

Information Visualization

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[@TWIyY29](#)

minard.txt ✕

```

1 basic
2 input,
3 (lonc latc city$ lont temp days date$ lonp latp surviv direc$ division),
4 (#4 #5 > $12 >> #5 #5 #5 $8 #6 #6 >> #6 >> $1 #3)
5 save minard
6 run
7 24.0 55.0 Kowno 37.6 0 6 Oct 18 24.0 54.9 340000 A 1
8 25.3 54.7 Wilna 36.0 0 6 Oct 24 24.5 55.0 340000 A 1
9 26.4 54.4 Smorgoni 33.2 -9 16 Nov 9 25.5 54.5 340000 A 1
10 26.8 54.3 Molodexno 32.0 -21 5 Nov 14 26.0 54.7 320000 A 1
11 27.7 55.2 Gloubokoe 29.2 -11 10 27.0 54.8 300000 A 1
12 27.6 53.9 Minsk 28.5 -20 4 Nov 28 28.0 54.9 280000 A 1
13 28.5 54.3 Studienska 27.2 -24 3 Dec 1 28.5 55.0 240000 A 1
14 28.7 55.5 Polotzk 26.7 -30 5 Dec 6 29.0 55.1 210000 A 1
15 29.2 54.4 Bobr 25.3 -26 1 Dec 7 30.0 55.2 180000 A 1
16 30.2 55.3 Witebsk 30.3 55.3 175000 A 1
17 30.4 54.5 Orscha 32.0 54.8 145000 A 1
18 30.4 53.9 Mohilow 33.2 54.9 140000 A 1
19 32.0 54.8 Smolensk 34.4 55.5 127100 A 1
20 33.2 54.9 Dorogobouge 35.5 55.4 100000 A 1
21 34.3 55.2 Wixma 36.0 55.5 100000 A 1
22 34.4 55.5 Chjat 37.6 55.8 100000 R 1
23 36.0 55.5 Mojaisk 37.5 55.7 98000 R 1
24 37.6 55.8 Moscou 37.0 55.0 97000 R 1
25 36.6 55.3 Tarantino 36.8 55.0 96000 R 1
26 36.5 55.0 Malo-jarosewli 35.4 55.3 87000 R 1
27 34.3 55.2 55000 R 1
28 33.3 54.8 37000 R 1

```

Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.

Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite. Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largeurs des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zones. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. — Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M.M. Thiers, de Ségur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre. Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davout qui avaient été détachés sur Minsk et Mohilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.

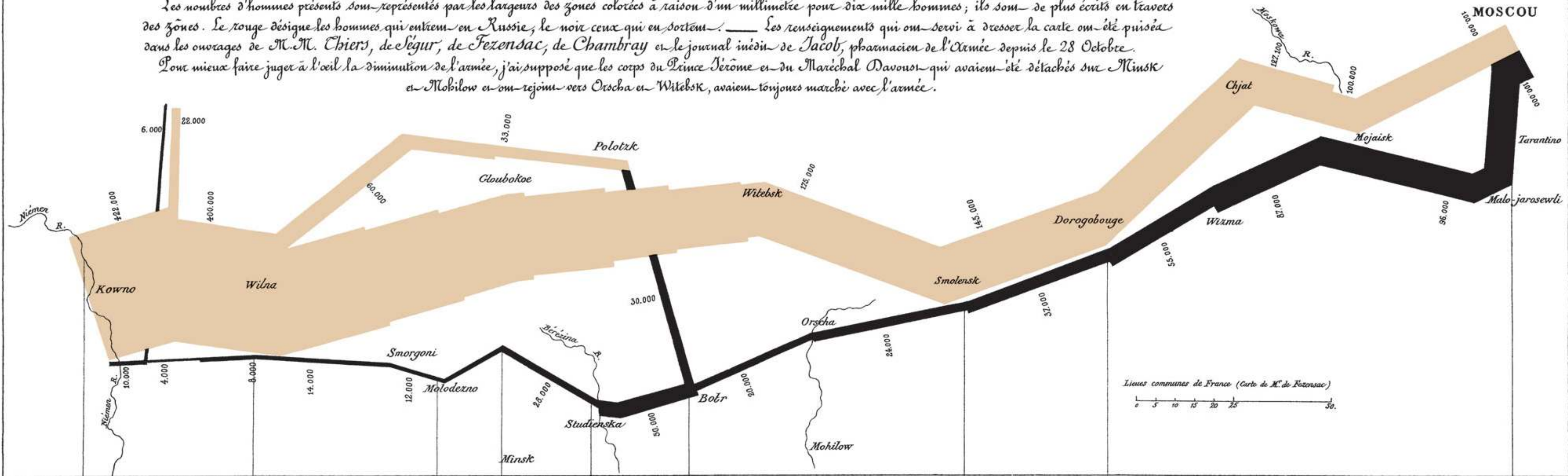
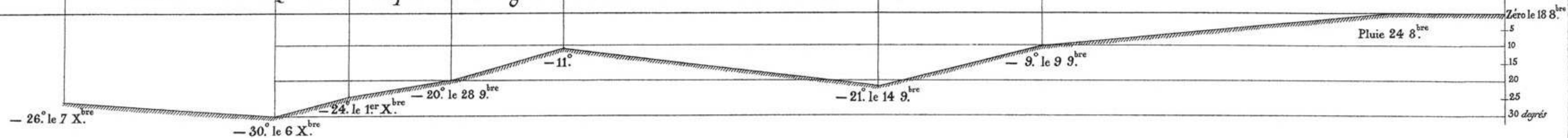
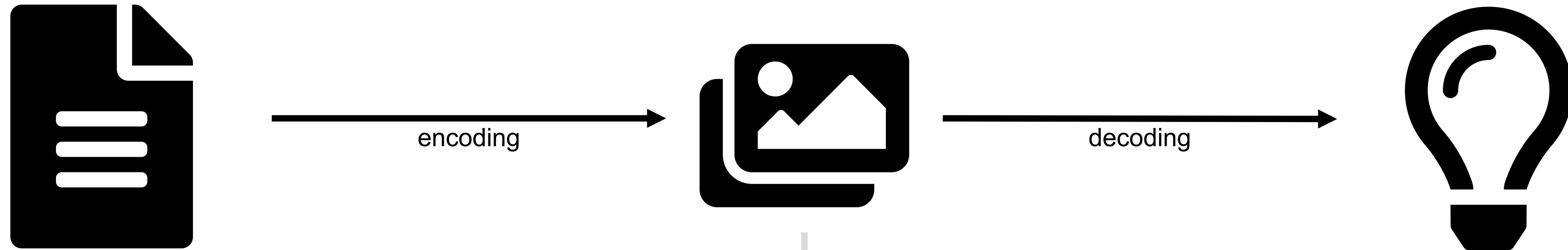


TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.



Les Cosaques passent au galop le Niemen gelé.

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 bandwidth)

People think in pictures

Pattern recognition

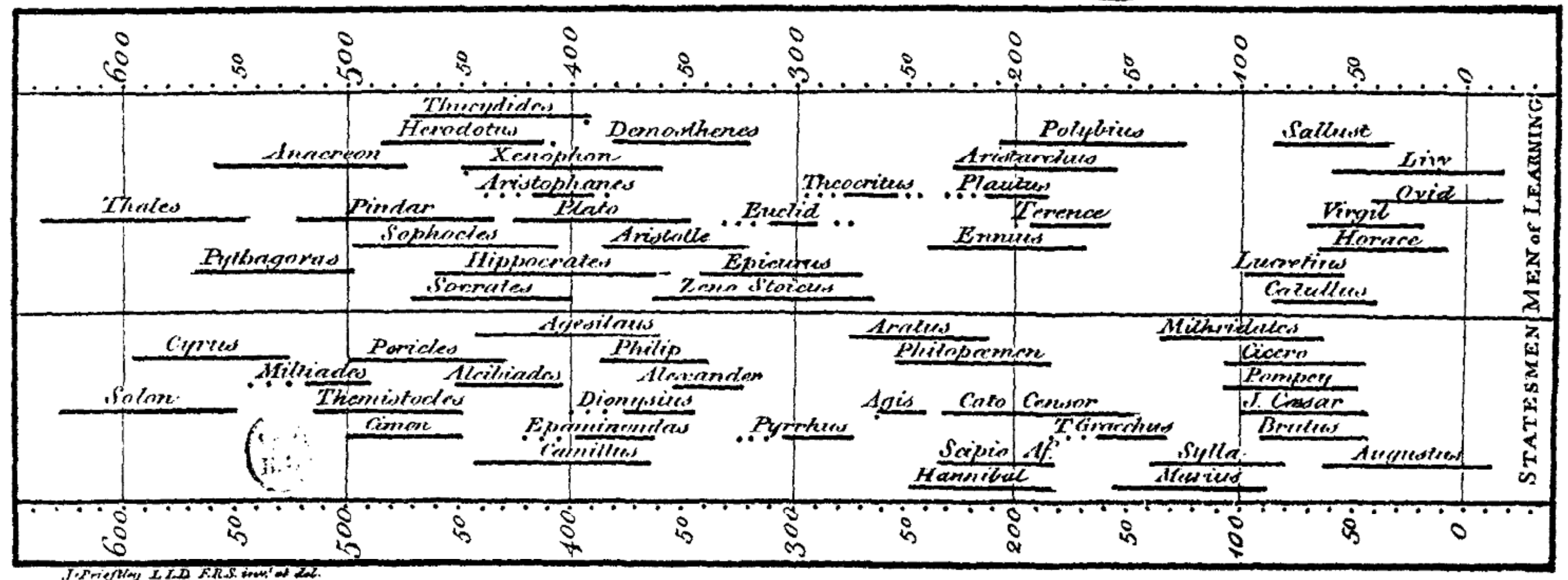
Pre-attentive perception

Joseph Priestley (1733-1804)

English chemist, natural philosopher, theologian, political theorist...

Created the first timeline chart

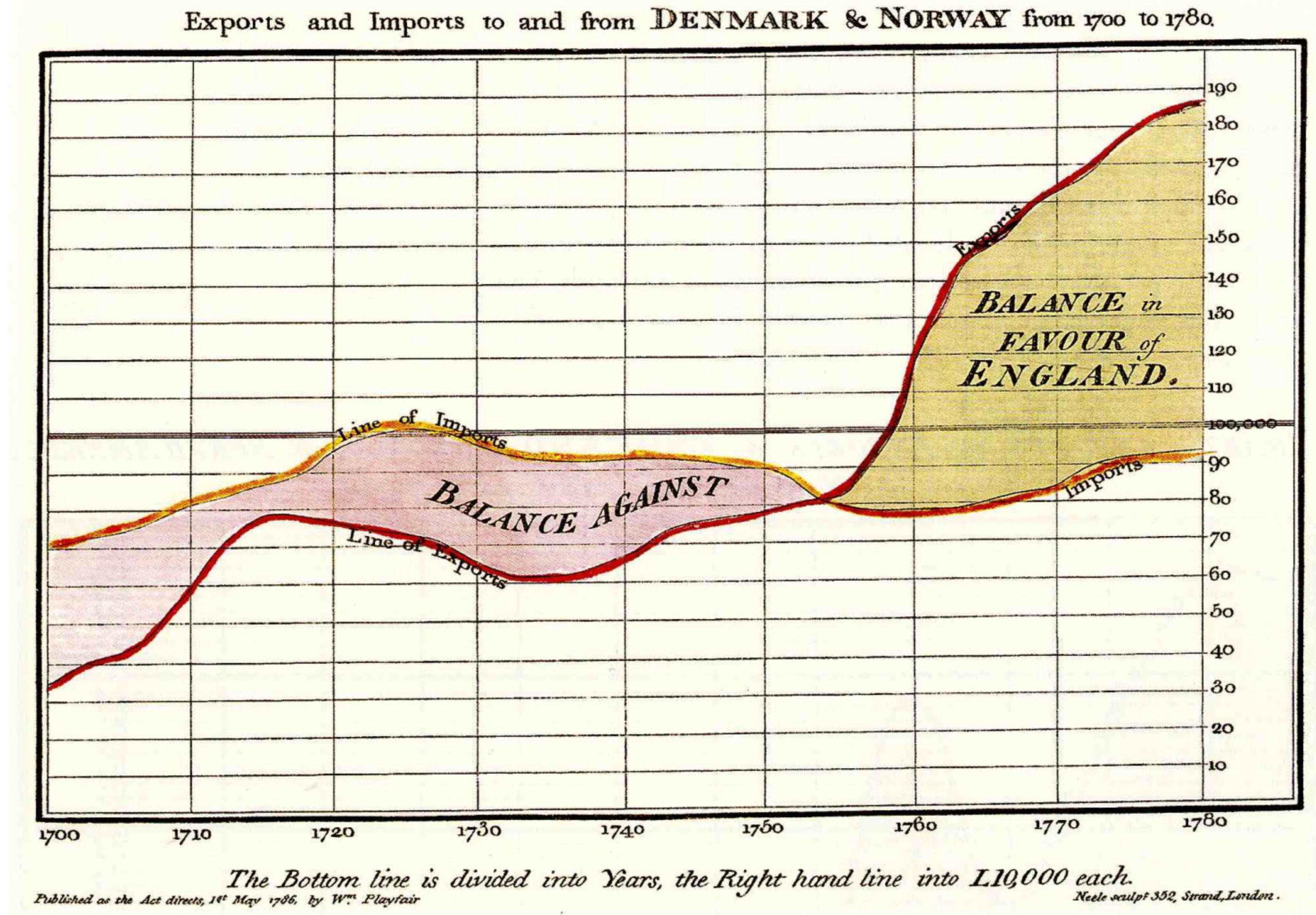
A Specimen of a Chart of Biography.

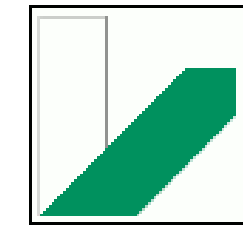


William Playfair (1759-1823)

Founder of graphical statistics

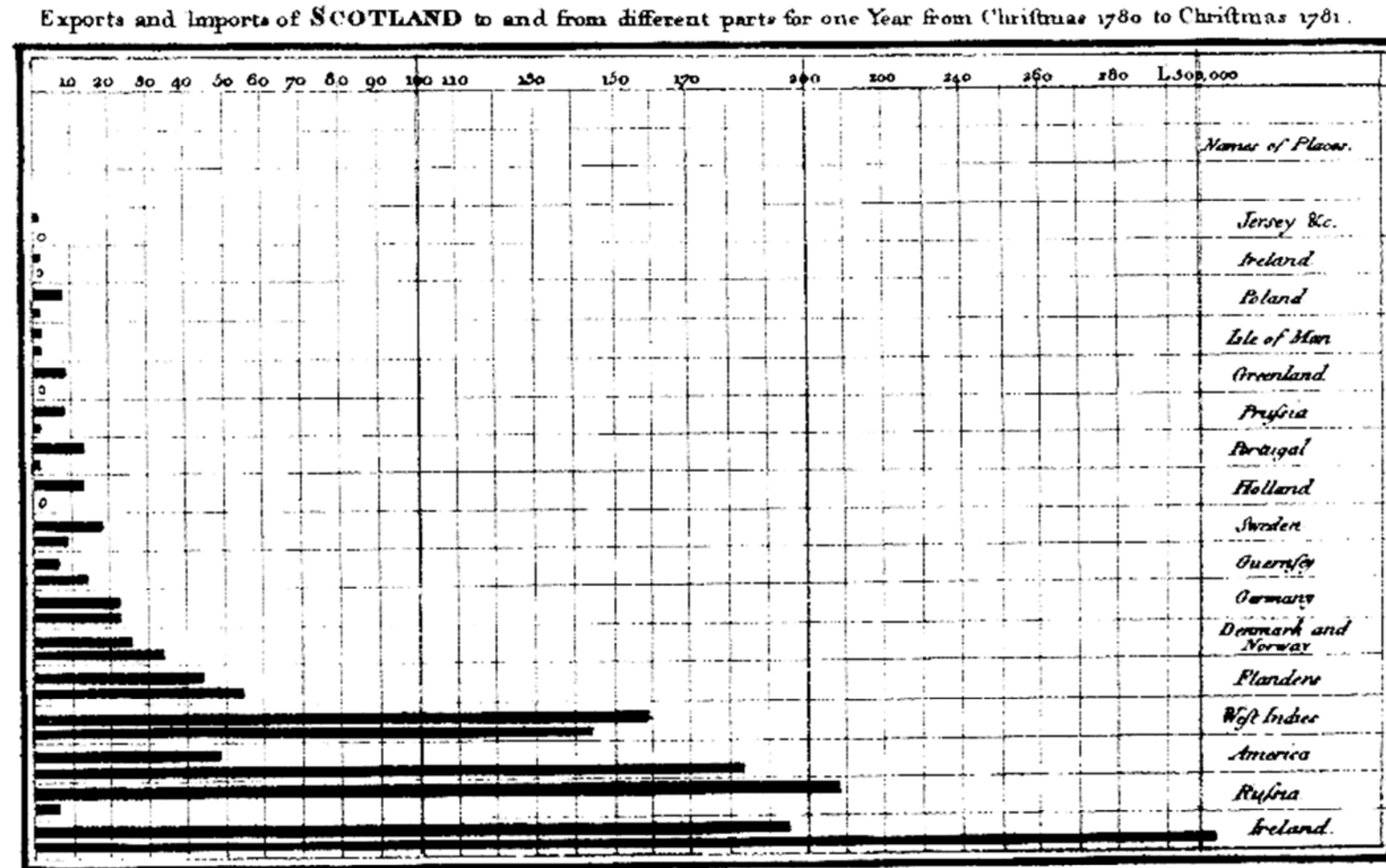
Commercial and
Political Atlas, 1786





William Playfair (1759-1823)

1786: Bar Chart



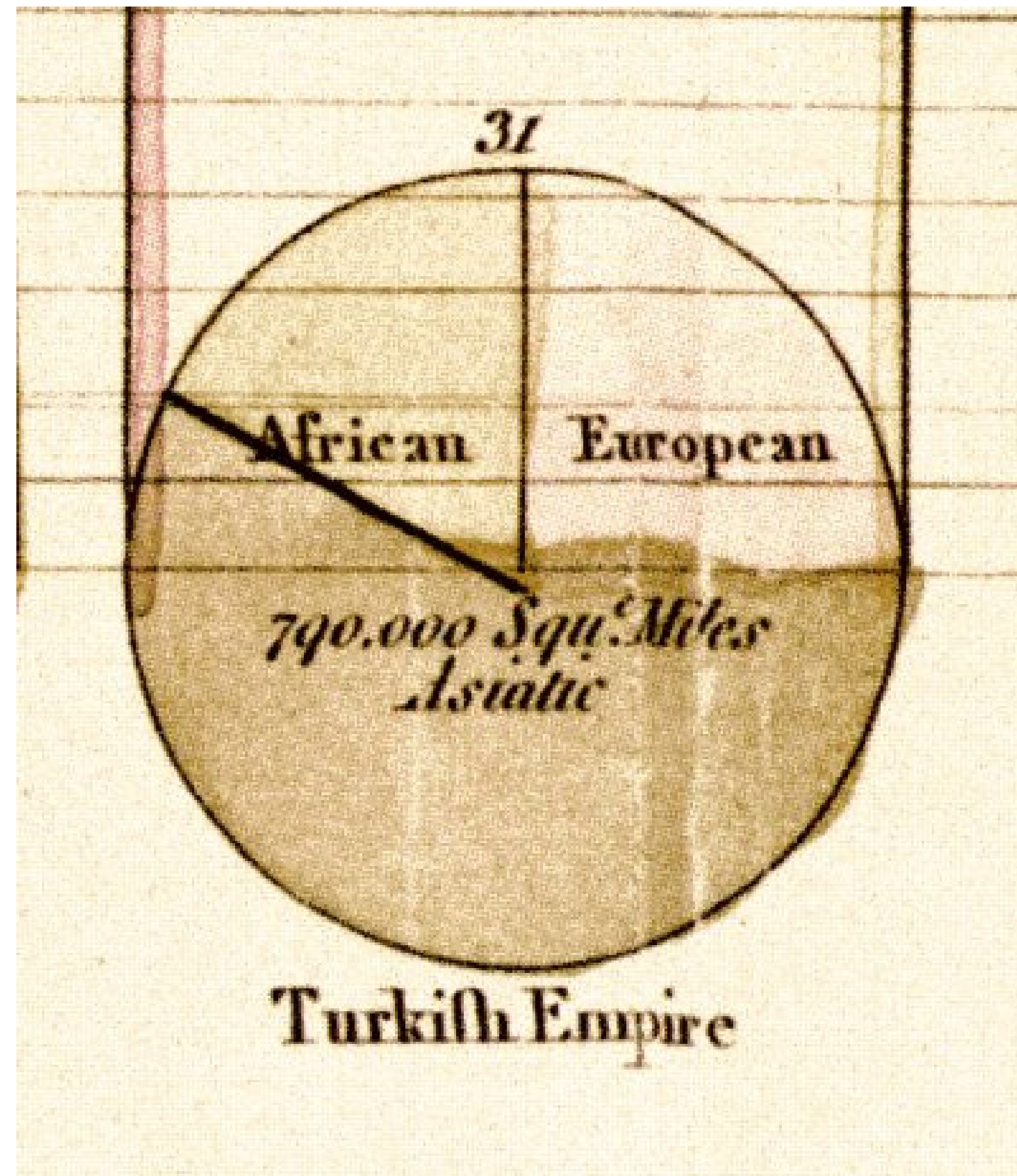
The Upright divisions are Ten Thousand Pounds each. The Black Lines are Exports the Ribbed lines Imports.

Published as the Act directs June 7th 1788 by W^m Playfair

Printed by J. Smith, Strand, London.

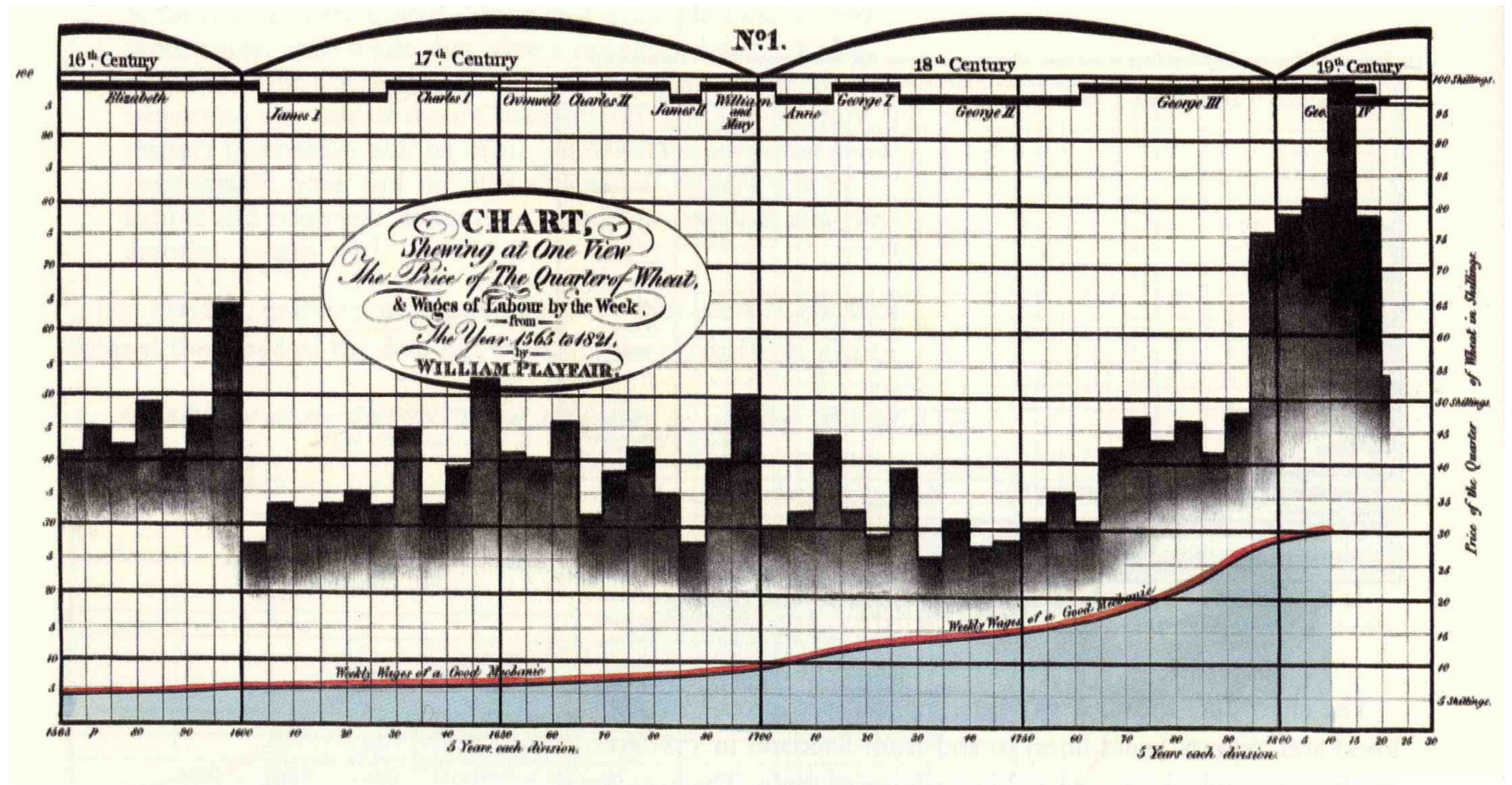
William Playfair (1759-1823)

1801: Pie Chart and Circle Graph



William Playfair (1759-1823)

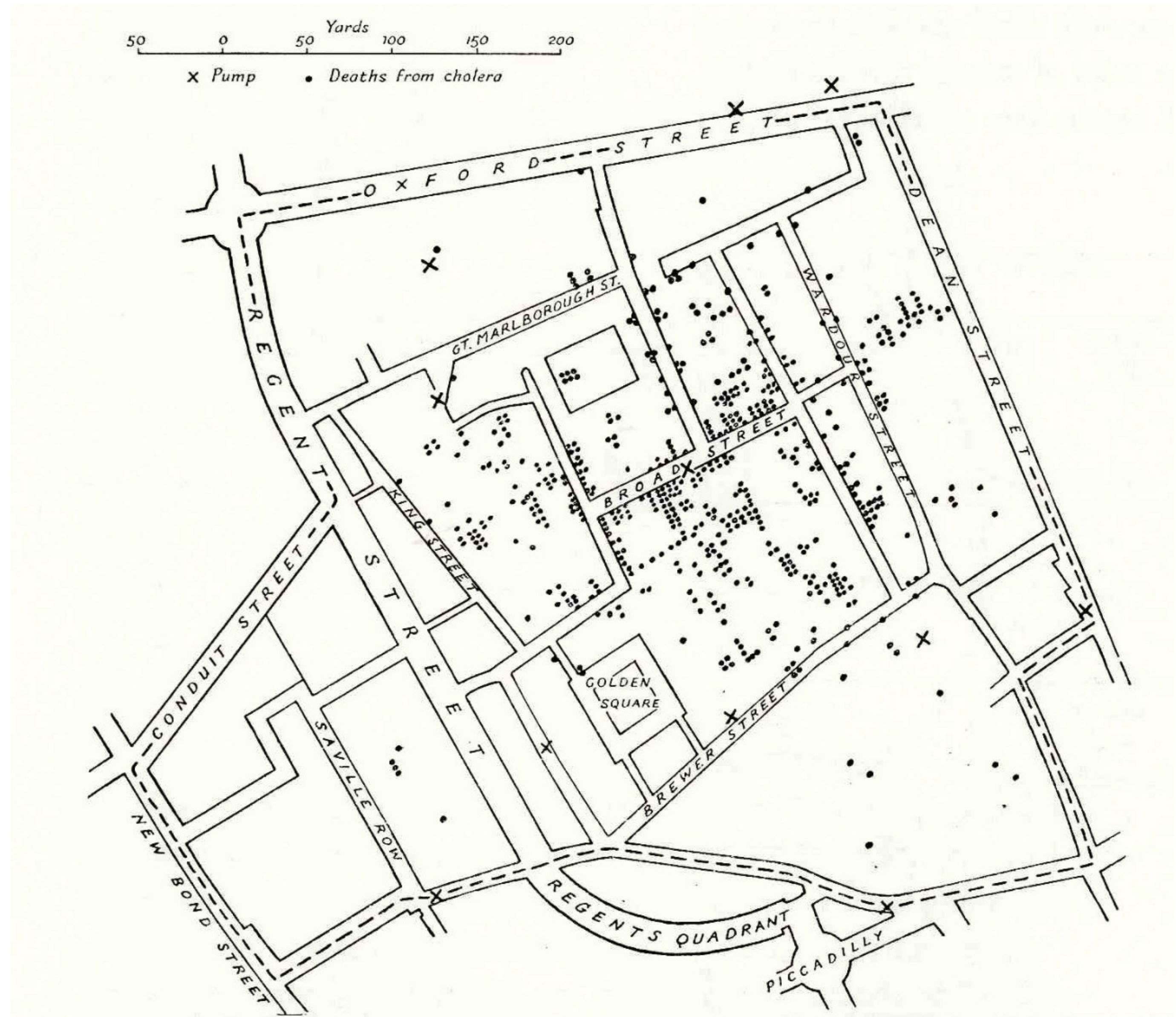
1821: Multivariate Visualization



John Snow (1813-1858)

