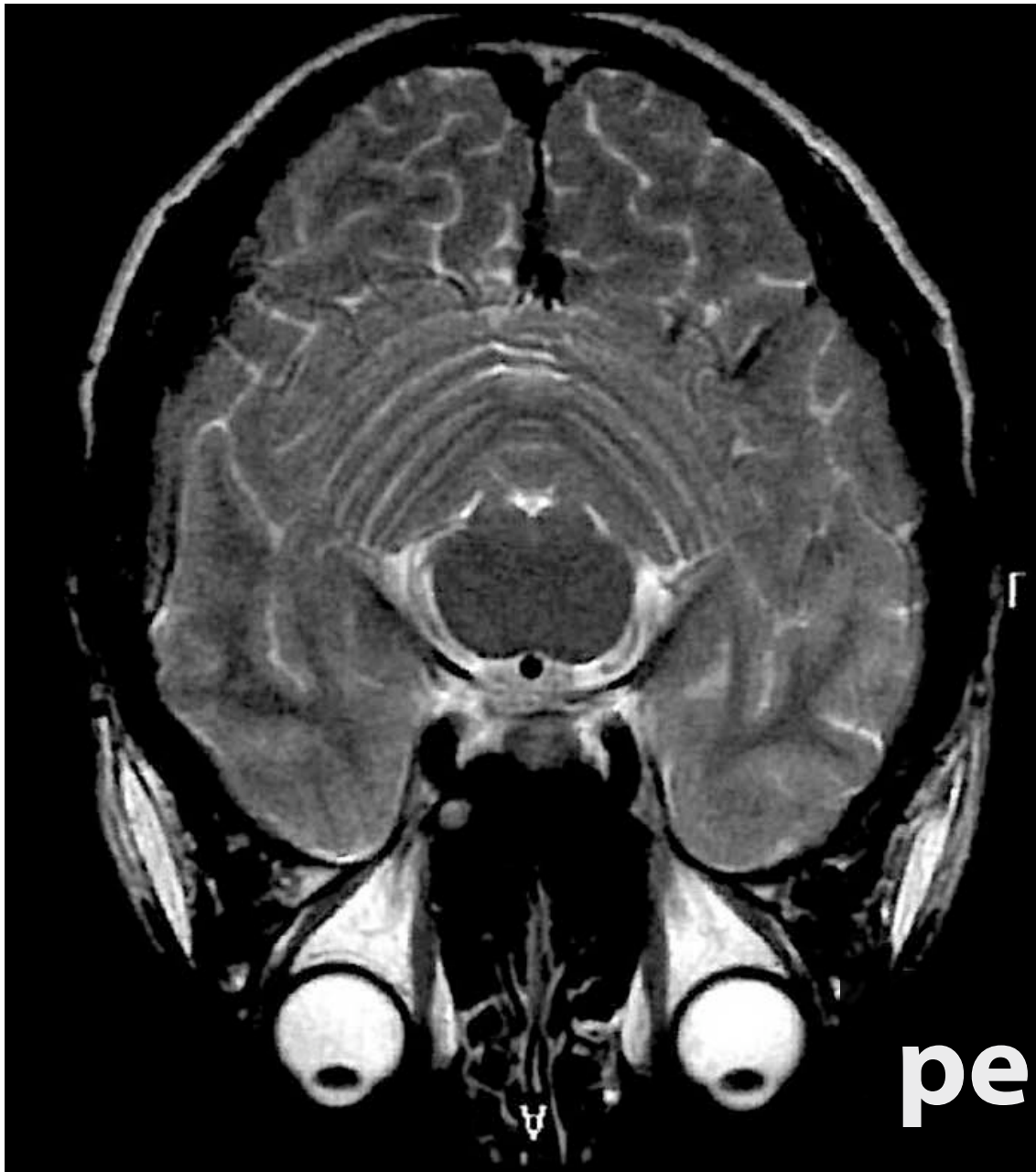


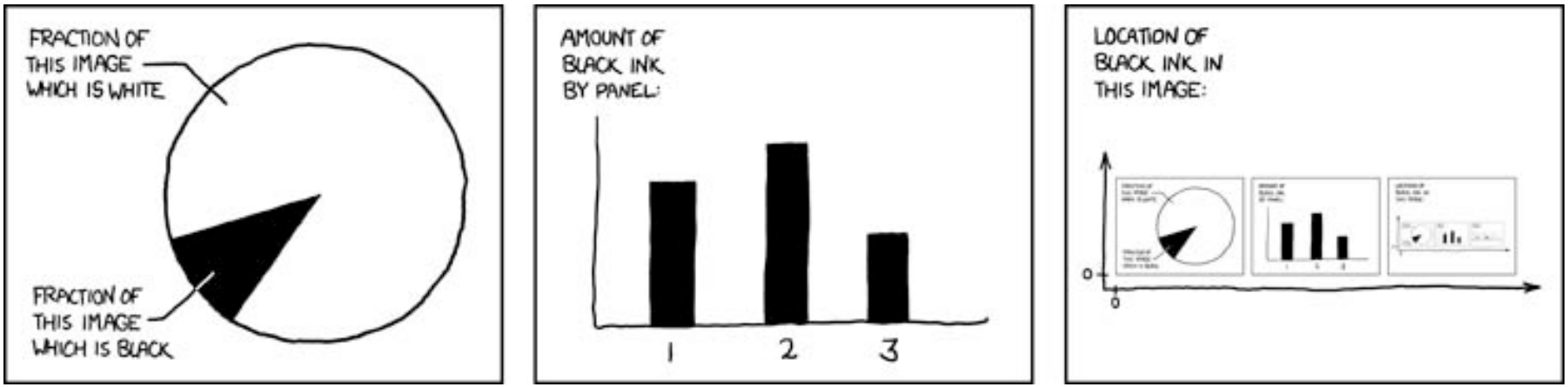
informations-
visualisierung

Wolfgang Aigner

aigner@ifs.tuwien.ac.at
http://ieg.ifs.tuwien.ac.at/~aigner/

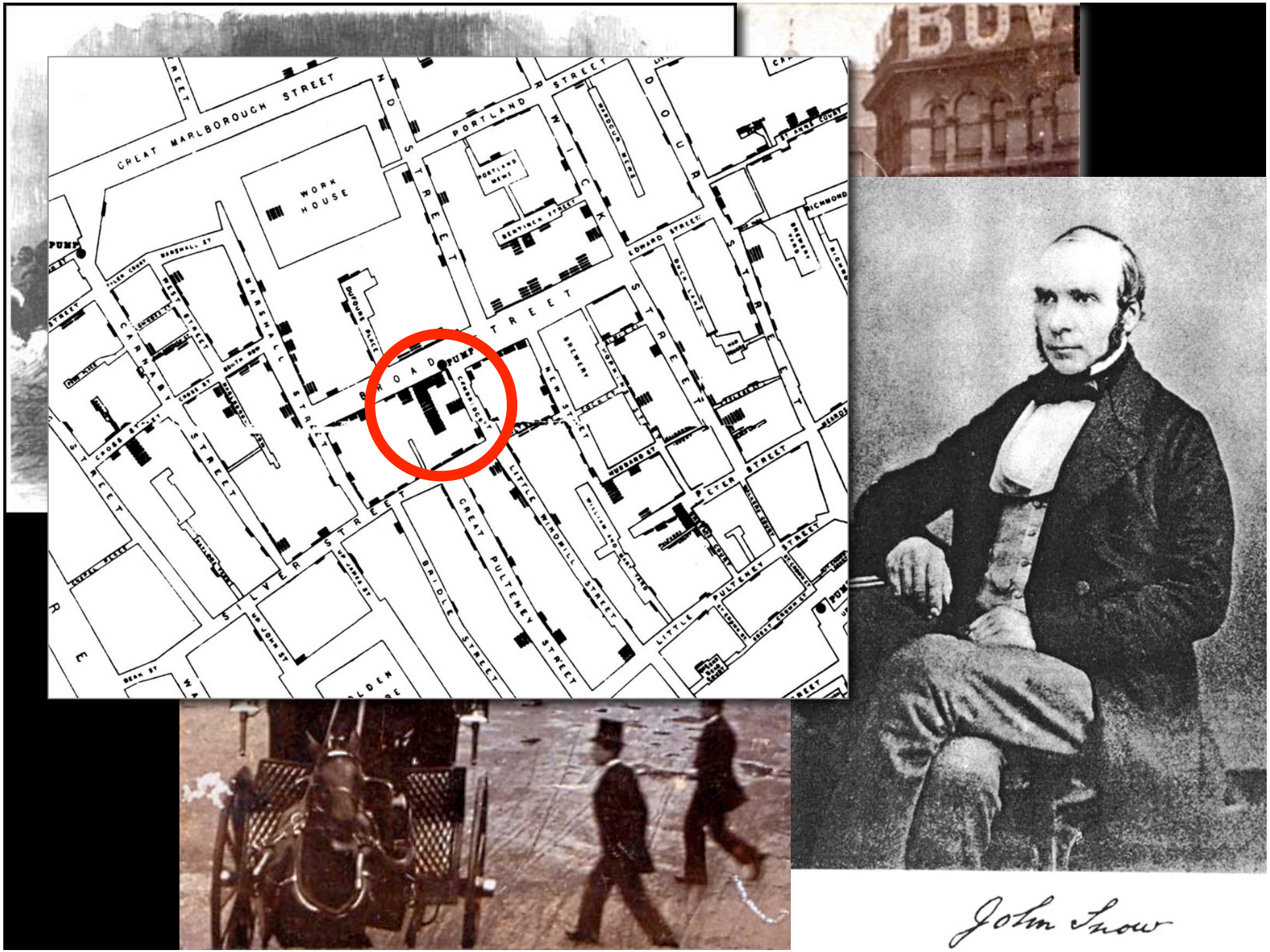
Version 1.1
26.10.2010

perception and **visualization**

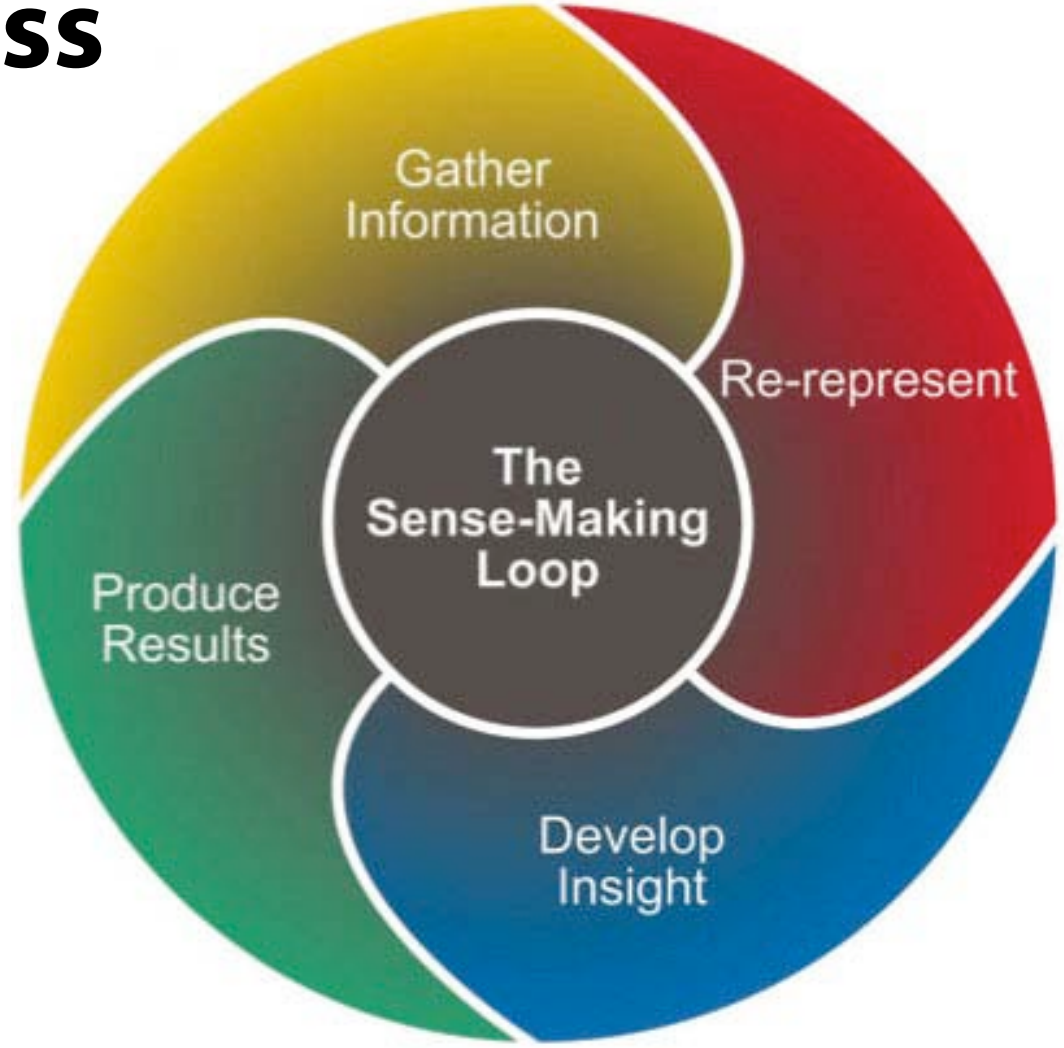


[http://xkcd.com/688/]

Part A
perception

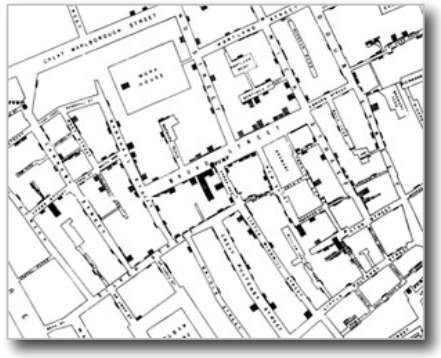

GREAT MARLBOROUGH STREET
WORK HOUSE
PORTLAND STREET
BROAD PUMP
BROAD STREET
GREAT PULTENEY STREET
BRIDLE STREET
LITTLE PULTENEY STREET
PETER STREET
RICHMOND
John Snow

Analytical Reasoning Process



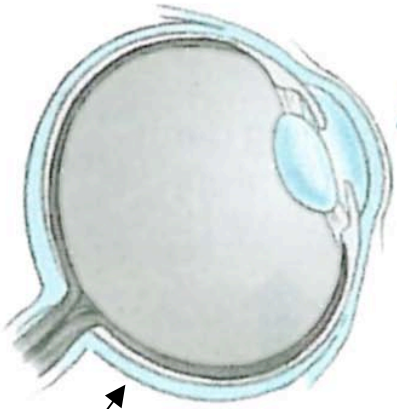
[Thomas & Cook, 2005]

Visual Perception

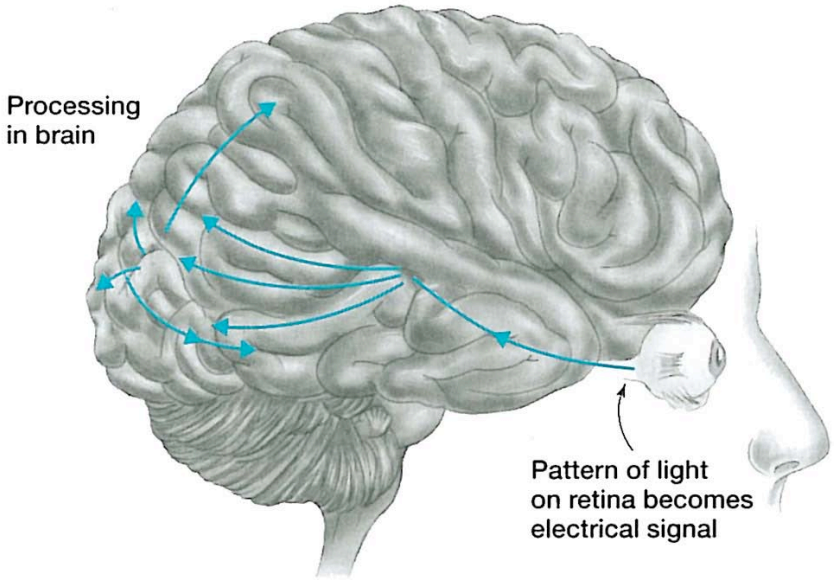


Light reflected from map

Dr. Snow's eye

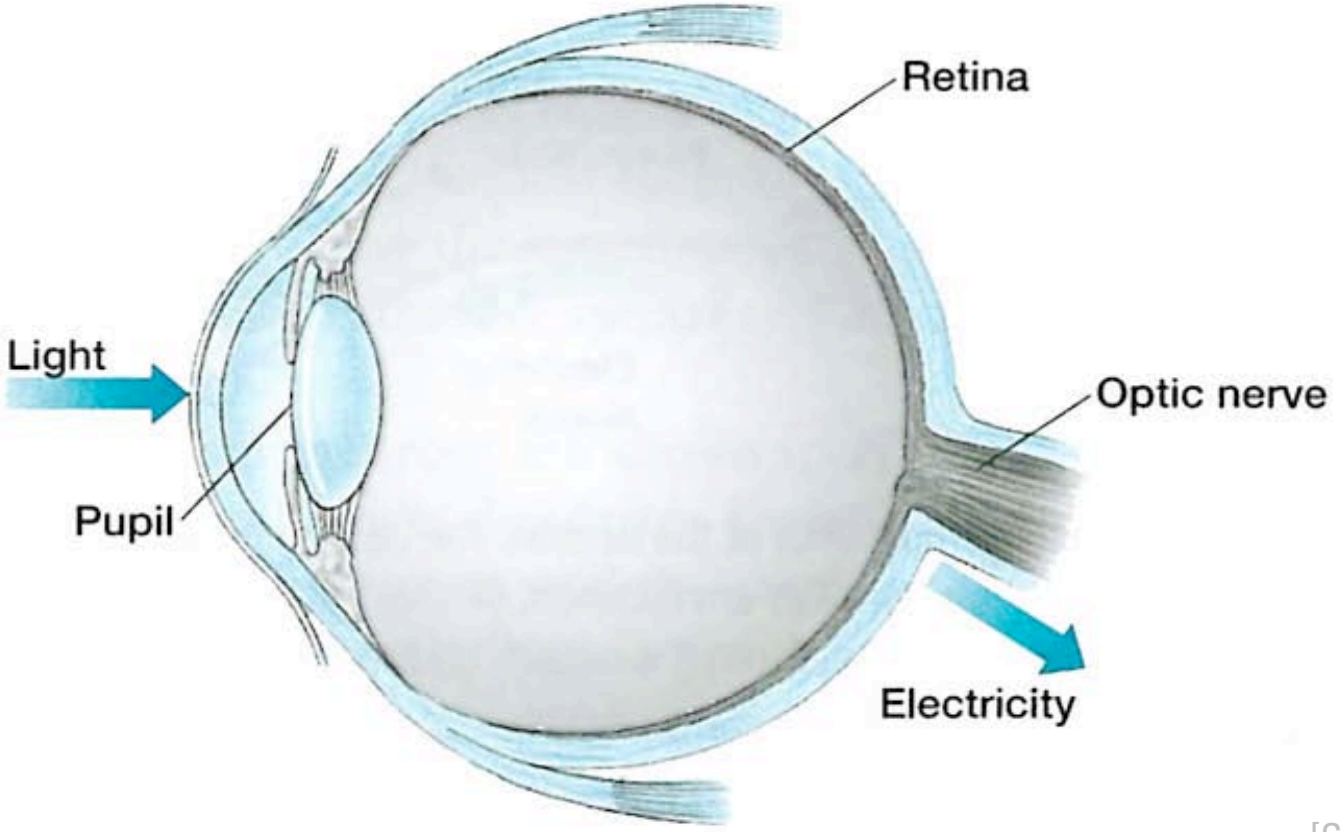


Pattern of light and dark
is formed on Dr. Snow's retina



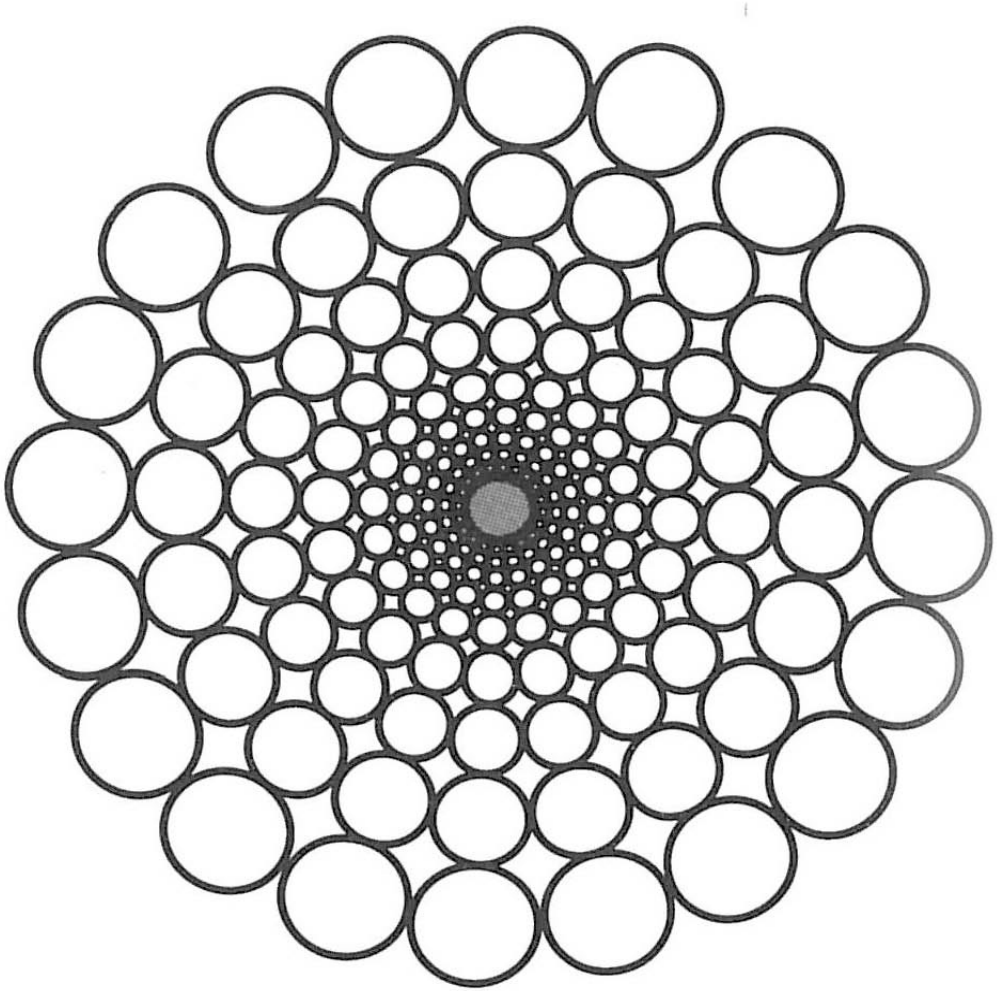
[Goldstein, 2005]

Human Eye



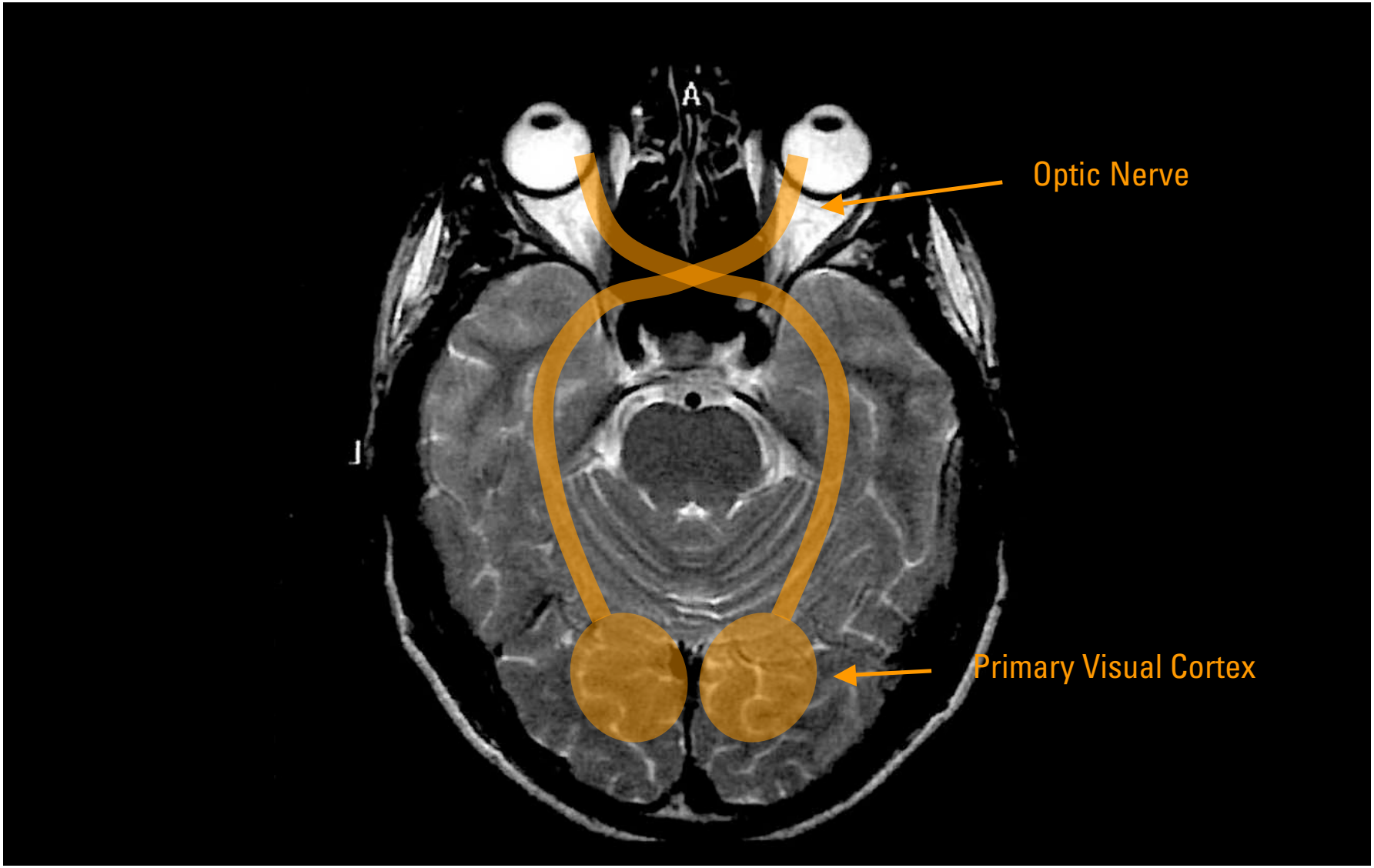
[Goldstein, 2005]

