Information Visualization

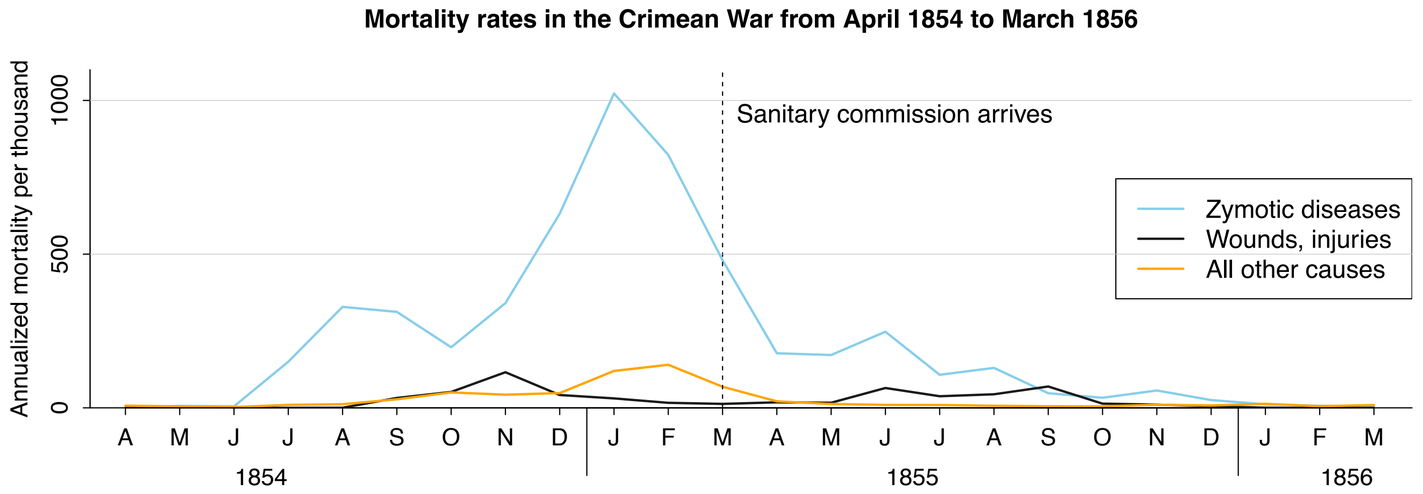
Visualization Review

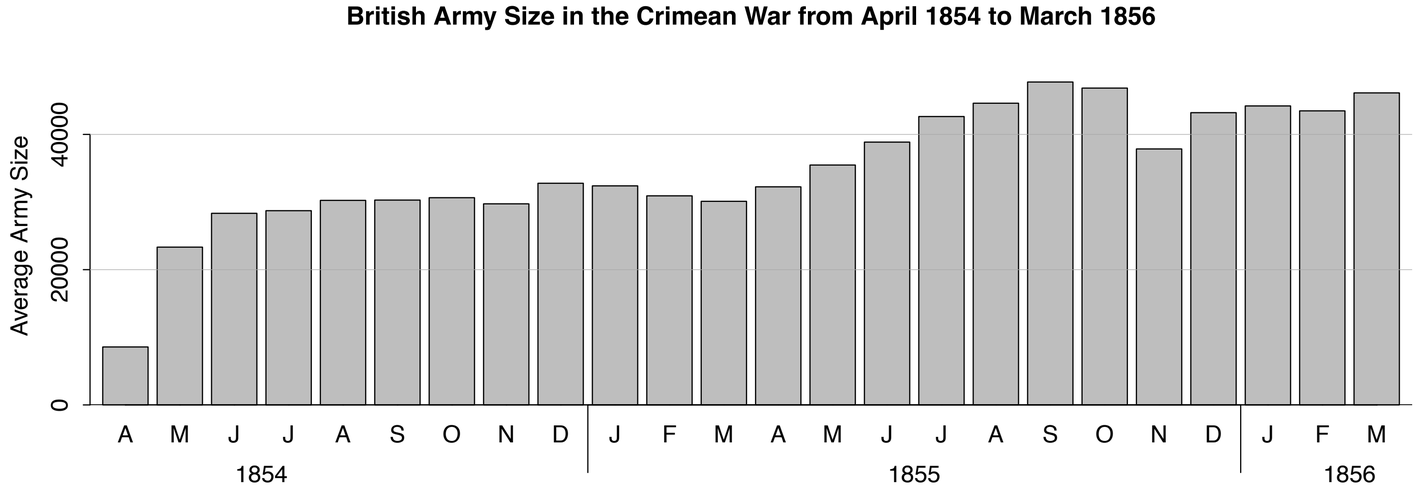
Dr. David Koop

What is **Information** Visualization (InfoVis)?

- Compared to…
  - Statistical Graphics
  - Infographics
  - Scientific Visualization

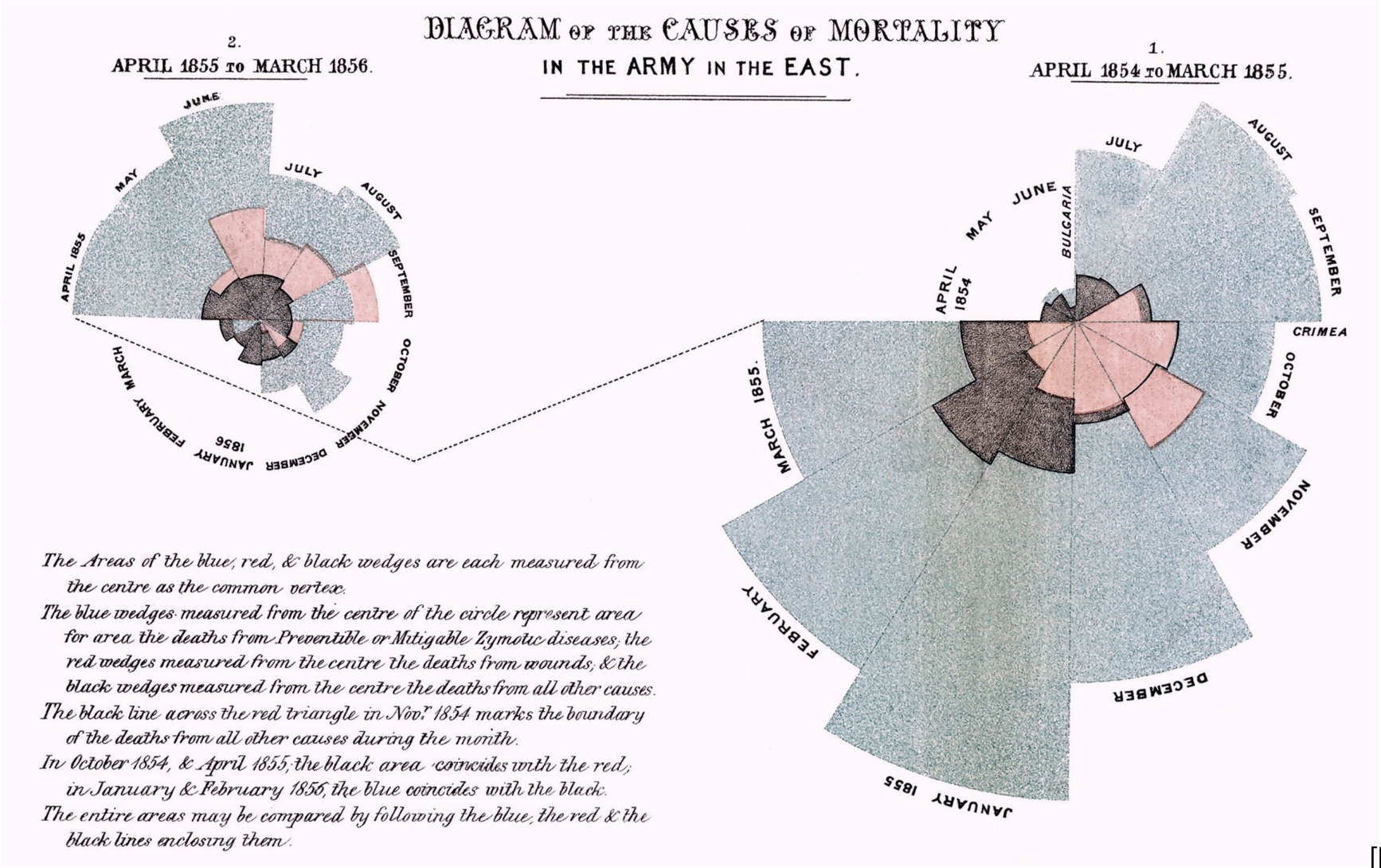
Gelman & Unwin's Version of Crimean War Data





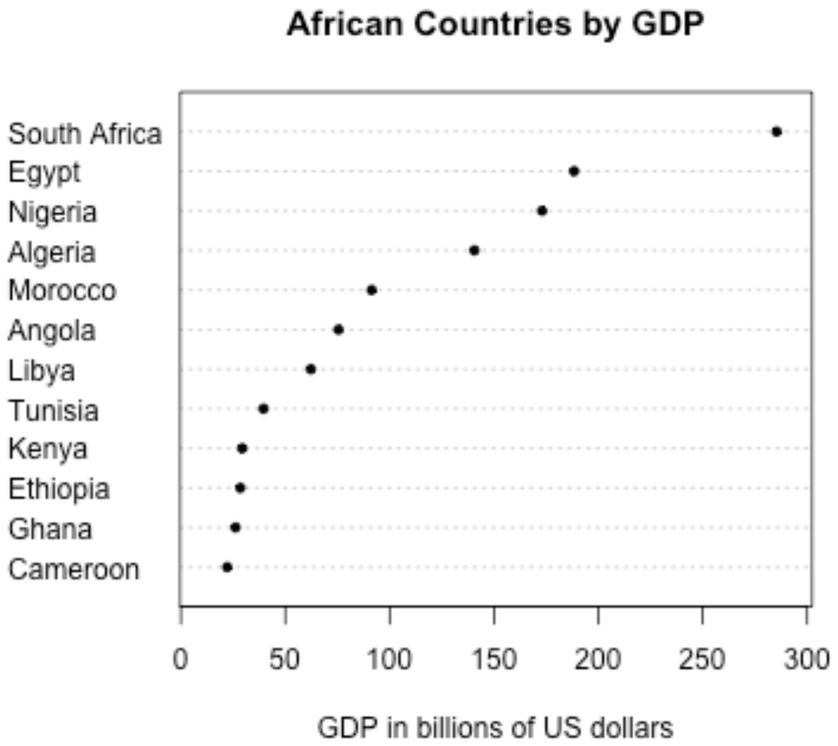
[Gelman and Unwin, 2014]

Nightingale's Coxcomb Diagram



[F. Nightingale, 1858]

Infographics Embellish Boring Plots?



[Gelman & Unwin]

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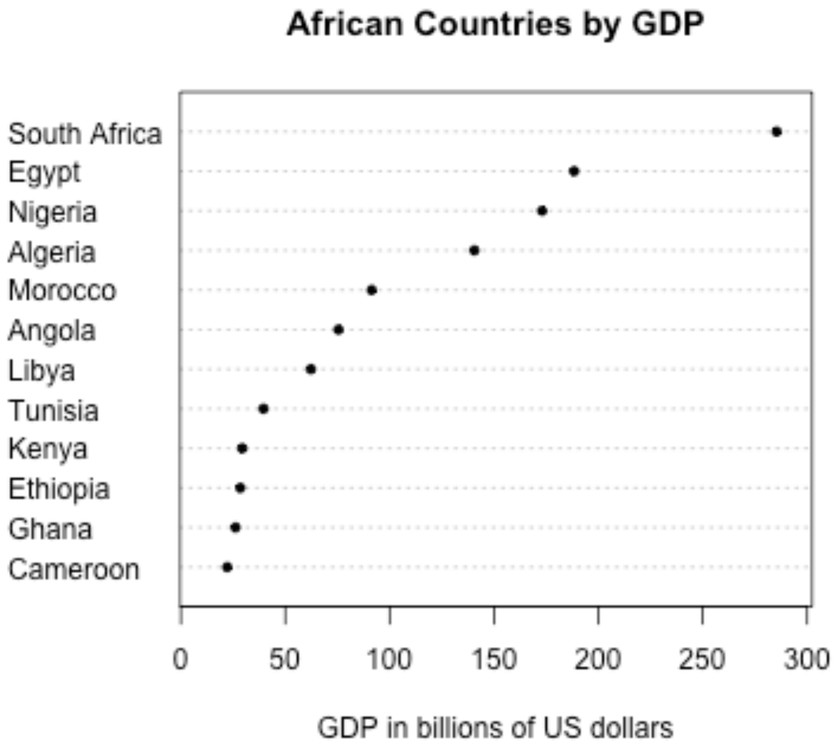