English physician

Data visualization for reasoning

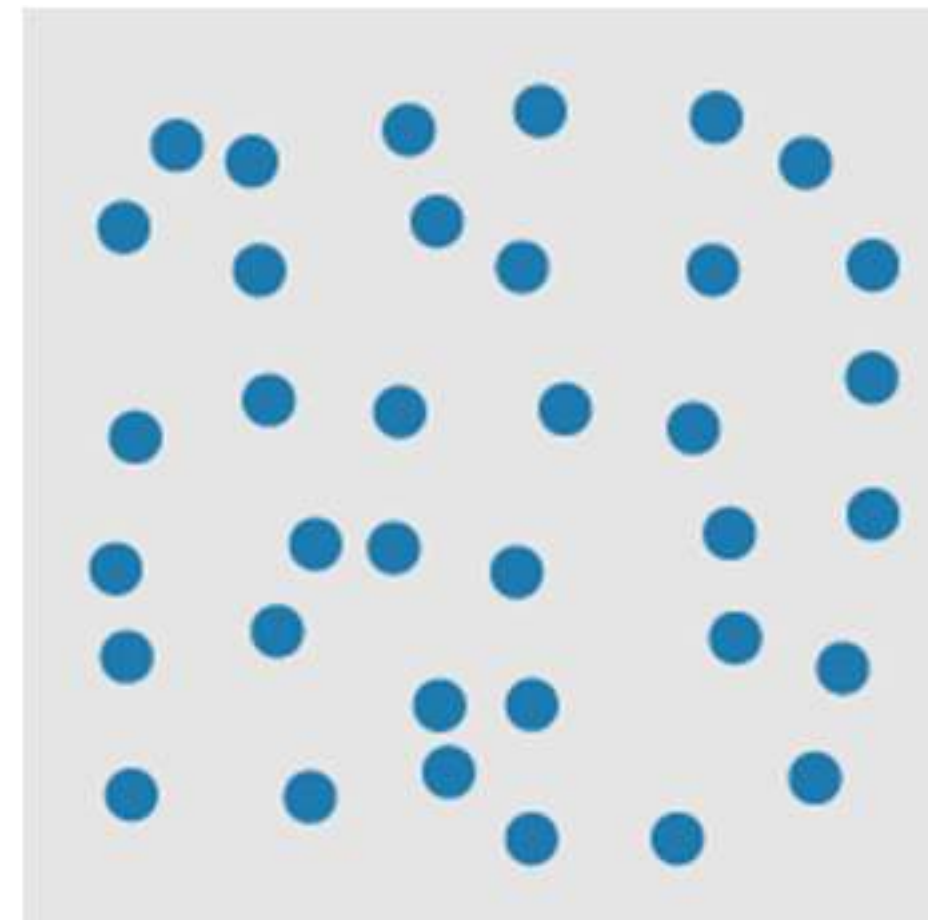


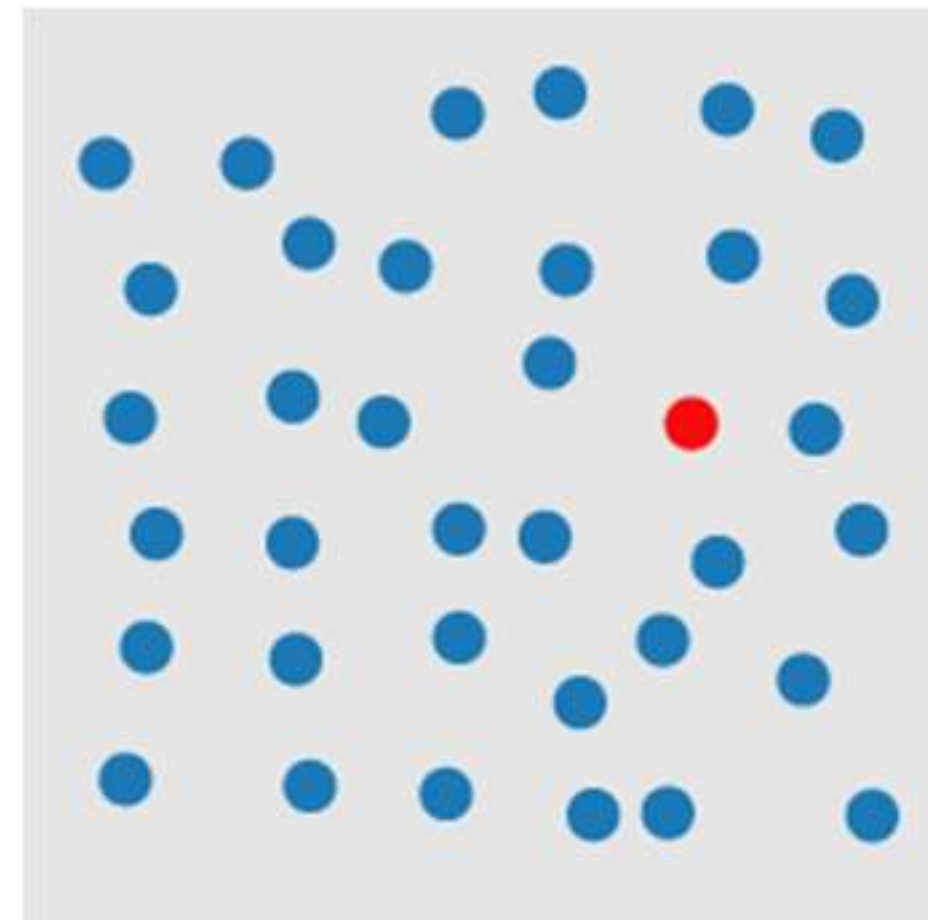
Highlighting: Preattentive Perception

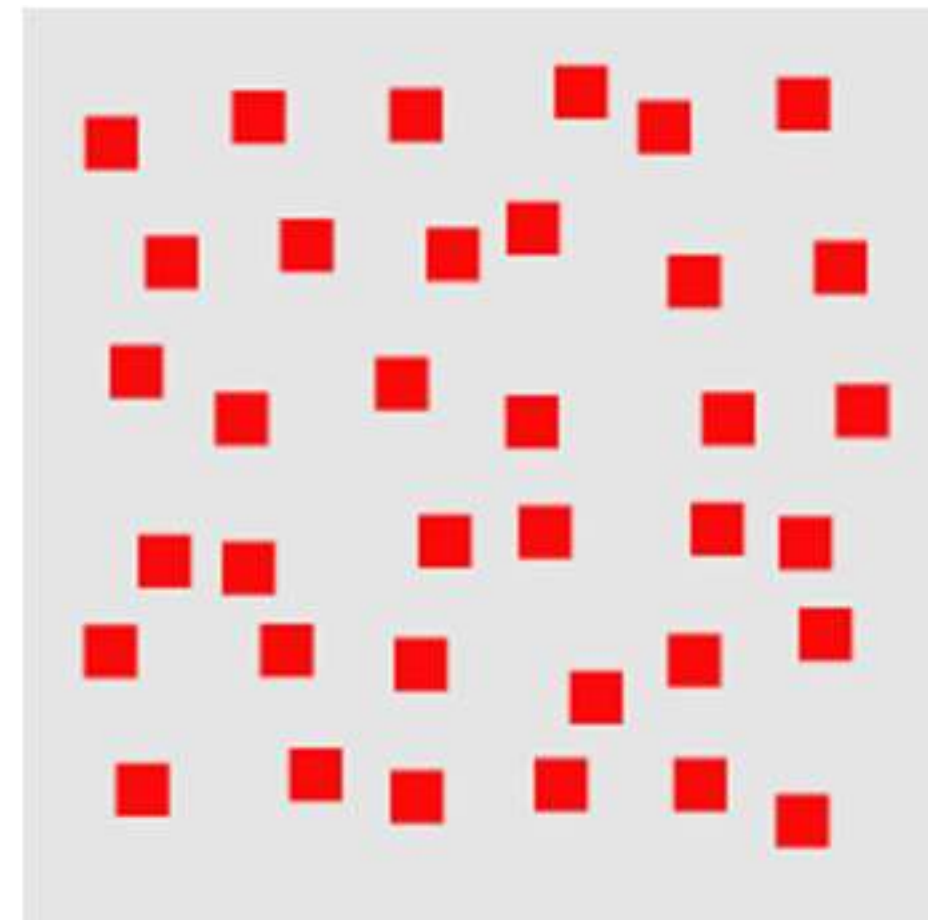
Do you see a red circle?

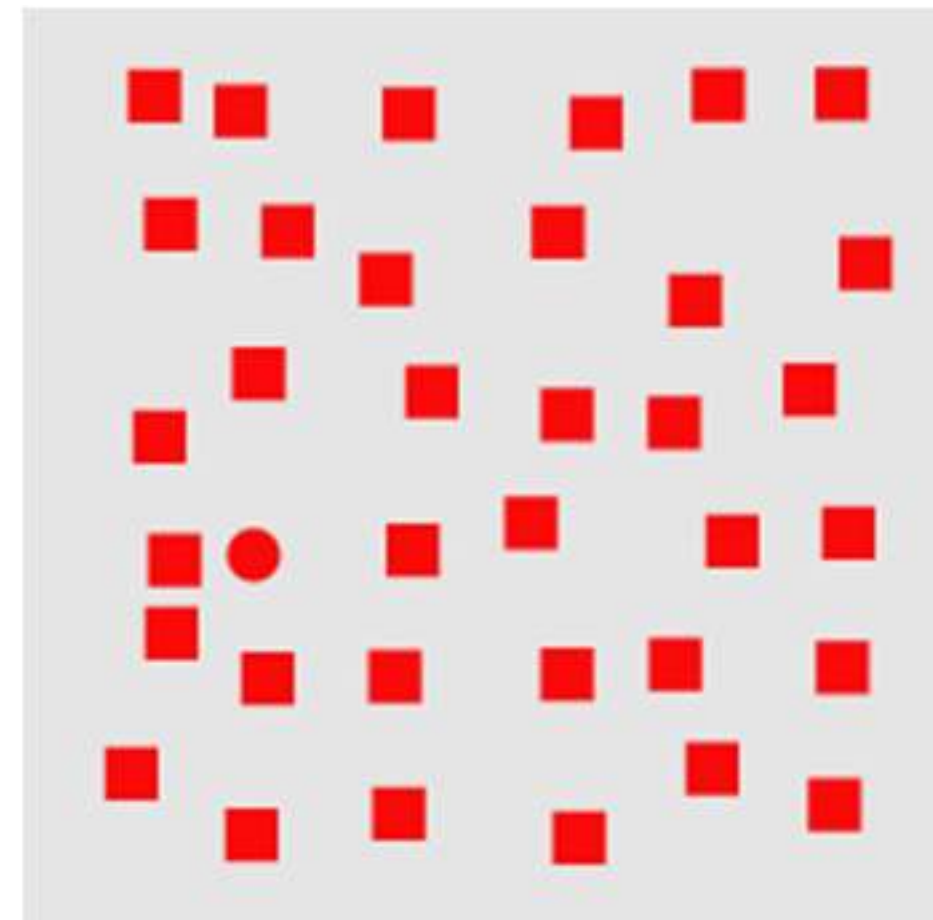
A preattentive task coming up...

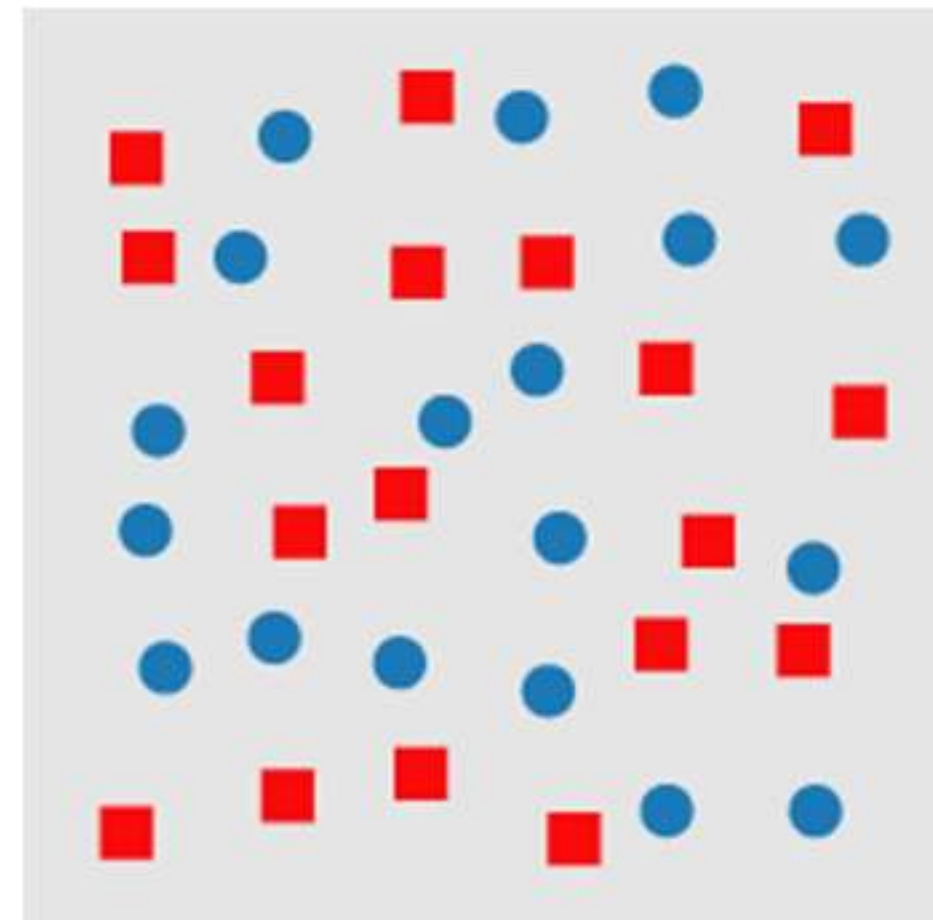
You will see a series of pictures, some with a red circle in it.

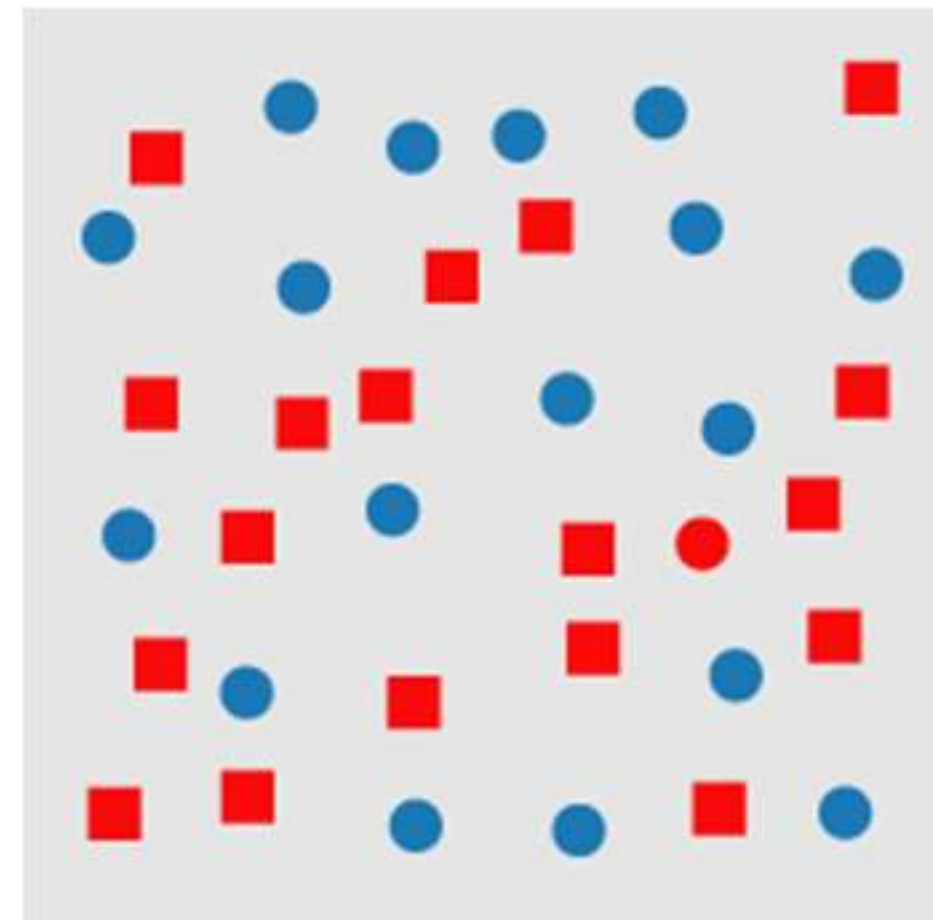








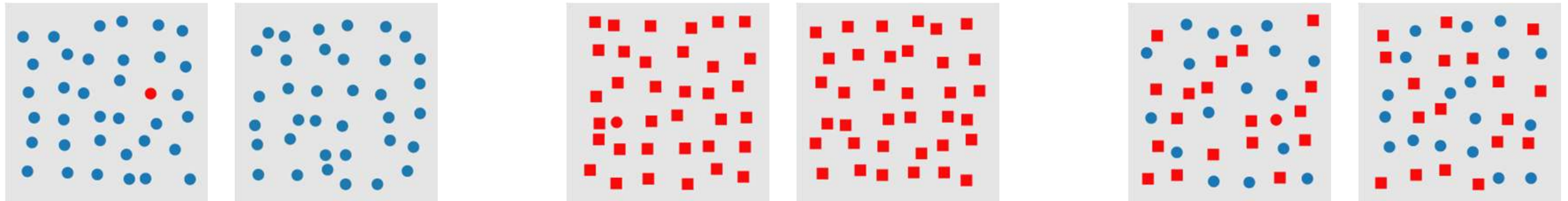




Did you see a red circle?

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

Combination of non-unique features cannot be processed preattentively



Preattentive Processing

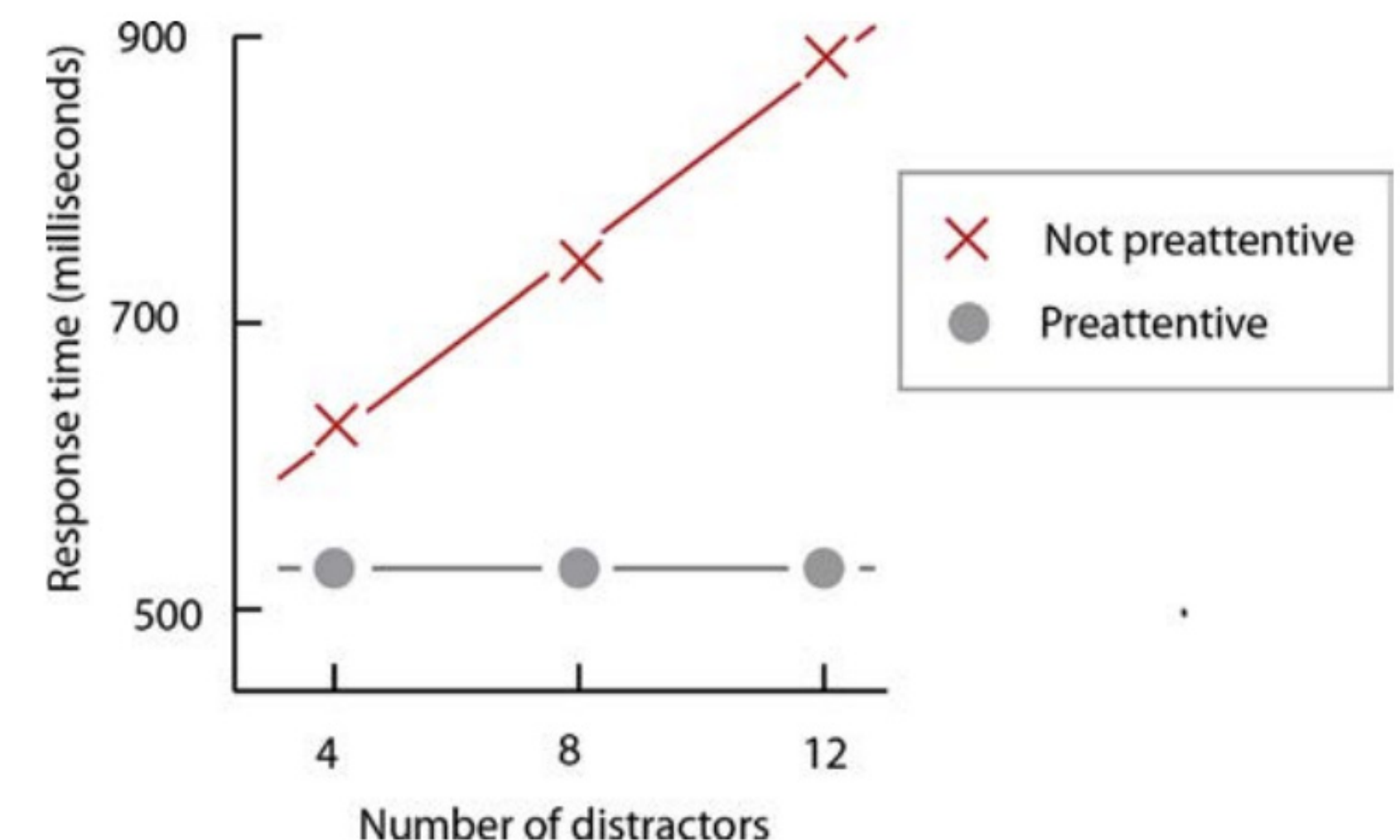
Neuroscientific concept

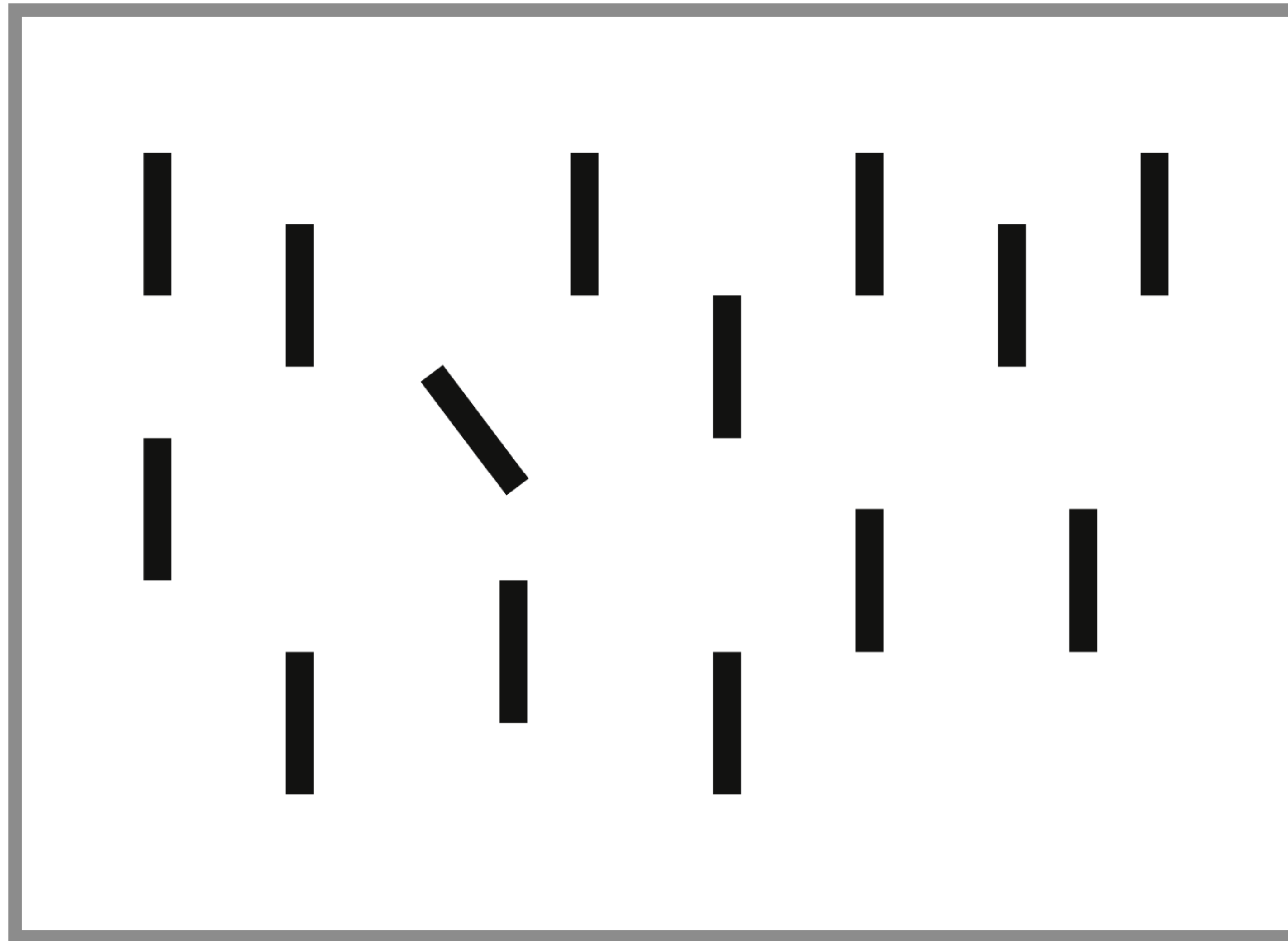
Can be thought of to occur before conscious attention

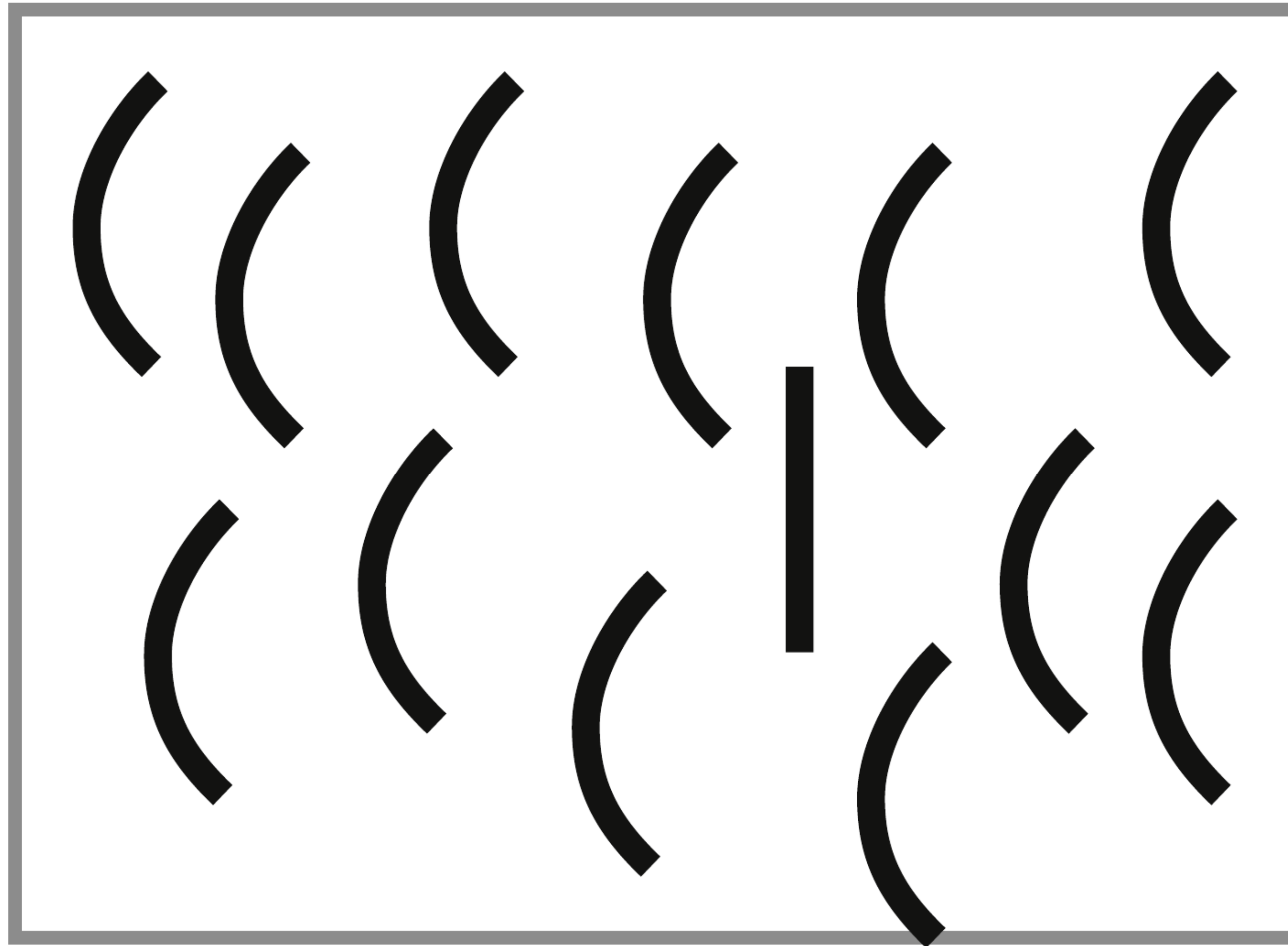
Usually detected by measuring the time to find a target element among distractors

