Visualization for Data Science
CMPT 733

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Outline

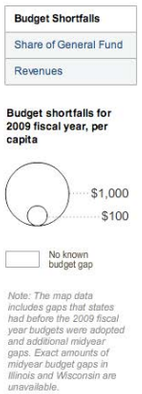
- Visualization: What, Why, and How?
- Motivational examples and goals
- Design principles

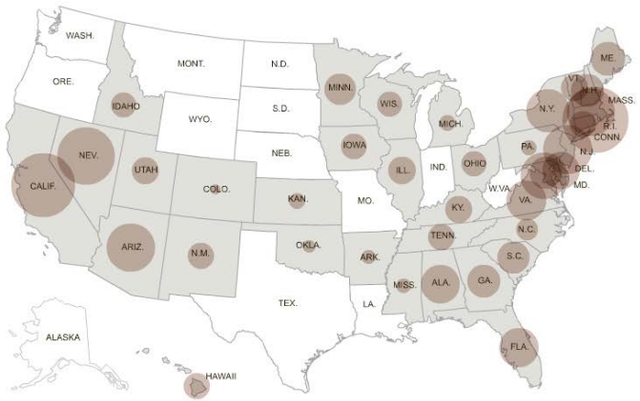
vi·su·al·ize

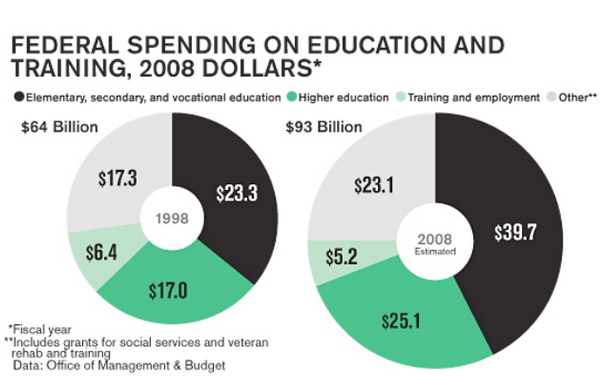
1. To form a mental image of
2. To make visible

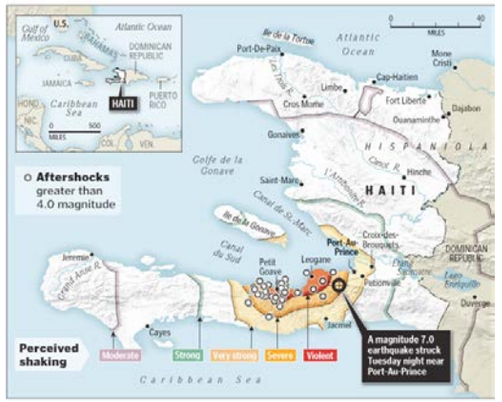
[The American Heritage Dictionary]

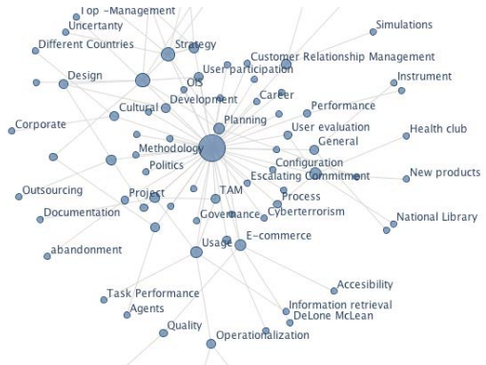
Visualization: To convey information through visual representations

