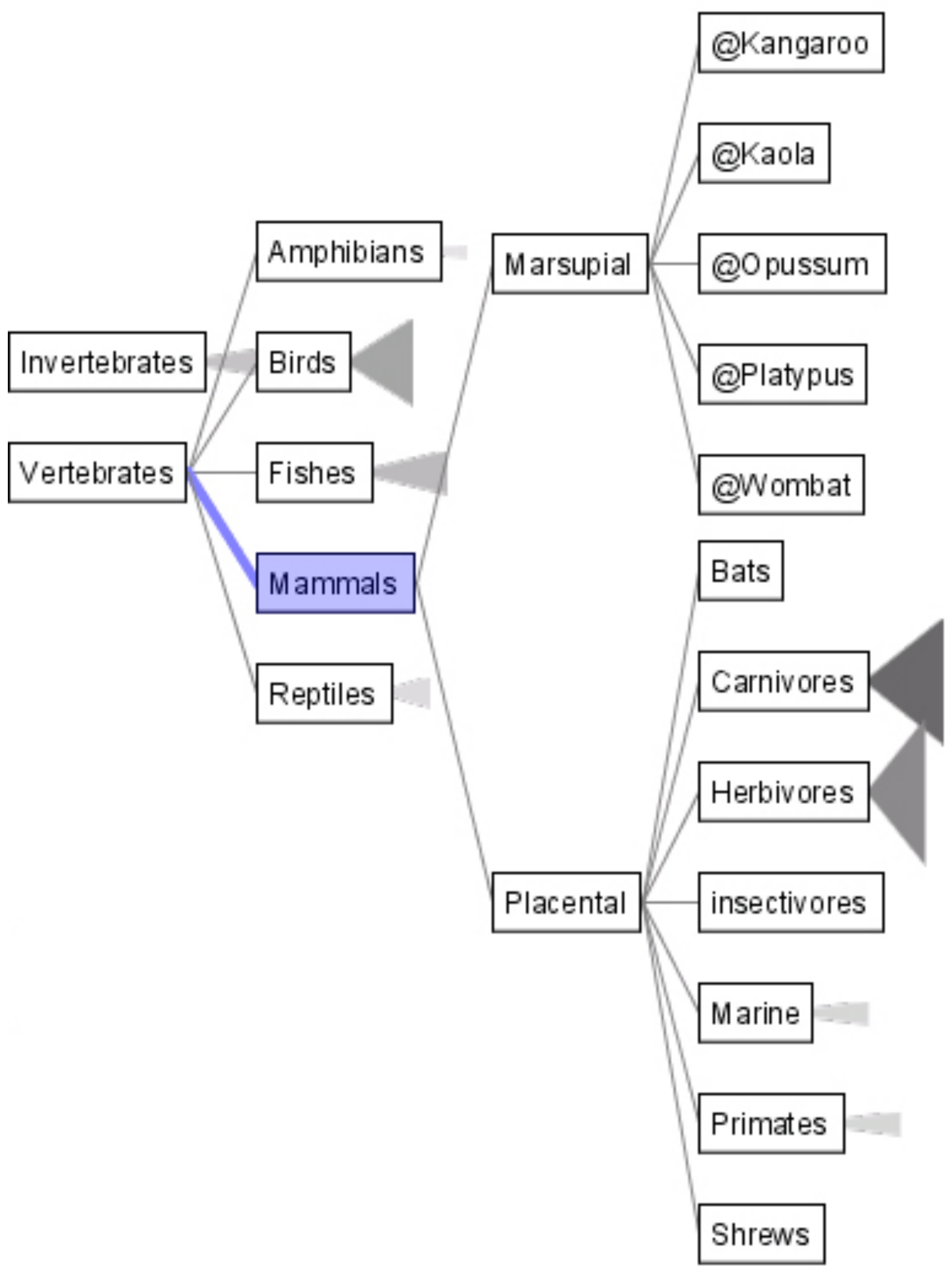
[Munzner (ill. Maguire), 2014]

