UNIVERSITÄT BAYREUTH

Information Visualization

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@TWlyY29

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minard.txt

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basic
input,
(lonc latc city$ lont temp days  date$   lonp  latp  surviv  direc$ division),
(#4 #5 > $12 >> #5 #5 #5 $8 #6 #6 >> #6 >> $1 #3)
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run
24.0 55.0 Kowno          37.6    0    6  Oct 18  24.0  54.9  340000  A  1
25.3 54.7 Wilna          36.0    0    6  Oct 24  24.5  55.0  340000  A  1
26.4 54.4 Smorgoni       33.2   -9   16  Nov 9   25.5  54.5  340000  A  1
26.8 54.3 Molodexno      32.0  -21    5  Nov 14  26.0  54.7  320000  A  1
27.7 55.2 Gloubokoe      29.2  -11   10          27.0  54.8  300000  A  1
27.6 53.9 Minsk          28.5  -20    4  Nov 28  28.0  54.9  280000  A  1
28.5 54.3 Studienska     27.2  -24    3  Dec 1   28.5  55.0  240000  A  1
28.7 55.5 Polotzk        26.7  -30    5  Dec 6   29.0  55.1  210000  A  1
29.2 54.4 Bobr           25.3  -26    1  Dec 7   30.0  55.2  180000  A  1
30.2 55.3 Witebsk                               30.3  55.3  175000  A  1
30.4 54.5 Orscha                                32.0  54.8  145000  A  1
30.4 53.9 Mohilow                               33.2  54.9  140000  A  1
32.0 54.8 Smolensk                              34.4  55.5  127100  A  1
33.2 54.9 Dorogobouge                           35.5  55.4  100000  A  1
34.3 55.2 Wixma                                 36.0  55.5  100000  A  1
34.4 55.5 Chjat                                 37.6  55.8  100000  R  1
36.0 55.5 Mojaisk                               37.5  55.7   98000  R  1
37.6 55.8 Moscou                                37.0  55.0   97000  R  1
36.6 55.3 Tarantino                             36.8  55.0   96000  R  1
36.5 55.0 Malo-jarosewli                        35.4  55.3   87000  R  1
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                                                33.3  54.8   37000  R  1
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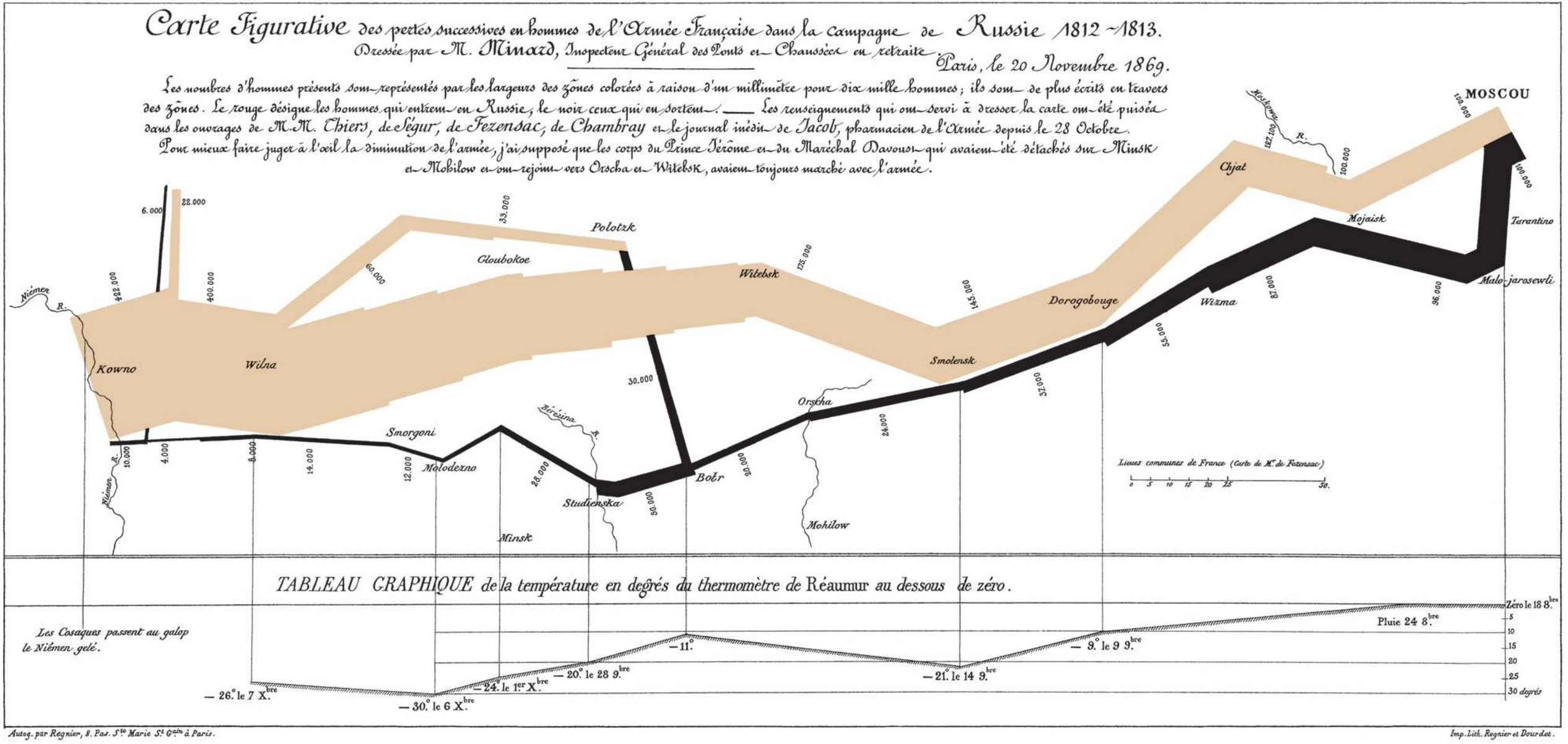
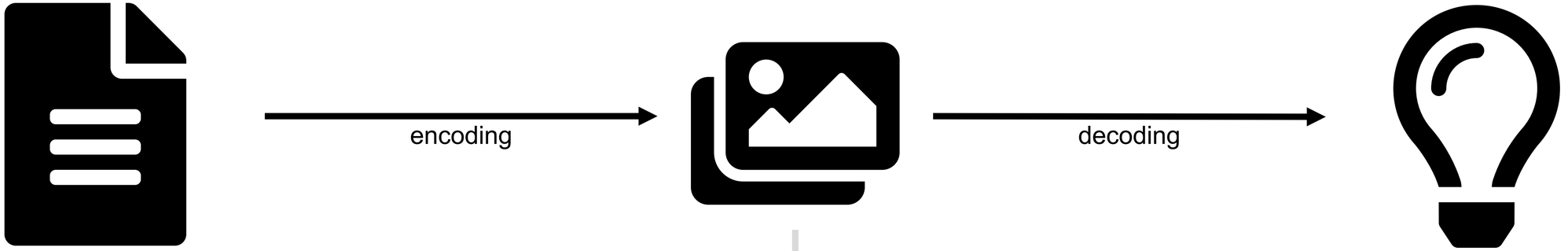


Minard, Charles Joseph (1869).

Information Visualization is a Form of Communication



Encoding:
Multivariate data is represented in two-dimensional space

Goal:
Show the data and avoid distortion
Reveal different levels of detail
Induce the viewer to think about the substance of data
Tell a story with your data

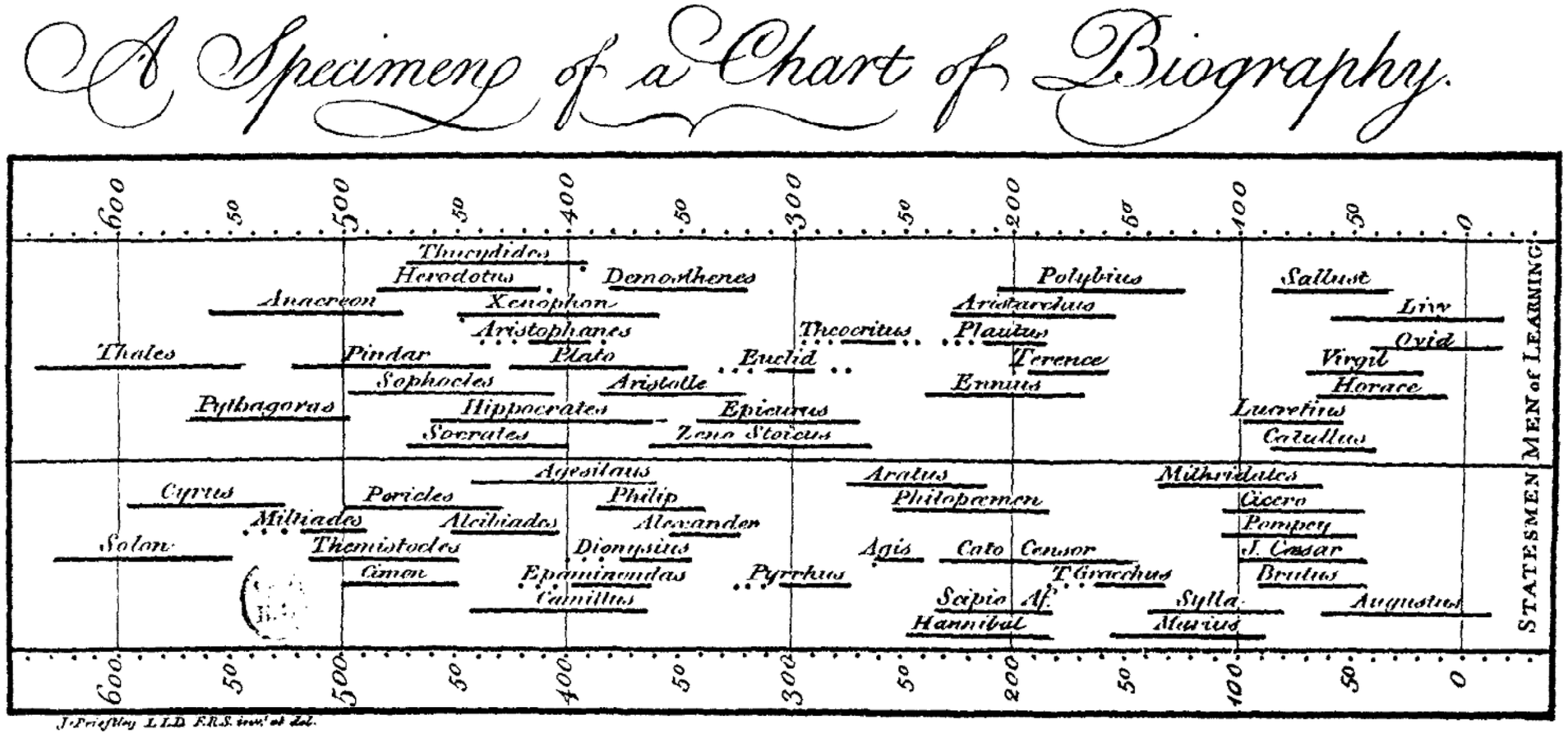
Decoding:
Derive information from data

How our brain works:
Brain is great at processing pictures (high bandwith)
People think in pictures
Pattern recognition
Pre-attentive perception

Joseph Priestley (1733-1804)

English chemist, natural philosopher, theologian, political theorist…

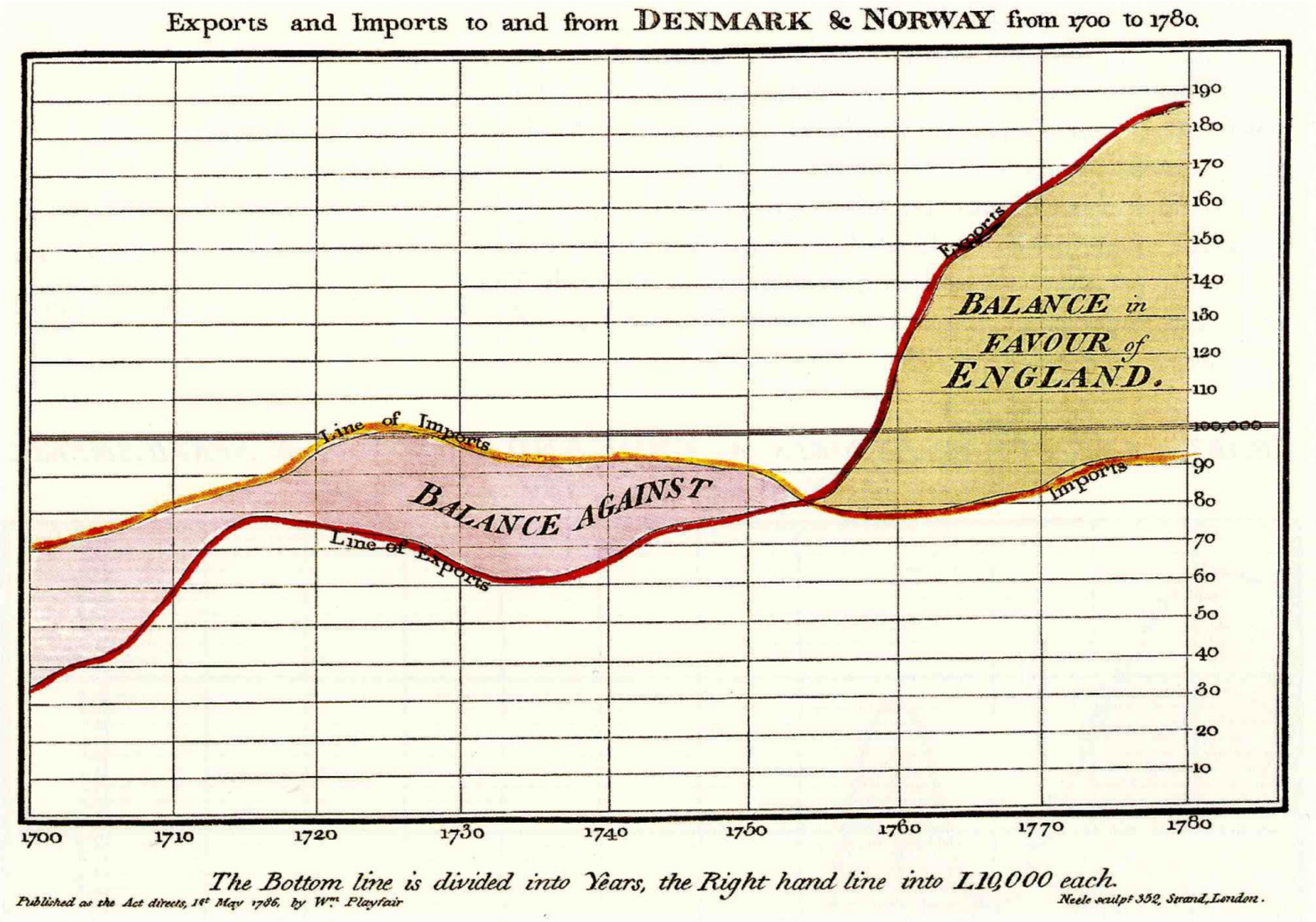
Created the first timeline chart



William Playfair (1759-1823)

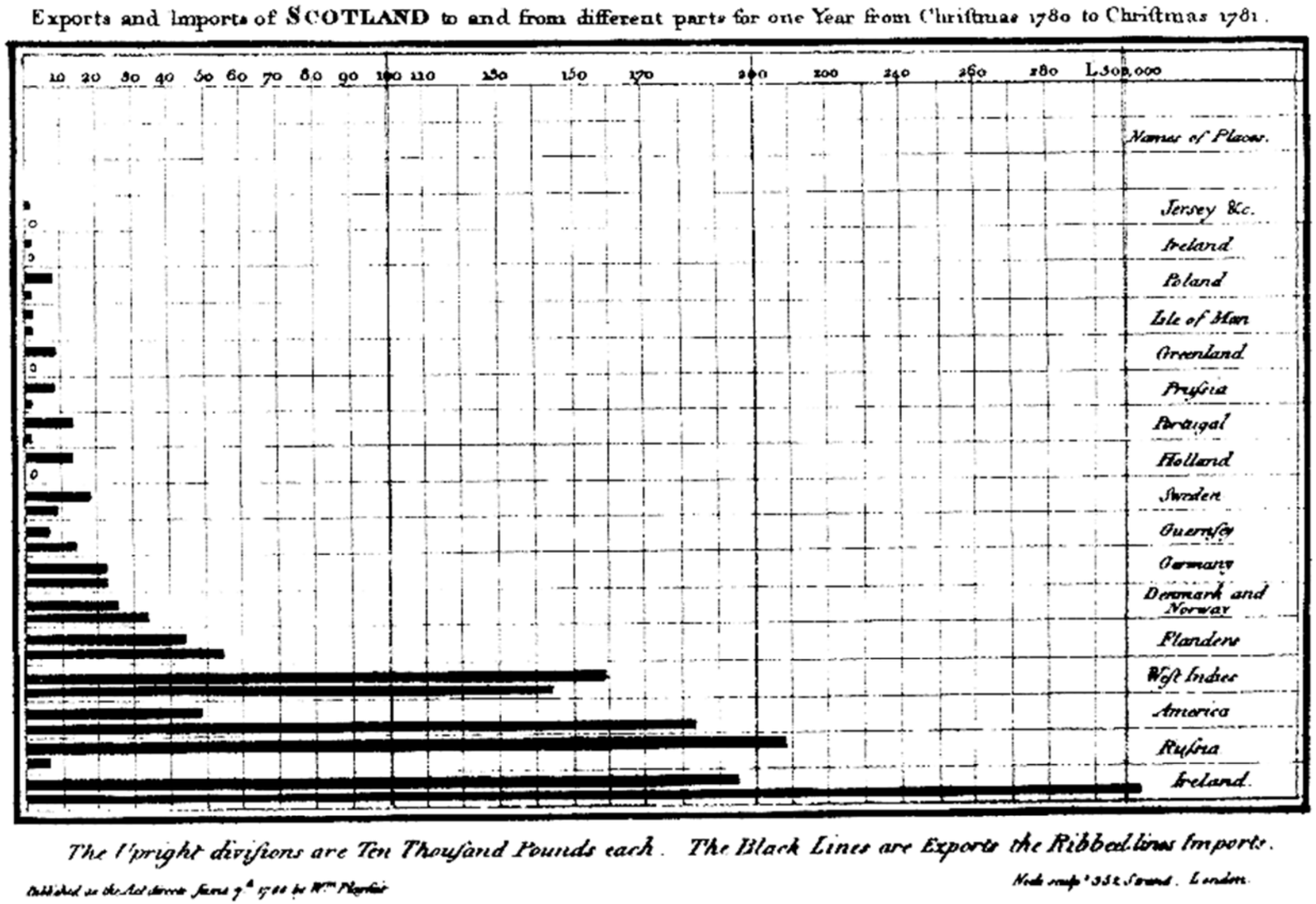
Founder of graphical statistics

Commercial and
Political Atlas, 1786



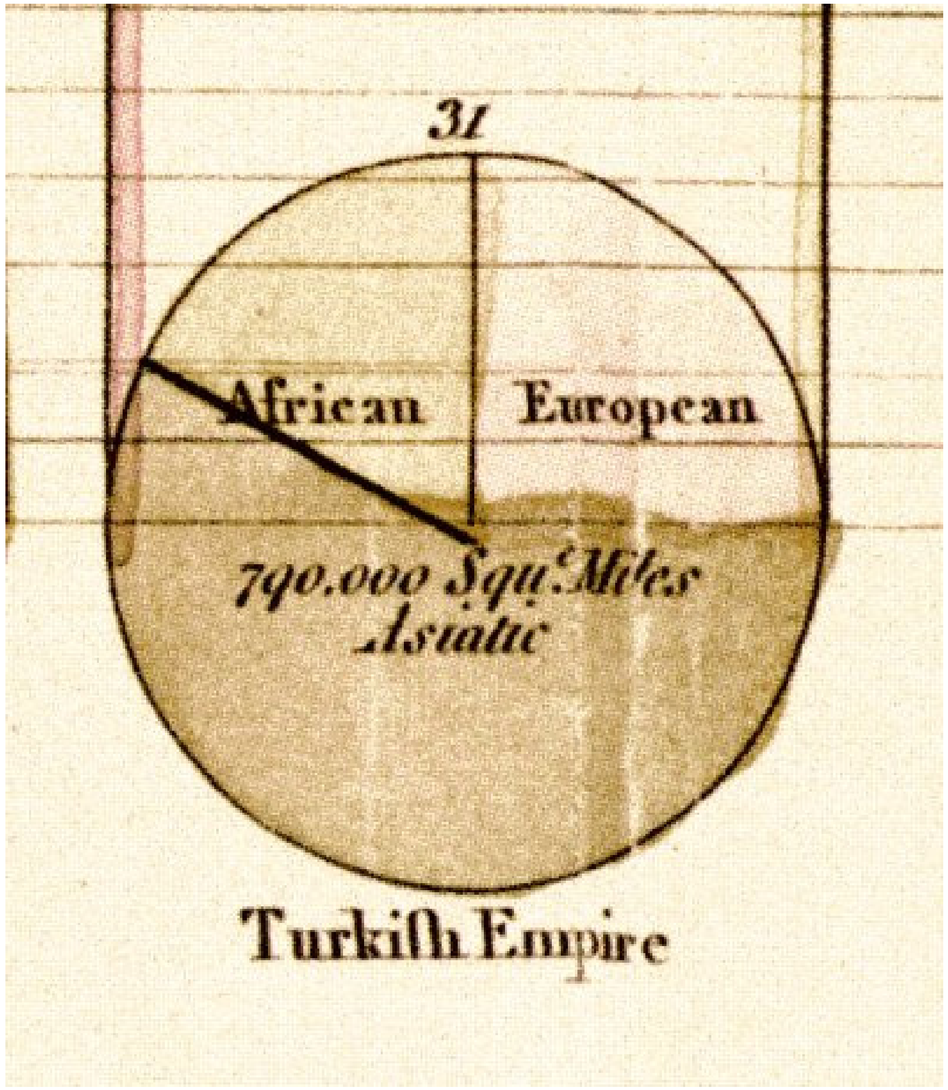
William Playfair (1759-1823)

1786: Bar Chart



William Playfair (1759-1823)

1801: Pie Chart and Circle Graph



William Playfair (1759-1823)

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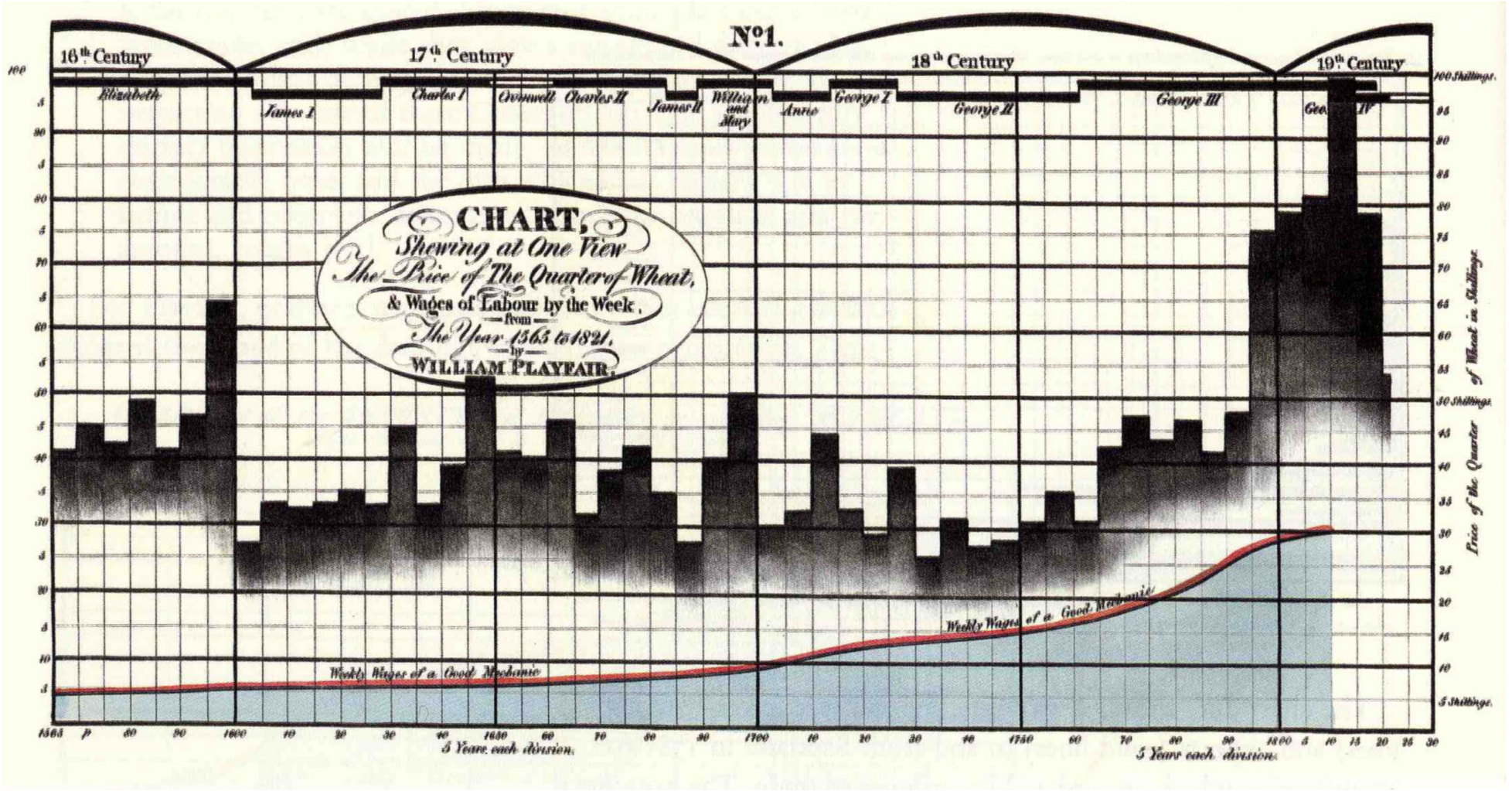
1821: Multivariate Visualization



John Snow (1813-1858)

English physician

Data visualization for reasoning

Snow, John (1854).

Highlighting: Preattentive Perception

Do you see a red circle?

A preattentive task coming up…

You will see a series of pictures, some with a red circle in it.

Healey, C., & Enns, J. (2011). Attention and visual memory in visualization and computer graphics. IEEE transactions on visualization and computer graphics, 18(7), 1170-1188.