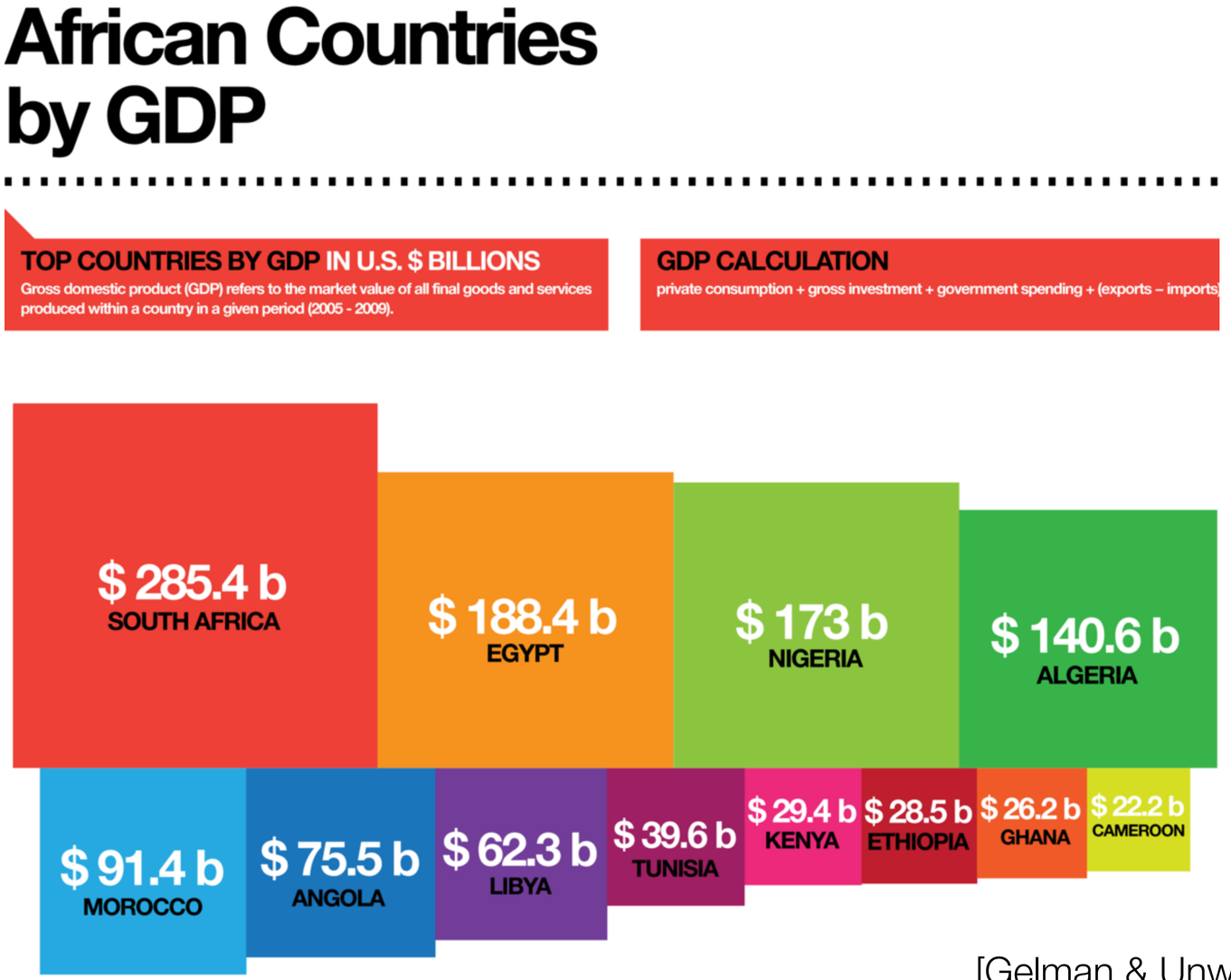

[Gelman & Unwin]

Visualization Organized by Data and Display Attributes

	Display Attributes		
	Given	***Constrained***	***Chosen***
Continuous	Images (e.g., medical) Fluid / gas flow, pressure distributions Molecular structures (distributions of mass, charge, etc.) Globe – distribution data (e.g., elevation levels)	Distortions of given / continuous ideas (e.g., flattened medical structures, 2D geographic maps, fish-eye lens views) Arrangement of numeric variable values	Continuous (high-dimensional) mathematical functions Continuous time-varying data, when time is mapped to a spatial dimension Regression analyses
Discrete	Classified data / images (e.g., segmented medical images) Air traffic positions Molecular structures (exact positions of components) Globe – discrete entity data (e.g., city locations)	Distortions of given / discrete ideas (e.g., 2D geographic maps, fish-eye lens views) Arrangement of ordinal or numeric variable values	Discrete time-varying data, when time is mapped to a spatial dimension Arbitrary entity-relationship data (e.g., file structures) Arbitrary multi-dimensional data (e.g., employment statistics)

[Tory & Möller]

Visualization Organized by Data and Display Attributes

SciVis

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[Tory & Möller]

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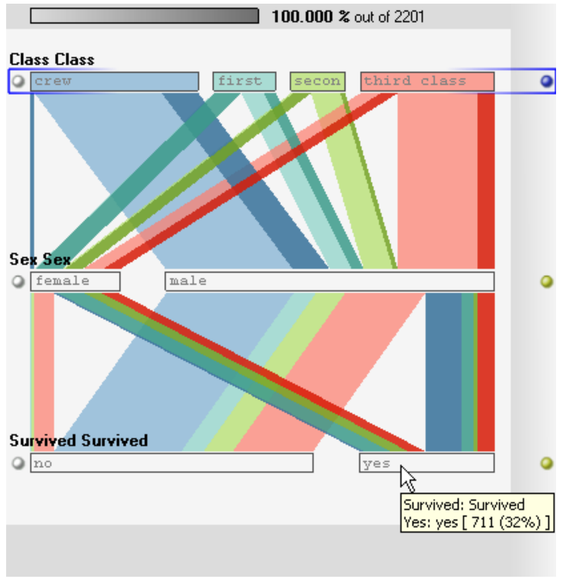
InfoVis

[Tory & Möller]

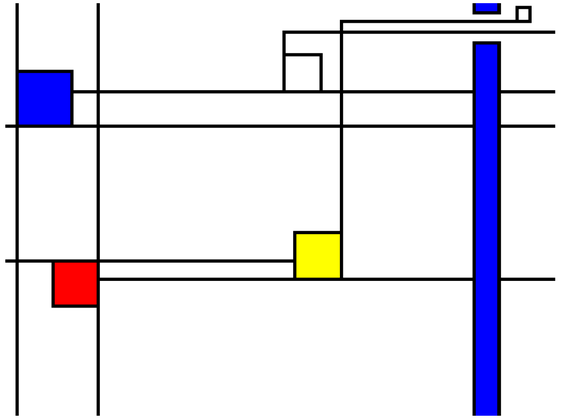
Kosara's Definition of Information Visualization

- It is based on (non-visual) data
- It produces an image
- The result is readable and recognizable

Pragmatic <-> Artistic Visualization



a)



b)

c)

Parallel Sets, etc.

Recognizable
Readable

Informative Art

Not Recognizable
Readable

Music Visualization, etc.

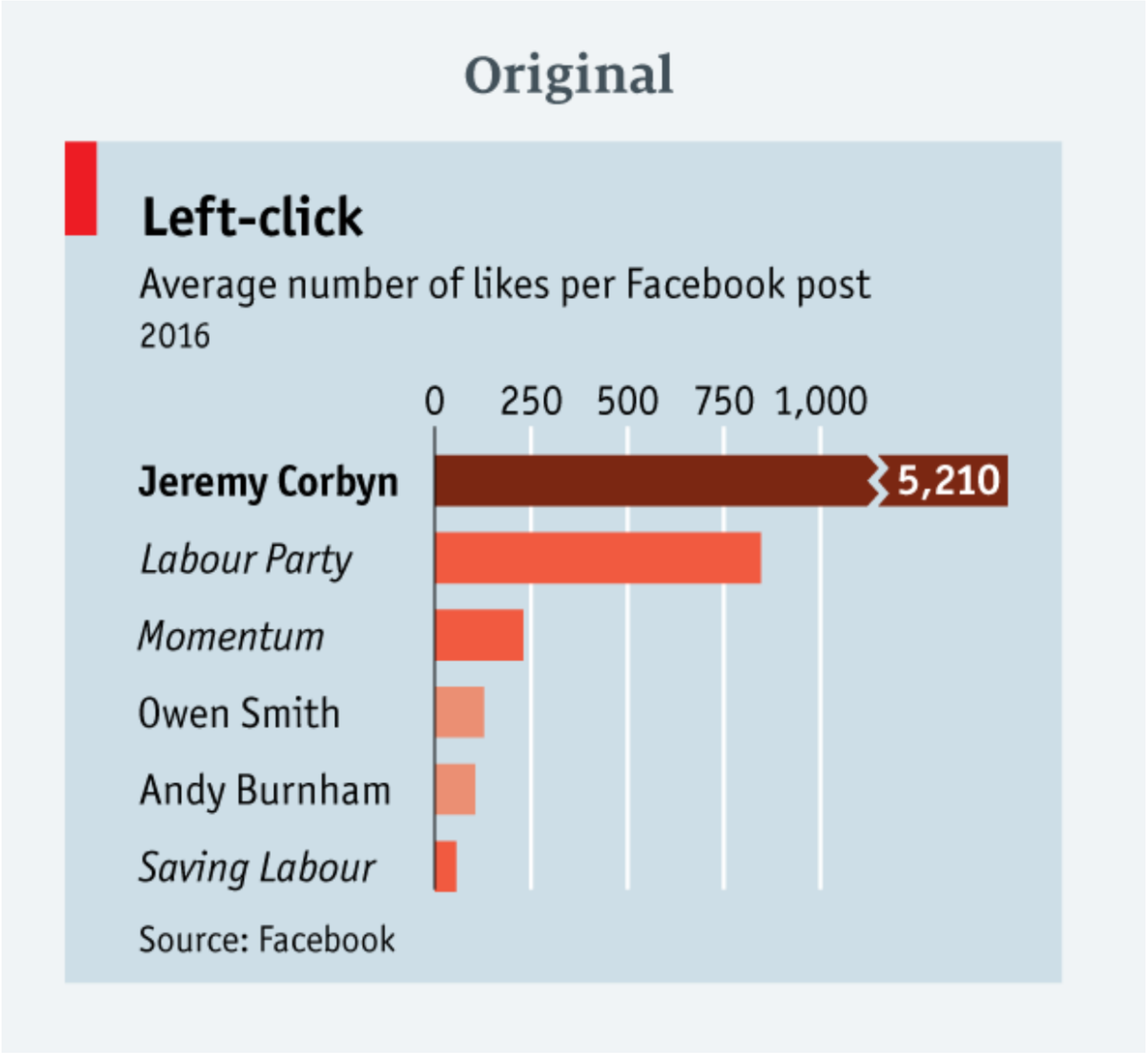
Not Recognizable
Not Readable

Pragmatic Visualization — Artistic Visualization

Utilitarian — Sublime

[R. Kosara]