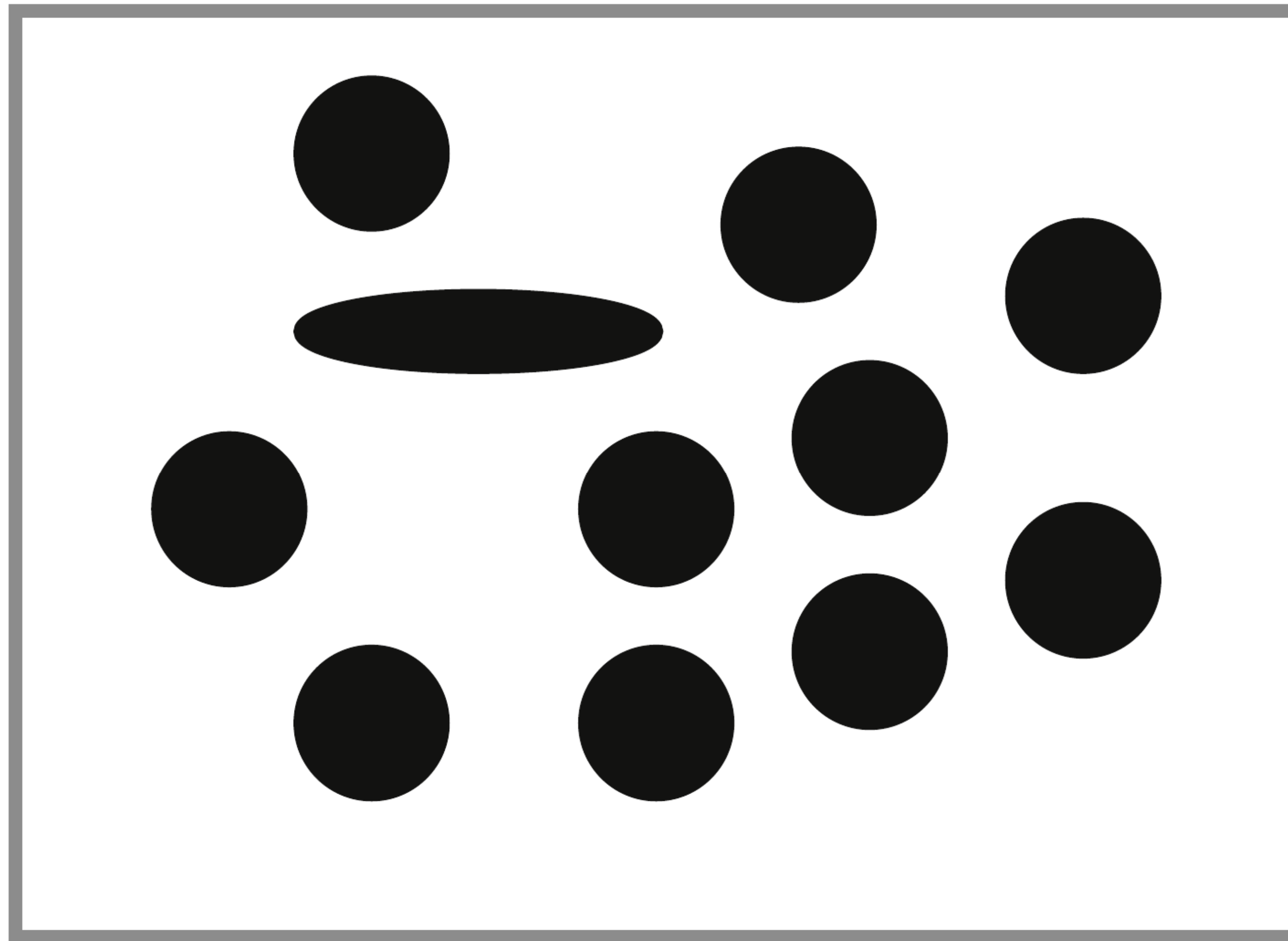
Exploited in information visualization to show things „at a glance“

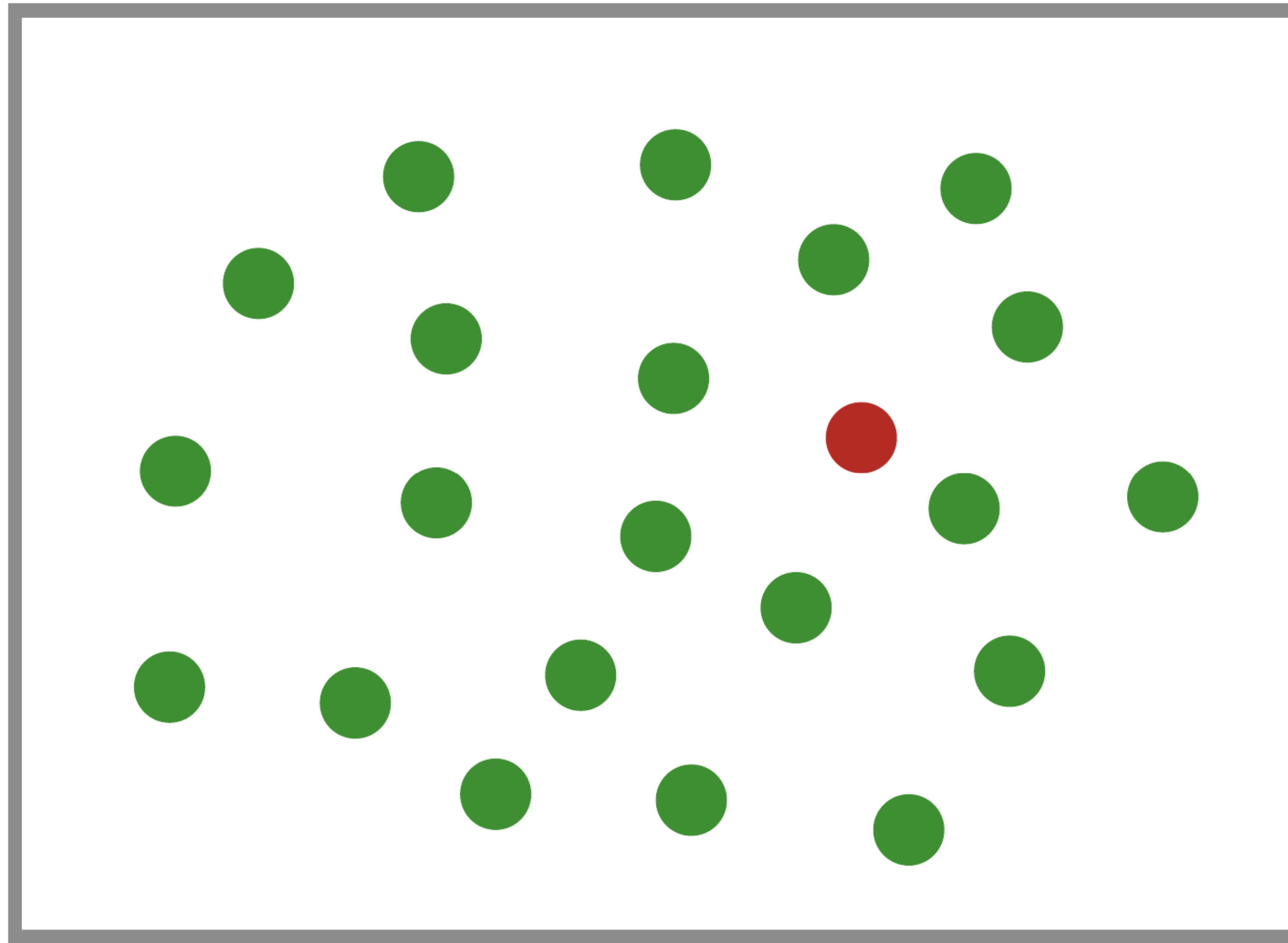
- Element detection
- Grouping
- Value Estimation
- Importance