Roadmap

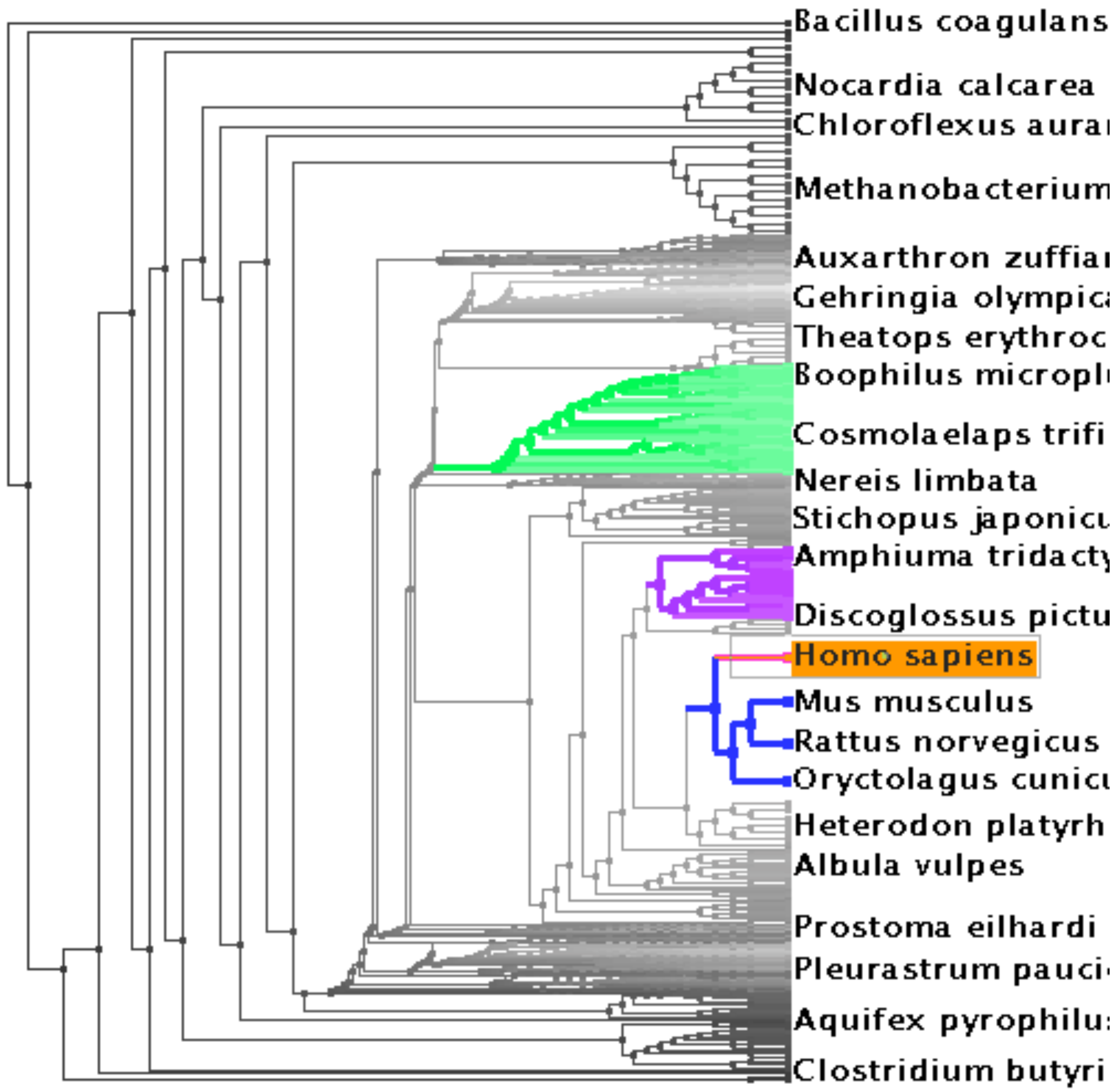


- What? → Data
  - Types
  - Semantics
- Why? → Tasks
  - Actions
  - Targets
- How → Vis Idioms/Techniques
  - Data Representation
  - Visual Encoding
  - Interaction Encoding