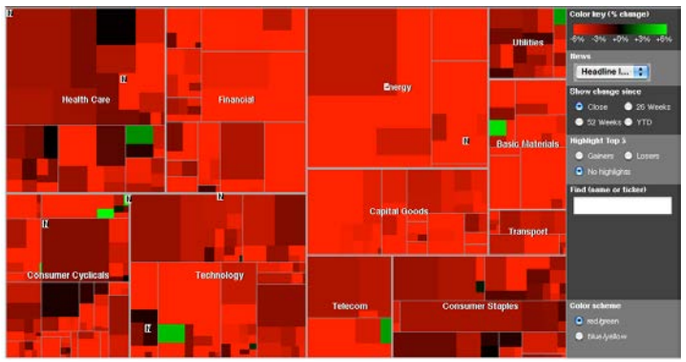


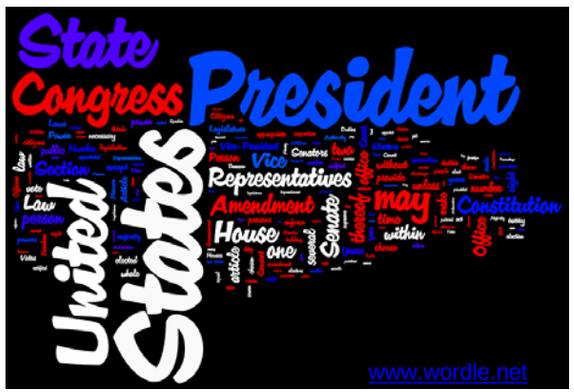






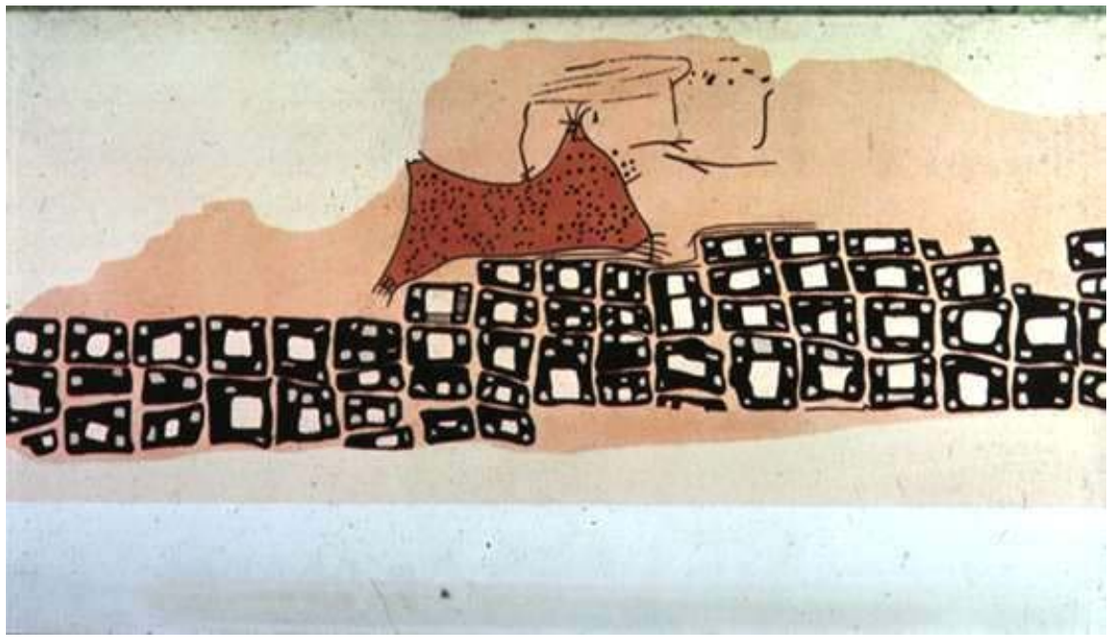






Visualization Goals

Map

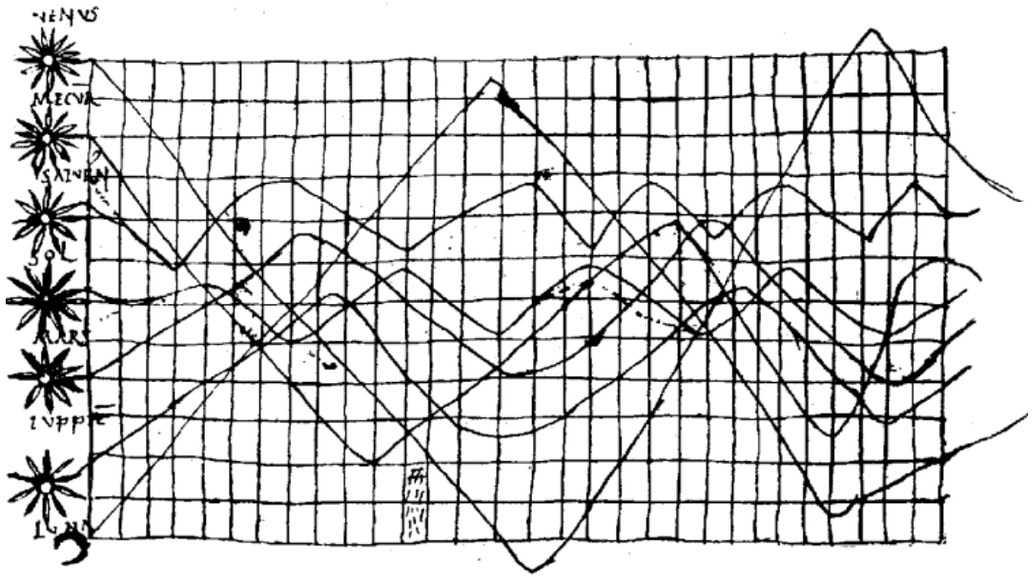


Konya town map, Turkey, c. 6200 BC

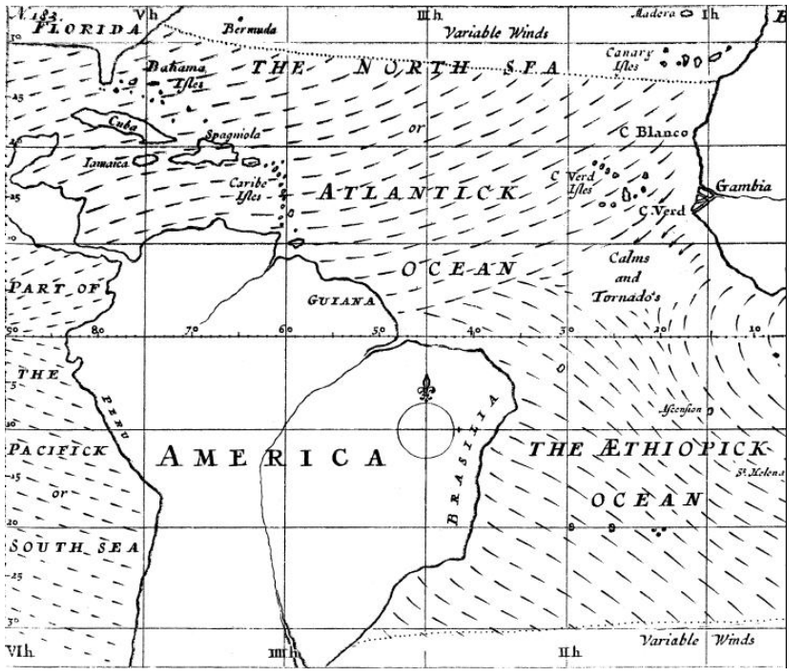
Anaximader's Map of the World

Anaximander of Miletus, c. 550 BC

Map

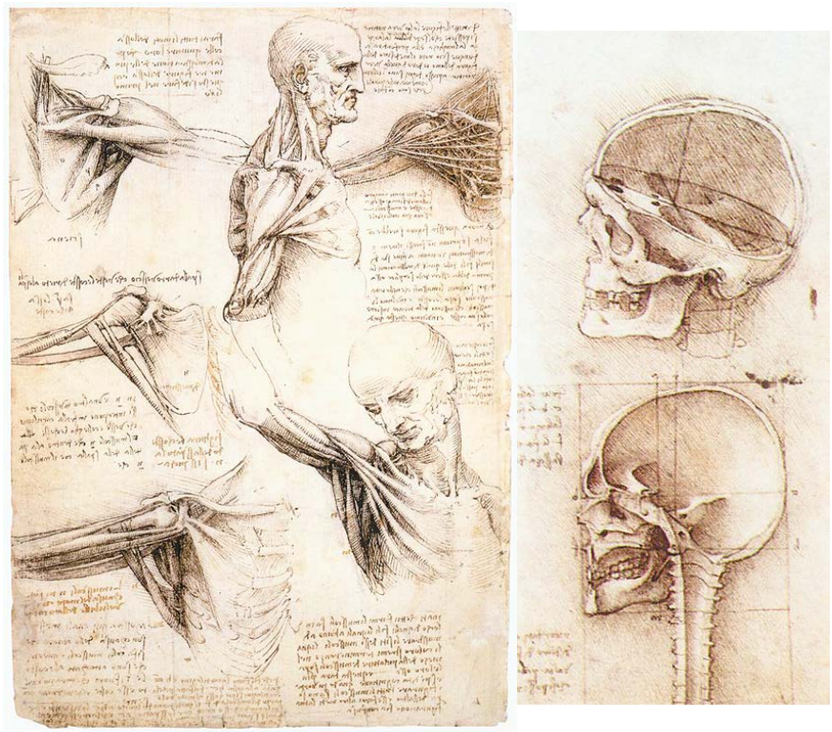


Planetary Movement Diagram, c. 950



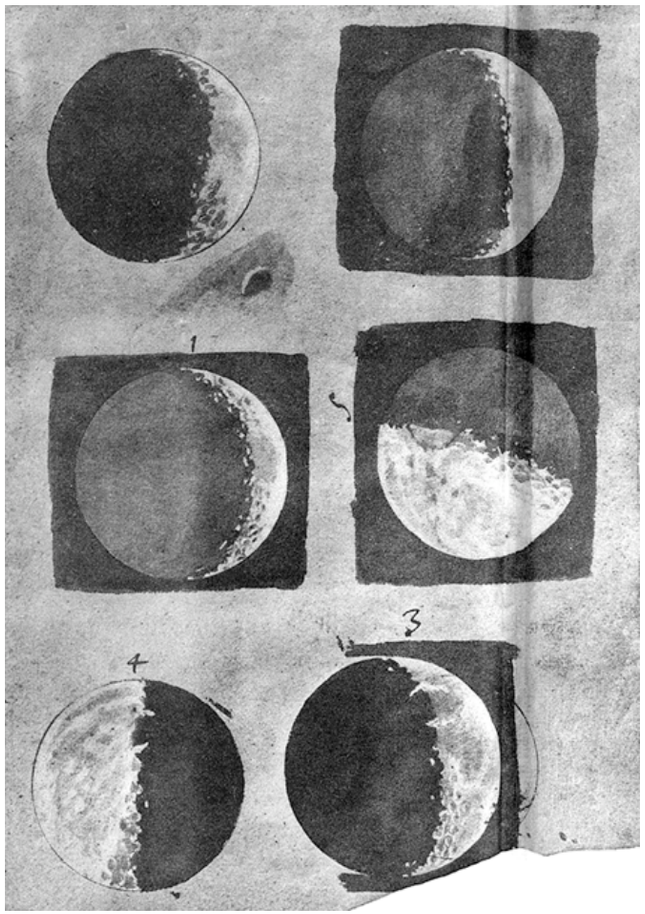
Halley's Wind Map, 1686

Record



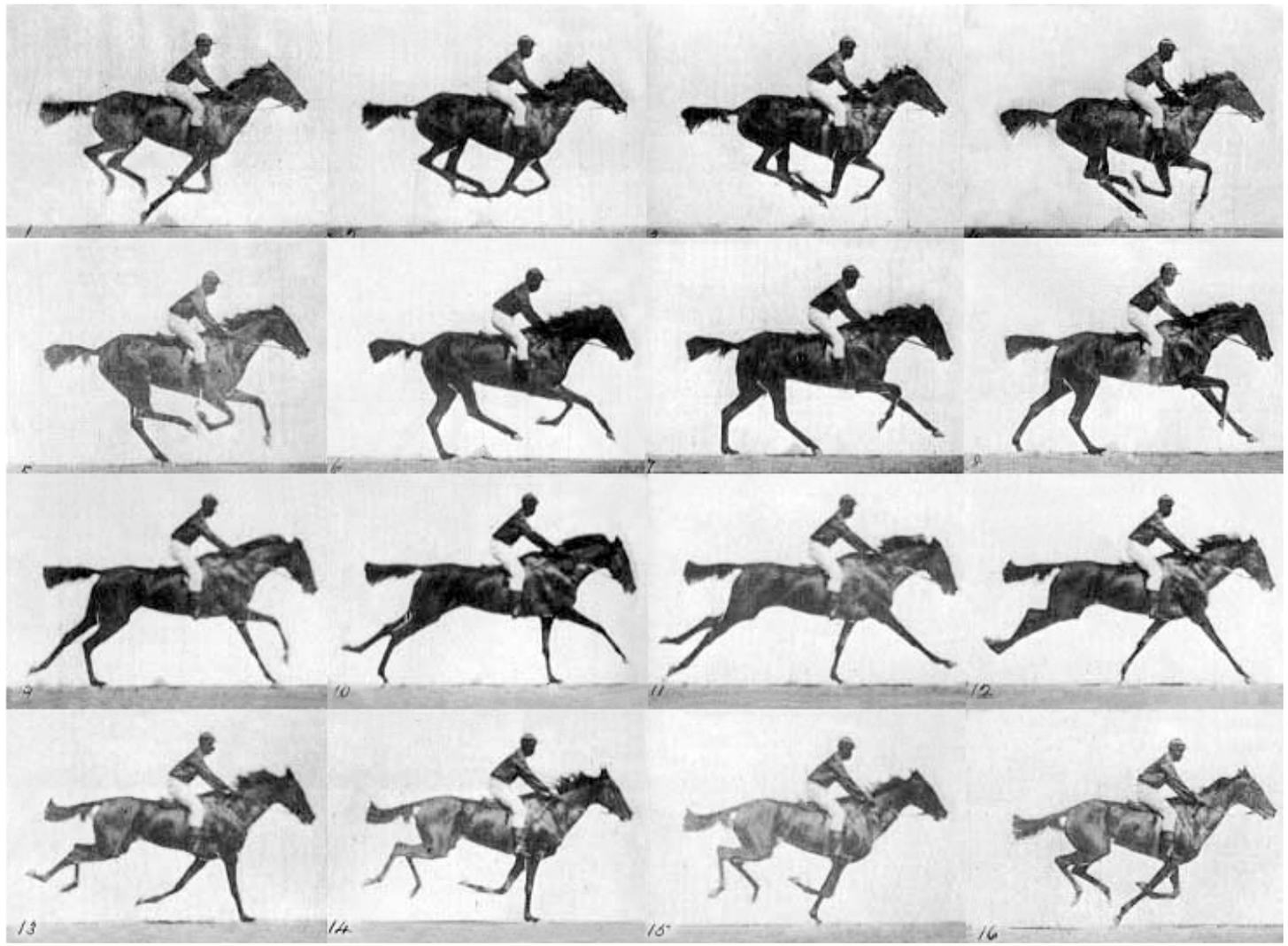
Leonardo Da Vinci, ca. 1500

William Curtis (1746-1799)