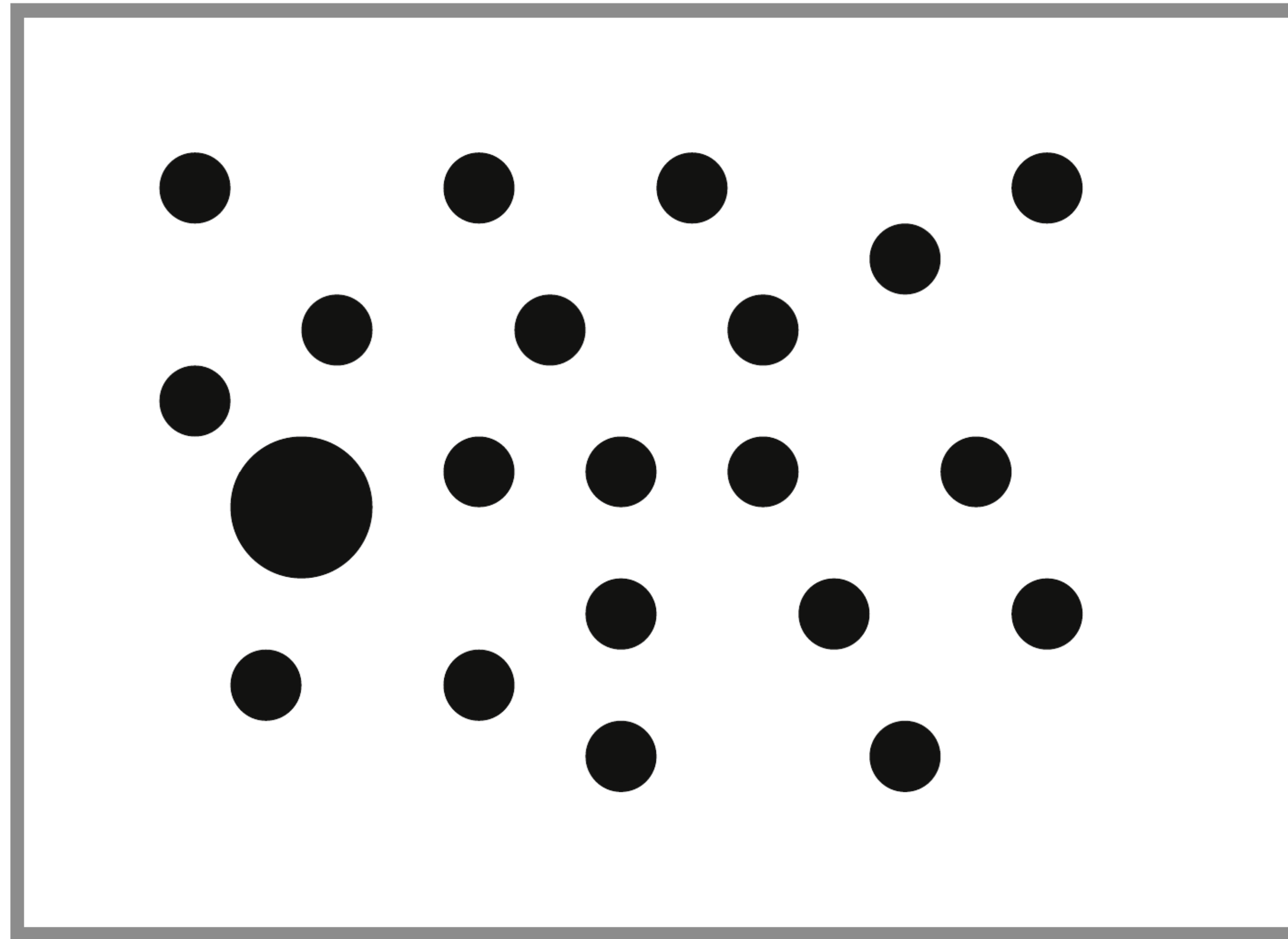


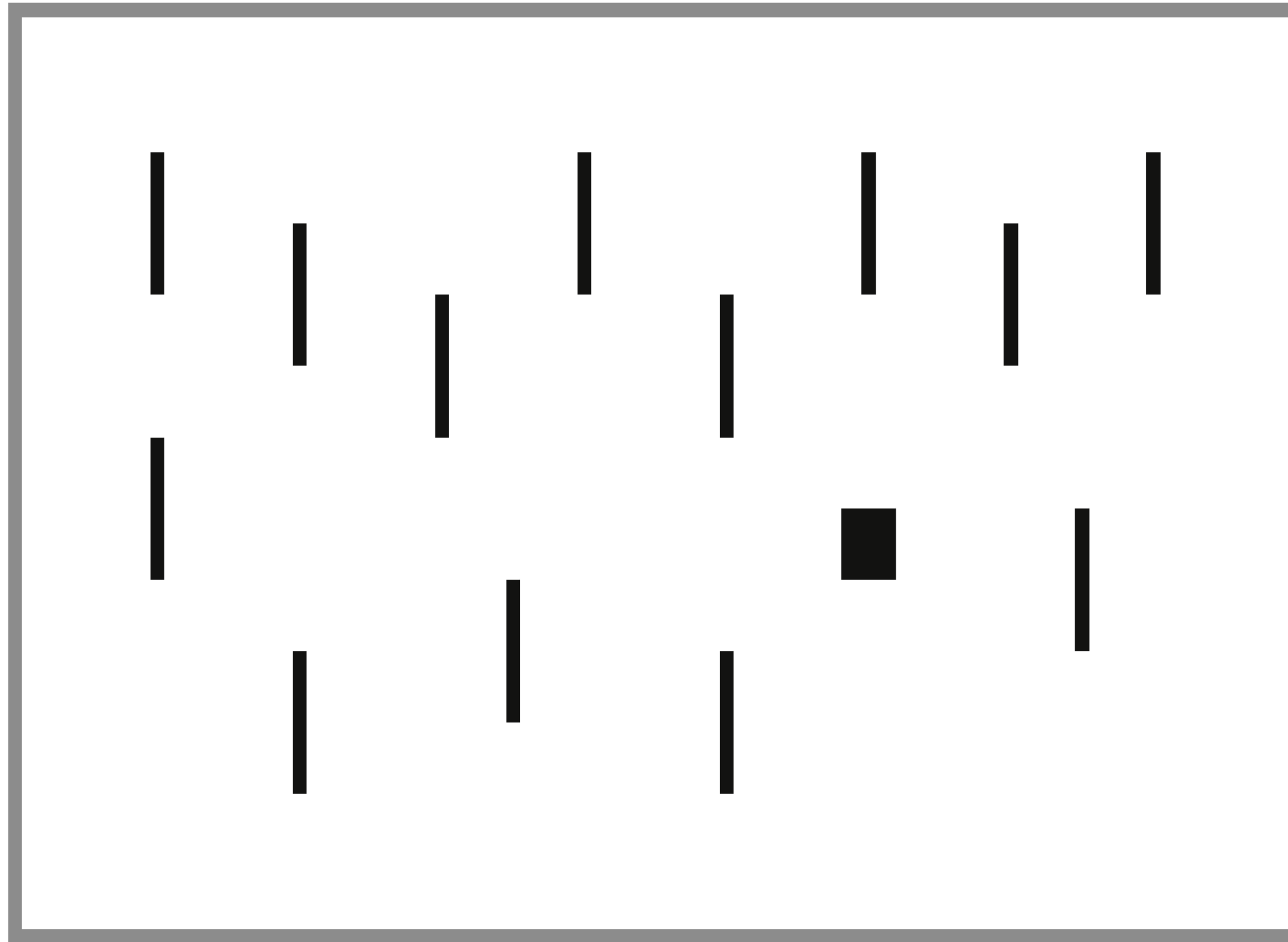


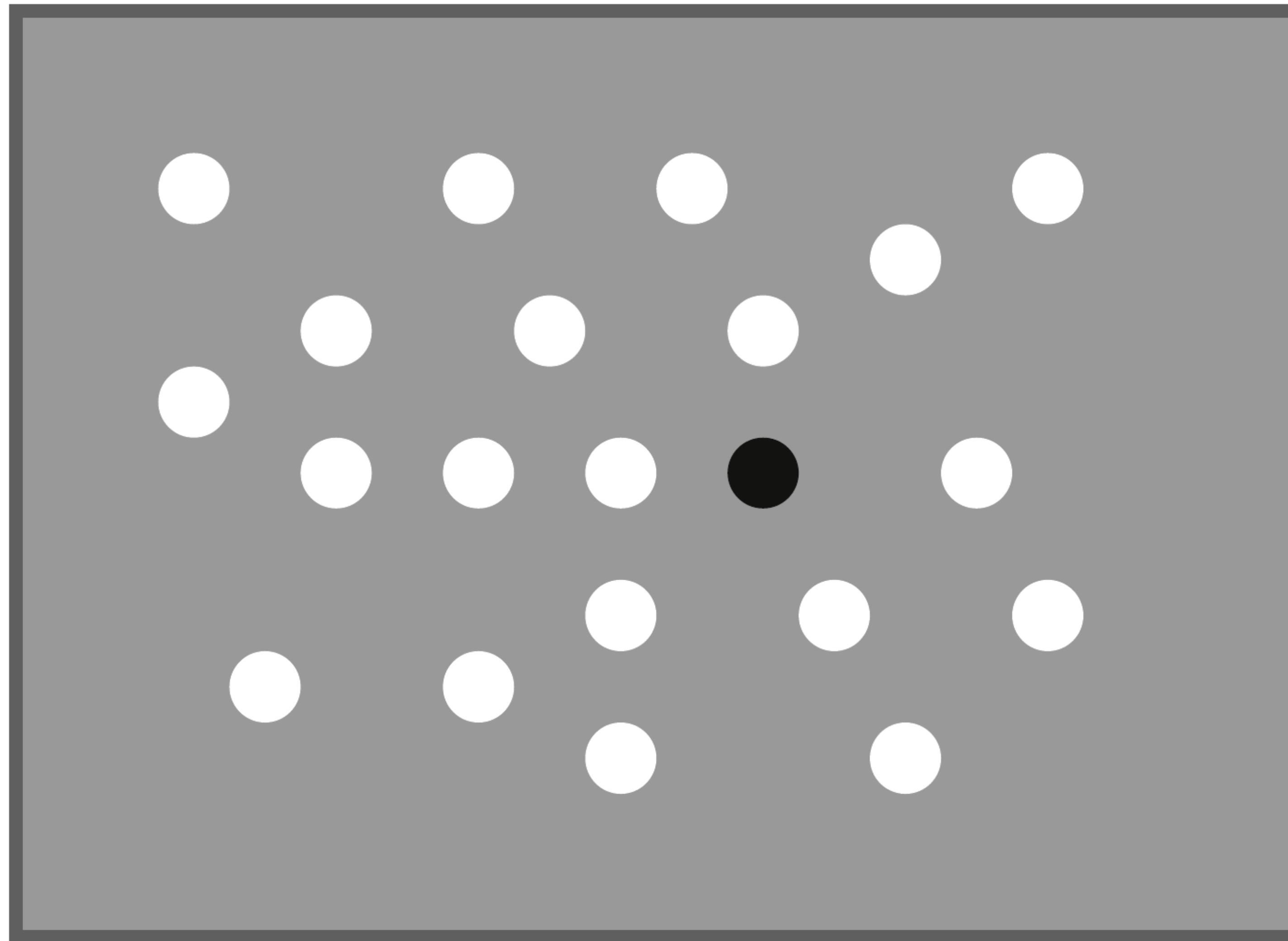


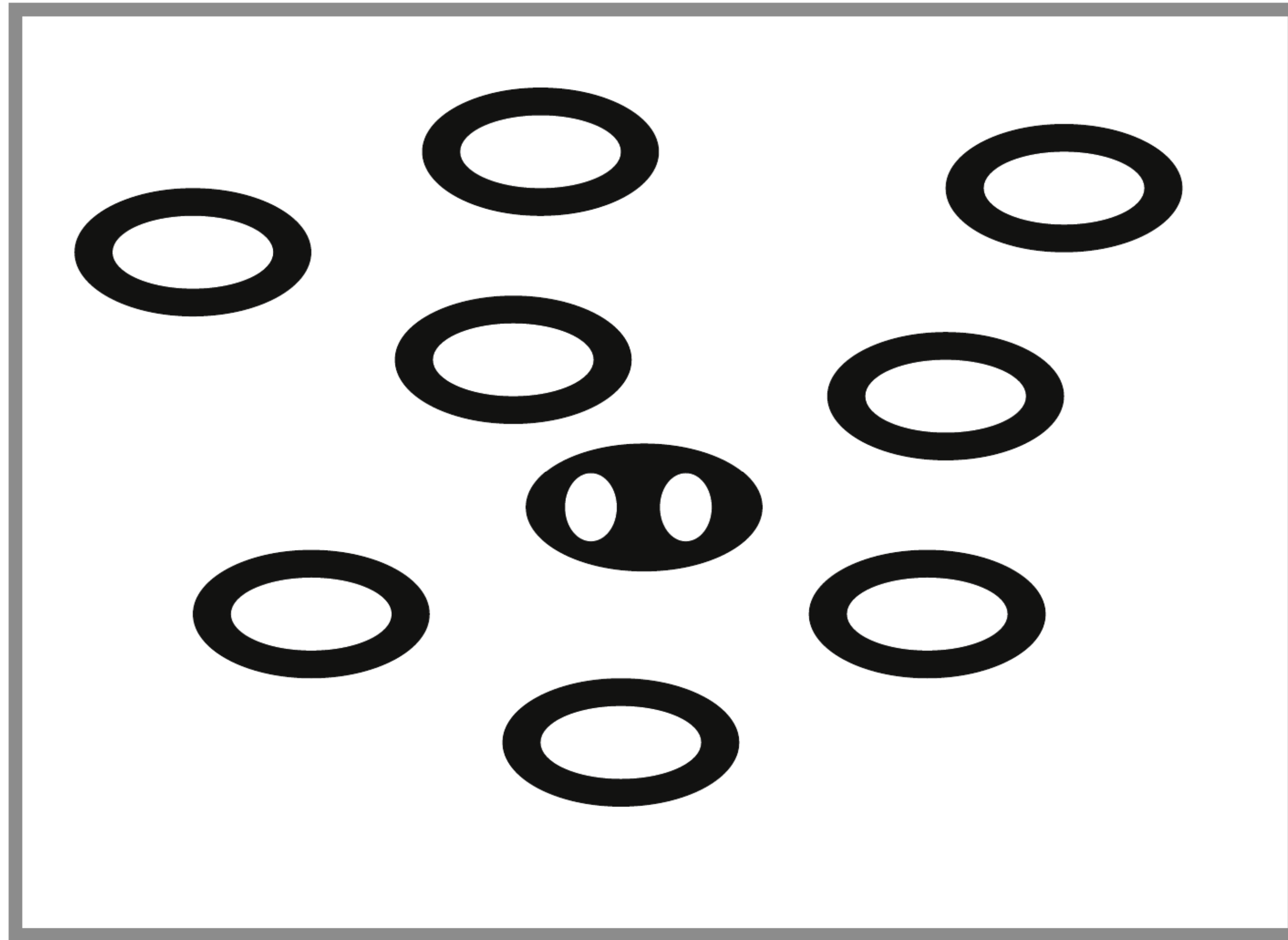


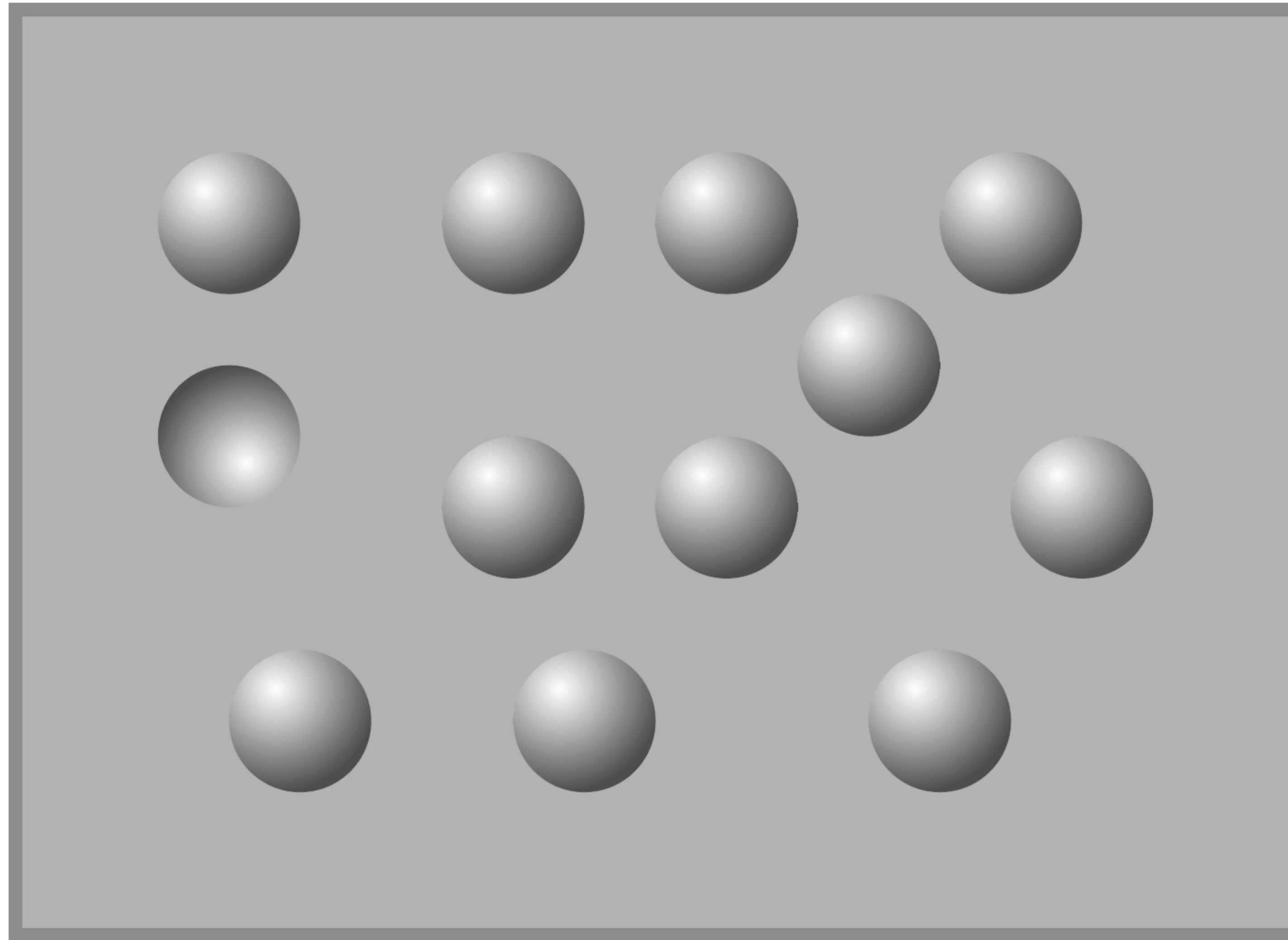


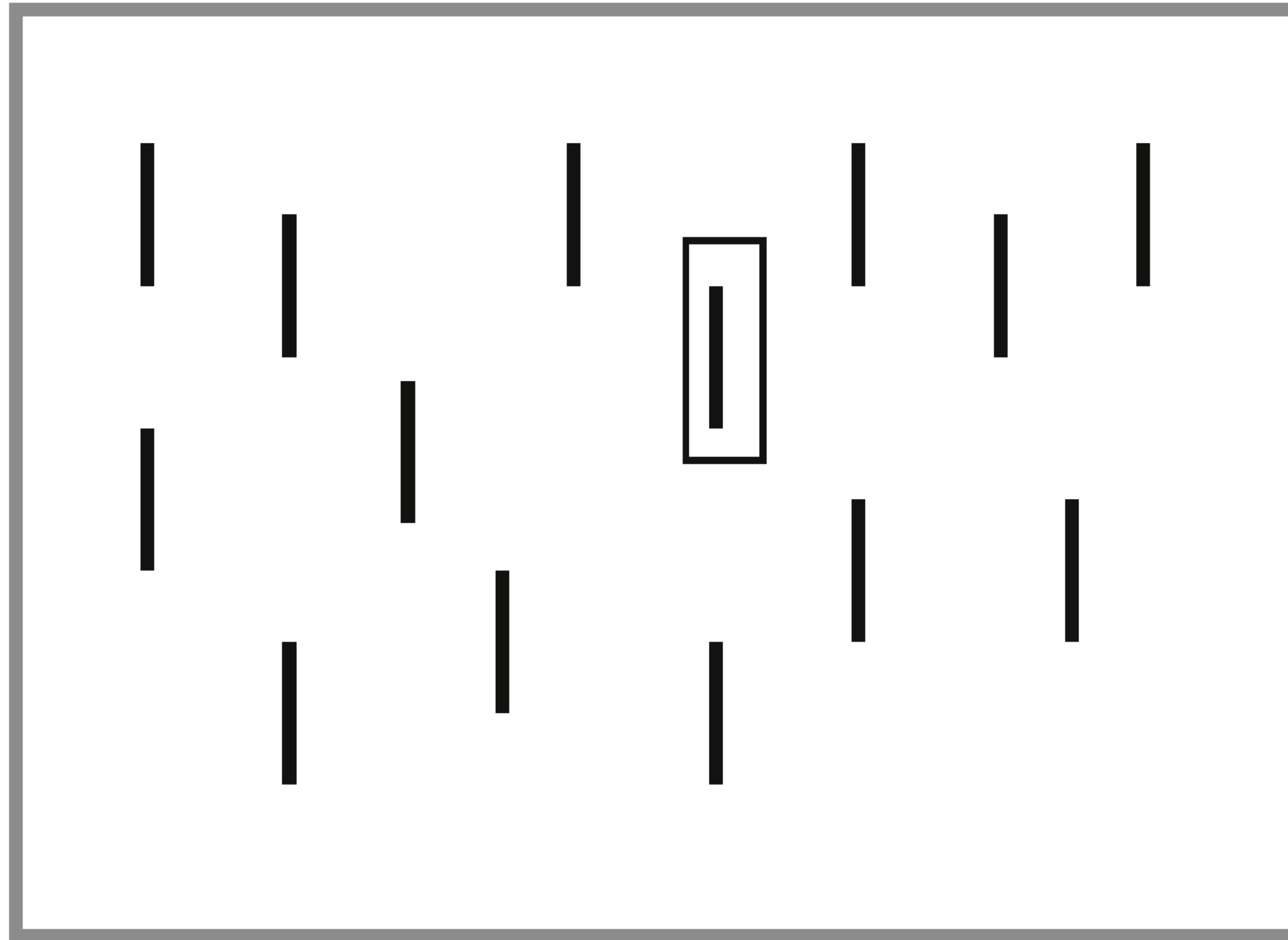


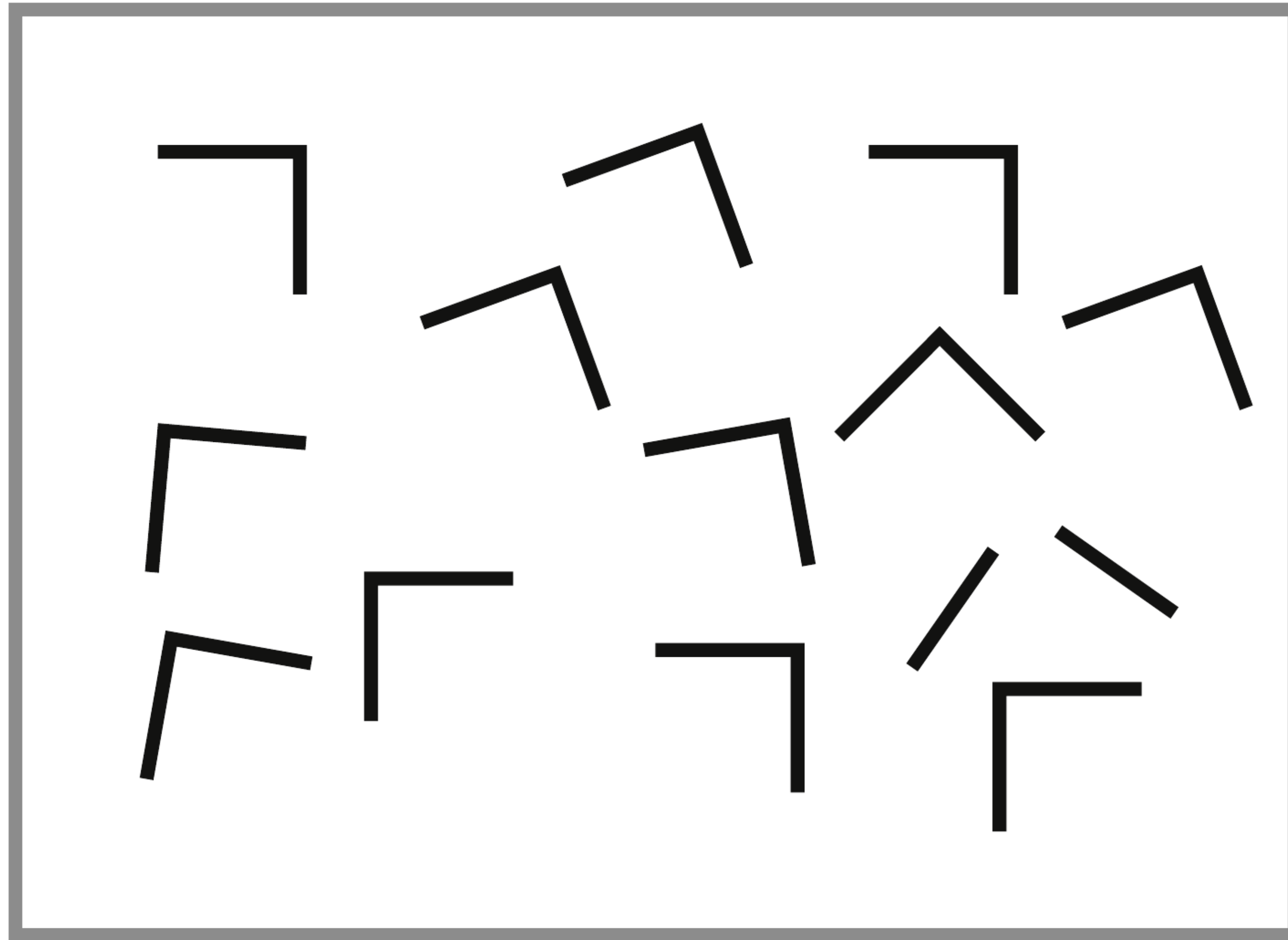


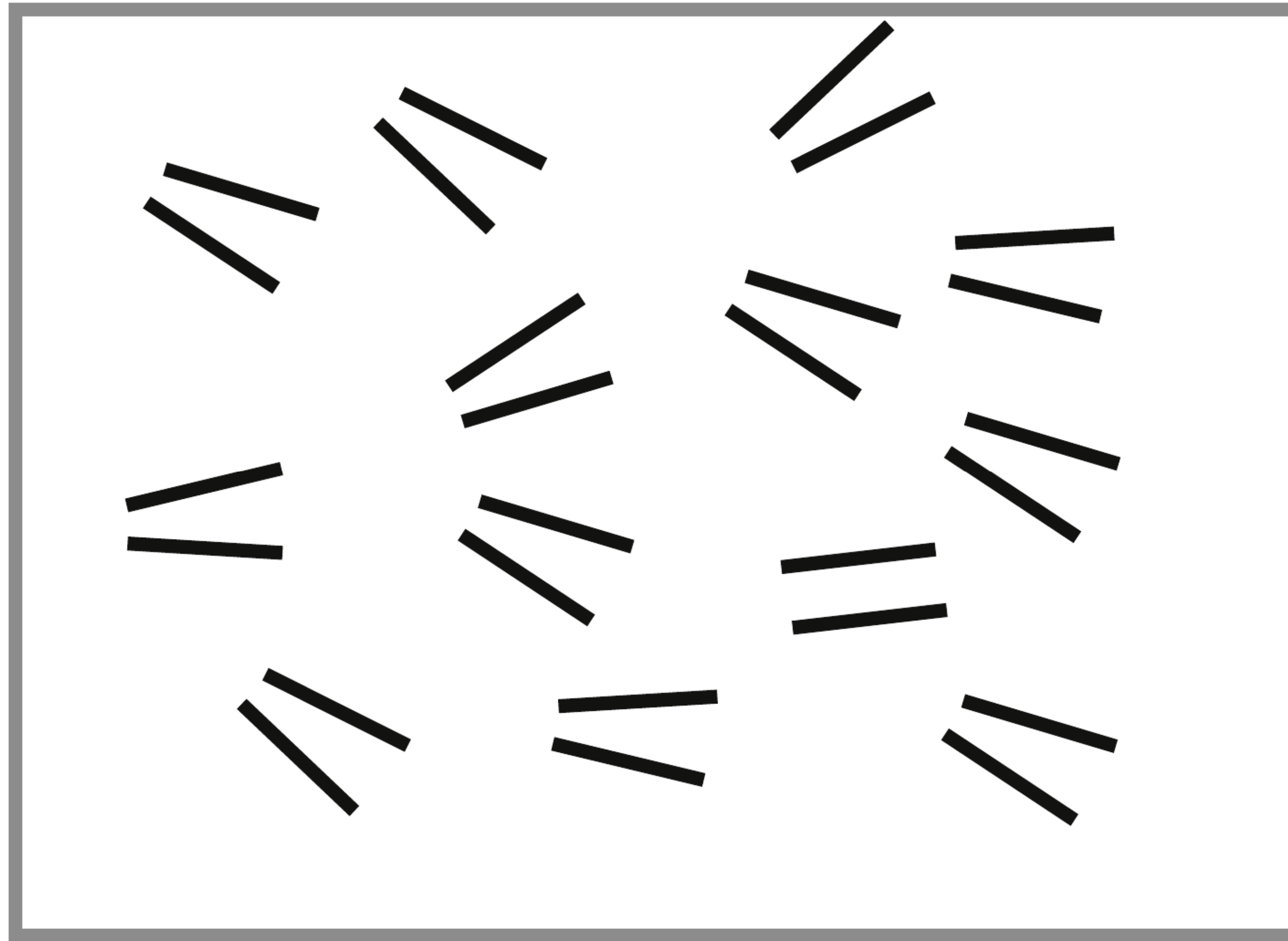












Preattentive Elements

Not all preattentive effects are equally strong

Attributes that guide the deployment of attention most:

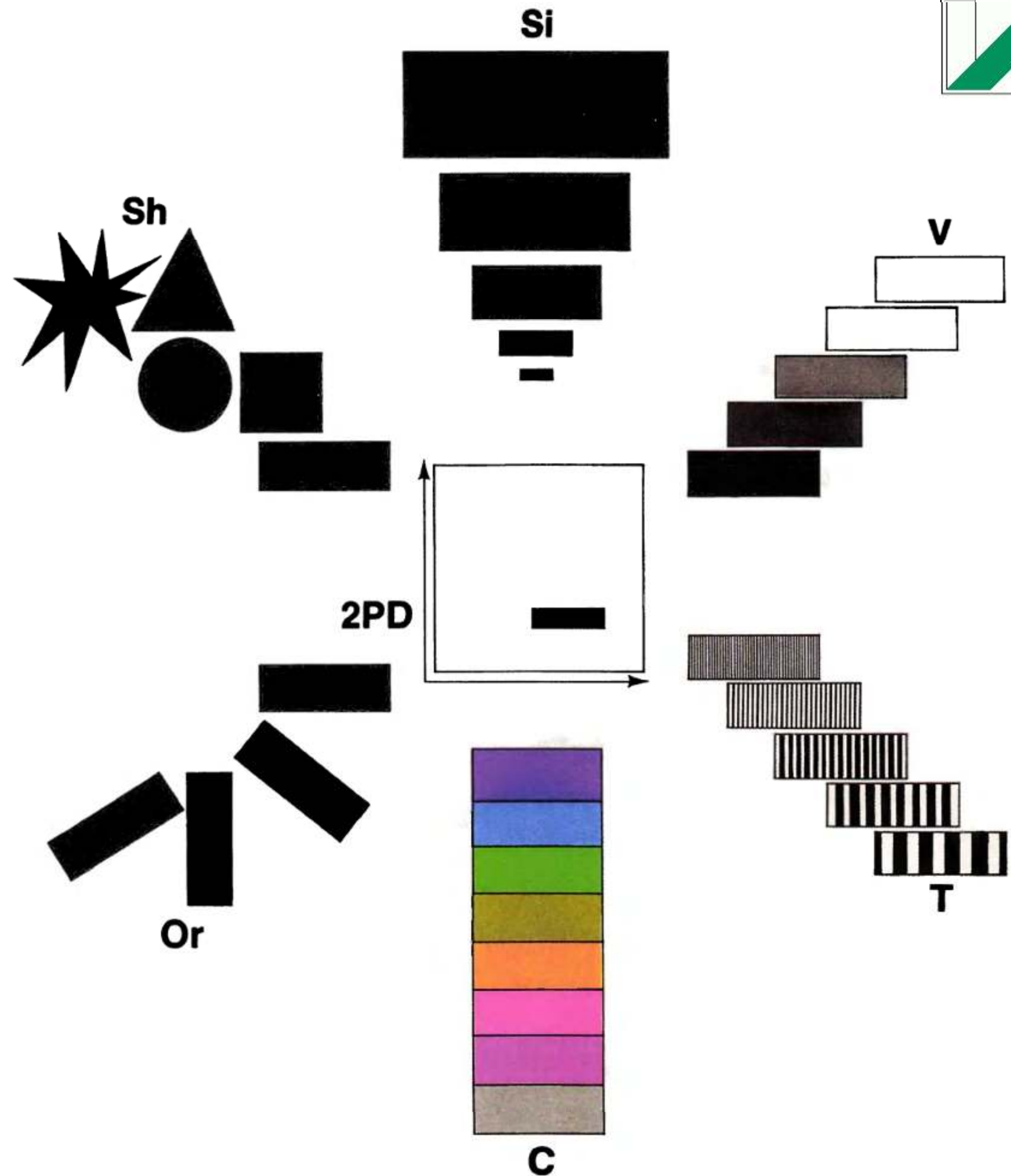
- Color
- Motion
- Orientation
- Size (including length and spatial frequency)

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

Graphical Elements

Graphical Elements

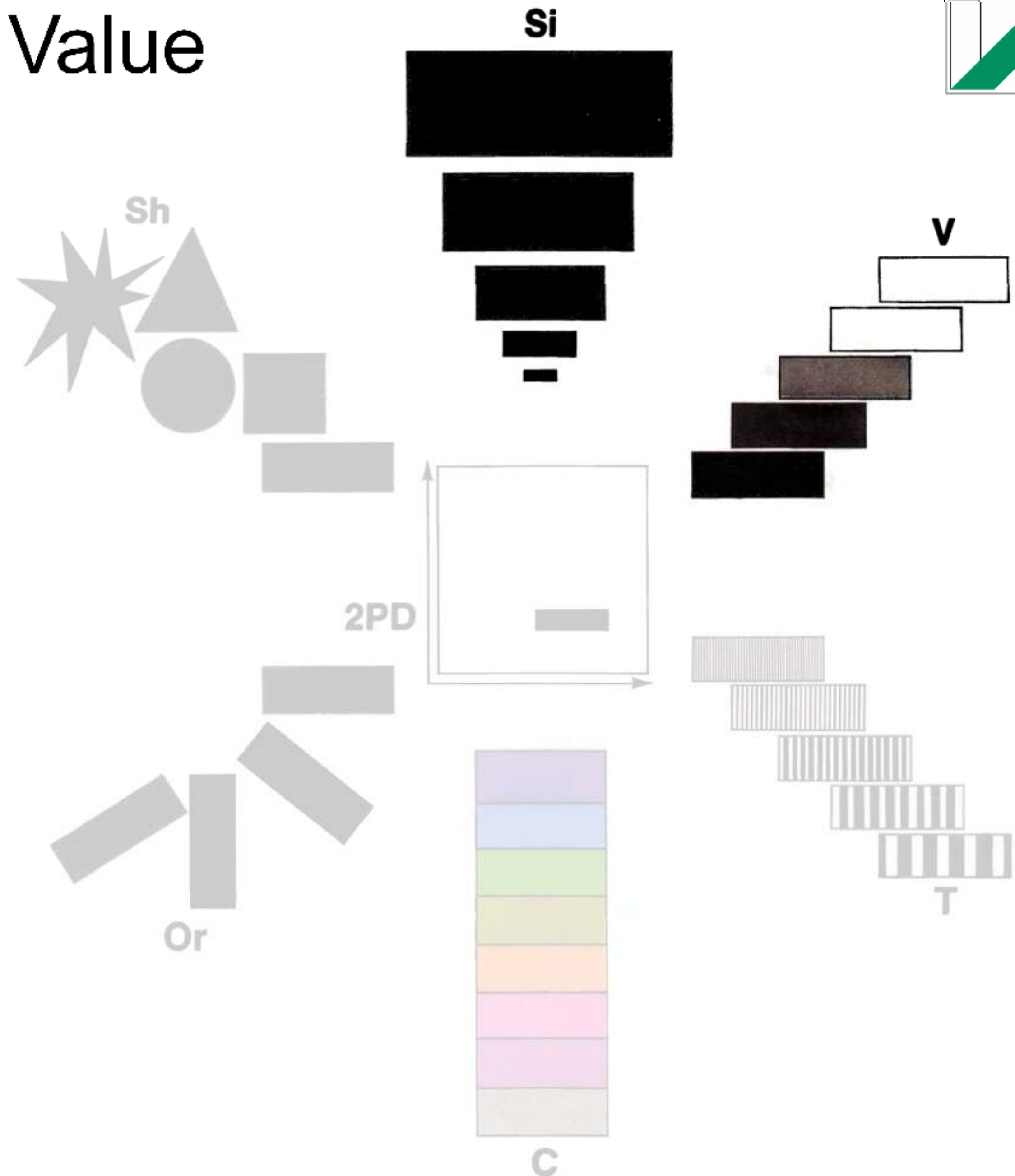
Position	: x,y location
Size	: length or area
Shape	: form
Orientation	: alignment
Value	: brightness
Texture	: patterns
Color	: hue & saturation



Graphical Elements: Size & Value

Great for showing

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

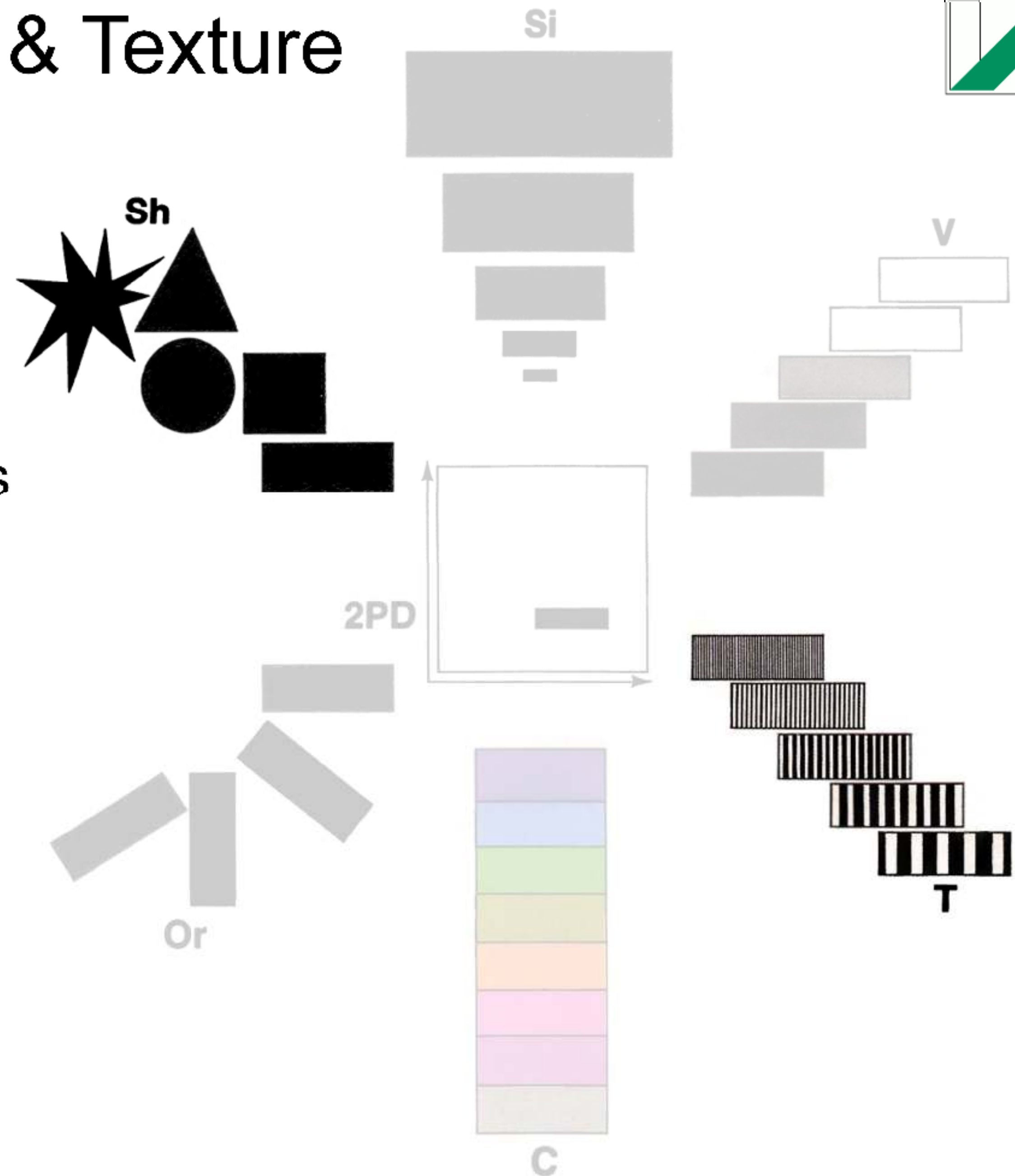


Graphical Elements: Shape & Texture

Great for showing

- Group membership

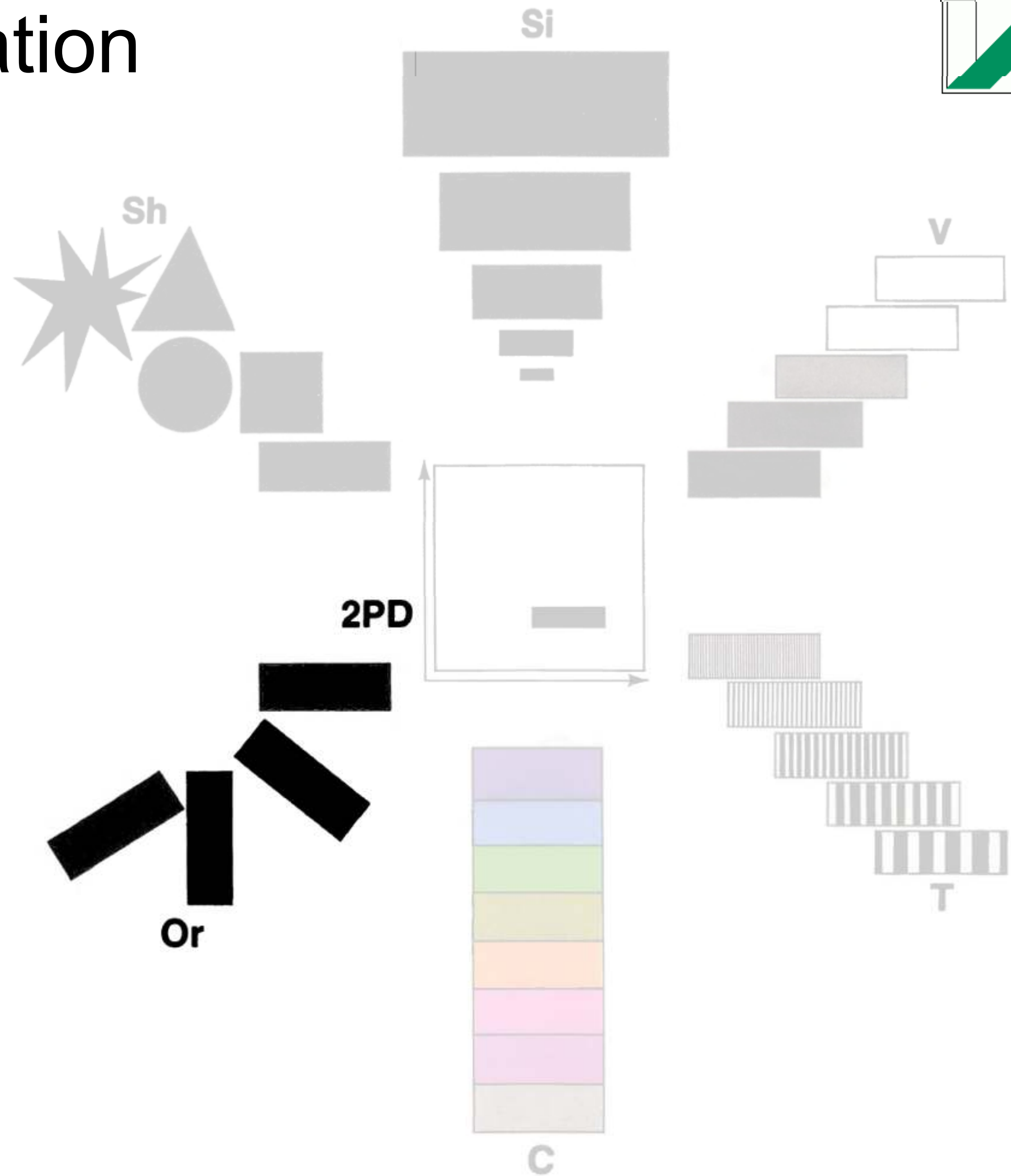
Texture can also be used to
encode different intensities/magnitudes



Graphical Elements: Orientation

Great for showing

- Movement
- Direction



Graphical Elements: Color

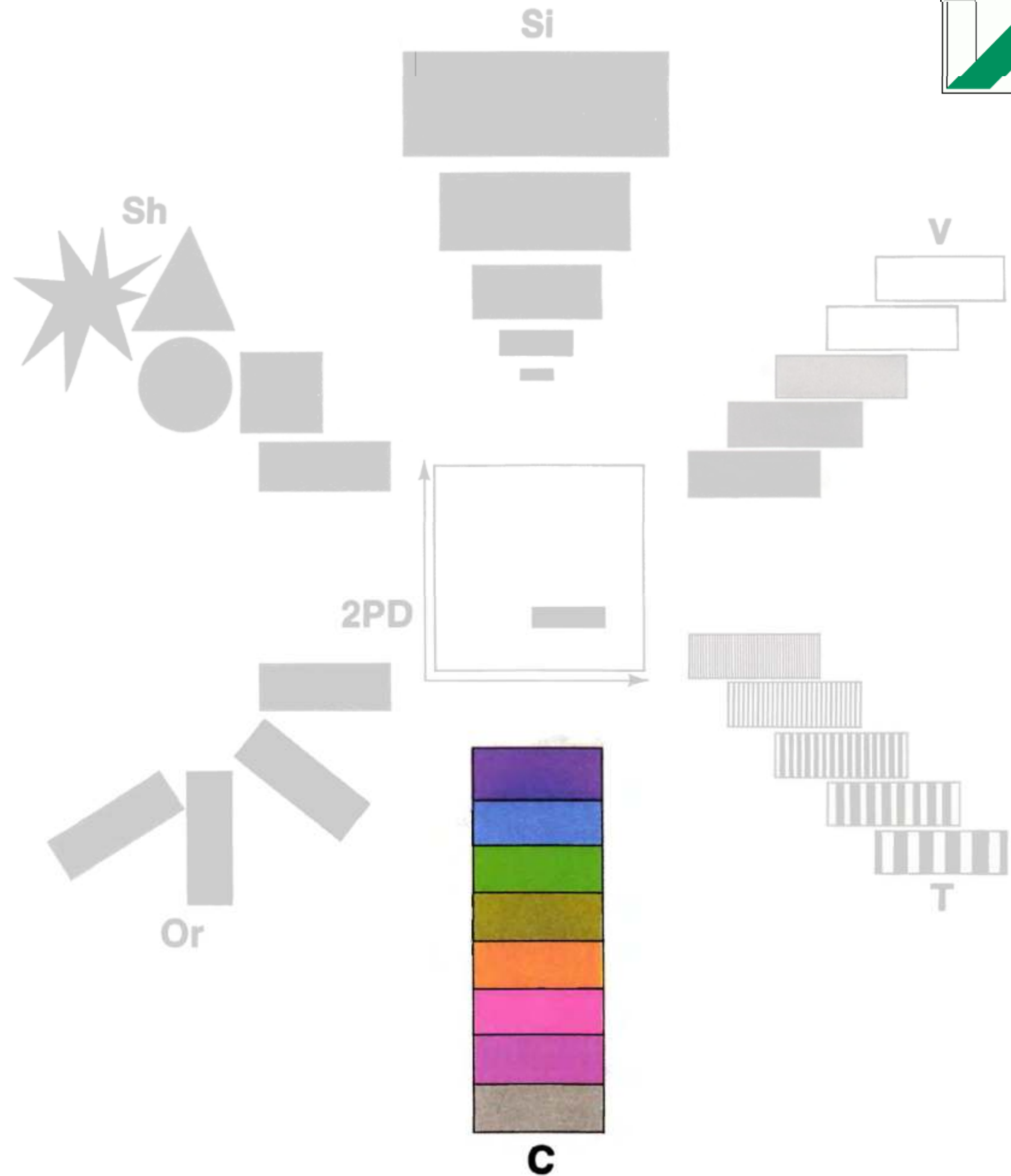
Color has two dimensions:

- Hue
for group membership
- Saturation
encodes intensities / magnitudes

Always requires a legend!