Analysis Example: Different "Idioms"



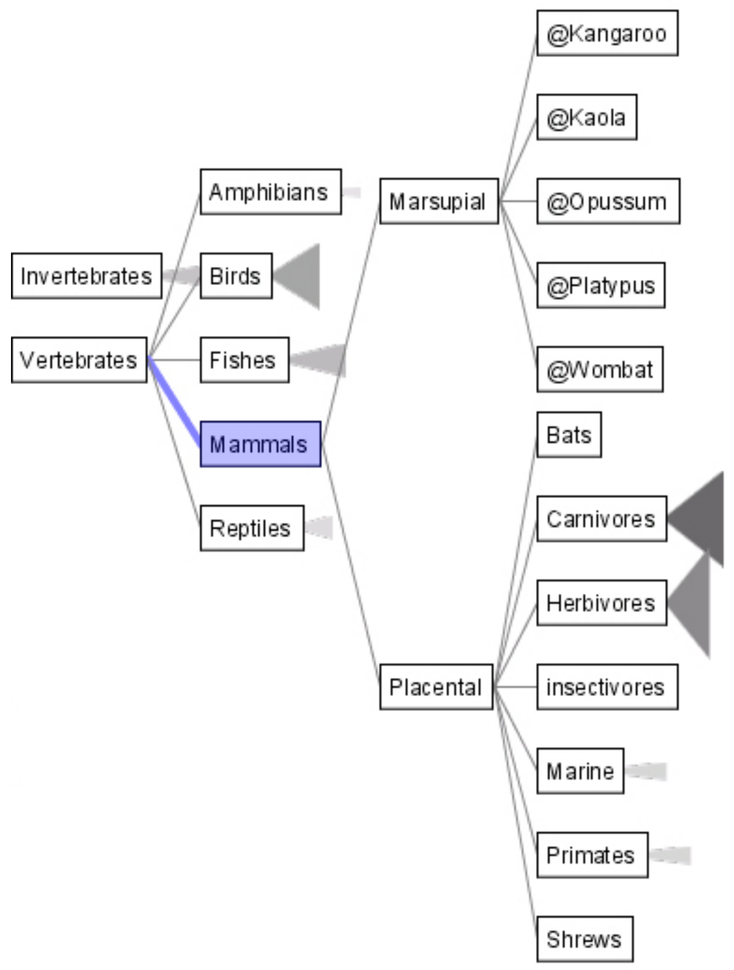
[SpaceTree, Grosjean et al.]