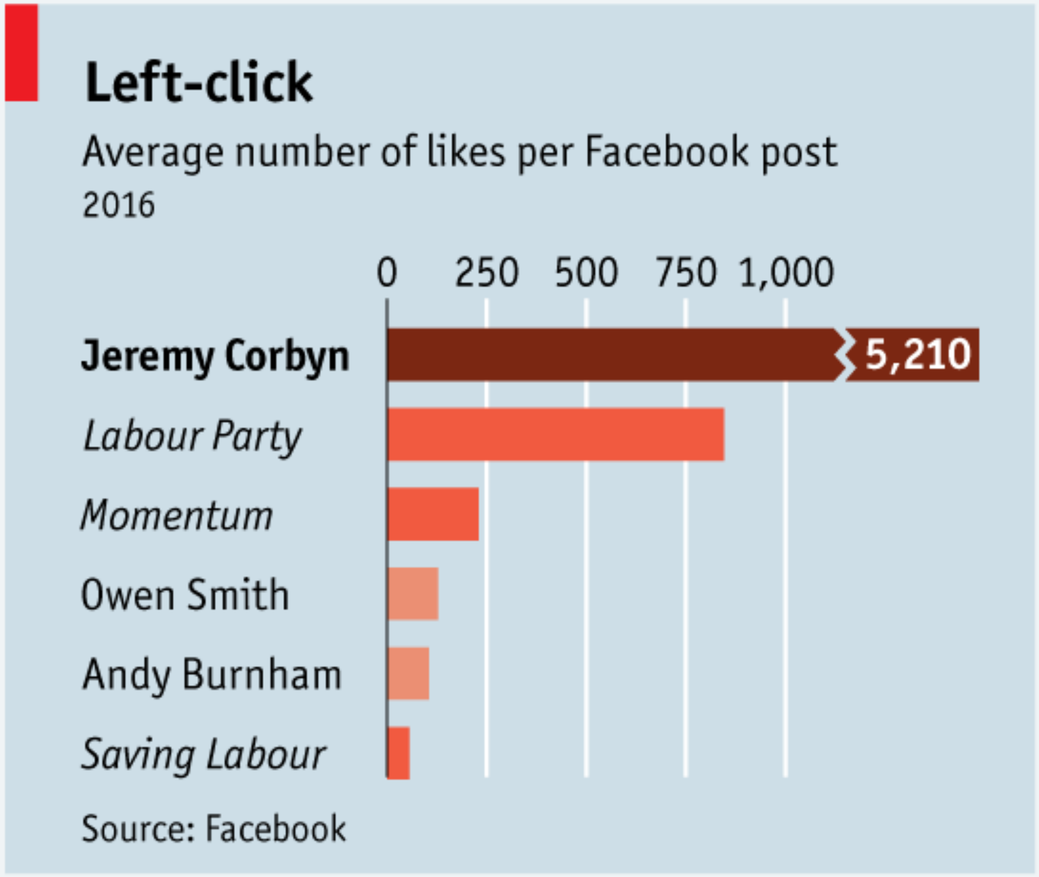
Visualization Rules



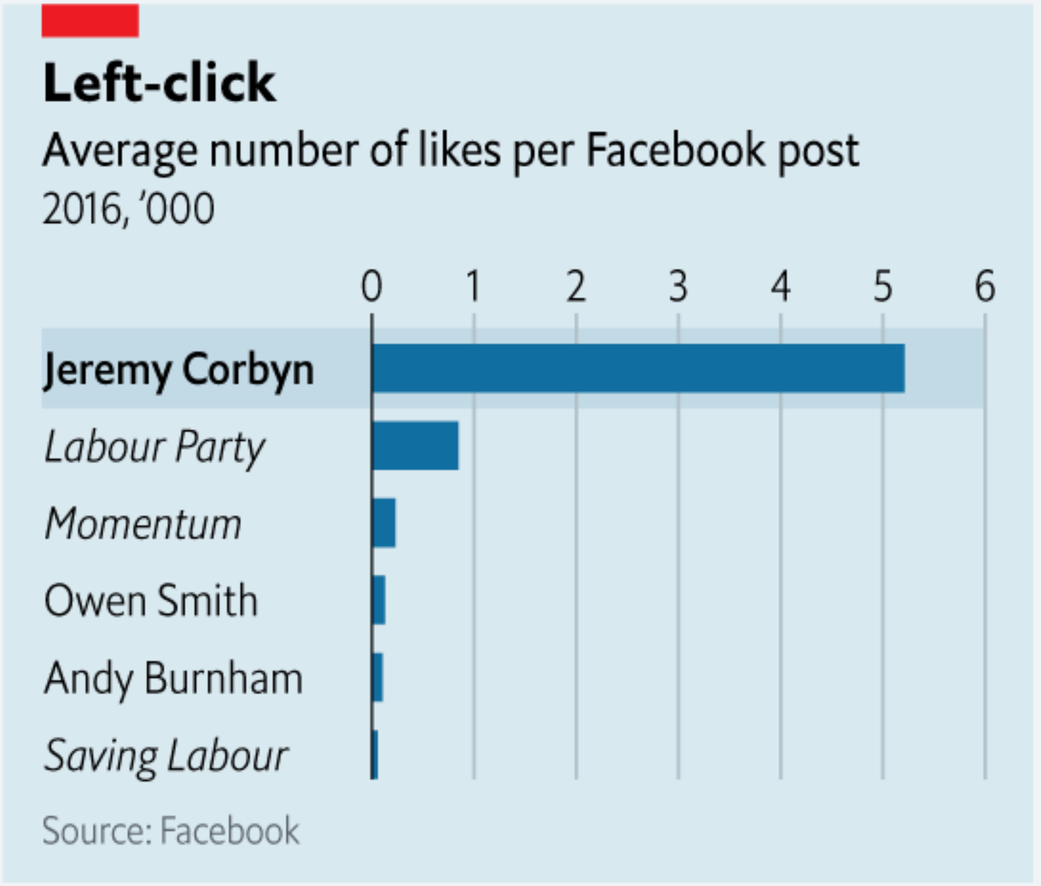
[S. Leo]

Visualization Rules

Original



Better



[S. Leo]

Can we break the rules?

Benefitting InfoVis with Visual Difficulties

	Cognitive efficiency	Visual difficulties
Cognitive operations	Minimize the cognitive steps required to process visualization	Induce constructive, self-directed cognitive activity on the part of the user
Data-ink ratio	Maximize the ratio of data to ink	Design representations that are most likely to engage a user to actively process the information
Organization	Choose the format which makes important information most visually salient	Choose the format that best stimulates deep cognitive reflection on the important data

[J. Hullman et al.]

About this course

- Course web page is authoritative:
  - http://faculty.cs.niu.edu/~dakoop/cs628-2021fa/
  - Schedule, Readings, Assignments will be posted online
  - Check the web site before emailing me
- Lectures: TuTh 9:30-10:45am in PM 252
- This is an Advanced (Tier 2) Graduate Course
  - Present and discuss cutting-edge topics
  - Work on research problems
- Requires **participation**: readings and discussions

Office Hours & Email

- Office hours will be held in person
  - Tu: 1:45-3pm, Th: 10:45am-12pm, or by appointment
- Please adhere to university regulations (Protecting the Pack)
- You do not need an appointment to stop by during scheduled office hours
- If you wish to meet virtually, please schedule an appointment
- If you need an appointment, please email me with **details** about what you wish to discuss and times that would work for you
- Many questions can be answered via email. **Please consider writing an email before scheduling a meeting.**

Expectations

- Be engaged:
  - Active participation
  - Constructive participation
- Work independently: self-directed and sustained
- Work collaboratively: learn from each other
- Put effort into this course:
  - Must put significant work in **each** week
  - Do not try to do everything before a deadline
  - Grading does not depend on fully successful research outcome

Interest Survey

- To be released soon on Blackboard
- Questions about your research background, interests, and topic preferences

- Identify topics and then schedule paper presentations

Writing

- Annotated Bibliography
- Survey Paper
- Project Paper

- Focus on improving writing quality and style
- Use LaTeX (Overleaf can provide assistance here)
- Would like to see your work turn into publications

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

— T. Munzner

Definition

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

Definition

	REMOTE	STATION	FF	SEN/DIS	7-D AFAS UNL	D AFAS/RMF U	JOINT RR TKT	7-D UNL	30-D UNL
1	R011	42ND STREET & 8TH AVENUE	00228985	00008471	00000441	00001455	00000134	00033341	00071255
2	R170	14TH STREET-UNION SQUARE	00224603	00011051	00000827	00003026	00000660	00089367	00199841
3	R046	42ND STREET & GRAND CENTRAL	00207758	00007908	00000323	00001183	00003001	00040759	00096613
4	R012	34TH STREET & 8TH AVENUE	00188311	00006490	00000498	00001279	00003622	00035527	00067483
5	R293	34TH STREET - PENN STATION	00168768	00006155	00000523	00001065	0000050		
6	R033	42ND STREET/TIMES SQUARE	00159382	00005945	00000378	00001205	0000006		
7	R022	34TH STREET & 6TH AVENUE	00156008	00006276	00000487	00001543	0000007		
8	R084	59TH STREET/COLUMBUS CIRCLE	00155262	00009484	00000589	00002071	0000005		
9	R020	47-50 STREETS/ROCKEFELLER	00143500	00006402	00000384	00001159	0000007		
10	R179	86TH STREET-LEXINGTON AVE	00142169	00010367	00000470	00001839	0000002		
11	R023	34TH STREET & 6TH AVENUE	00134052	00005005	00000348	00001112	0000006		
12	R029	PARK PLACE	00121614	00004311	00000287	00000931	0000007		
13	R047	42ND STREET & GRAND CENTRAL	00100742	00004273	00000185	00000704	0000012		
14	R031	34TH STREET & 7TH AVENUE	00095076	00003990	00000232	00000727	00001459	00024284	00038671
15	R017	LEXINGTON AVENUE	00094655	00004688	00000190	00000833	00000754	00020018	00055066
16	R175	8TH AVENUE-14TH STREET	00094313	00003907	00000286	00001144	00000256	00038272	00074661
17	R057	BARCLAYS CENTER	00093804	00004204	00000454	00001386	00001491	00039113	00068119
18	R138	WEST 4TH ST-WASHINGTON SQ	00093562	00004672	00000251	00000965	00000127	00031628	00074458

NYC Subway Fare Data

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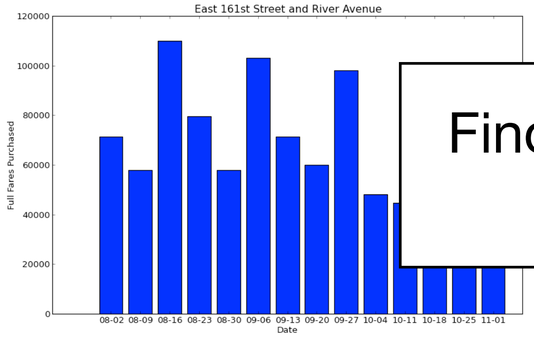
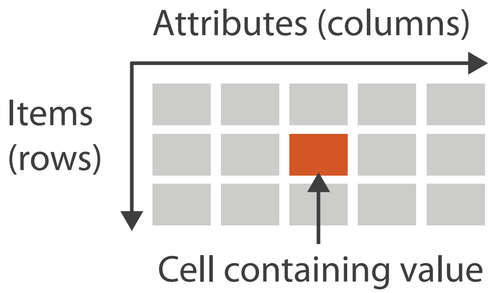


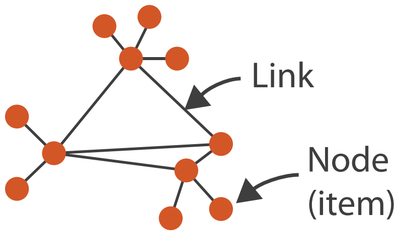
Find Interesting NYC Subway Ridership Patterns

Dataset Types

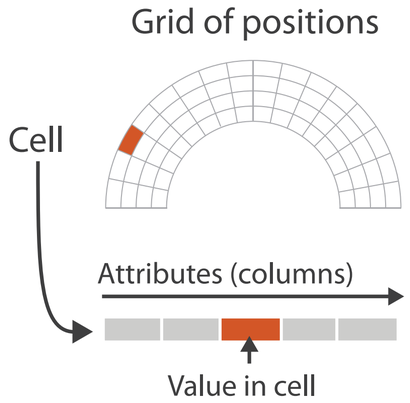
➔ Tables



➔ Networks

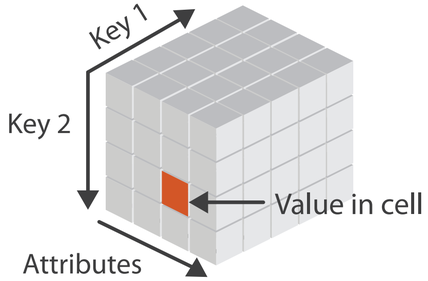


➔ Fields (Continuous)

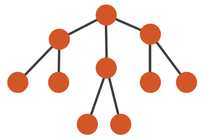


➔ Geometry (Spatial)

➔ *Multidimensional Table*



➔ *Trees*



+ Sets
+ Text

[Munzner (ill. Maguire), 2014]

Data Items & Attributes

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		7/17/07
32	7/16/07	2-High	Medium Box		7/18/07
32	7/16/07	2-High	Medium Box		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	5	4-Not Specified	Small Pack	0.44	6/6/05
69	5	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	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

attribute

item

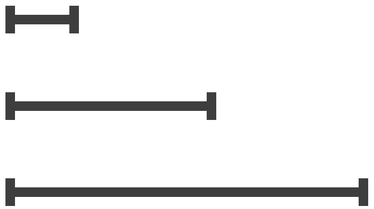
Attribute Types

➔ Categorical

➔ Ordered

➔ *Ordinal*

➔ *Quantitative*



[Munzner (ill. Maguire), 2014]

Categorial, Ordinal, and Quantitative

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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
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quantitative
ordinal
categorical

Categorial, Ordinal, and Quantitative

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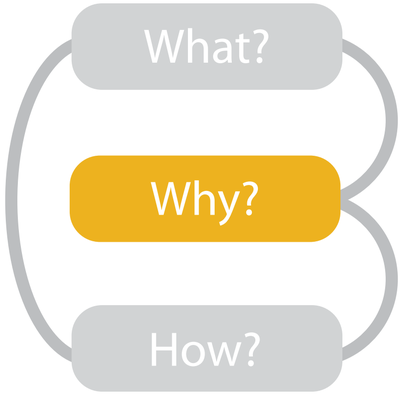
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

quantitative
ordinal
categorical

Definition

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

Tasks



Why?