May have unintended meaning

More on colors later

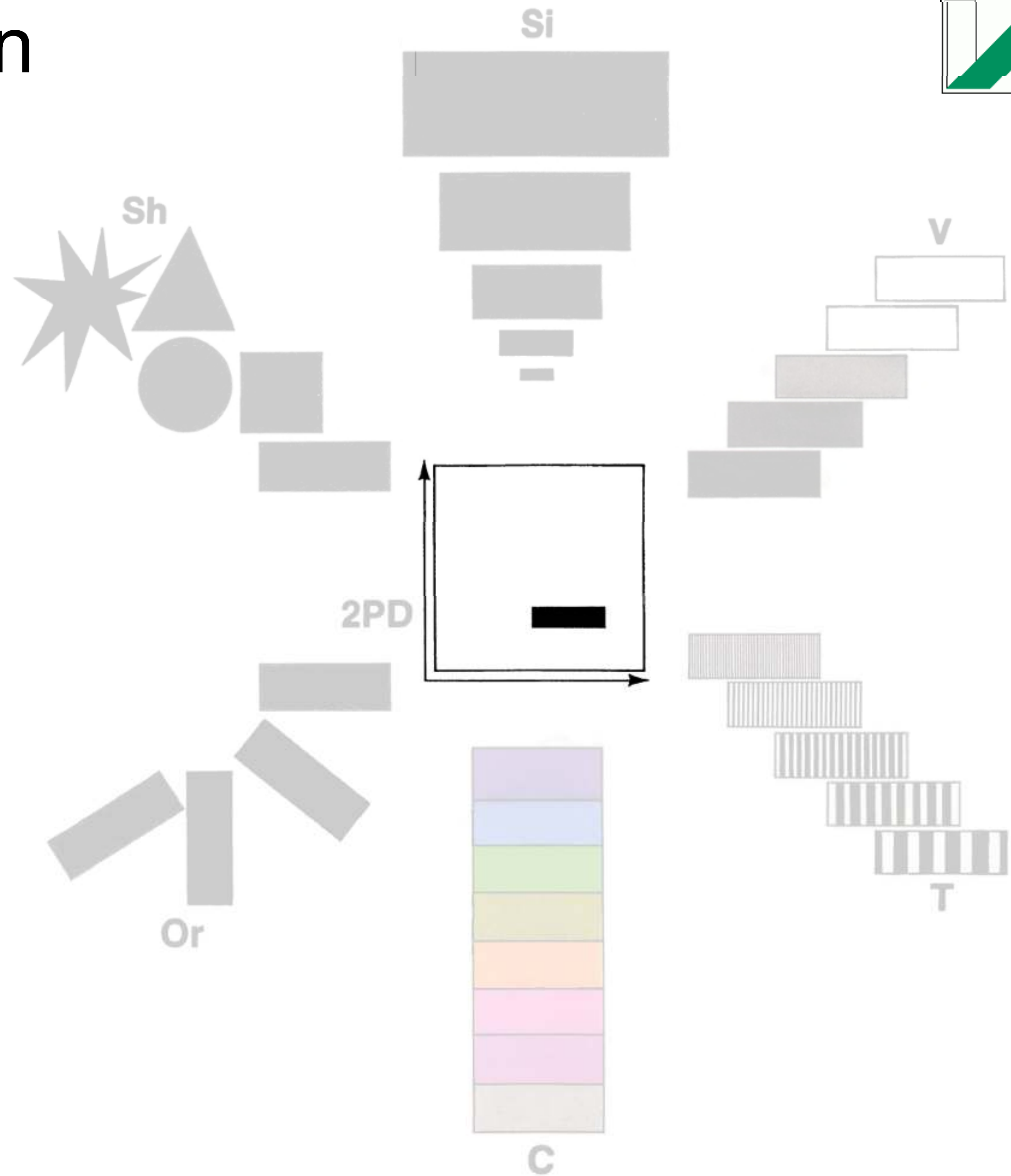


Graphical Elements: Position

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!



Perceived Grouping

Classical grouping by

b) Proximity

c) Color

d) Size

e) Common Fate

f) Good continuation

g) Closure

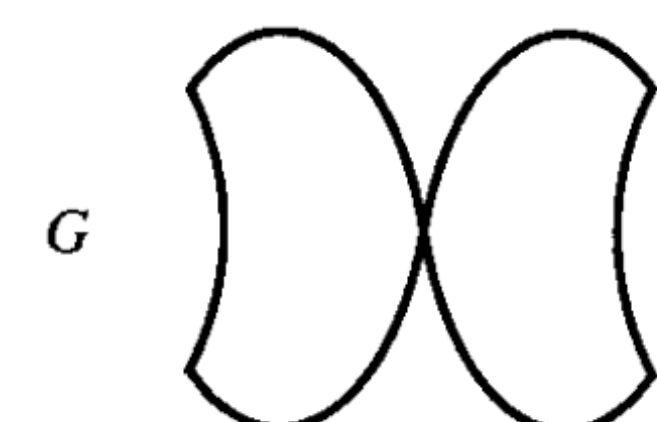
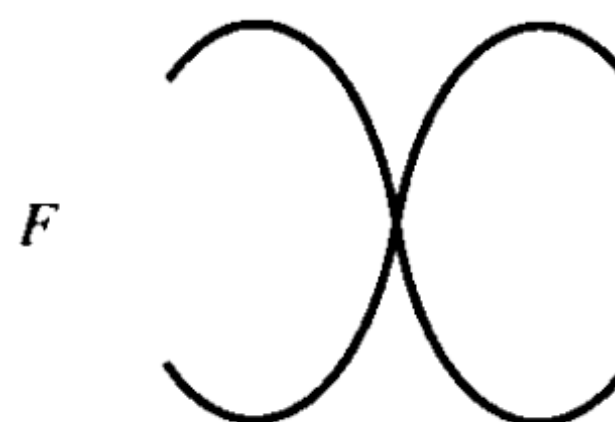
A ● ● ● ● ● ● ● ●

B ●● ●● ●● ●●

C ● ● ○ ○ ● ● ○ ○

D ●● ●● ● ● ●● ●● ● ●

E ↑● ↑● ↓● ↓● ↑● ↑● ↓● ↓●



Gestalt Theory

Scientific efforts to understand pattern perception

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

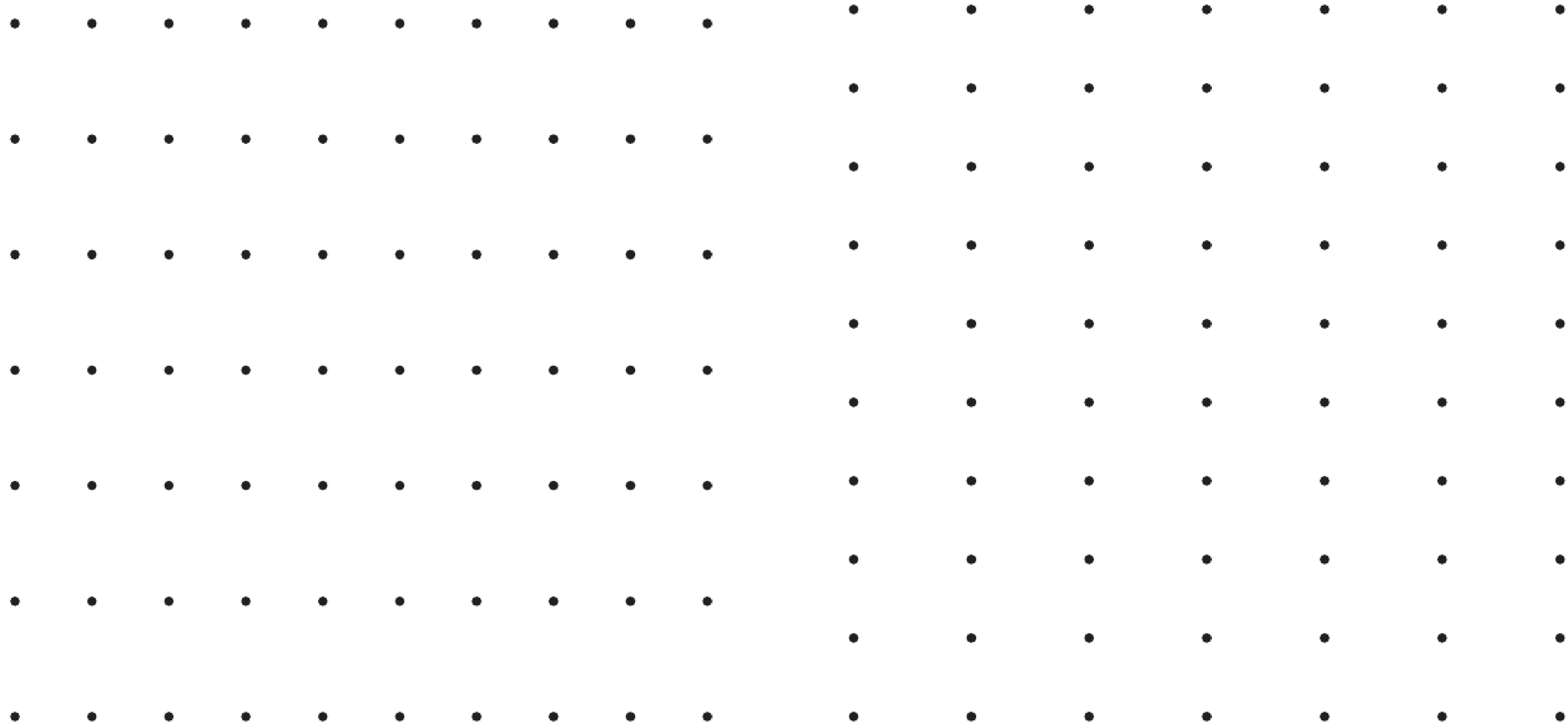
e.g. based on proximity, similarity, connectedness, continuity, symmetry, closure, relative size, and common fate

Often translated into design principles for information visualization

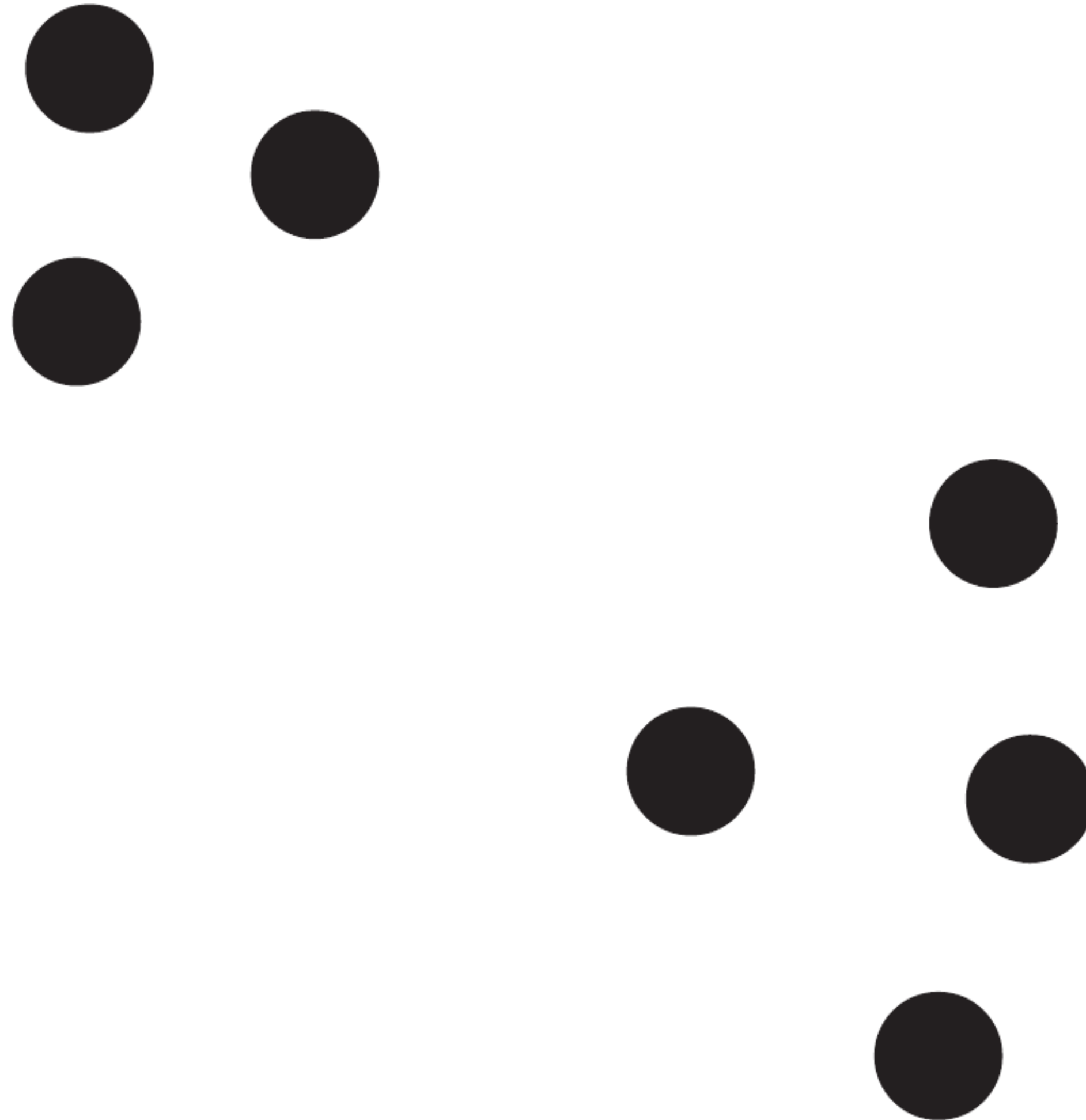
Use these elements to think about how to organize data so that important structures will be perceived

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

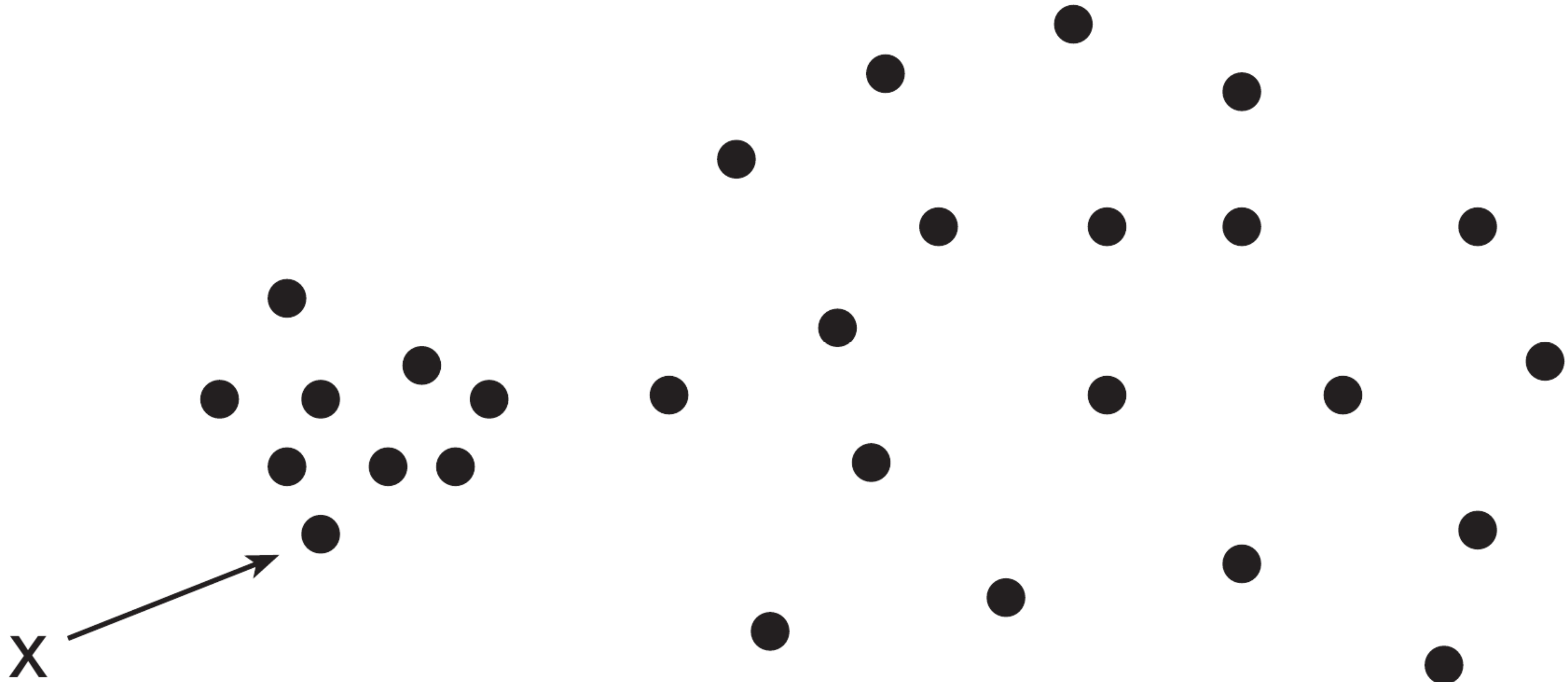
Proximity



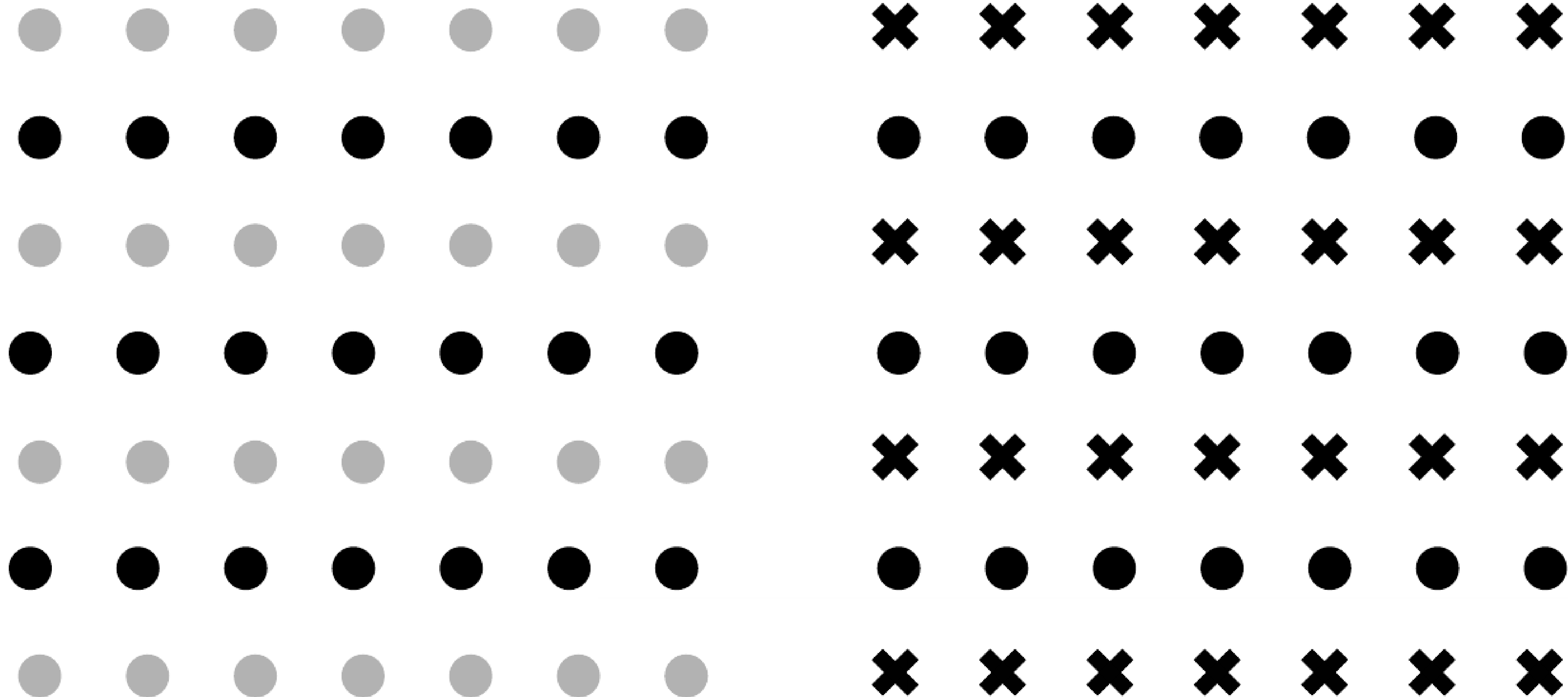
Proximity



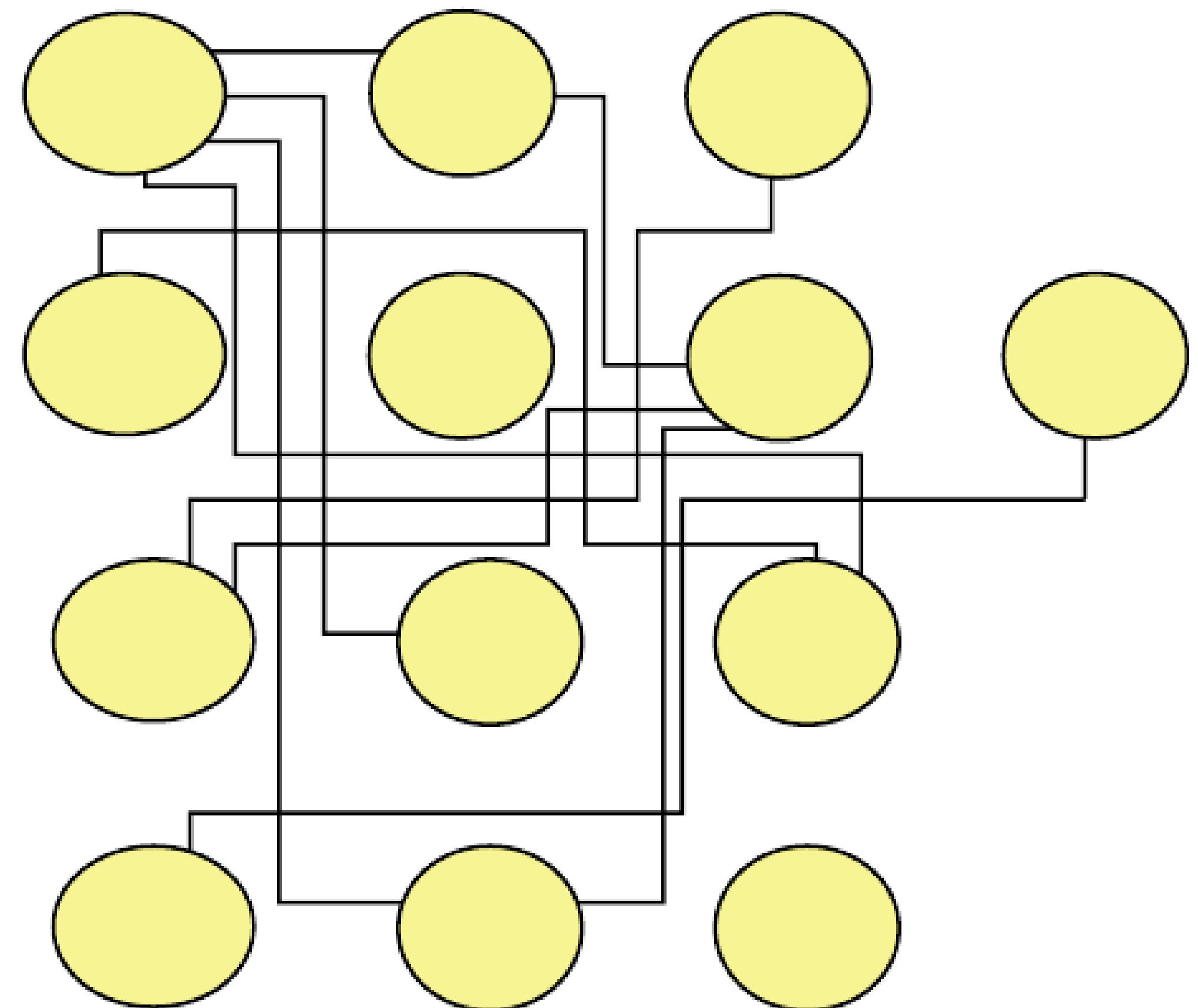
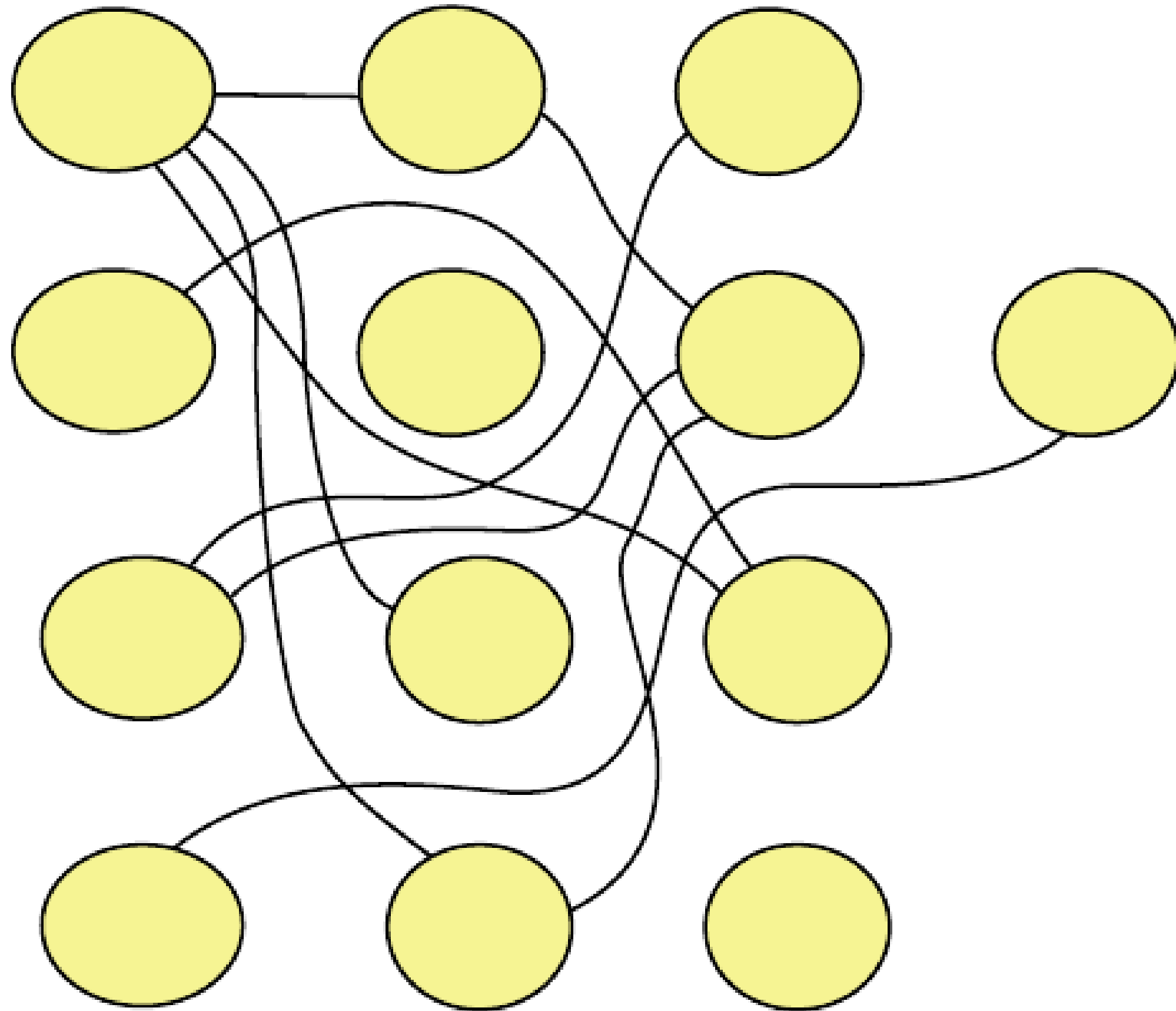
Spatial Concentration