Brain Pixel



[Ware, 2008]

Visual Perception



Immediate perception

Immediate understanding - no learning necessary

Behaviour can't be forgotten

- Optical illusions are seen even when knowing that they are illusions

Sensual immediacy

- Certain phenomena are perceived very quickly because they are not learned but „hardwired" in the brain

Studied by brain research

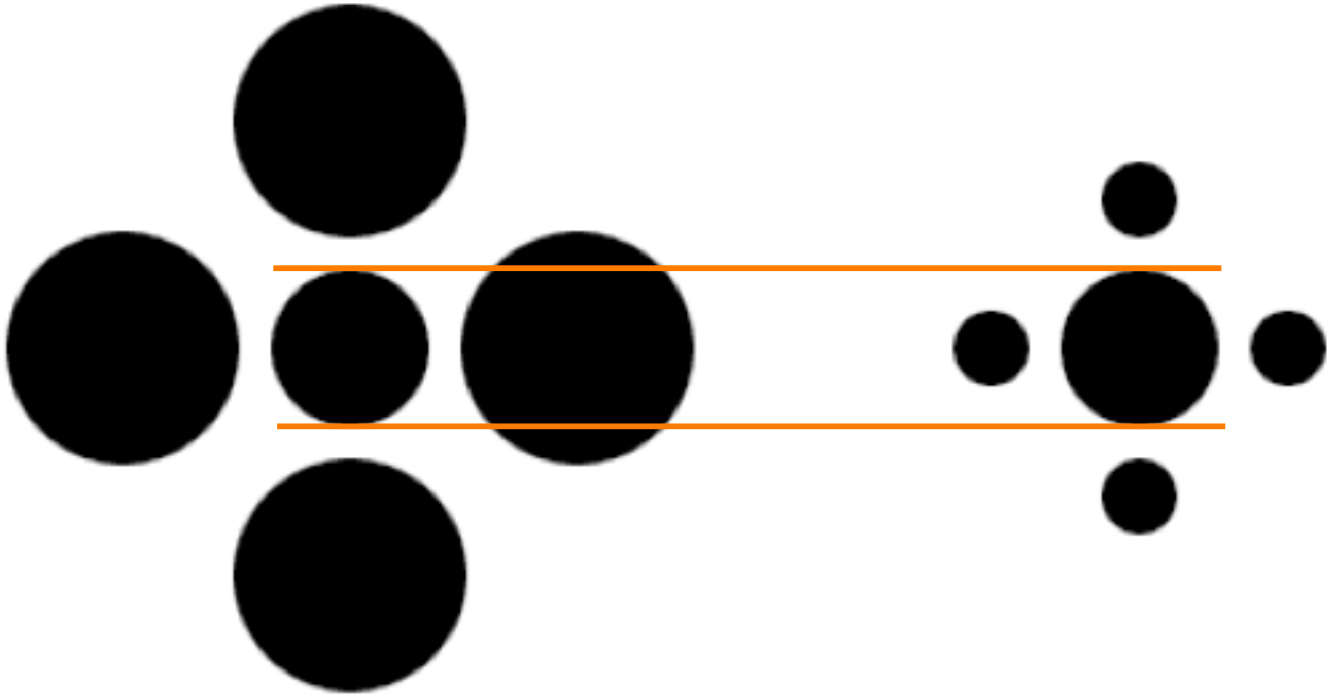
Effective and stable

Mostly innate and cultural invariant

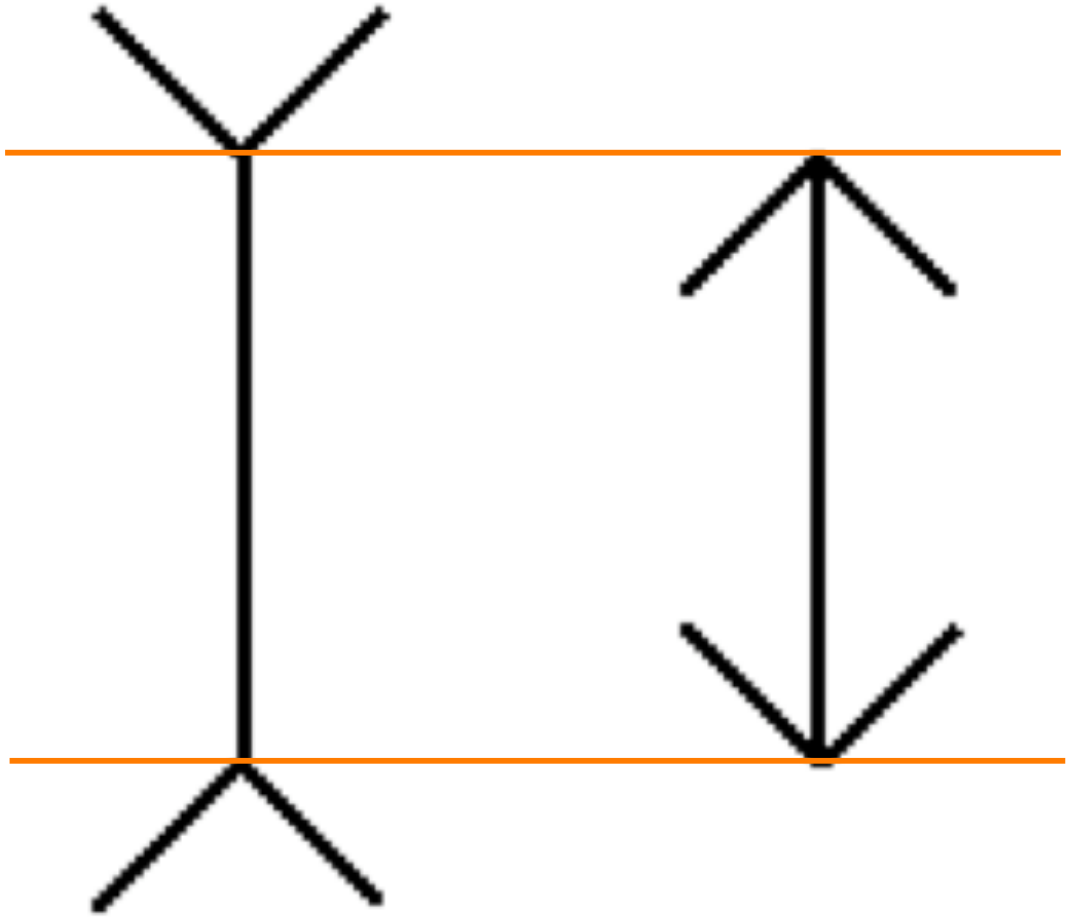
Phenomena of immediate perception (e.g., color and pattern perception) can be generalized to mankind

But also learned differentiations of the brain: most perceptual processes are based on a combination of innate and learned mechanisms

Optical illusions



Müller-Lyer Illusion



Conventional representations

Hard to learn

- e.g., script

Easy to forget

- But there are visual representations that can't be forgotten easily (e.g., numbers)

Embedded within cultural context

Powerful form of representation

- e.g., mathematical symbols

Easy to change

Studied by e.g., psychology, sociology, HCI

Preattentive Processing

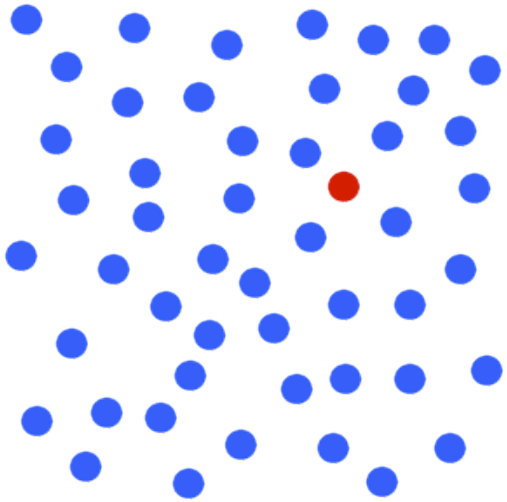
Preattentive Processing

1561321203658413076510374627
4173127527327592732990709742
1703707774179527931749270973
4019743217909370945179279417

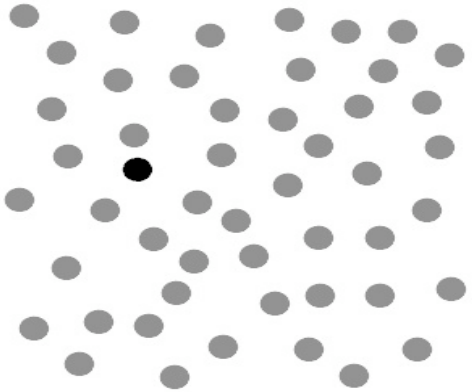
1561321203658413076510374627
4173127527327592732990709742
1703707774179527931749270973
4019743217909370945179279417

Color

Hue

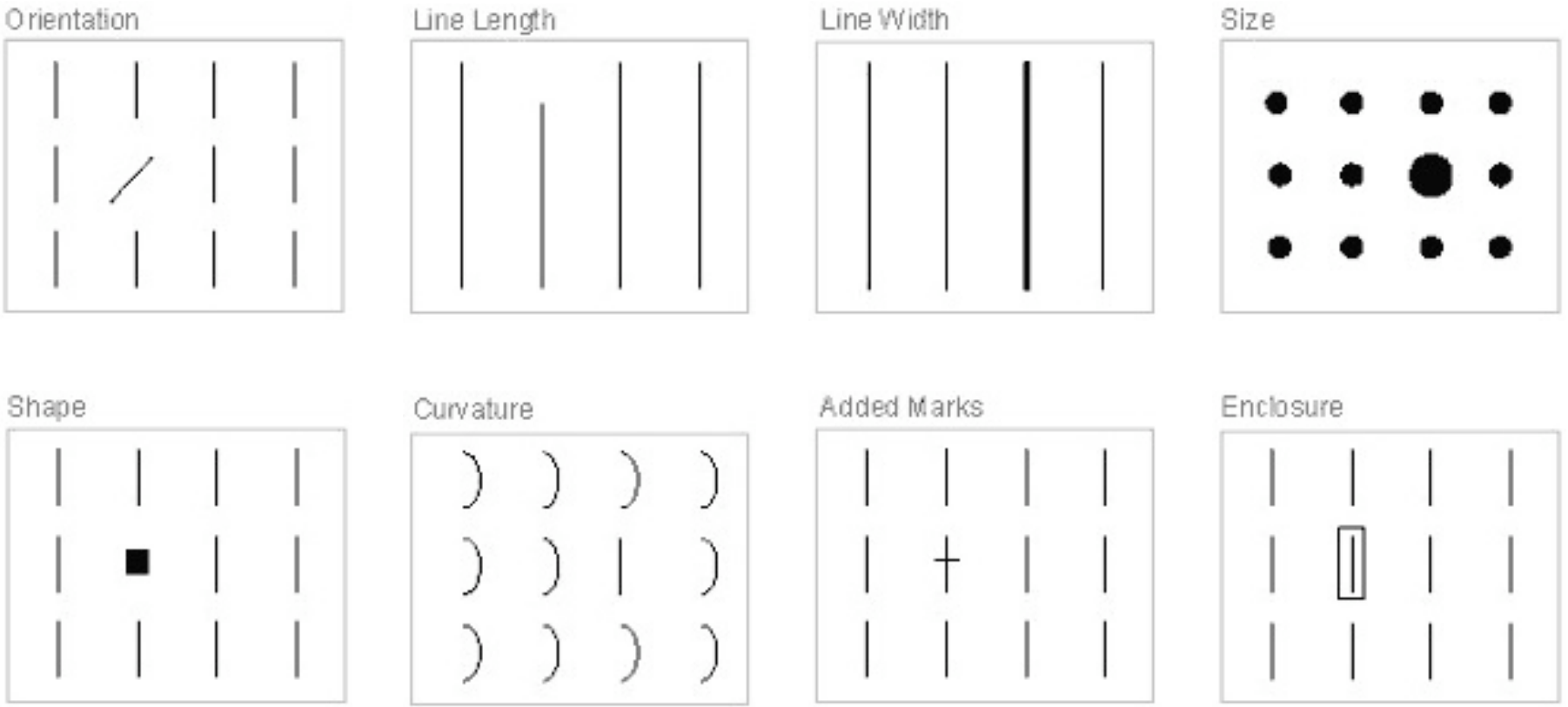


Intensity



[Dürsteler, 2006]

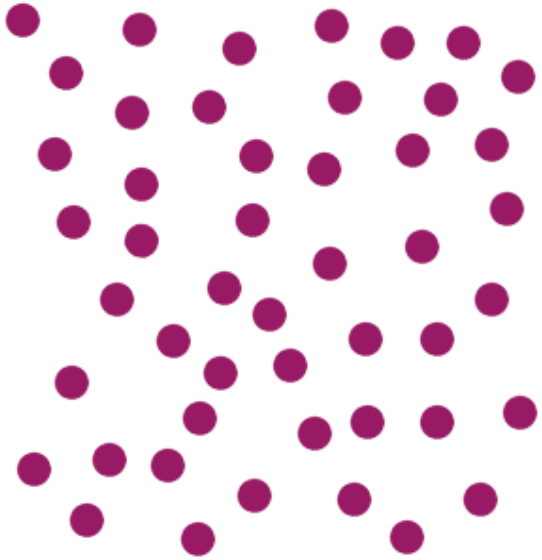
Form



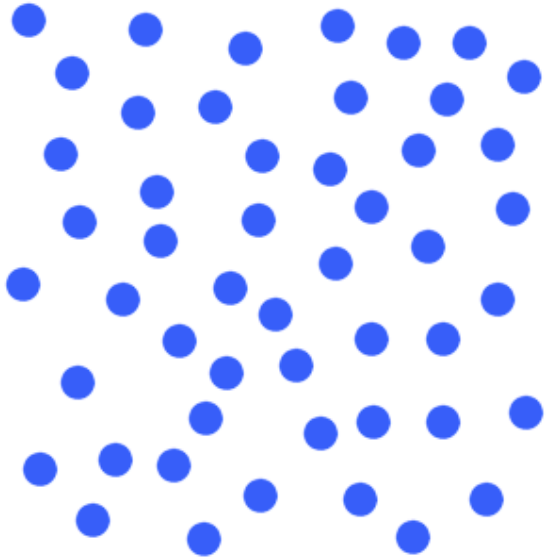
[Few, 2004]

Movement

(Direction of) motion



Flicker



[Dürsteler, 2006]

Gestalt Laws

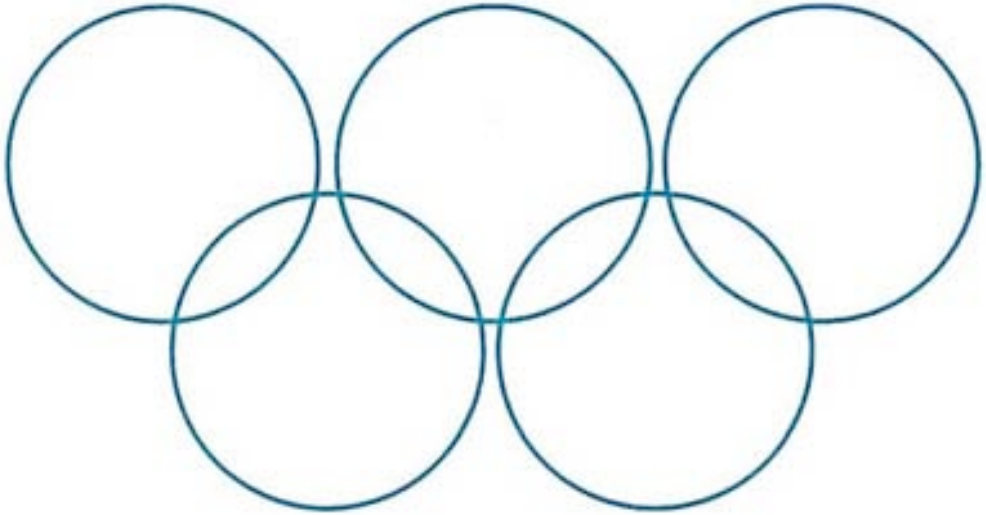
Proximity

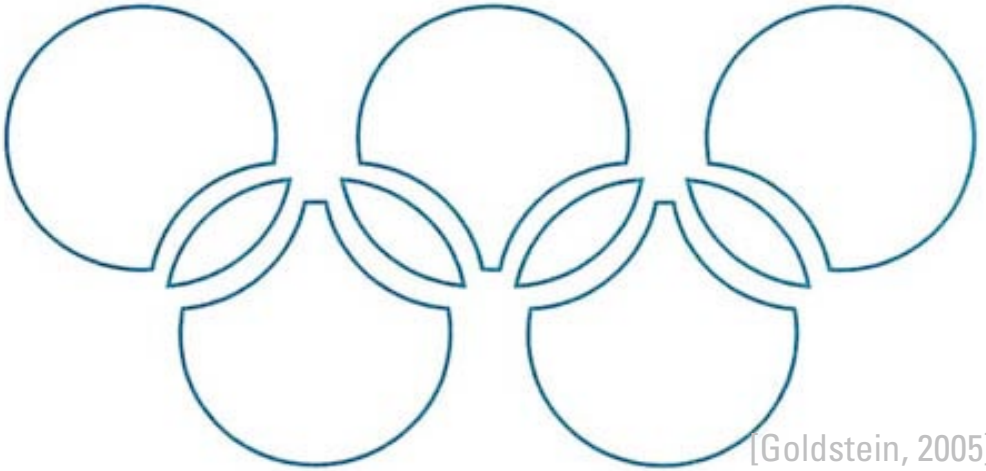
[Winkler, 2005]

Similarity

[Winkler, 2005]

Prägnanz





[Goldstein, 2005]

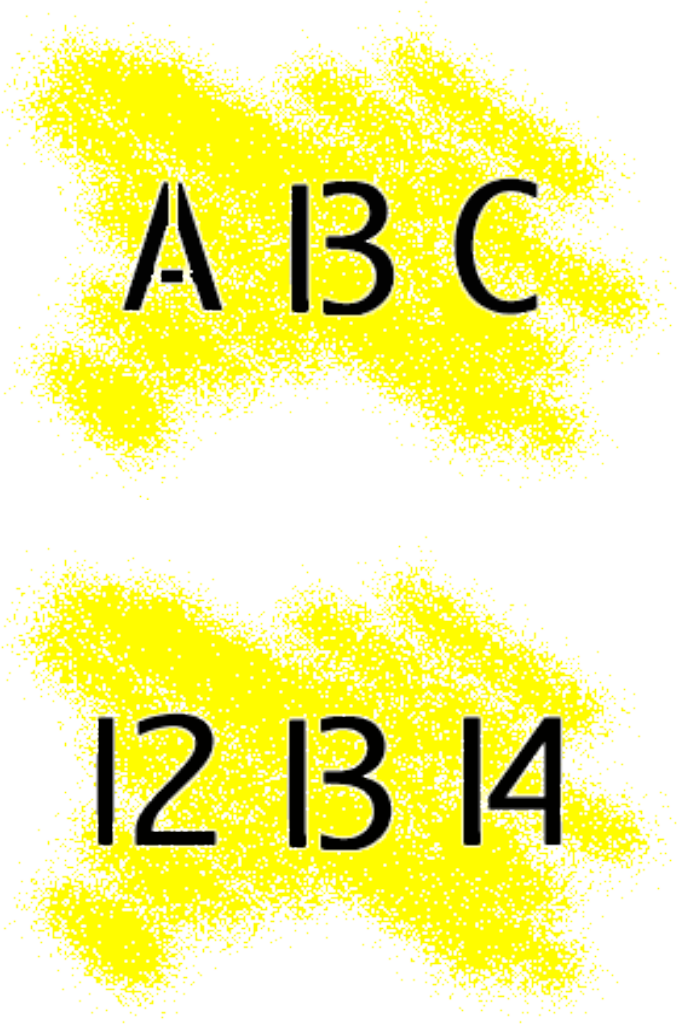
Good Continuation

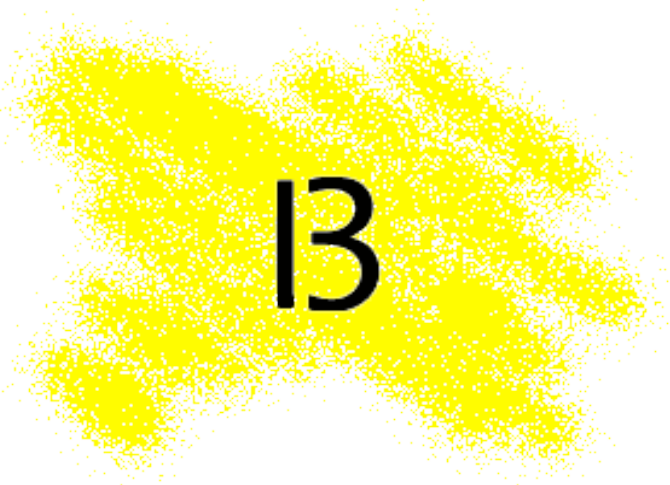
[Winkler, 2005]

Common Fate

[Pedroza, 2005]

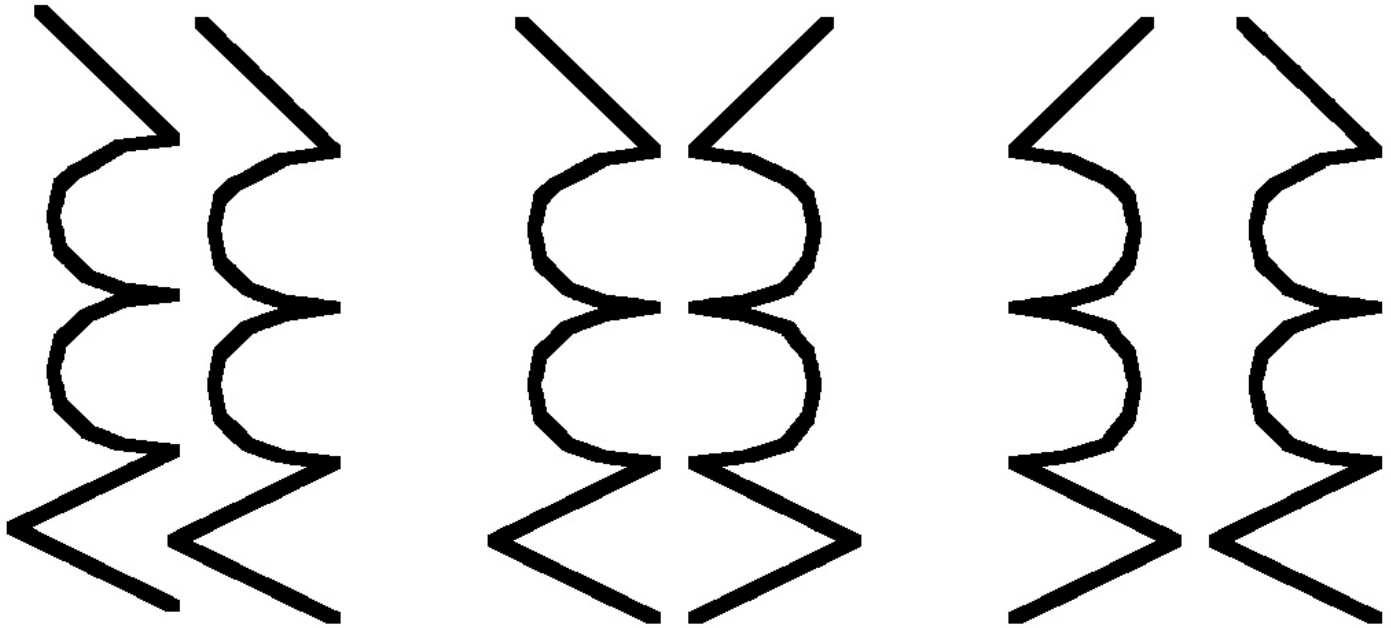
Familiarity





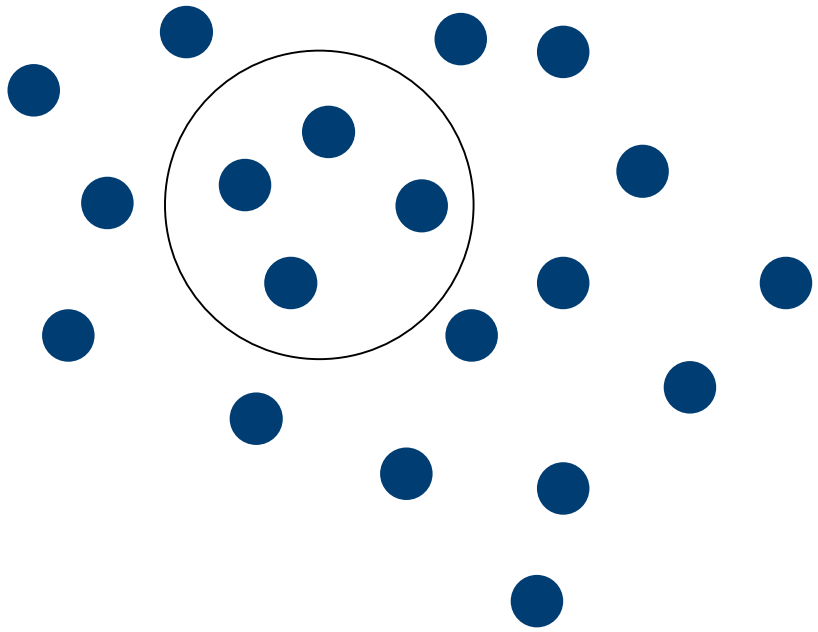
[Schmidt, 2005]