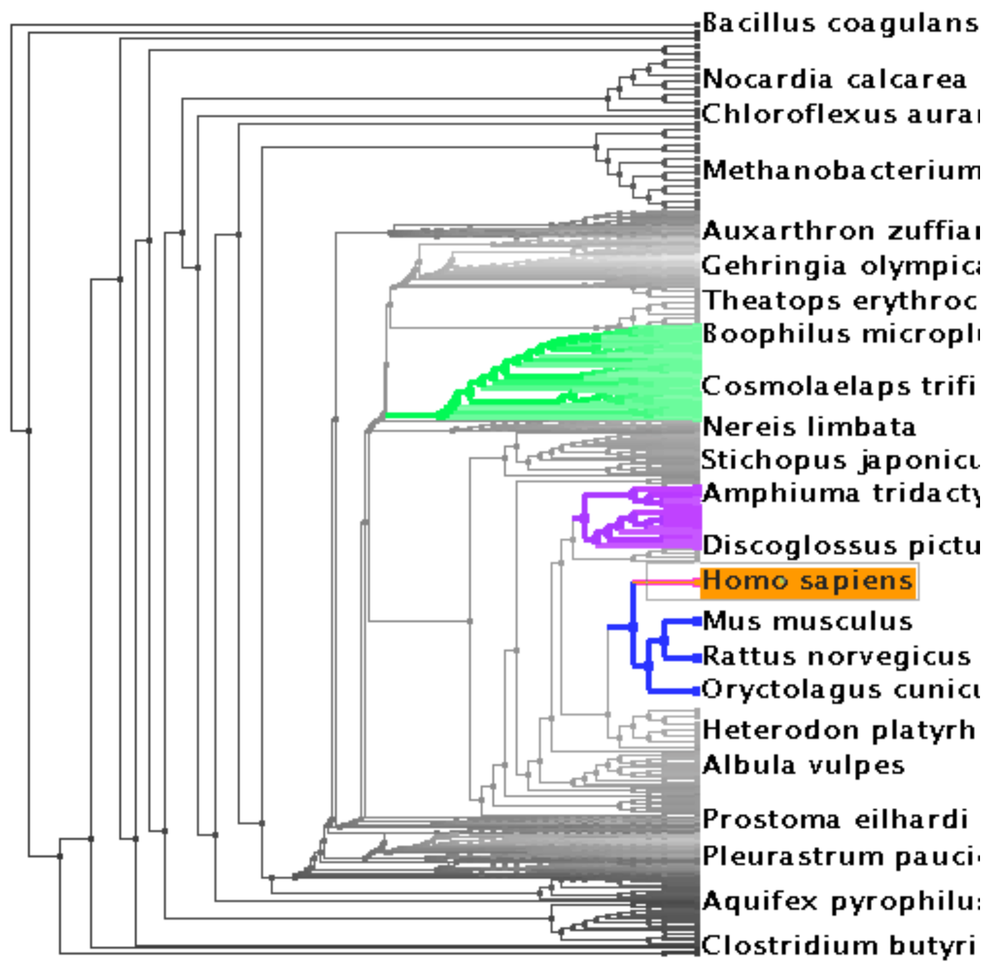


[TreeJuxtaposer, Munzner et al.]

“Idiom” Comparison

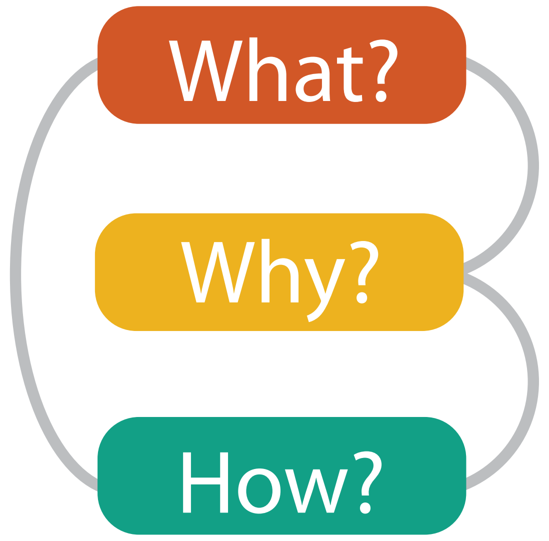
SpaceTree **TreeJuxtaposer**





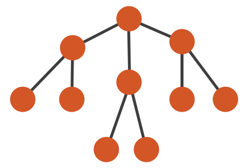
[SpaceTree: Supporting Exploration in Large Node Link Tree, Design Evolution and Empirical Evaluation. Grosjean, Plaisant, and Bederson. Proc. InfoVis 2002, p 57–64.]

[TreeJuxtaposer: Scalable Tree Comparison Using Focus+Context With Guaranteed Visibility. ACM Trans. on Graphics (Proc. SIGGRAPH) 22:453– 462, 2003.]



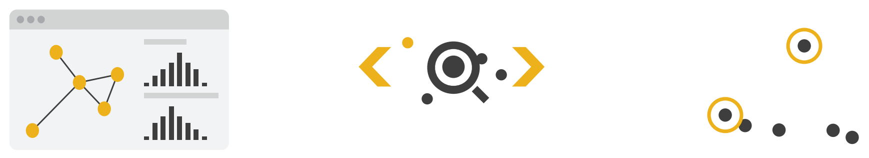
What?