Actions

Analyze

- Consume
  - *Discover*
  - *Present*
  - *Enjoy*
- Produce
  - *Annotate* (tag)
  - *Record*
  - *Derive*

Search

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

Query

- Identify
- Compare
- Summarize

Targets

All Data

- Trends
- Outliers
- Features

Attributes

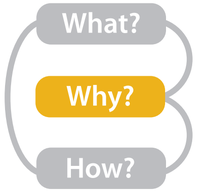
- One
  - *Distribution*
  - *Extremes*
- Many
  - *Dependency*
  - *Correlation*
  - *Similarity*

Network Data

- Topology
- *Paths*

Spatial Data

- Shape



[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

Definition

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

Why Visual?

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

[F. J. Anscombe]

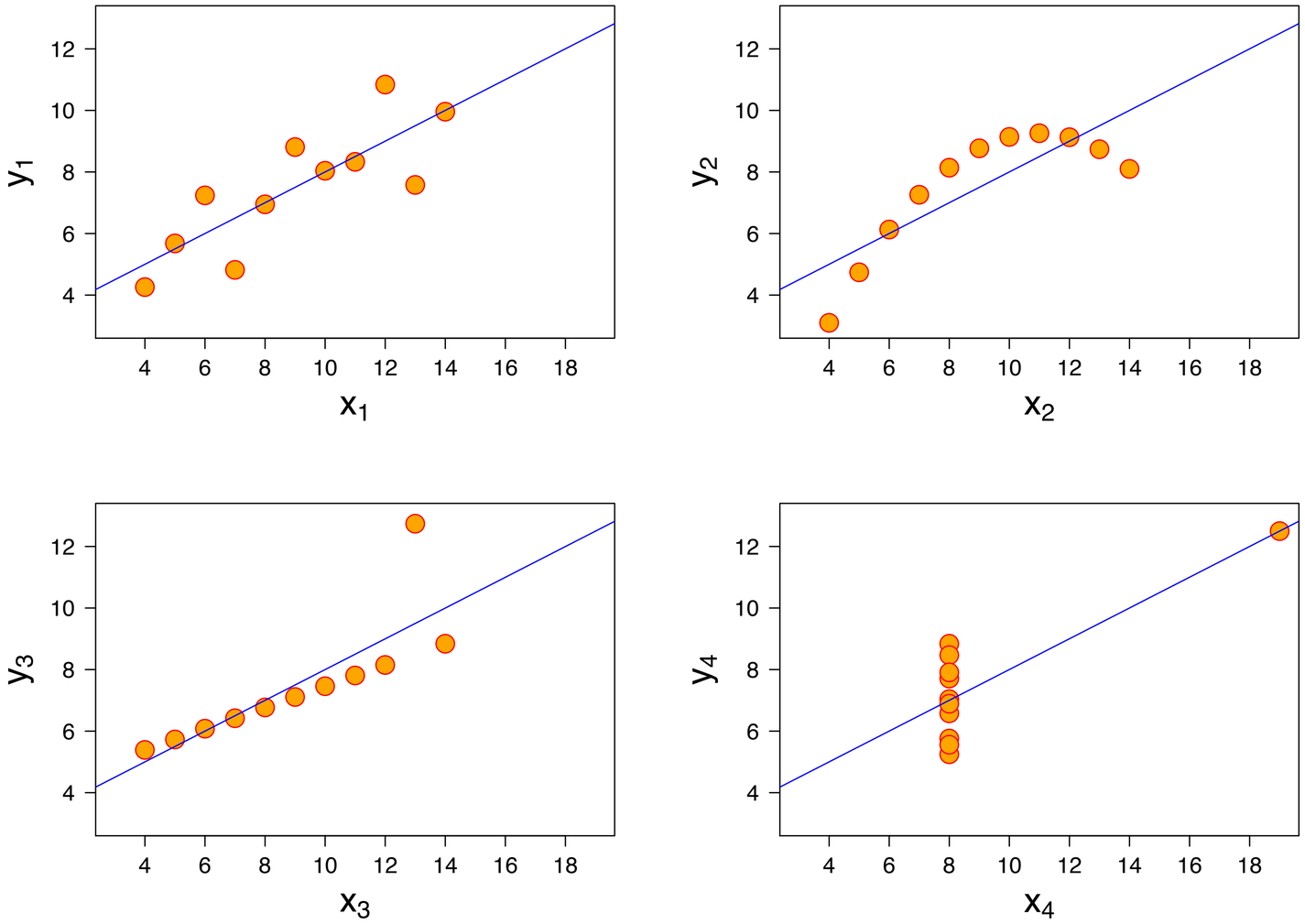
Why Visual?

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Mean of x	9
Variance of x	11
Mean of y	7.50
Variance of y	4.122
Correlation	0.816

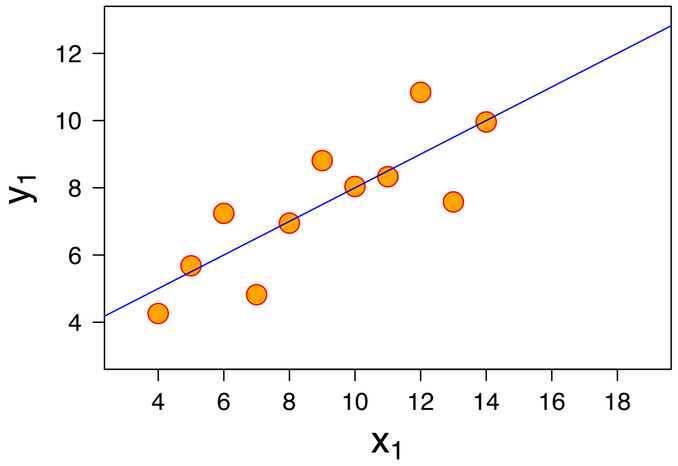
[F. J. Anscombe]

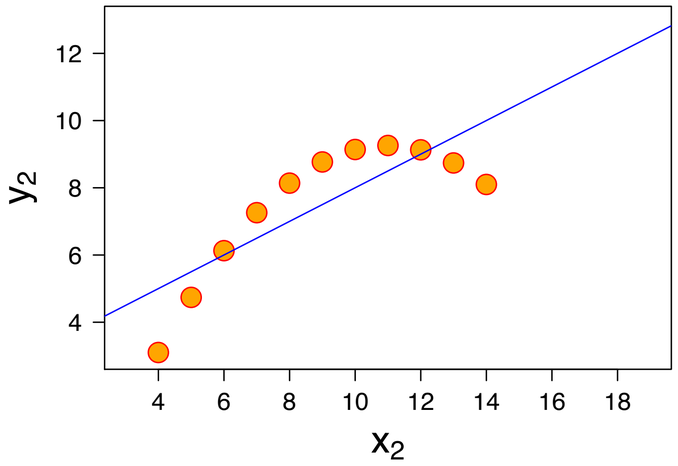
Why Visual?

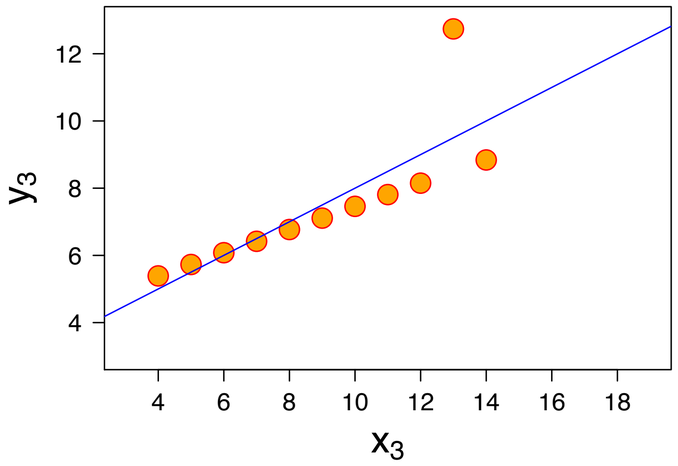


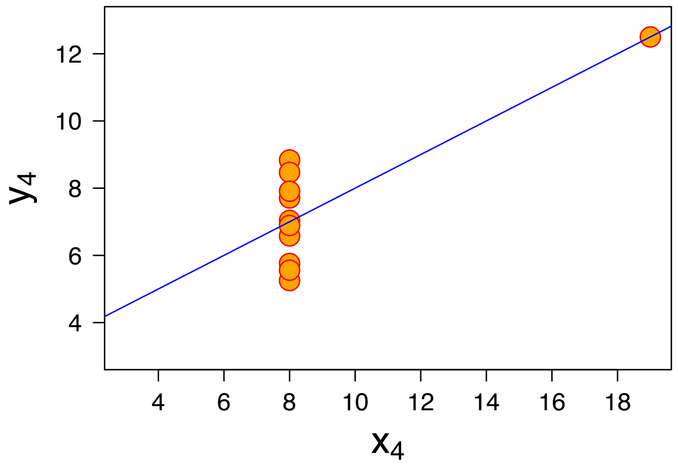
[F. J. Anscombe]

Why Visual?





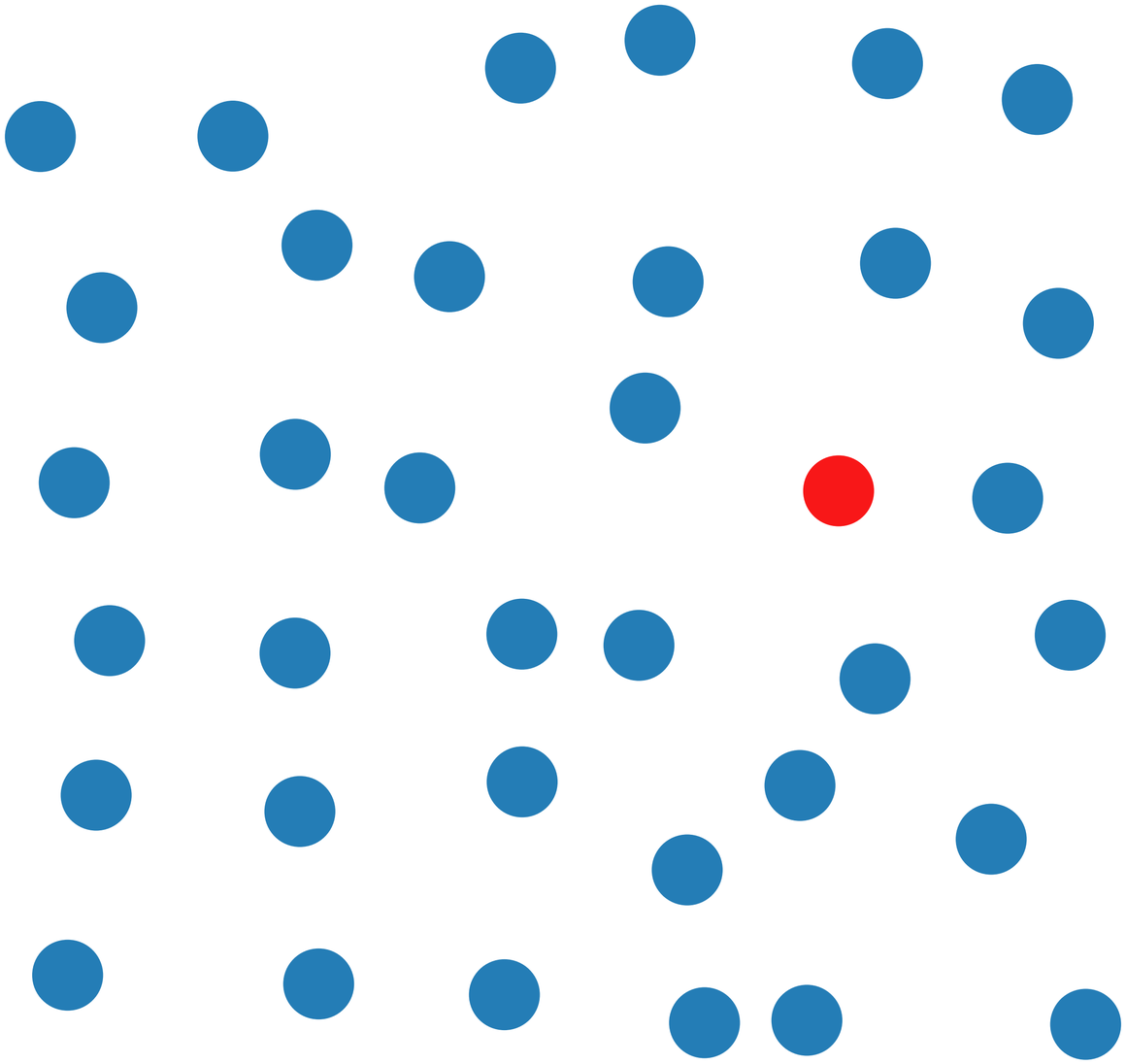




Mean of x	9
Variance of x	11
Mean of y	7.50
Variance of y	4.122
Correlation	0.816