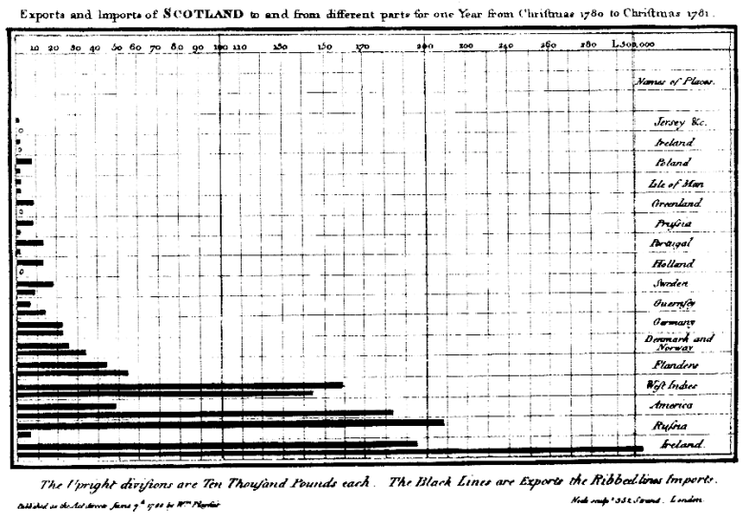
Galileo Galilei, 1616

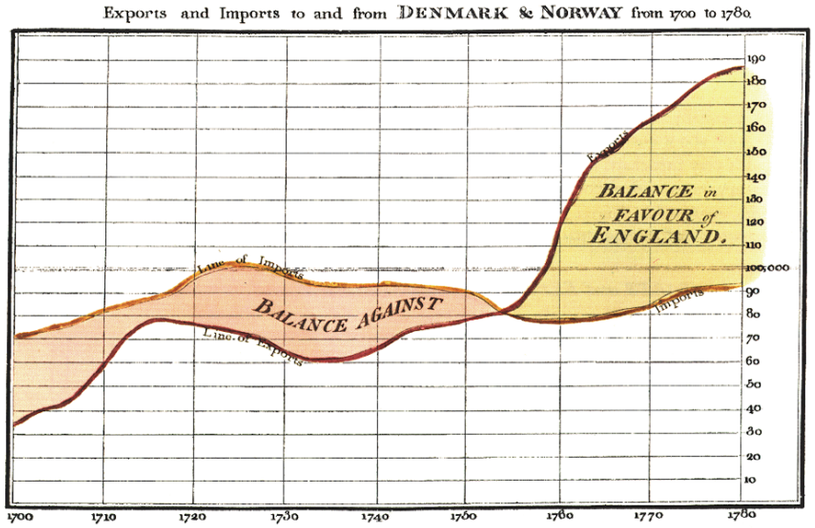
Record



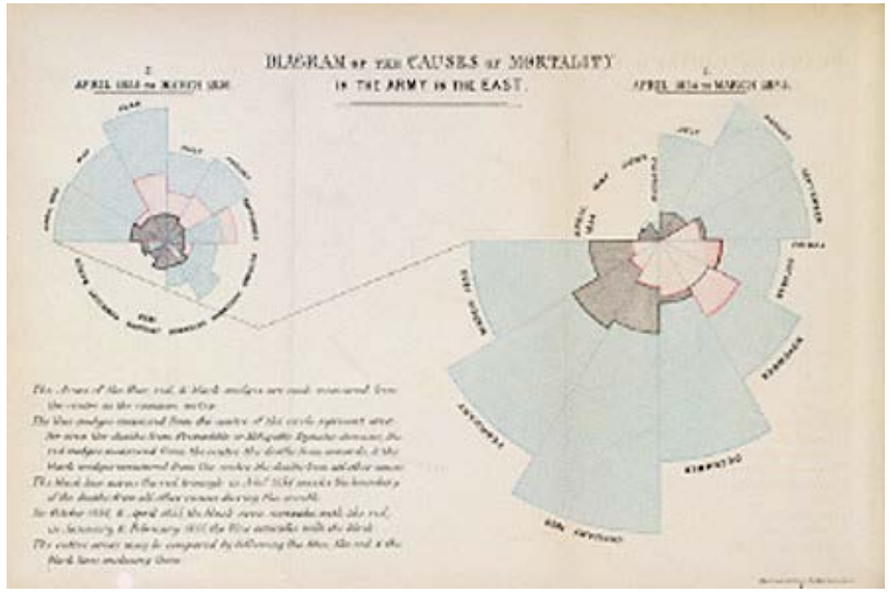
E. J. Muybridge, 1878

Abstract





W. Playfair, 1786

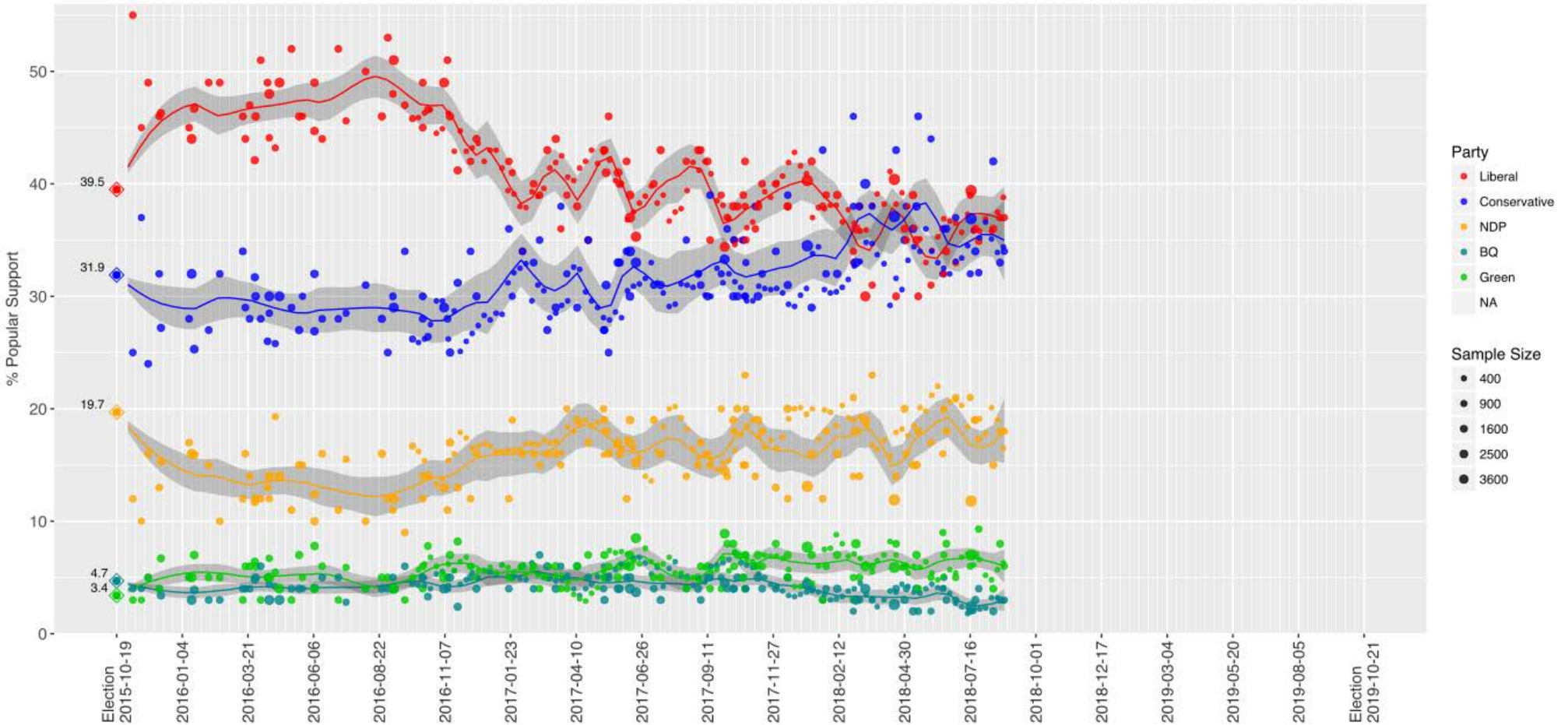


F. Nightingale, 1856

wikipedia.org

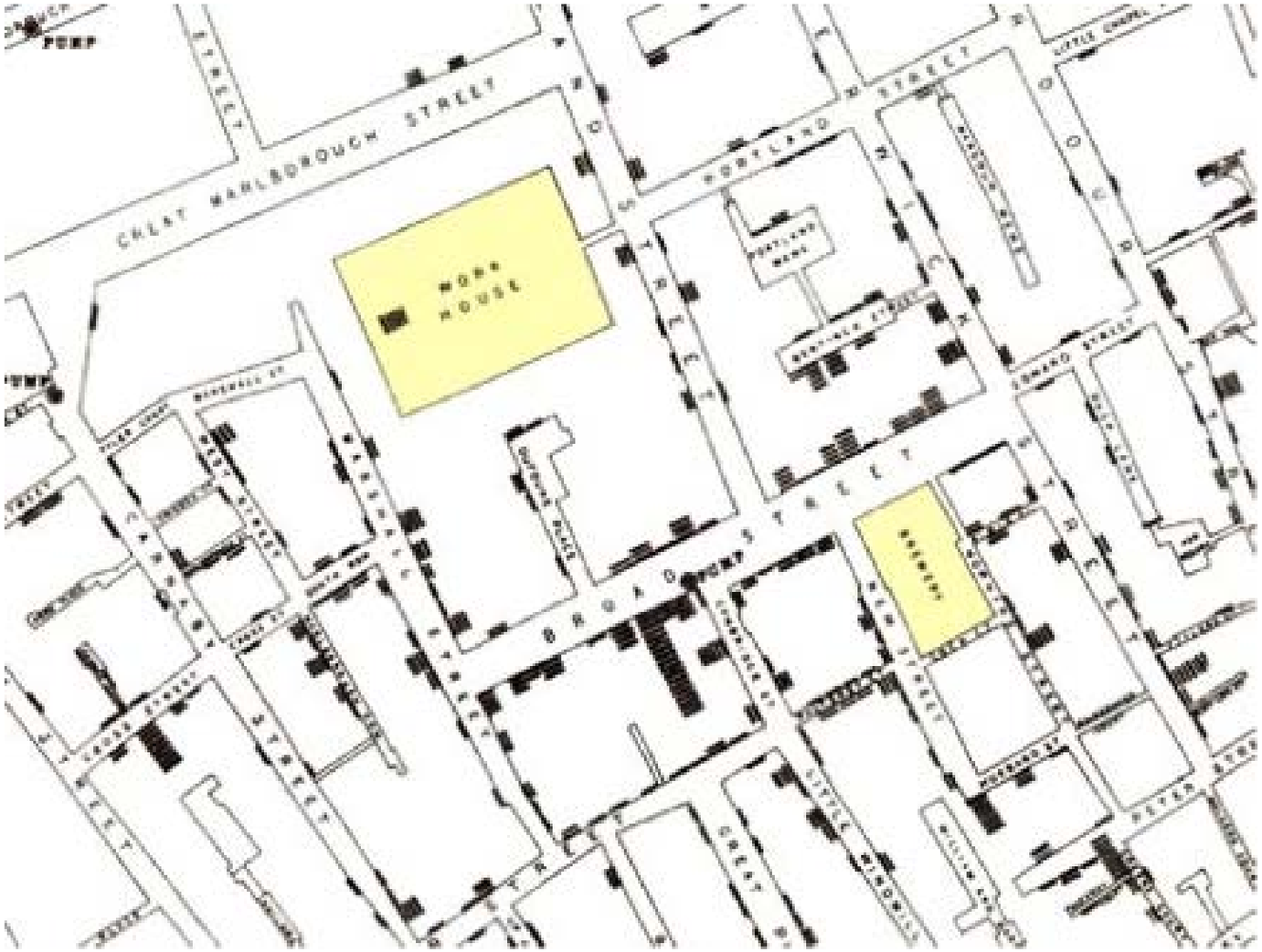
Abstract

Canadian pre-campaign voting intentions for the federal election 2019



wikipedia.org

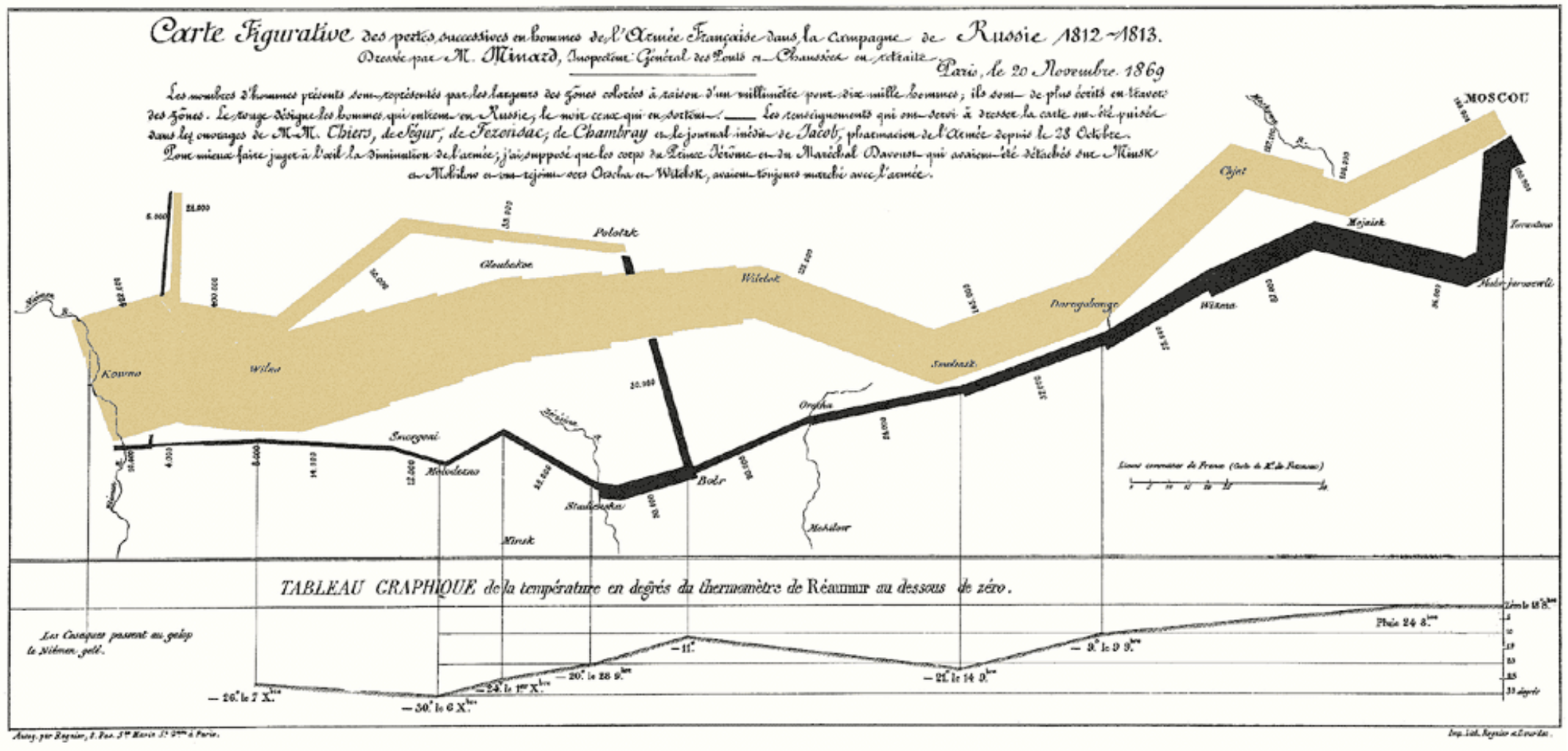
Discover



John Snow, 1854

E. Tufte, Visual Explanations, 1997

Discover



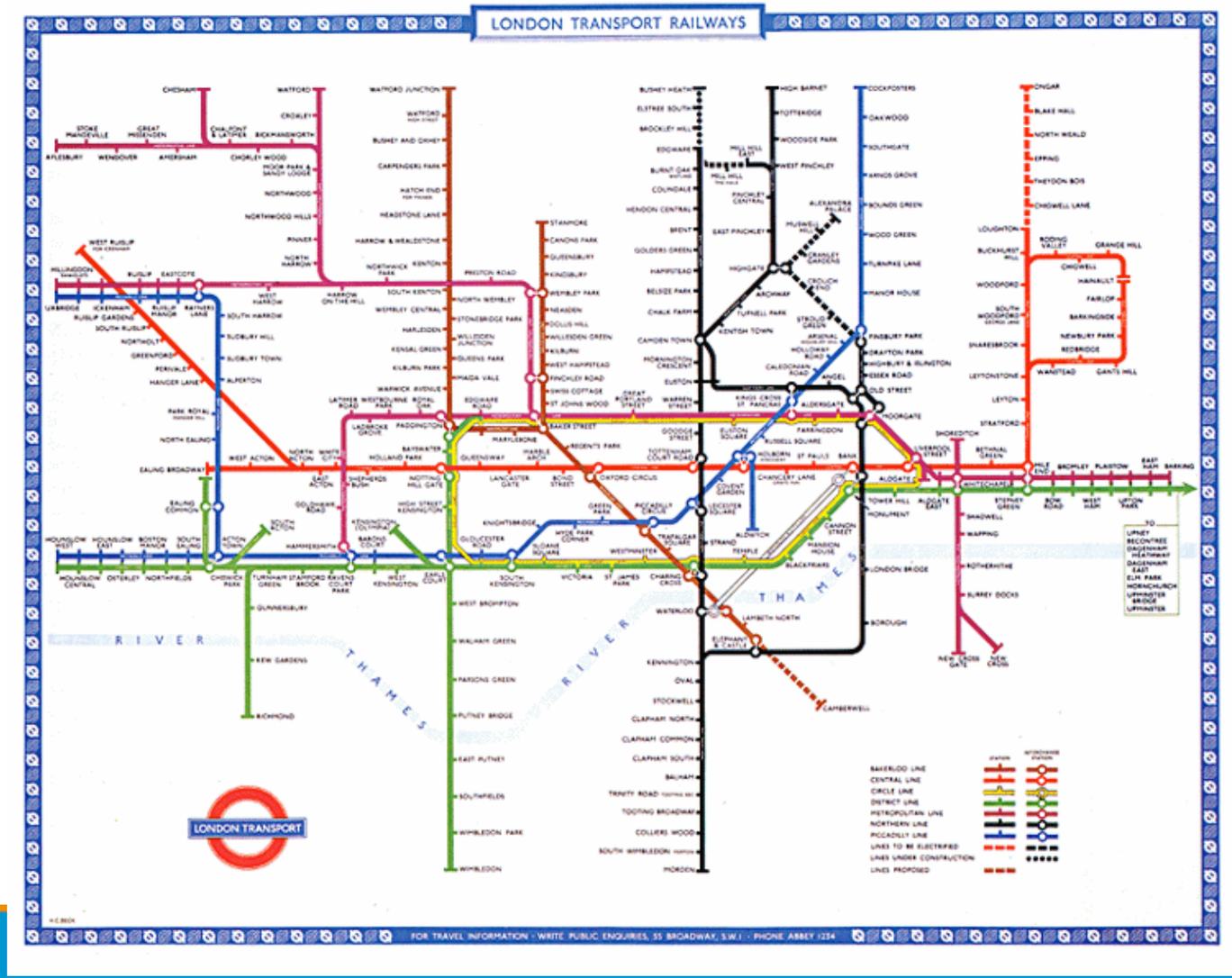
C.J. Minard, 1869

E. Tufte, Writings, Artworks, News

Clarify

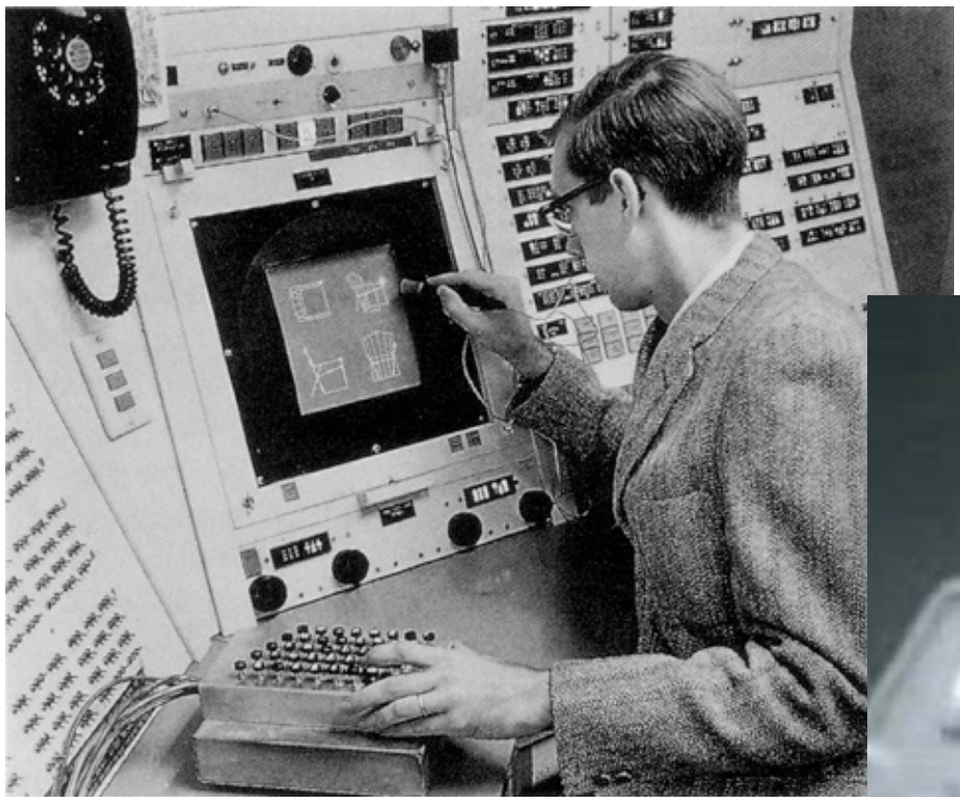
London Subway Map, 1927

Clarify