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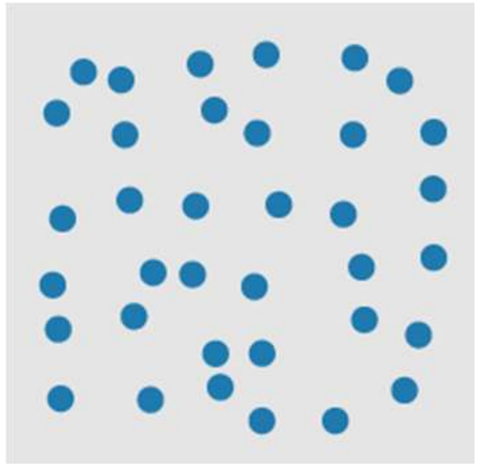

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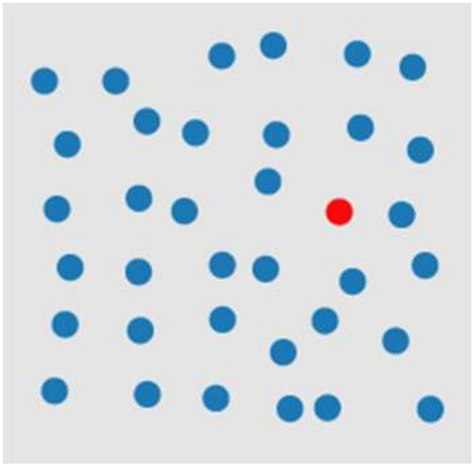

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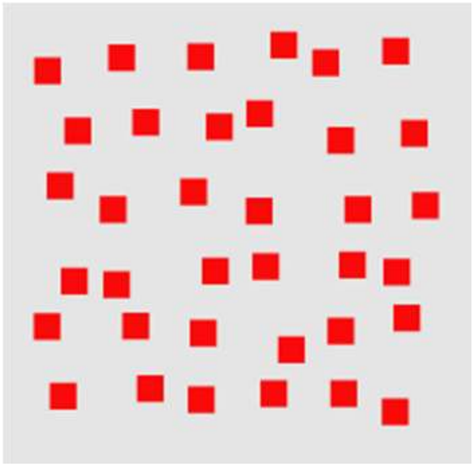

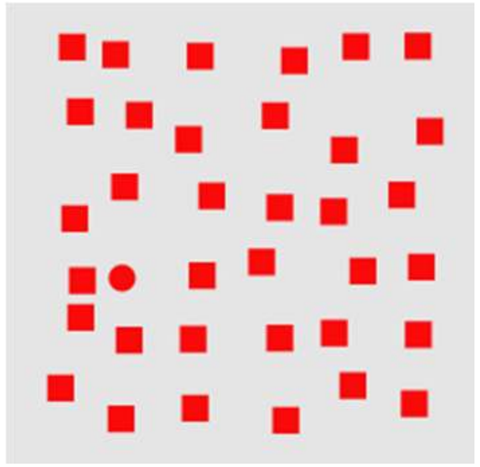

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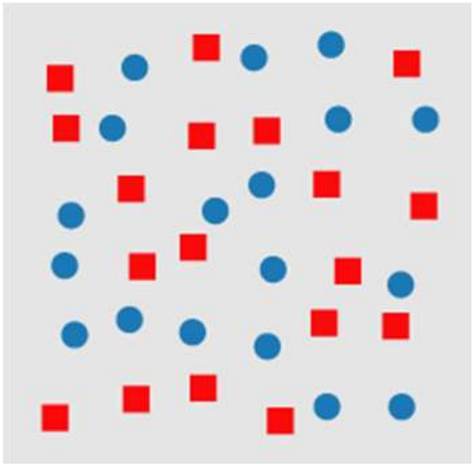

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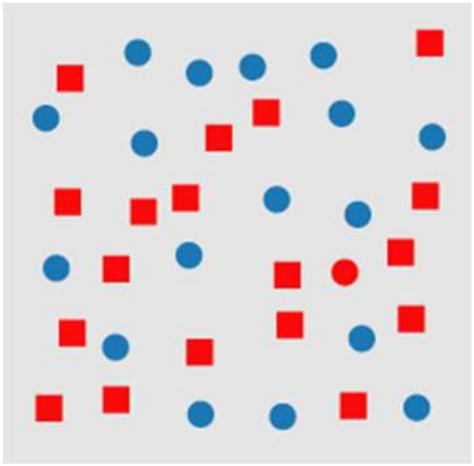
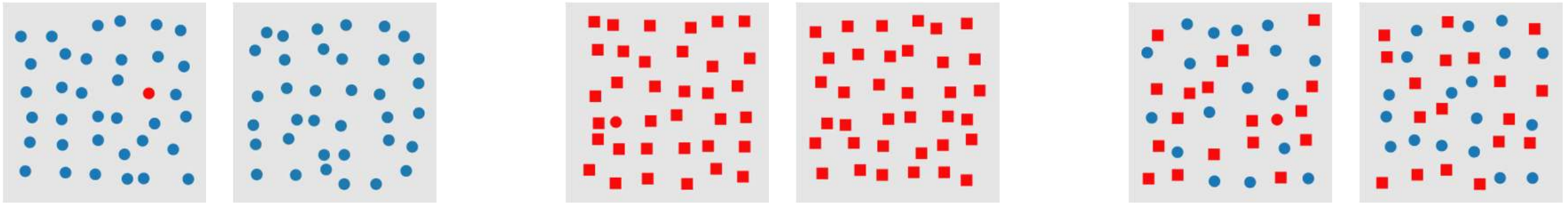


Did you see a red circle?

A unique visual property in the target allows it to „pop out“ of a display

Combination of non-unique features cannot be processed preattentively



Healey, C., & Enns, J. (2011). Attention and visual memory in visualization and computer graphics. IEEE transactions on visualization and computer graphics, 18(7), 1170-1188.

Preattentive Processing

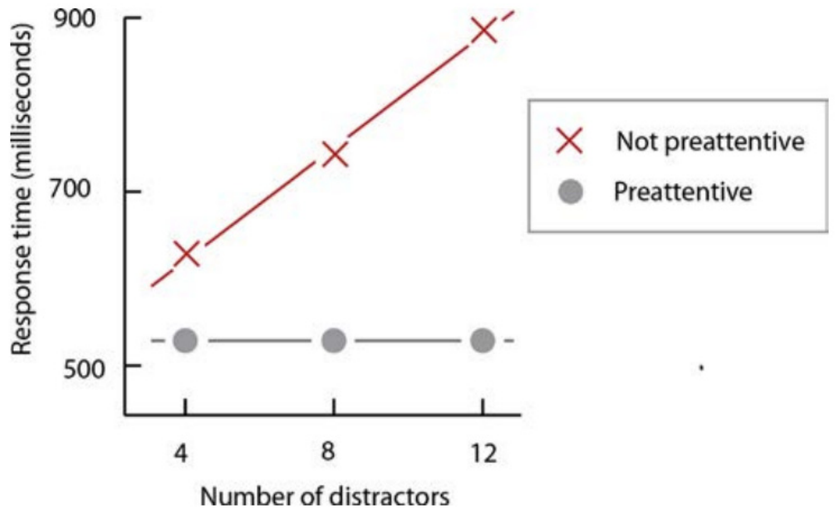
Neuroscientific concept

Can be thought of to occur before conscious attention

Usually detected by measuring the time to find a target element among distractors

Exploited in information visualization to show things „at a glance“

- Element detection
- Grouping
- Value Estimation
- Importance



Ware, C. (2019). Information visualization: perception for design. Morgan Kaufmann.

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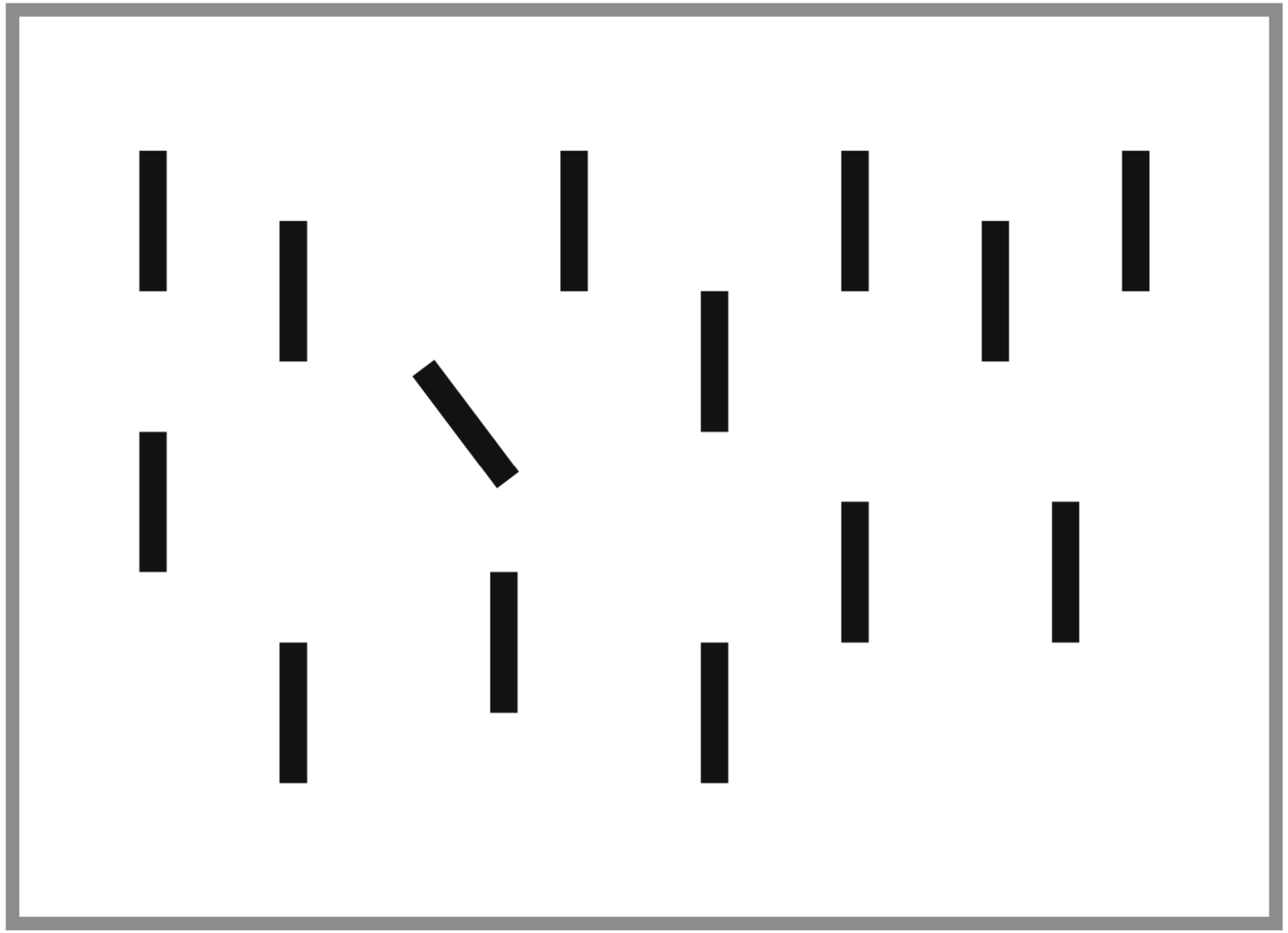

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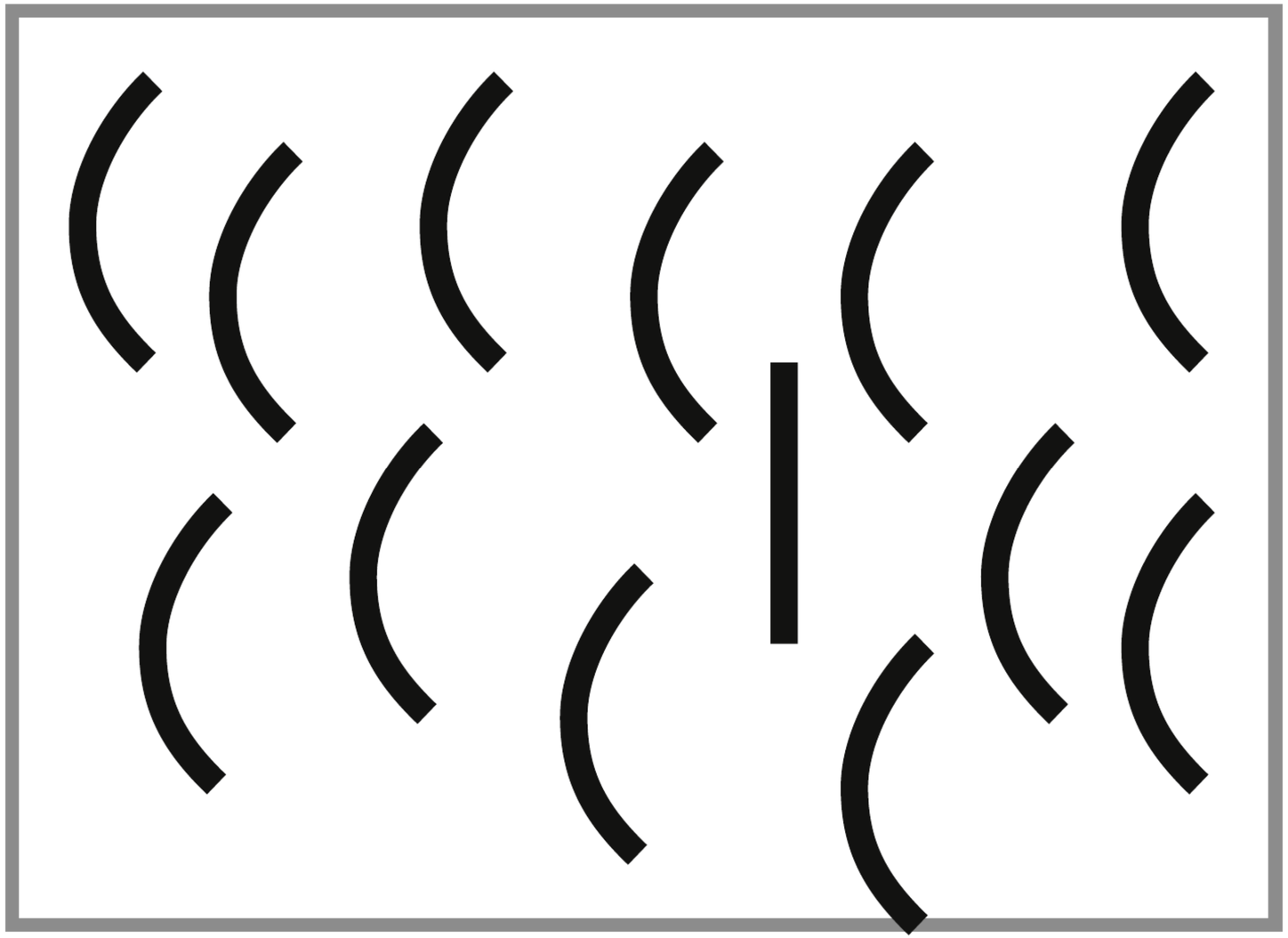

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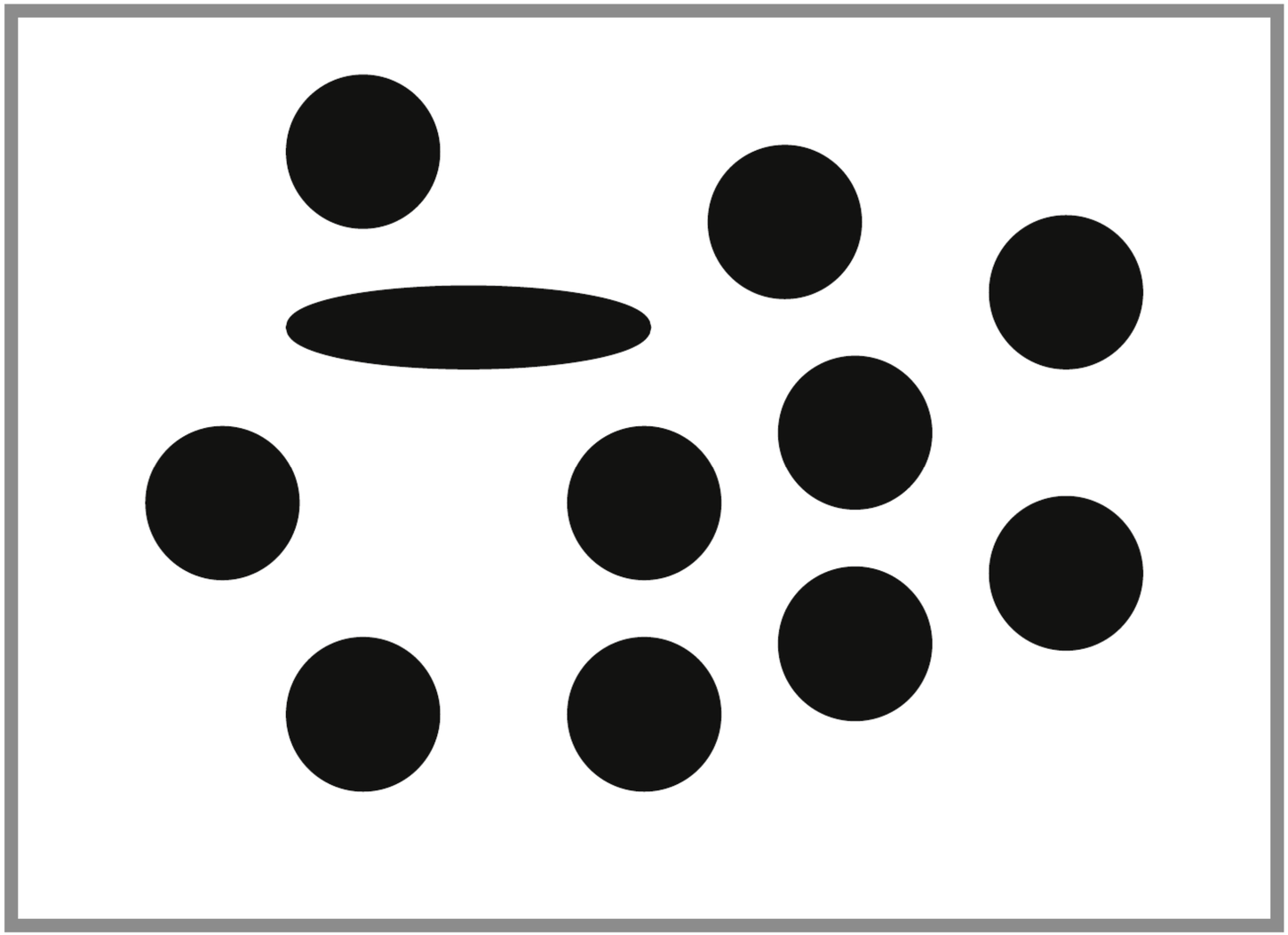

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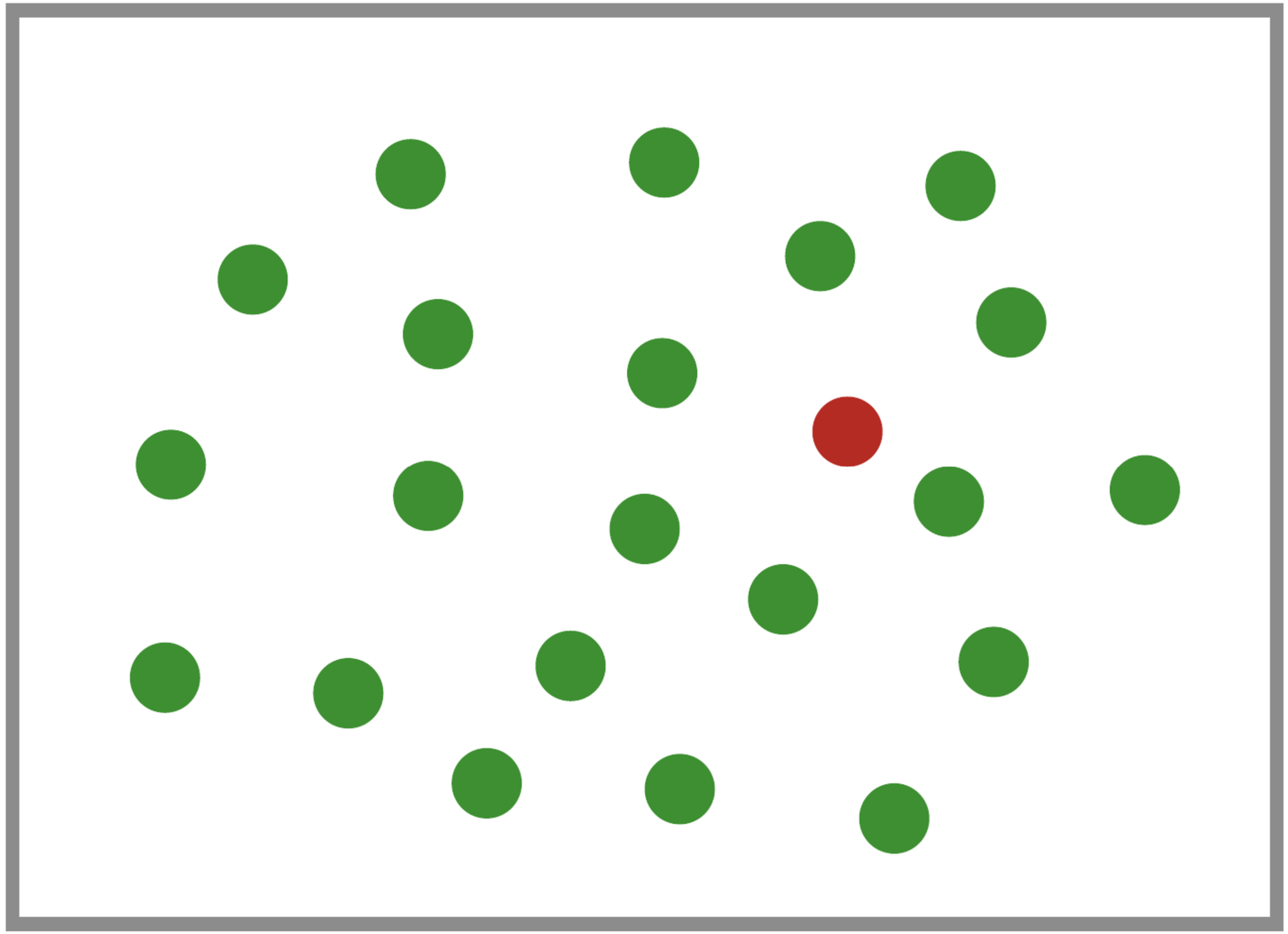

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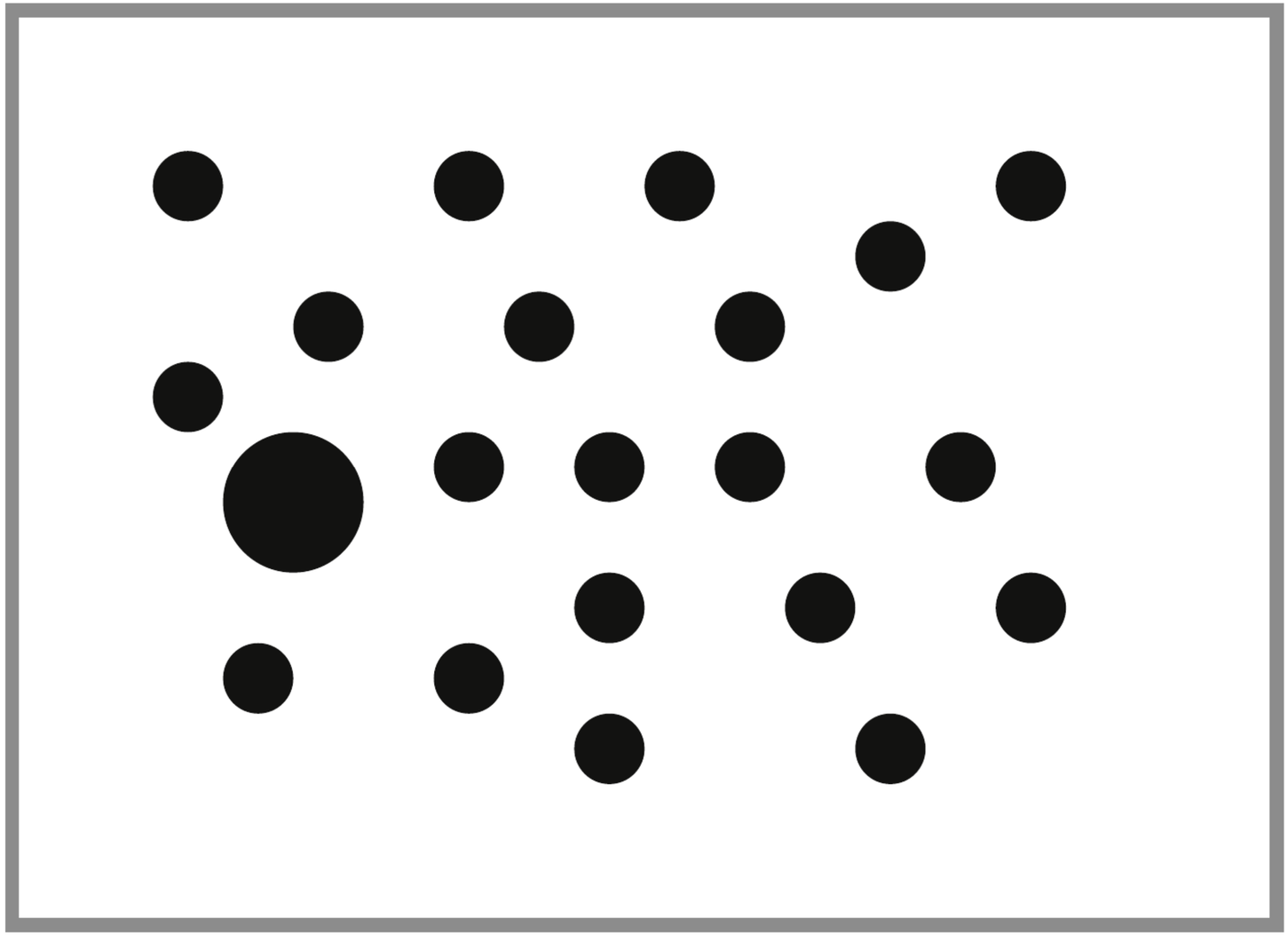