- **Tree**

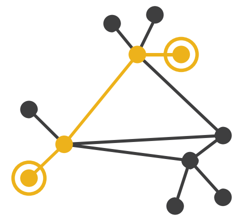


Why?

- **Actions**
  - Present
  - Locate
  - Identify

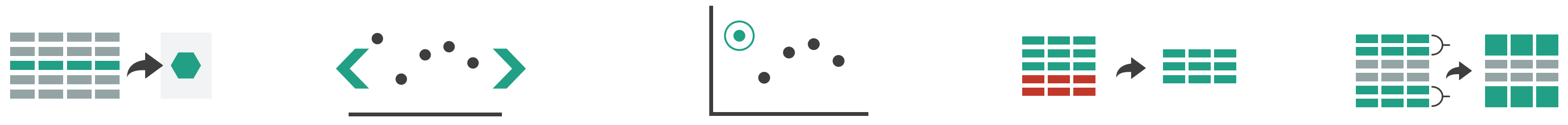


- **Targets**
  - Path between two nodes



How?

- **SpaceTree**
  - Encode
  - Navigate
  - Select
  - Filter
  - Aggregate

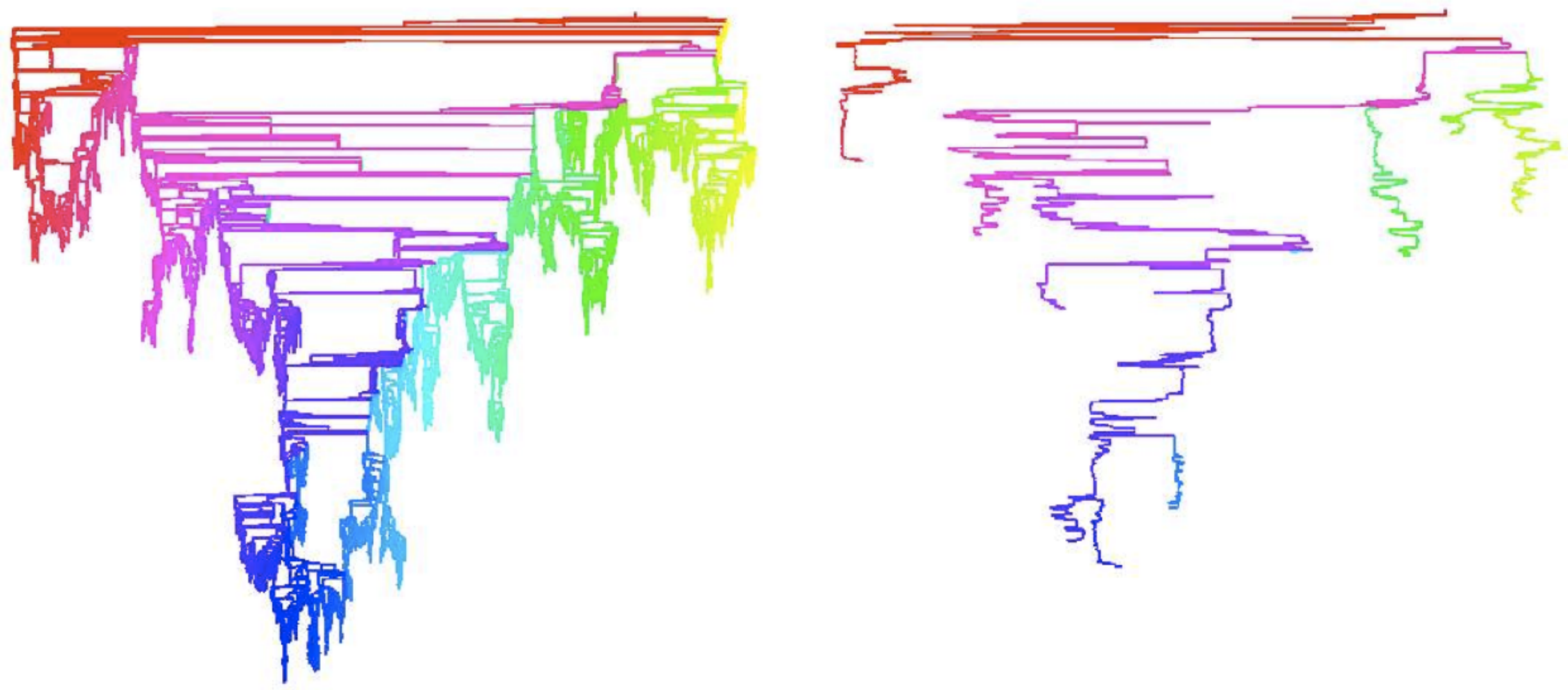


- **TreeJuxtaposer**
  - Encode
  - Navigate
  - Select
  - Arrange