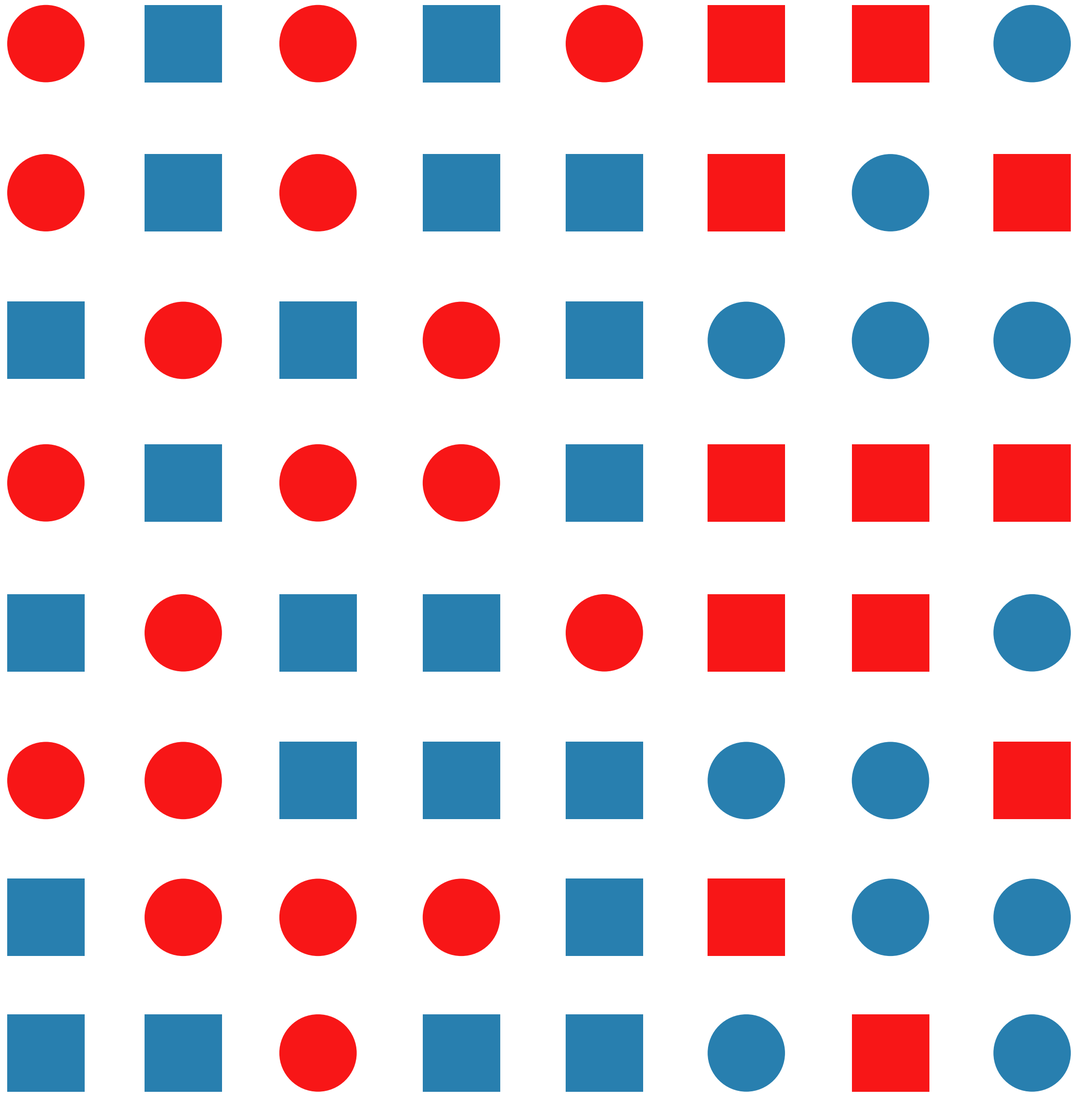
[F. J. Anscombe]

Visual Pop-out



[C. G. Healey]

Visual Perception Limitations

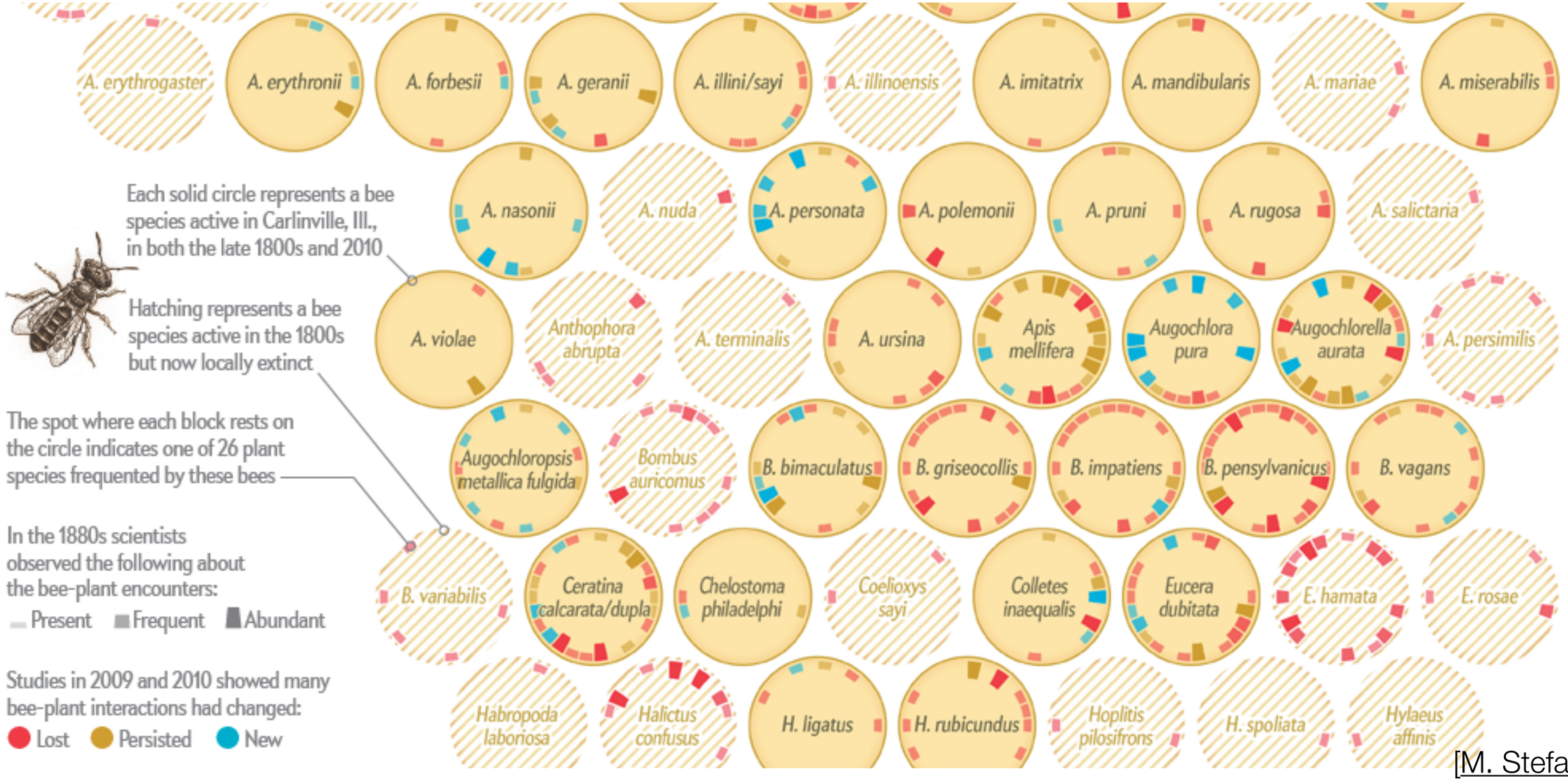


[C. G. Healey]

Definition

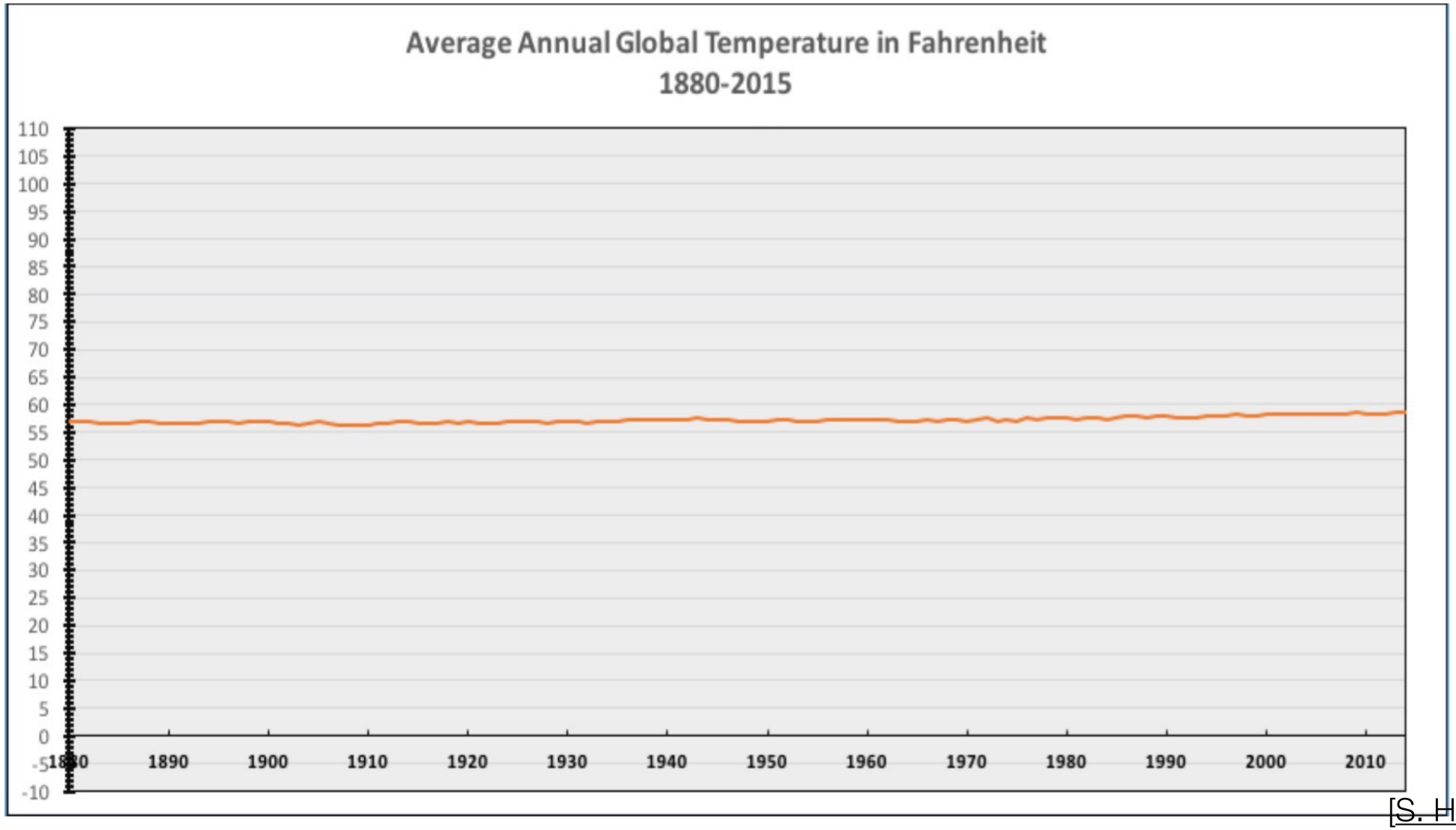
"Computer-based visualization systems provide visual representations of datasets **designed** to help people carry out tasks more effectively"