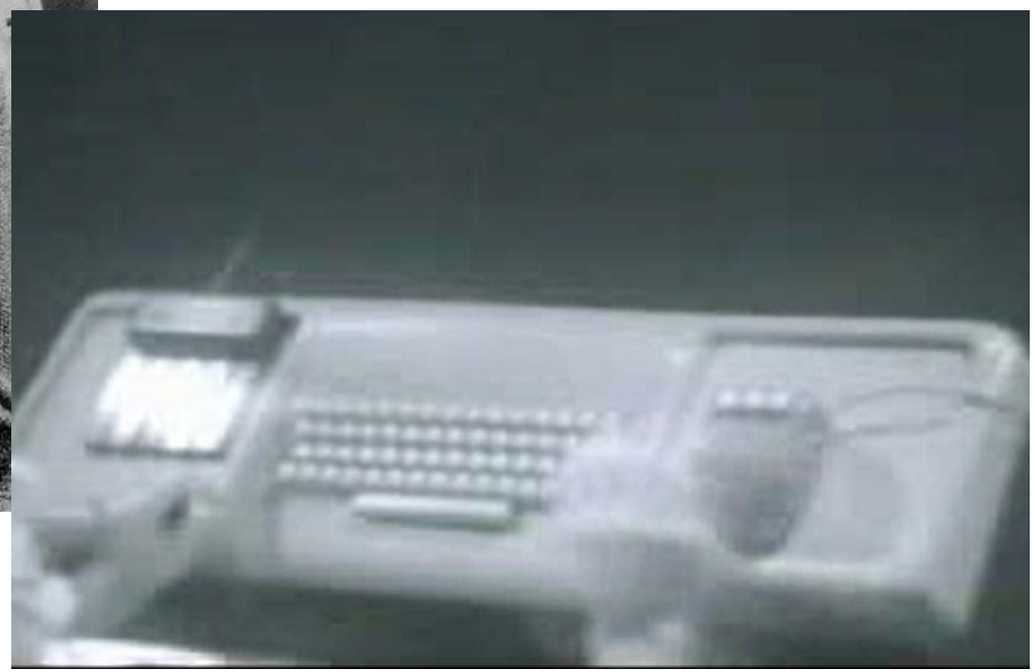


Harry Beck, 1933

Interact



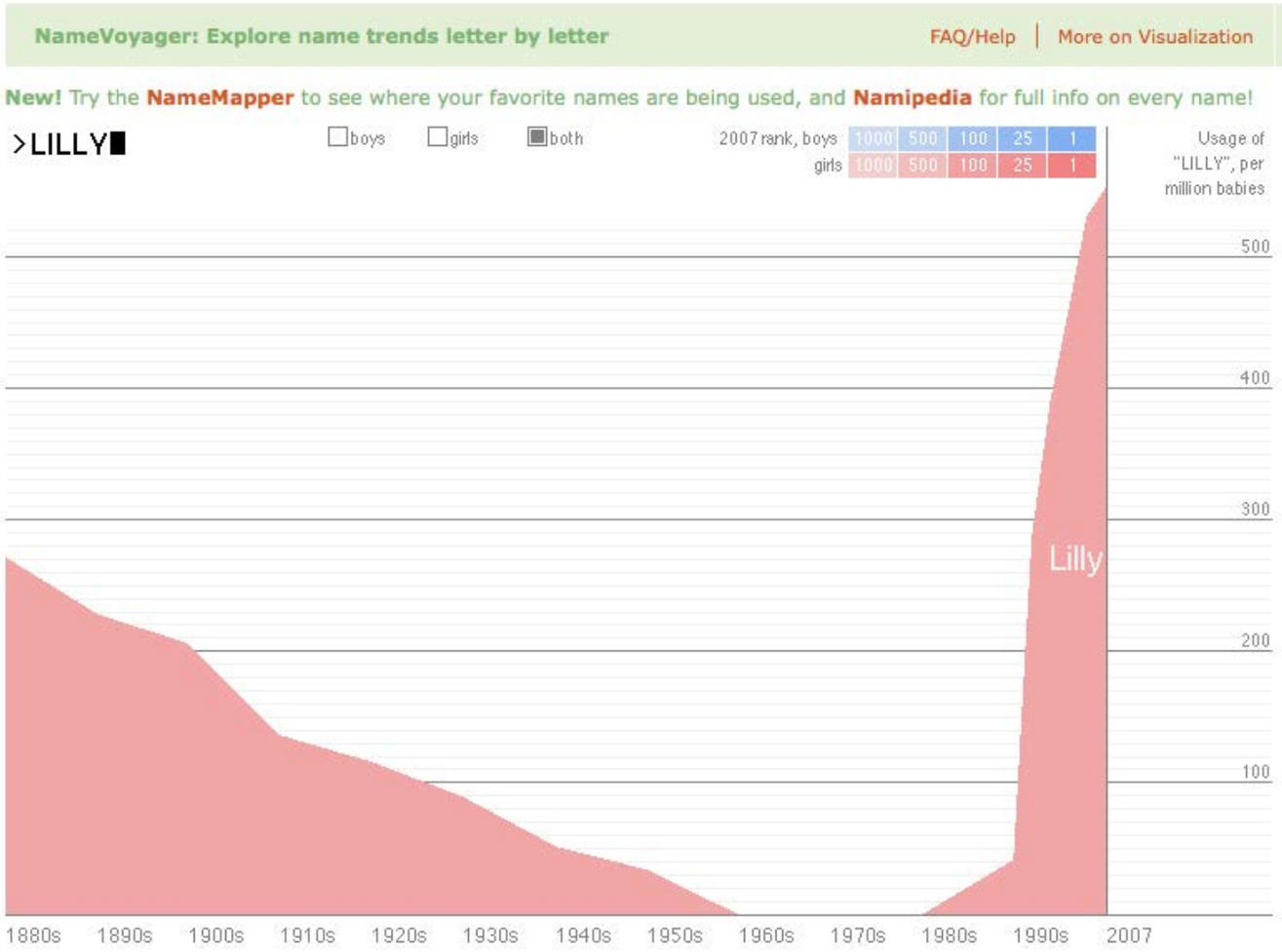
Ivan Sutherland, Sketchpad, 1963



Doug Engelbart, 1968

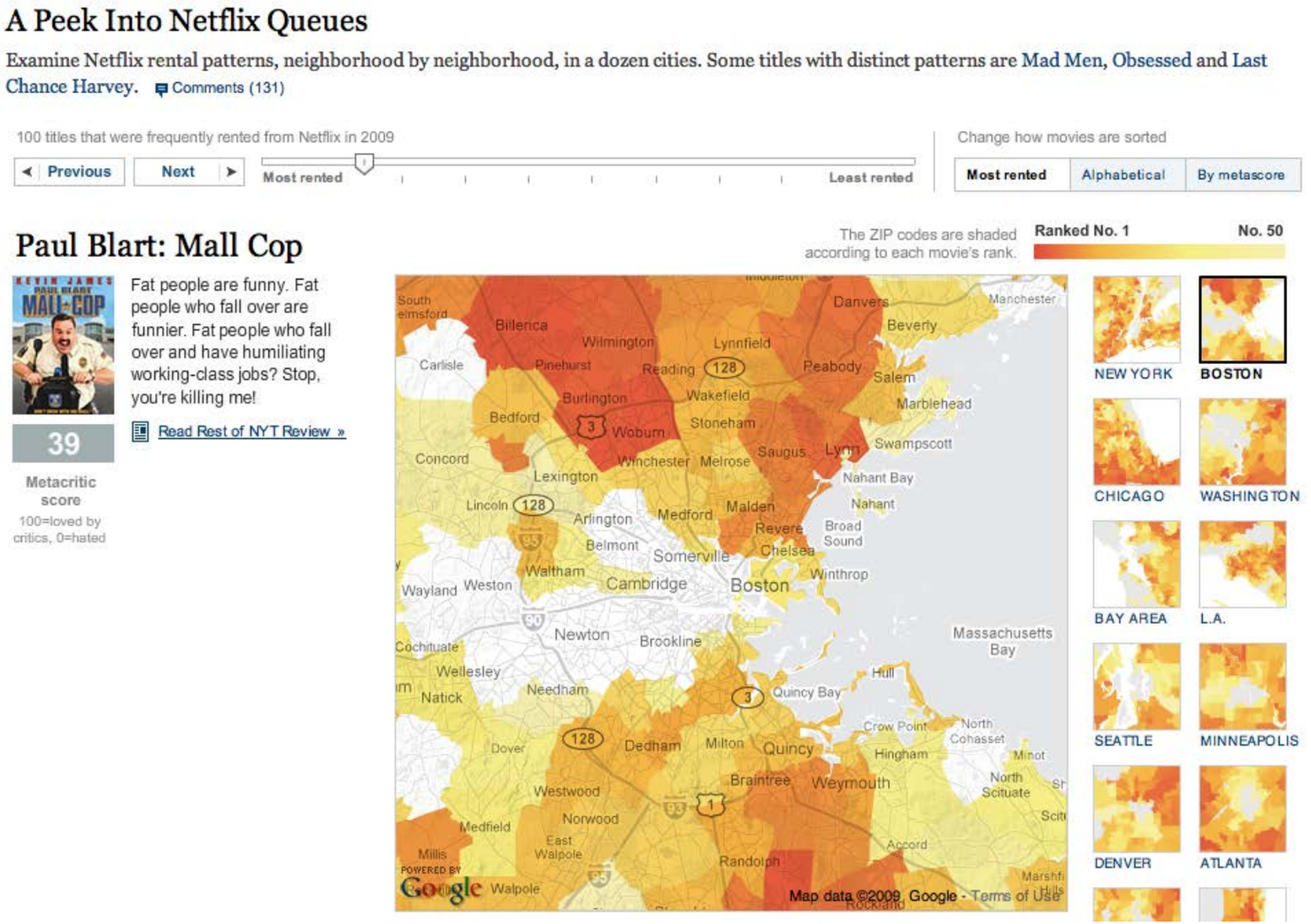
[play Engelbart.mov]

Interact



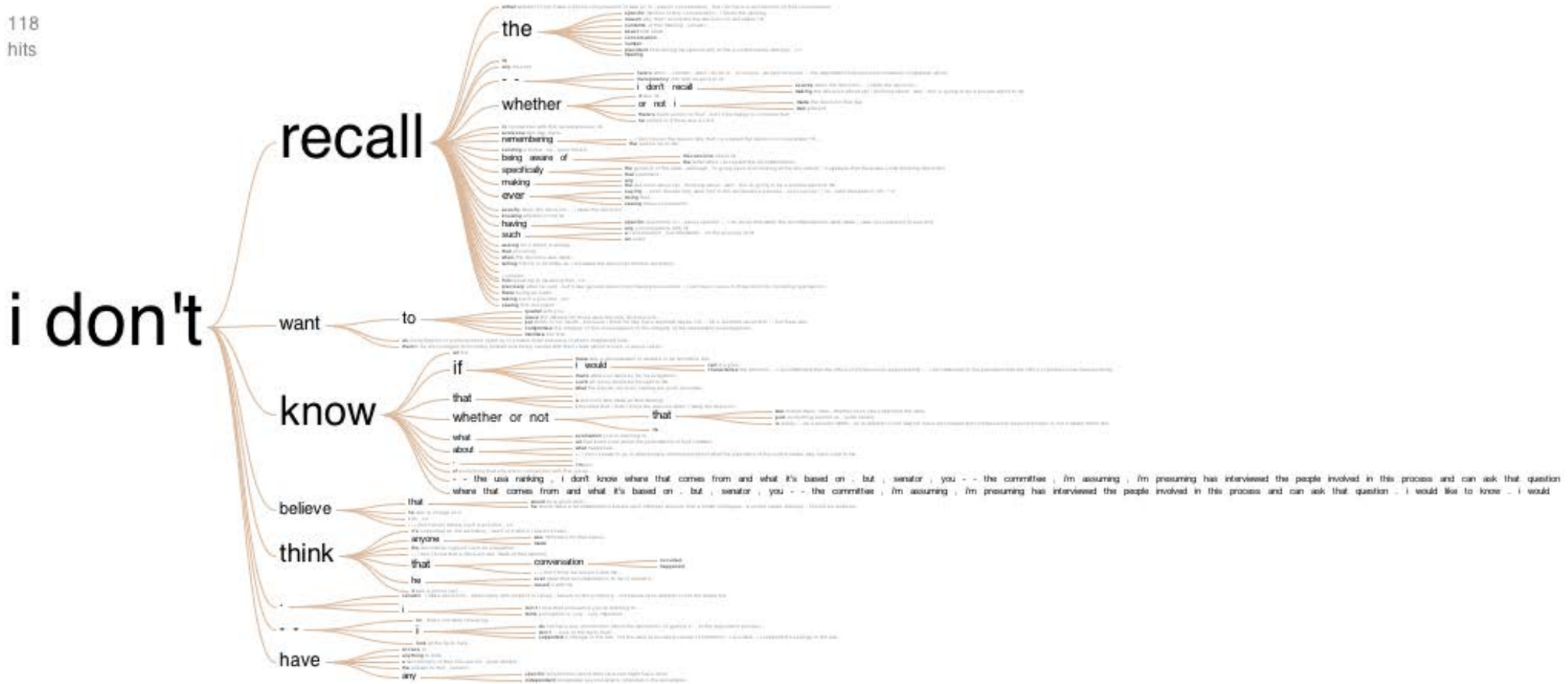
M. Wattenberg, 2005

Interact



NY Times

Communicate



"Many Eyes", M. Wattenberg 2007

Communicate

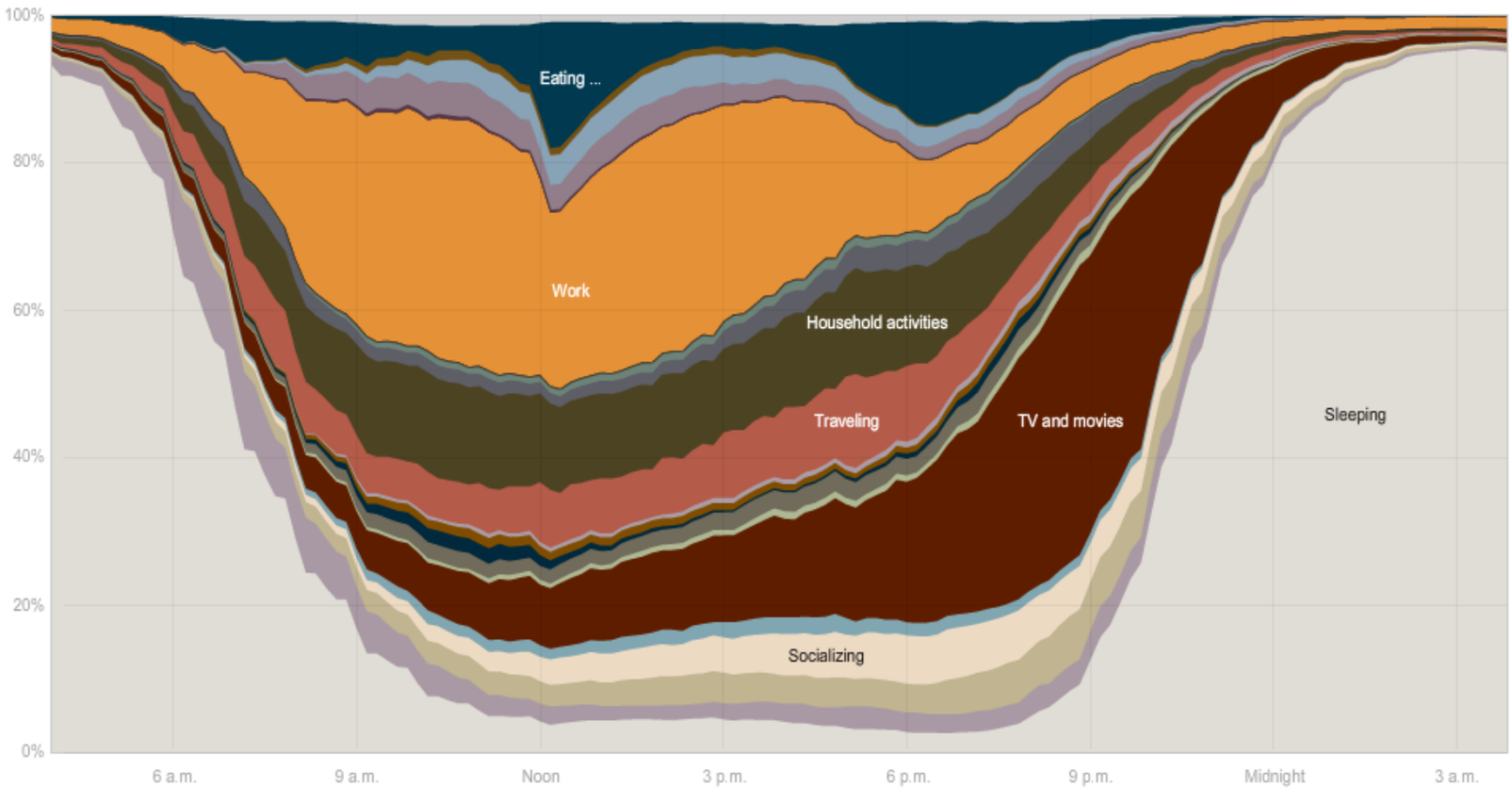
How Different Groups Spend Their Day

The American Time Use Survey asks thousands of American residents to recall every minute of a day. Here is how people over age 15 spent their time in 2008. Related article

Everyone

Sleeping, eating, working and watching television take up about two-thirds of the average day.