Shape



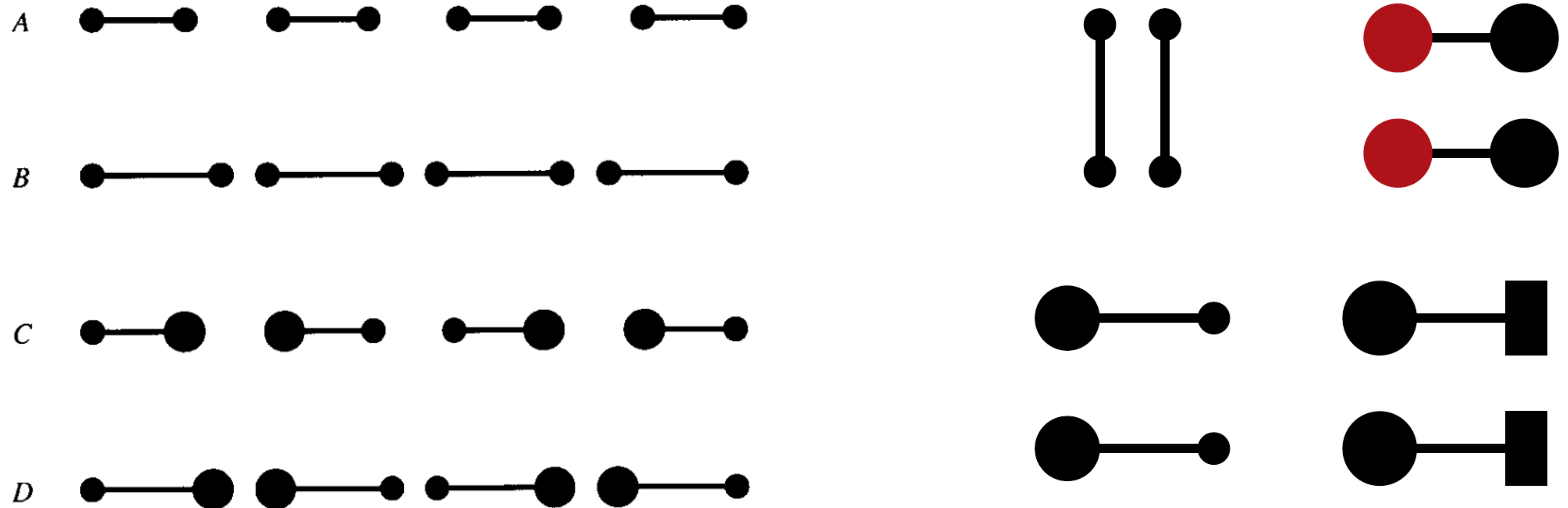
Connectedness



Uniform Connectedness

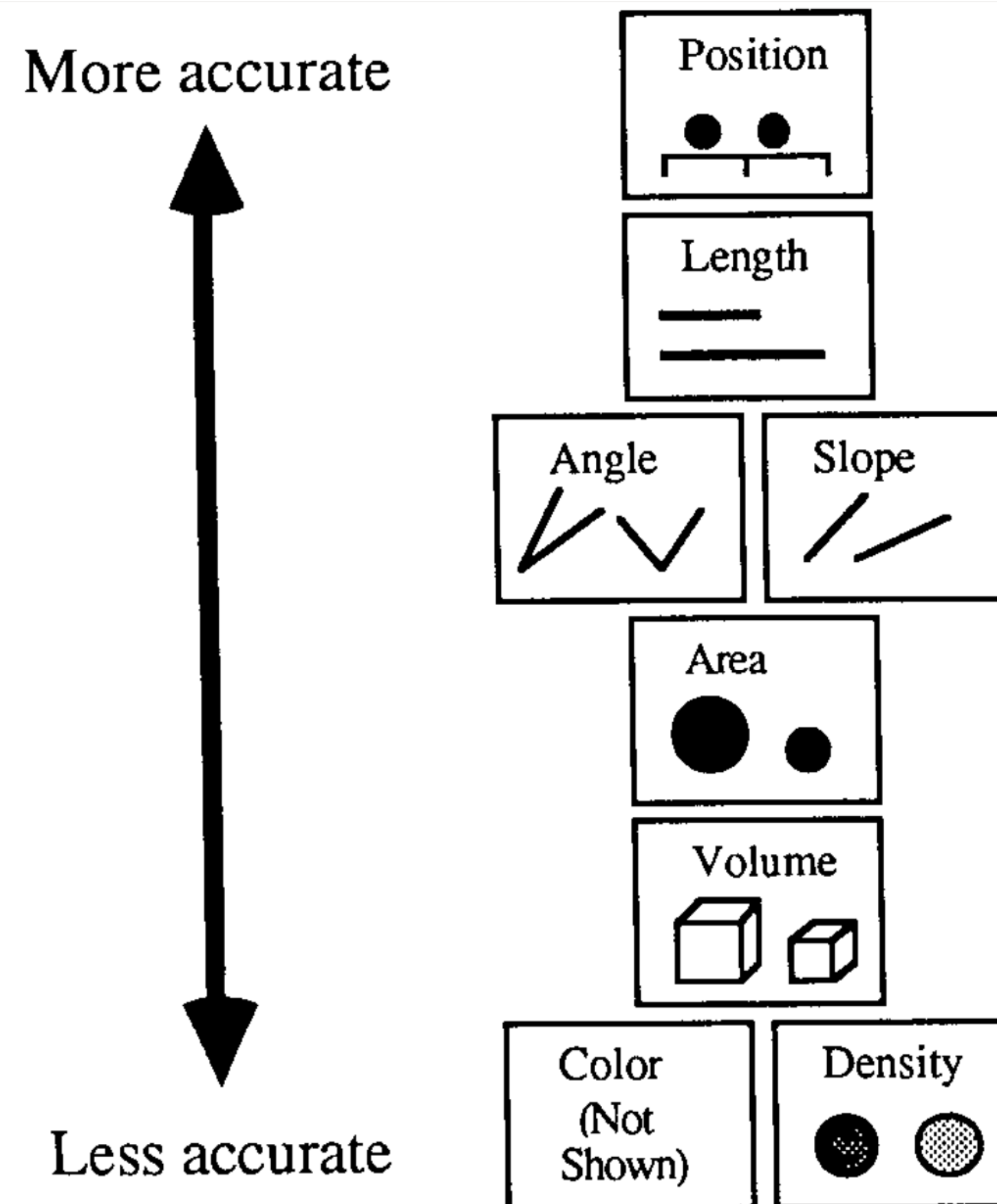
Principle of perceptual organization

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

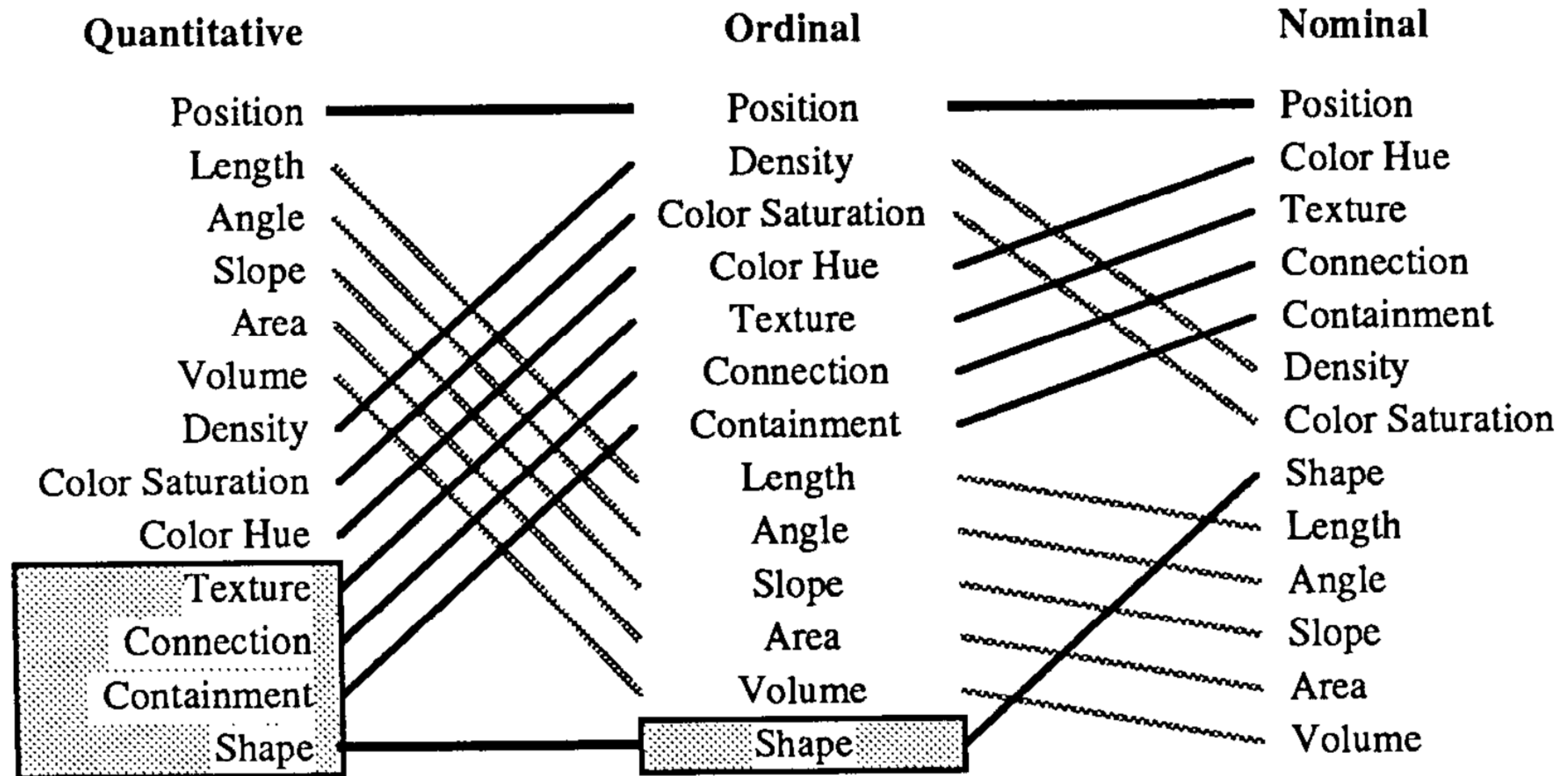


Different Graphical Elements for Different Types of Data

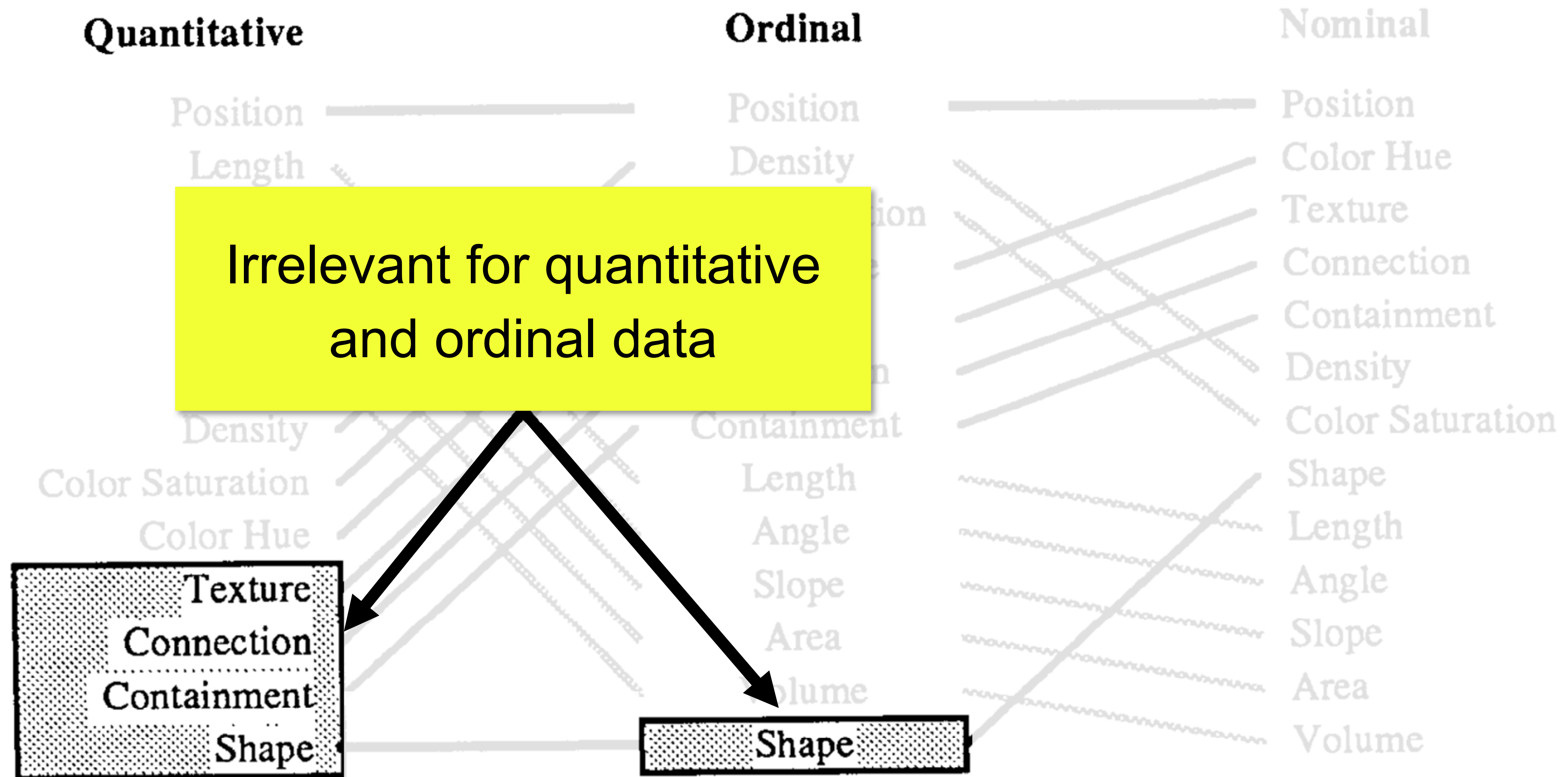
Encoding Quantitative Information



Encoding Data Types



Encoding Data Types



Encoding Data Types

Quantitative

Position

Length

Ordinal

Position

Density

Nominal

Position

Color Hue

Texture

Connection

Containment

Density

Color Saturation

Shape

Length

Angle

Slope

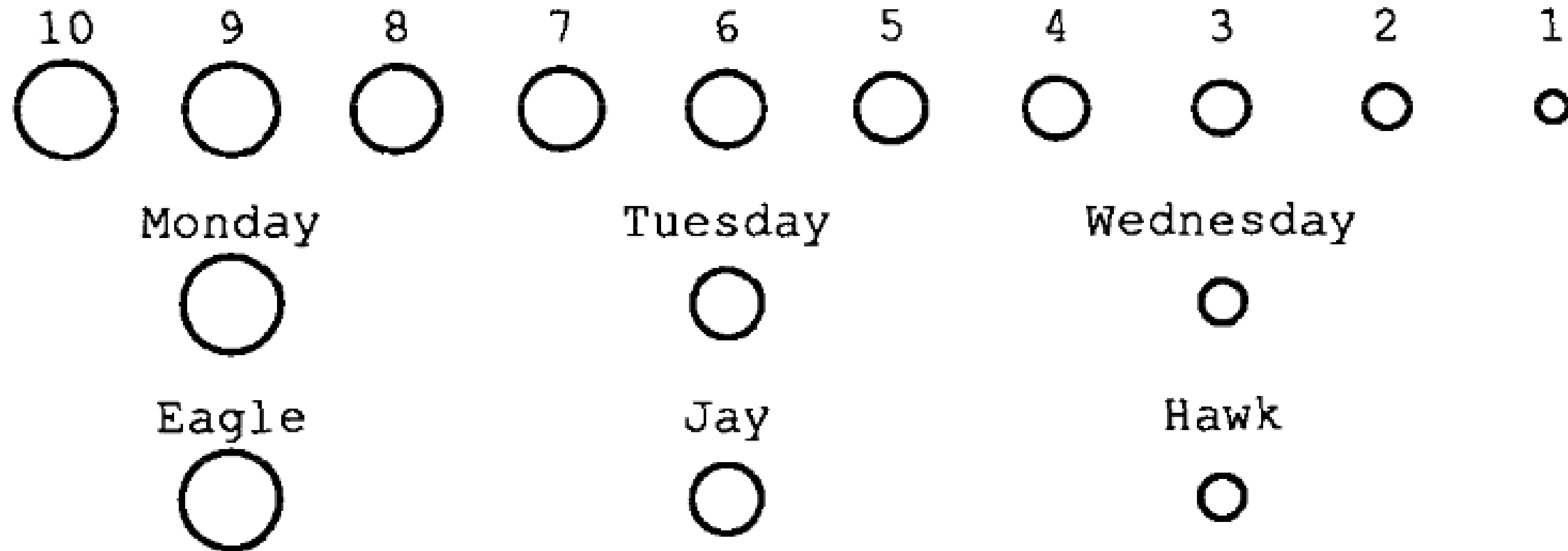
Area

Volume

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

Use it wisely!

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



Beware of the Scaling Problem When Using Area

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



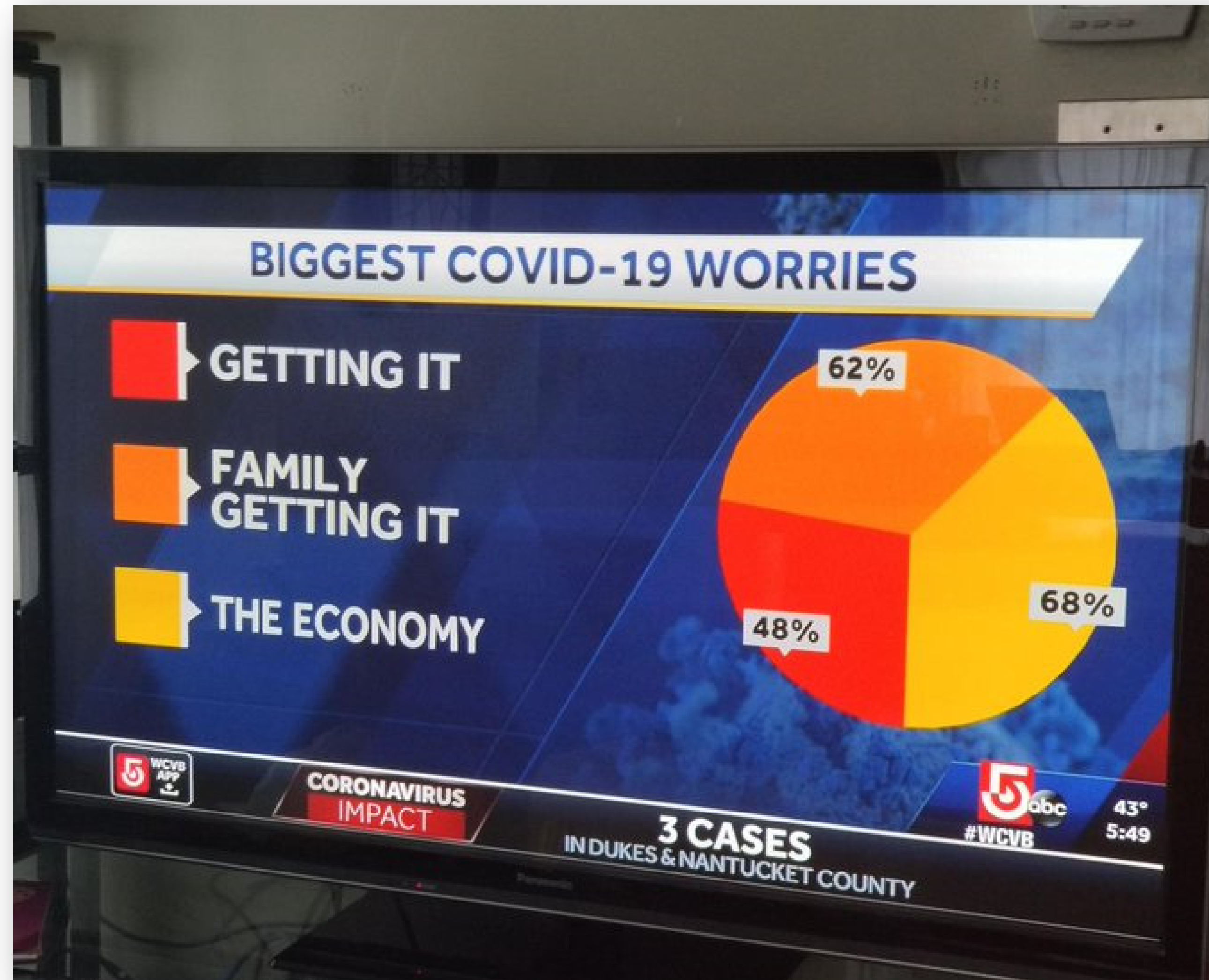
Perceived magnitude of area: 1.60
Actual magnitude of area: 2.00



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

Graphical Integrity

People are 178% worried

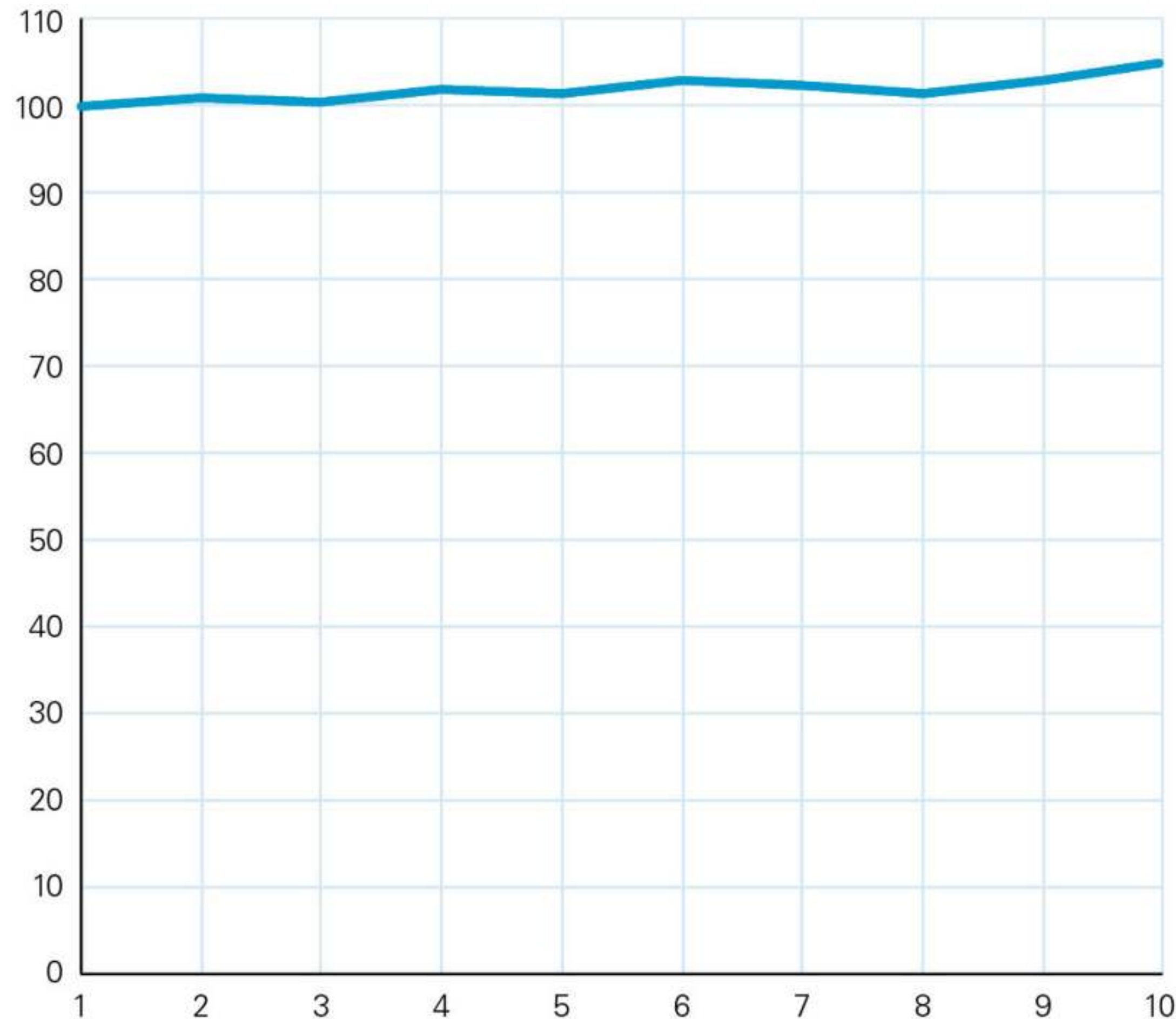


Trust only the statistics that you have falsified yourself



Assume these sales figures:

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

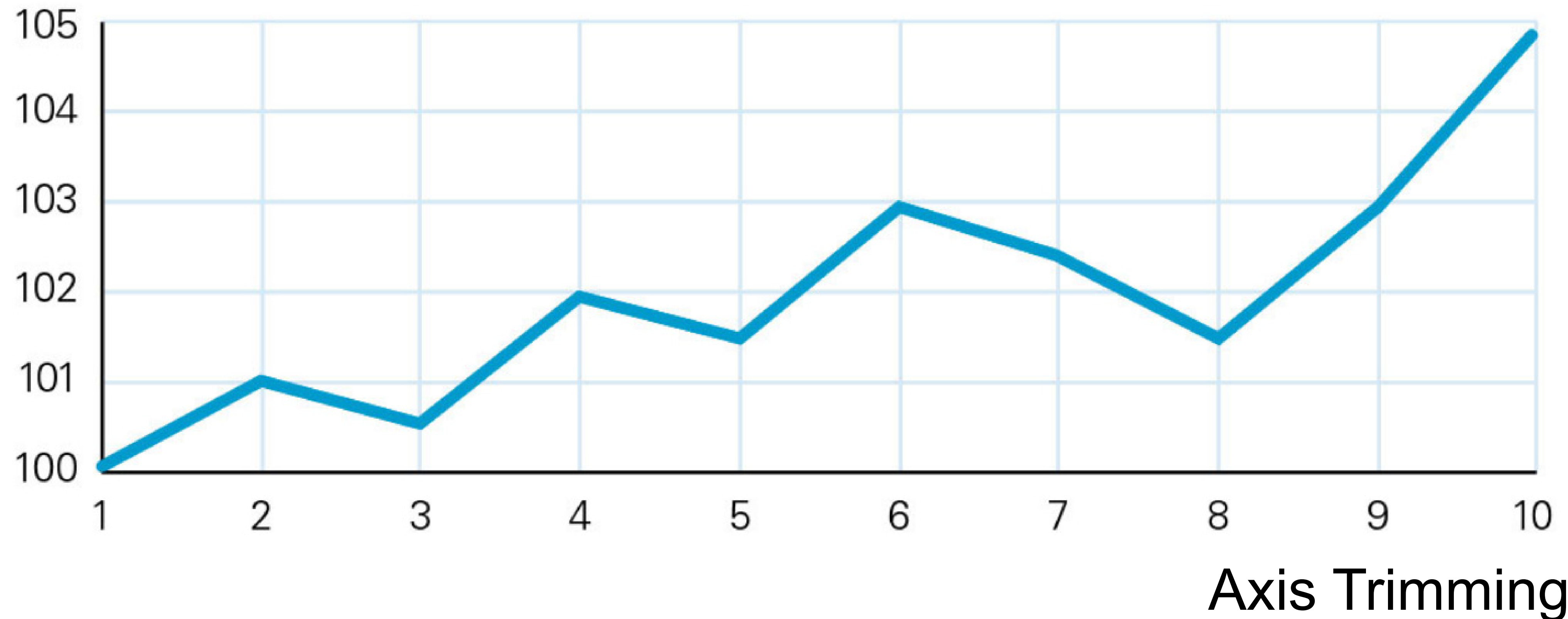


Trust only the statistics that you have falsified yourself



Assume these sales figures:

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

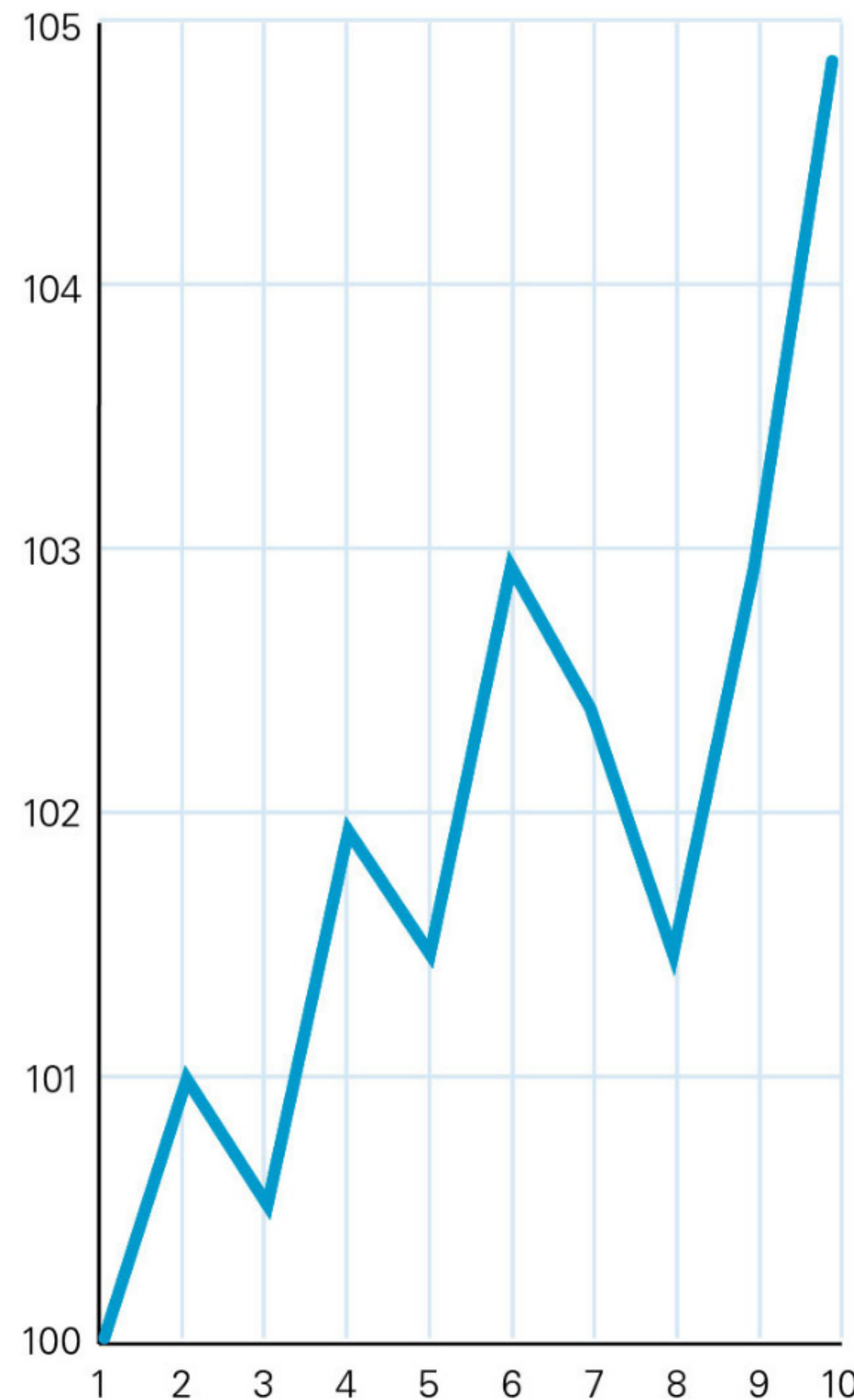


Trust only the statistics that you have falsified yourself



Assume these sales figures:

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



Axis Expansion /
Compression

Trust only the statistics that you have falsified yourself



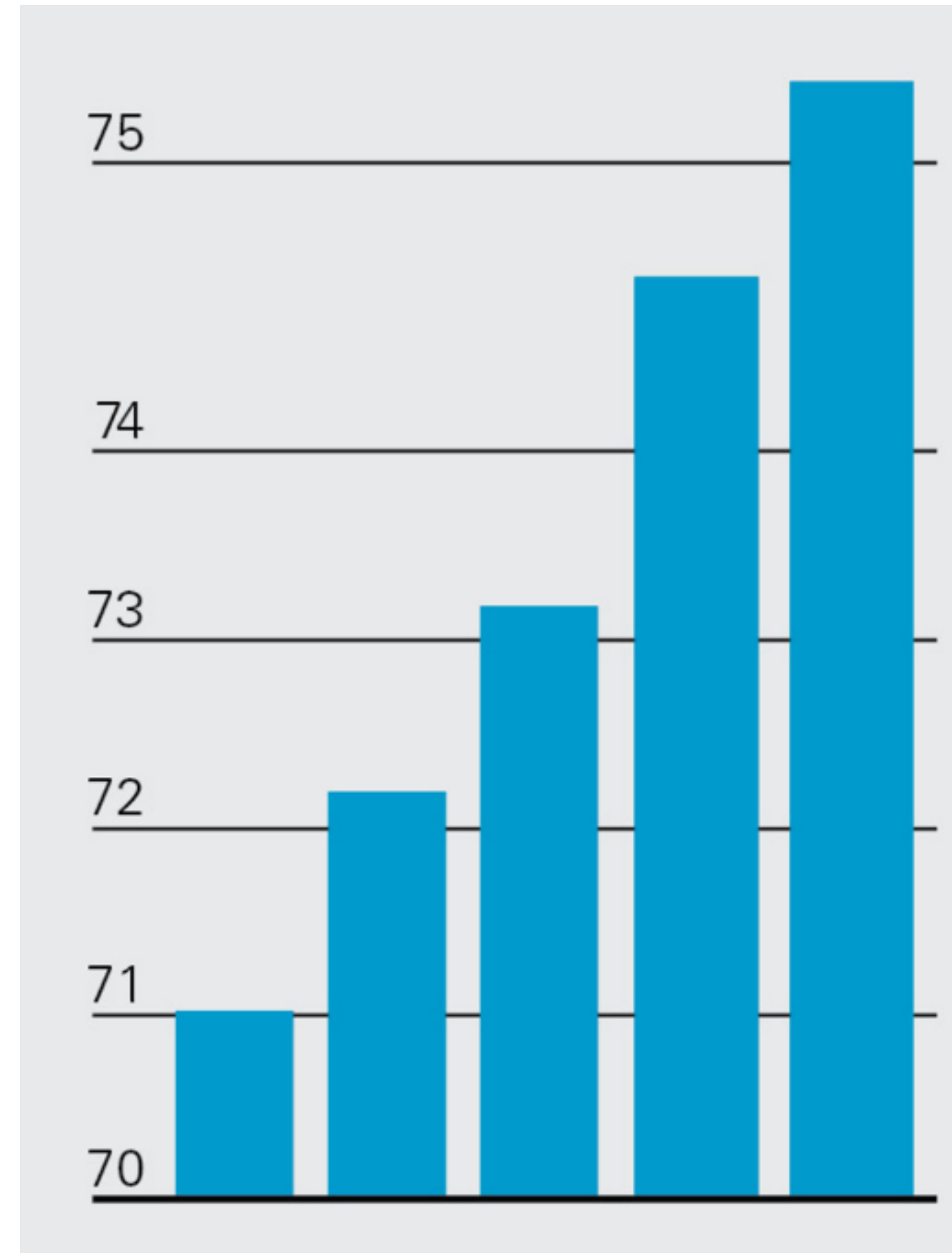
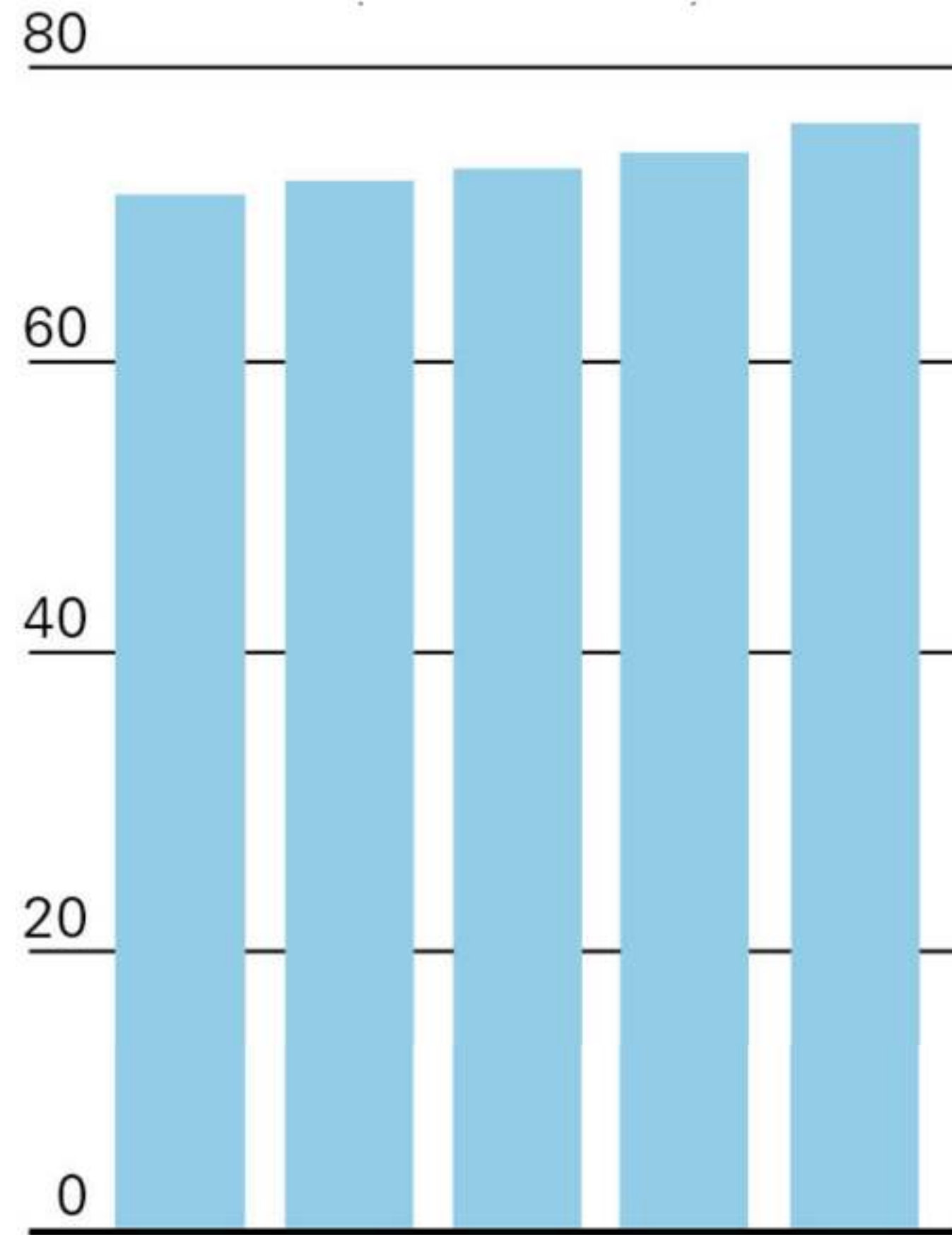
Assume these sales figures:

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



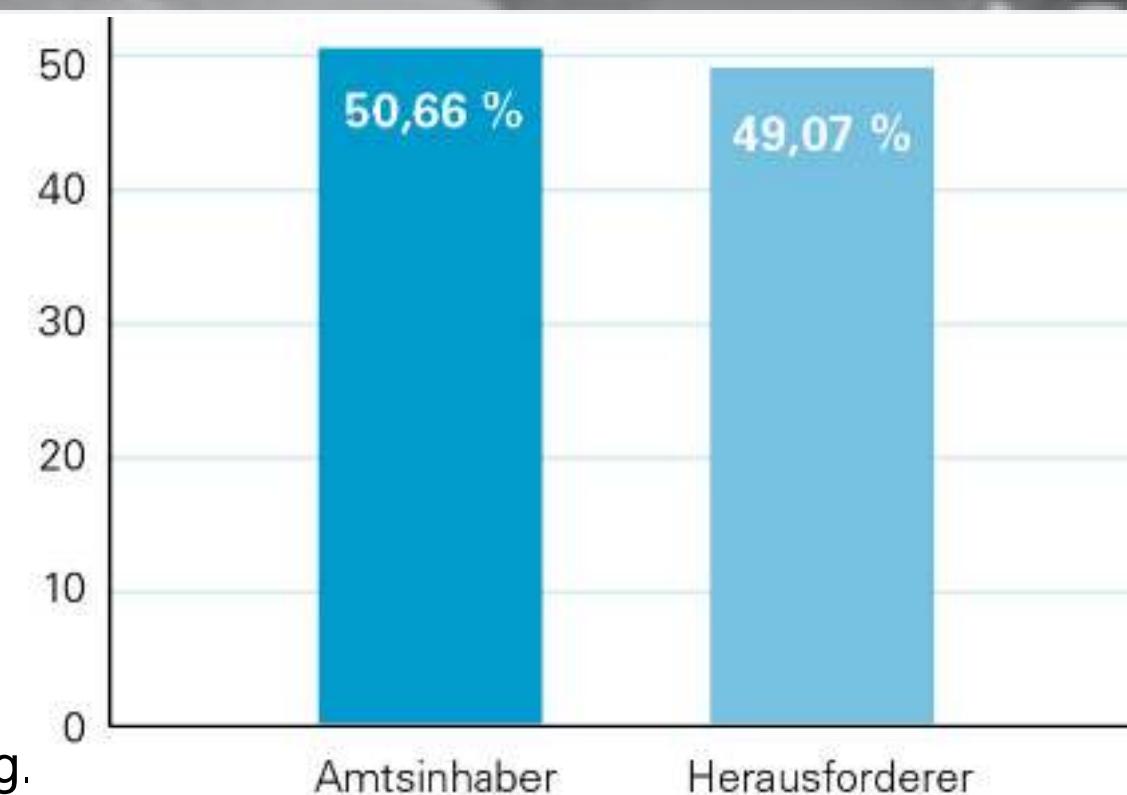
Remove Labels

Trust only the statistics that you have falsified yourself



Trimming of Axis

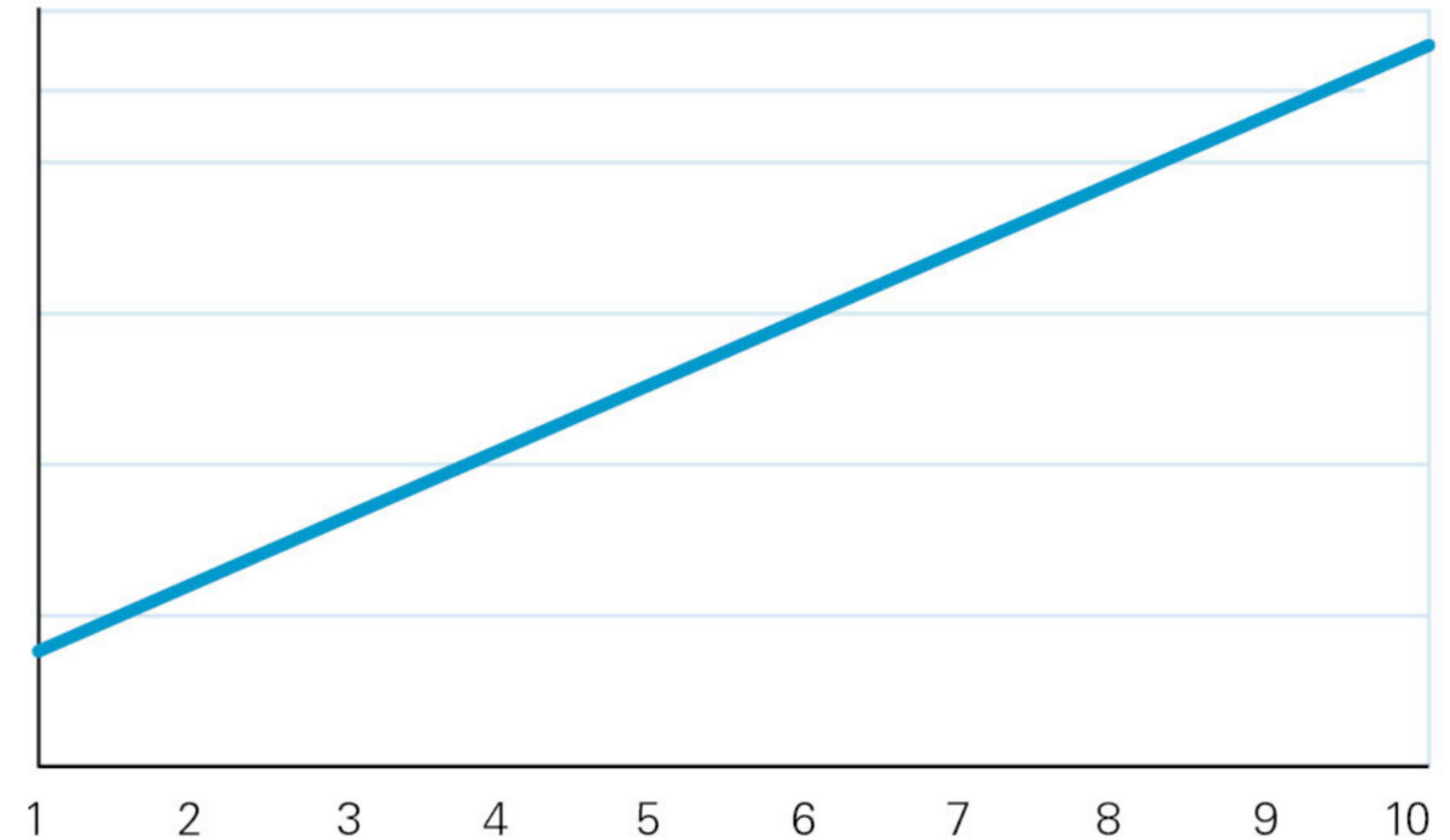
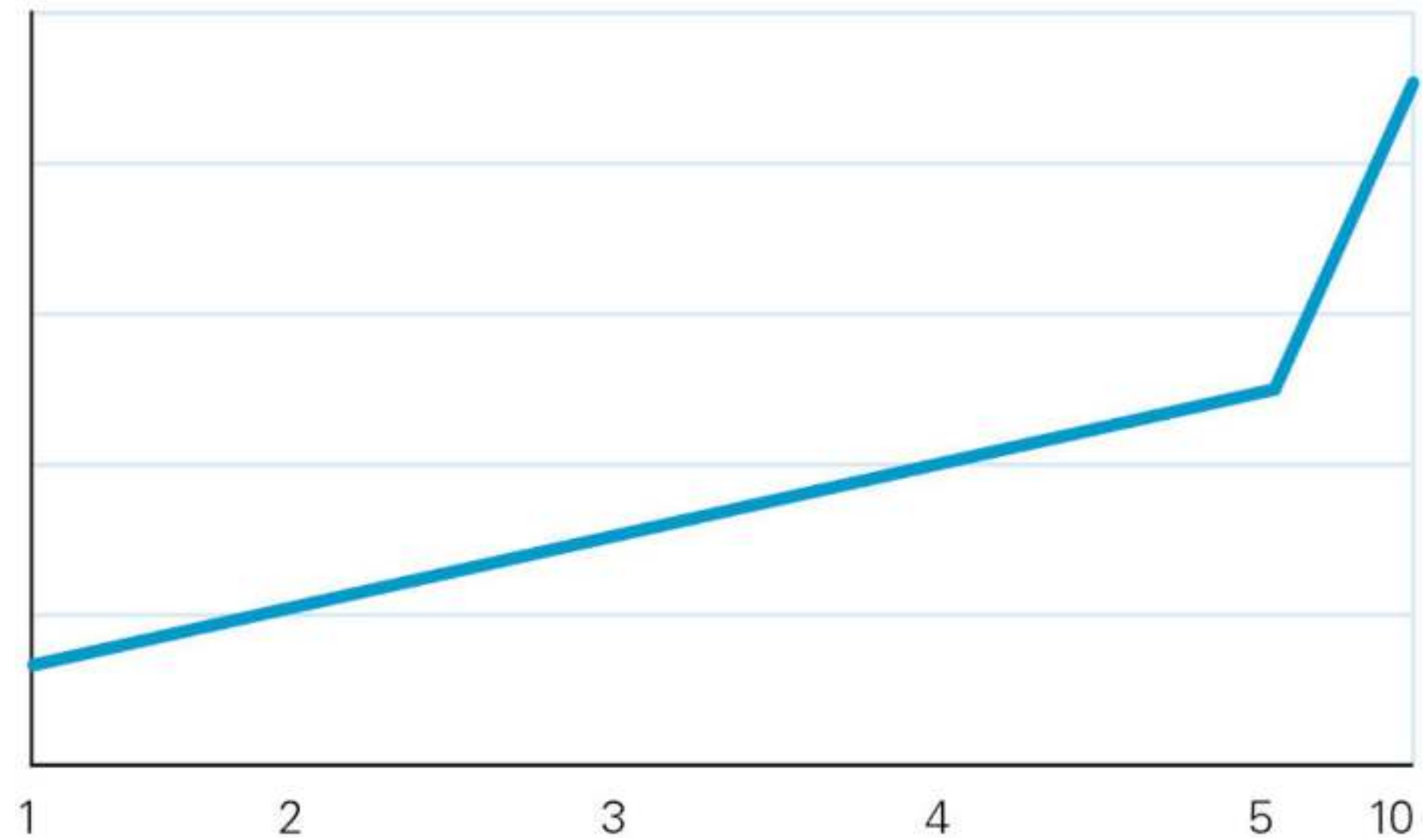
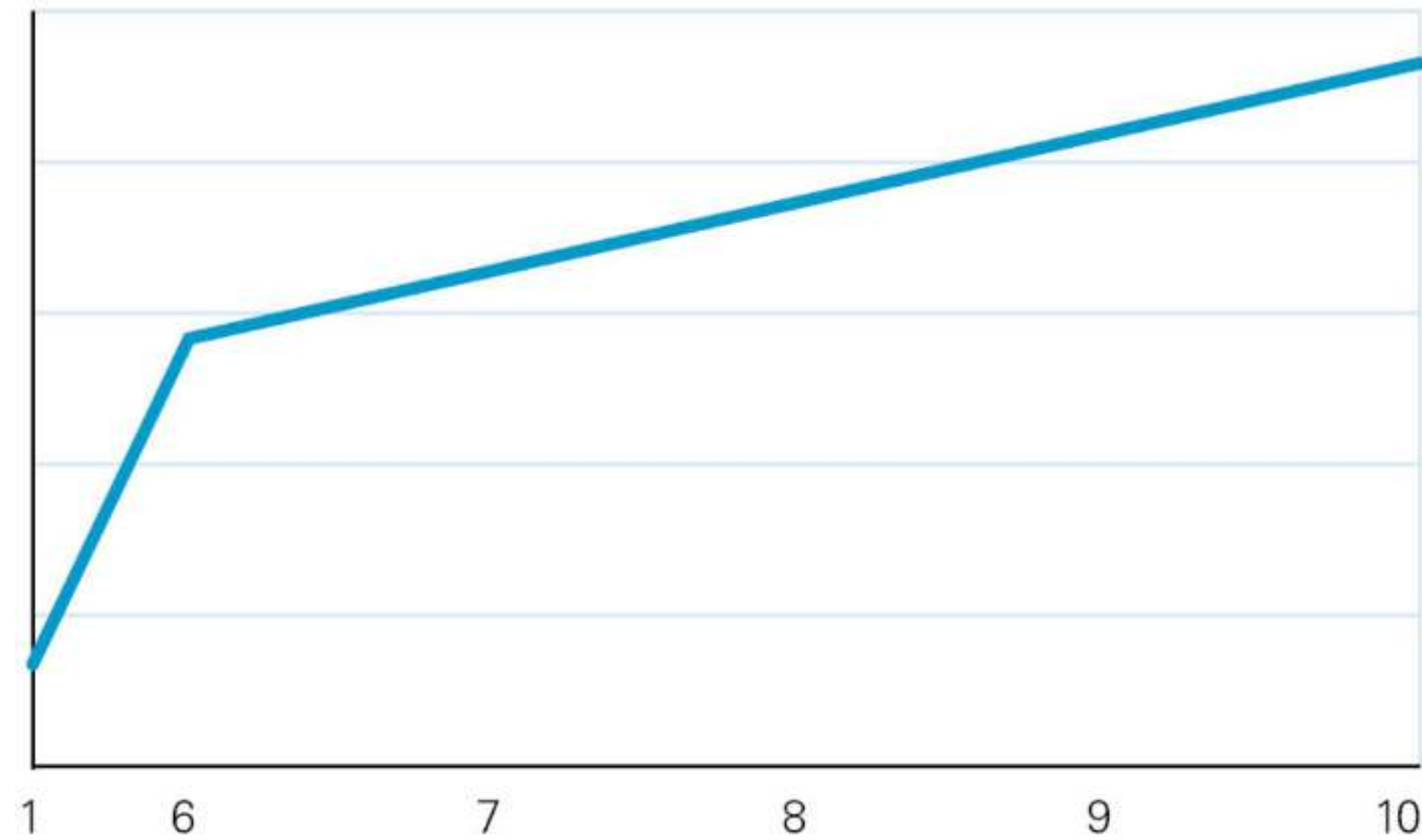
Trust only the statistics that you have falsified yourself