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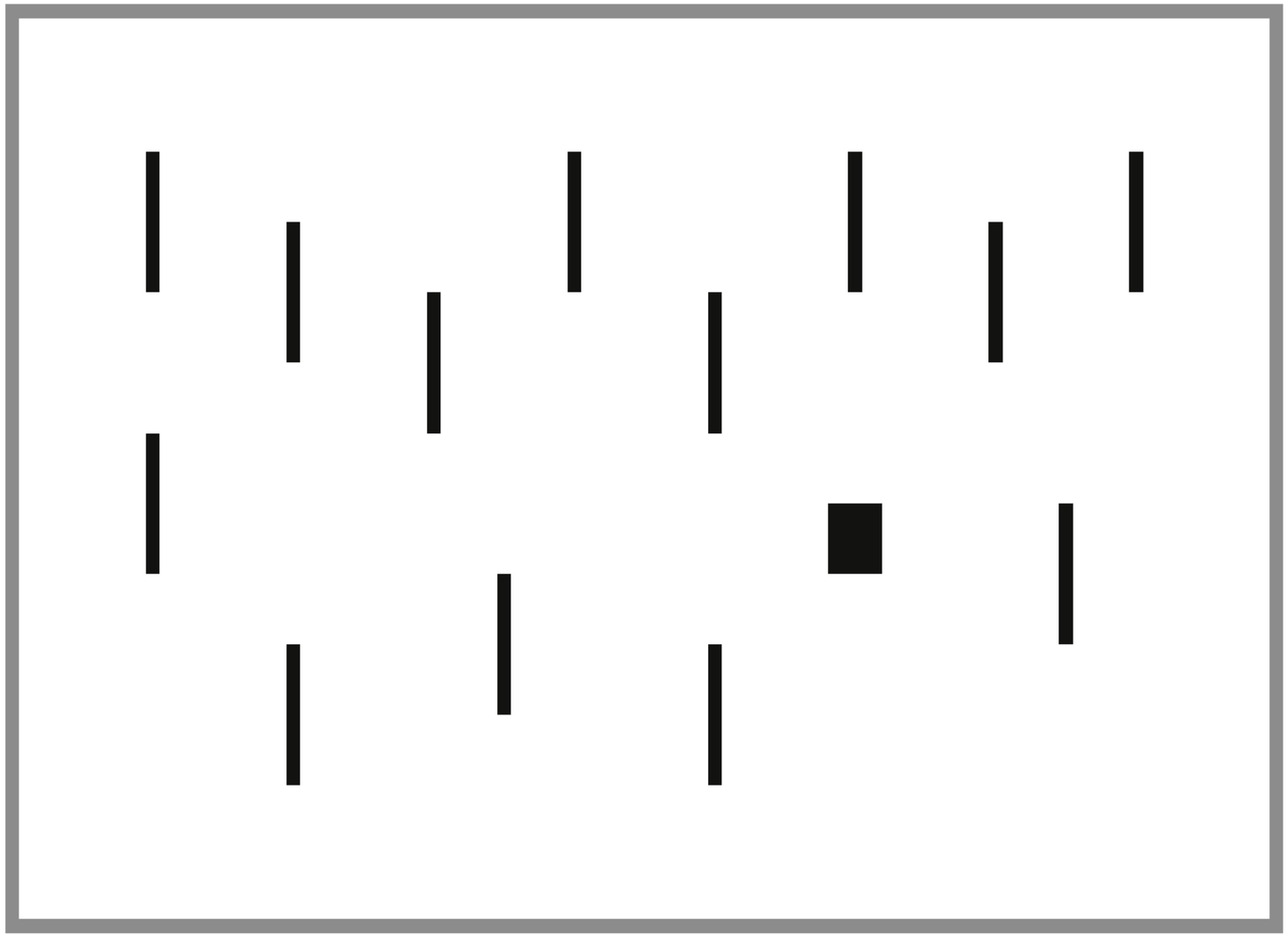

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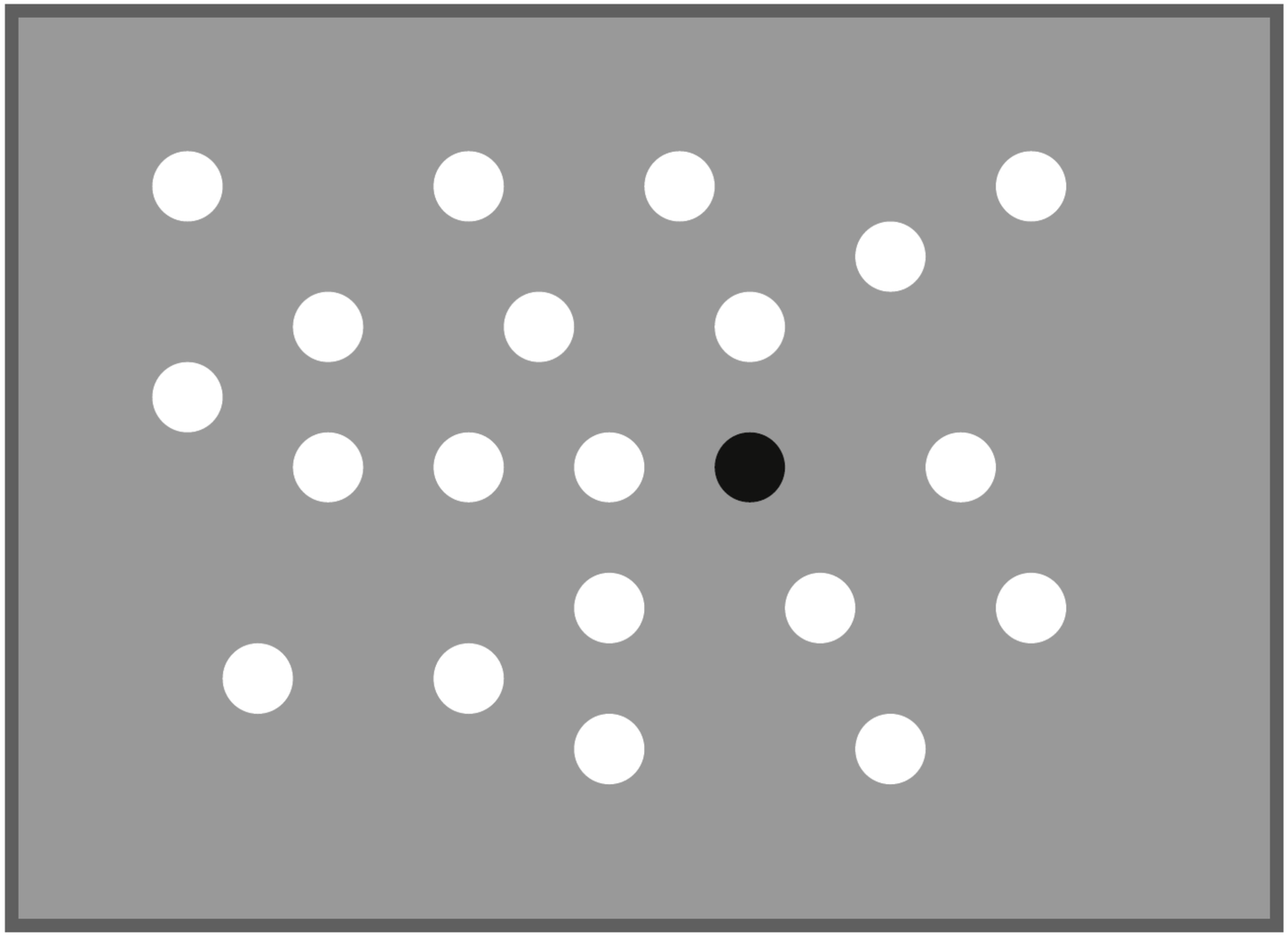

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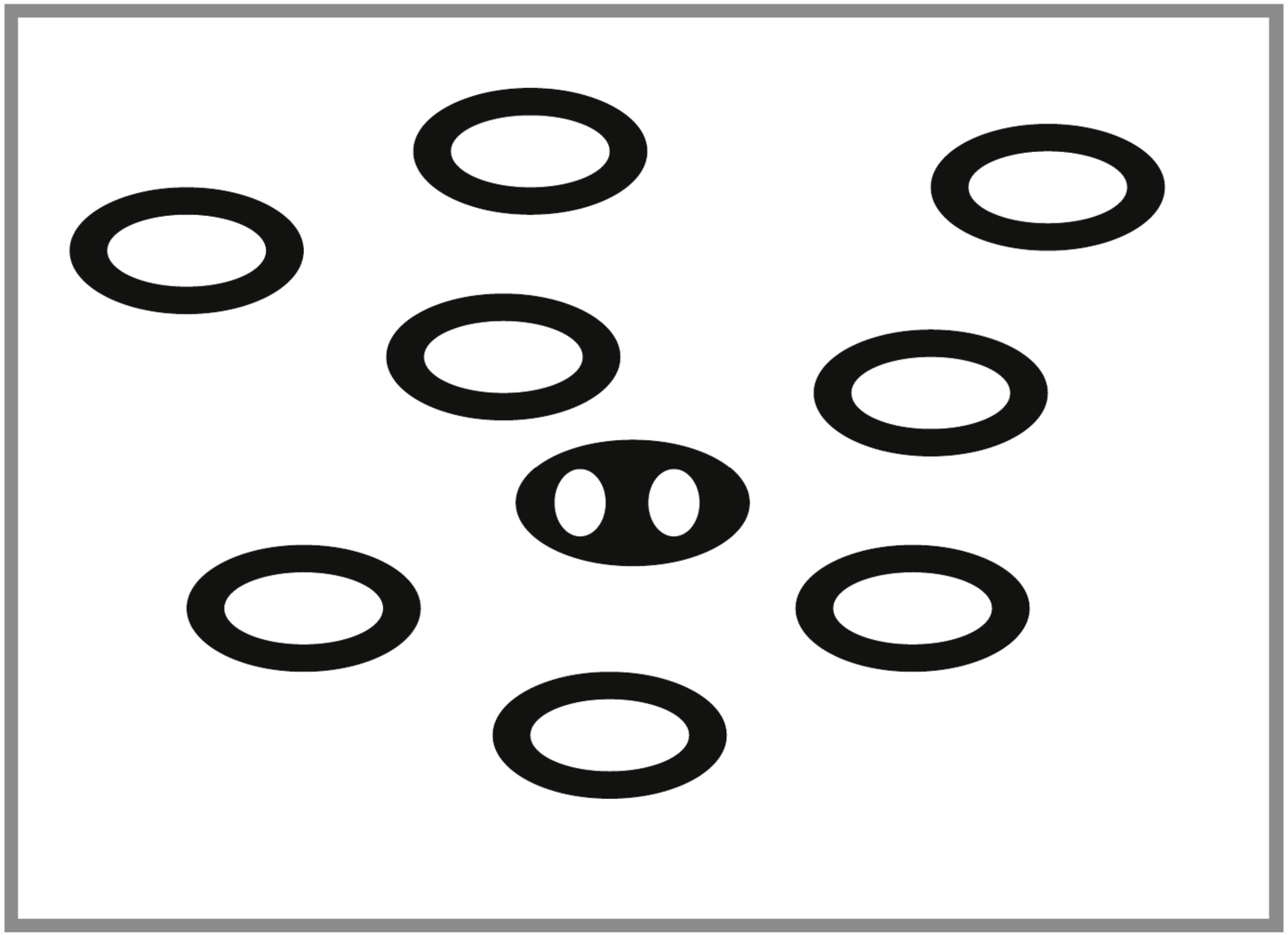

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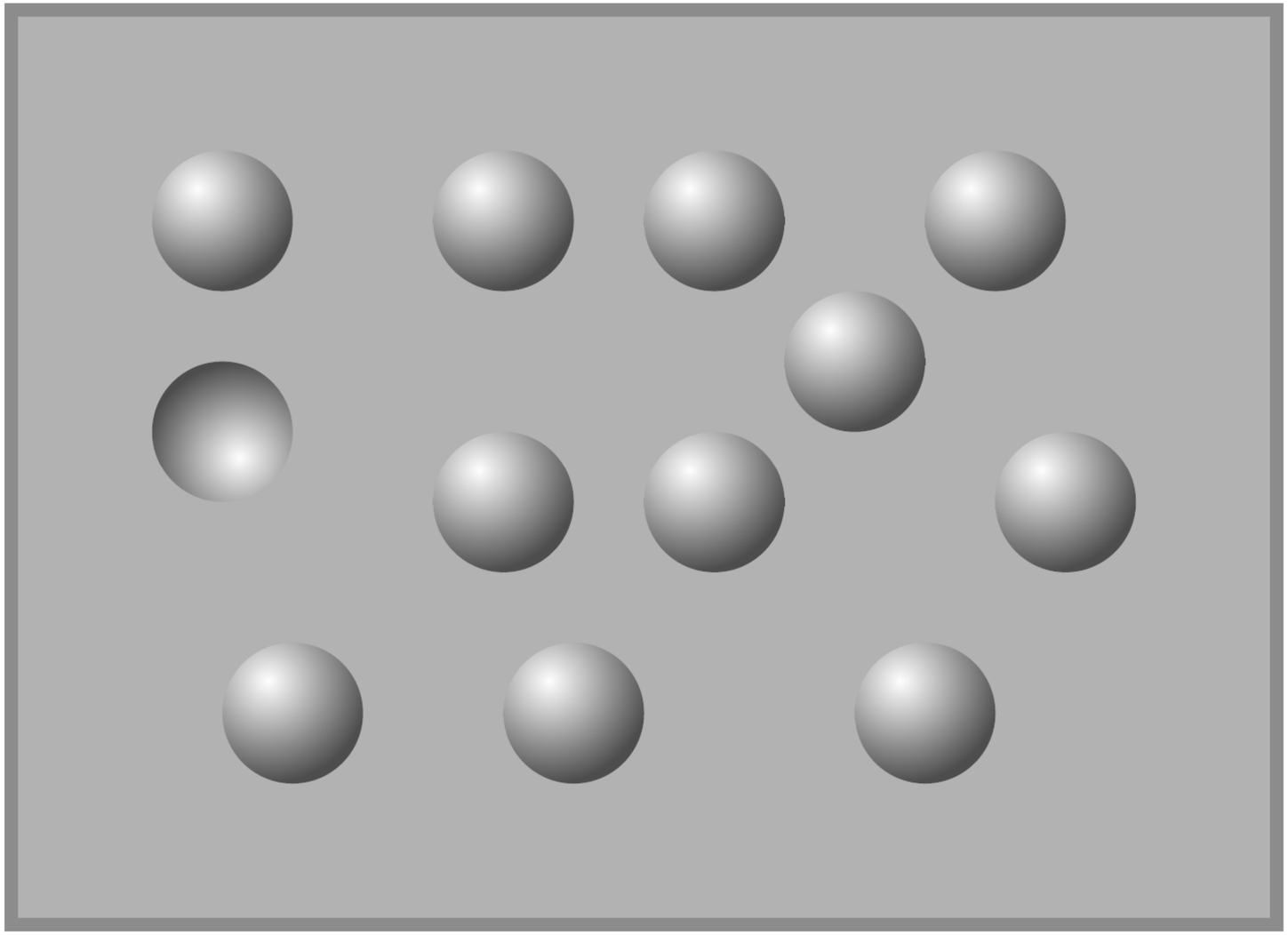

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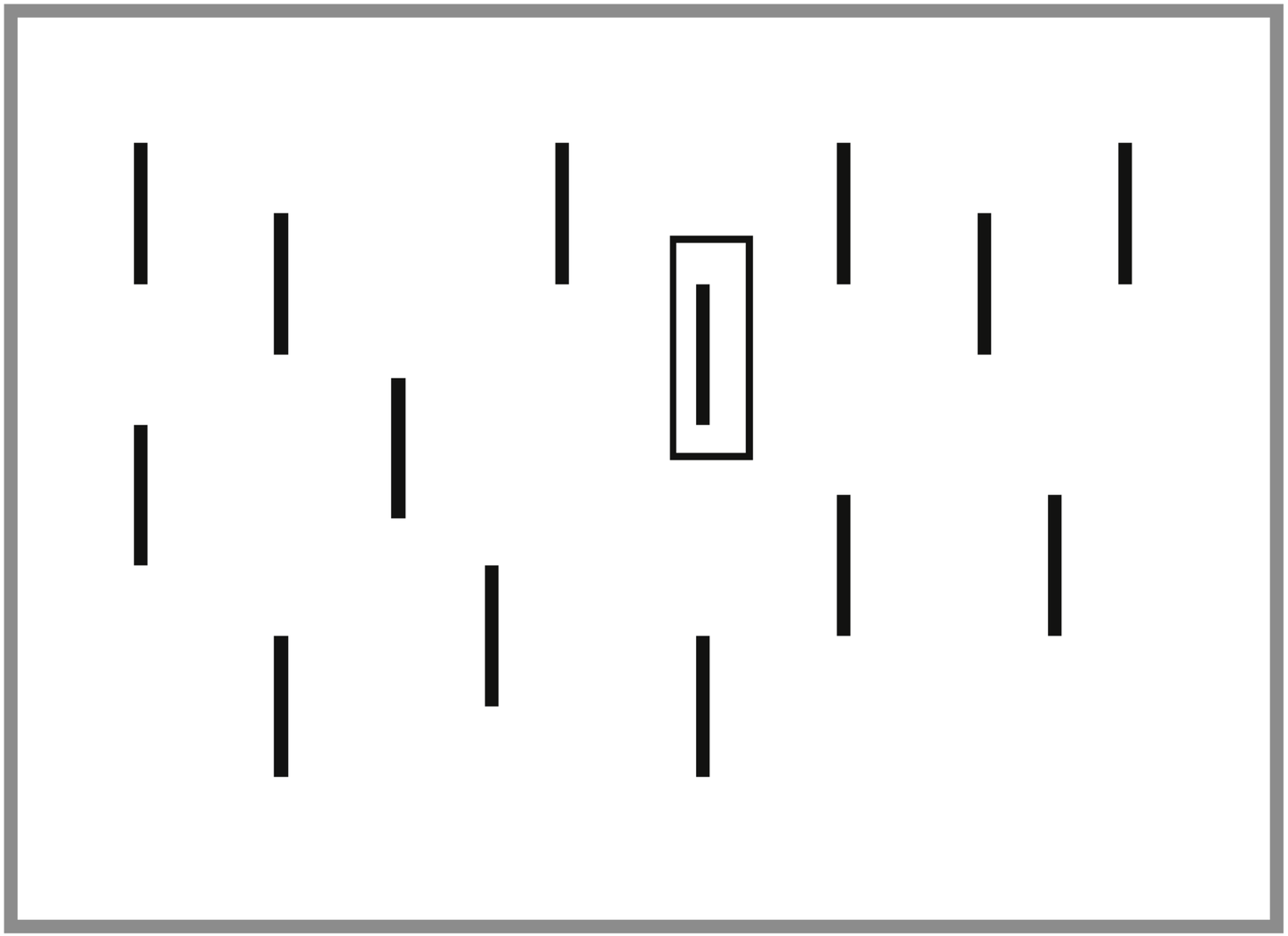

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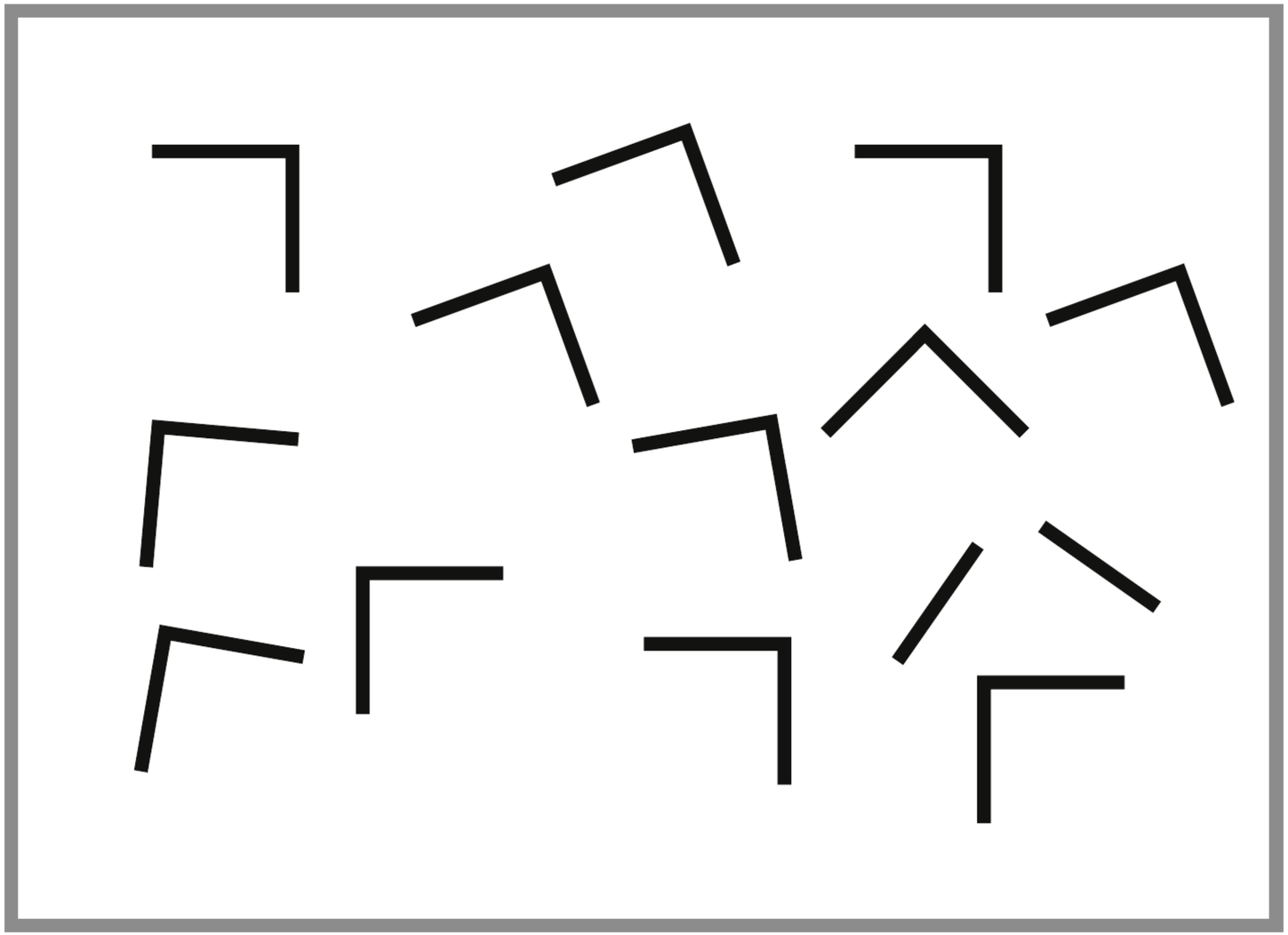

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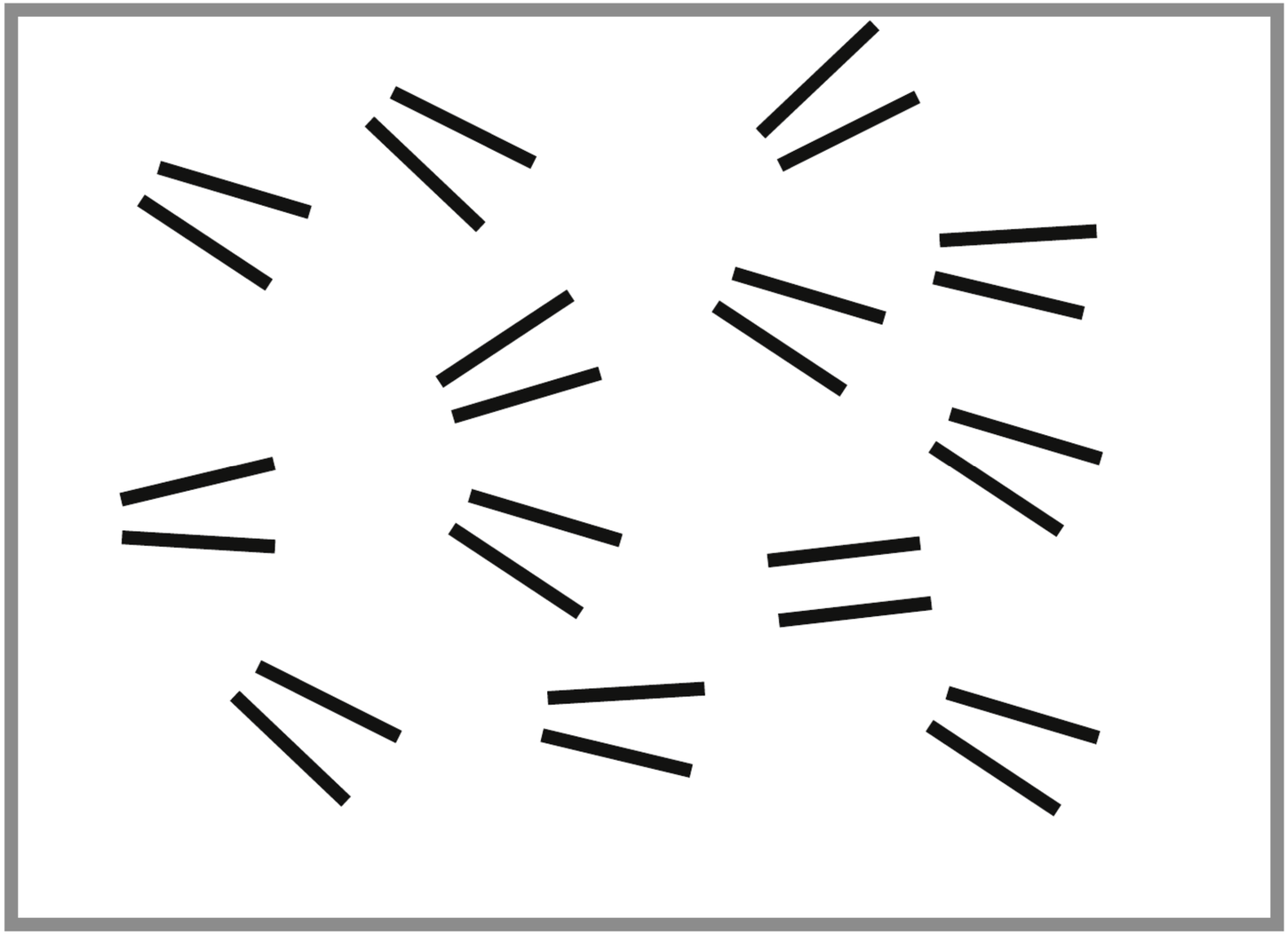

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Preattentive Elements

Not all preattentive effects are equally strong

Attributes that guide the deployment of attention most:

- Color
- Motion
- Orientation
- Size (including length and spatial frequency)

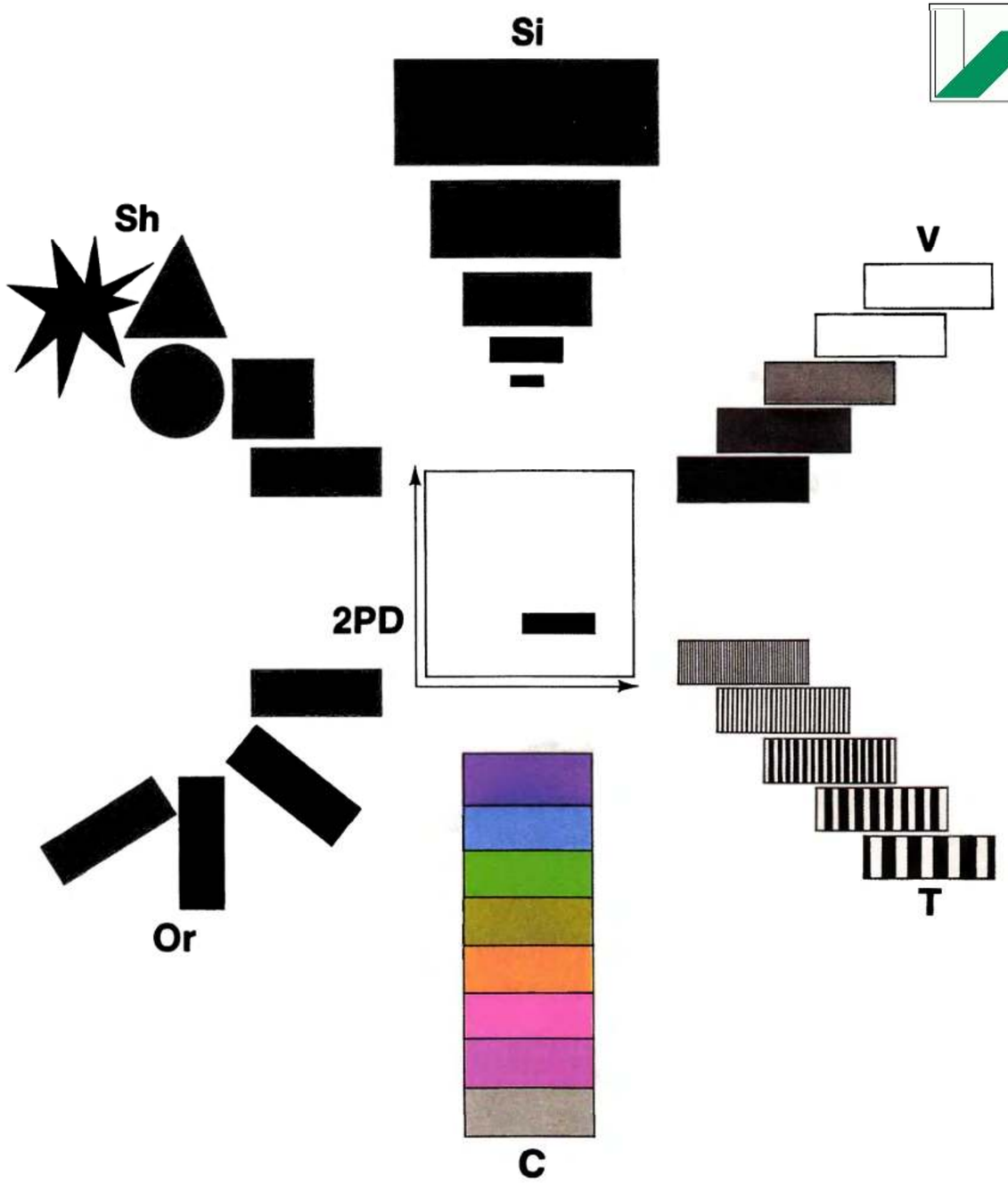
Other attributes are probable, but supported by less studies or with controversial results

Wolfe, J. M., & Horowitz, T. S. (2004). What attributes guide the deployment of visual attention and how do they do it?. Nature reviews neuroscience, 5(6), 495-501.