Everyone	Employed	White	Age 15-24	H.S. grads	No children
Men	Unemployed	Black	Age 25-64	Bachelor's	One child
Women	Not in lab...	Hispanic	Age 65+	Advanced	Two+ children



NY Times

Inspire / Tell a Story

Hans Rosling, TED 2006

Visualization

- To convey information through visual representations

  Map
  Record
  Abstract
  Discover
  Clarify
  Interact
  Communicate
  Inspire

Goals

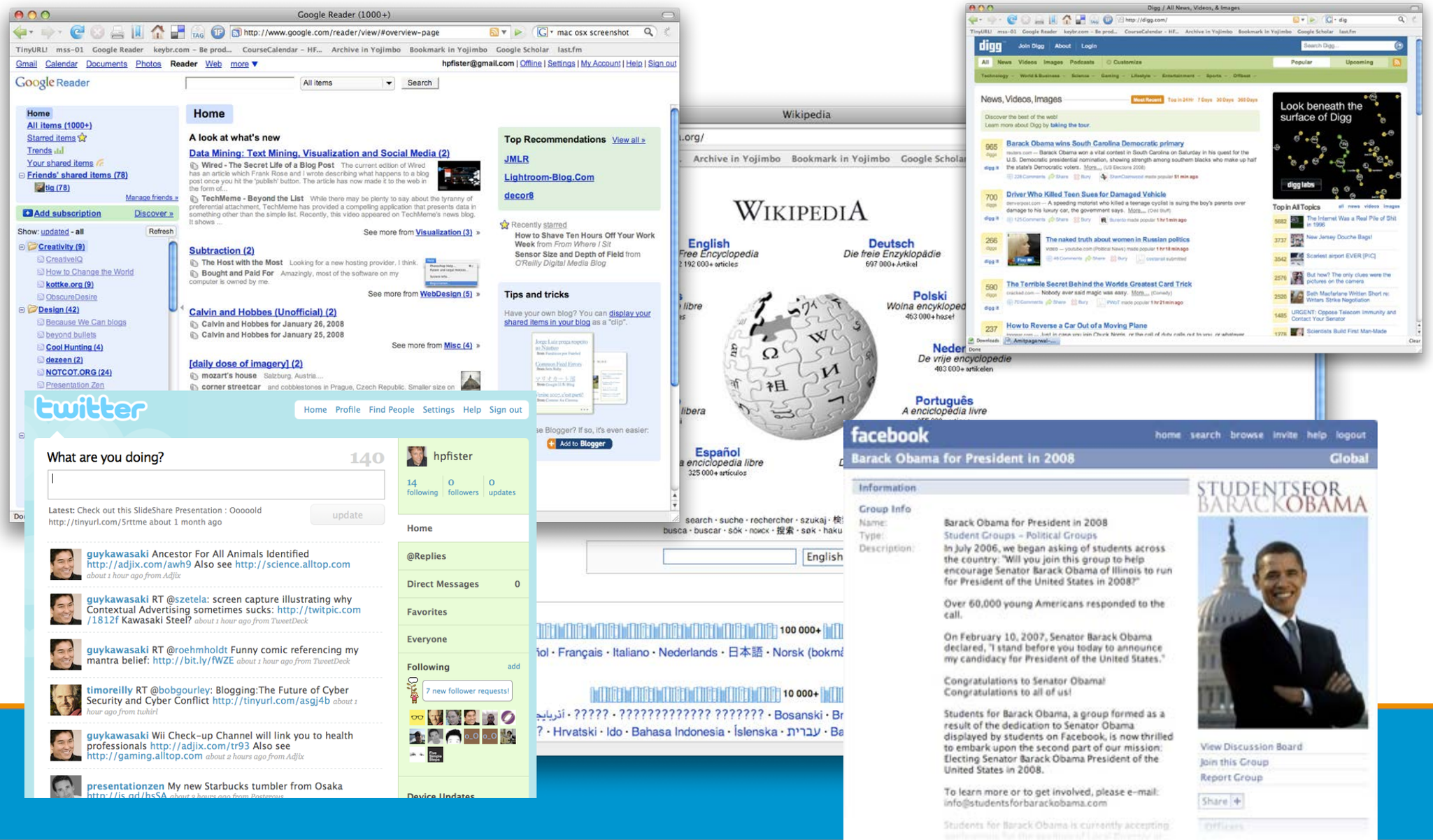
- Insight and analysis
  - Extract the information content
  - Make things and relationships visible
  - Analyze the data by means of the visual representation
- Communication
  - Allow the non–expert to understand
  - Guide the expert into the right direction
- Exploration
  - Interactive control
  - Use visual representation to understand the phenomena

- “The purpose of computing is insight not numbers” (Hamming 1962)

What is Visualization?

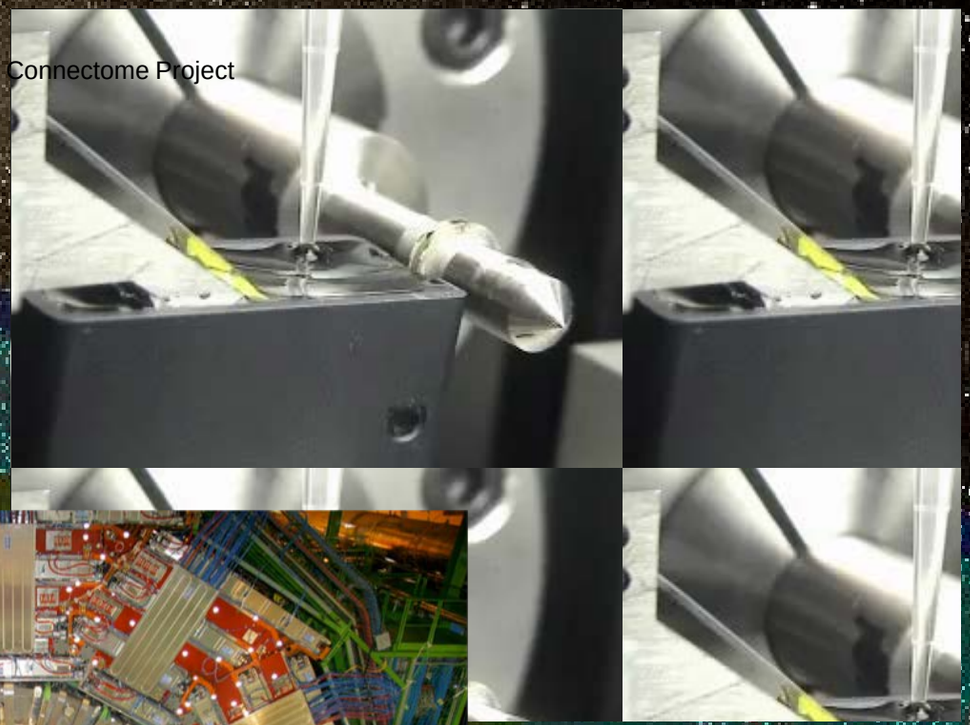
- What?
- Why?
- Who?
- How?

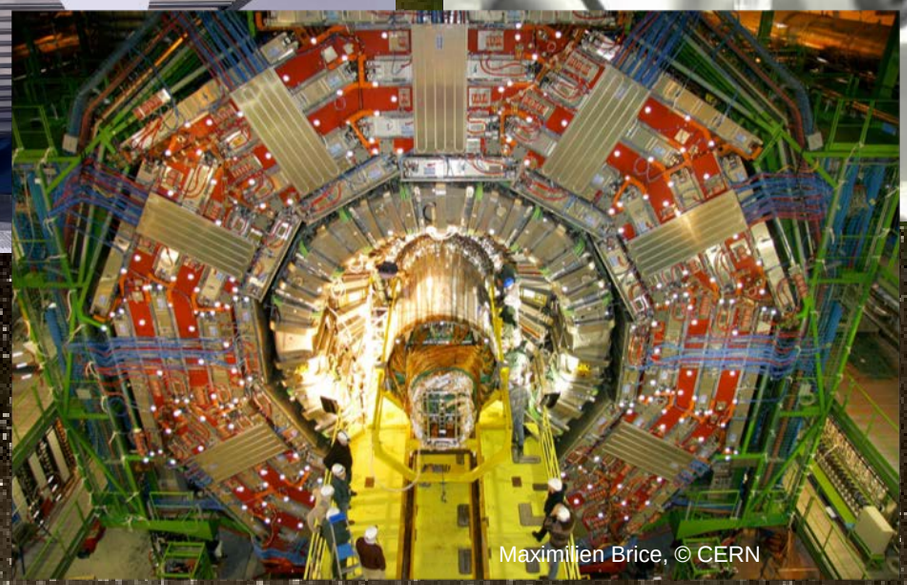
Information Explosion / Big Data



Instrument Data Explosion


Sloan Digital Sky Survey


ATLUM / Connectome Project


Maximilien Brice, © CERN

“The Industrial Revolution of Data”

Joe Hellerstein, UC Berkeley

Limits of Cognition

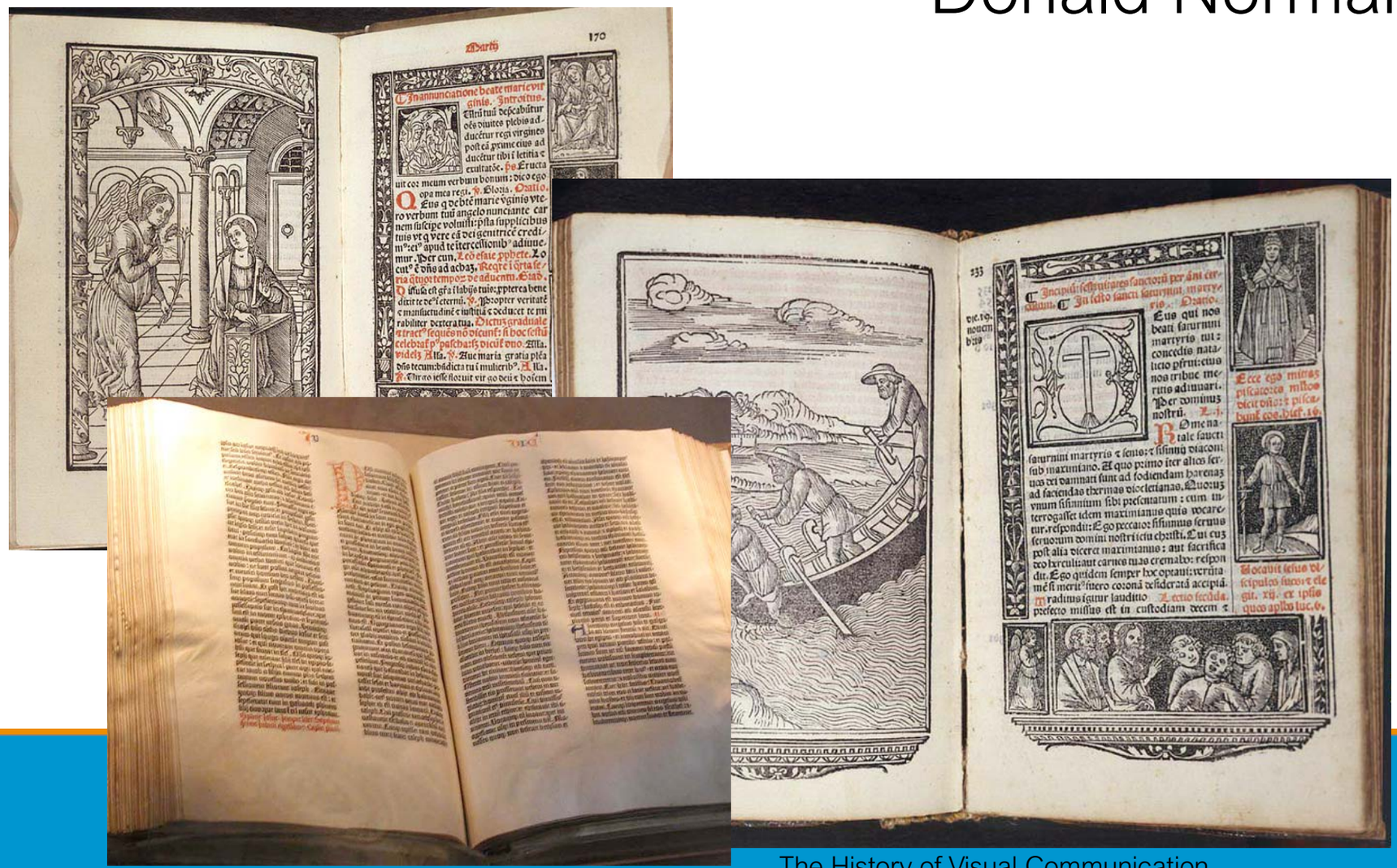
Daniel J. Simons and Daniel T. Levin, Failure to detect changes to people during a real world interaction, 1998

“It is things that make us smart.”

Donald Norman

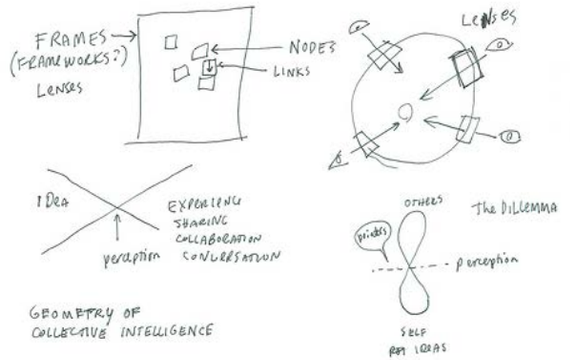
“It is things that make us smart.”