Symmetry

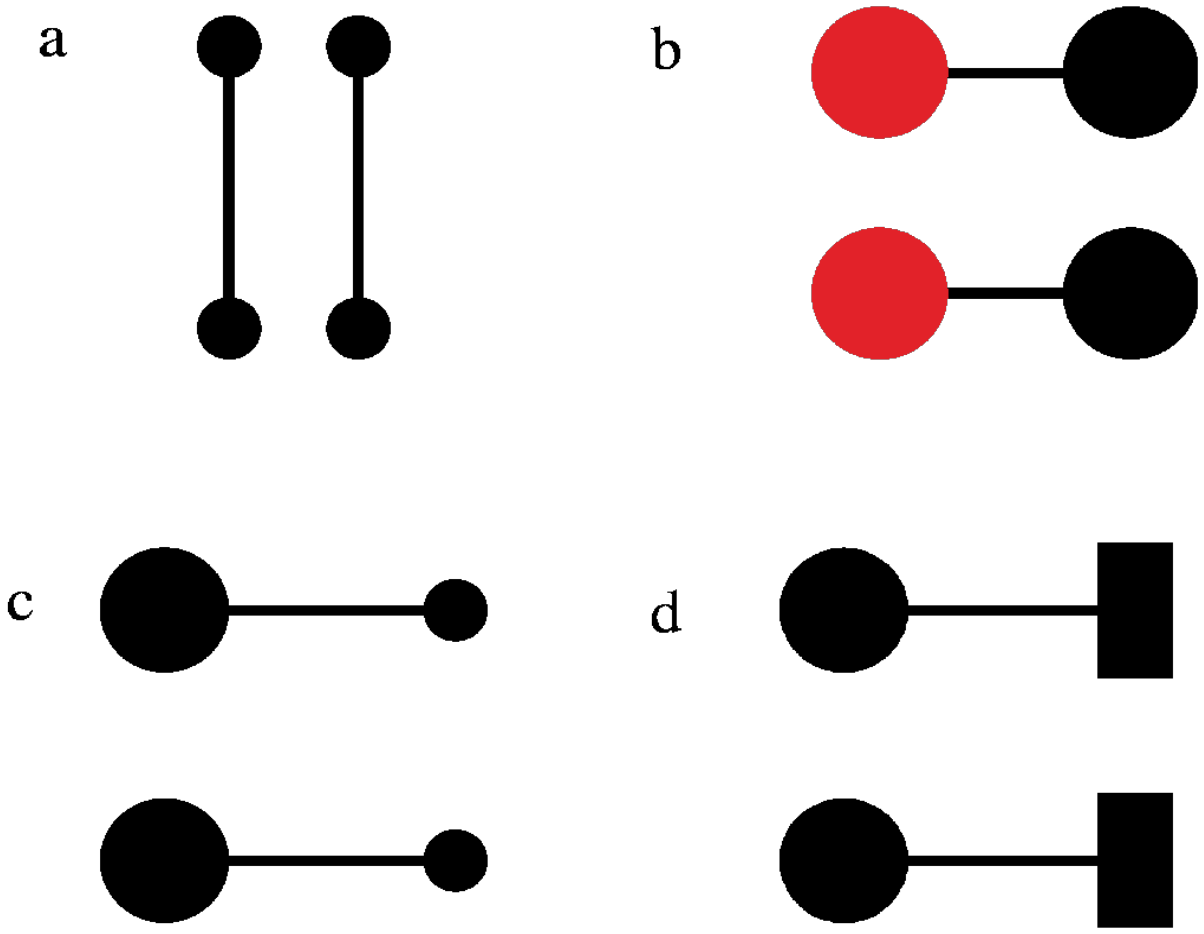


[Ware, 2004]

Enclosure

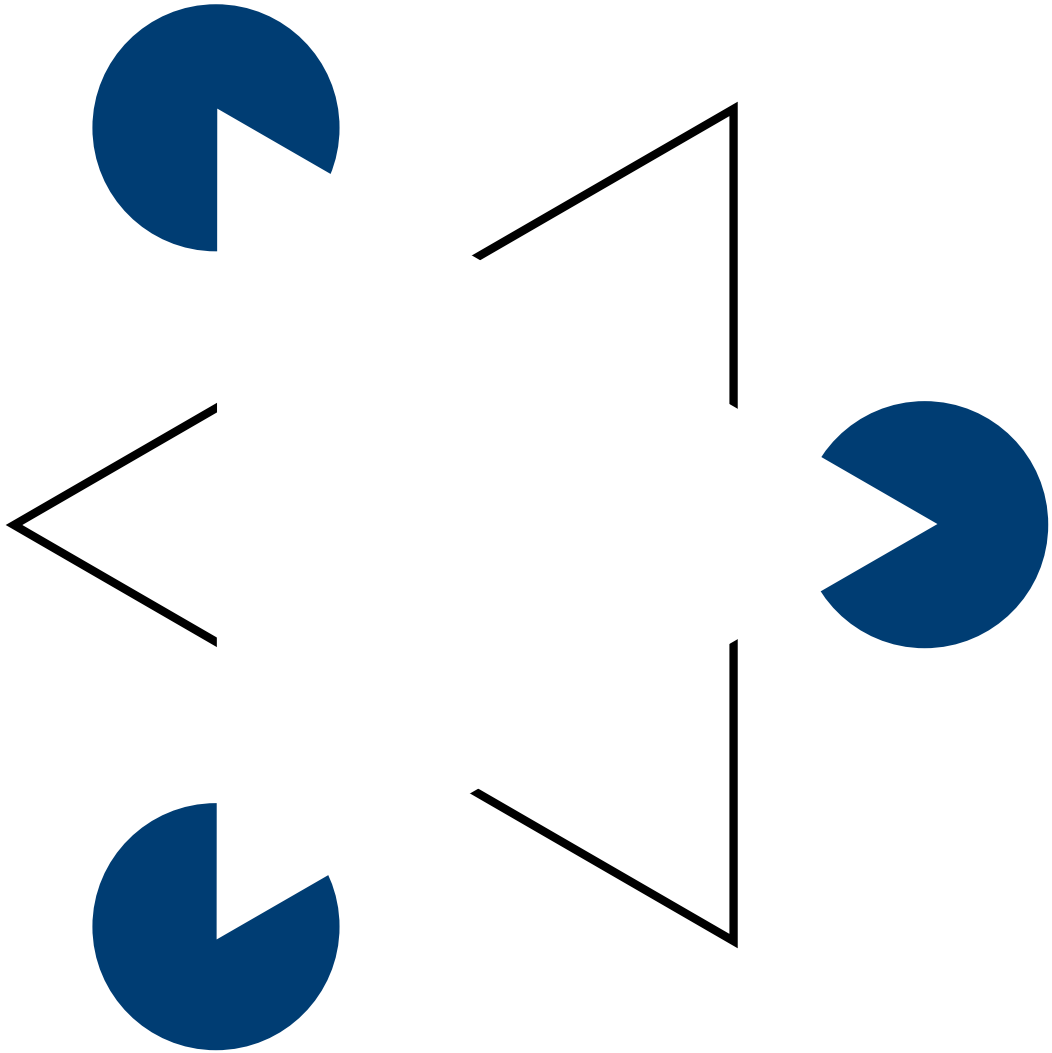


Connection



[Ware, 2004]

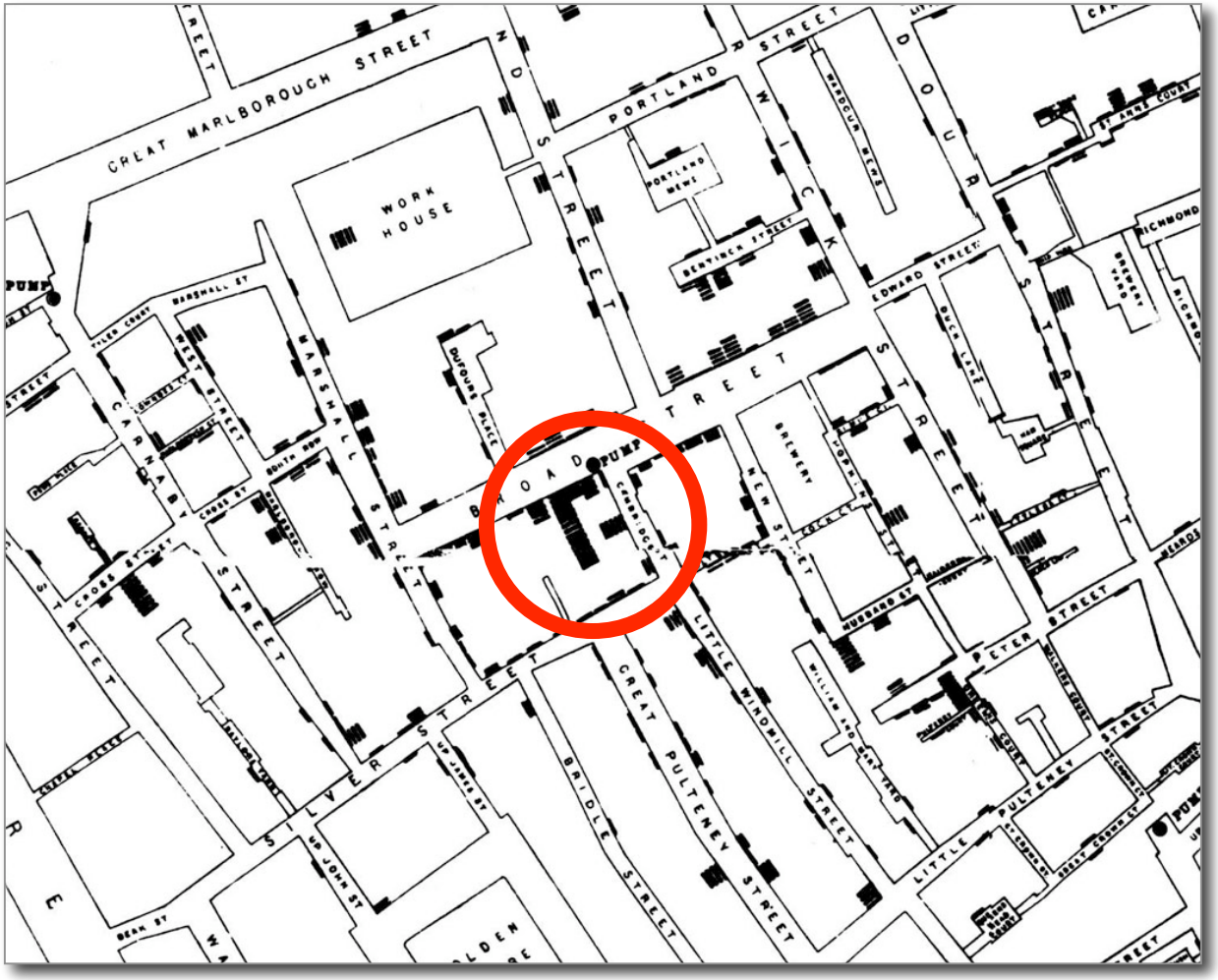
Closure



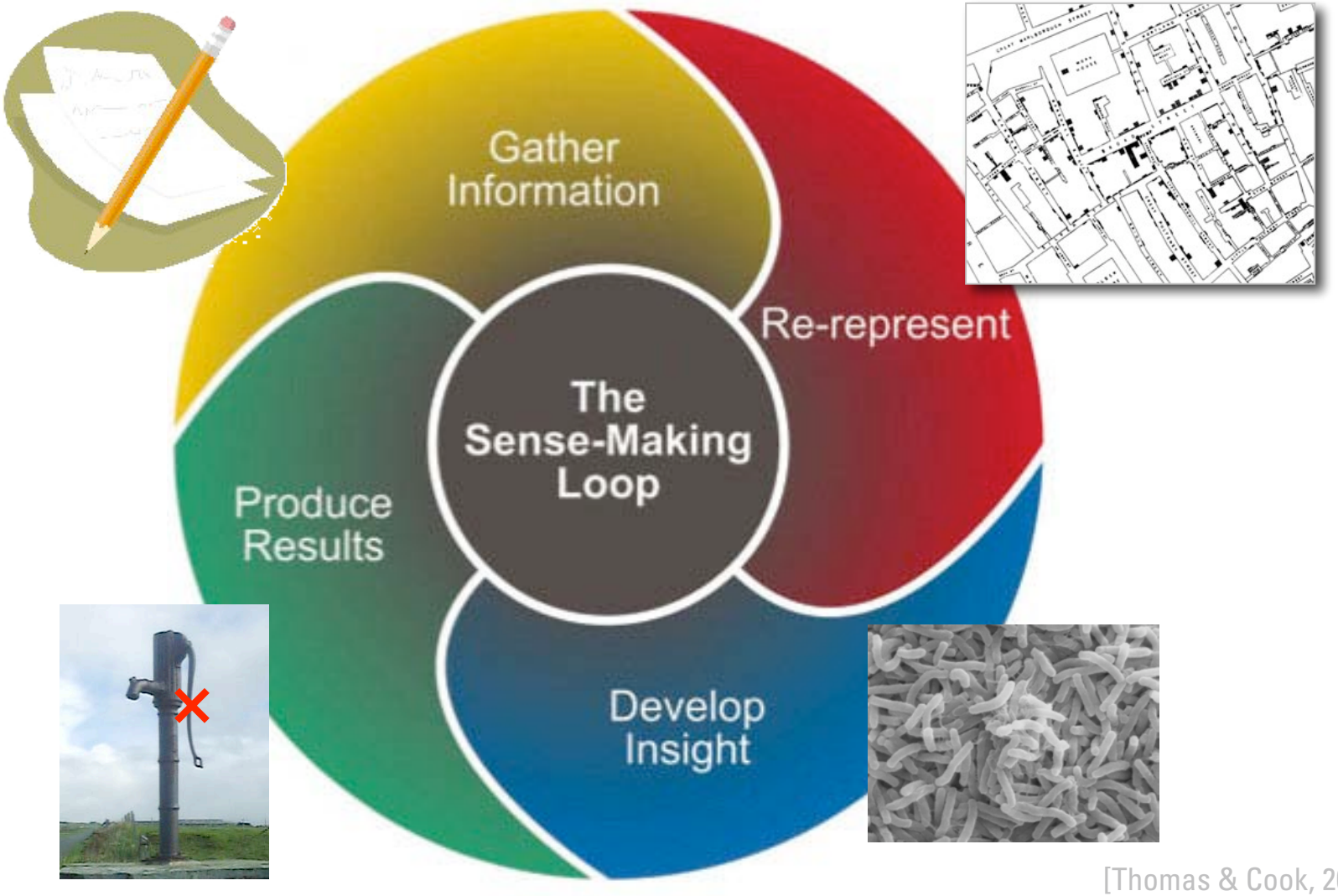
Change Blindness

Inattentional Blindness

Cognition


GREAT MARLBOROUGH STREET
WORK HOUSE
PORTLAND STREET
BROAD STREET
PUMP
MARSHALL STREET
CARNABY STREET
BRIDLE STREET
GREAT PULTENEY STREET
LITTLE PULTENEY STREET
PETER STREET
RICHMOND

Analytical Reasoning Process



[Thomas & Cook, 2005]

Resources

[Thomas and Cook, 2005] J.J. Thomas and K.A. Cook, eds., Illuminating the Path: The Research and Development Agenda for Visual Analytics, IEEE CS Press, 2005; http://nvac.pnl.gov/agenda.stm.

[Card et al., 1999] Card, S. and Mackinlay, J. and Shneiderman, B., Readings in Information Visualization: Using Vision to Think, Morgan Kaufmann Publishers, 1999.

★ [Healey, 2009] Christopher G. Healey, Perception in Visualization, Retrieved at: November 2, 2009. http://www.csc.ncsu.edu/faculty/healey/PP/index.html

[Dürsteler, 2005] Juan C. Dürsteler, Processes that pop out, Inf@Vis! (The digital magazine of InfoVis.net), Created at: Feb. 12, 2006, Retrieved at: Feb. 16, 2006, http://www.infovis.net/printMag.php?num=179&lang=2

[Few, 2004] Stephen Few, Data Presentation: Tapping the Power of Visual Perception, intelligent enterprise, September 2004. http://www.intelligententerprise.com/showArticle.jhtml?articleID=31400009

[Bertin, 1981] Bertin, J. Graphics and Graphic Information Processing. Walter De Gruyter, Inc., Berlin, 1981.

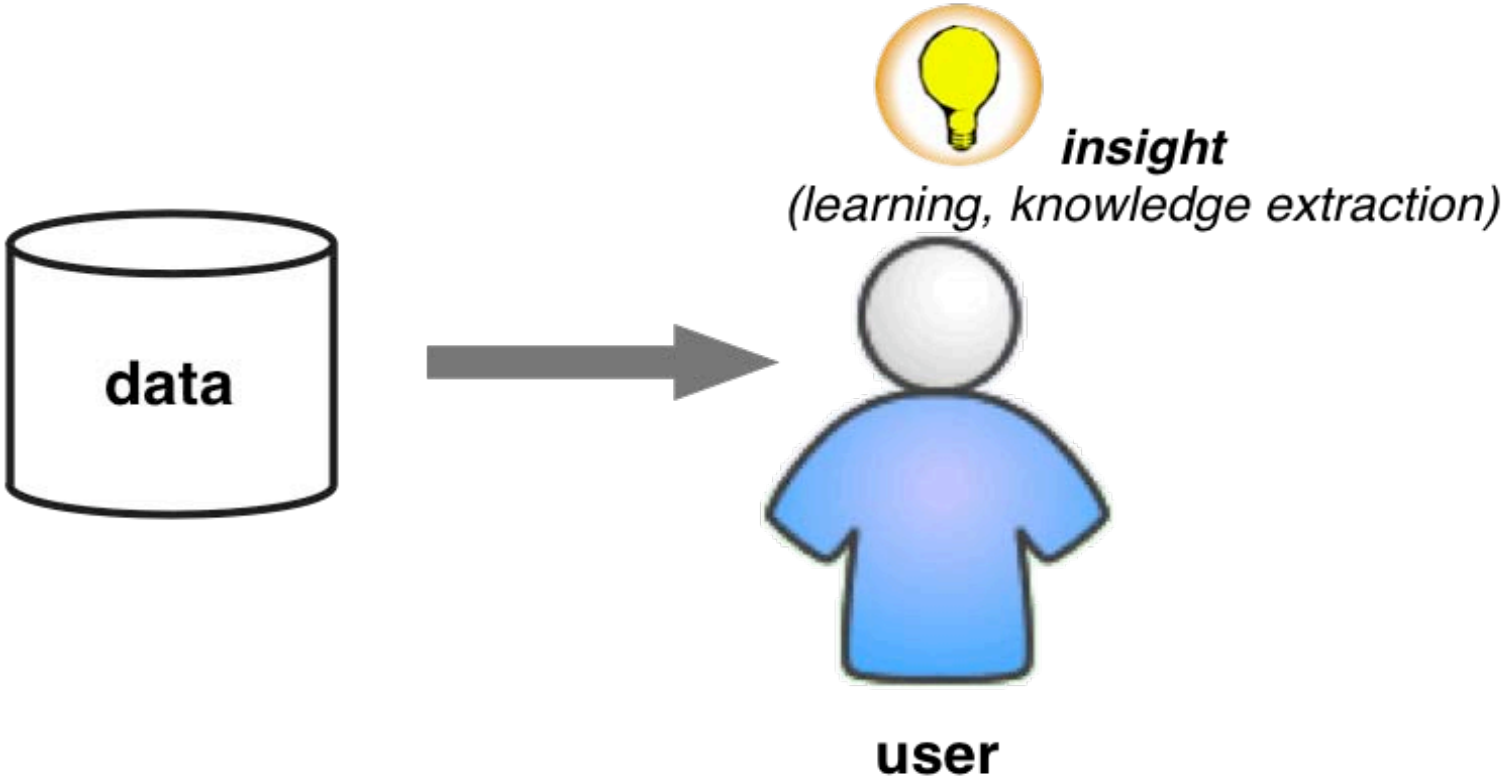
★ [Ware, 2008] Ware, C. Visual Thinking for Design, Morgan Kaufmann, Burlington, MA, 2008.

[Ware, 2004] Ware, C., Information Visualization: Perception for Design, Second Edition, Morgan Kaufmann, San Francisco, 2004.

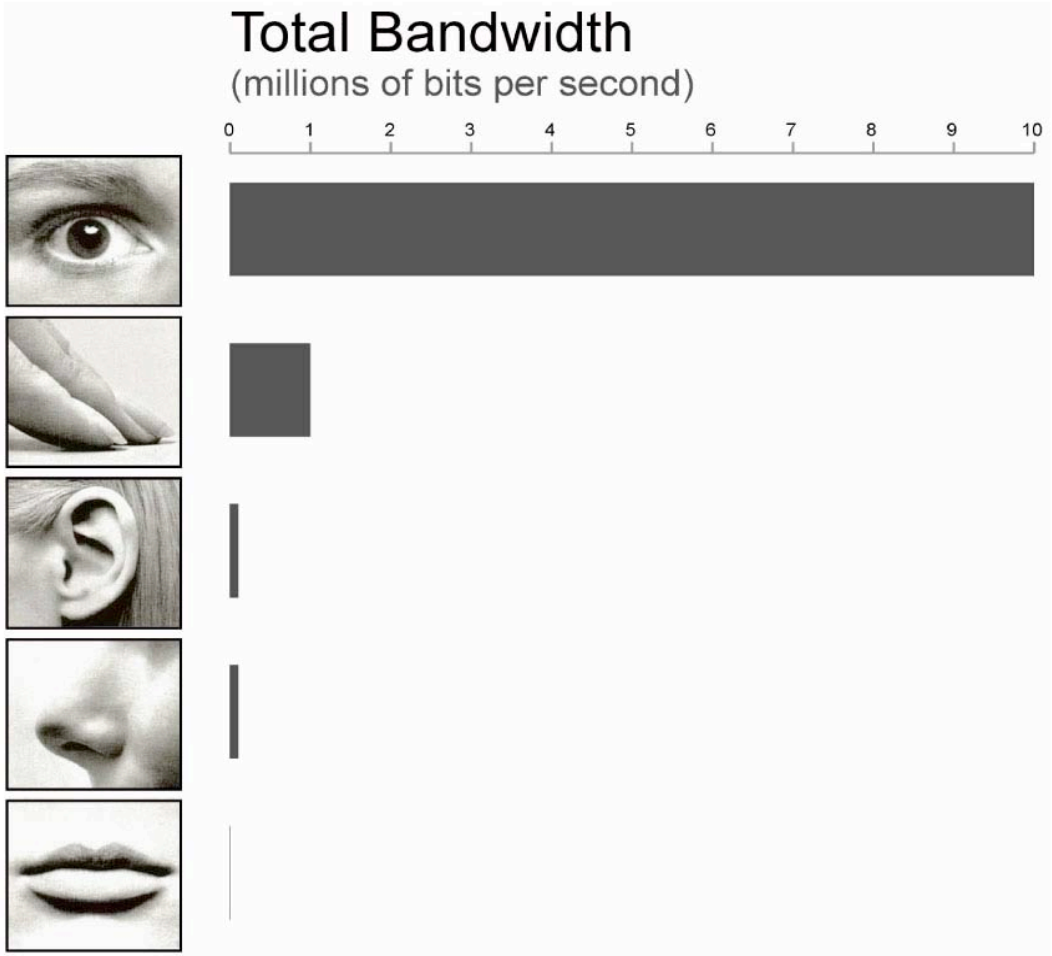
[Goldstein, 2005] Goldstein, Bruce. Cognitive Psychology, Thomson Wadsworth, 2005.

Part B
visualization

Goal



Why visualization?



[Few, 2006]

Why visualization?