Graphical Elements

Graphical Elements

Position	: x,y location
Size	: length or area
Shape	: form
Orientation	: alignment
Value	: brightness
Texture	: patterns
Color	: hue & saturation

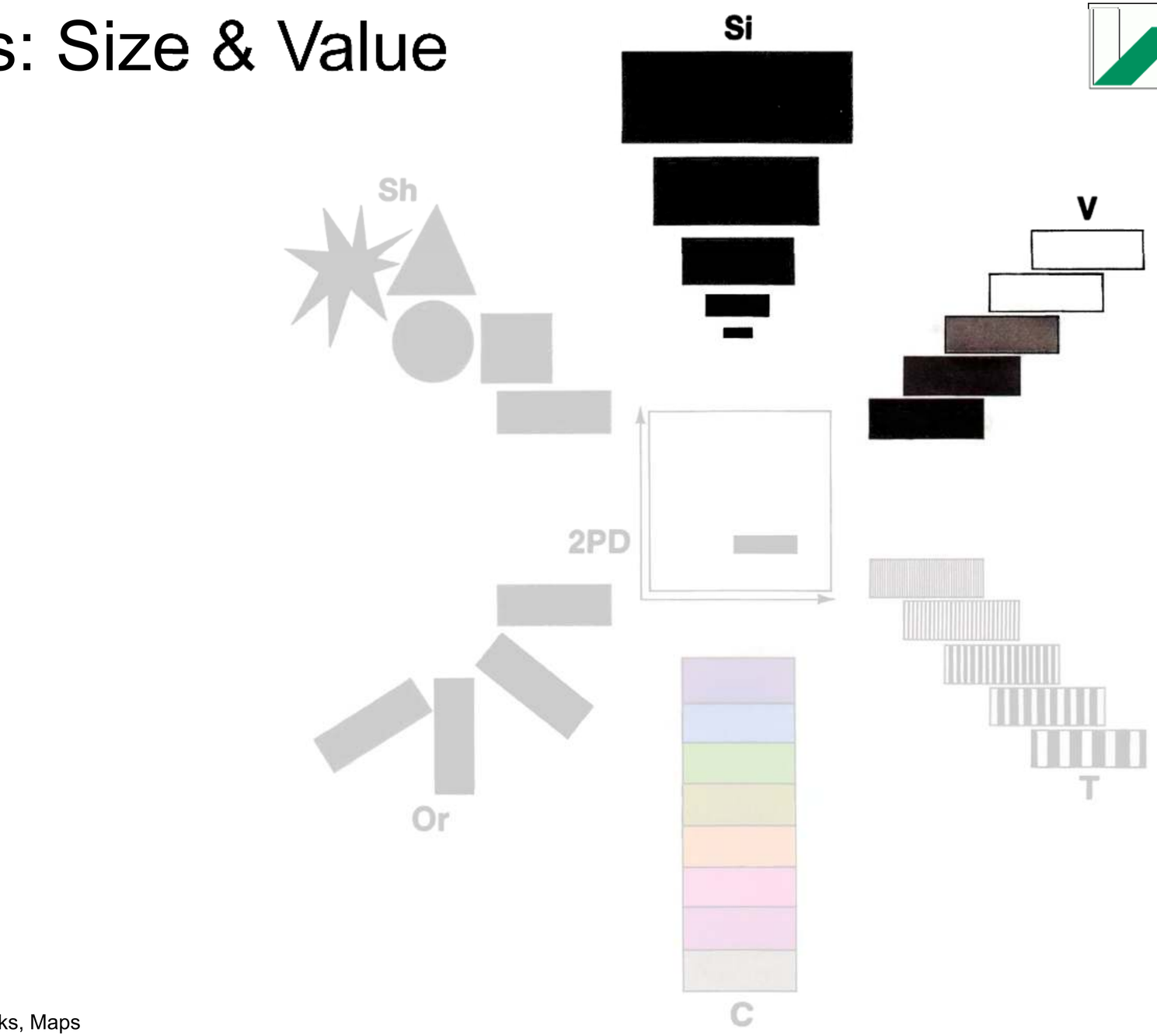


Jacques Bertin (1983): Semiology of Graphs: Diagrams, Networks, Maps

Graphical Elements: Size & Value

Great for showing

- Different intensities
- Different magnitudes
- More/less
- Larger/smaller



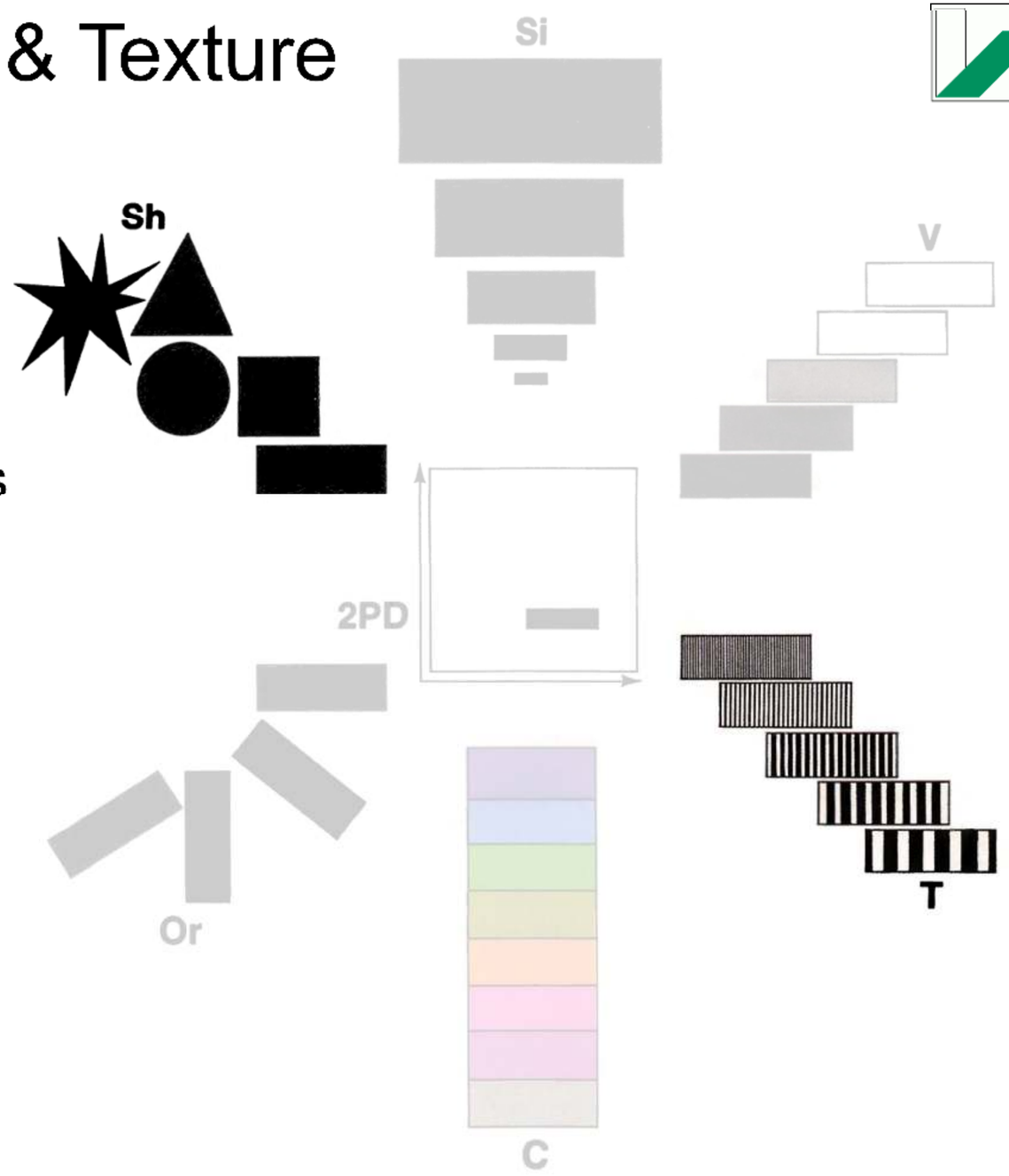
Jacques Bertin (1983): Semiology of Graphs: Diagrams, Networks, Maps

Graphical Elements: Shape & Texture

Great for showing

- Group membership

Texture can also be used to
encode different intensities/magnitudes

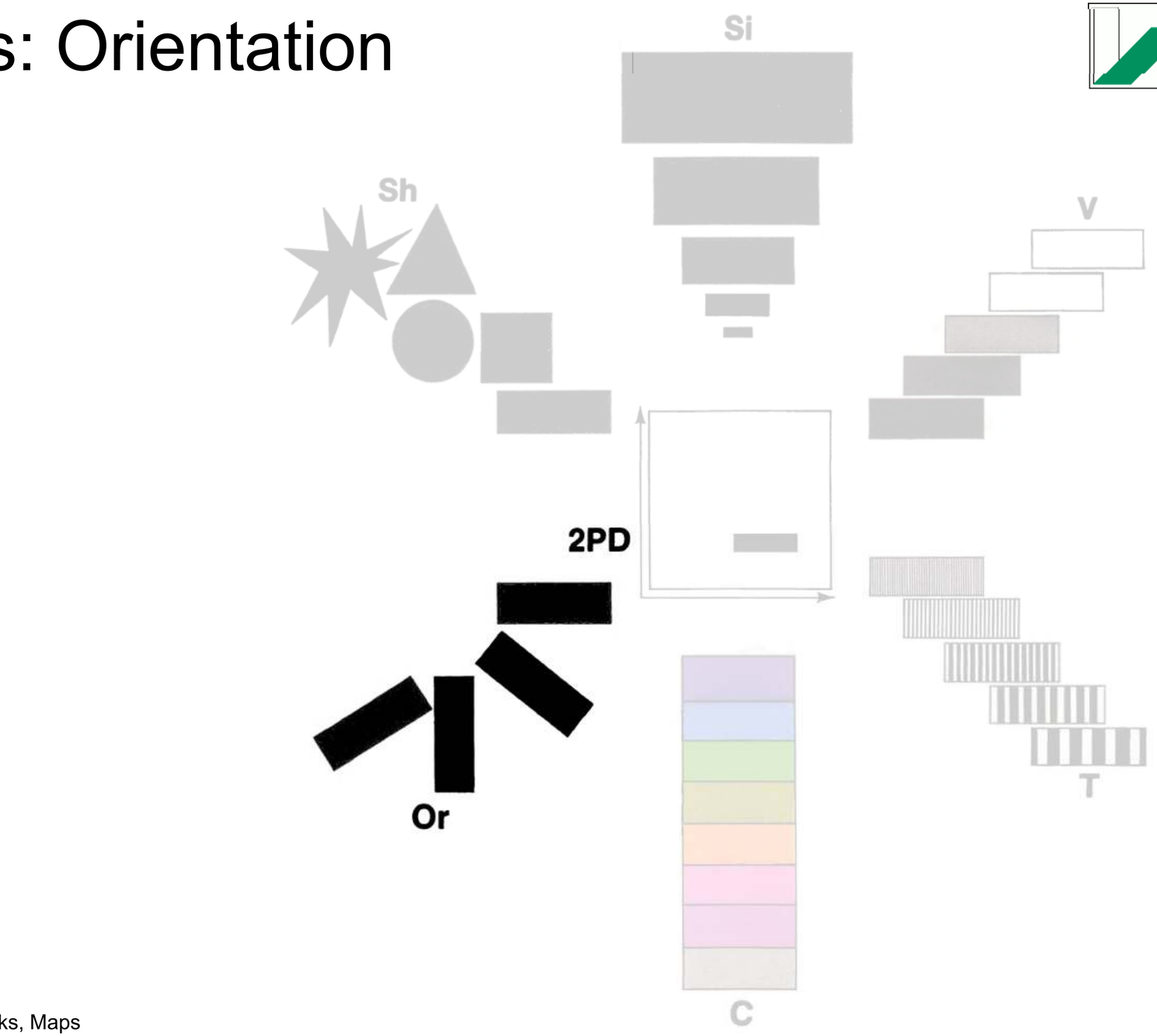


Jacques Bertin (1983): Semiology of Graphs: Diagrams, Networks, Maps

Graphical Elements: Orientation

Great for showing

- Movement
- Direction



Jacques Bertin (1983): Semiology of Graphs: Diagrams, Networks, Maps

Graphical Elements: Color

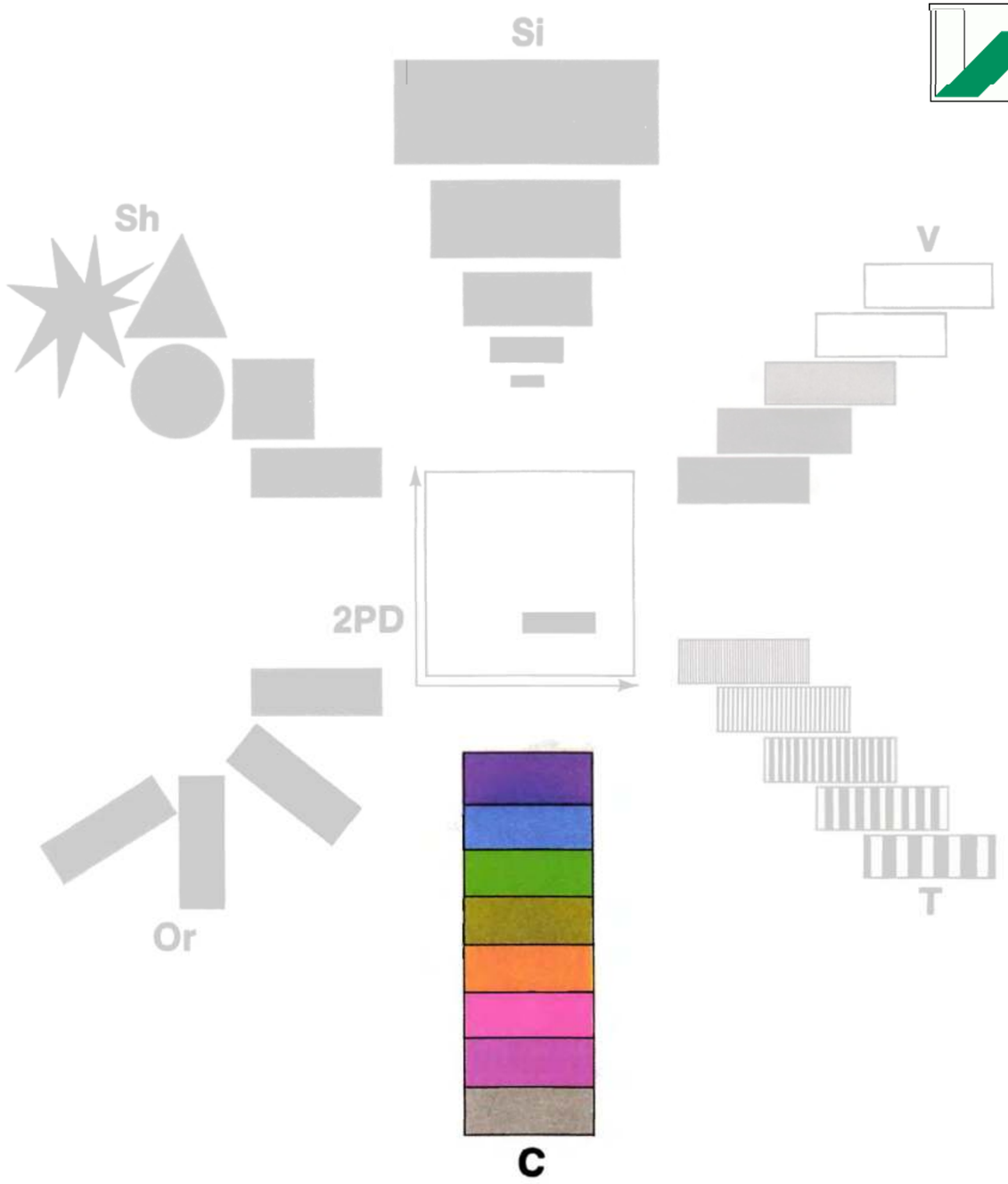
Color has two dimensions:

- Hue
  for group membership
- Saturation
  encodes intensities / magnitudes

Always requires a legend!

May have unintended meaning

More on colors later



Jacques Bertin (1983): Semiology of Graphs: Diagrams, Networks, Maps

Graphical Elements: Position

Great for showing

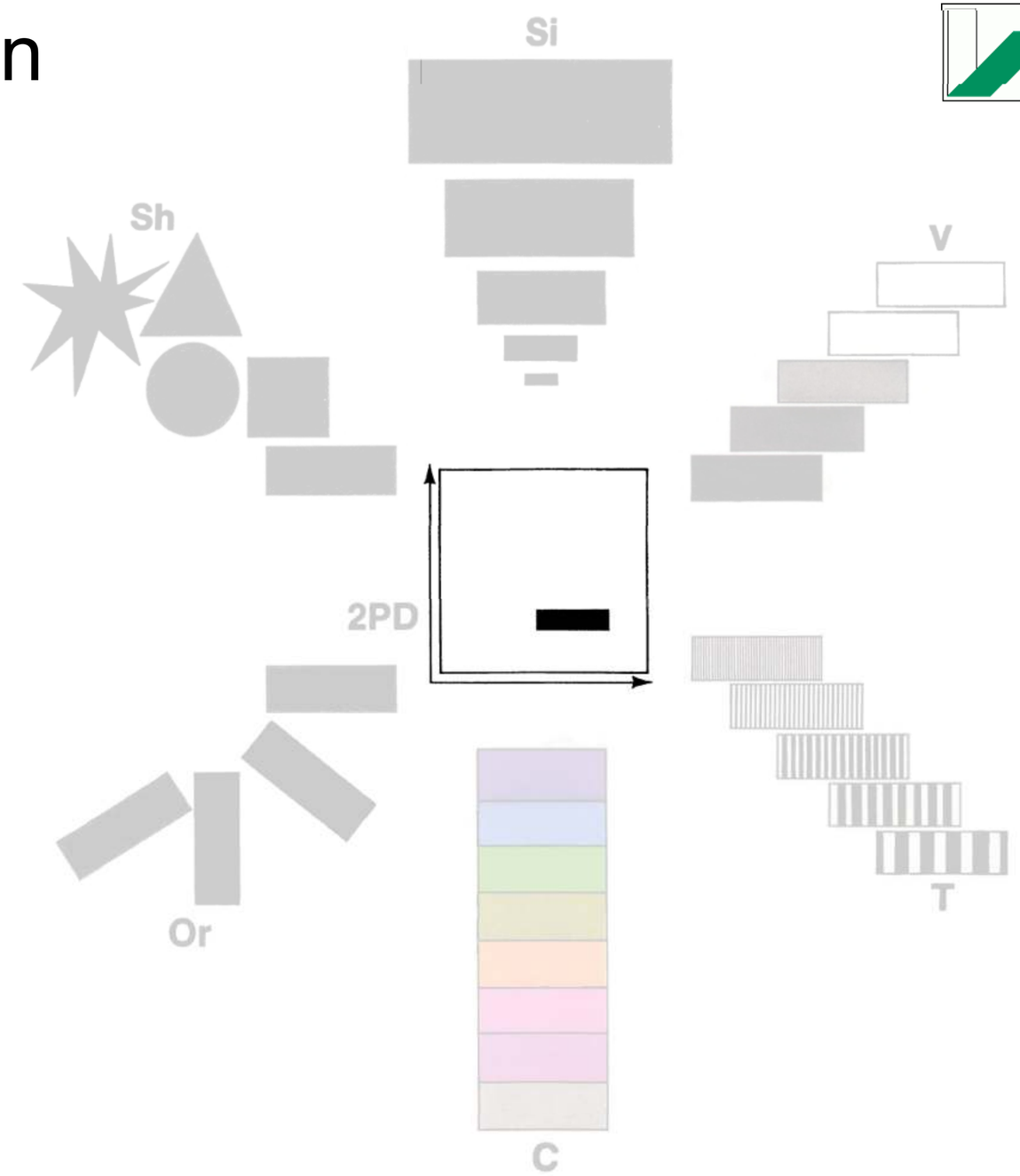
- Group membership

  elements in close distance belong together
- Importance

  things above others are more important
- Trends

  our brain interpolates between
  points and sees connections
- Movement

Very powerful design element!



Jacques Bertin (1983): Semiology of Graphs: Diagrams, Networks, Maps

Perceived Grouping

Classical grouping by

b) Proximity

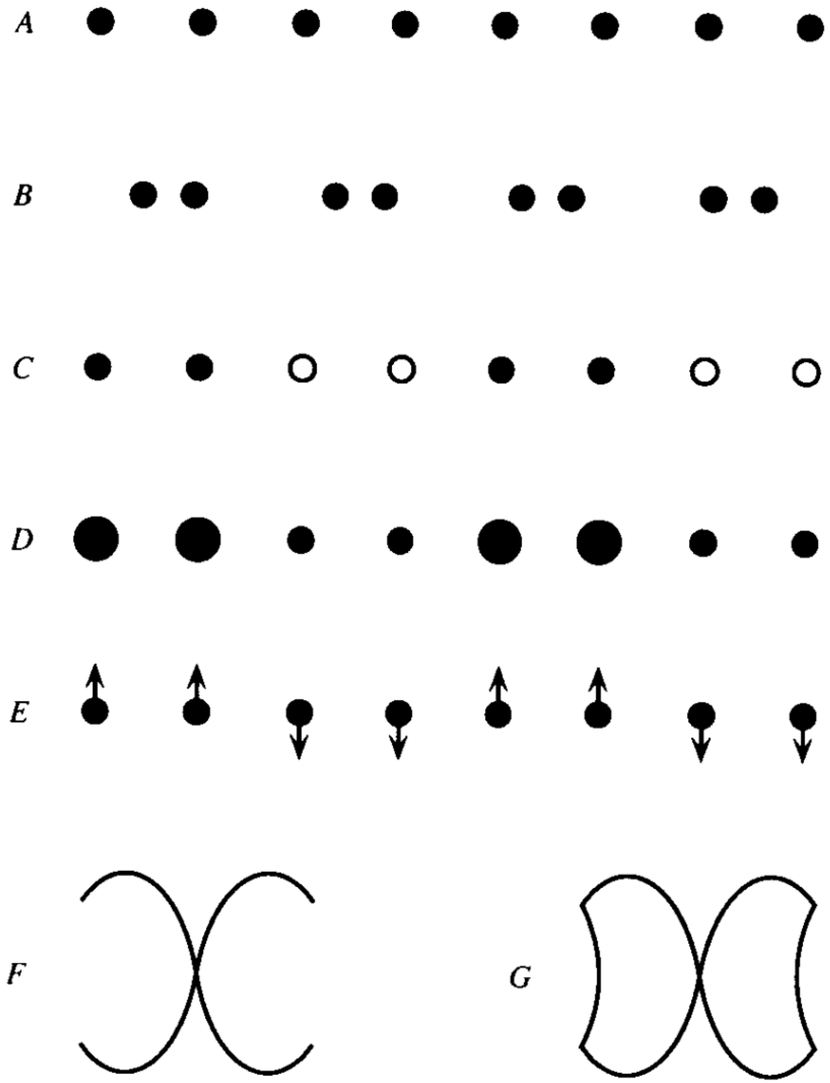
c) Color

d) Size

e) Common Fate

f) Good continuation

g) Closure



Wertheimer, M. (1923). Untersuchungen zur Lehre von der Gestalt II. Psycologische Forschung 4, 301–350. Translation published in Ellis, W.(1938). A source book of Gestalt psychology, 71-88.