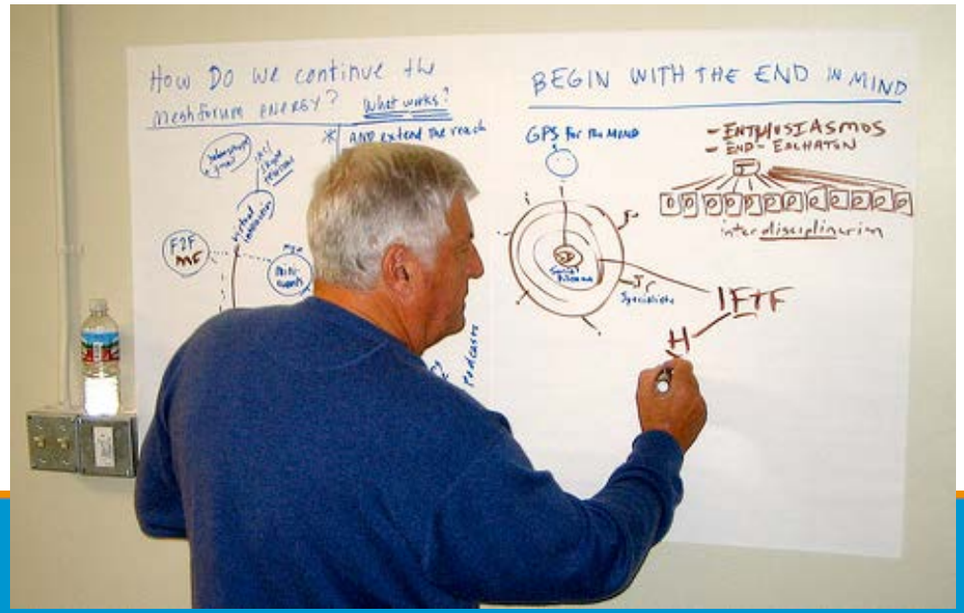
Donald Norman



“It is things that make us smart.”

Donald Norman





Visual Thinking Collection, Dave Grey

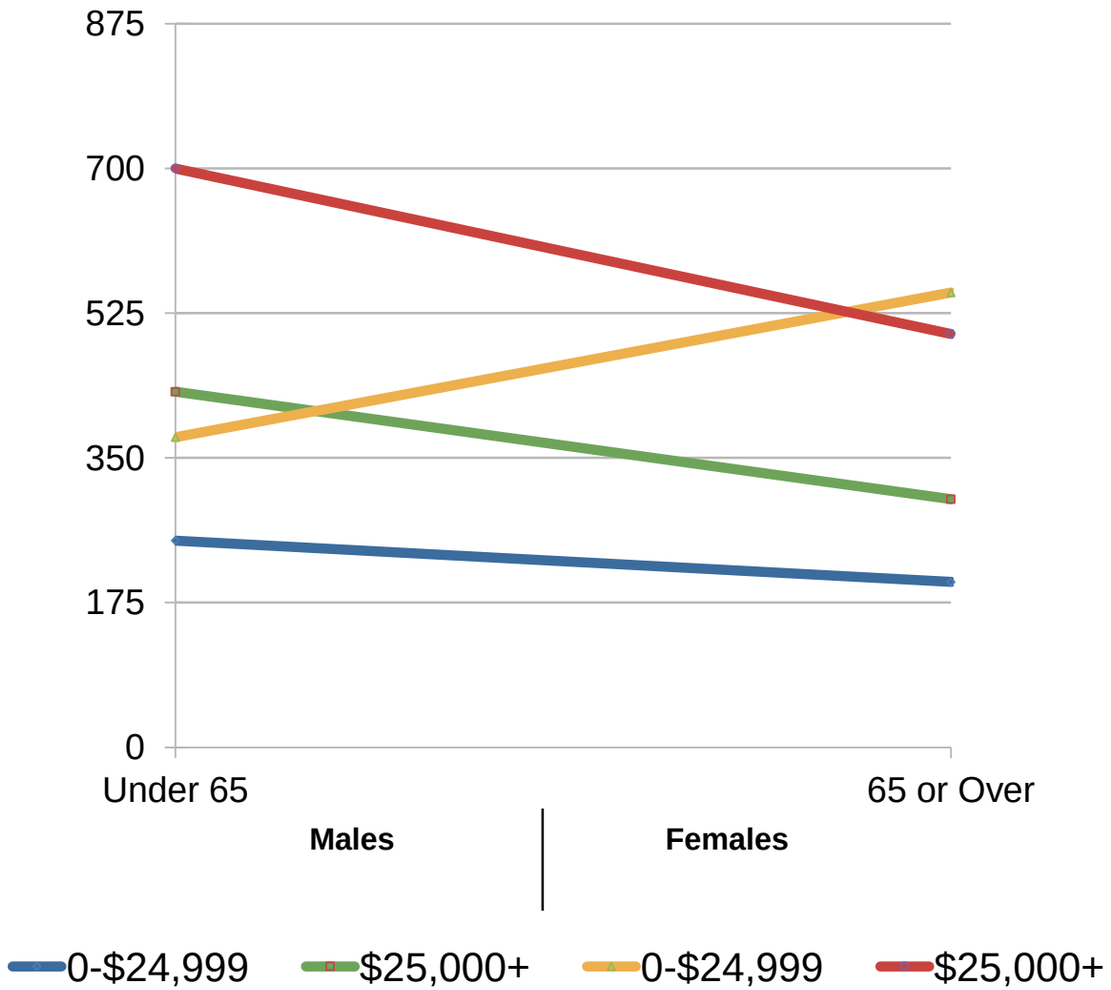
Idea Maps, by Jamie Nast

Mental Queries

Which gender or income level group shows different effects of age on triglyceride levels?

	Males		**Females**	
Income Group	Under 65	65 or Over	Under 65	65 or Over
0-$24,999	250	200	375	550
$25,000+	430	300	700	500

Visual Queries

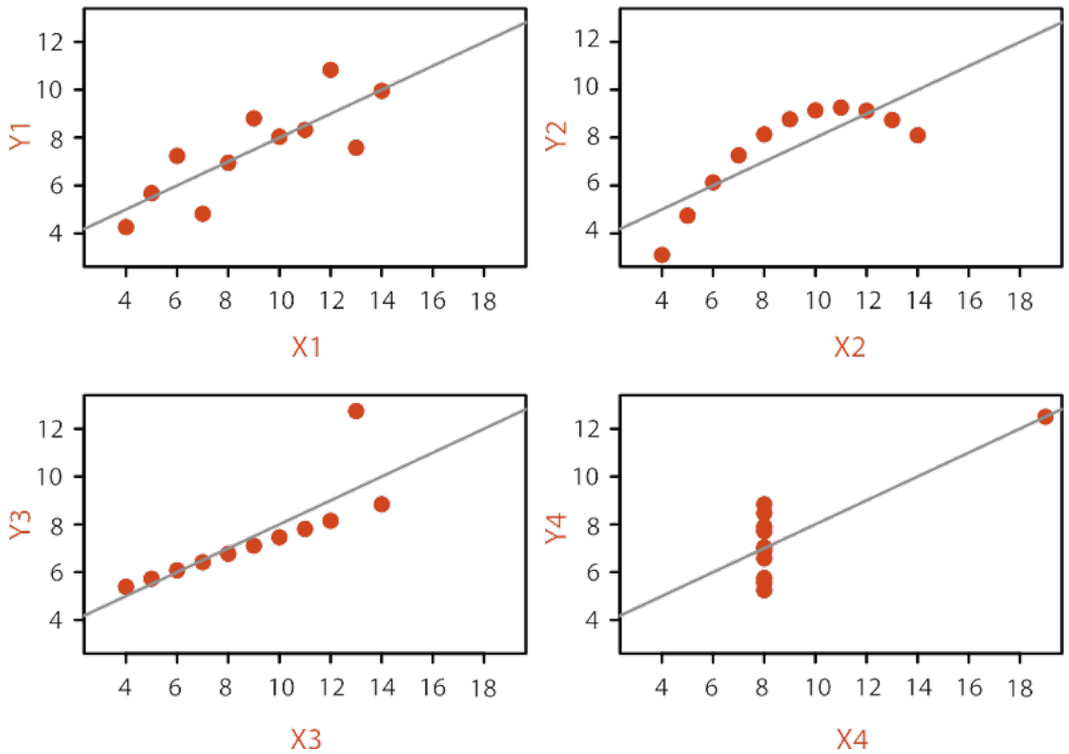


Slide after Stephen Kosslyn, Clear and to the Point

Visualization

- Helps us think
- Reduces load on working memory
- Offloads cognition
- Uses the power of human perception

Why use an external representation?

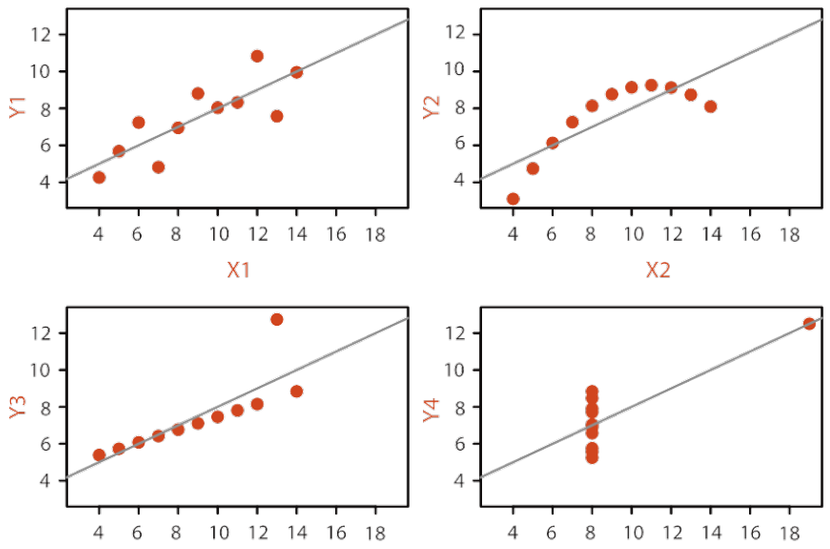


- Replace cognition with perception

	I		II		III		IV	
	x	y	x	y	x	y	x	y
	10	8,04	10	9,14	10	7,46	8	6,58
	8	6,95	8	8,14	8	6,77	8	5,76
	13	7,58	13	8,74	13	12,74	8	7,71
	9	8,81	9	8,77	9	7,11	8	8,84
	11	8,33	11	9,26	11	7,81	8	8,47
	14	9,96	14	8,1	14	8,84	8	7,04
	6	7,24	6	6,13	6	6,08	8	5,25
	4	4,26	4	3,1	4	5,39	19	12,5
	12	10,84	12	9,13	12	8,15	8	5,56
	7	4,82	7	7,26	7	6,42	8	7,91
	5	5,68	5	4,74	5	5,73	8	6,89
SUM	99,00	82,51	99,00	82,51	99,00	82,50	99,00	82,51
AVG	9,00	7,50	9,00	7,50	9,00	7,50	9,00	7,50
STDEV	3,32	2,03	3,32	2,03	3,32	2,03	3,32	2,03

[F. J. Anscombe, 1973]

Why represent all the data?



I		II		III		IV	
x	y	x	y	x	y	x	y
10	8,04	10	9,14	10	7,46	8	6,58
8	6,95	8	8,14	8	6,77	8	5,76
13	7,58	13	8,74	13	12,74	8	7,71
9	8,81	9	8,77	9	7,11	8	8,84
11	8,33	11	9,26	11	7,81	8	8,47
14	9,96	14	8,1	14	8,84	8	7,04
6	7,24	6	6,13	6	6,08	8	5,25
4	4,26	4	3,1	4	5,39	19	12,5
12	10,84	12	9,13	12	8,15	8	5,56
7	4,82	7	7,26	7	6,42	8	7,91
5	5,68	5	4,74	5	5,73	8	6,89
SUM	99,00	82,51	99,00	82,51	99,00	82,50	99,00	82,51
AVG	9,00	7,50	9,00	7,50	9,00	7,50	9,00	7,50
STDEV	3,32	2,03	3,32	2,03	3,32	2,03	3,32	2,03

- Summaries lose information, details matter
  - Confirm expected and find unexpected patterns
  - Assess validity of statistical model

Defining Visualization (Vis)

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

["Visualization Analysis and Design" by T. Munzner, 2014]

Why have a human in the loop?

- Not needed when automatic solution is trusted
- Good for ill-specified anlaysis problems
  - Common setting: "What questions can we ask?"

Why have a human in the loop?

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

Munzner, T. (2014)

Long-term use

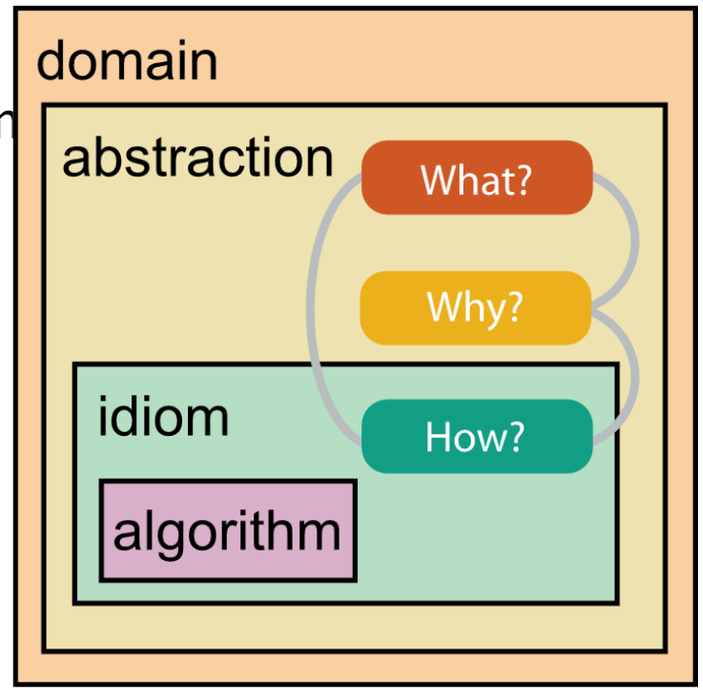
- Exploratory analysis of scientific data
- Presentation of known results

Short-term use

- For **developers** of automatic solutions:
  - Understand requirements for model development
  - Refine/debug and determine parameters
- For **end users** of automatic solutions: verify, build trust

Analysis framework: four *levels*

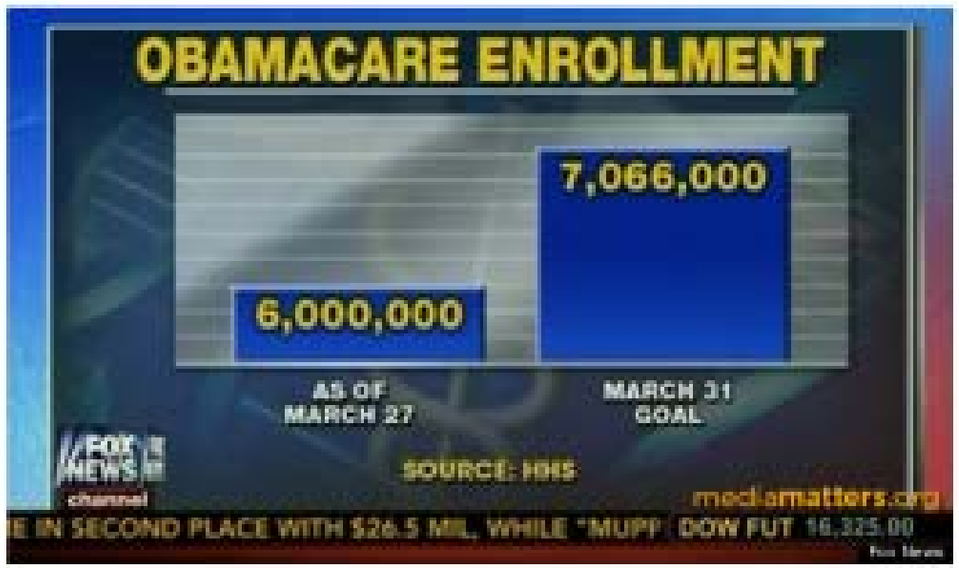
- ***Domain*** situation: Who are the target users?
- ***Abstraction***: Translate from specifics of domain to vocabulary of vis
- **What** is shown? *Data abstraction*
  - Don't just draw what you're given: transform to new form
- **Why** is the user looking at it? *Task abstraction*
- **How** is it shown? ***Idiom***
  - Visual encoding idiom: How to draw
  - Interaction idiom: How to manipulate
- ***Algorithm***: efficient computation