Increasing cognitive resources

such as by using a visual resource to expand human working memory

Reducing search

such as by representing a large amount of data in a small space

Enhancing the recognition of patterns

such as when information is organized in space by its time relationships

Supporting the easy perceptual inference of relationships

that are otherwise more difficult to induce

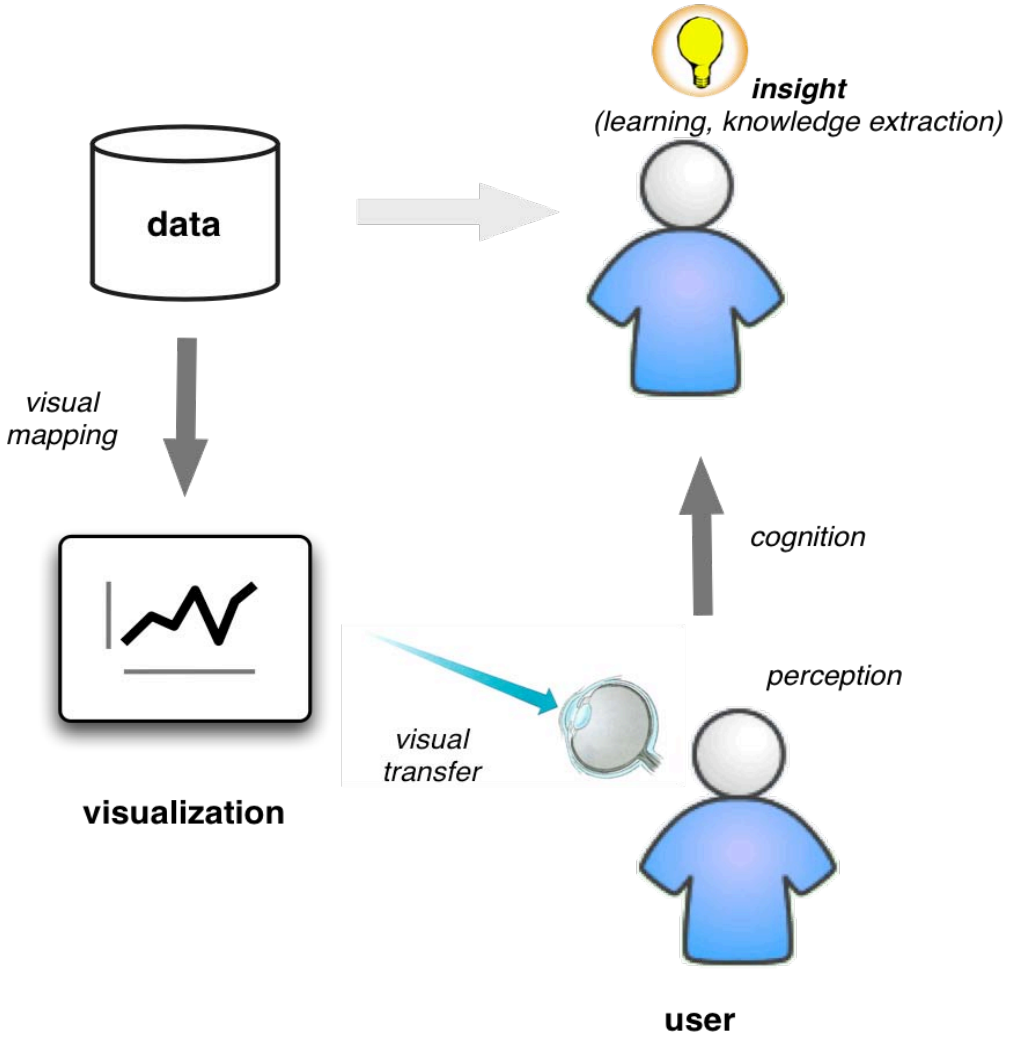
Perceptual monitoring of a large number of potential events

Providing a manipulable medium

that, unlike static diagrams, enables the exploration of a space of parameter values

[Card et al., 1999]

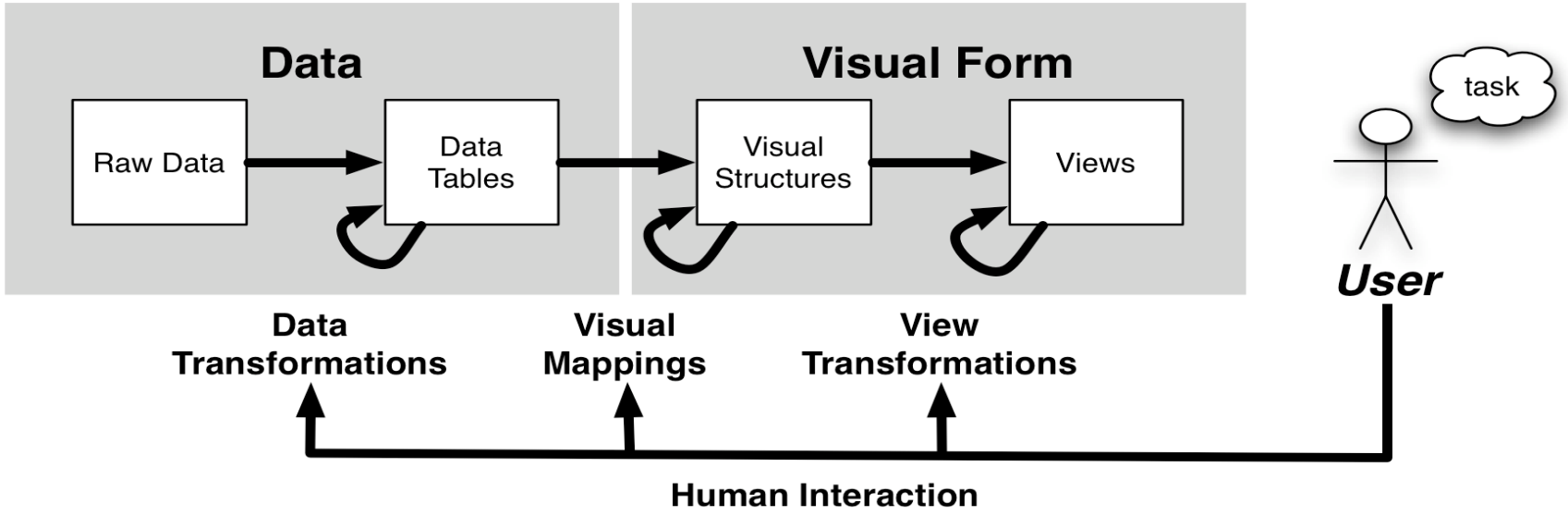
Method


insight
(learning, knowledge extraction)
data
visual
mapping
cognition
perception
visual
transfer
visualization
user

InfoVis Reference Model

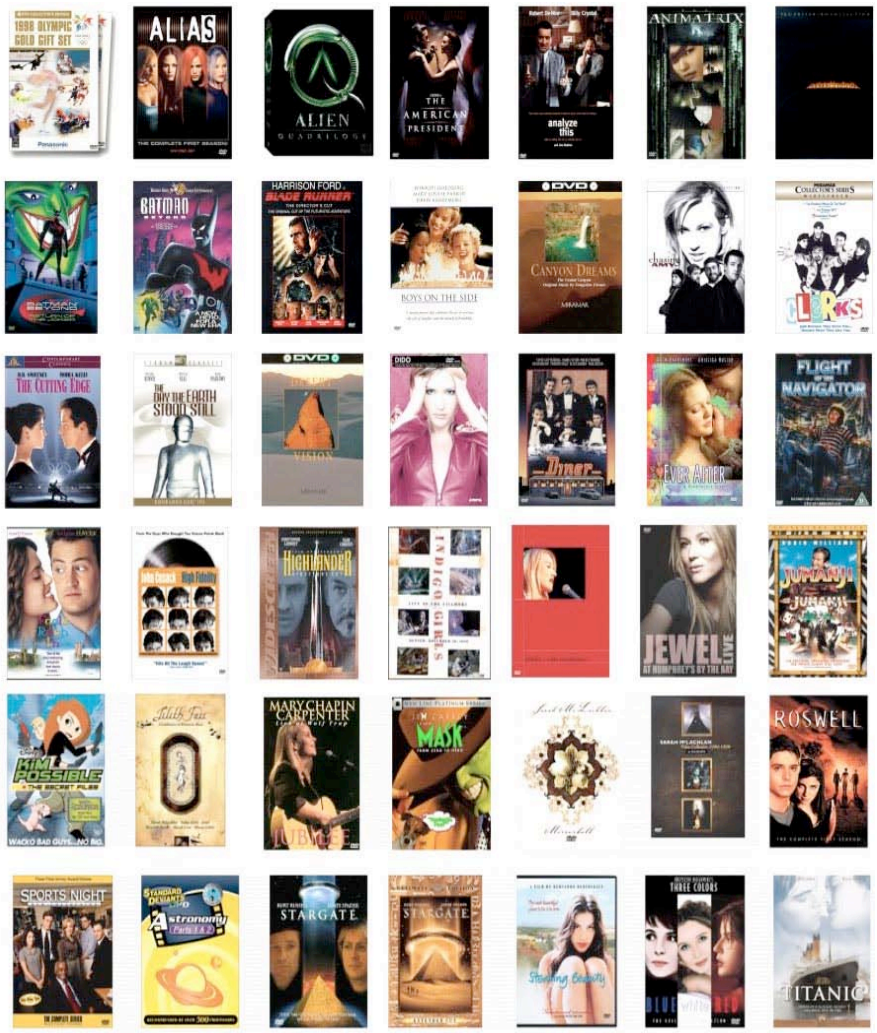
informations-visualisierung

[Card et al., 1999]



Raw Data: idiosyncratic formats
Data Transformations: Mapping raw data into an organization appropriate for visualization
Data Tables: relations (cases by variables) + metadata
Visual Mappings: Encoding abstract data into a visual representation
Visual Structures: spatial substrates + marks + graphical properties
View Transformations: Changing the view or perspective onto the visual presentation
Views: graphical parameters (position, scaling, clipping, ...)
Human Interaction: User influence at any level

Data



year

length

popularity

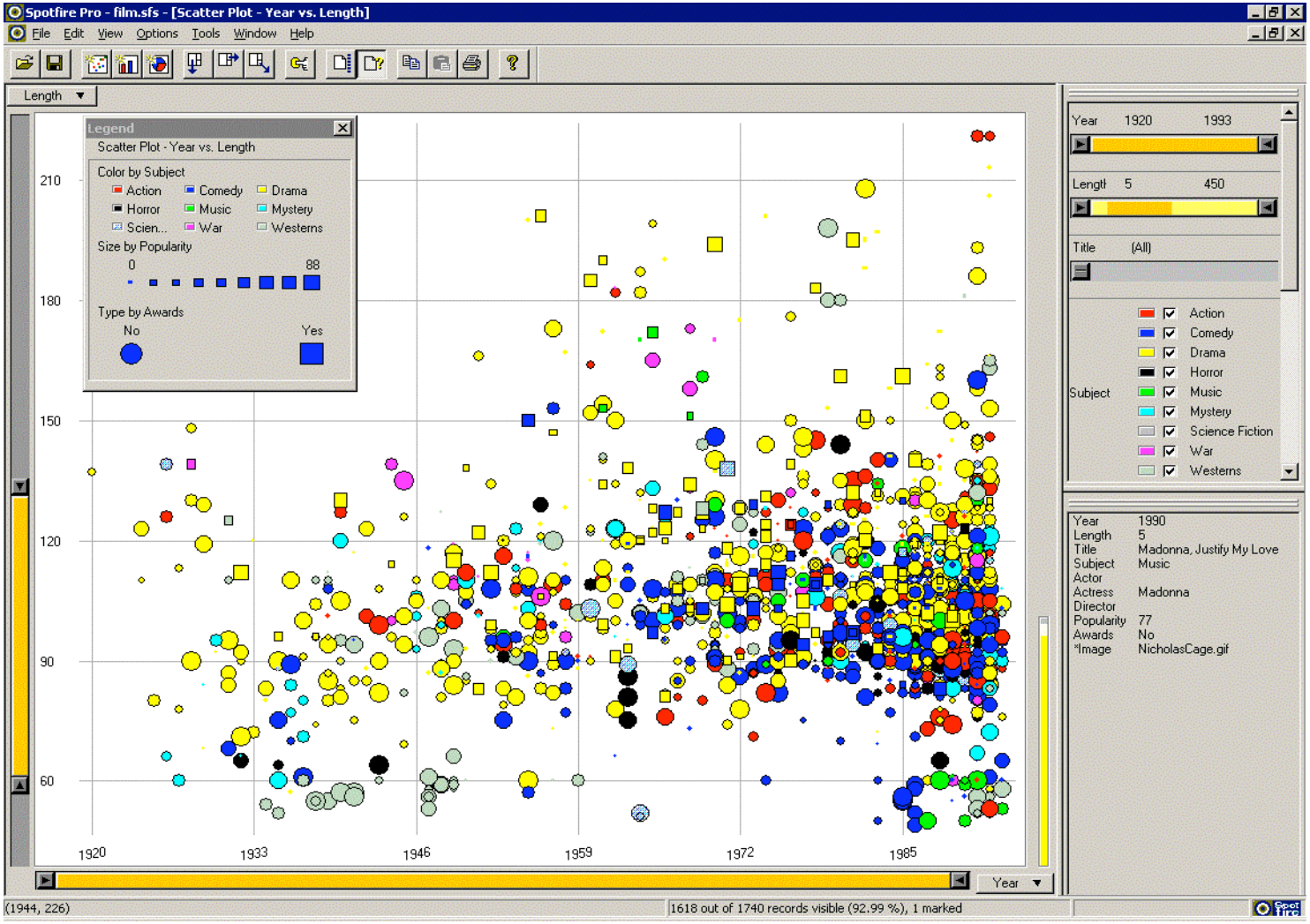
subject

award?

[garysaid.com]

Visual Mapping

informations-visualisierung



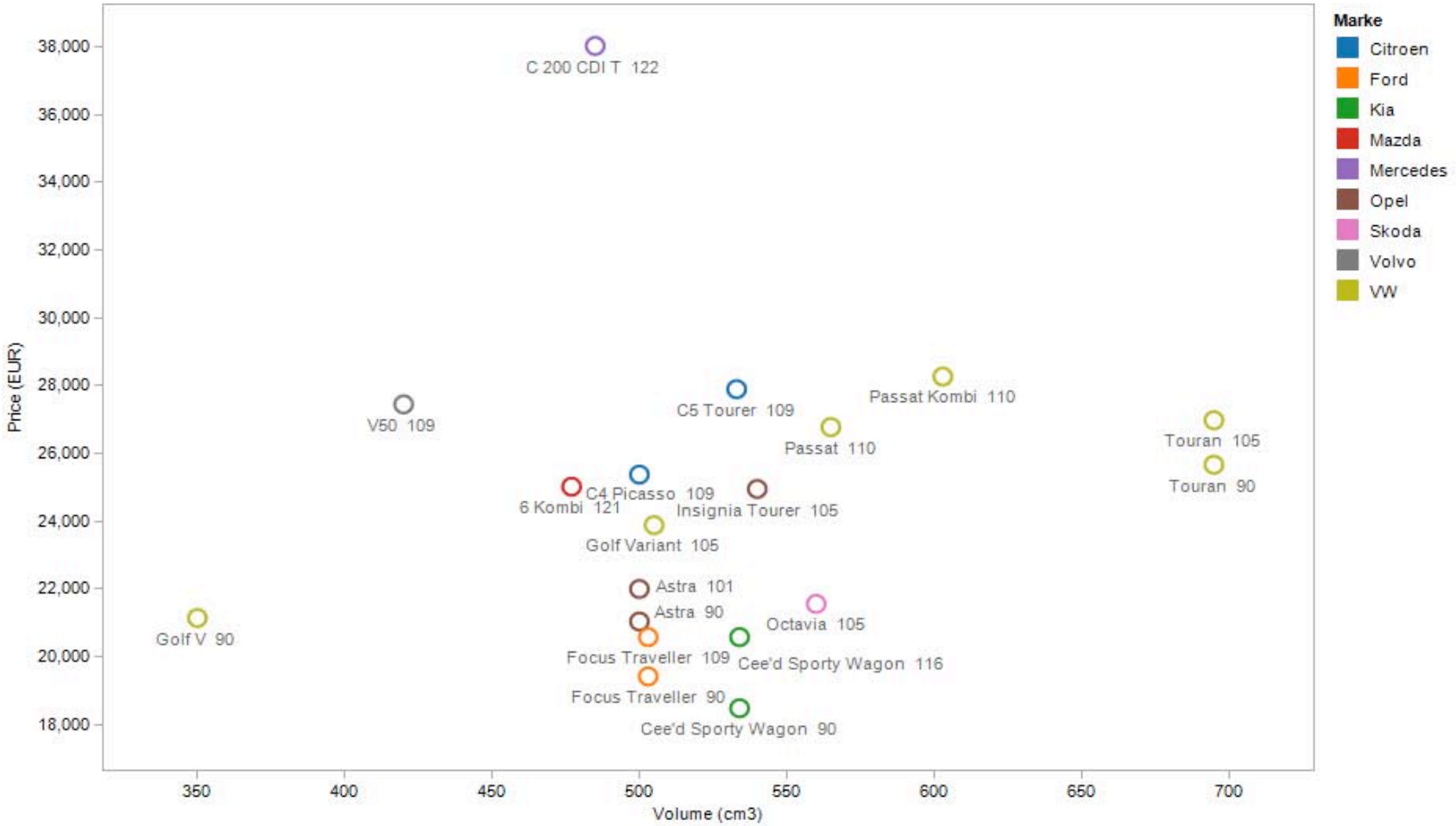
[Spotfire]

Raw data

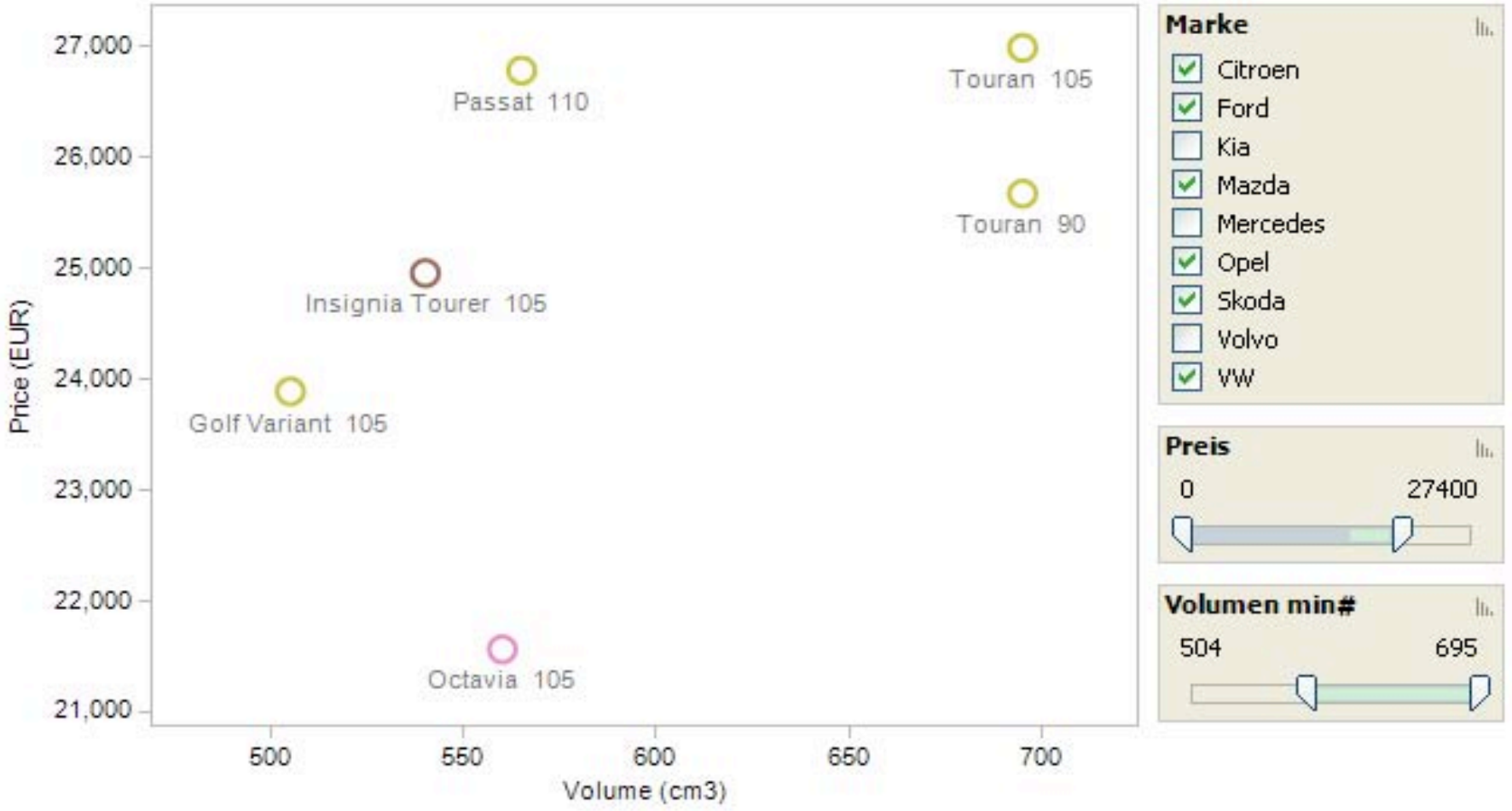
Brand	Type	Volume	Price
Kia	Cee'd Sporty Wagon	534	18490
Ford	Focus Traveller	503	19430
Ford	Focus Traveller	503	20590
Kia	Cee'd Sporty Wagon	534	20590
Opel	Astra	500	21050
VW	Golf V	350	21155
Skoda	Octavia	560	21570
Opel	Astra	500	22010
VW	Golf Variant	505	23894
Opel	Insignia Tourer	540	24960
Mazda	6 Kombi	477	25030
Citroen	C4 Picasso	500	25386
VW	Touran	695	25676
VW	Passat	565	26786
VW	Touran	695	26990
Volvo	V50	420	27460
Citroen	C5 Tourer	533	27907
VW	Passat Kombi	603	28280
Mercedes	C 200 CDI T	485	38038

Visual Mapping

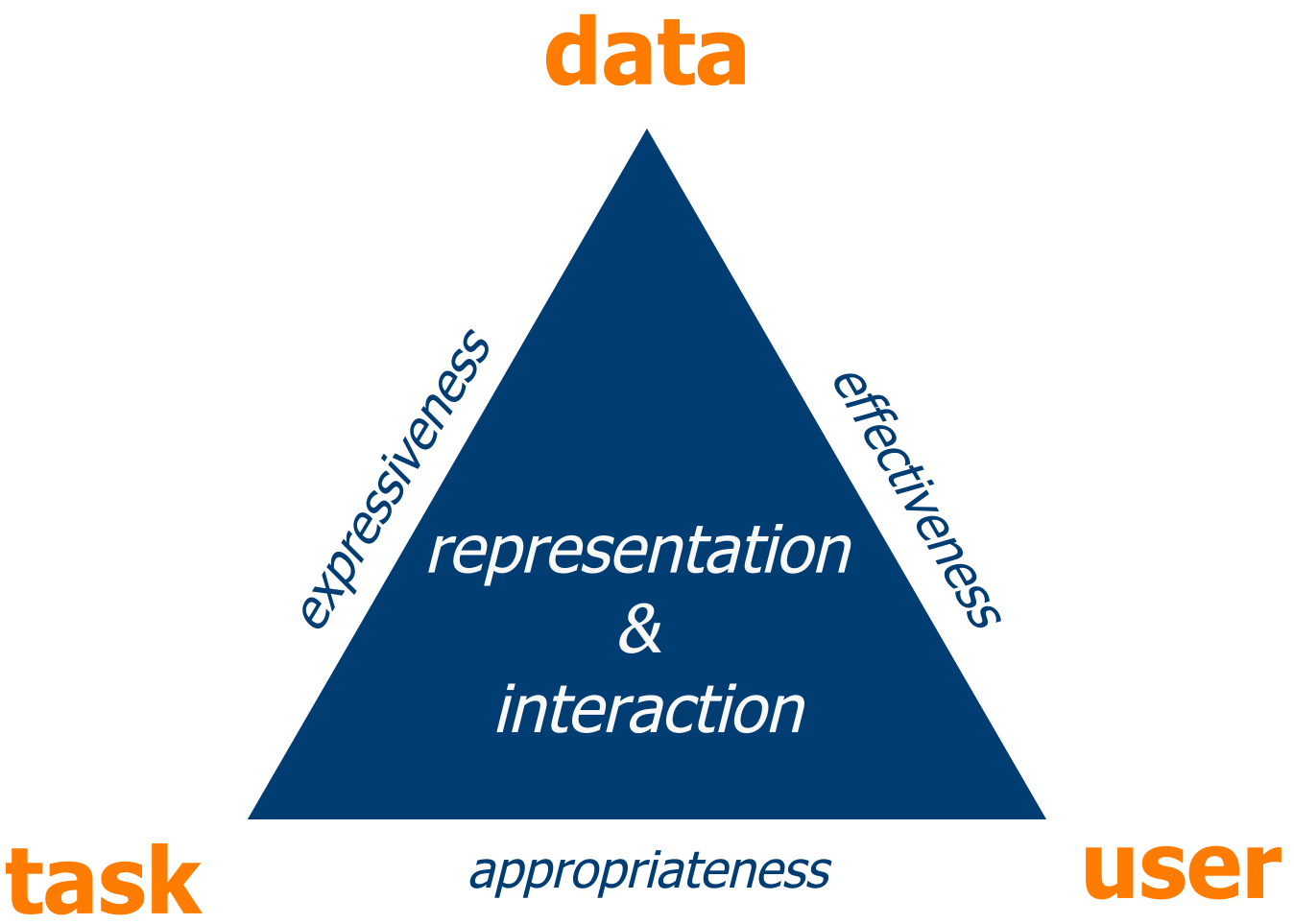
informations-
visualisierung



Interactivity / Dynamic Queries



Visualization Design



Expressiveness

A visualization is considered to be **expressive** if the relevant information of a dataset (and only this) is expressed by the visualization. The term "relevant" implies that expressiveness of a visualization can only be assessed regarding a **particular user** working with the visual representation to achieve **certain goals**.

„A visualization is said to be expressive ***if and only if*** *it encodes* ***all the data relations*** *intended and* ***no other*** *data relations."* [Card, 2008, p. 523]

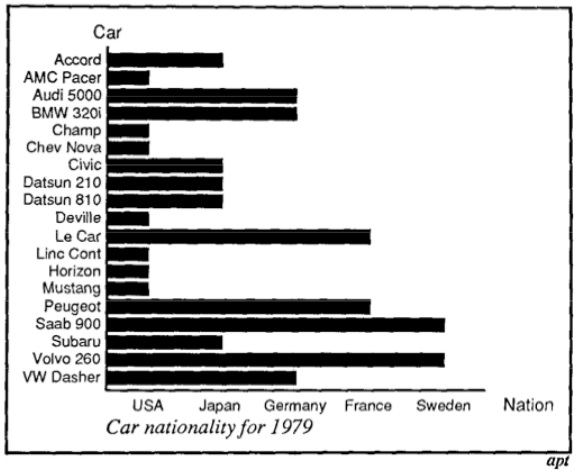


Fig. 11. Incorrect use of a bar chart for the *Nation* relation. The lengths of the bars suggest an ordering on the vertical axis, as if the USA cars were longer or better than the other cars, which is not true for the *Nation* relation.