Gestalt Theory

Scientific efforts to understand pattern perception

Gestalt laws: set of robust rules describing how we see patterns

e.g. based on proximity, similarity, connectedness, continuity, symmetry, closure, relative size, and common fate

Often translated into design principles for information visualization

Use these elements to think about how to organize data so that important structures will be perceived

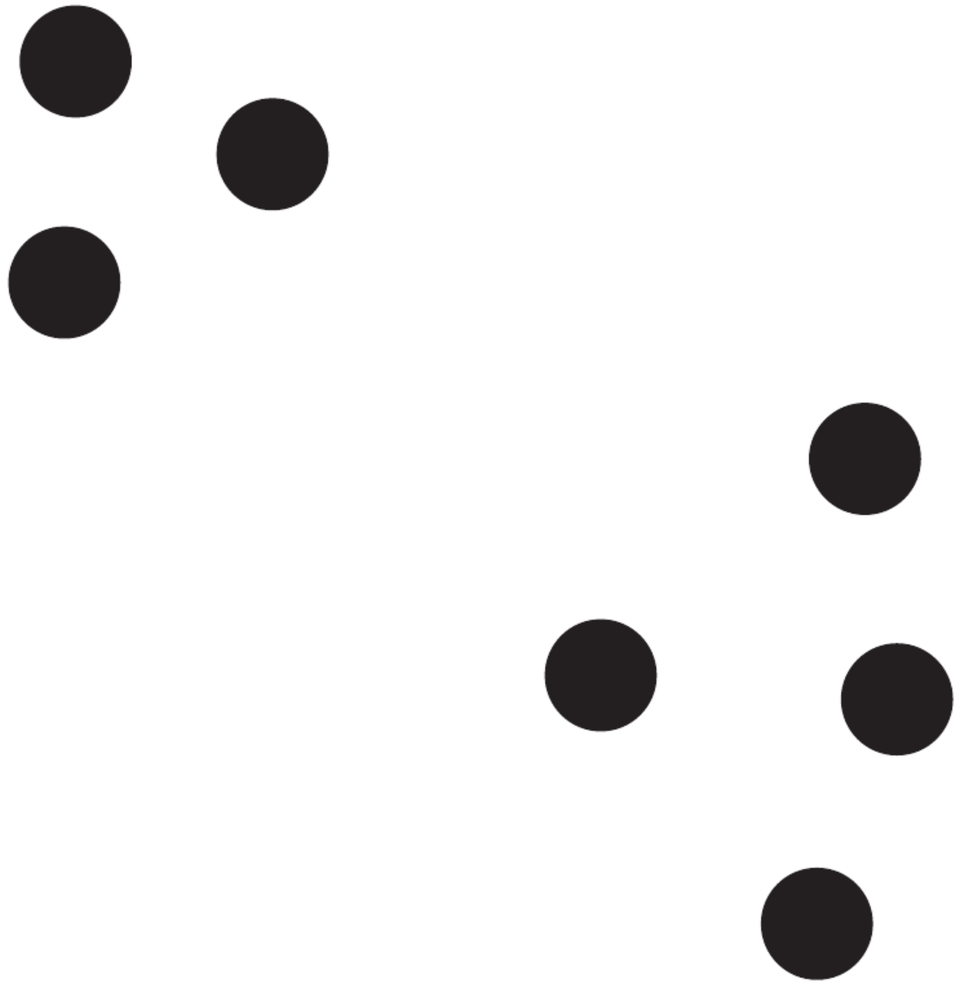
„If we can map information structures to readily perceived patterns, then those structures will be more easily interpreted.„

Ware, C. (2019). Information visualization: perception for design. Morgan Kaufmann.

Proximity

Ware, C. (2019). Information visualization: perception for design. Morgan Kaufmann.

Proximity



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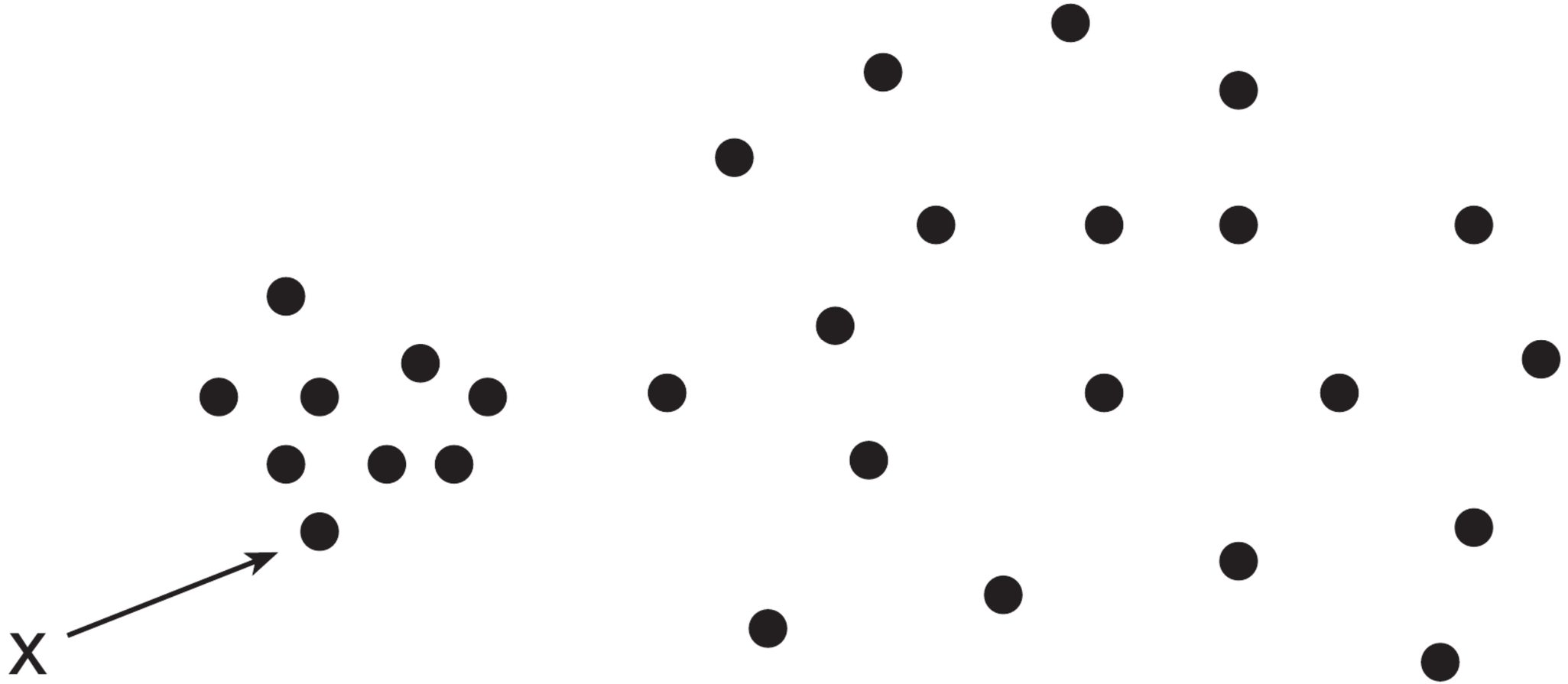
Spatial Concentration



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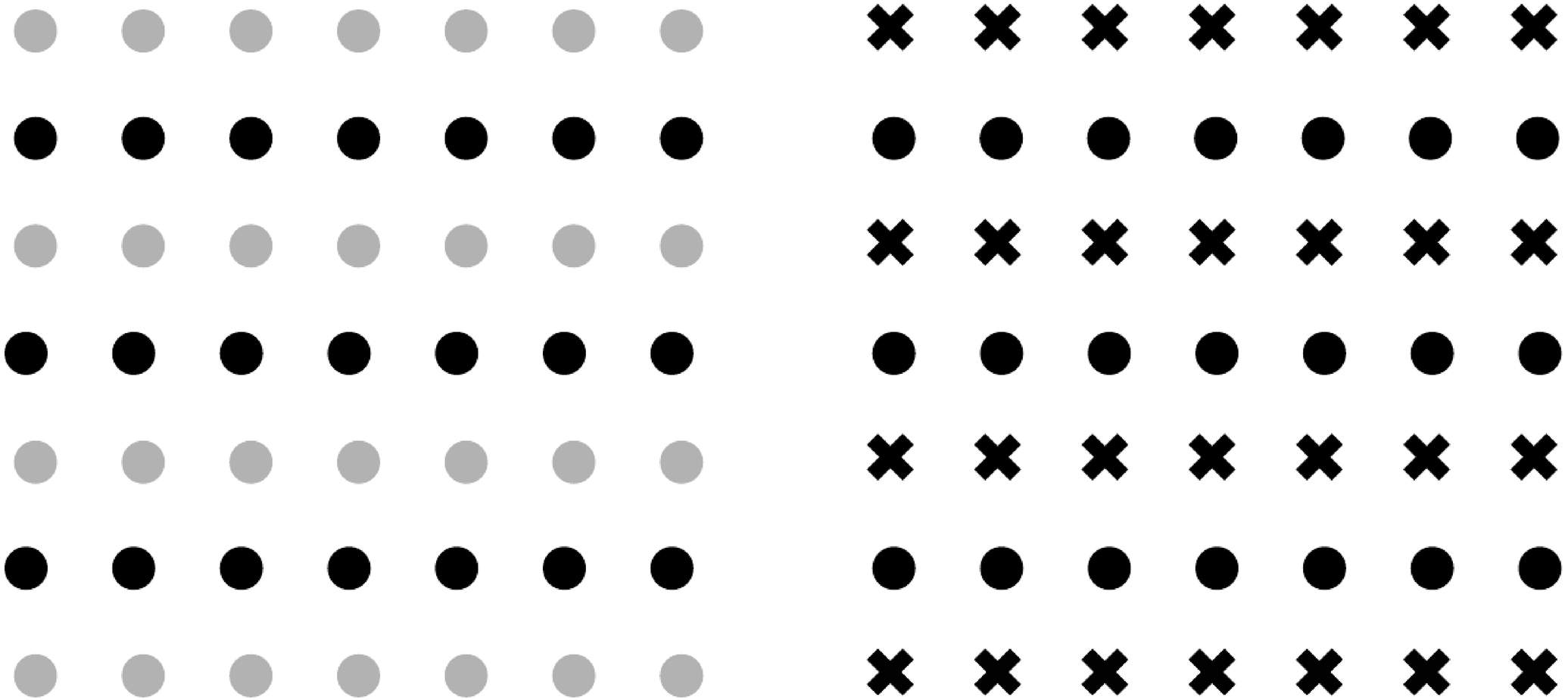
Shape



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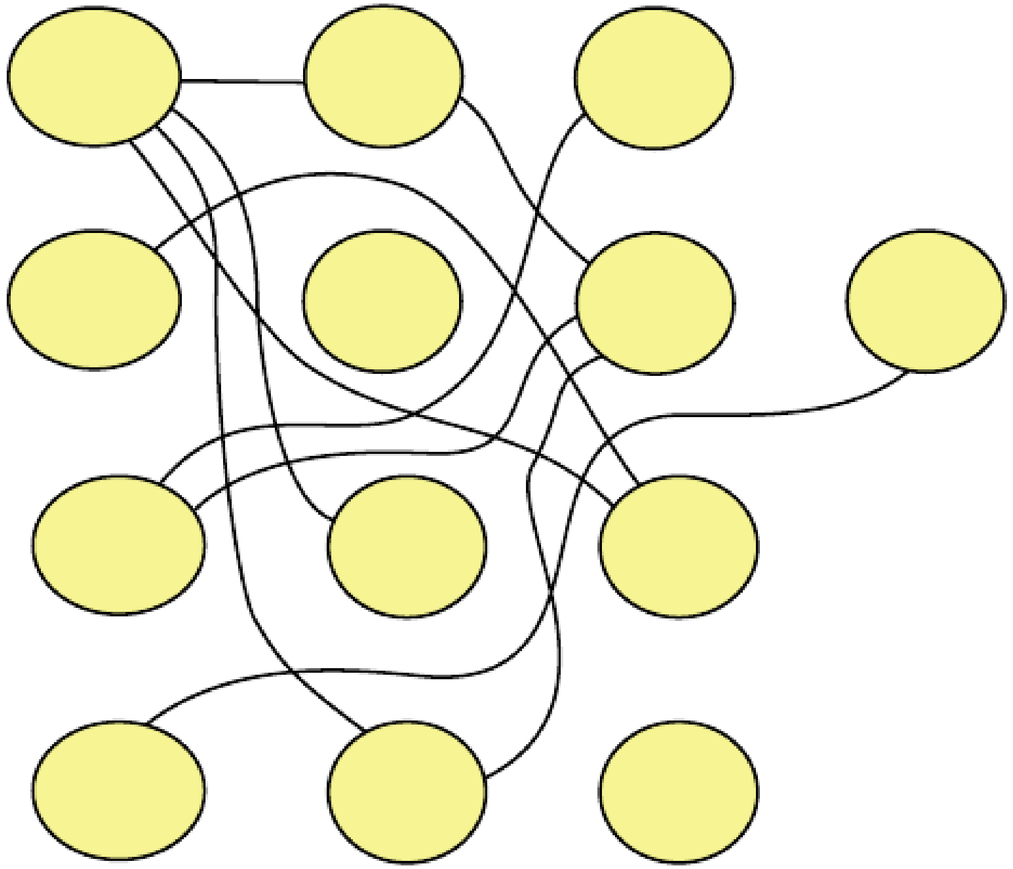
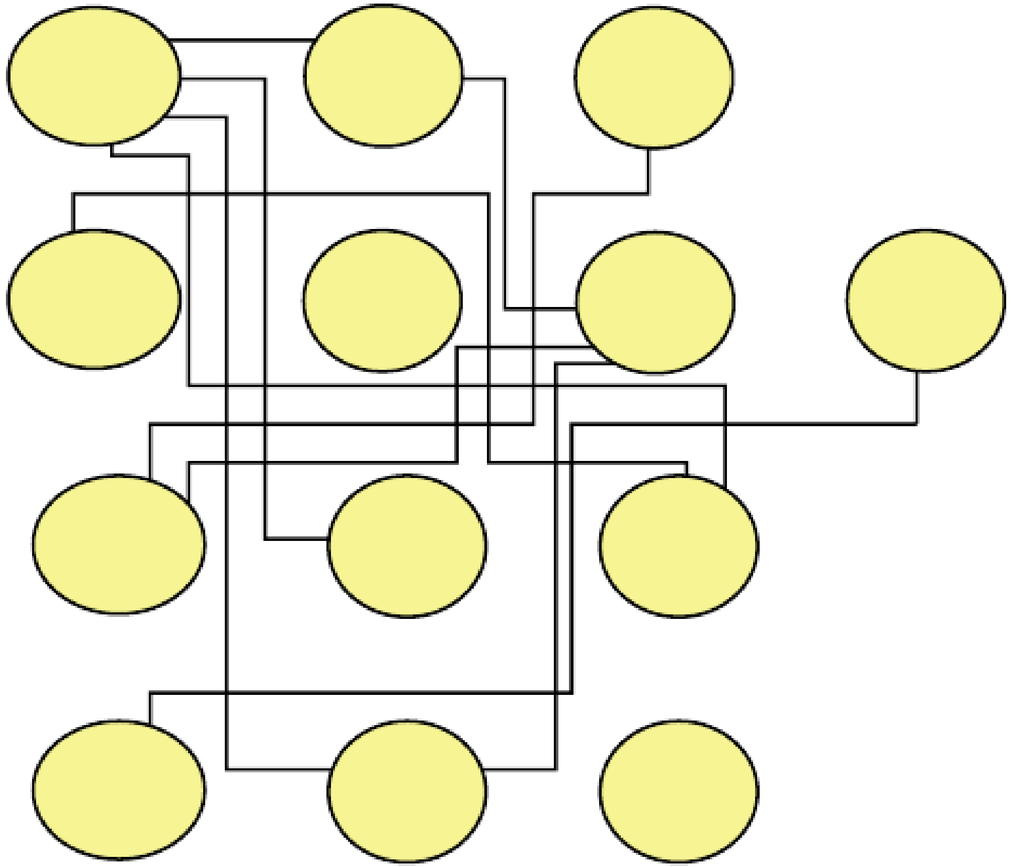
Connectedness





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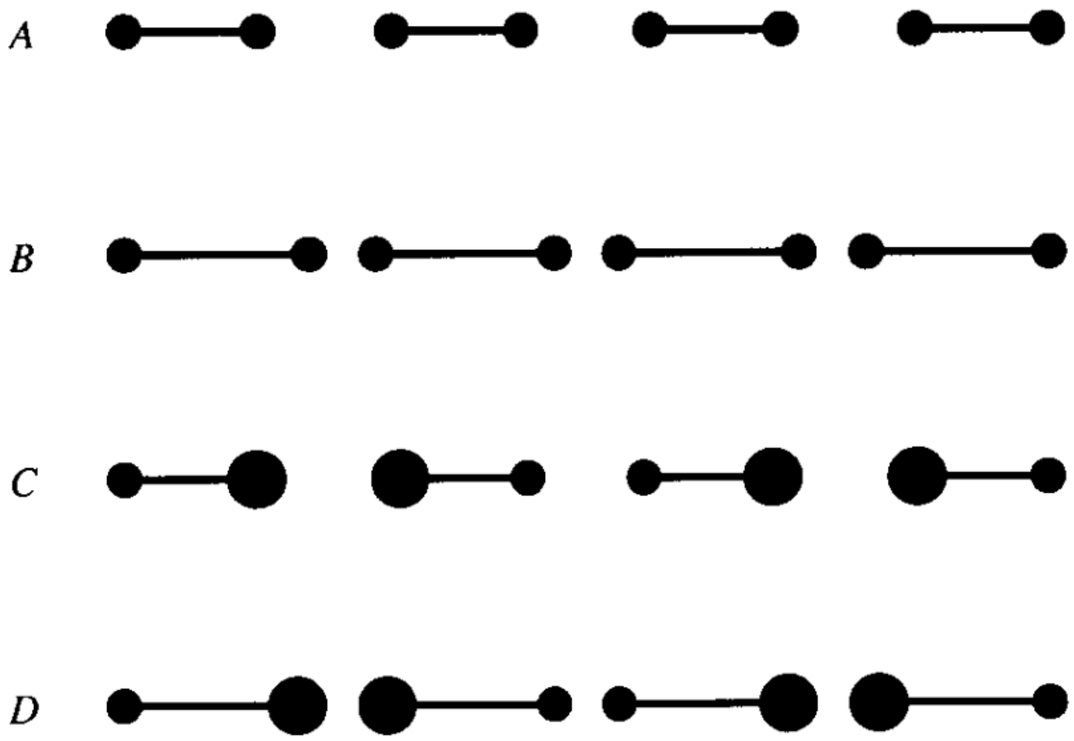
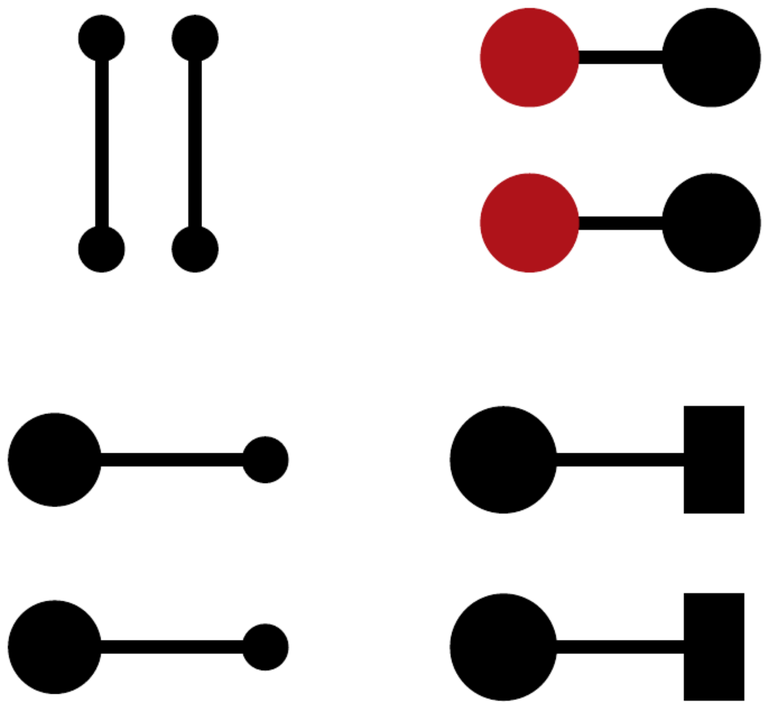
Uniform Connectedness

Principle of perceptual organization

Connectedness can „overwrite“ classical grouping factors proximity, color, size, shape

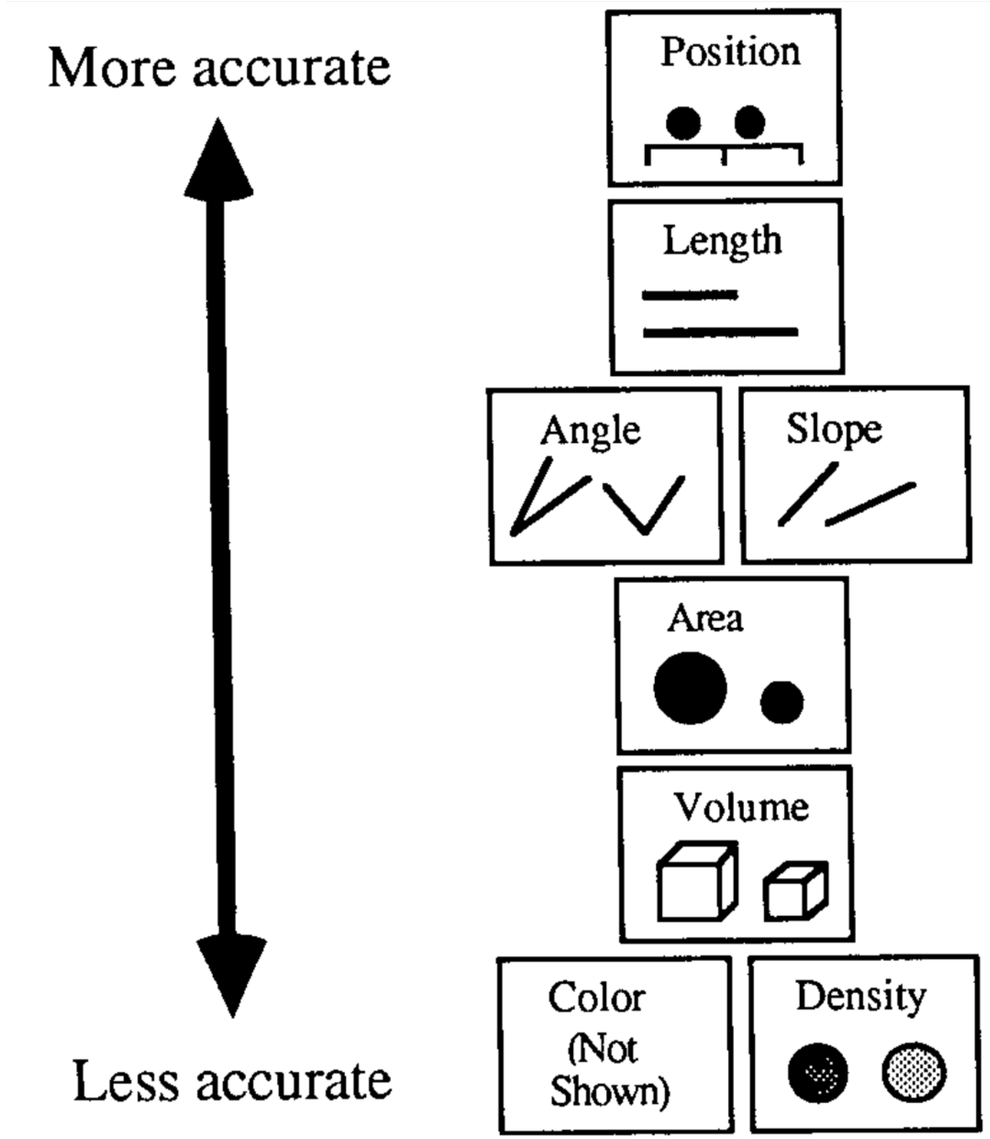




Palmer, S., & Rock, I. (1994). Rethinking perceptual organization: The role of uniform connectedness. Psychonomic bulletin & review, 1(1), 29-55.
Ware, C. (2019). Information visualization: perception for design. Morgan Kaufmann.