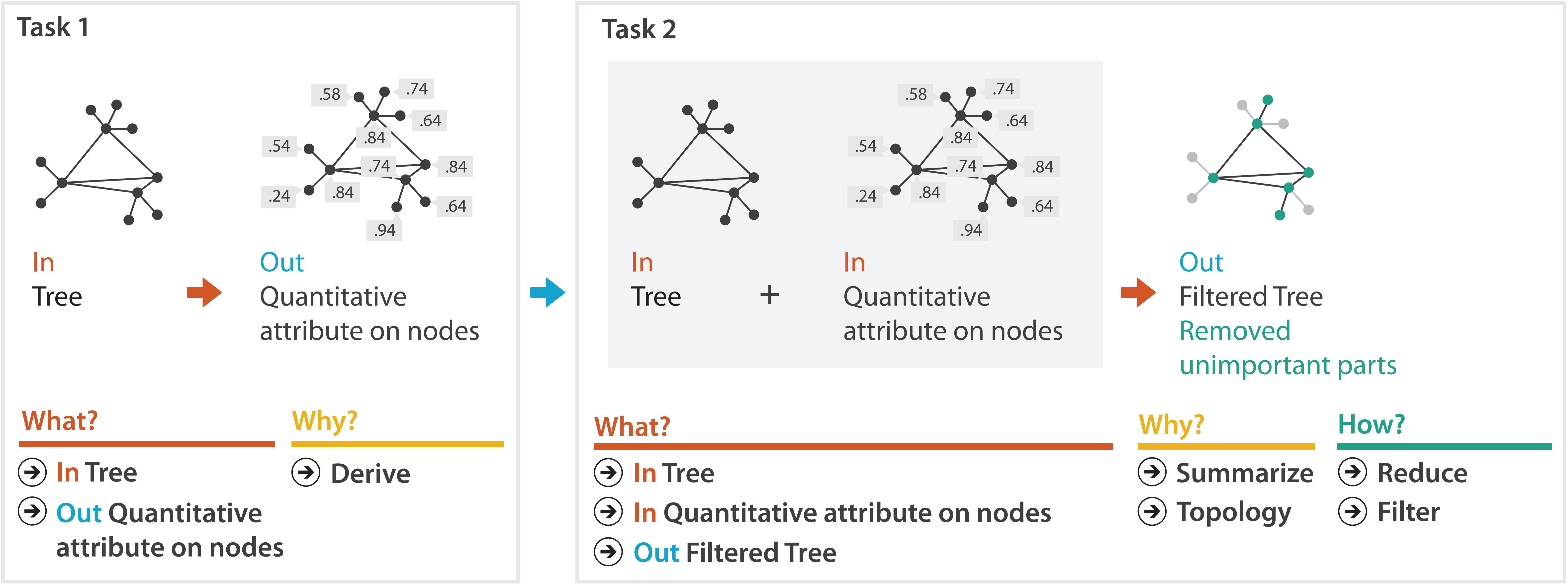
[Munzner (ill. Maguire), 2014]

Analysis Example: Derivation

- Strahler number
  - centrality metric for trees/networks
  - derived quantitative attribute
  - draw top 5K of 500K for good skeleton



[Using Strahler numbers for real time visual exploration of huge graphs. Auber. Proc. Intl. Conf. Computer Vision and Graphics, pp. 56–69, 2002.]



[Munzner (ill. Maguire), 2014]