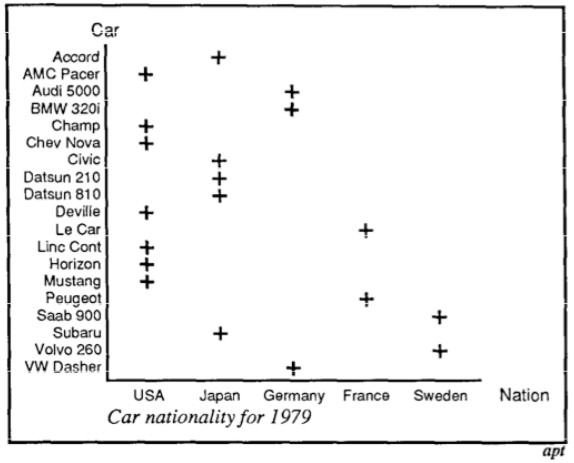


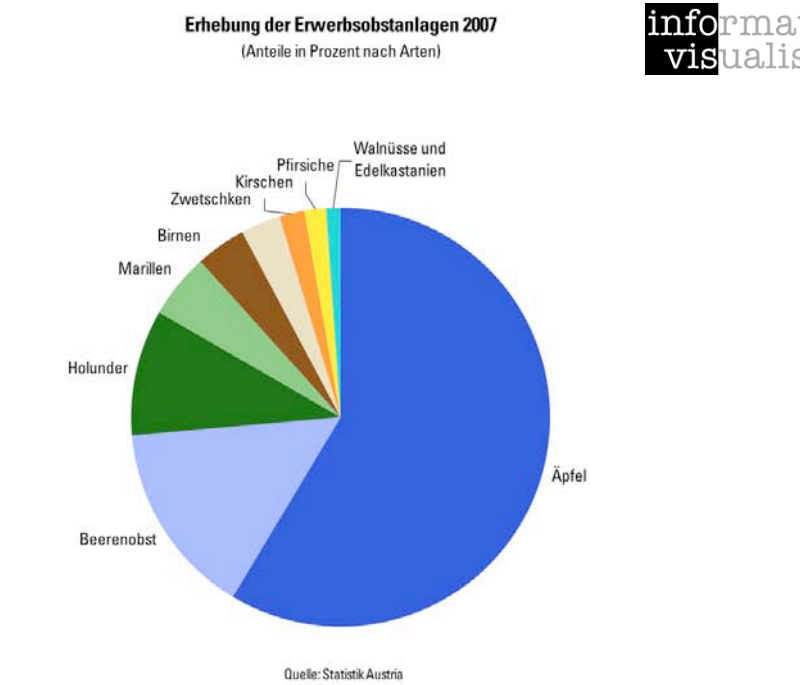
Fig. 12. Correct use of a plot chart for the *Nation* relation. Since bar charts encode ordered domain sets, plot charts are conventionally used to encode nominal domain sets. The ordering of the labels on the axes is ignored.

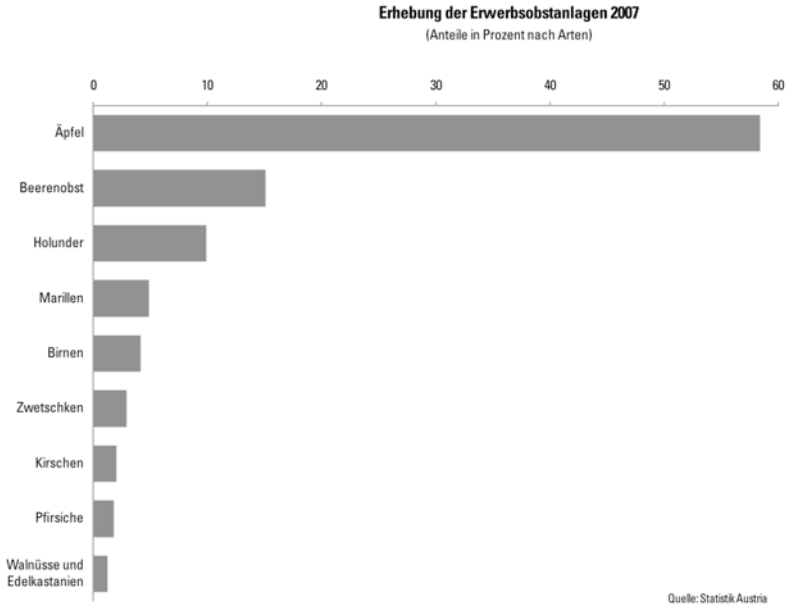
[Mackinlay, 1986]

Effectiveness

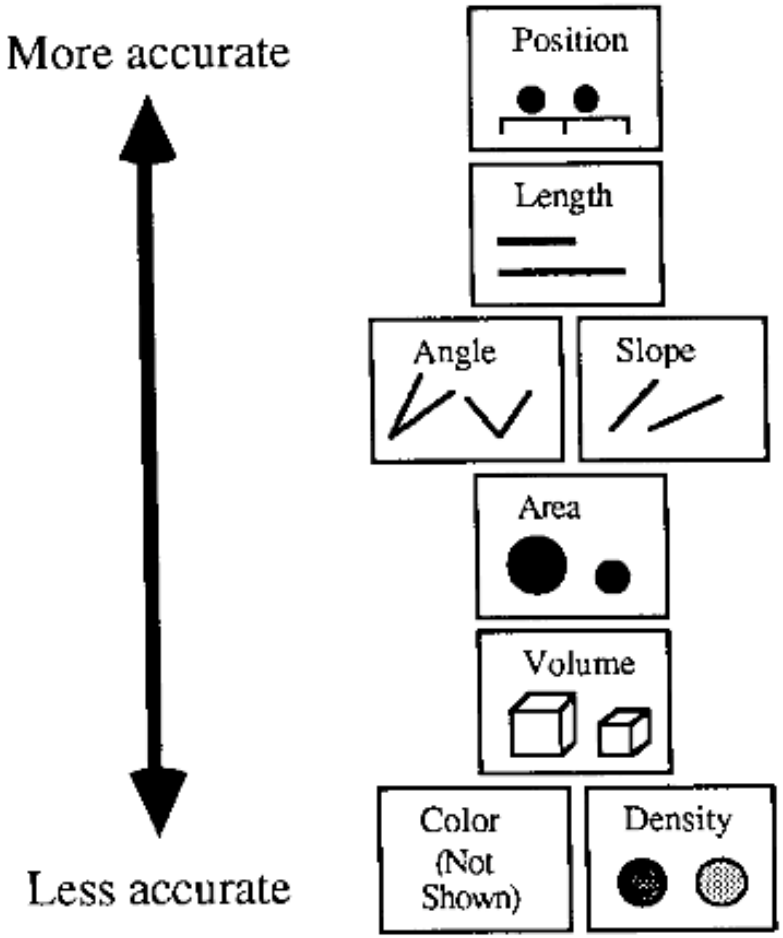
A visualization is effective if it **addresses the capabilities of the human visual system**. Since perception, and hence the mental image of a visual representation, varies among users, effectiveness is **user-dependent**. Nonetheless, some general rules for effective visualization have been established in the visualization community.

„Effectiveness criteria identify which of these graphical languages [that are expressive], in a given situation, is the most effective at exploiting the capabilities of the output medium and the human visual system.“
[Mackinlay, 1986]

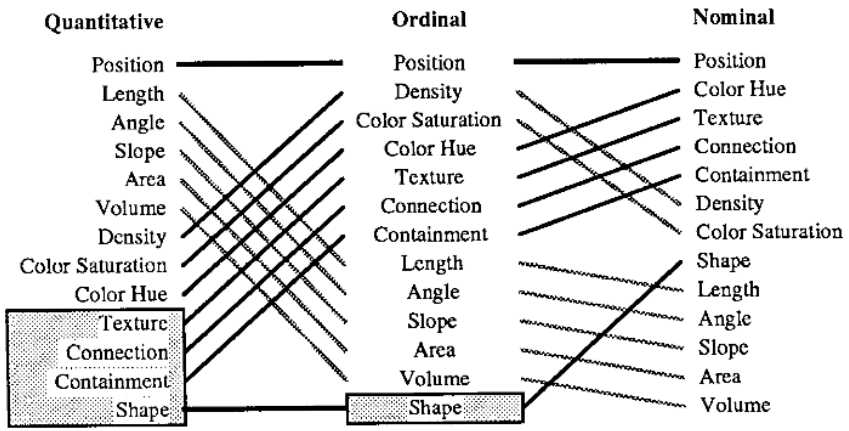




Visual Variables



[Cleveland & McGill, 1984]



[Mackinlay, 1987]

Relative judgements

Which of the two bars is longer?

Steven‘s Law

As the dimension of an attribute increases, the degree at which we underestimate it increases

Appropriateness

[Schumann and Müller, 2000]

Appropriateness regards the tradeoff between efforts required for creating the visual representation and the benefits yielded by it. If this tradeoff is balanced, the visualization is considered to be appropriate.

Model of Van Wijk:

n users use visualization *V* to visualize a data set *m* times each where each session takes *k* exploratory steps and time *T*

C_i ... Initial development costs

C_u ... Initial costs per user (e.g., selection, acquisition, learning, tailoring)

C_s ... Initial costs per session (e.g., data conversion, specification)

C_e ... Perception and exploration costs (e.g., spend time to view and understand, modify, and tune)

$W(\Delta K)$ ... Value of acquired knowledge $\Delta K = K(T) - K(0)$

Total costs:

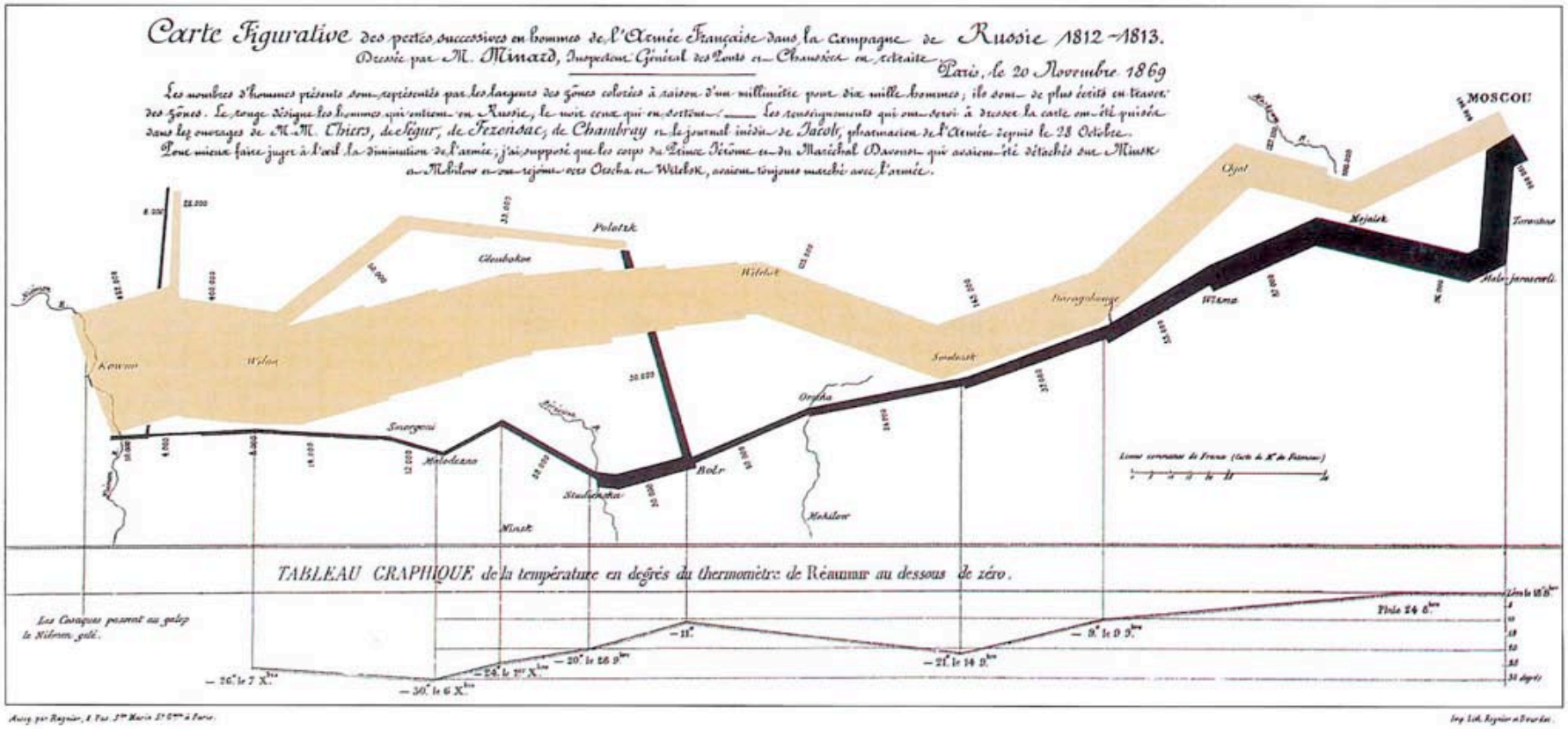
$$\mathbf{C = C_i + n*C_u + n*m*C_s + n*m*k*C_e}$$

Overall profit:

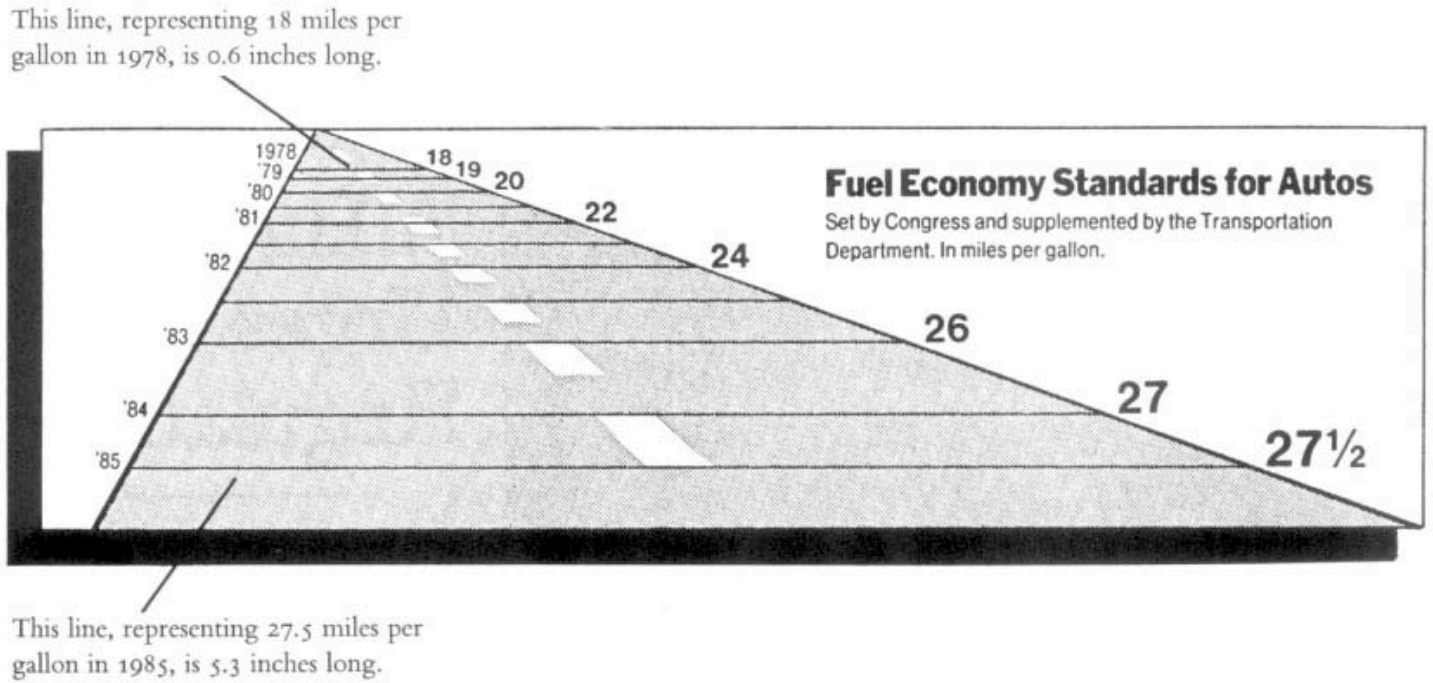
$$\mathbf{F = n*m*(W(\Delta K) - C_s - k*C_e) - C_i - n*C_u}$$

[Van Wijk, 2006]

Graphical Excellence



Tell the truth about the data

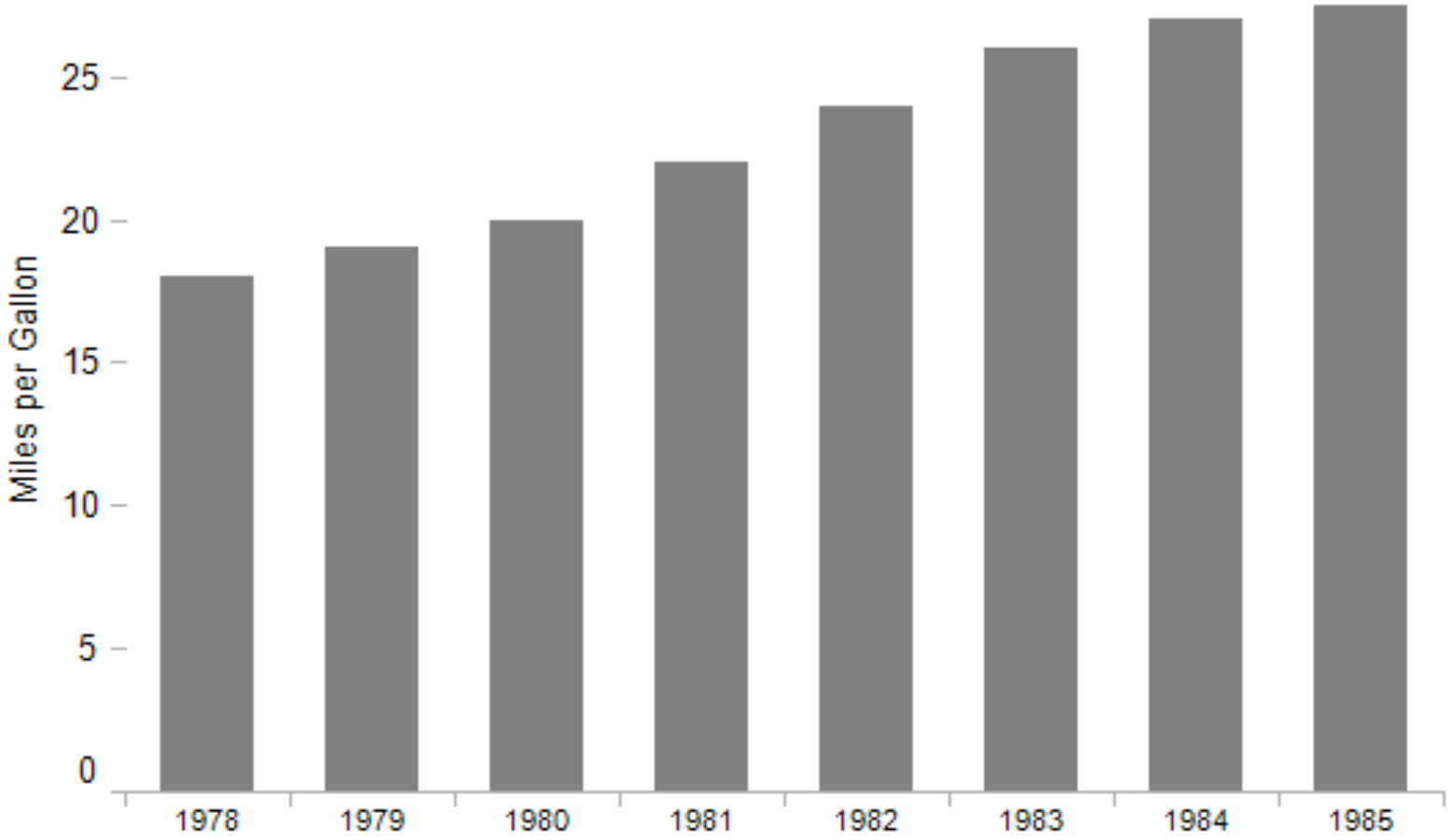


$$\text{Data Effect} = \frac{27.5 - 18}{18} = 0.53, \qquad \text{Graph Effect} = \frac{5.3 - .6}{.6} = 7.83,$$

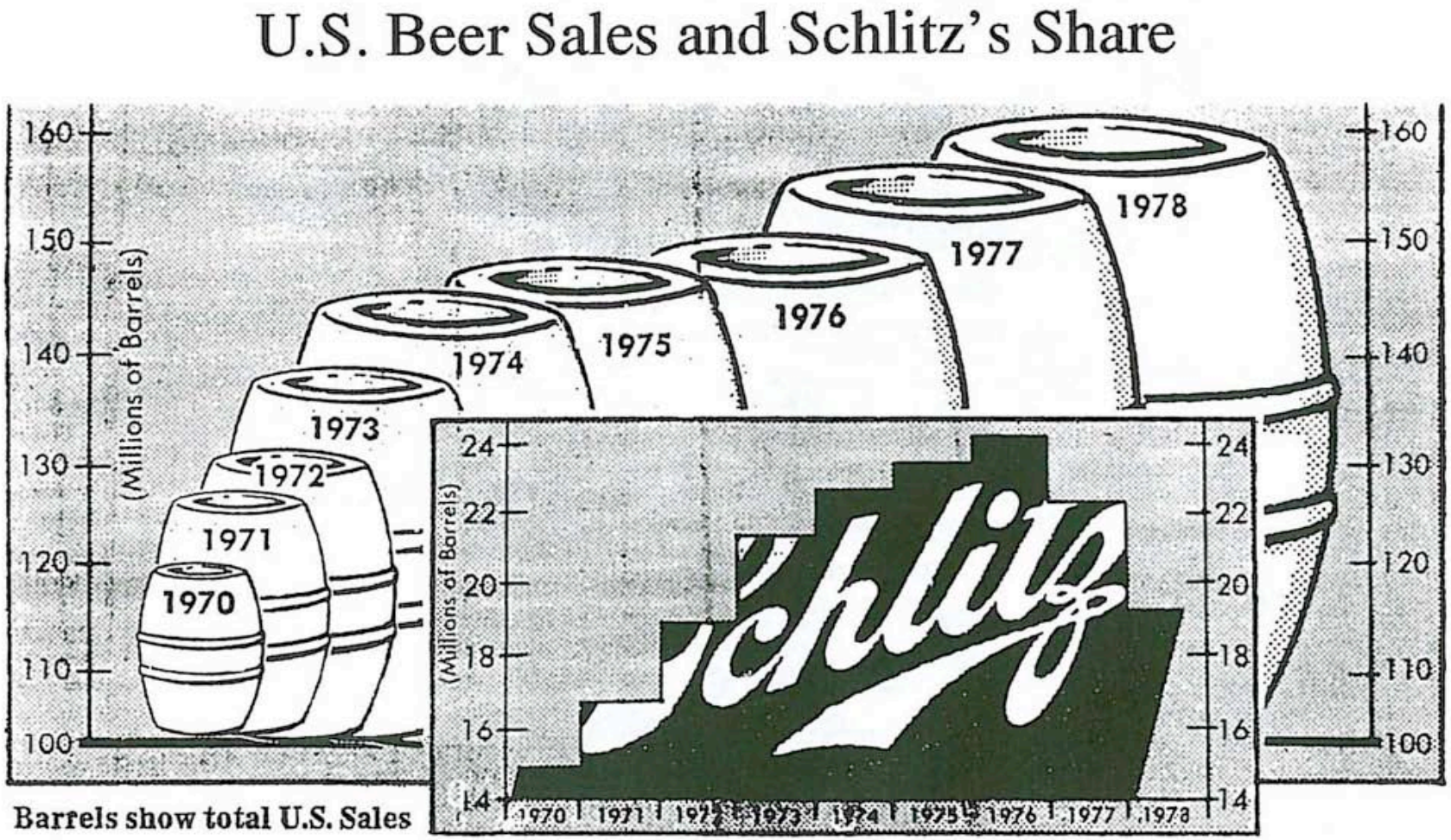
[Tufte, 1983]