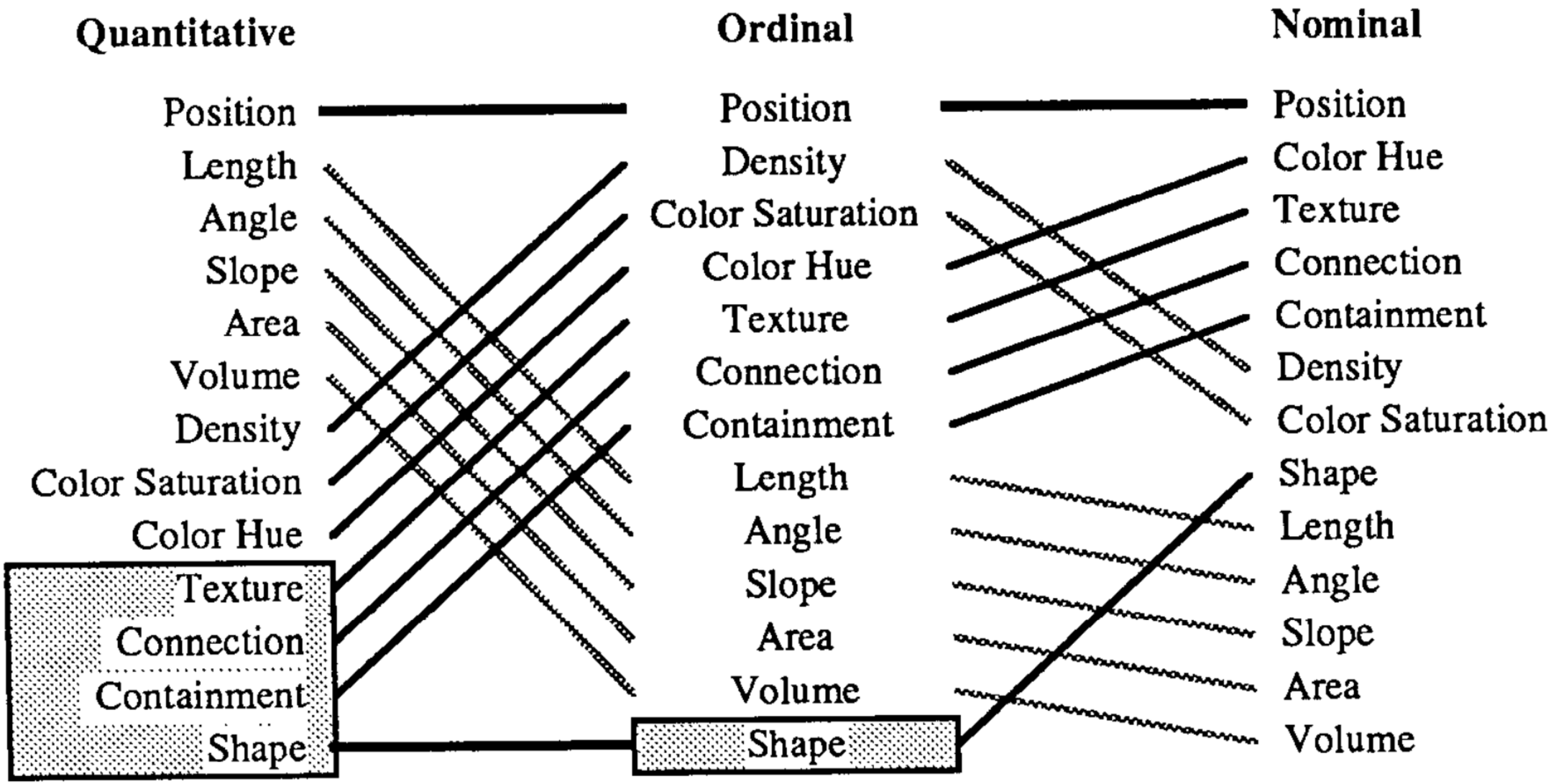
Different Graphical Elements for Different Types of Data

Encoding Quantitative Information



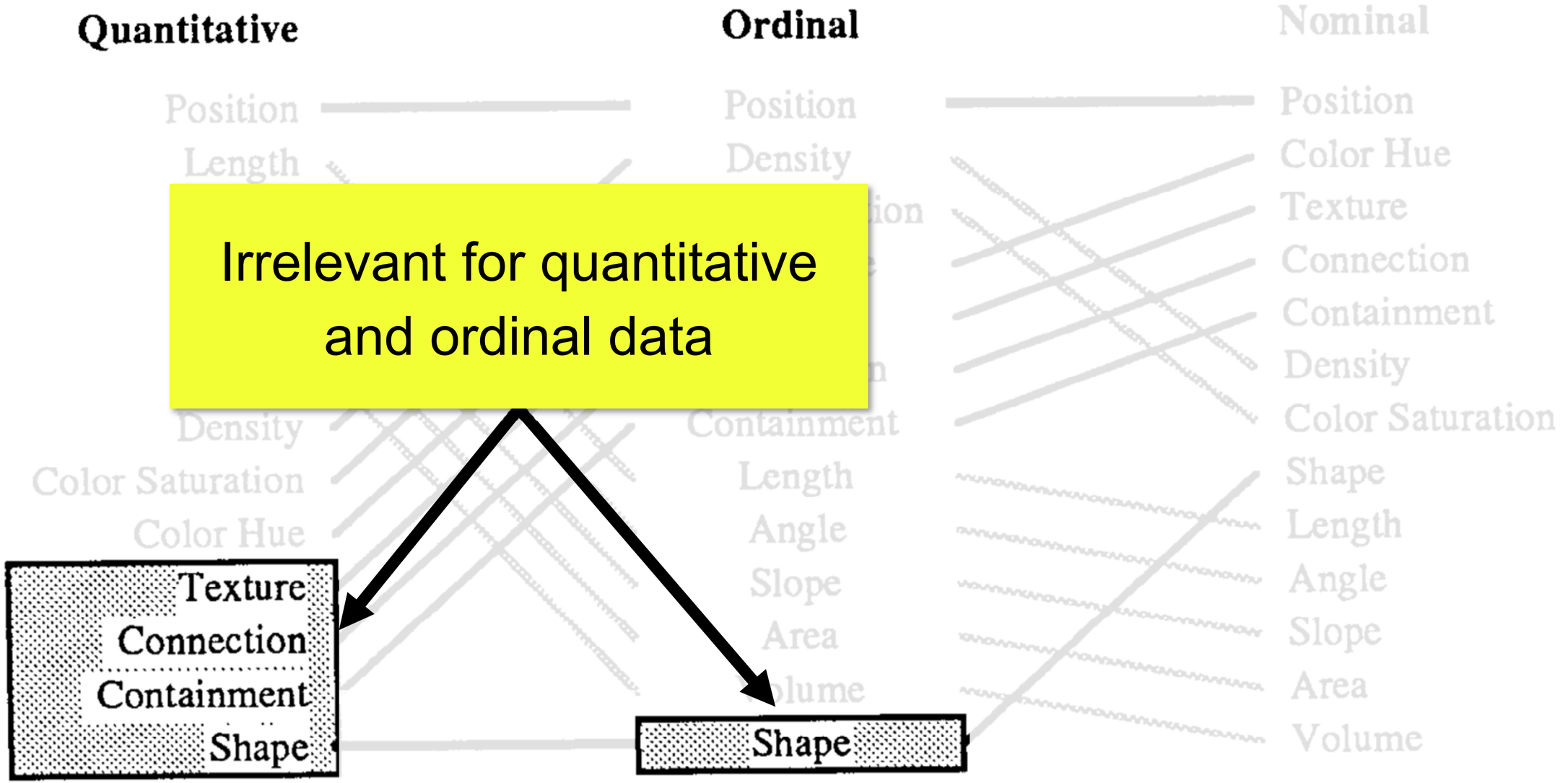
Mackinlay, Jack. "Automating the design of graphical presentations of relational information." *ACM Transactions On Graphics (Tog)* 5.2 (1986): 110-141.

Encoding Data Types



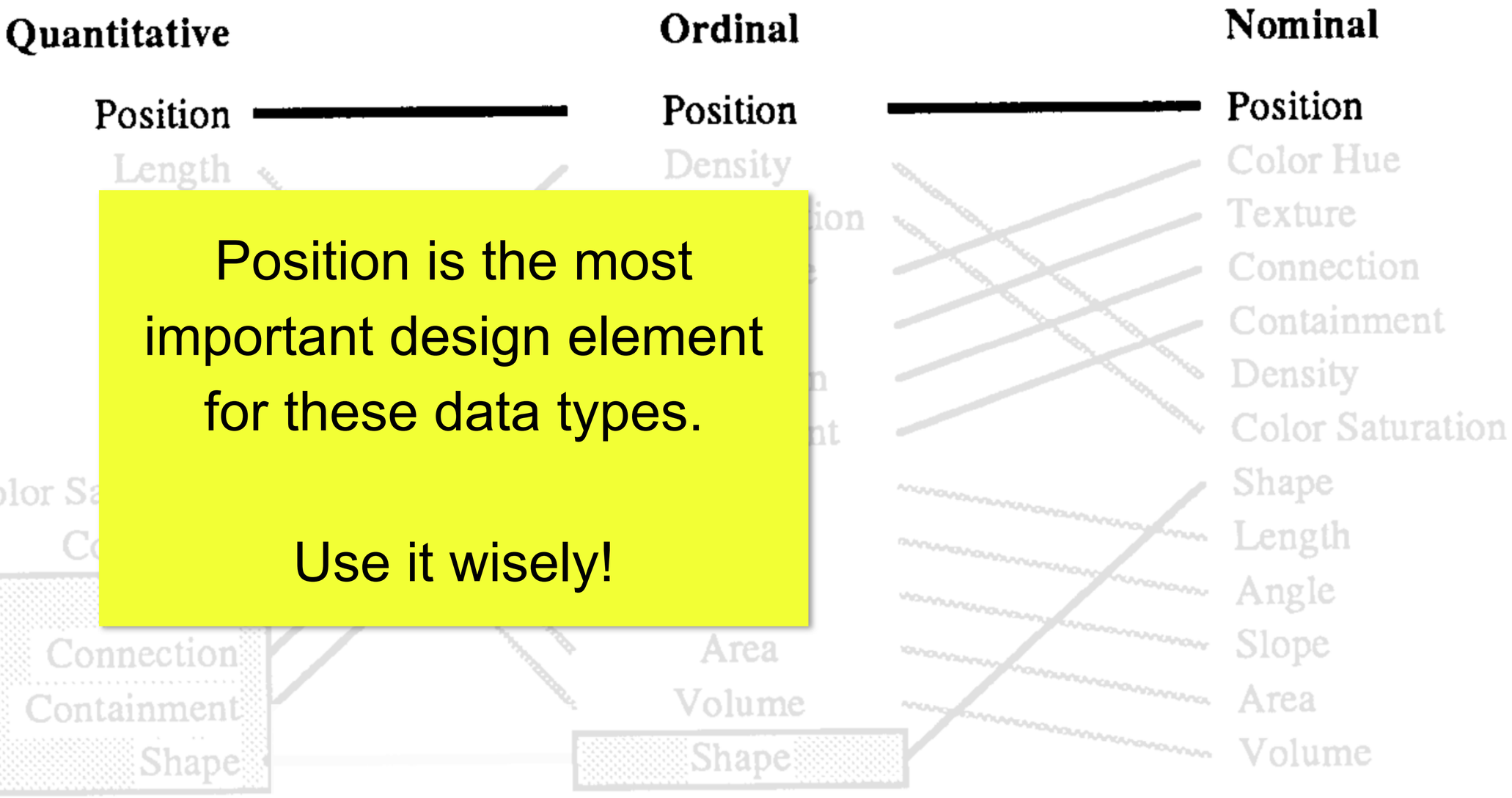
Mackinlay, Jack. "Automating the design of graphical presentations of relational information." *ACM Transactions On Graphics (Tog)* 5.2 (1986): 110-141.

Encoding Data Types



Mackinlay, Jack. "Automating the design of graphical presentations of relational information." *ACM Transactions On Graphics (Tog)* 5.2 (1986): 110-141.

Encoding Data Types

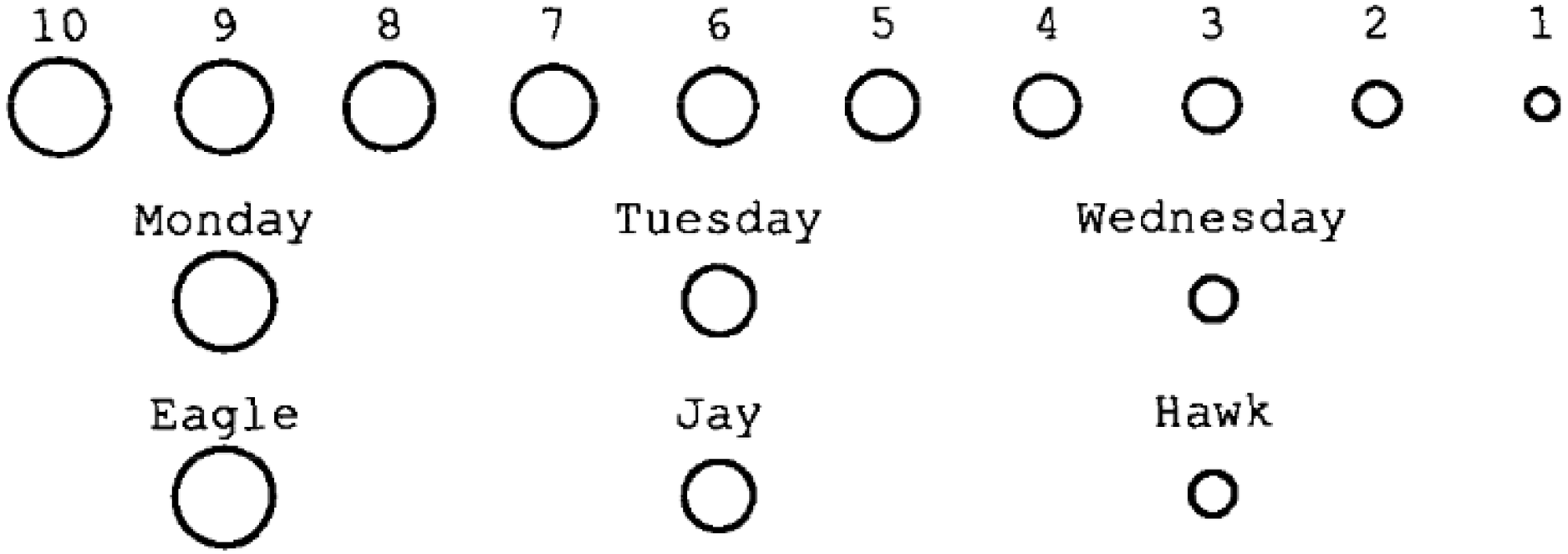


Position is the most important design element for these data types.

Use it wisely!

Mackinlay, Jack. "Automating the design of graphical presentations of relational information." *ACM Transactions On Graphics (Tog)* 5.2 (1986): 110-141.

Effectiveness of Using a Shapes‘ Area



Quantitative information:
shows order among elements;
misjudgements expected if laid out randomly

Ordinal information
make sure to vary sizes enough

Nominal information
group assignments are visible;
step sizes are an issue;
order is perceived

Mackinlay, Jack. "Automating the design of graphical presentations of relational information." *ACM Transactions On Graphics (Tog)* 5.2 (1986): 110-141.

Beware of the Scaling Problem When Using Area

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Perceived and actual magnitude differ

Psychophysical power law

$$\psi = k\phi^{\beta}$$

- ψ Sensation magnitude
- ϕ Stimulus magnitude
- k mostly irrelevant constant
- β signature of a sensory continuum

Continuum	Measured Exponent (β)	Doubled Stimulus (2^{β})	Stimulus Condition
Visual length	**1.0**	**2.0**	**Projected line**
Visual area	**0.7**	**1.6**	**Projected square**
Redness (saturation)	**1.7**	**3.2**	**Red-gray mixture**
Loudness	0.67	1.6	Sound pressure of 3000Hz tone
Lightness	1.2	2.3	Reflectance of gray papers
Cold	1	2.0	Metal contact on arm
Warmth	1.6	3.0	Metal contact on arm
Taste	1.4	2.6	Salt
Taste	0.8	1.7	Saccharine
…			

Stevens, S. S. (1975). Psychophysics : introduction to its perceptual, neural, and social prospects.
Lodge, M. (1981). Magnitude scaling: Quantitative measurement of opinions (No. 25). SAGE Publications

Perceived and Actual Magnitude

Perceived magnitude of area: 1.60
Actual magnitude of area: 2.00

Perceived magnitude of area: 2.00
Actual magnitude of area: 2.69

Graphical Integrity

People are 178% worried

https://twitter.com/dergigi/status/1243315176000180224/

Trust only the statistics that you have falsified yourself

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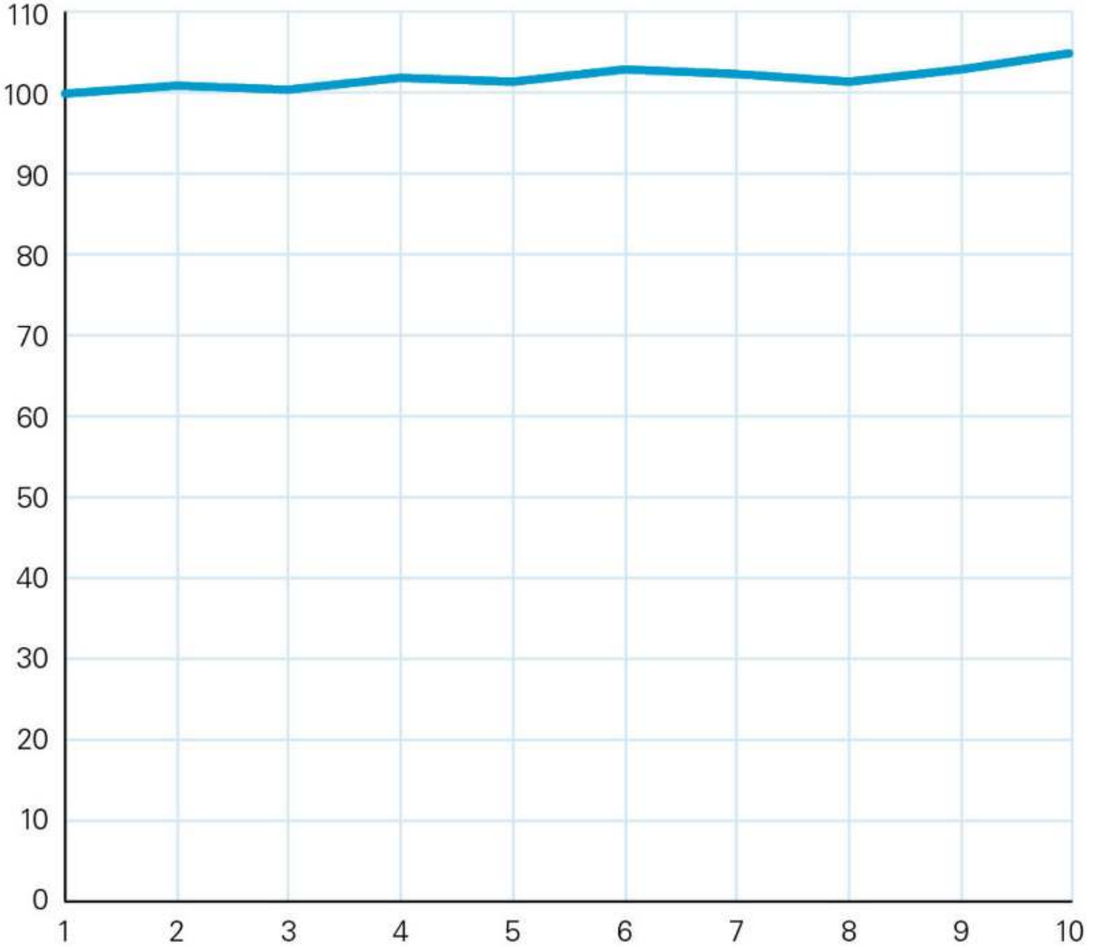
Assume these sales figures:

100 101 100,5 102 101,5 103 102,5 101,5 103 105



Krämer, W. (2015). So lügt man mit Statistik. Campus Verlag.

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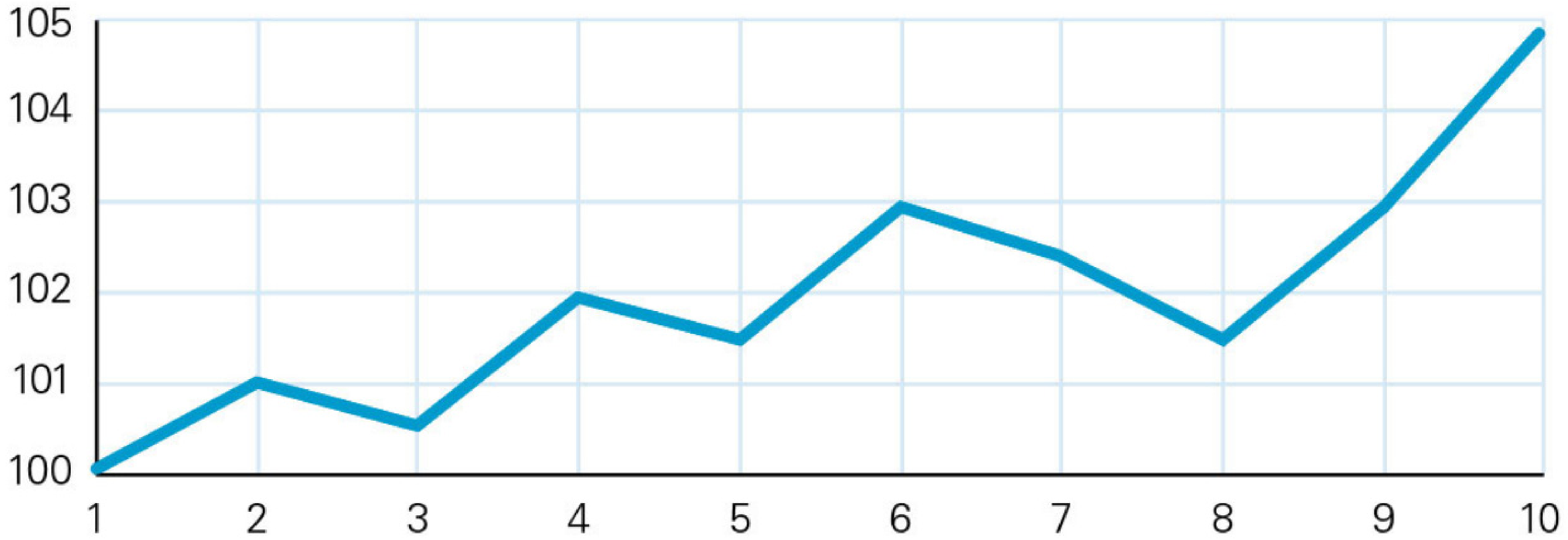
UNIVERSITÄT BAYREUTH

Assume these sales figures:

100 101 100,5 102 101,5 103 102,5 101,5 103 105



Axis Trimming

Krämer, W. (2015). So lügt man mit Statistik. Campus Verlag.

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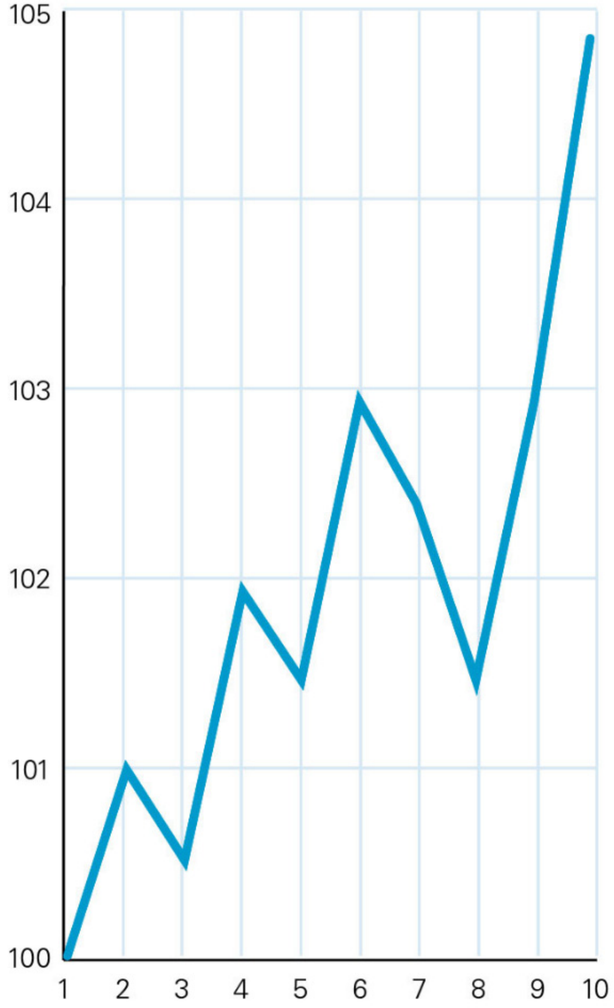
Assume these sales figures:

100 101 100,5 102 101,5 103 102,5 101,5 103 105



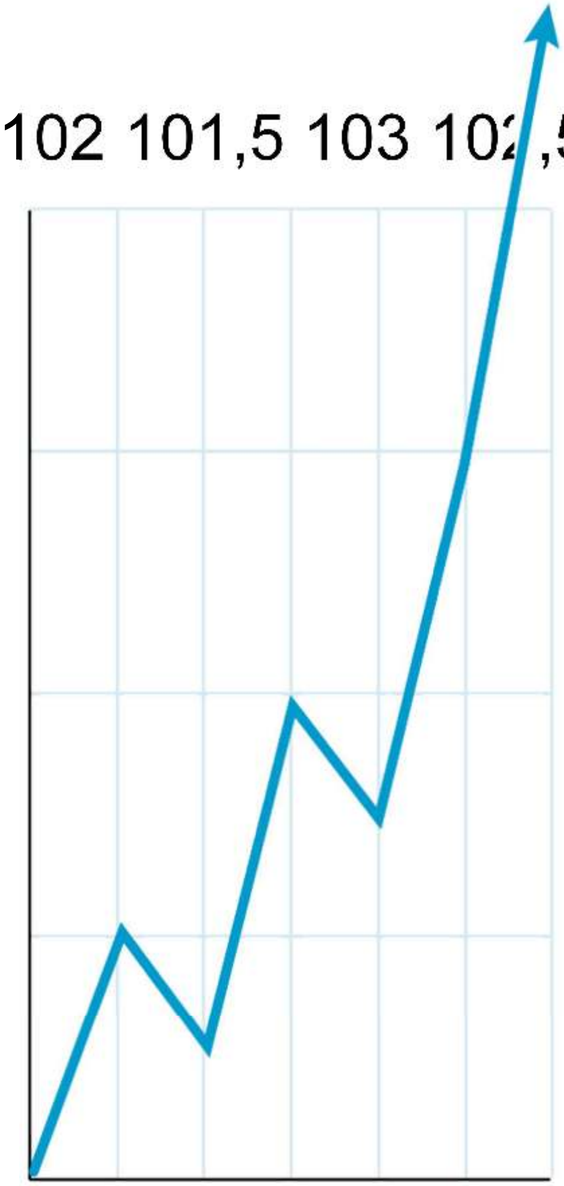
Axis Expansion / Compression

Krämer, W. (2015). So lügt man mit Statistik. Campus Verlag.

Trust only the statistics that you have falsified yourself

Assume these sales figures:

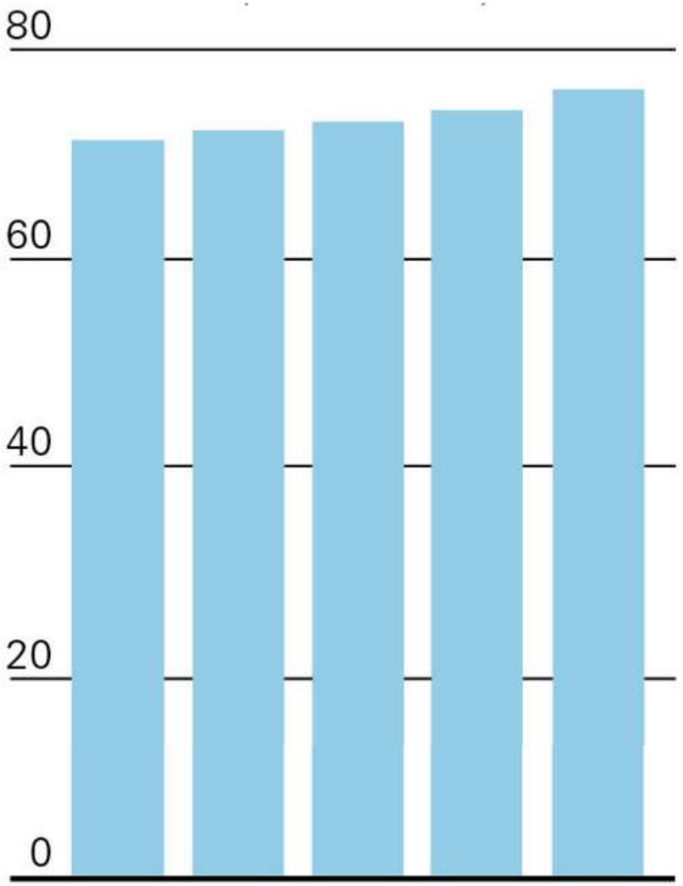
100 101 100,5 102 101,5 103 102,5 101,5 103 105

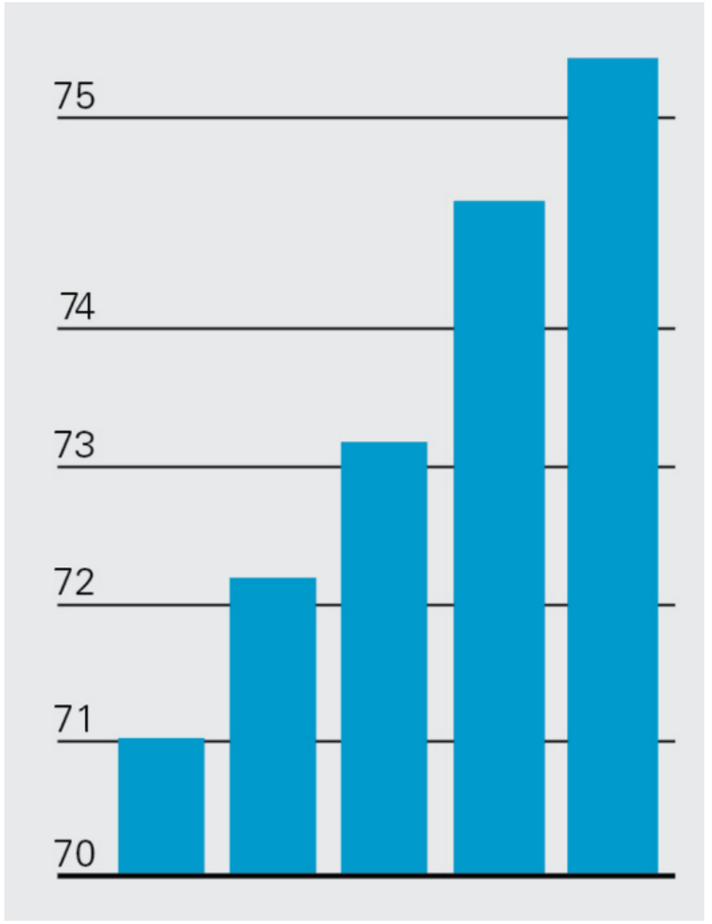


Remove Labels

Krämer, W. (2015). So lügt man mit Statistik. Campus Verlag.