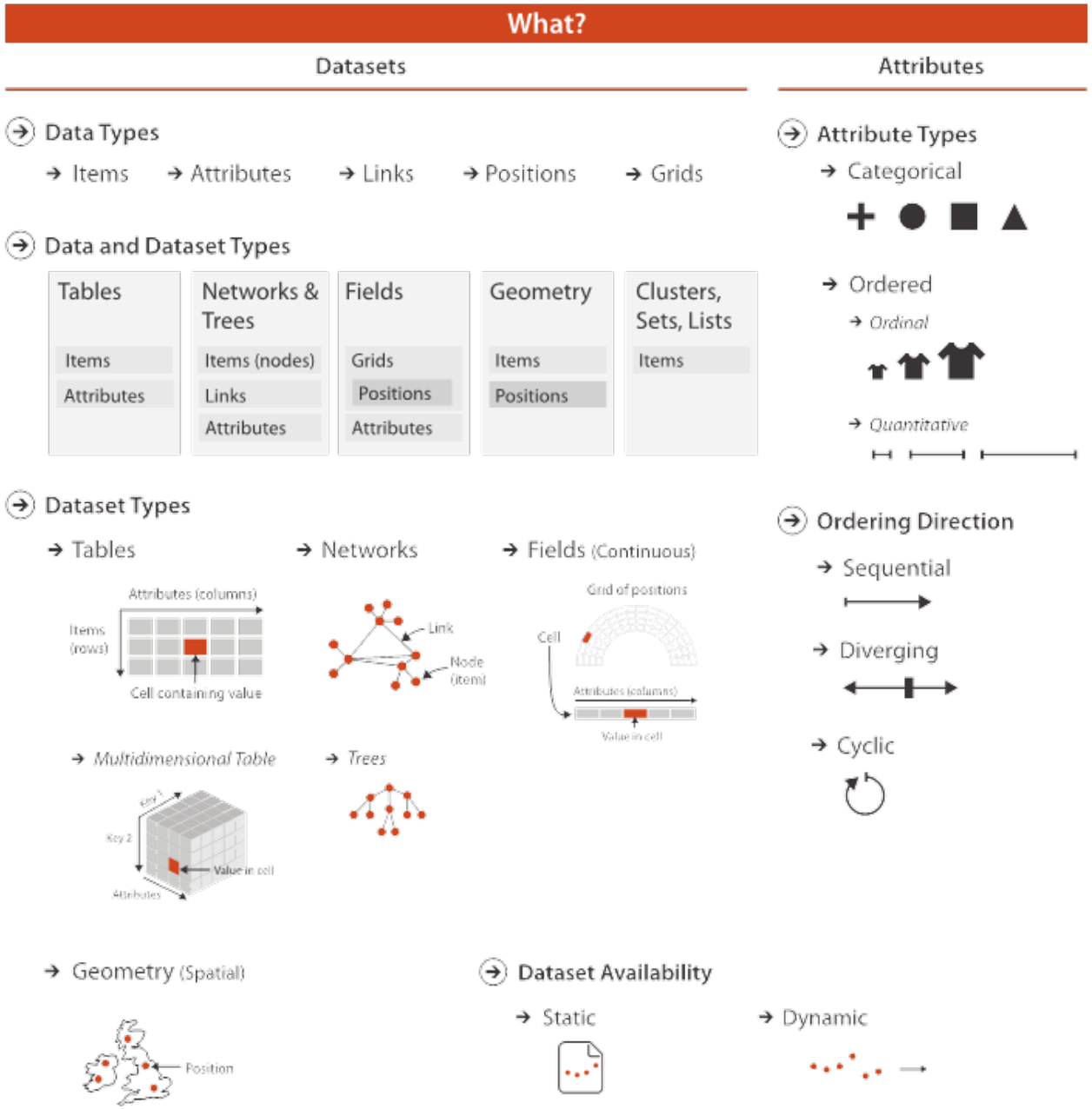
[A Nested Model of Visualization Design and Validation.
Munzner. IEEE TVCG 15(6):921-928, 2009 (Proc. InfoVis 2009).]

Pitfalls

- WTF Visualizations (http://viz.wtf)
- Without **knowing the principles**, you might make a lot of mistakes like this!



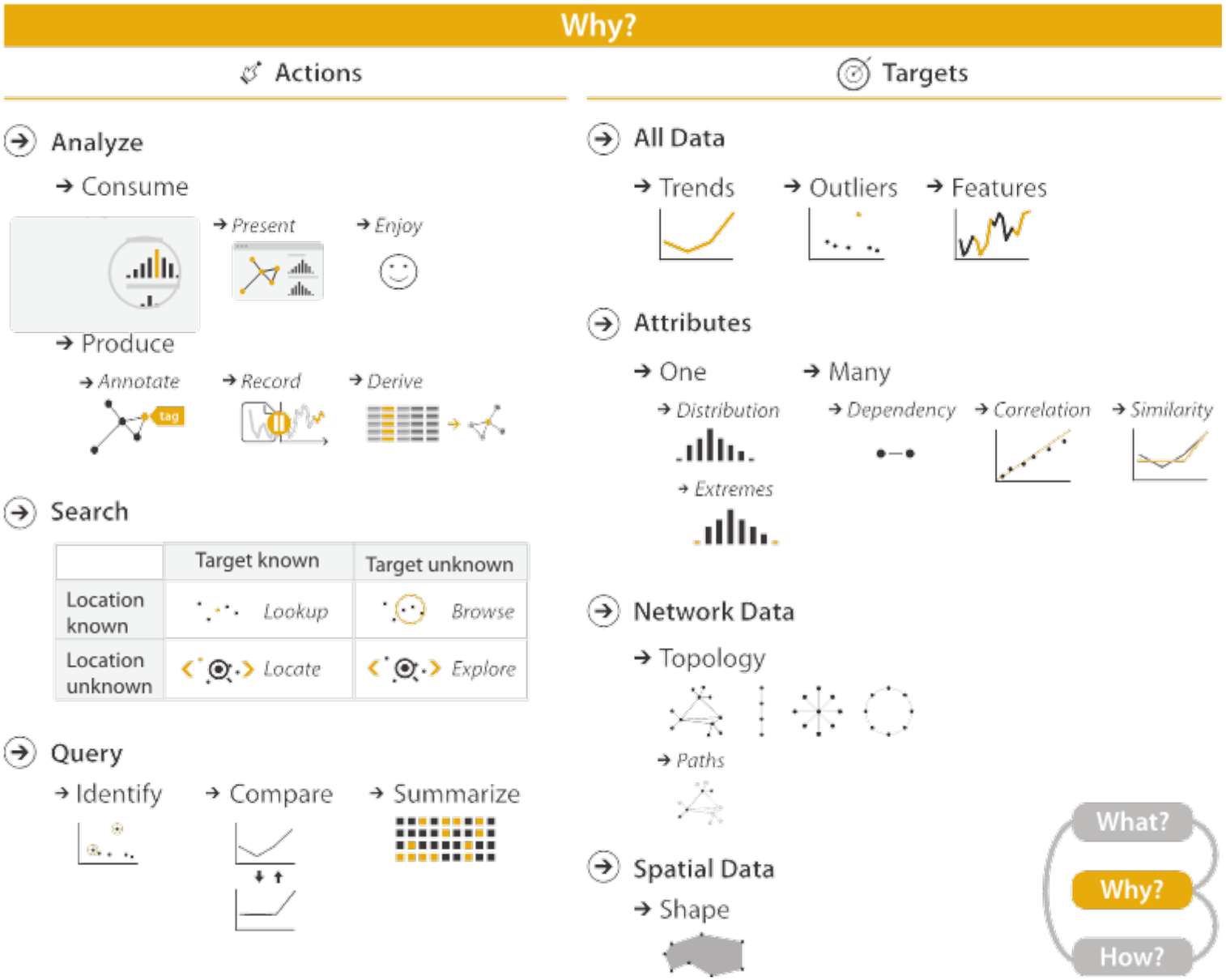
Understand
Data, Task, and Encoding



Data Types

- Items and attributes as rows and columns of tables
- Position and time are special attributes
- Spatial data on grids makes computation easier

[T. Munzner, 2014]



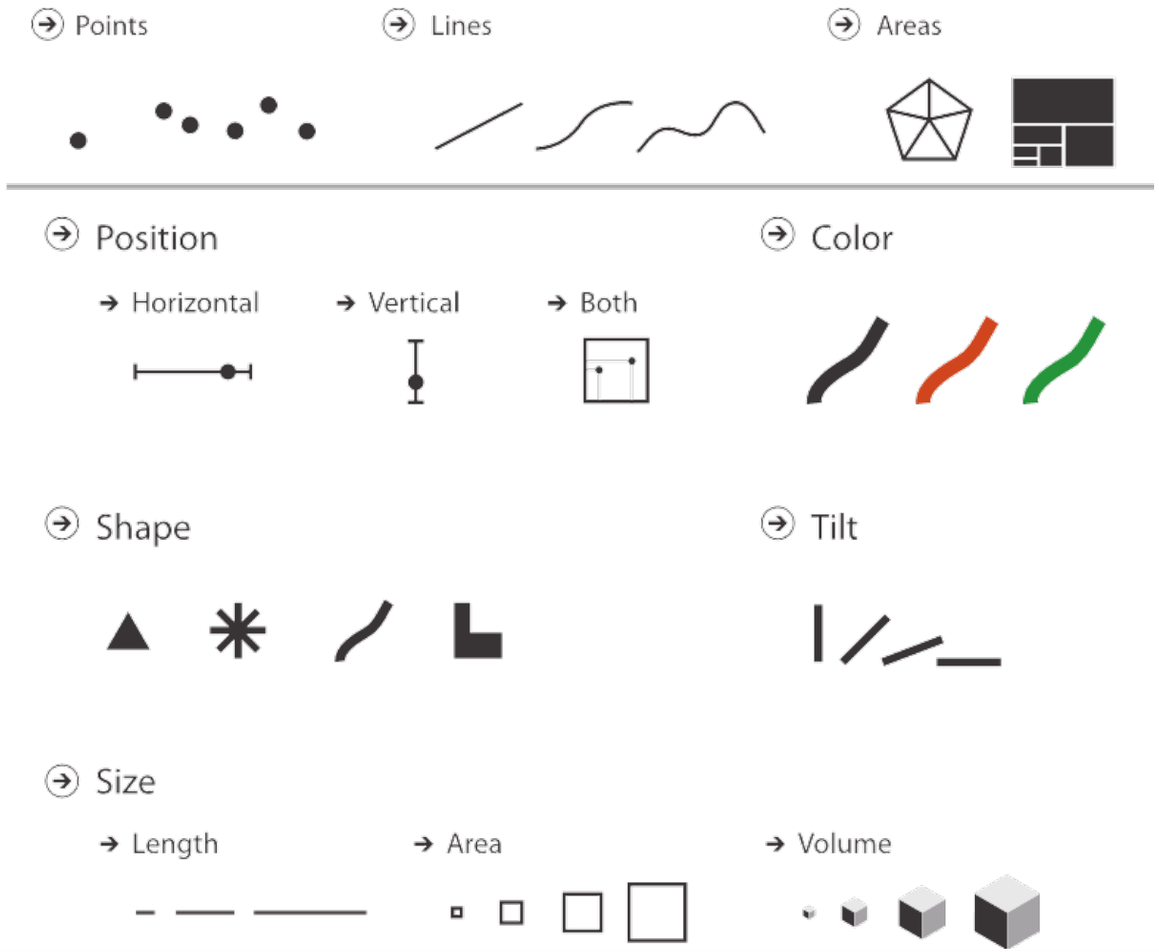
Tasks

- Actions
  - Analyze
  - Search
  - Query
- Targets
  - Item & Attributes
  - Topology & Shape

[T. Munzner, 2014]

Visual Encoding – How?