$$\text{Lie Factor} = 14.8$$

Fuel Economy Standard Redesign

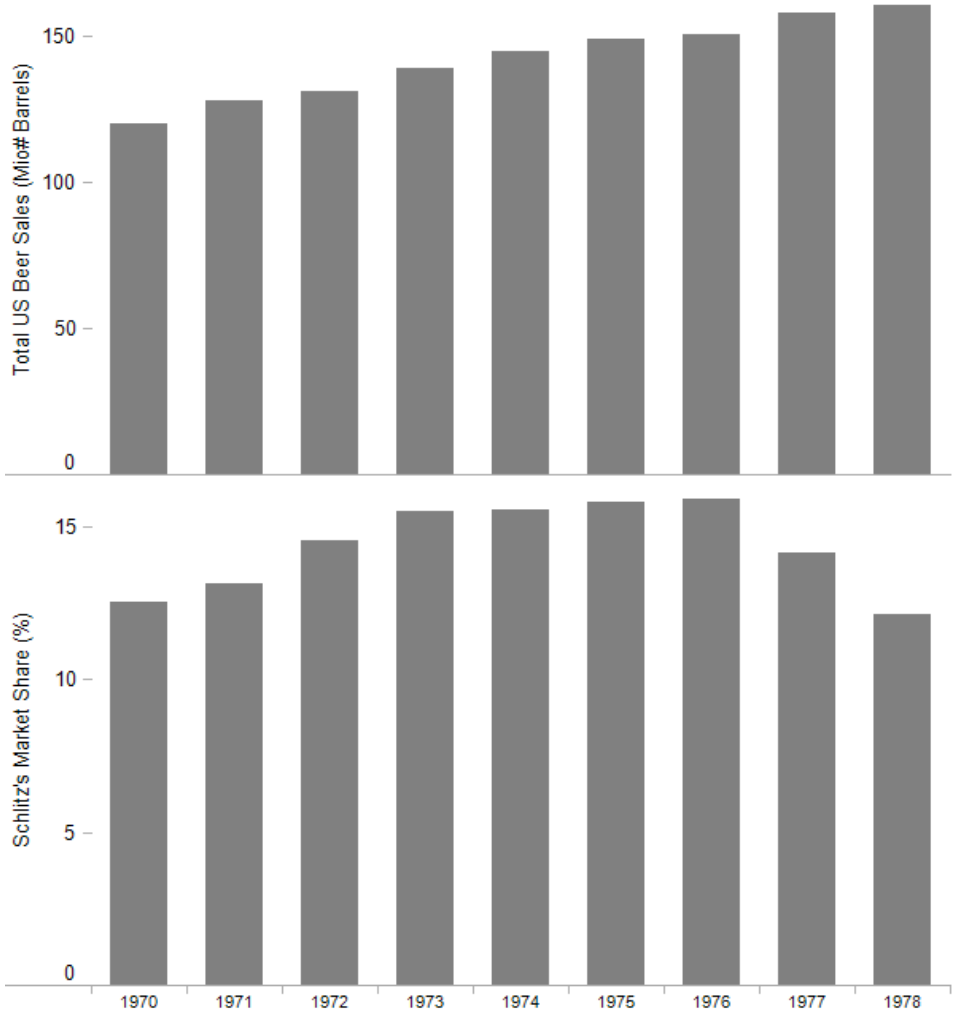


Lie Factor

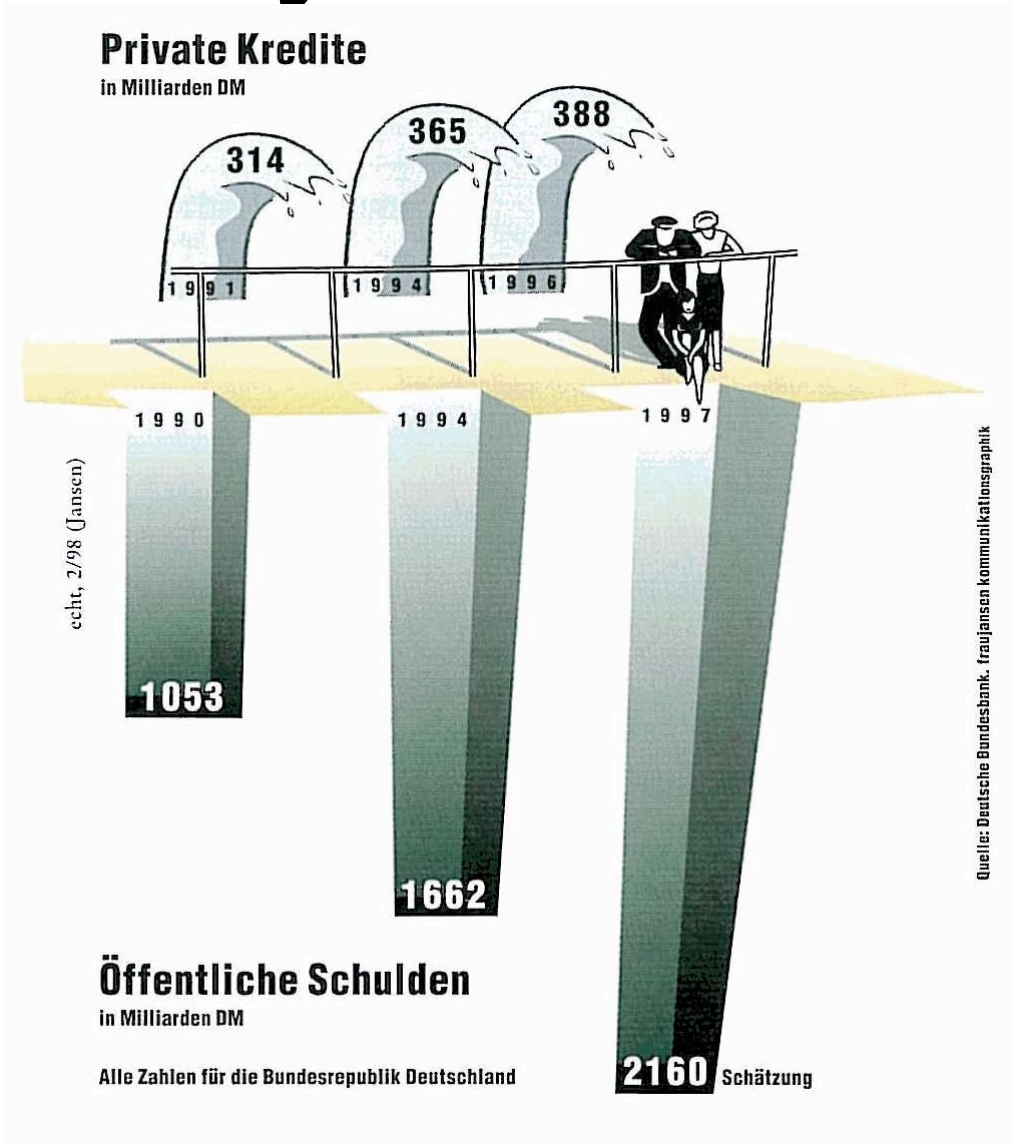

U.S. Beer Sales and Schlitz's Share
(Millions of Barrels)
160
150
140
130
120
110
100
1970
1971
1972
1973
1974
1975
1976
1977
1978
Barrels show total U.S. Sales
(Millions of Barrels)
24
22
20
18
16
14
Schlitz
1970 1971 1972 1973 1974 1975 1976 1977 1978

Beer Sales Redesign

informations-
visualisierung



Avoid Chartjunk



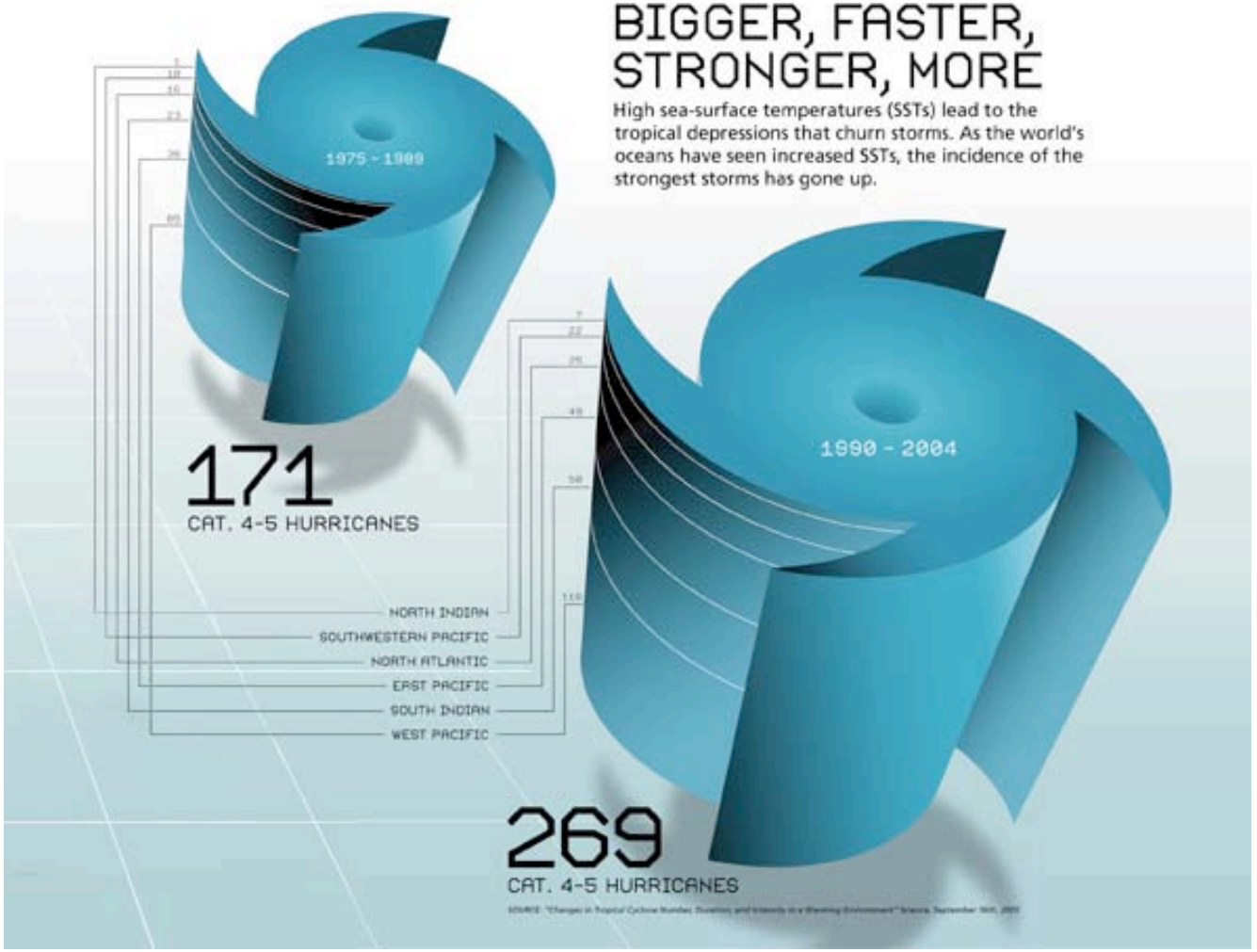
[Jansen & Scharfe, 1999]

Tufte Design Principles

1. Above all else show the data.
2. Maximize the data-ink ratio.
3. Erase non-data-ink.
4. Erase redundant data-ink.
5. Revise and edit.

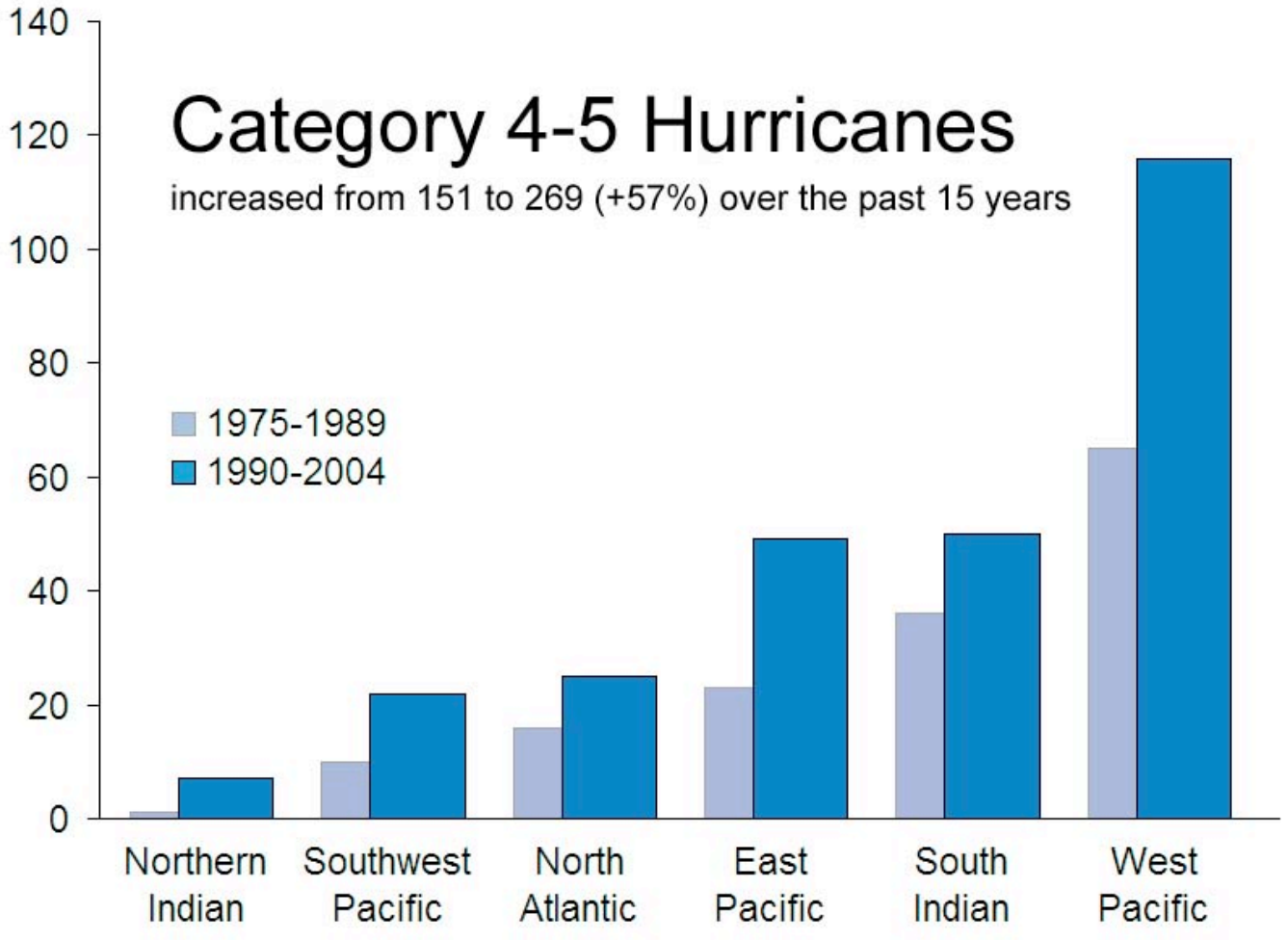
[Tufte, 1983]

Example



[Seed, 2006] Edit Staff, State of the Planet - Bigger, Faster, Stronger, More, Seed - seedmagazine.com, Created at: April 20, 2006, Retrieved at: June 21, 2006. http://www.seedmagazine.com/news/2006/04/state_of_the_planet.php

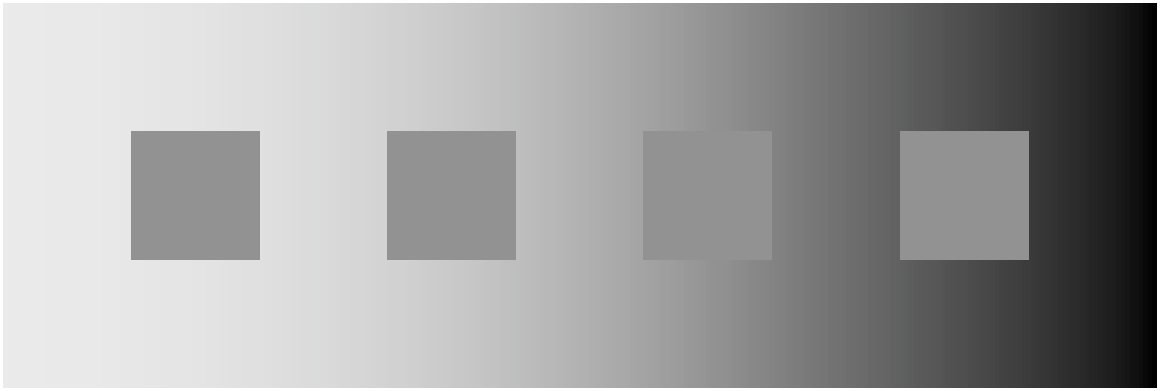
Redesign



[Weber et al., 2006] Sonja Weber, Christof Kopfer, Matteo Savio, Nicole Brosch, Category 4-5 Hurricances, Created at: November 14, 2006, Retrieved at: November 3, 2009. http://www.infovis-wiki.net/index.php?title=Image:Verbessert3.jpg

Using Color

Color Context



Rule #1: If you want different objects of the same color in a table or graph to look the same, make sure that the background--the color that surrounds them--is consistent.

Rule #2: If you want objects in a table or graph to be easily seen, use a background color that contrasts sufficiently with the object.

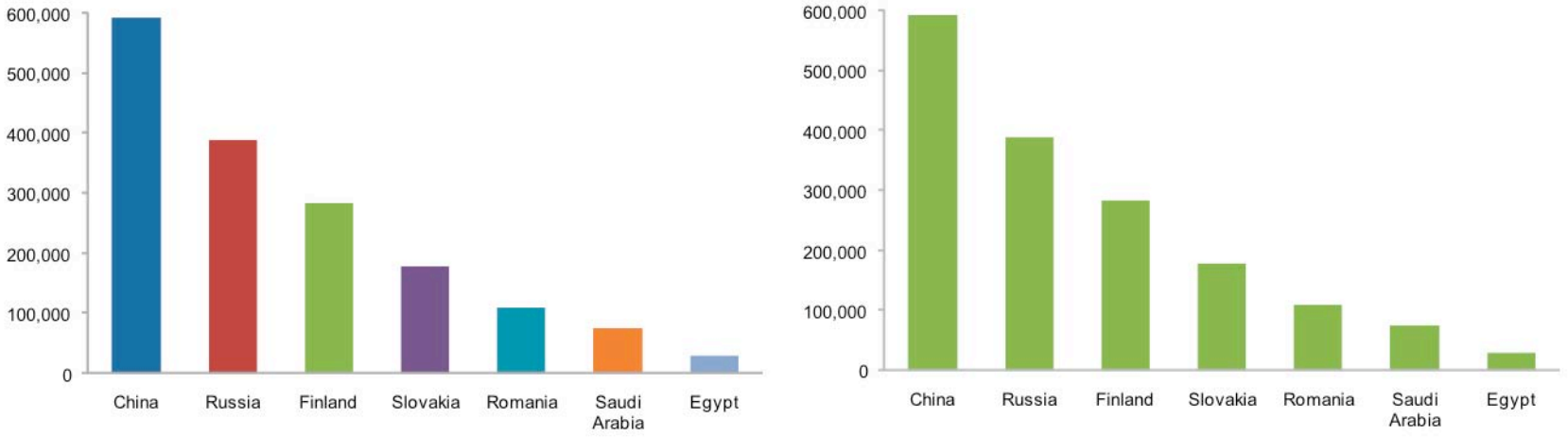
[Few, 2008]

Color Usage

Rule #3: Use color only when needed to serve a particular communication goal.

Rule #4: Use different colors only when they correspond to differences of meaning in the data.

- To highlight particular data
- To group items
- To encode quantitative values



[Few, 2008]

Color Usage

Rule #5: Use soft, natural colors to display most information and bright and/or dark colors to highlight information that requires greater attention.

[Few, 2008]

Palette Types

Categorical

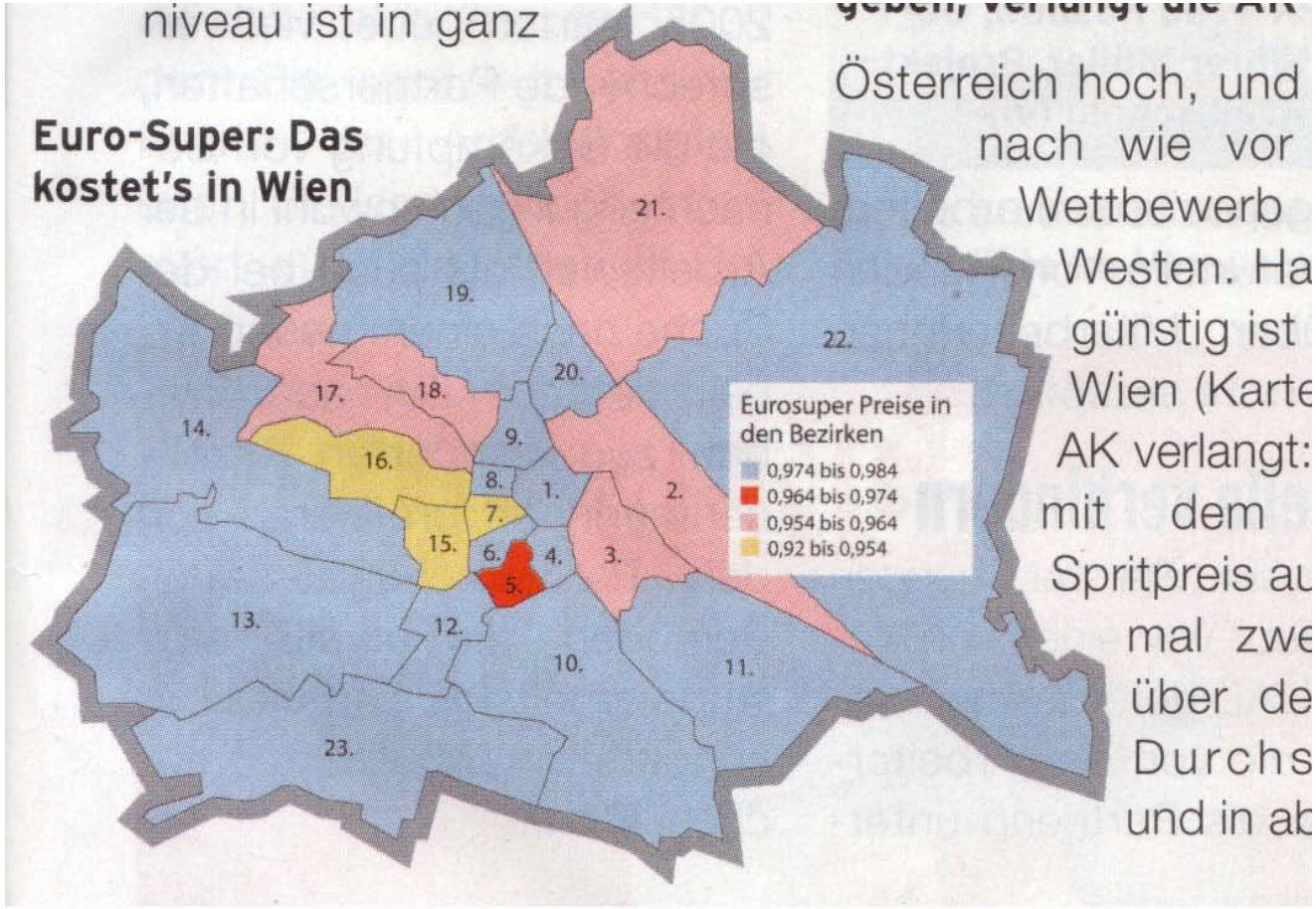
Sequential

Diverging

Rule #6: When using color to encode a sequential range of quantitative values, stick with a single hue (or a small set of closely related hues) and vary intensity from pale colors for low values to increasingly darker and brighter colors for high values.

[Few, 2008]

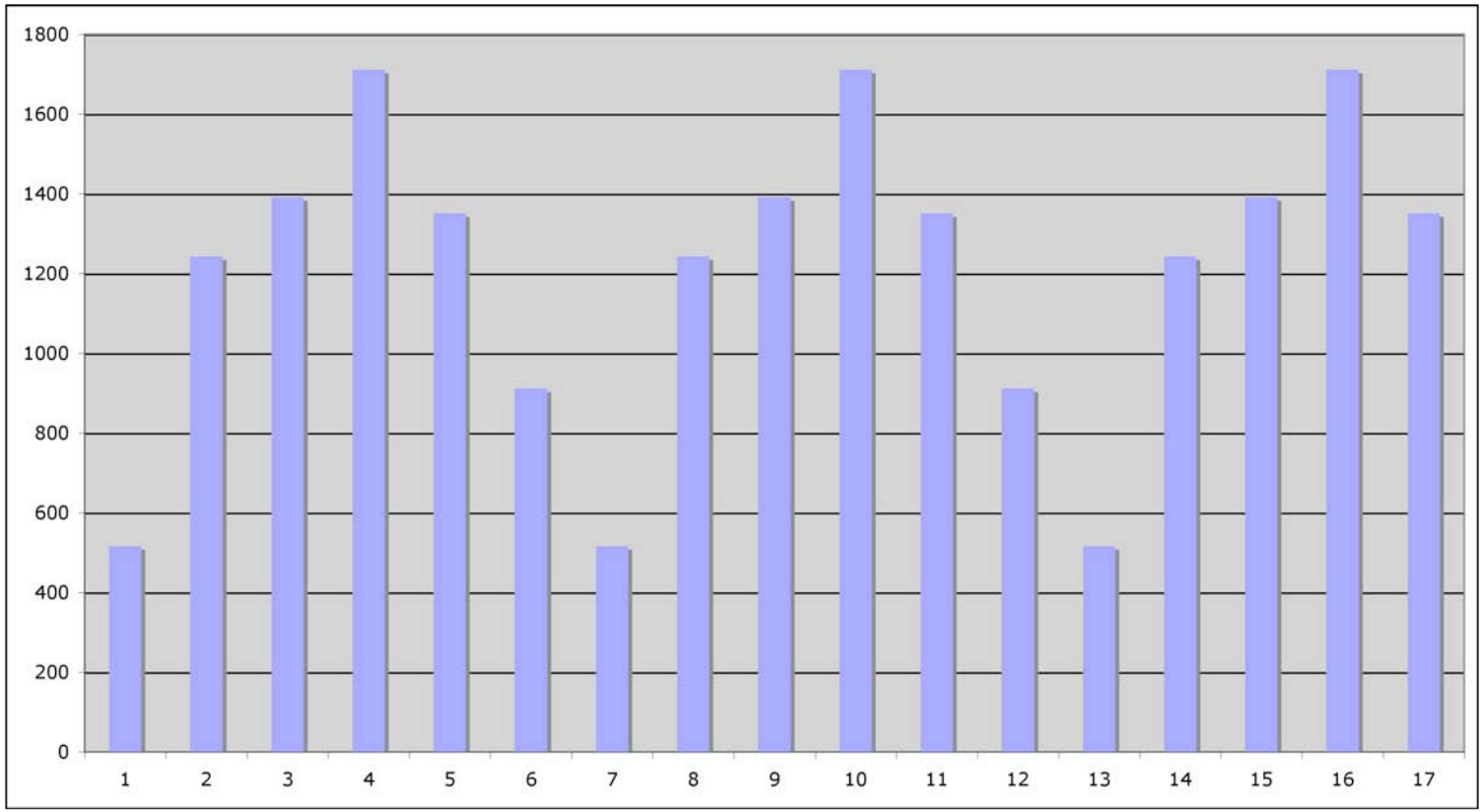
Example



Quelle: AK Für Sie, Mitgliederzeitschrift der AK Wien,

De-emphasize non-data components

Rule #7: Non-data components of tables and graphs should be displayed just visibly enough to perform their role, but no more so, for excessive salience could cause them to distract attention from the data.