Trust only the statistics that you have falsified yourself





Trimming of Axis

Krämer, W. (2015). So lügt man mit Statistik. Campus Verlag.

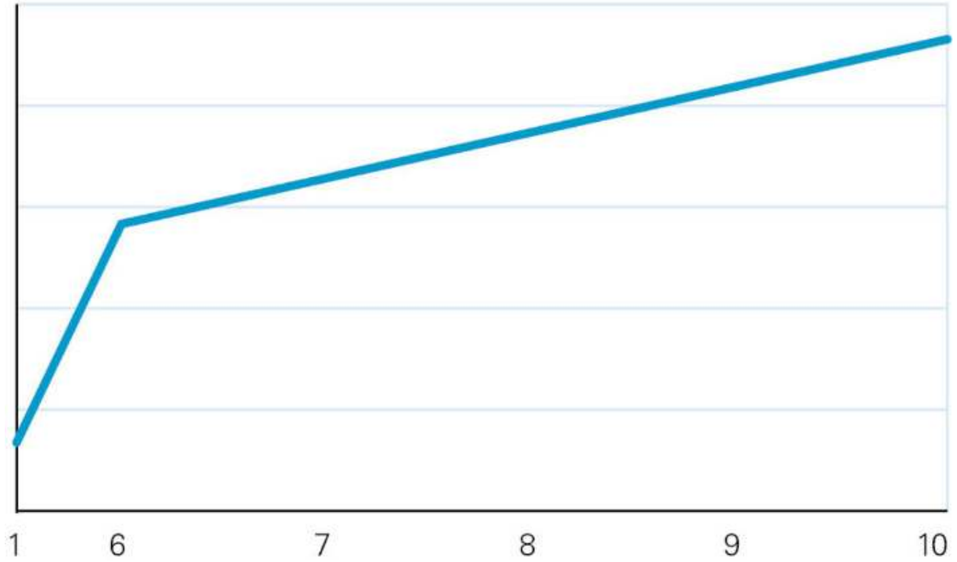
Trust only the statistics that you have falsified yourself

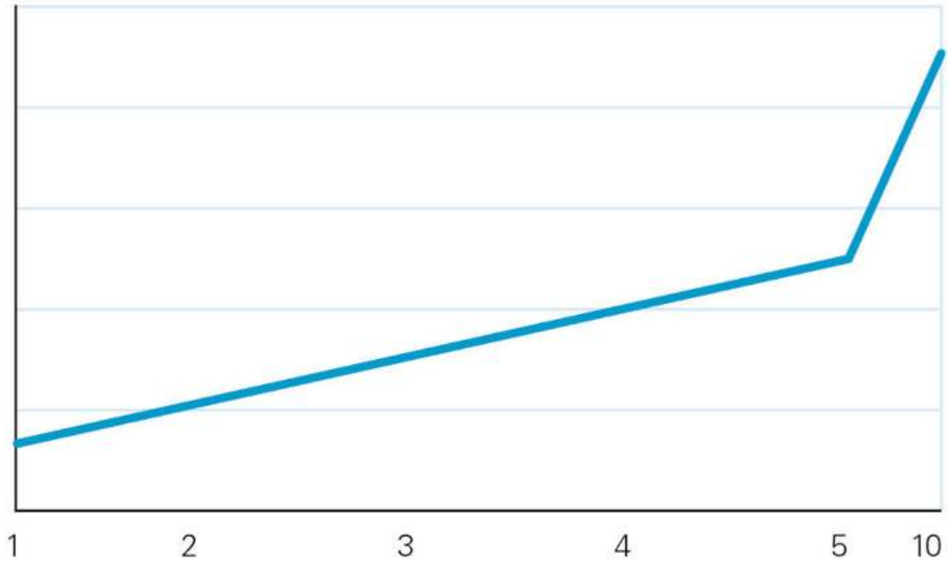
A Venezualian election

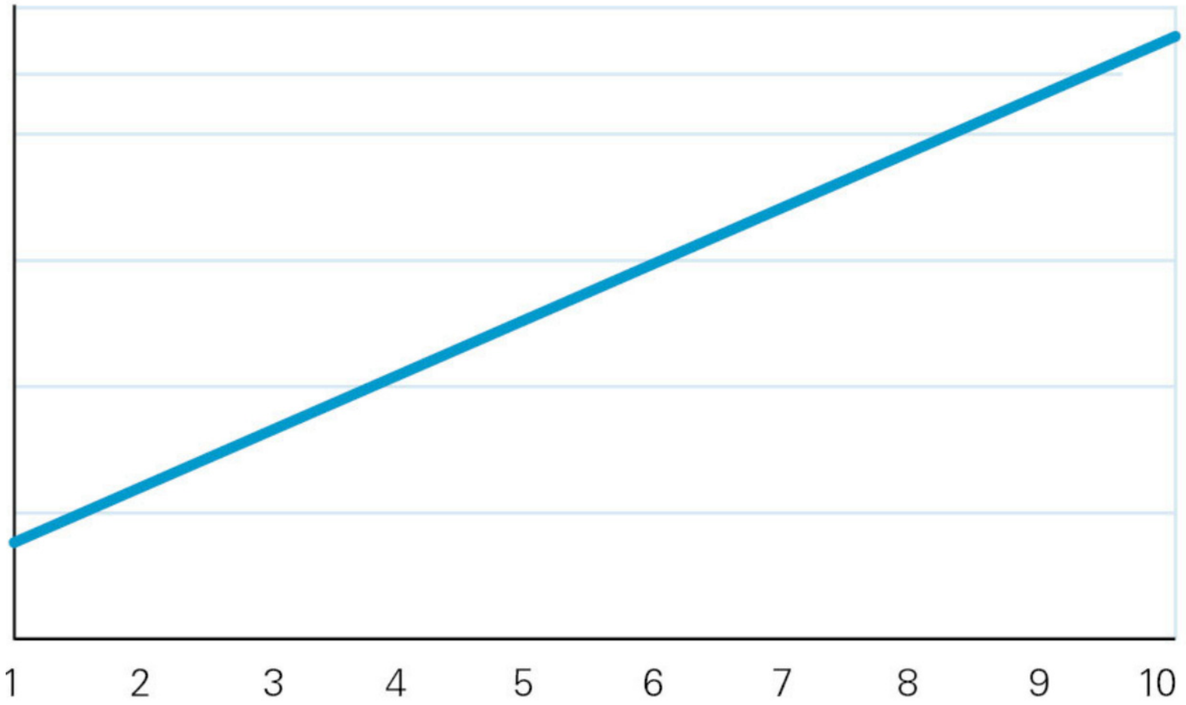
Trimming of Axis

Krämer, W. (2015). So lügt man mit Statistik. Campus Verlag.

Trust only the statistics that you have falsified yourself



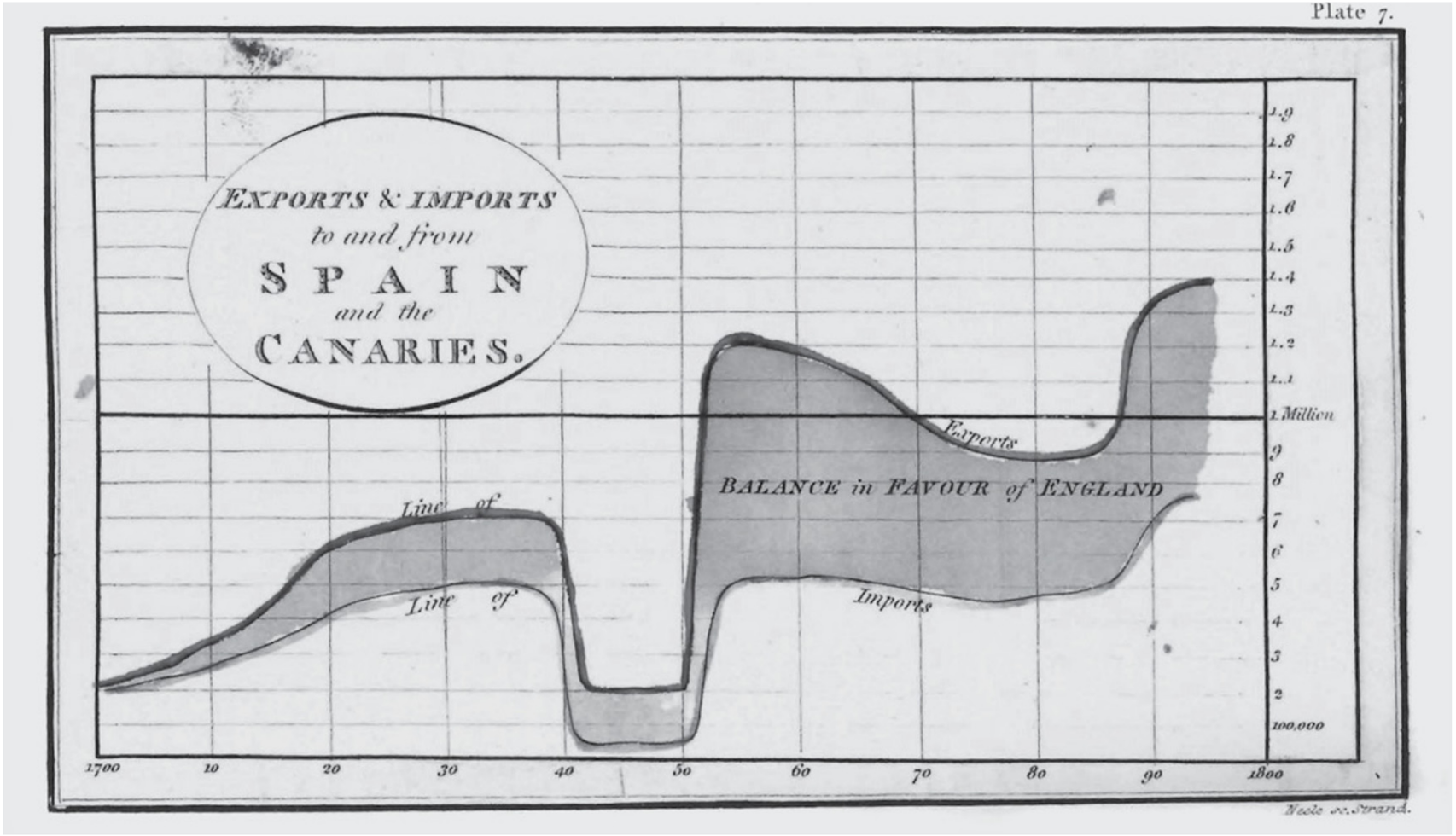


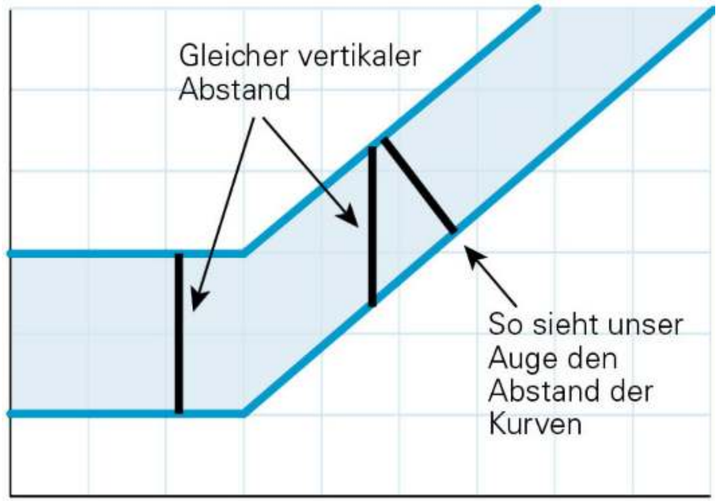


Partial Expansion / Compression of Axis

Krämer, W. (2015). So lügt man mit Statistik. Campus Verlag.

Trust only the statistics that you have falsified yourself





Our eye interprets distances not perpendicularly, but orthogonal

The thing with curves

Krämer, W. (2015). So lügt man mit Statistik. Campus Verlag.

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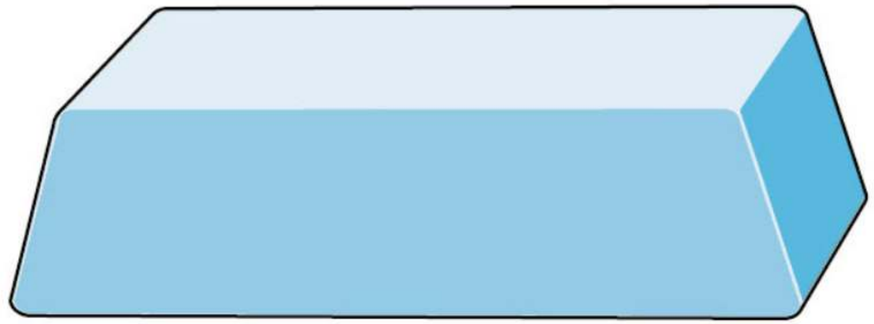
A

B

In both cases edge lengths were doubled.

B‘s area is 4 times the area of A
B‘s volume 8 times the volume of A

A



B

Perception of Areas and Volumes

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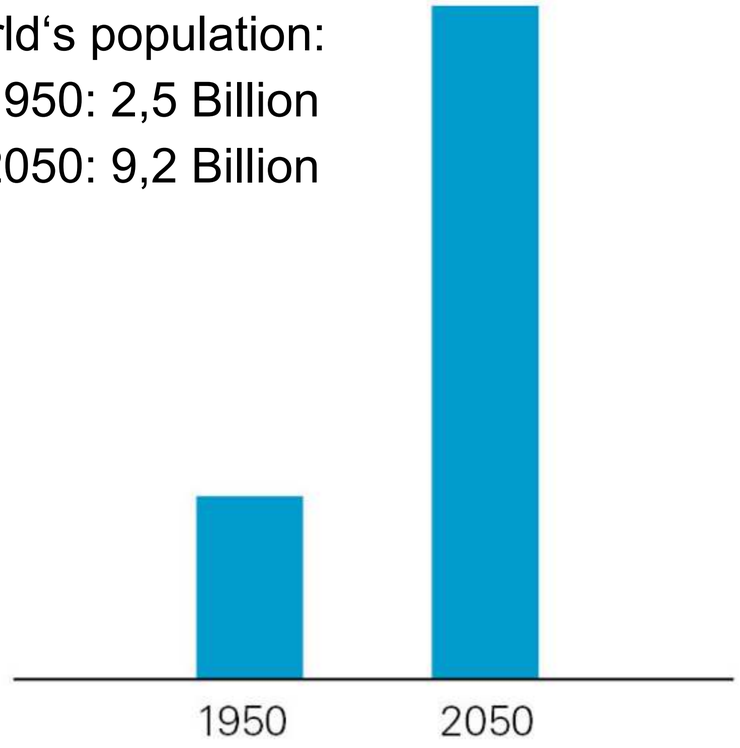
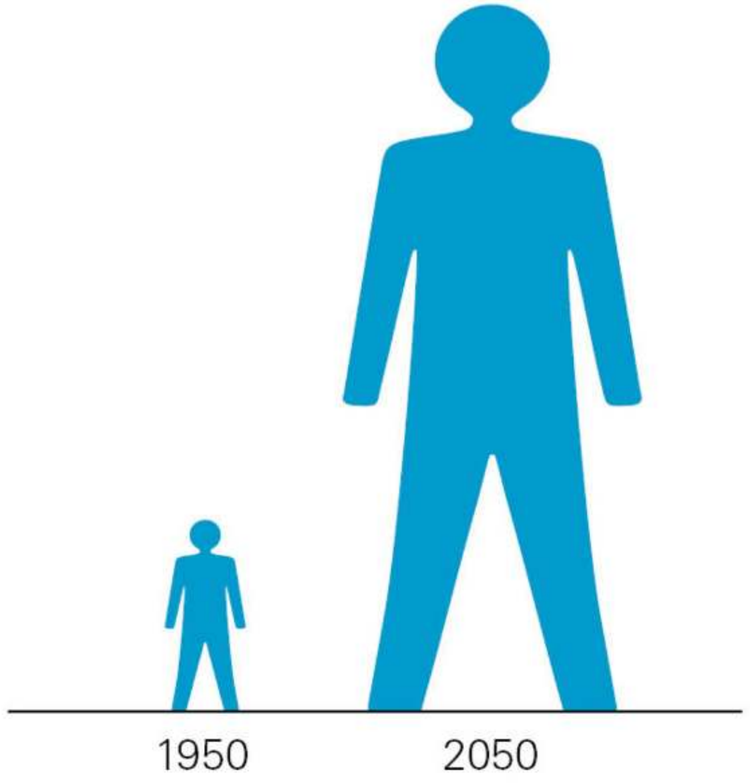
World‘s population:

- 1950: 2,5 Billion
- 2050: 9,2 Billion

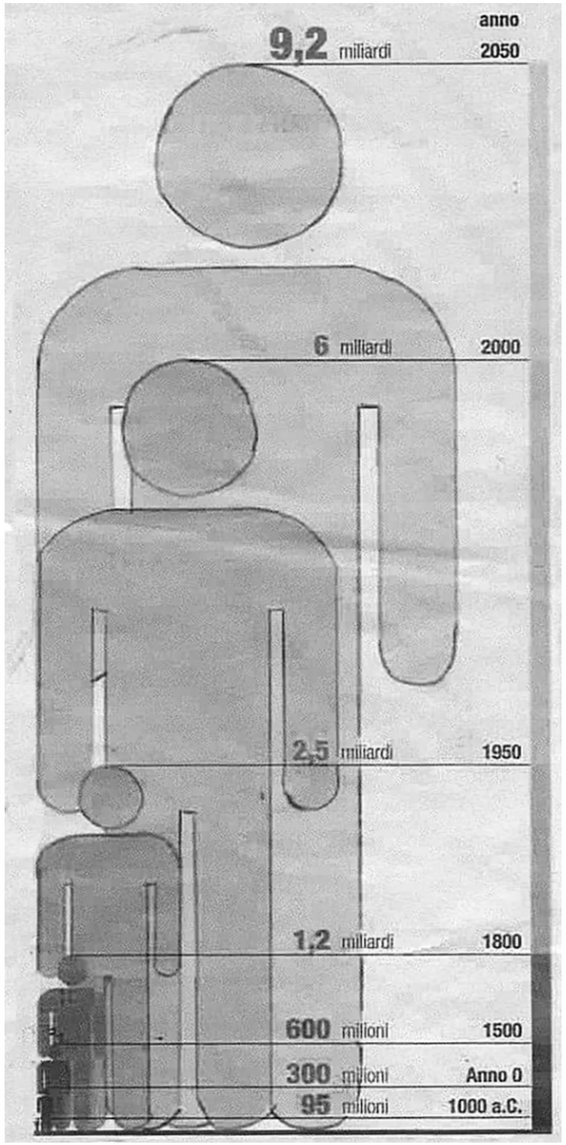




Pictograms have height and width scaled with ratio 2,5:9,2.

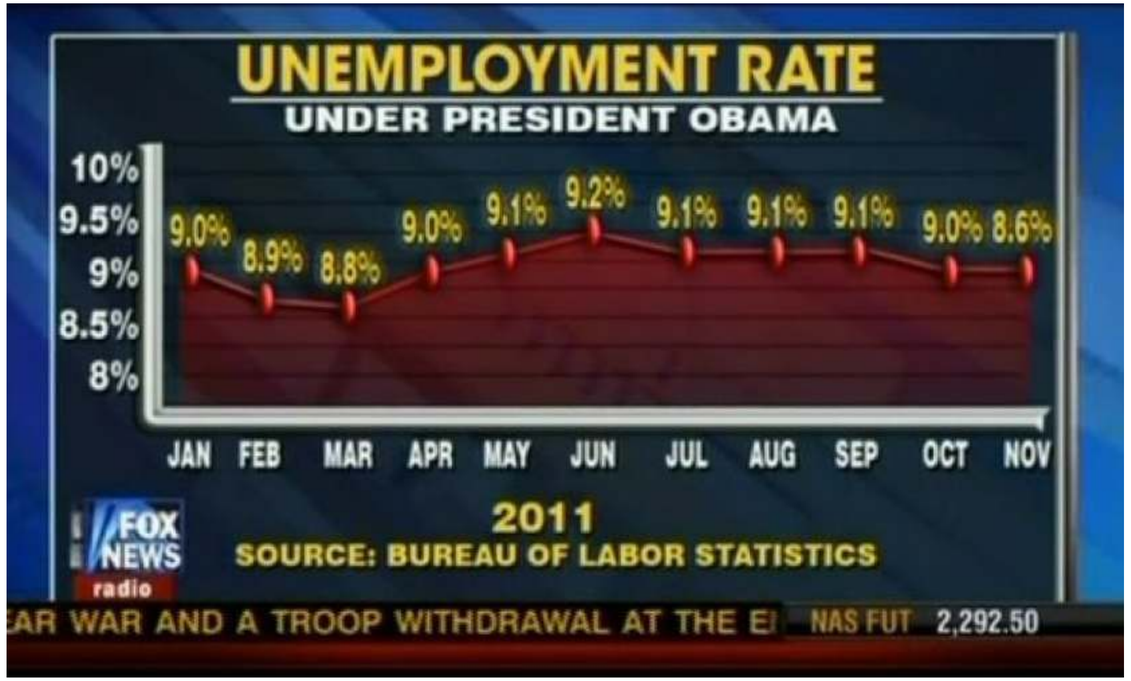
The ratio of areas becomes 2,5:33,8!

Stacking the pictograms further perturbs the perception of ratios.



Krämer, W. (2015). So lügt man mit Statistik. Campus Verlag.

Graphical Integrity

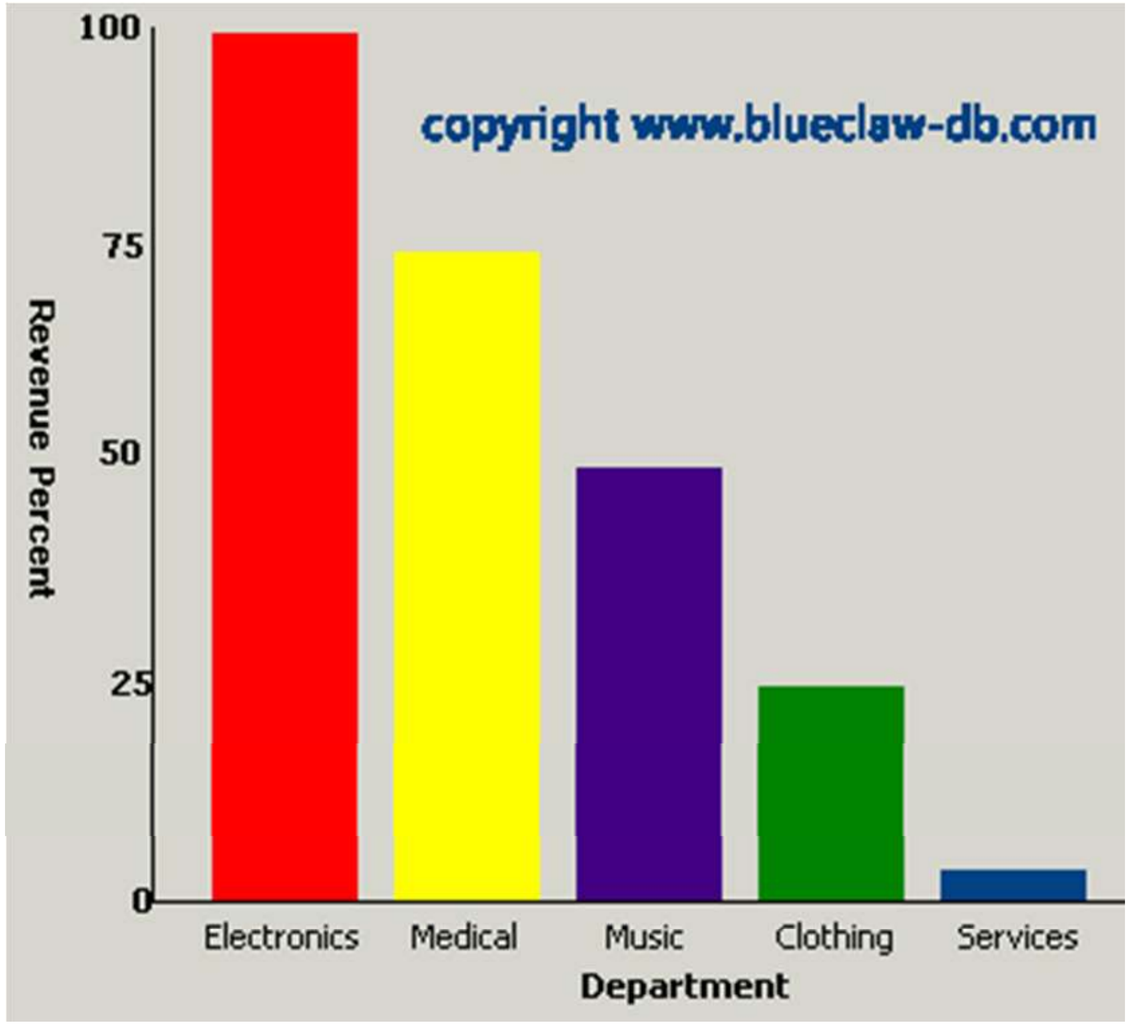


> As to the propriety and justness of representations sums of money, and time, by parts of space, tho' verey readily agreed to by most men, yet a few seem to apprehend that there may possibly be some deceptions in it, of which they are not aware

William Playfair,
The Commercial and Political Atlas (1786) [Tufte2001]

Color

Colors: Get it right in black and white



Color

- Create a color scheme
- Be consistent across visualizations
- Do your colors carry additional information?