Design Example



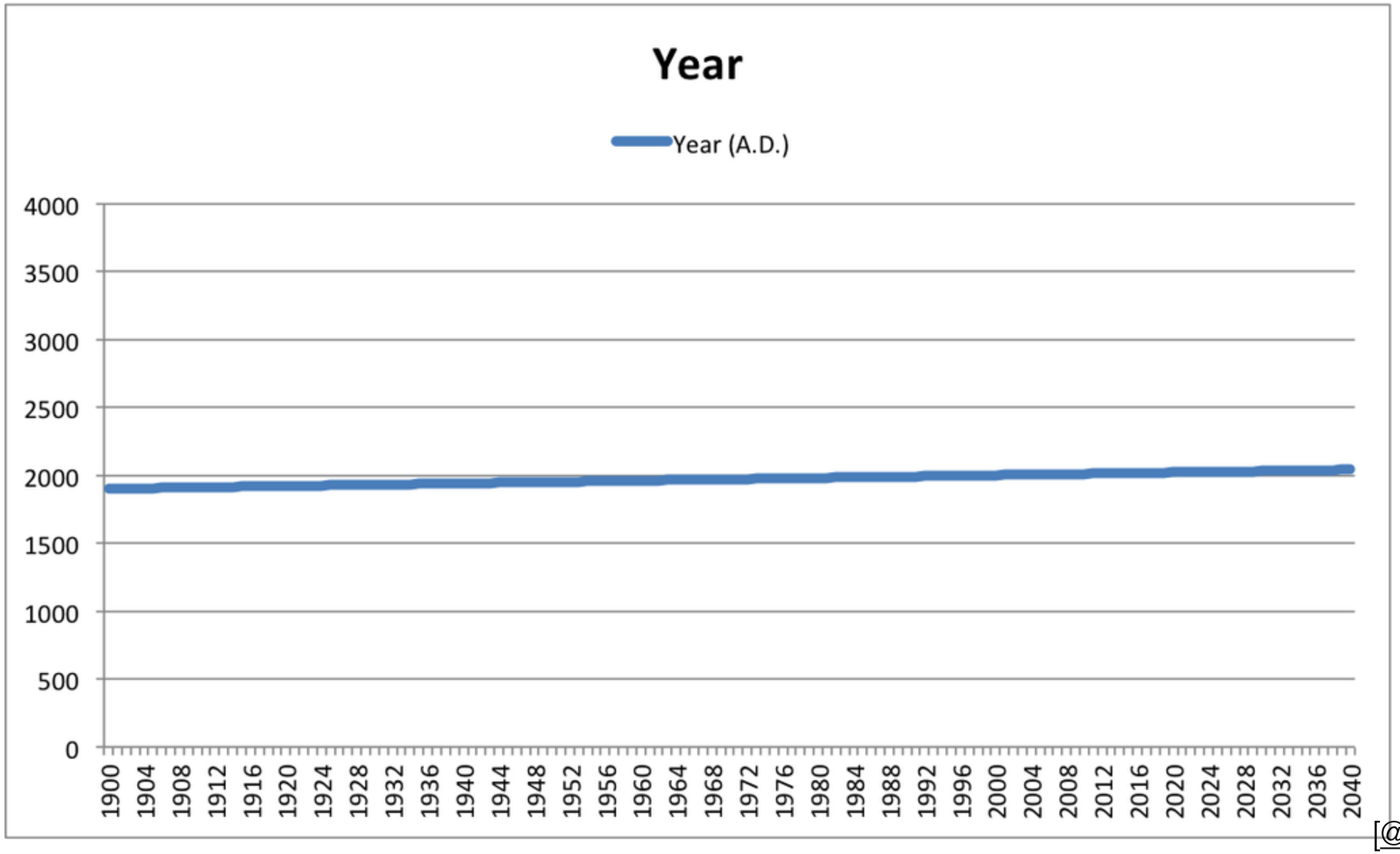
[M. Stefaner, 2013]

Impact of Design Choices: y-axis Scale



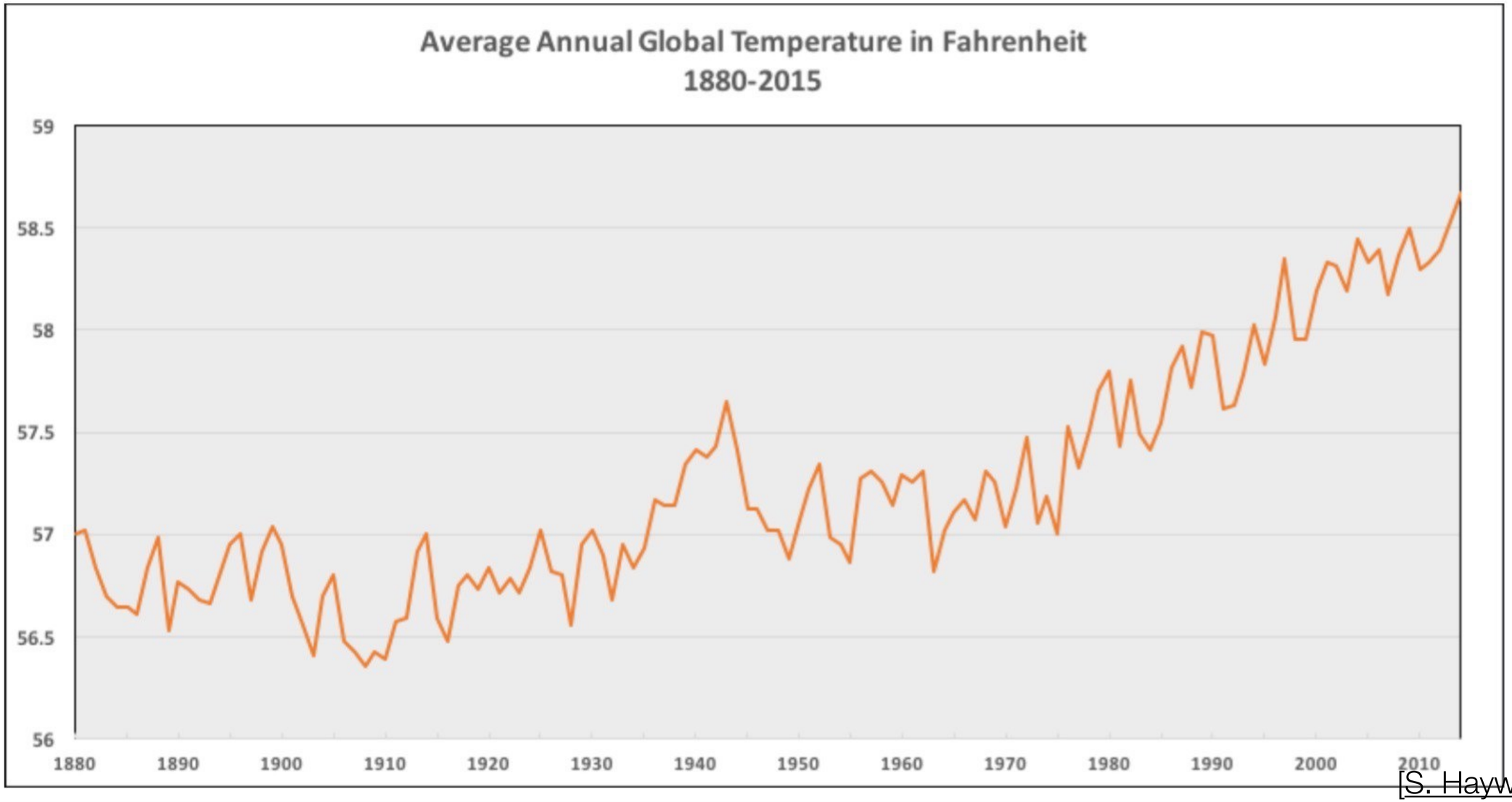
[S. Hayward, 2015]

Impact of Design Choices: y-axis Scale



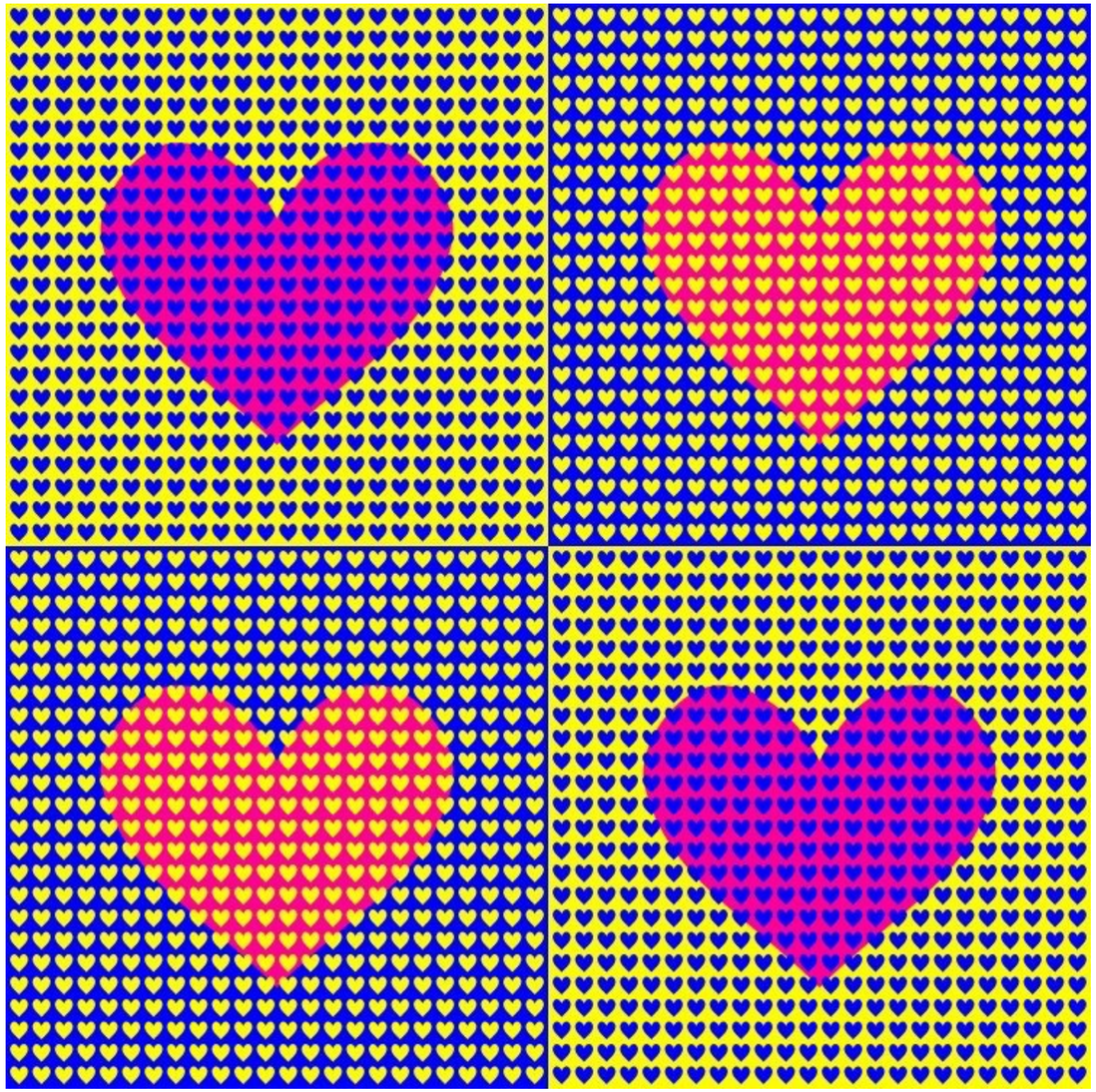
[@bizweekgraphics]