[Few, 2008]

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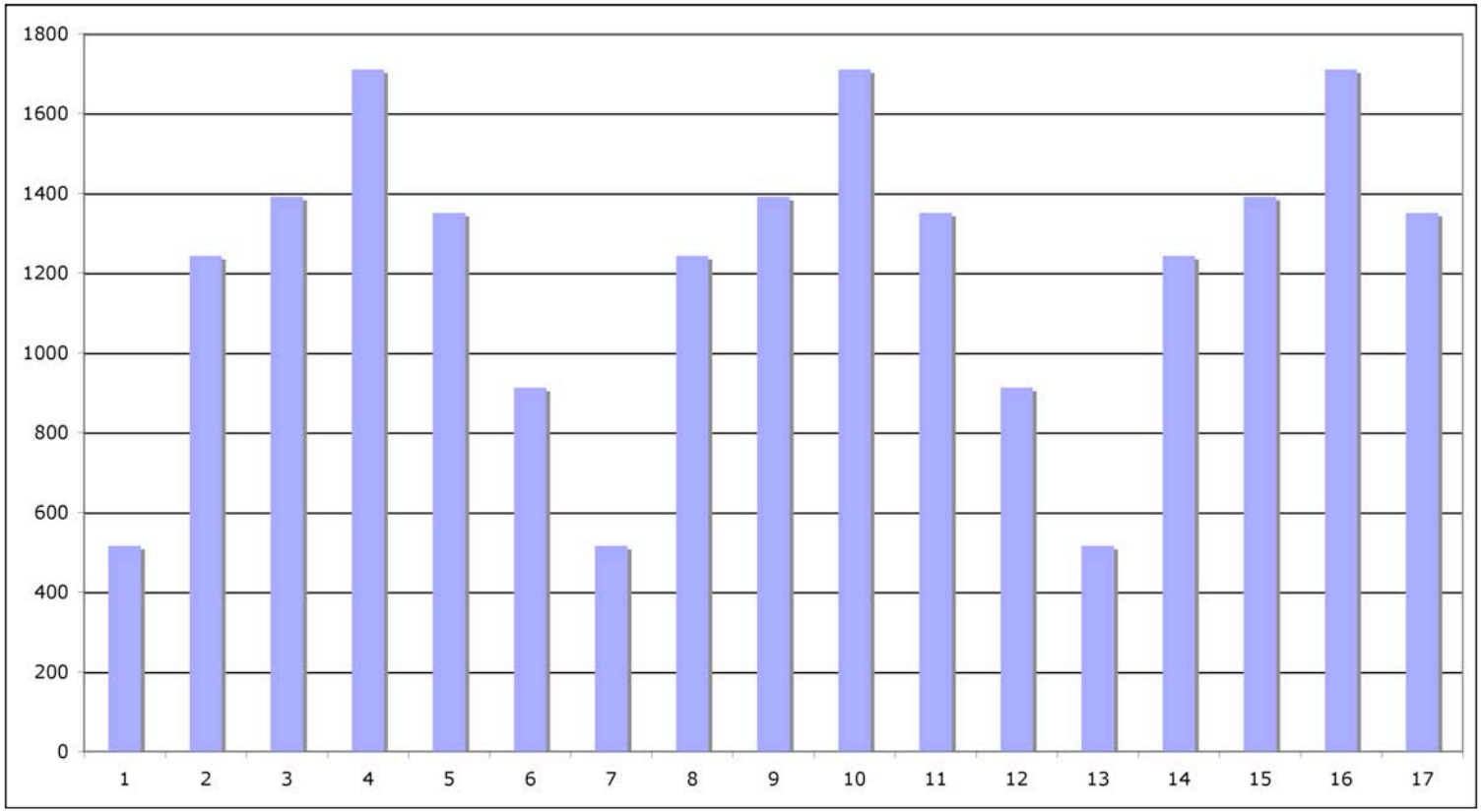

[Few, 2008]

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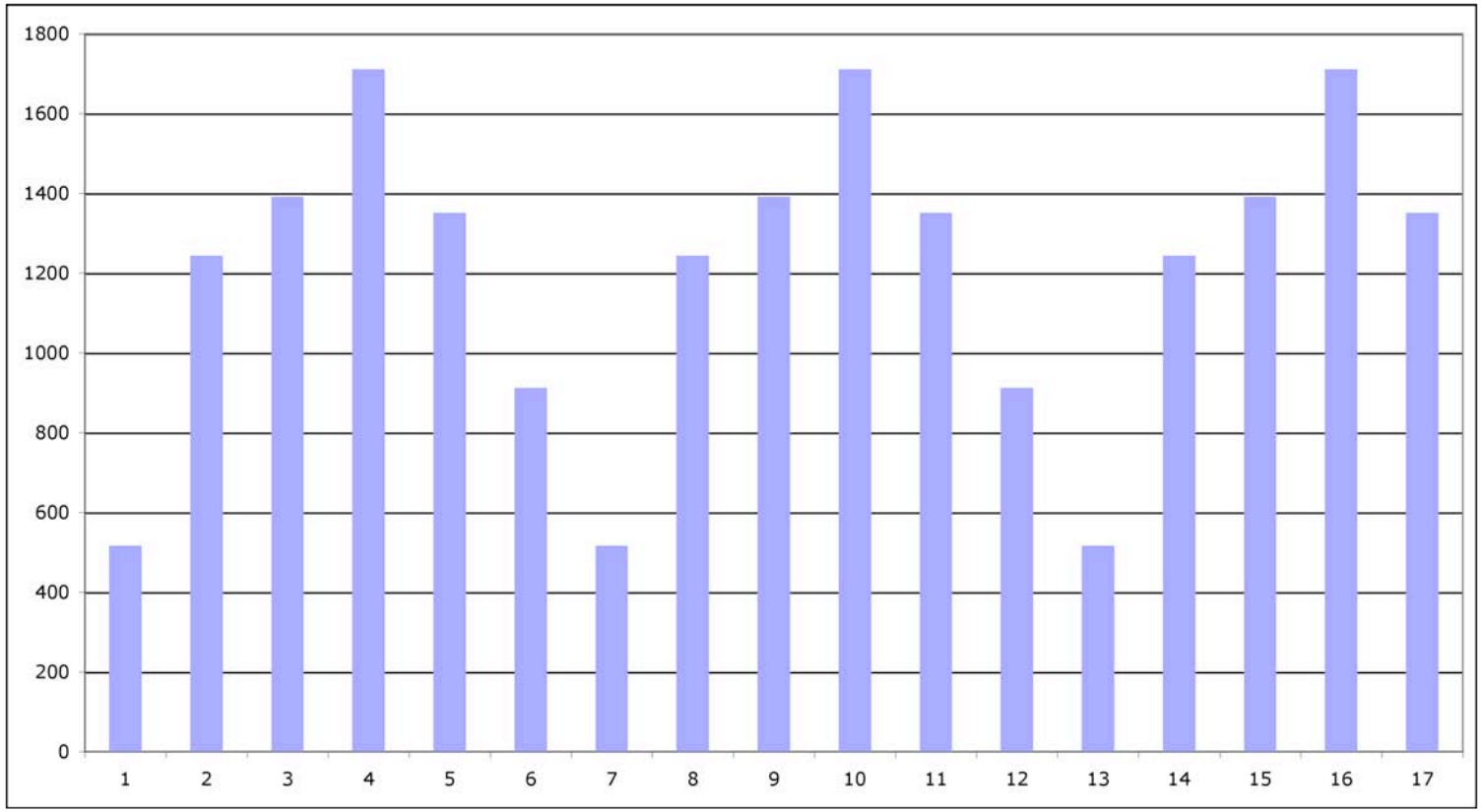

[Few, 2008]

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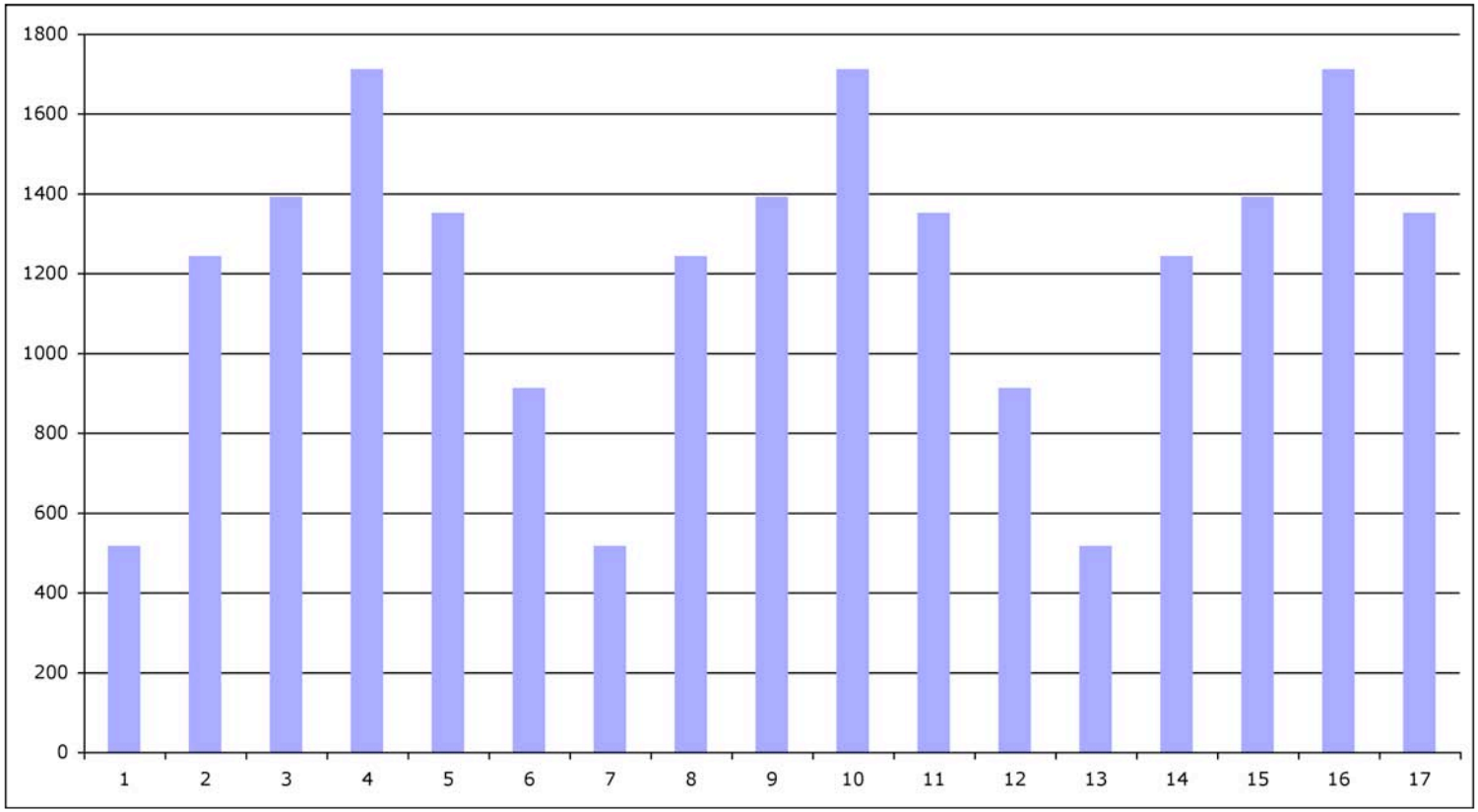

[Few, 2008]

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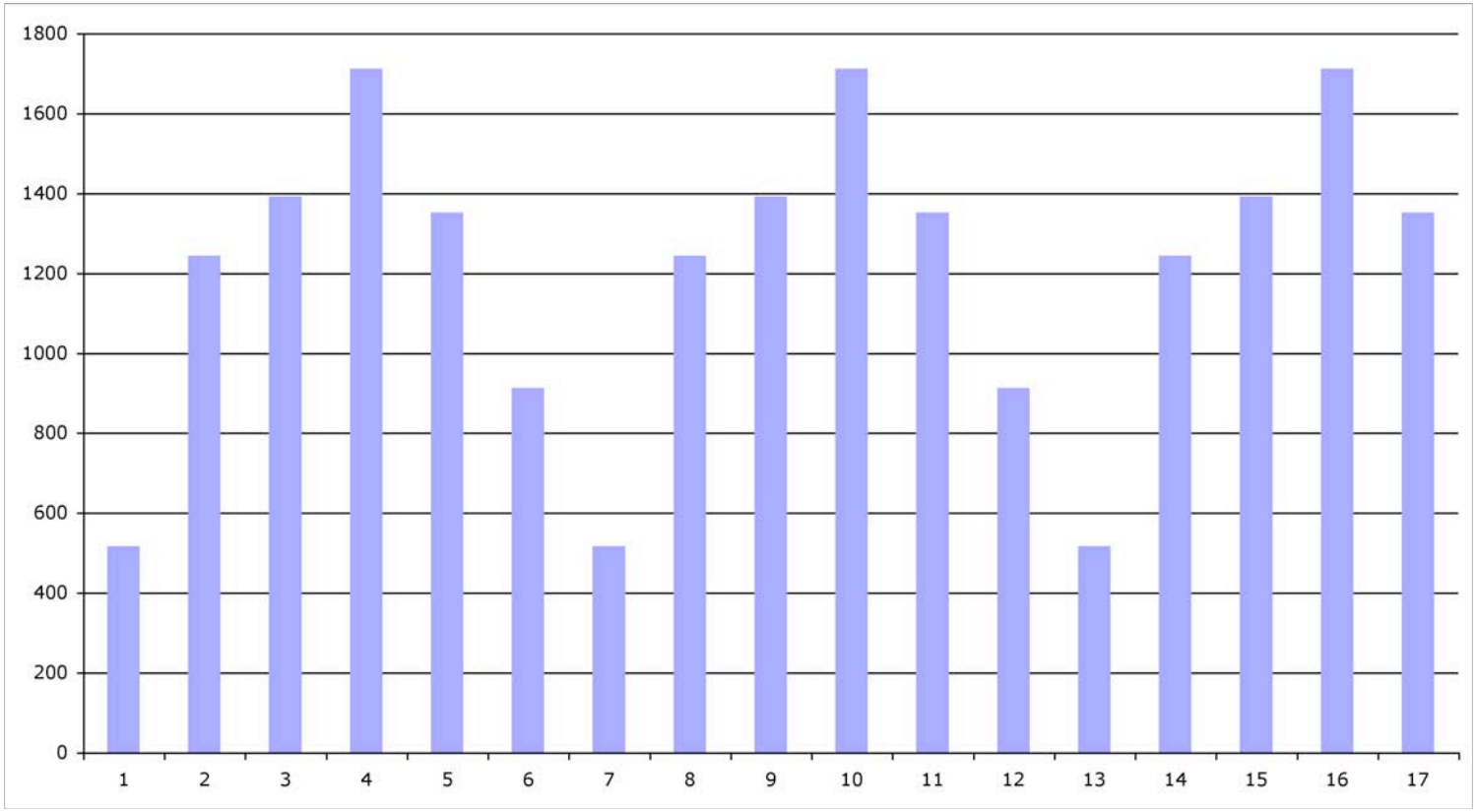

[Few, 2008]

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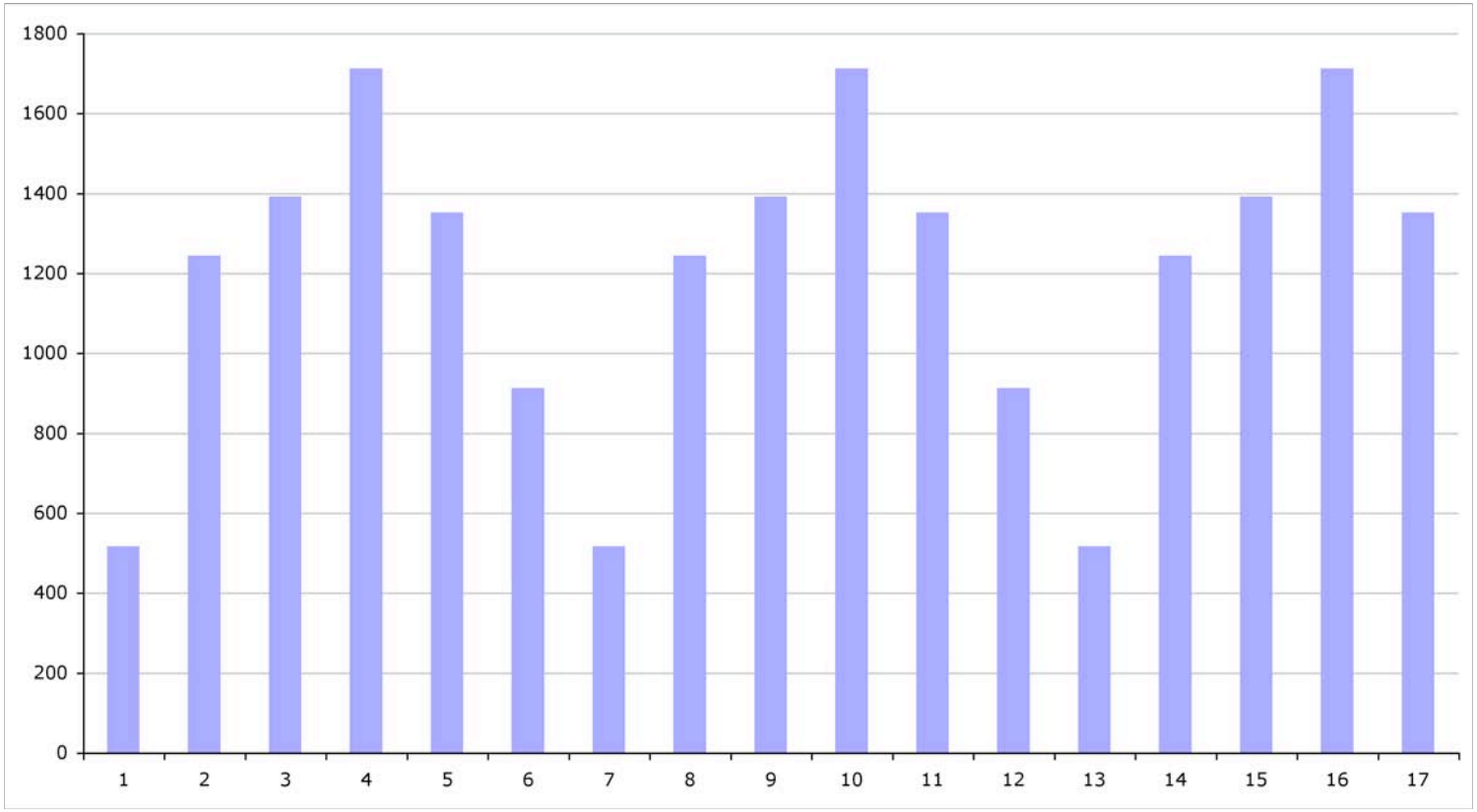

[Few, 2008]

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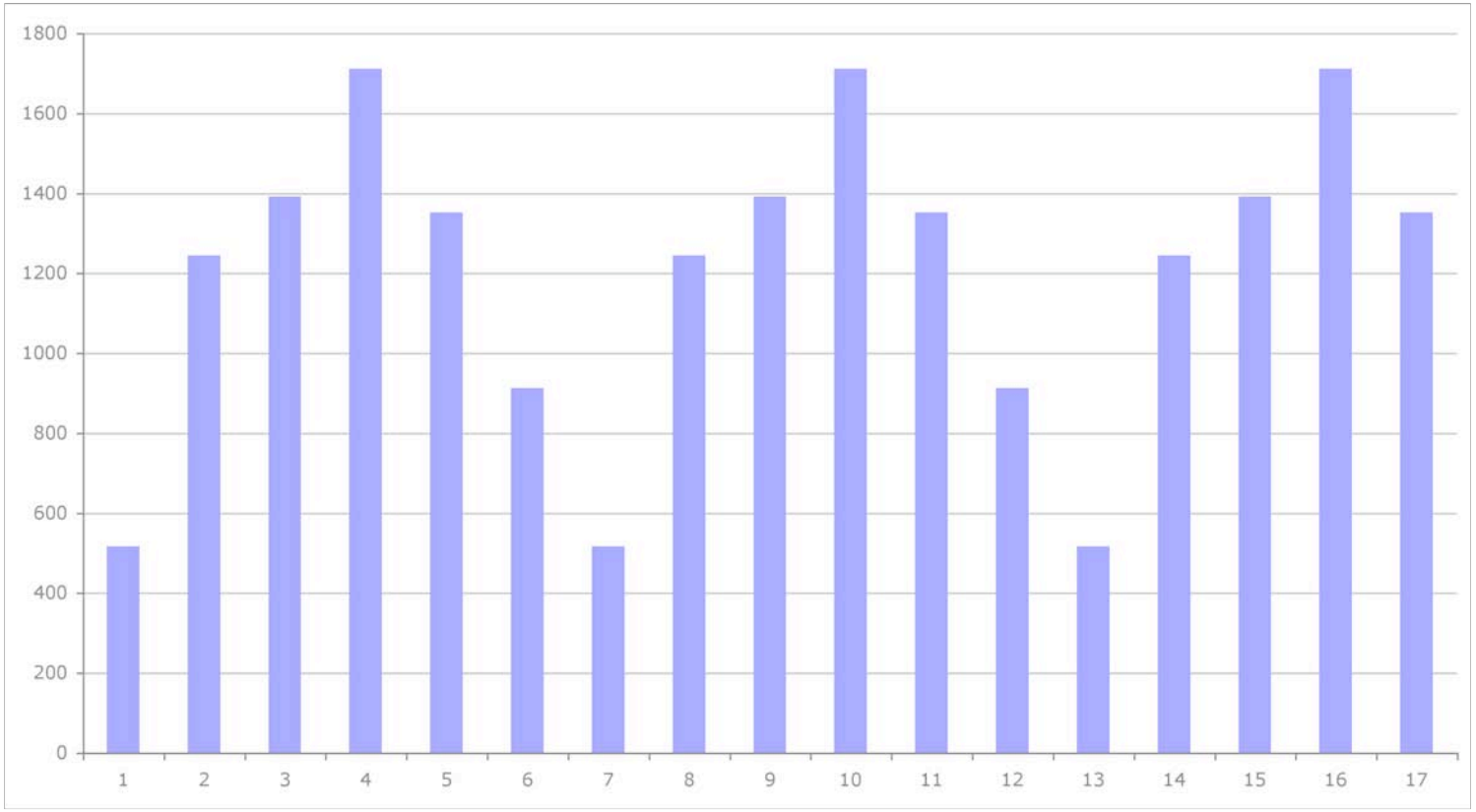

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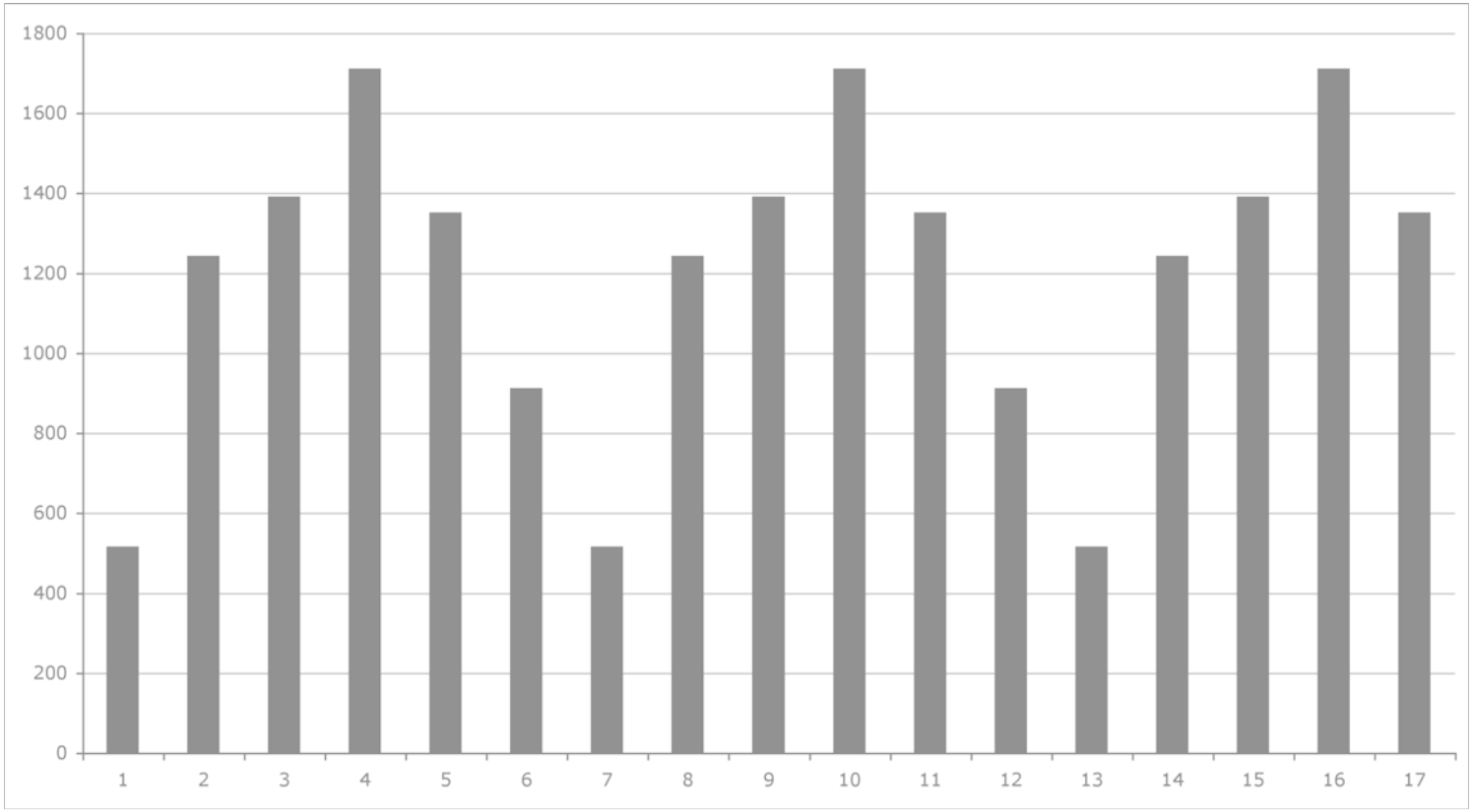