Caveat: Colors often have meaning

Online tools can assist you in creating appealing palettes

https://paletton.com/
https://colorbrewer2.org/
https://www.toptal.com/designers/colorfilter
…

Online Tools (among others)

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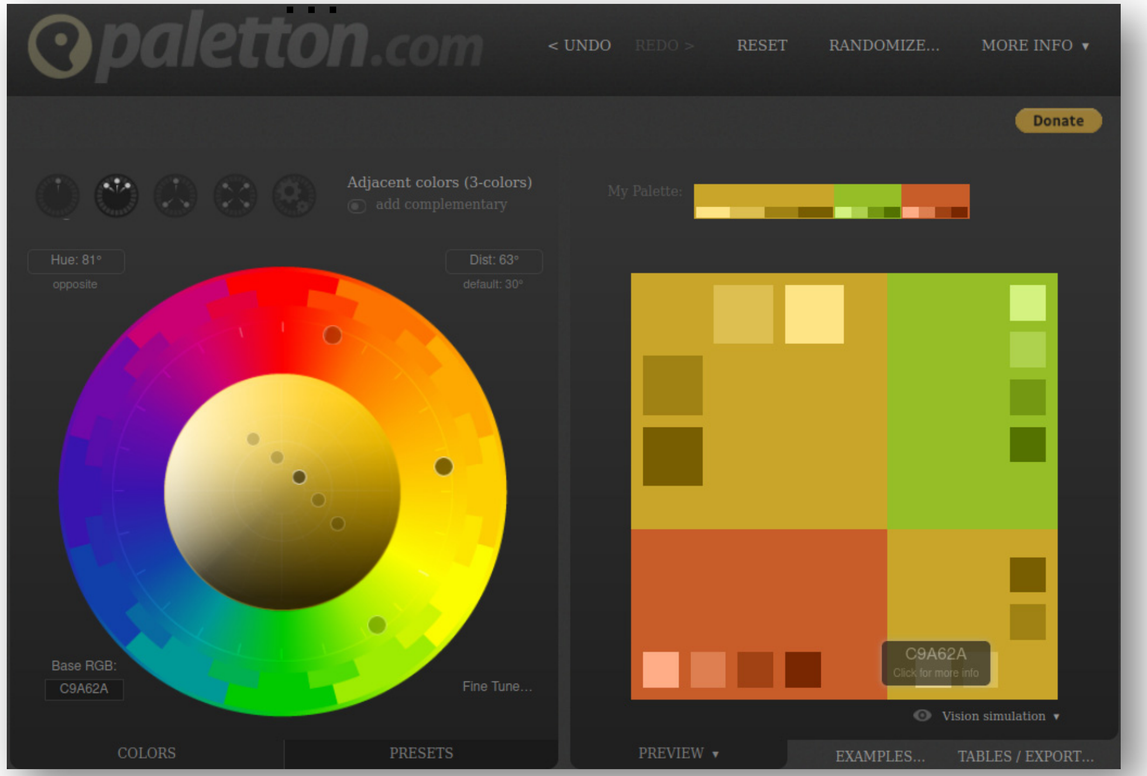
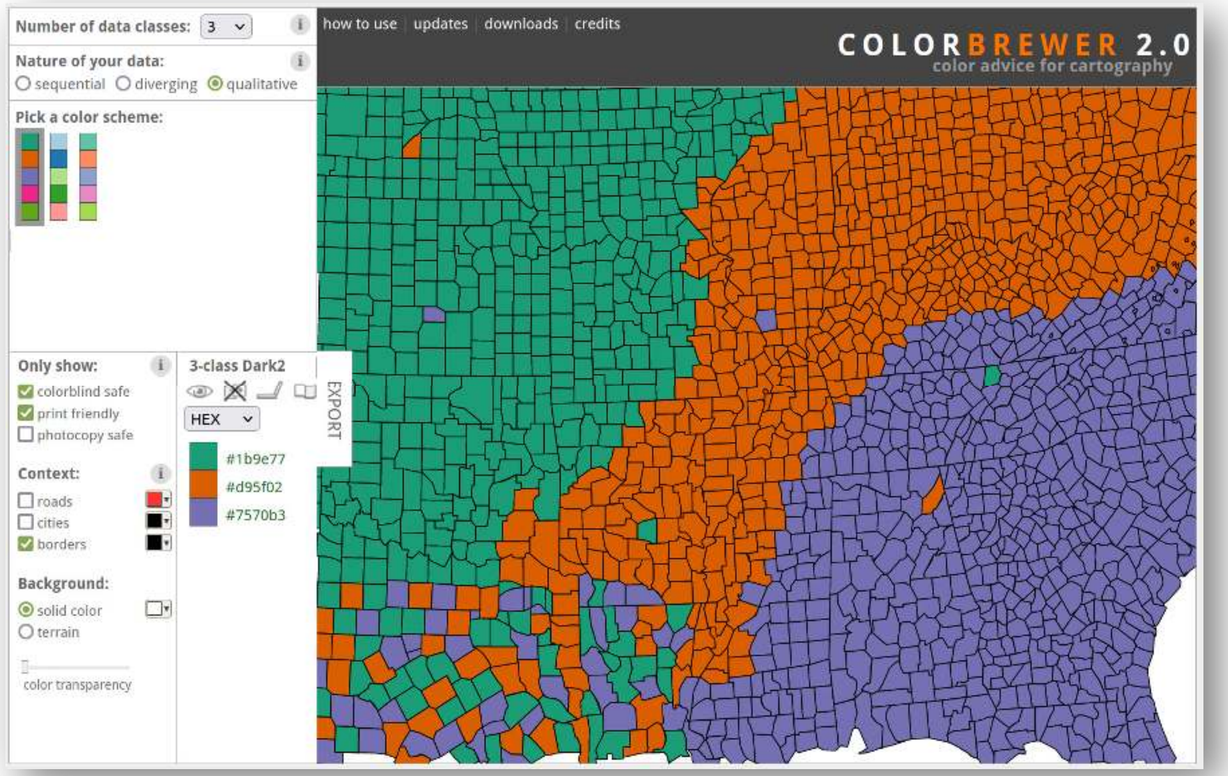
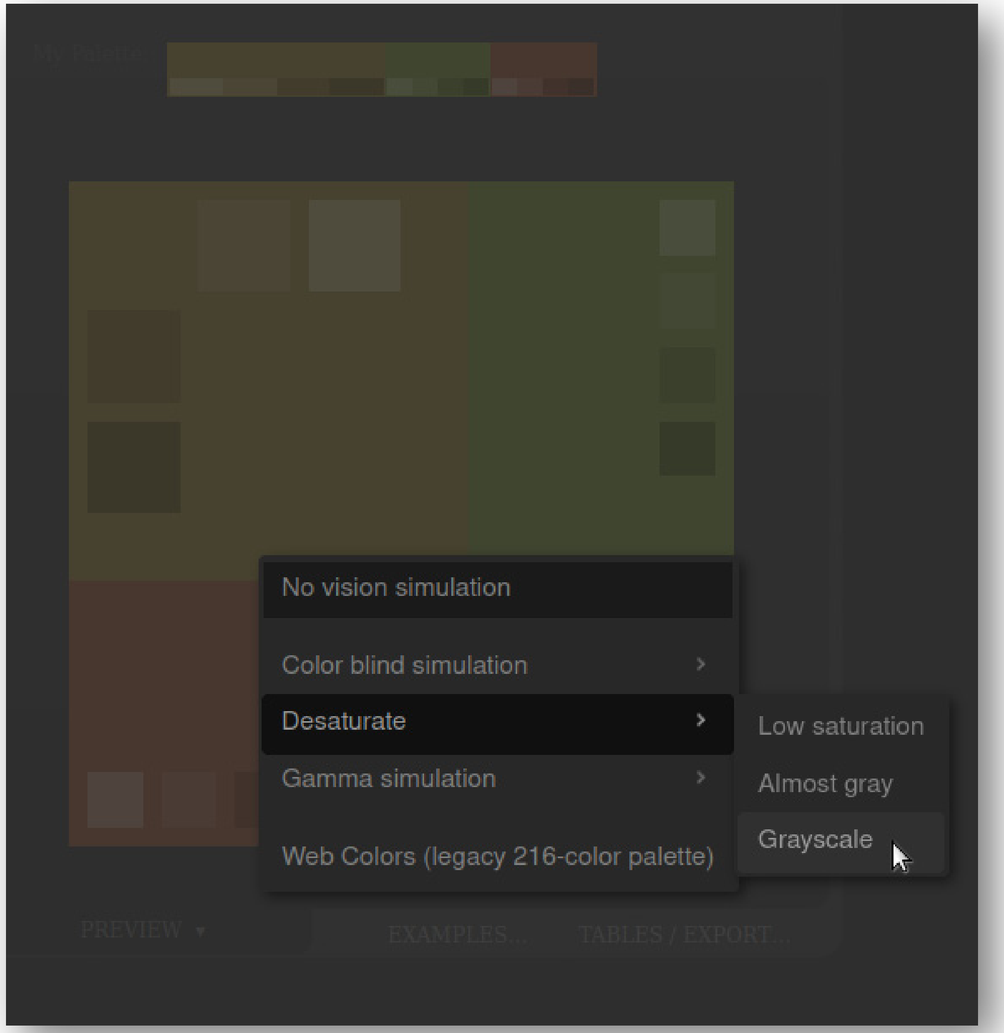
https://paletton.com/

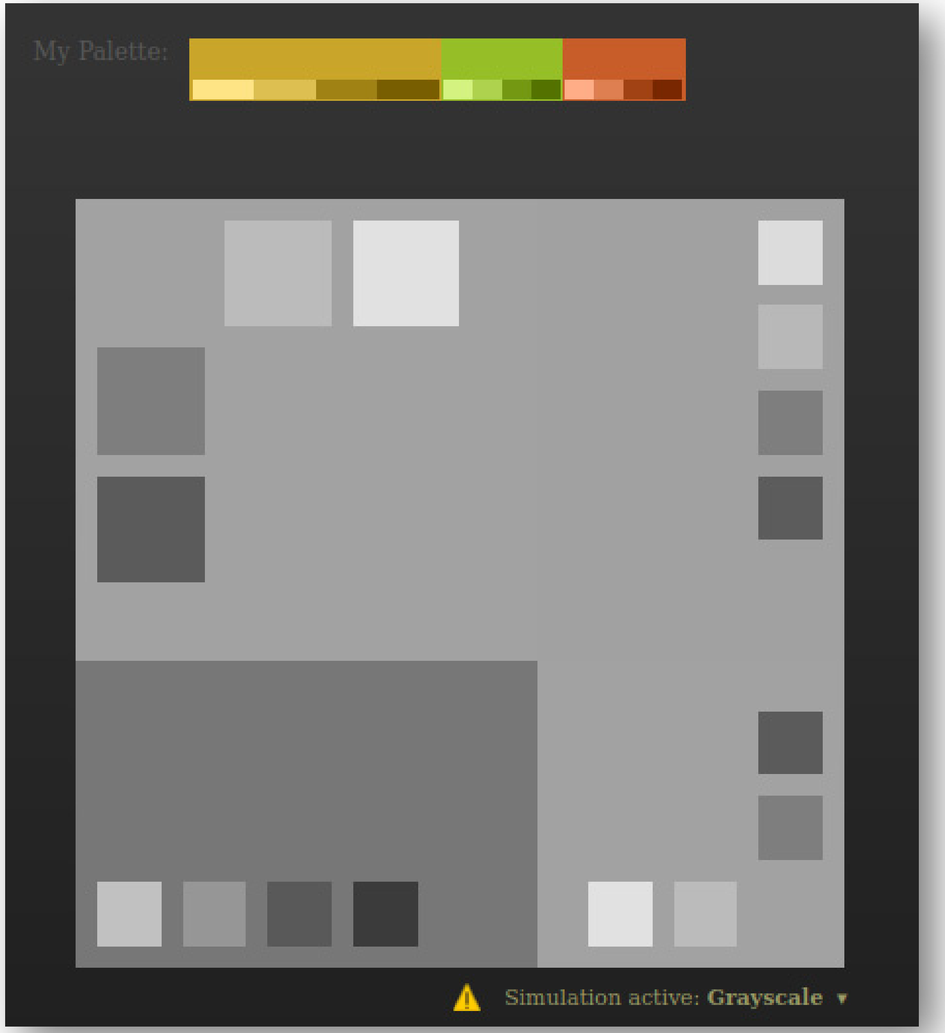


https://colorbrewer2.org/



Example: Paletton.com





Optimize colors for brightness, not hue!

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The Cubehelix color scheme is optimized for color scales as it varies in hue and value to retain contrast

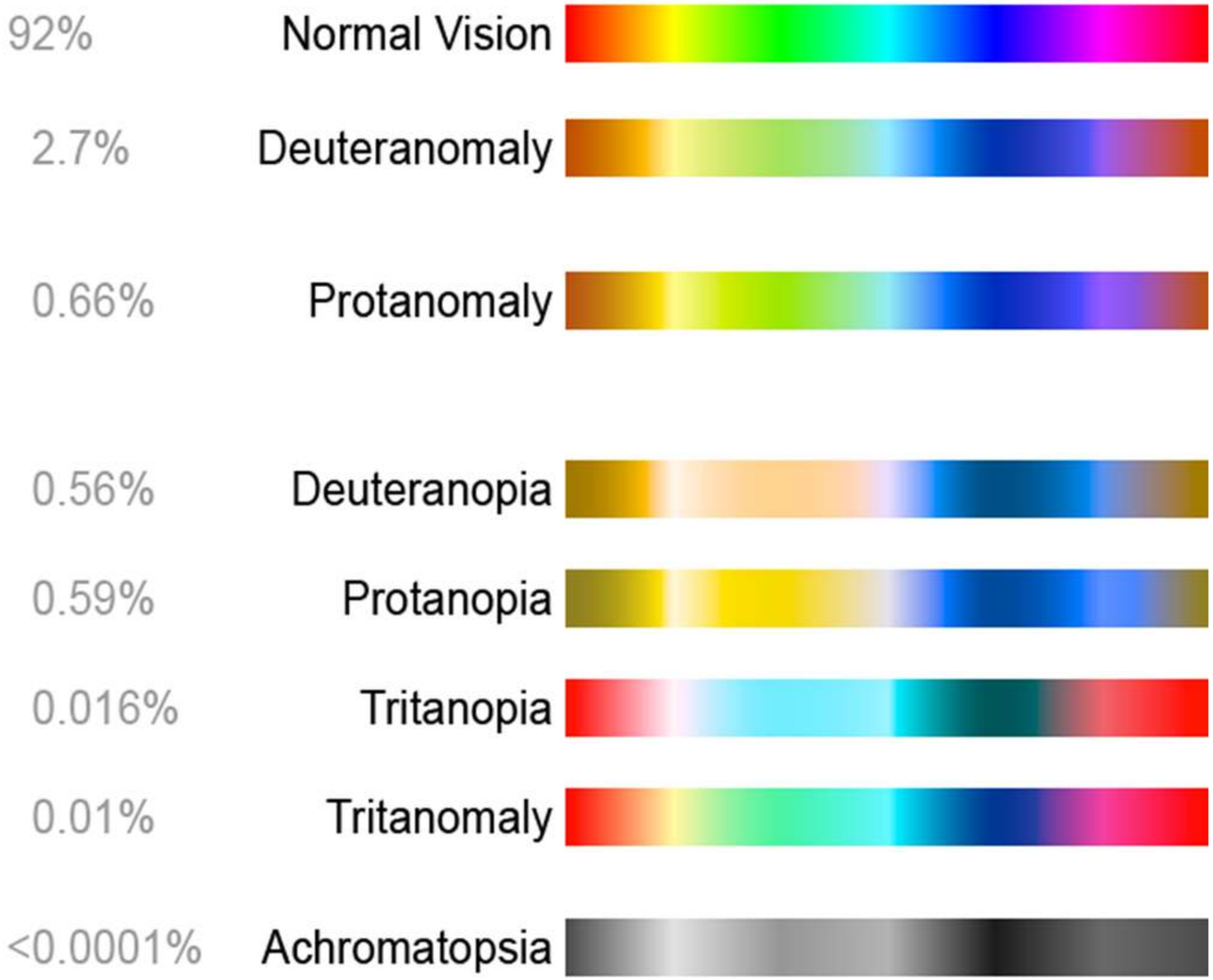
The „rainbow“ scale would be inefficient for gradual differences when viewed in grayscale!

http://labrigger.com/blog/2014/07/28/cubehelix-color-scheme/comment-page-1/

Color Blindness

Decreased ability to see color or differences in color

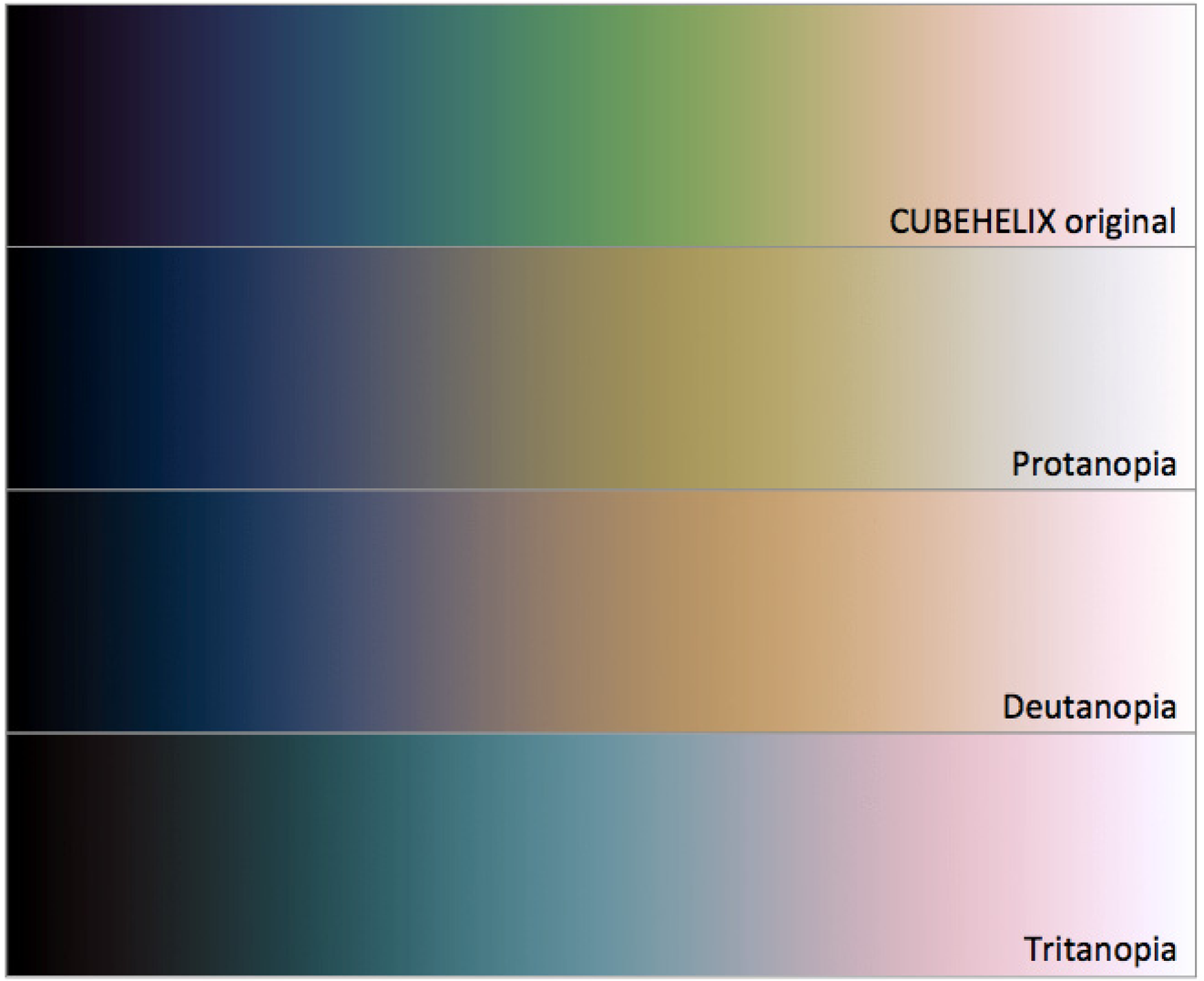
- Deuteranomaly (most common):
  affects 6% of males, 0.4% of females.
  „Green weakness“
- Protanomaly:
  affects 1% of males, 0.01% of females.
  less sensitive to red light
- Deuteranopia:
  affects 1% of males.
- Protanopia:
  affects 1% of males.
- Tritanopia:
  <1% of males and females.
- Tritanomaly:
  < 0.01% for males and females.



https://commons.wikimedia.org/wiki/File:Color_blindness.png

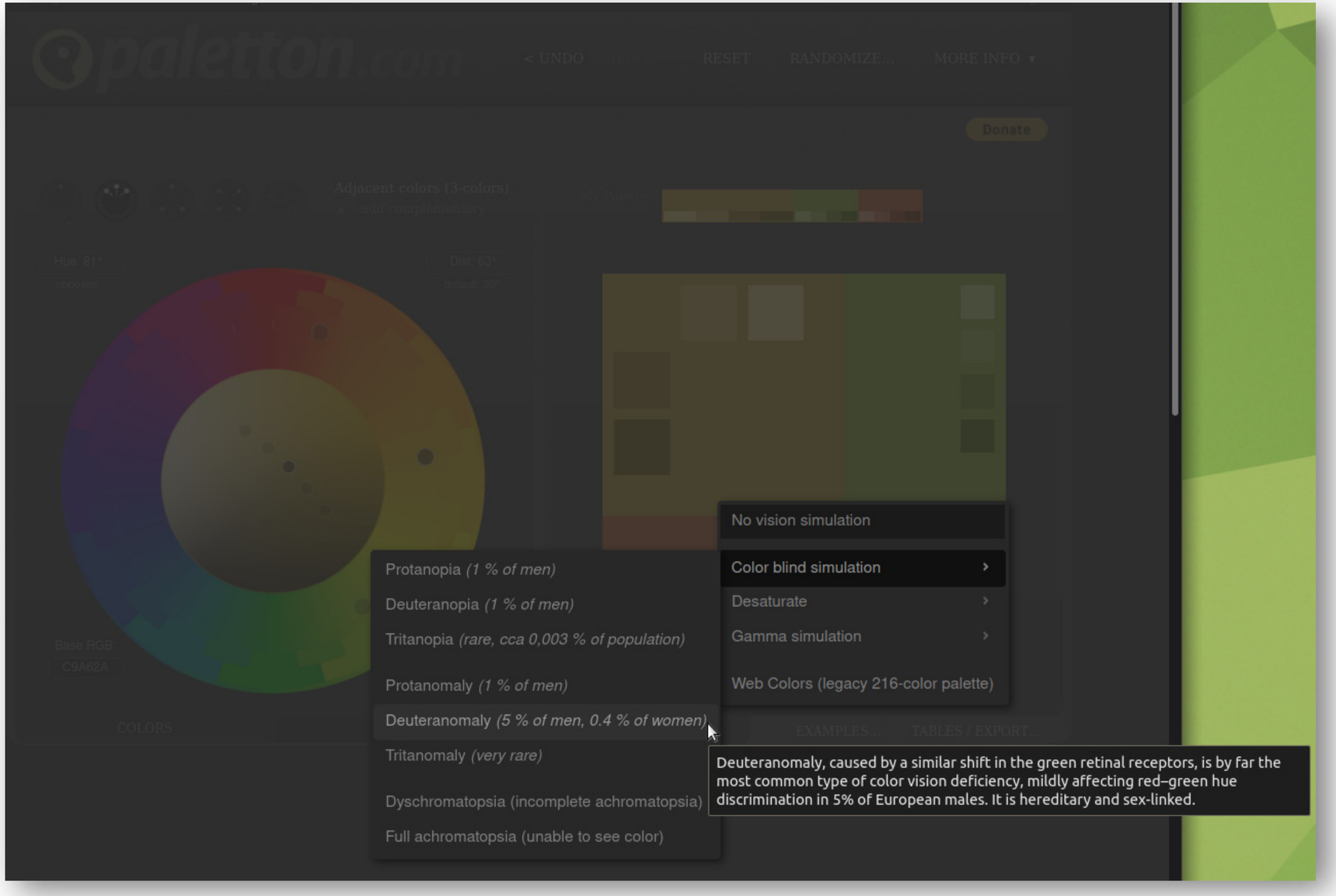
Color Scheme for Color Blindness

Thanks to the constant change in saturation, the cubehelix color scheme provides enough discriminative power for various deficiencies



https://ifweassume.blogspot.com/2013/05/cubehelix-or-how-i-learned-to-love.html
https://www.toptal.com/designers/colorfilter
Green, D. A. (2011). A colour scheme for the display of astronomical intensity images. Bulletin of the Astronomical Society of India, 39, 289-295.

Vision simulations



Wrap-Up

Graphical excellence

is a matter of substance, statistics, and design

consists of complex ideas communicated with clarity, precision, and efficiency

give the viewer the greatest number of ideas in shortest time with

the least ink in the smallest space

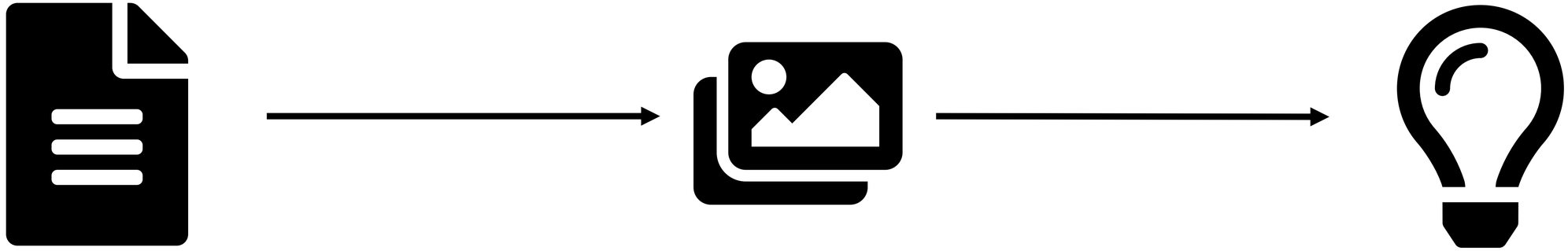
is nearly always multivariate

requires telling the truth about the data

induce the viewer to think about the substance rather than the methodology

Tufte, Edward R. *The visual display of quantitative information*, 1983.

Information Visualization is a Form of Communication



How to support effective communication:

- Explain mapping of data to visual elements
- Be consistent also across visualizations
- Use graphical elements to support your narrative

Acknowledgement

Thanks to Jürgen Pfeffer and his lecture on information visualization!

Thanks.

mirco.schoenfeld@uni-bayreuth.de