Impact of Design Choices: y-axis Scale



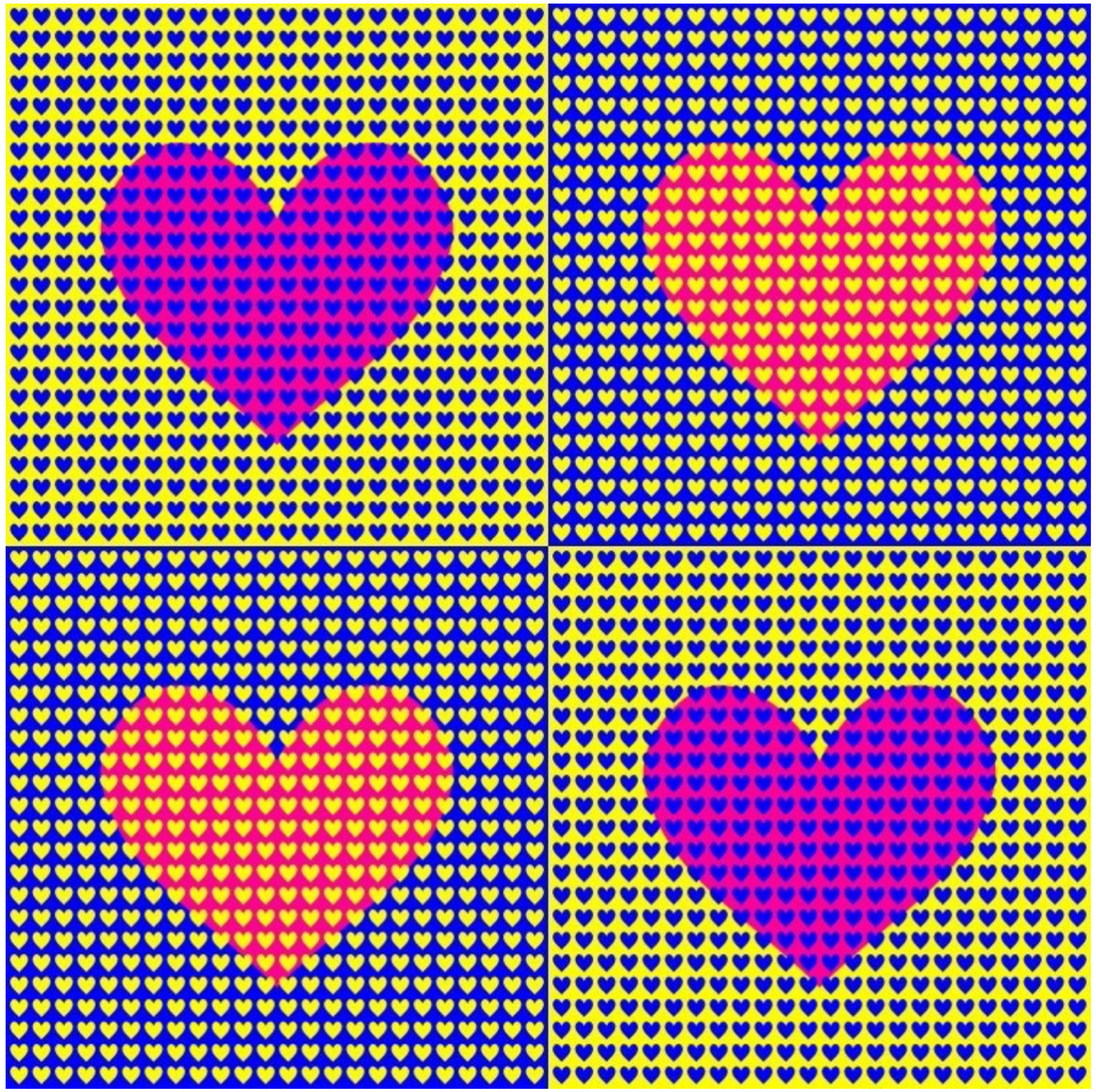
[S. Hayward, 2015]

Impact of Design Choices: color



[A. Kitaoka]

Impact of Design Choices: color



Red, yellow, blue

Purple, orange do not exist!

[A. Kitaoka]

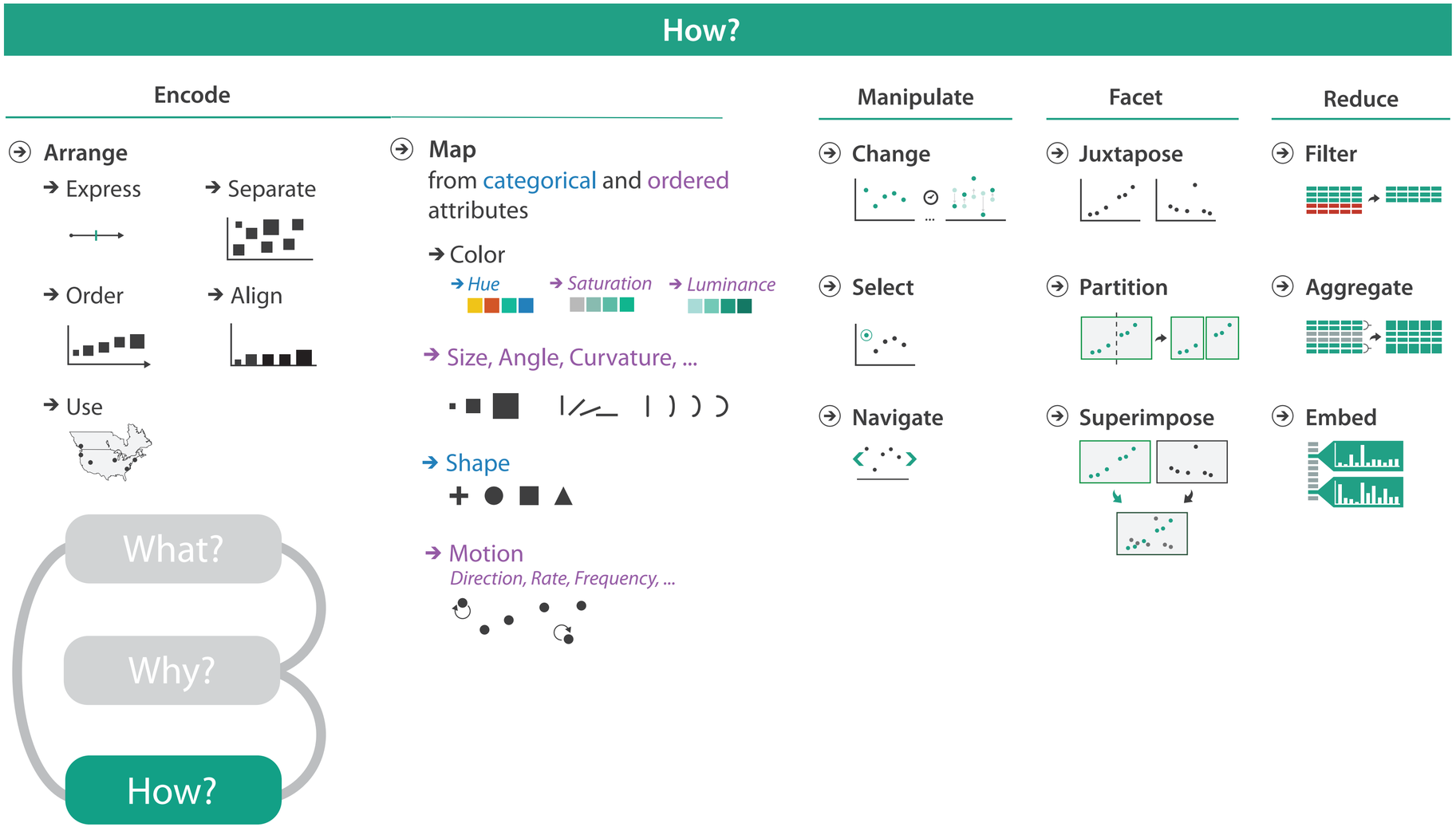
Design

[Munzner (ill. Maguire), 2014]

Definition

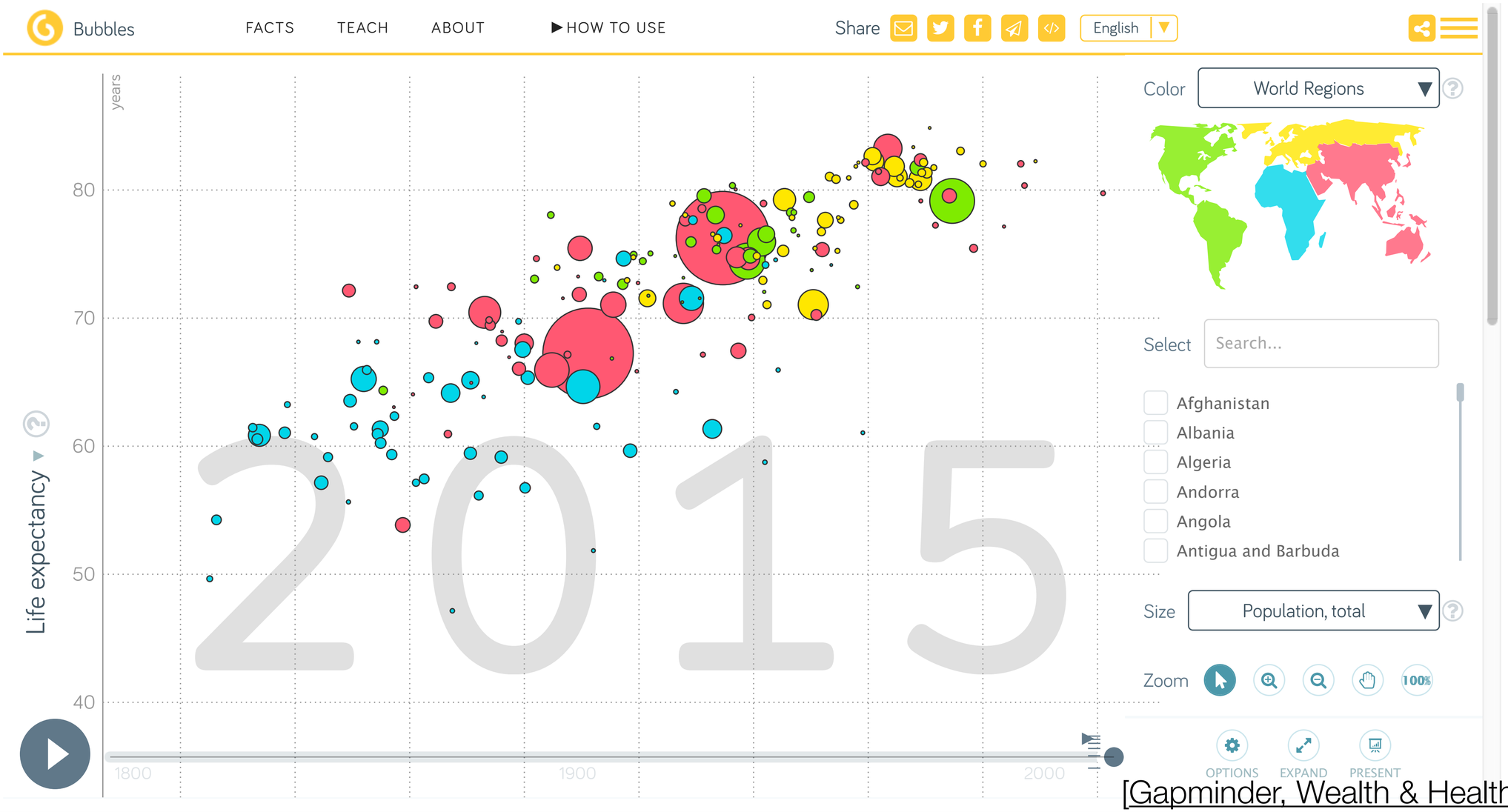
"Computer-based visualization systems provide visual representations of datasets designed to **help** people carry out tasks more effectively"

How do we do visualization?



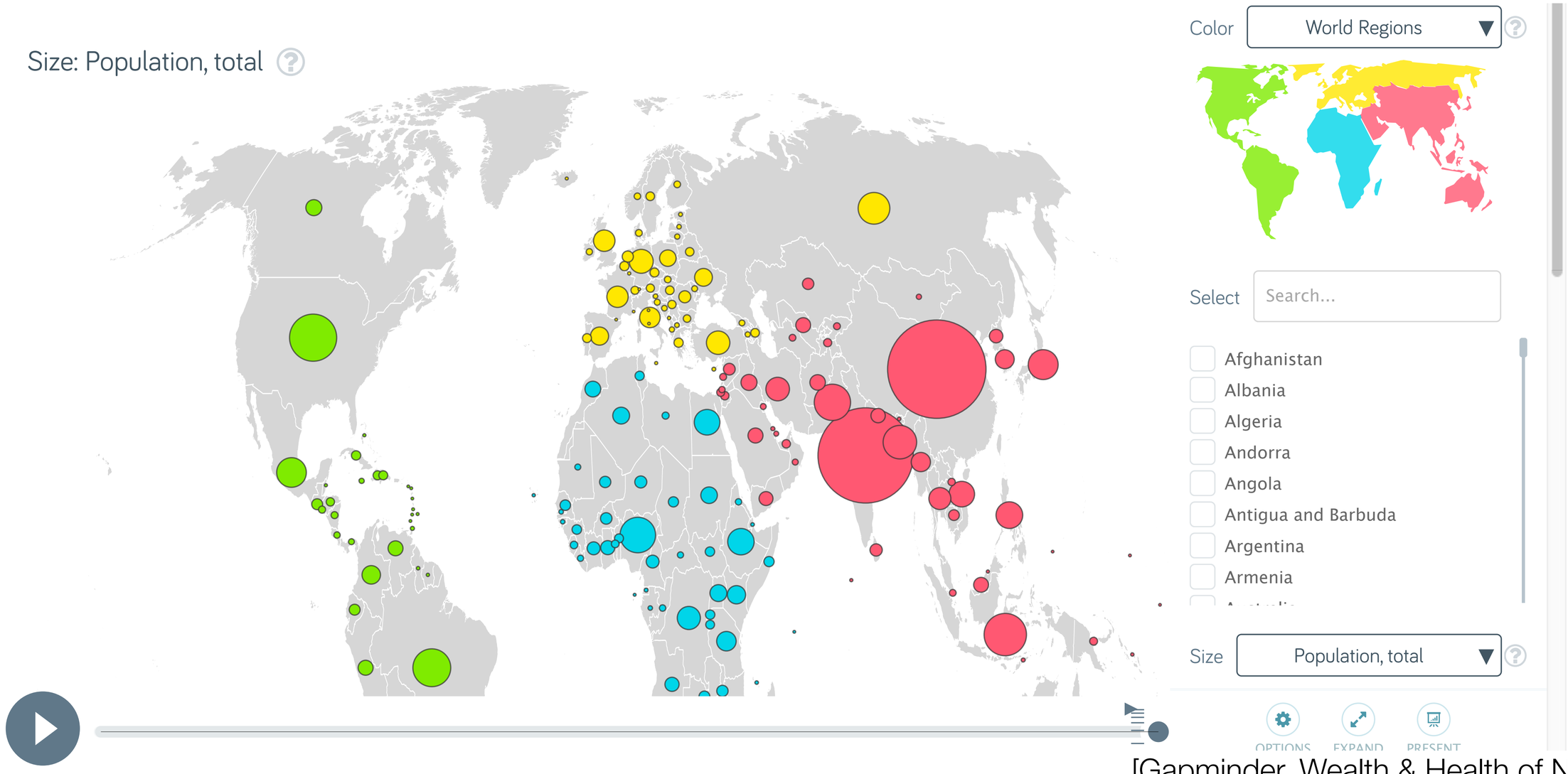
[Munzner (ill. Maguire), 2014]