[Few, 2008]

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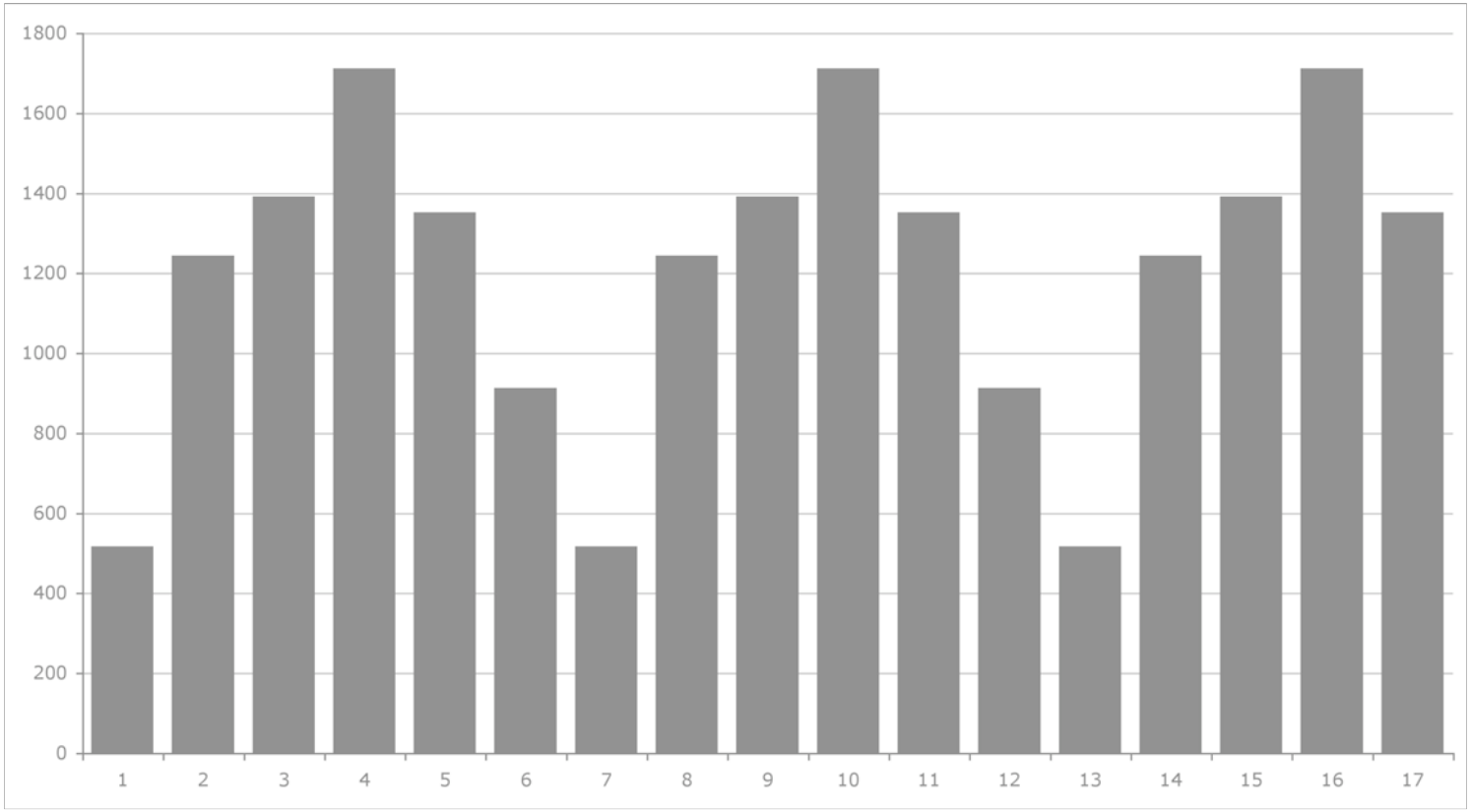

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informations-visualisierung

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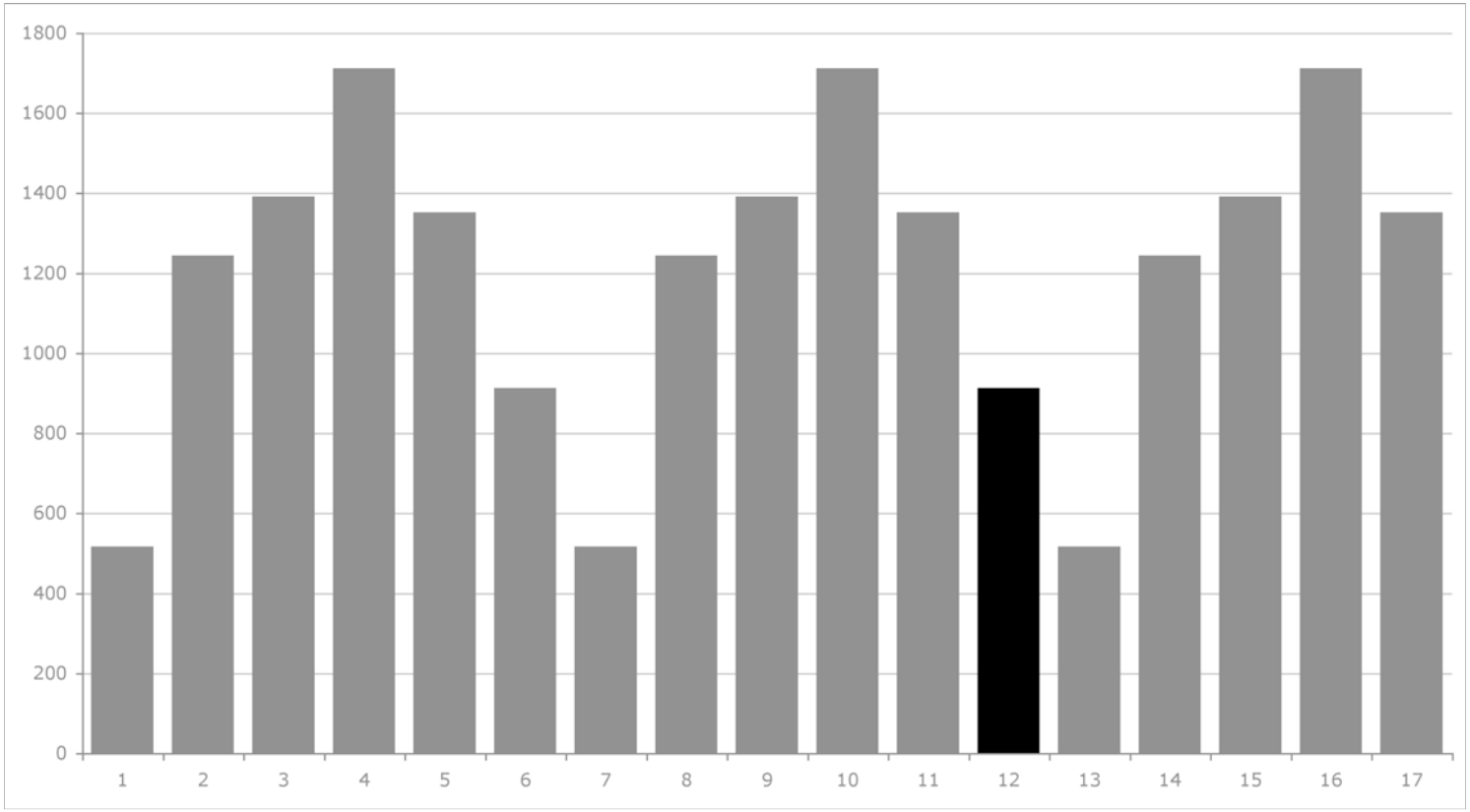

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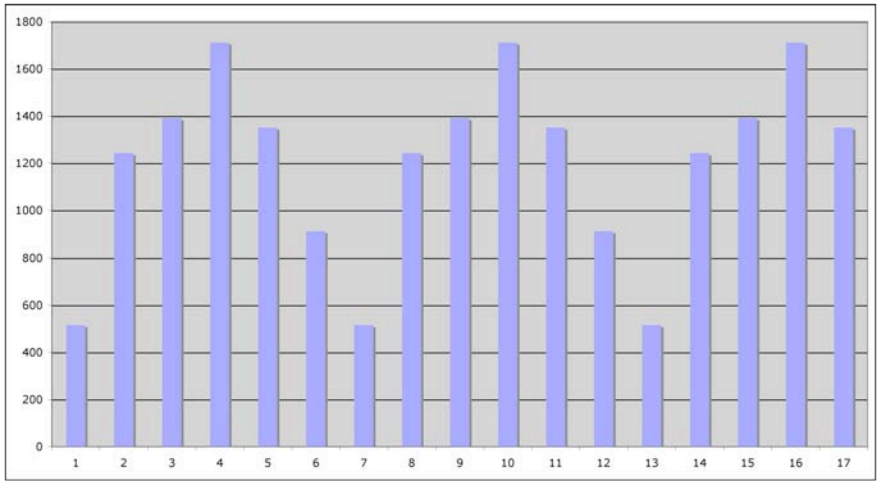
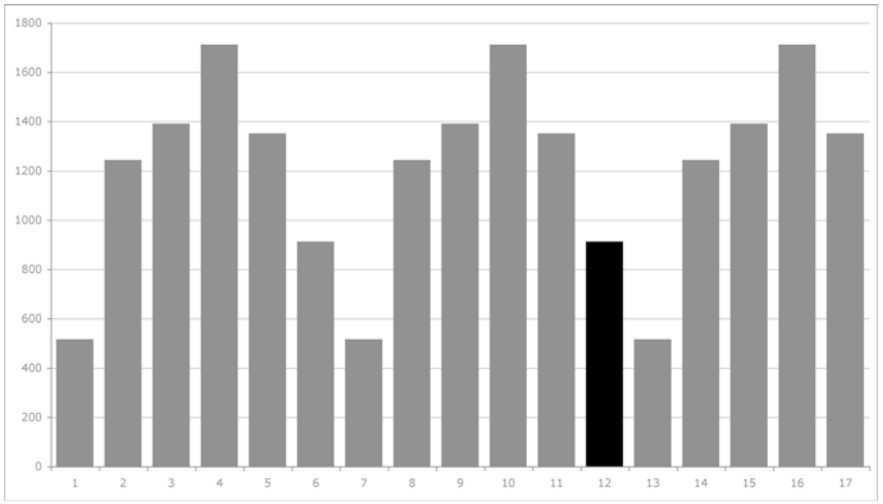
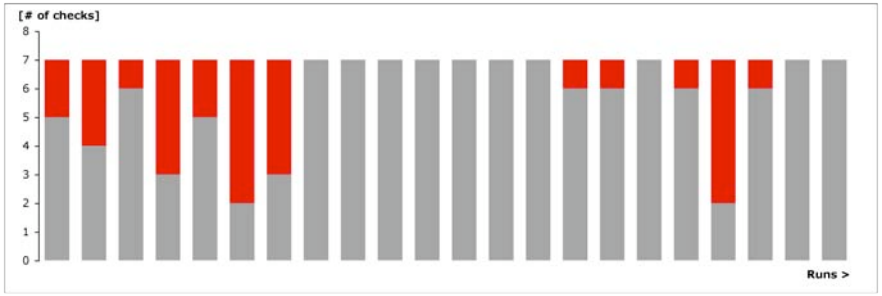




[Few, 2008]

Avoid Red-Green

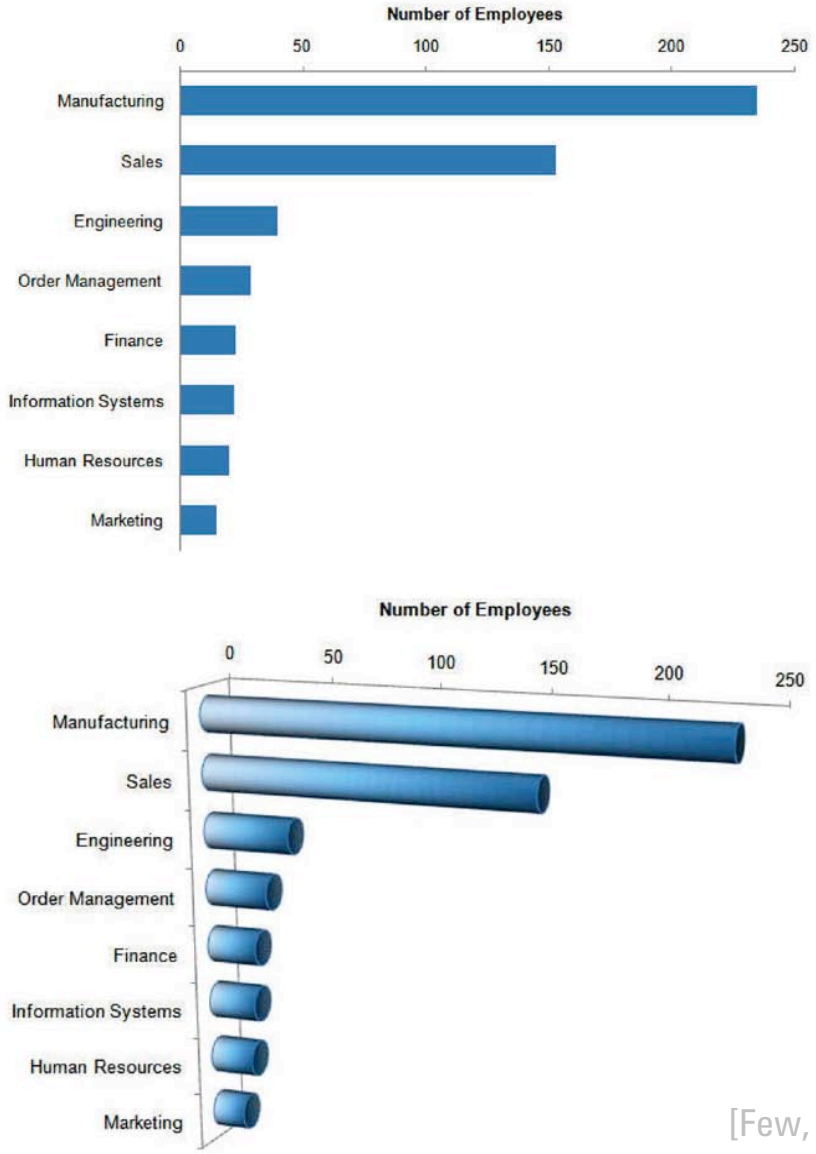
Rule #8: To guarantee that most people who are colorblind can distinguish groups of data that are color coded, avoid using a combination of red and green in the same display.



[Few, 2008]

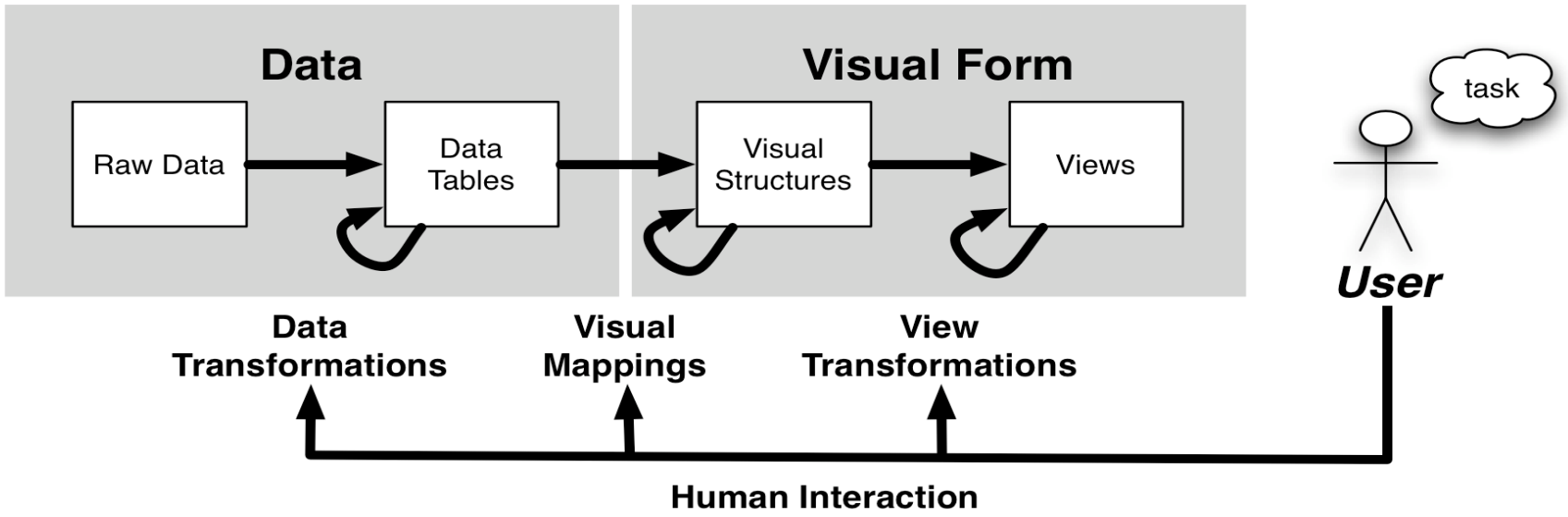
Avoid visual effects

Rule #9: Avoid using visual effects in graphs.



[Few, 2008]

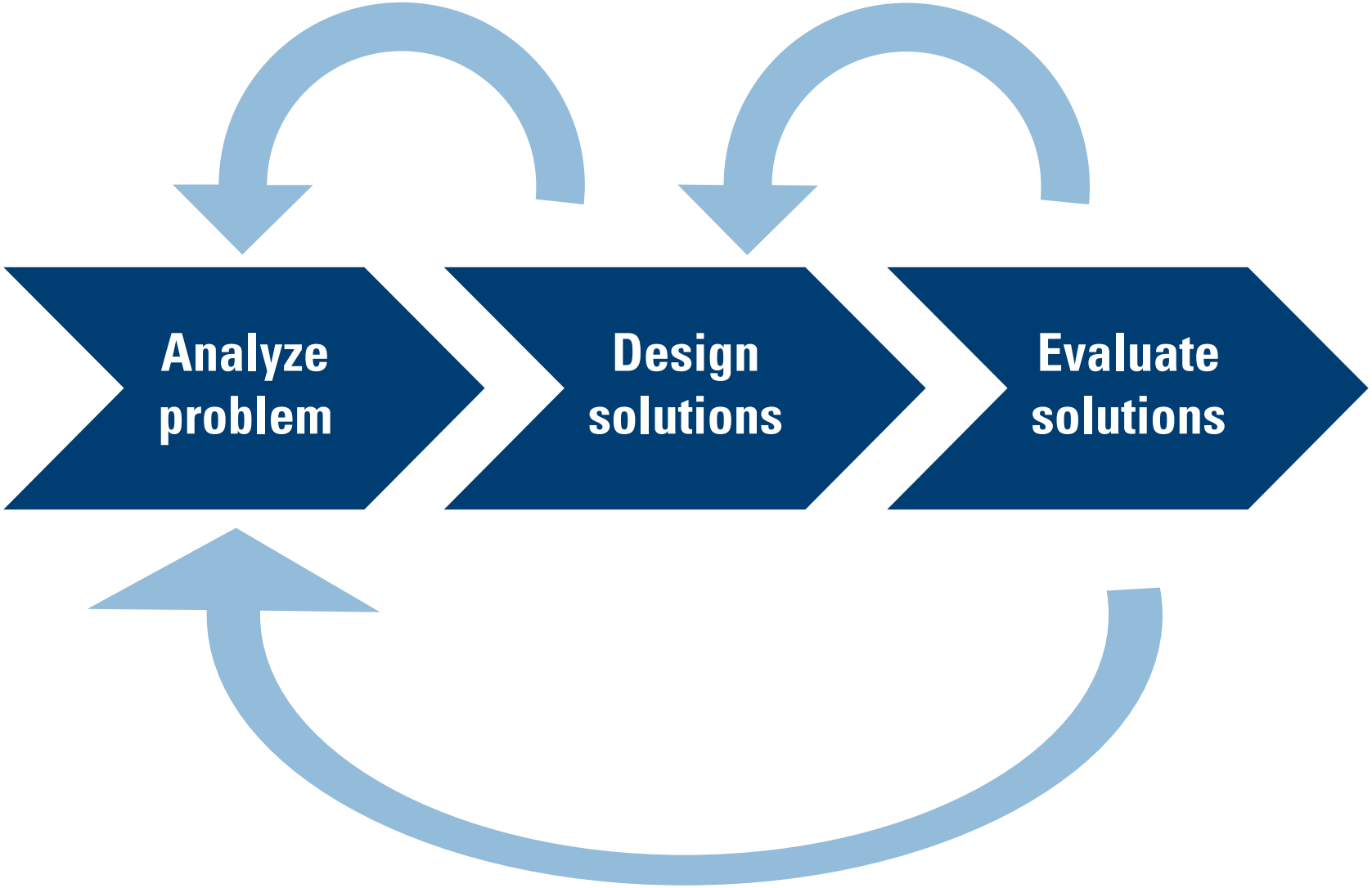
InfoVis Reference Model



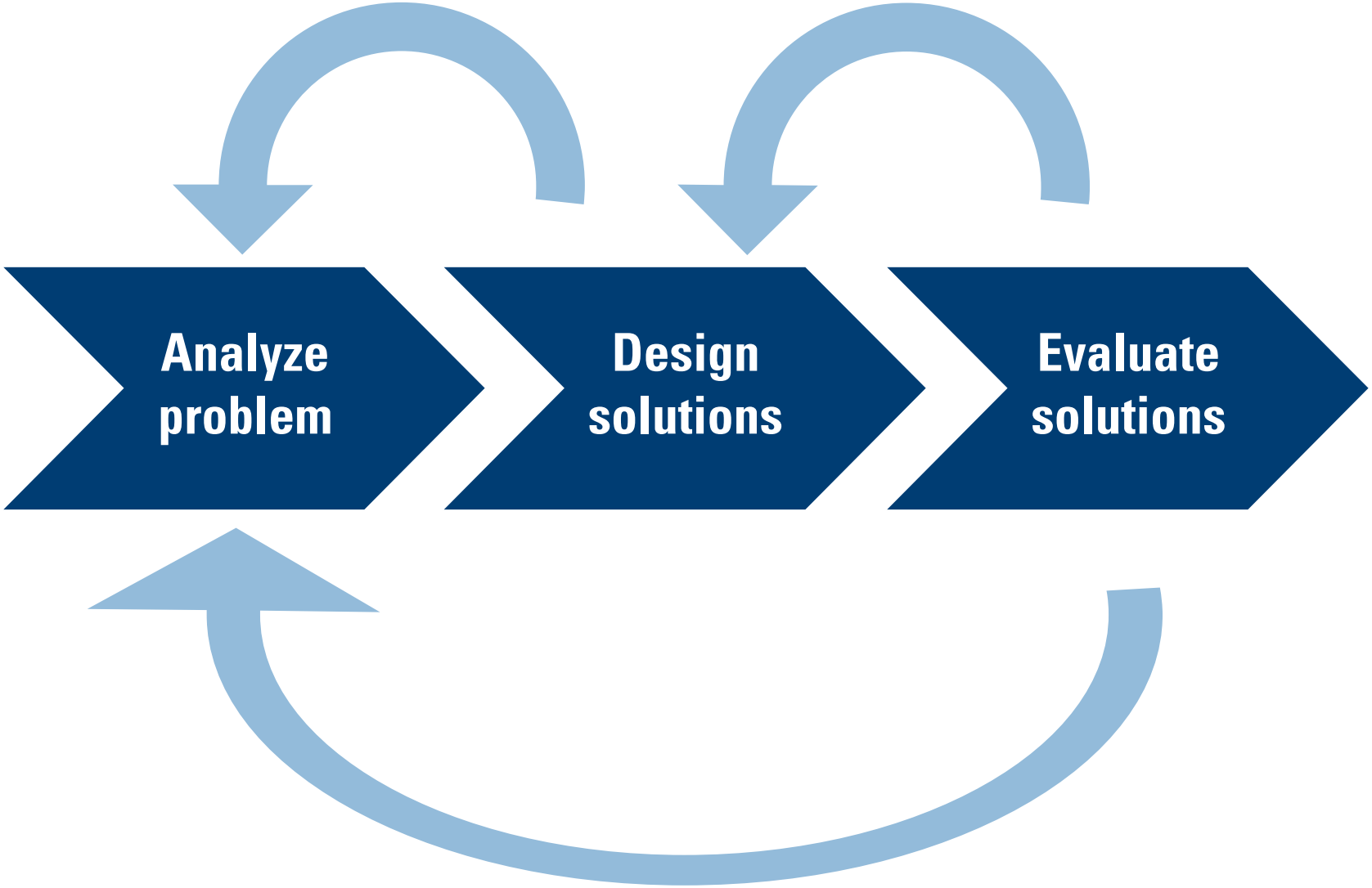
Raw Data: idiosyncratic formats
Data Transformations: Mapping raw data into an organization appropriate for visualization
Data Tables: relations (cases by variables) + metadata
Visual Mappings: Encoding abstract data into a visual representation
Visual Structures: spatial substrates + marks + graphical properties
View Transformations: Changing the view or perspective onto the visual presentation
Views: graphical parameters (position, scaling, clipping, ...)
Human Interaction: User influence at any level

[Card et al., 1999]

Visualization Design Process



Visualization Design Process



Resources

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Acknowledgements

Thanks to Monika Lanzenberger, Margit Pohl and Markus Rester whose slides form the basis of this presentation.