- Marks
  - Geometric primitives
- Channels
  - Appearance of marks
  - Redundant coding with multiple channels possible



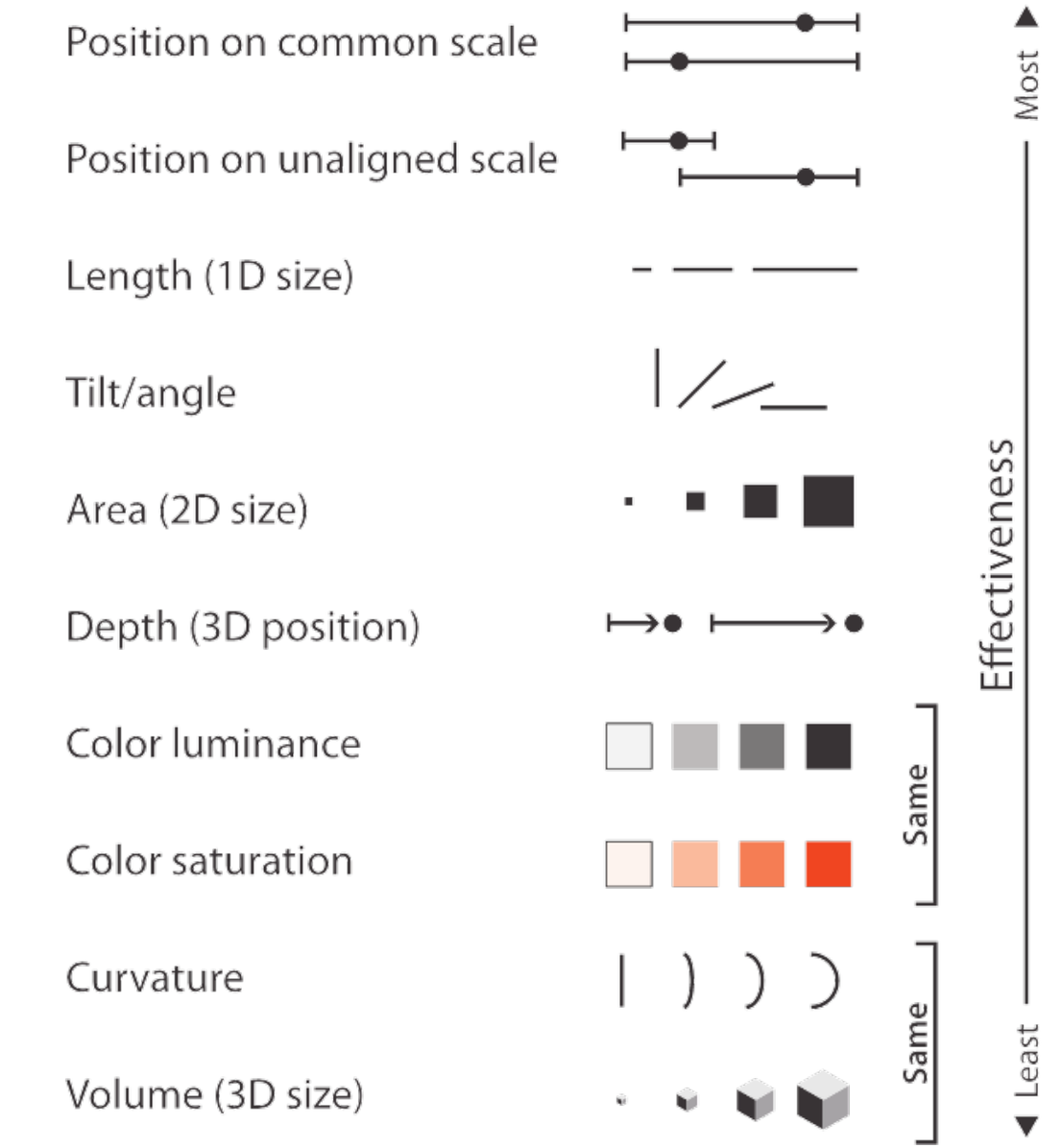
[T. Munzner, 2014]

Design Principles for Task Effective Visualization

Resource limitations

- **Computational** limits
  - Processing time and system memory
- **Human** limits
  - Human attention and memory
  - Understanding abstractions
- **Display** limits
  - Pixels are precious
  - Information density tradeoff: Info encoding vs unused whitespace

Magnitude Channels: Ordered Attributes



Identity Channels: Categorical Attributes

Expressiveness principle

- **Match channel and data characteristics**

Effectiveness principle

- **Encode important attributes with higher ranked channels**

[T. Munzner, 2014]

Chart Design: Simplifying

Example from Tim Bray

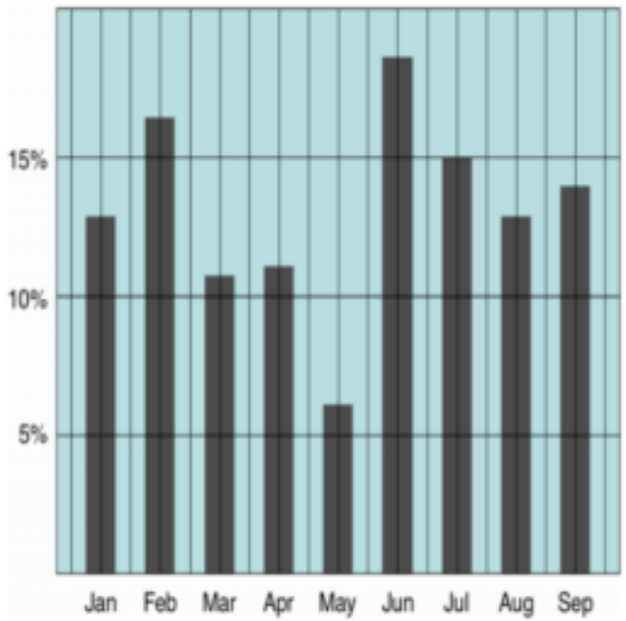
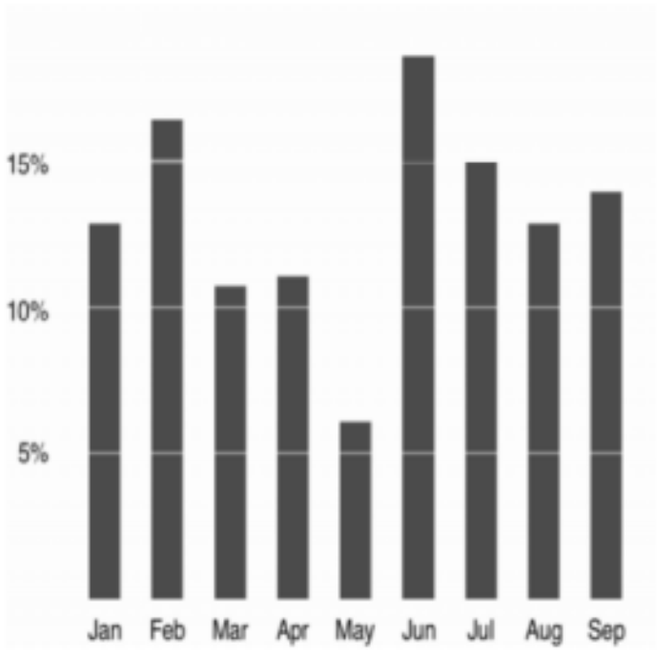


Chart Design: Simplifying

Example from Tim Bray

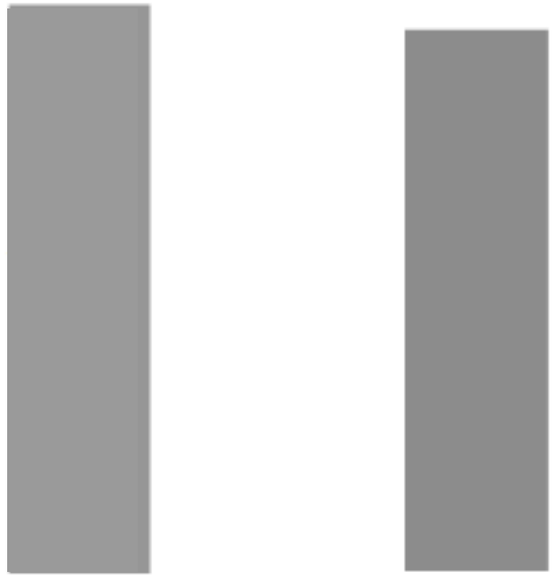


Principle 2: Understand Magnitudes

Which one is brighter?

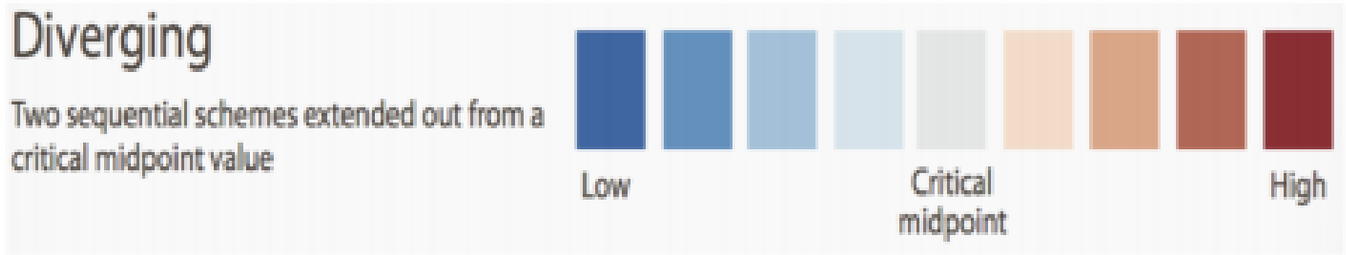
Principle 2: Understand Magnitudes

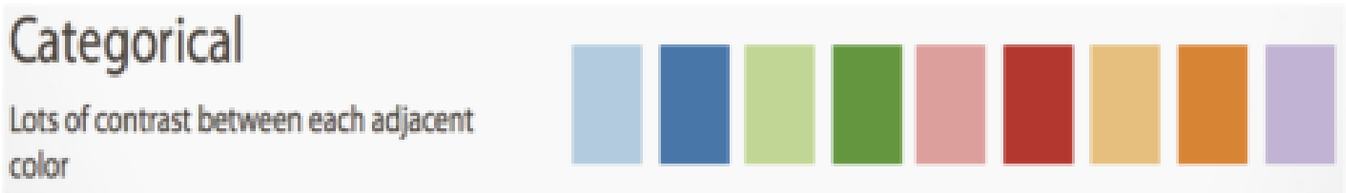
Which one is longer?



Principle 3: Use Color

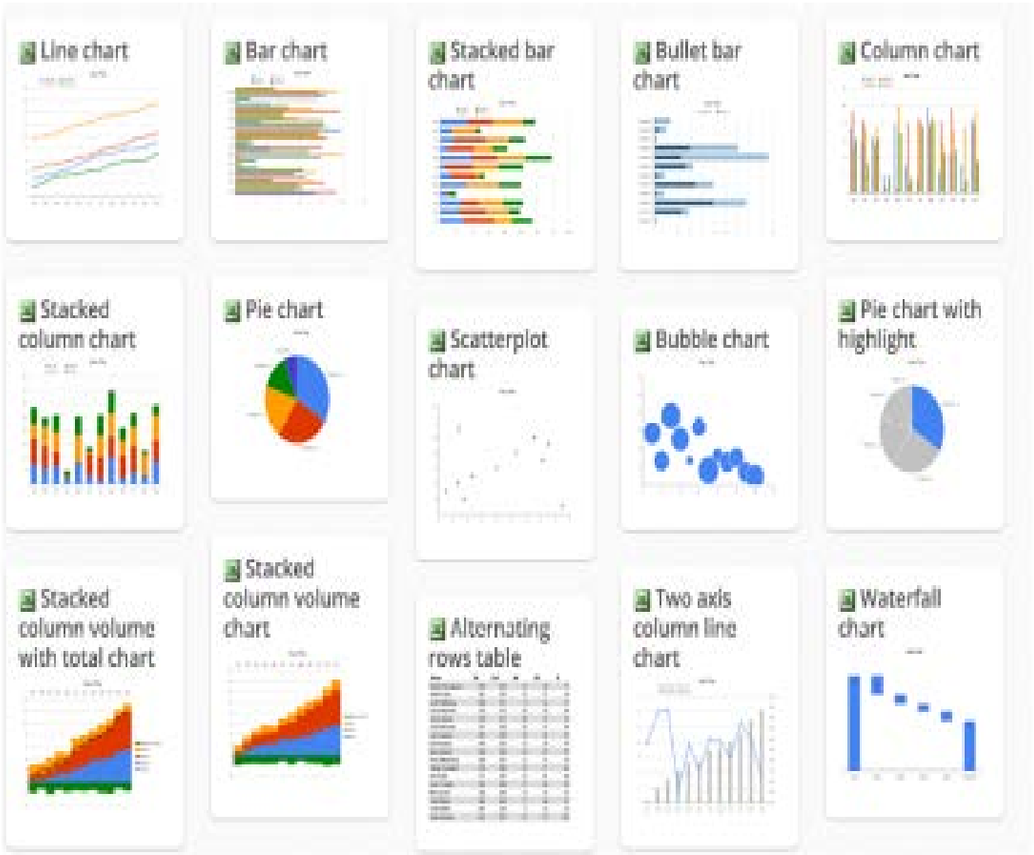
- **Make your visualization look beautiful**
  - Colour Lovers: http://www.colourlovers.com
- **Work for different kinds of data**





Principle 4: Use Structure

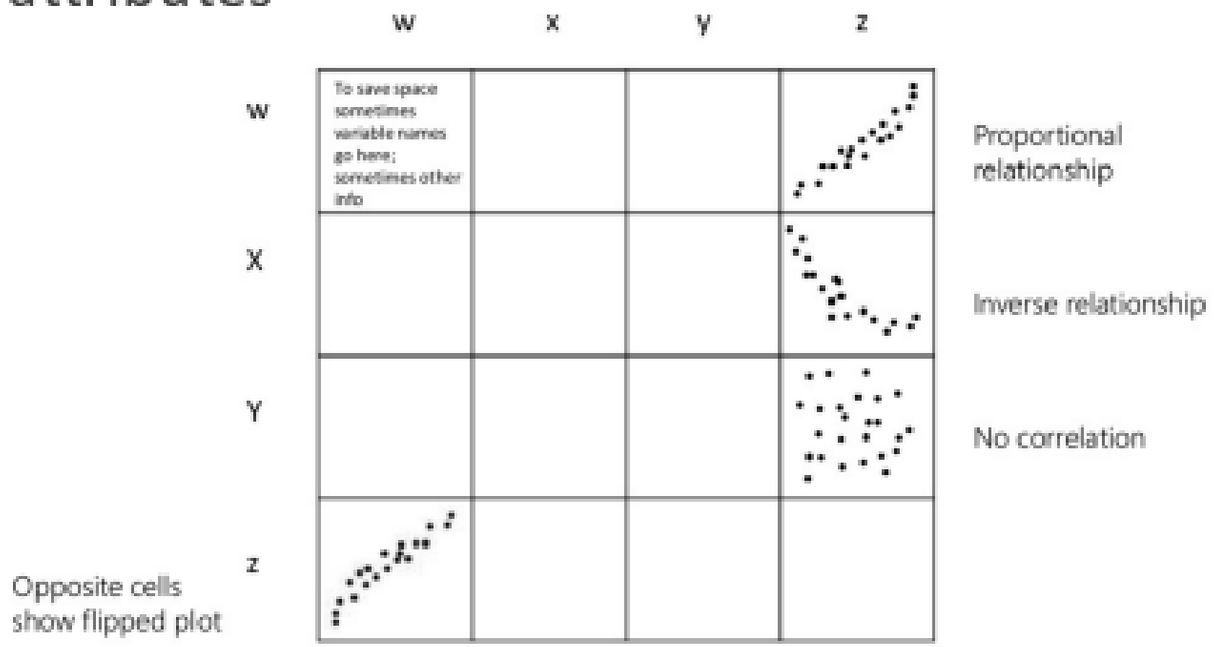
- Chart chooser: http://labs.juiceanalytics.com



Principle 4: Use Structure

Correlation Visualization

- Consider a table with n=4 attributes



Sources

- Tamara Munzner's "Visualization Analysis and Design", 2014
- Jiannan Wang's CMPT 733 slides, Spring 2017
- Torsten Möller's Visualization course, Spring 2018