Visual Encoding



[Gapminder, Wealth & Health of Nations]

Another Visual Encoding



[Gapminder, Wealth & Health of Nations]

Visual Encoding

- How do we encode data visually?
  - **Marks** are the basic graphical elements in a visualization
  - **Channels** are ways to control the appearance of the marks
- Marks classified by dimensionality:

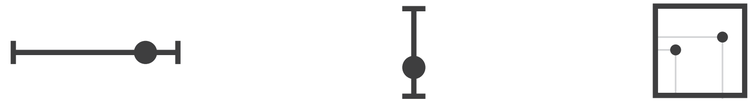
Points **Lines** **Areas**

- Also can have surfaces, volumes
- Think of marks as a mathematical definition, or if familiar with tools like Adobe

Visual Channels

Position

- Horizontal
- Vertical
- Both



Color

Shape

Tilt

Size

- Length
- Area
- Volume

[Munzner (ill. Maguire), 2014]

Definition

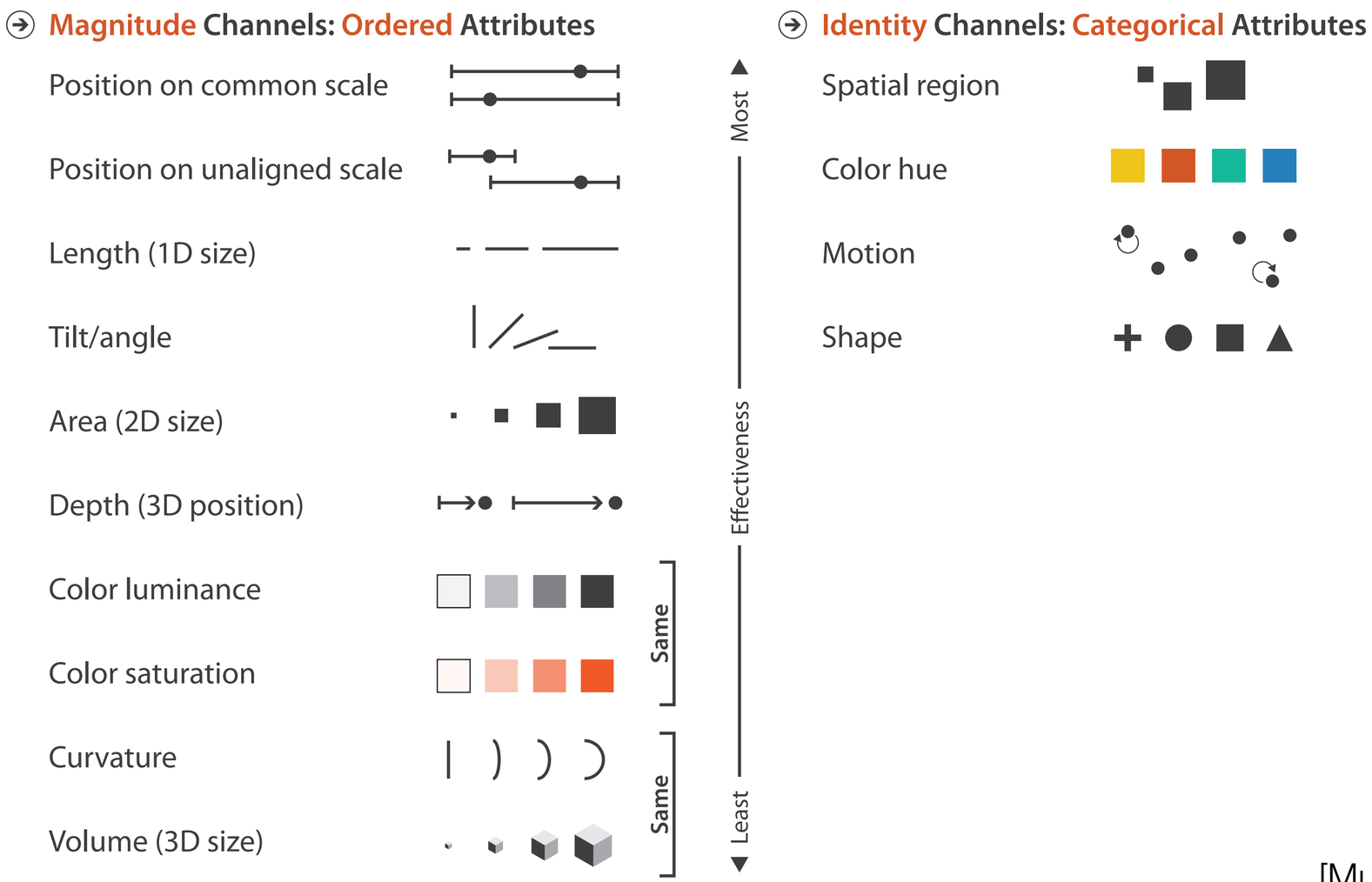
"Computer-based visualization systems provide visual representations of datasets designed to help people carry out tasks more **effectively**"

Expressiveness and Effectiveness

- **Expressiveness Principle**: all data from the dataset and nothing more should be shown
  - Do encode ordered data in an ordered fashion
  - Don’t encode categorical data in a way that implies an ordering
- **Effectiveness Principle**: the most important attributes should be the most **salient**
  - Saliency: how noticeable something is
  - How do the channels we have discussed measure up?

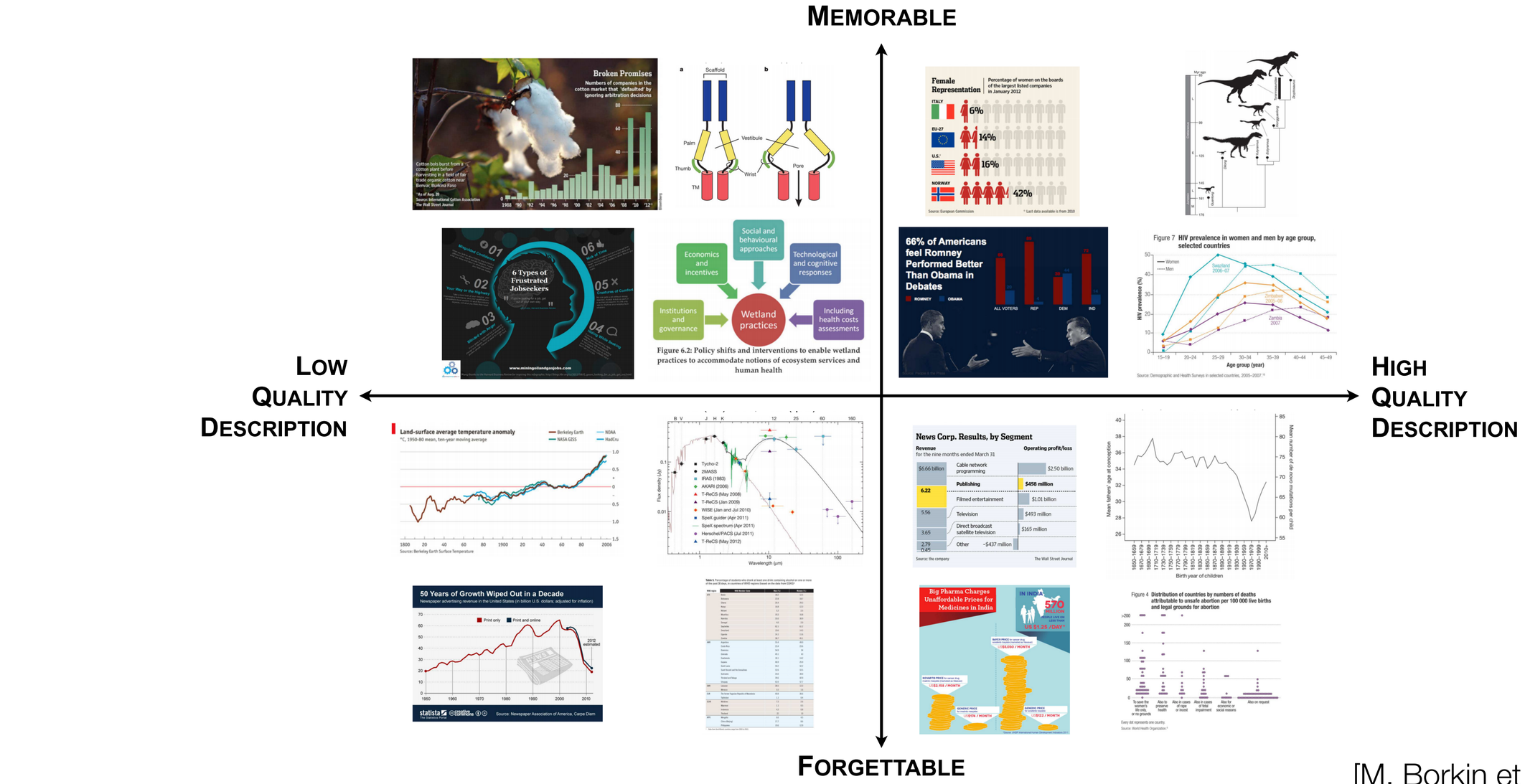
Channels by Effectiveness

Channels: Expressiveness Types and Effectiveness Ranks



[Munzner (ill. Maguire), 2014]

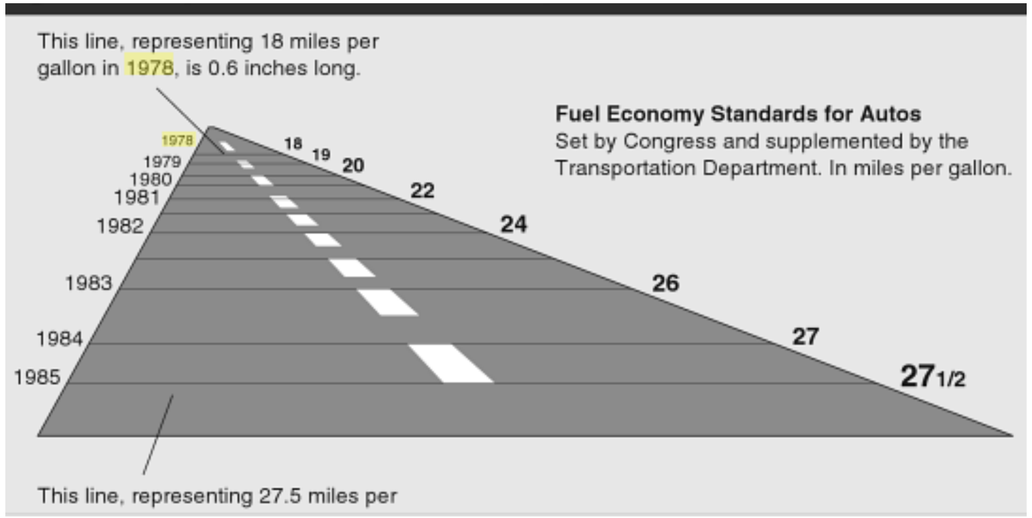
What about Memorability or Engagement?



[M. Borkin et al., InfoVis 2015]

Design Guidelines

- Tufte:
  - Show data variation, not design variation
  - Clear, detailed, and thorough labeling and appropriate scales
  - Size of the graphic effect should be directly proportional to the numerical quantities ("lie factor")



Design Analysis: What is Wrong Here?