A Venezualian election

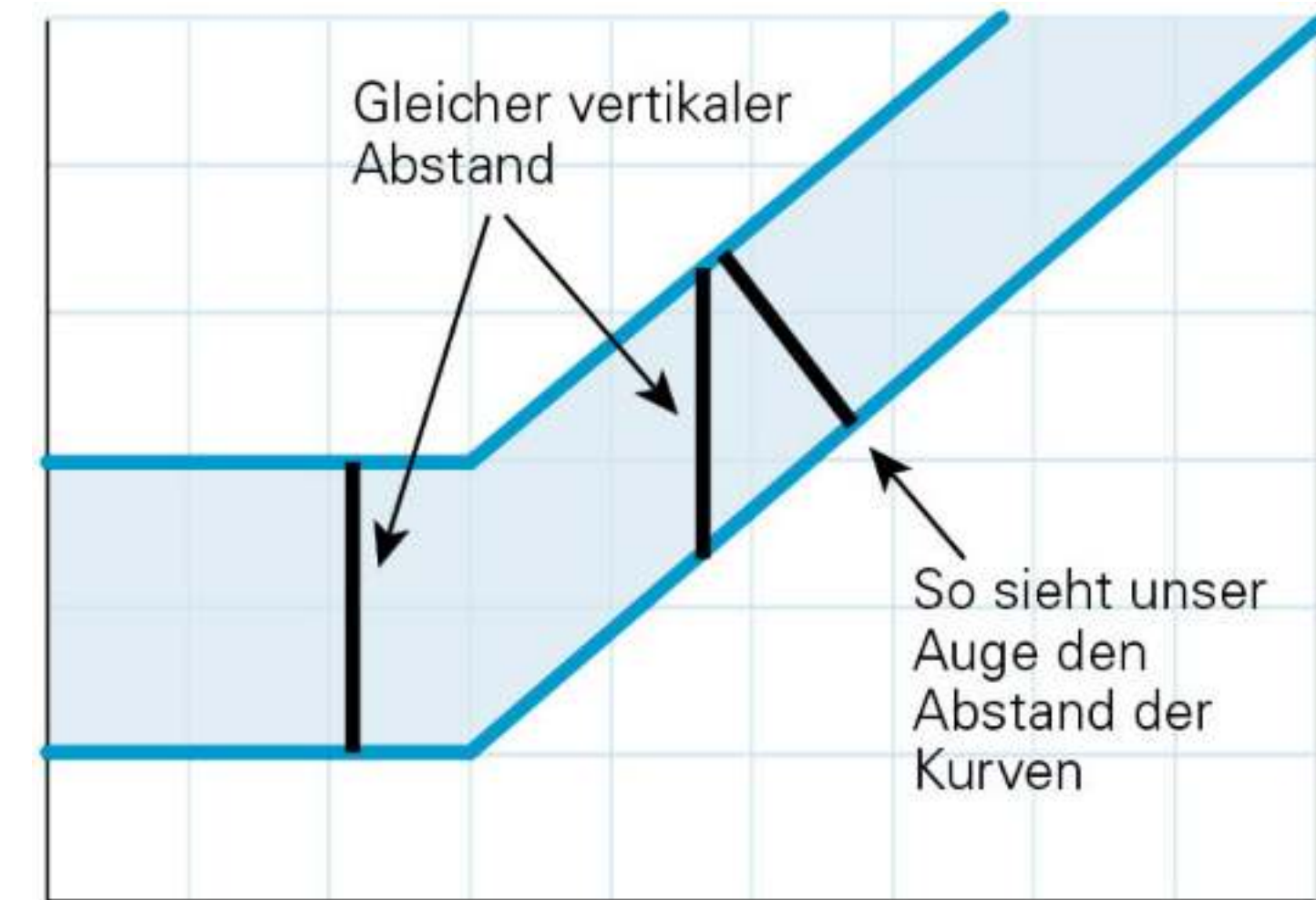
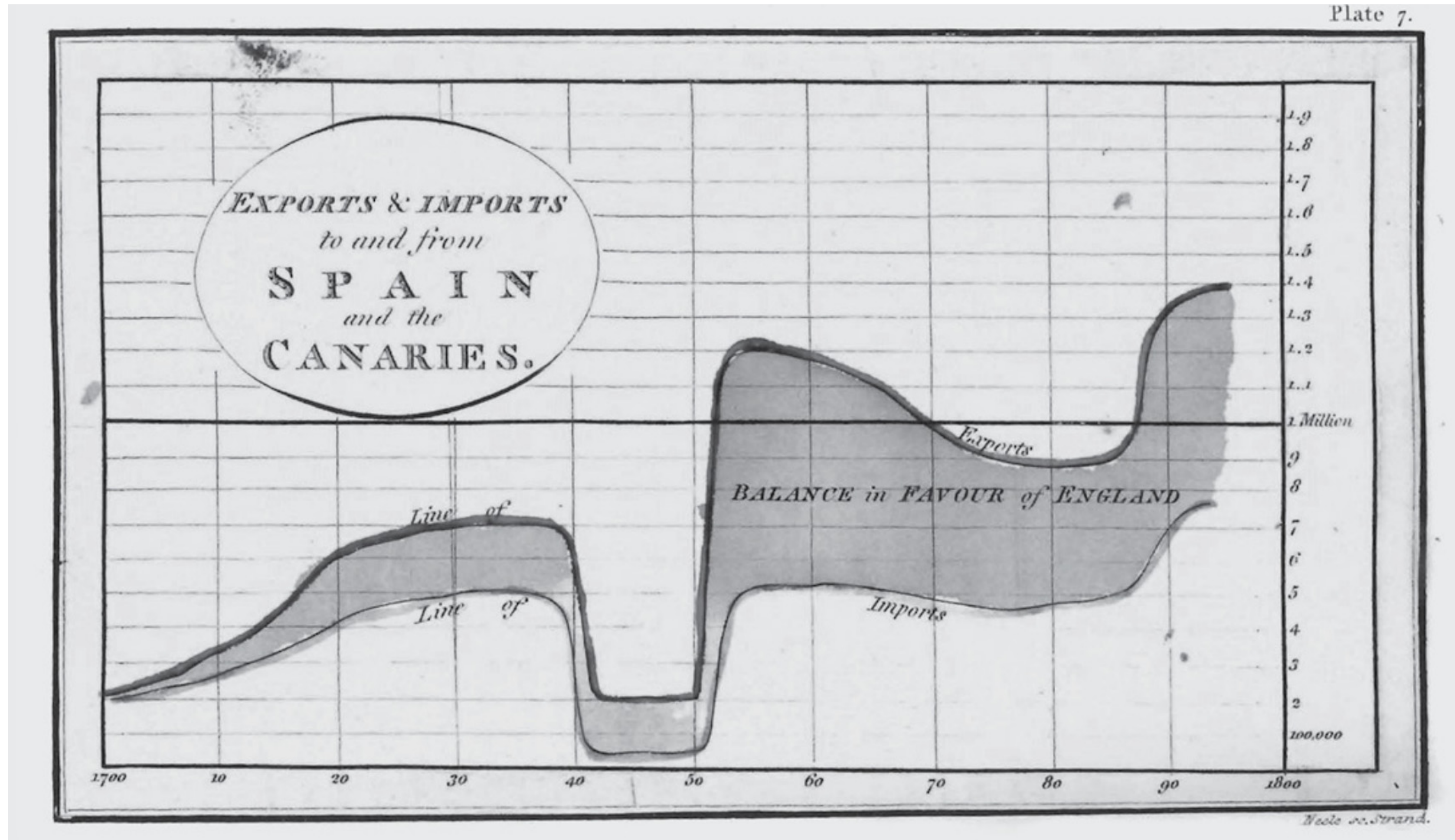
Trimming of Axis

Trust only the statistics that you have falsified yourself



Partial Expansion /
Compression of Axis

Trust only the statistics that you have falsified yourself



Our eye interprets distances not perpendicularly, but orthogonal

The thing with curves

Trust only the statistics that you have falsified yourself



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



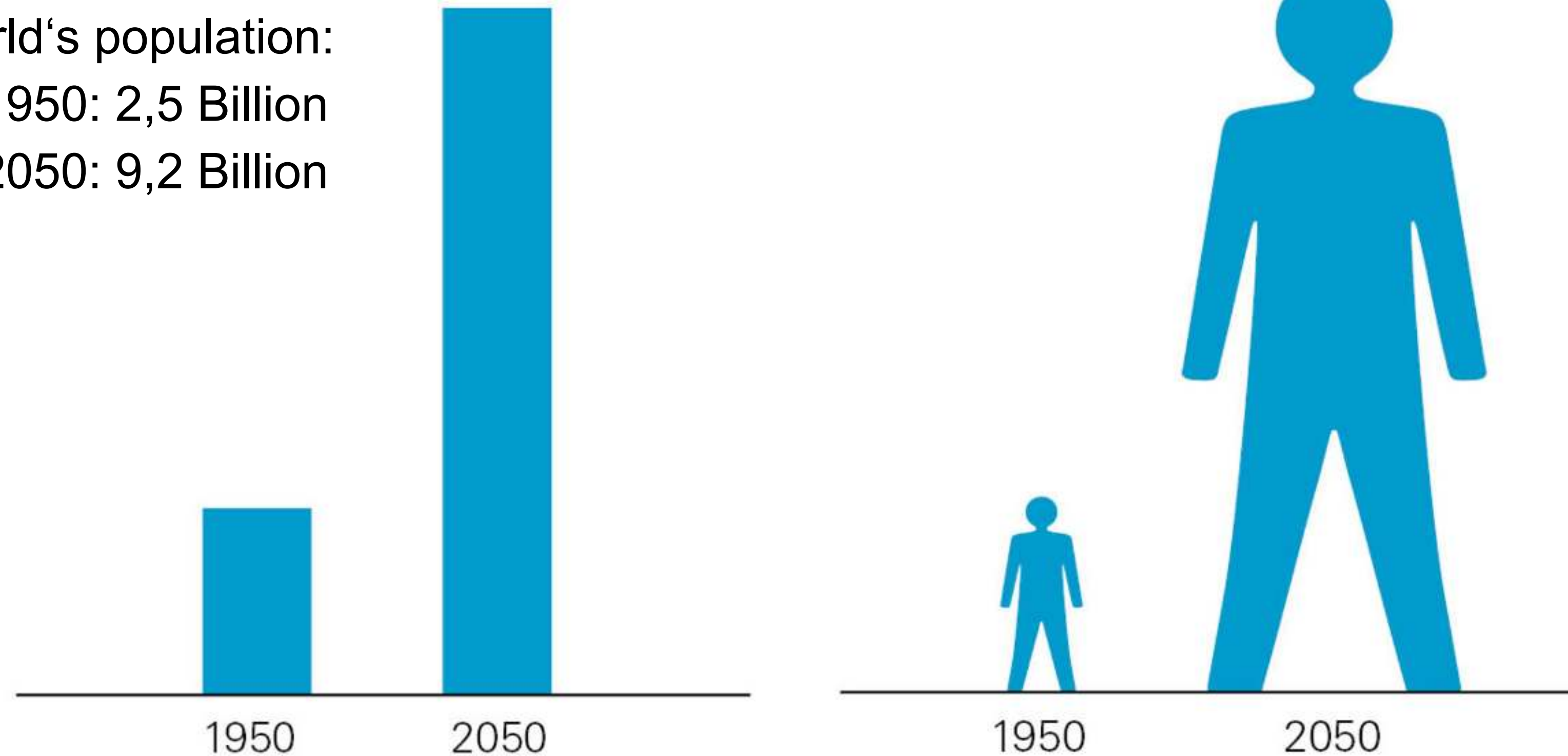
B

Perception of Areas and Volumes

Trust only the statistics that you have falsified yourself

World's population:

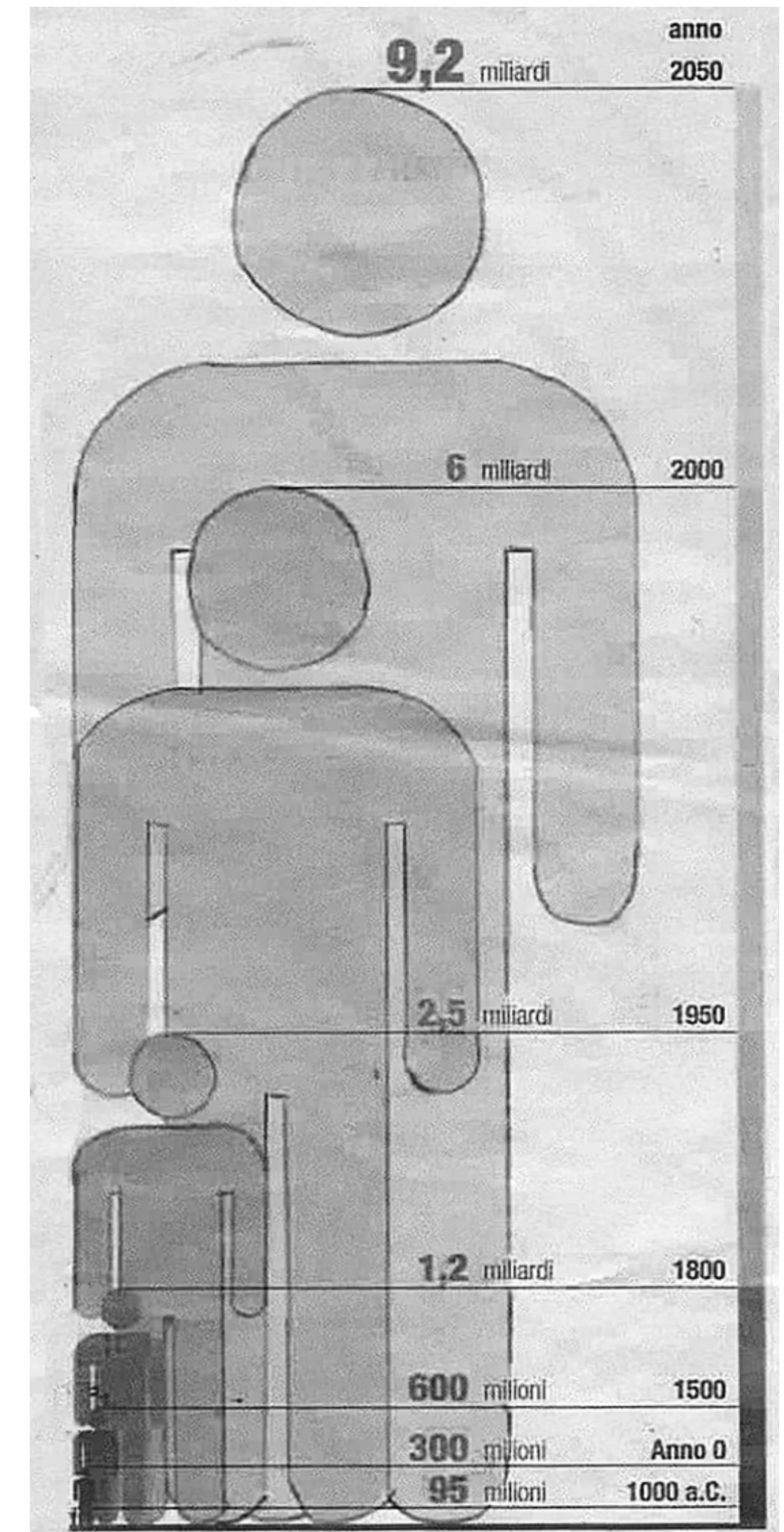
- 1950: 2,5 Billion
- 2050: 9,2 Billion



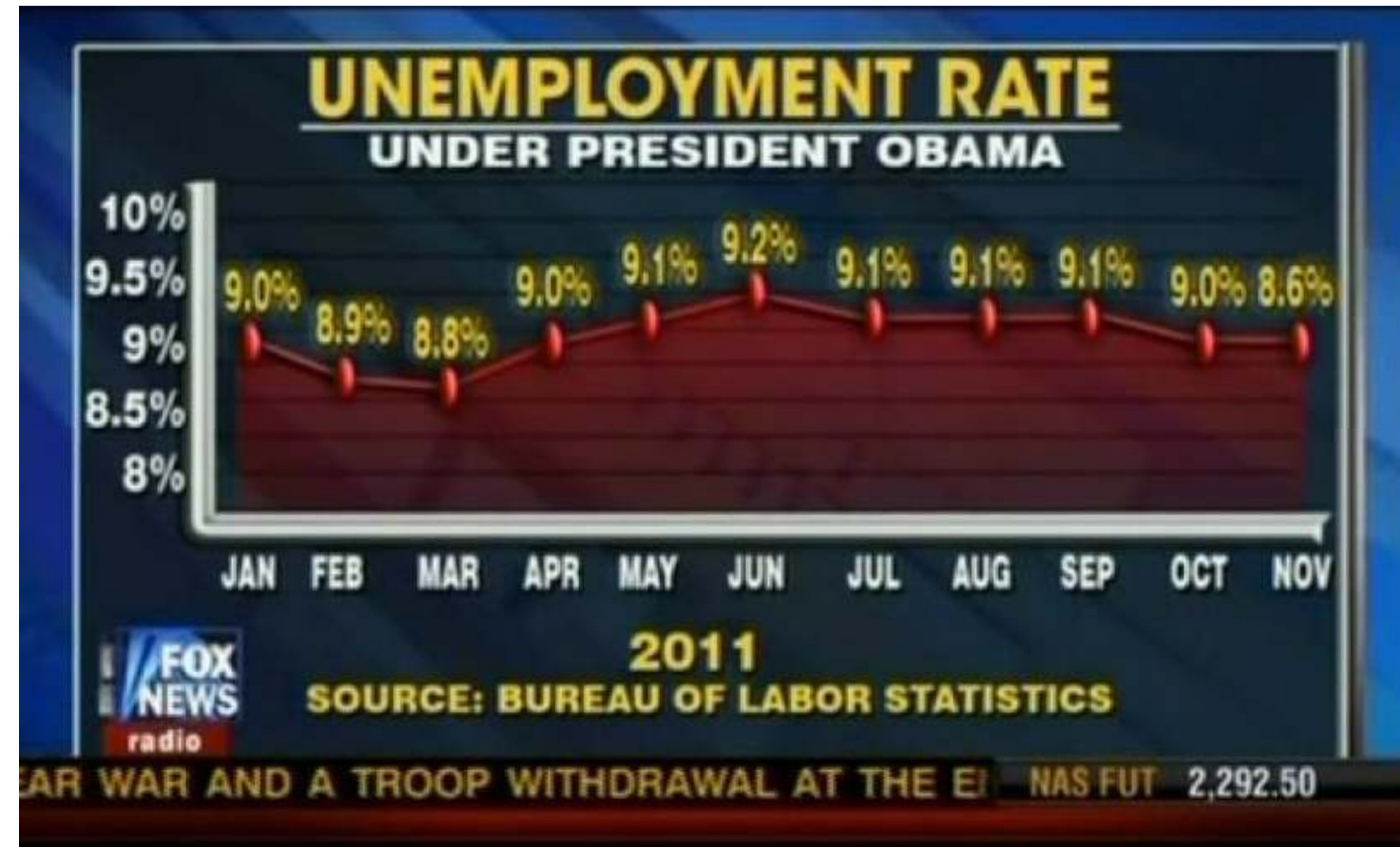
Pictograms have height and width scaled with ratio 2,5:9,2.

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

Stacking the pictograms further perturbs the perception of ratios.



Graphical Integrity



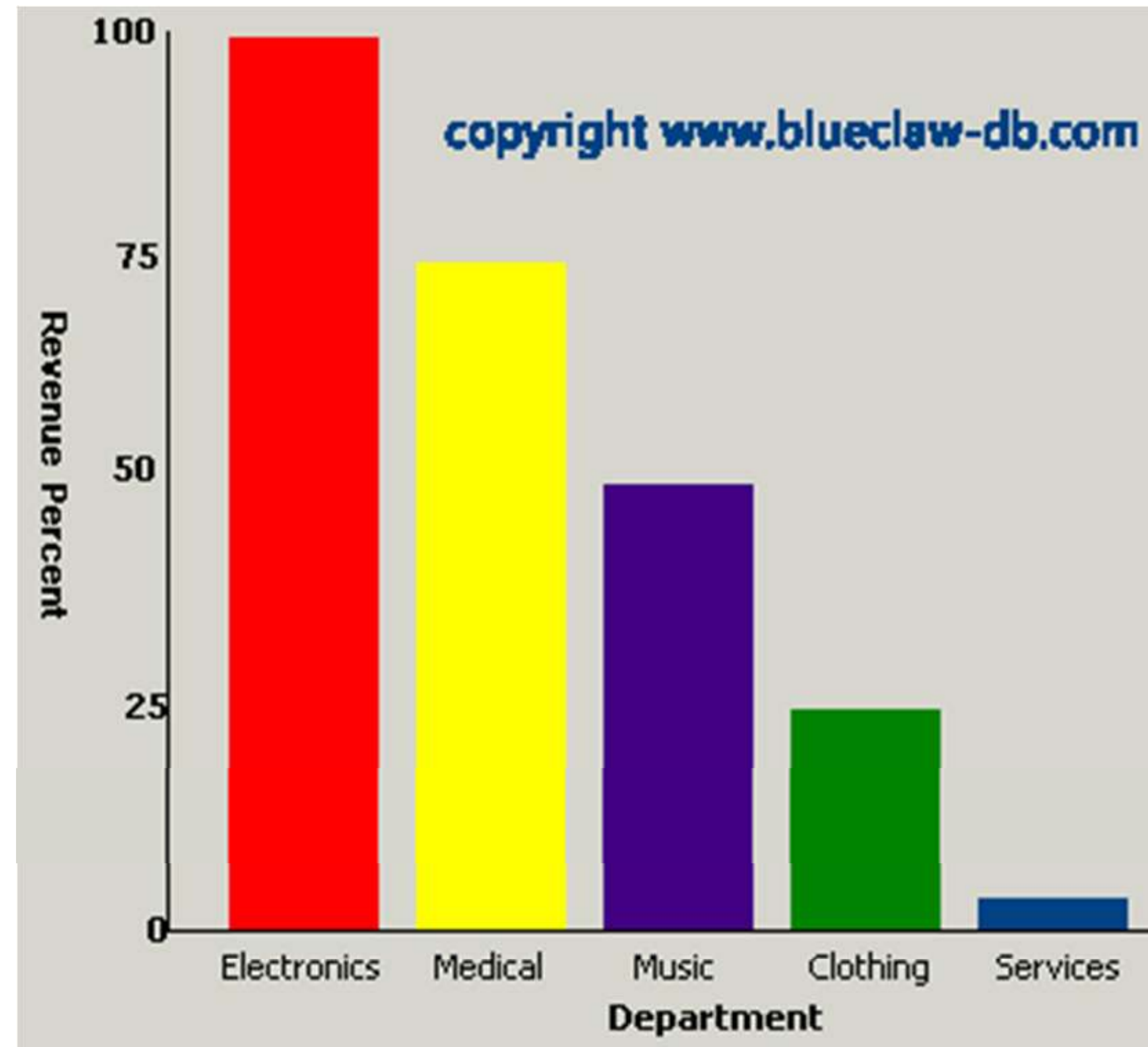
“

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/>

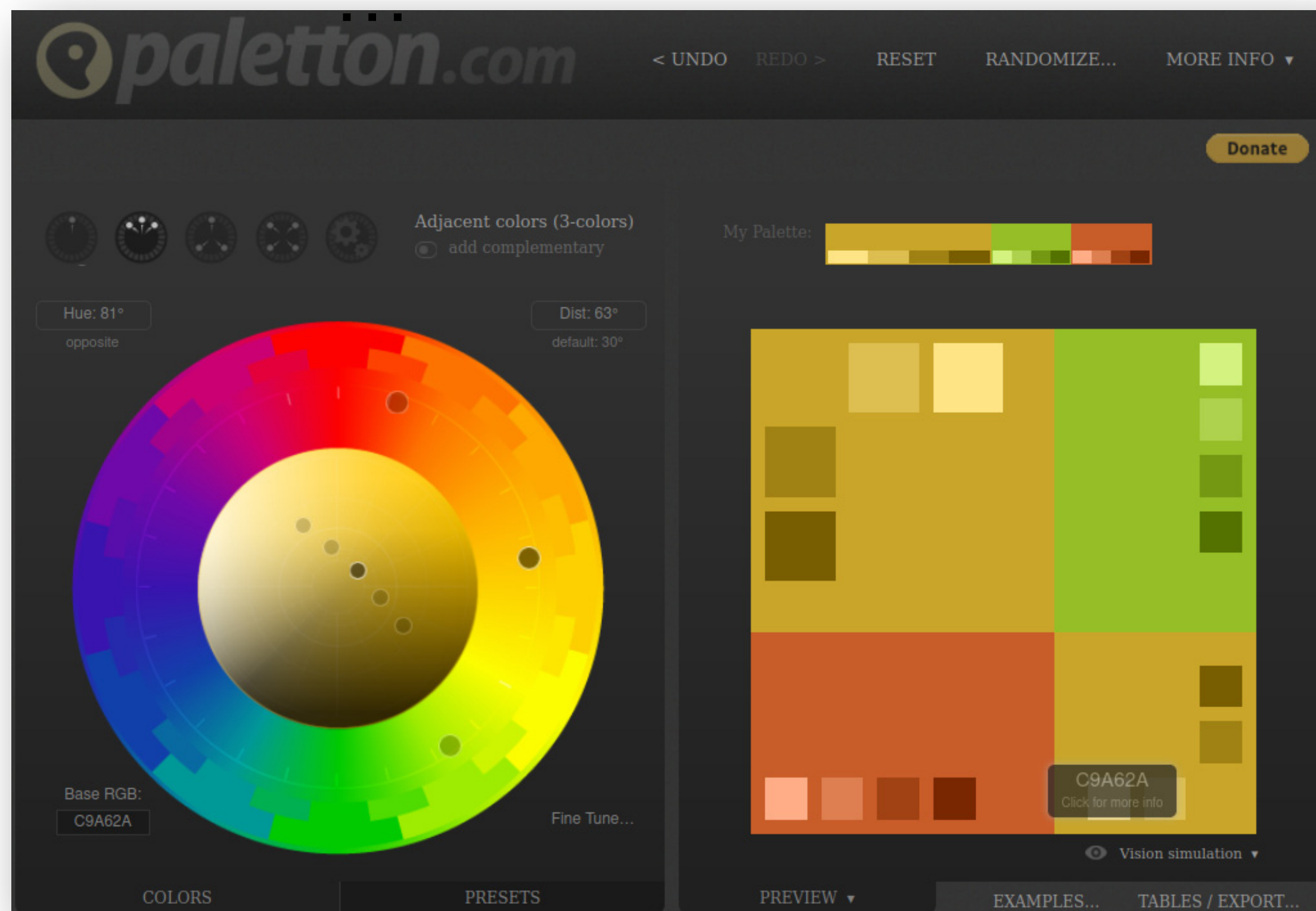
<https://colorbrewer2.org/>

<https://www.toptal.com/designers/colorfilter>

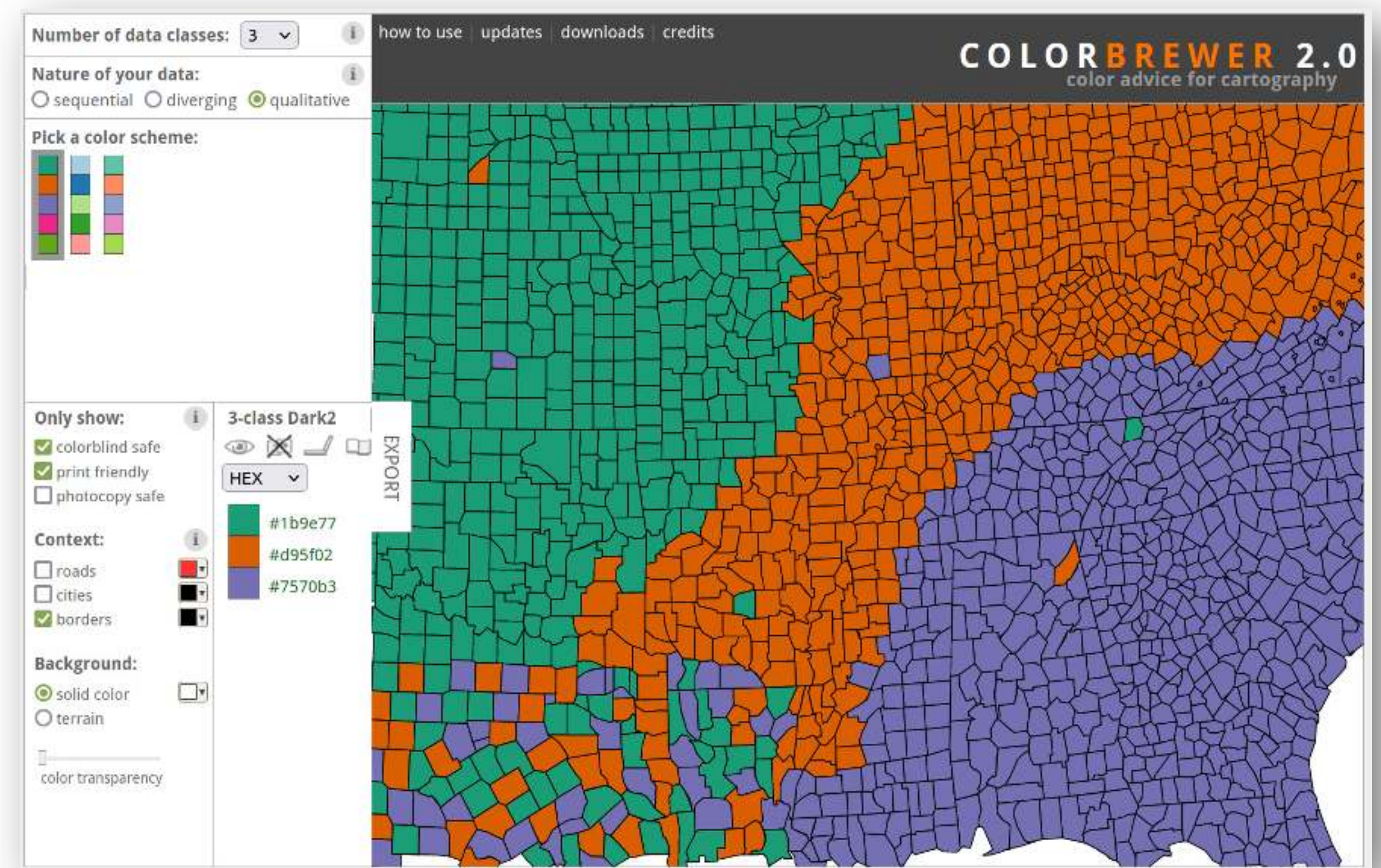
...

Online Tools (among others)

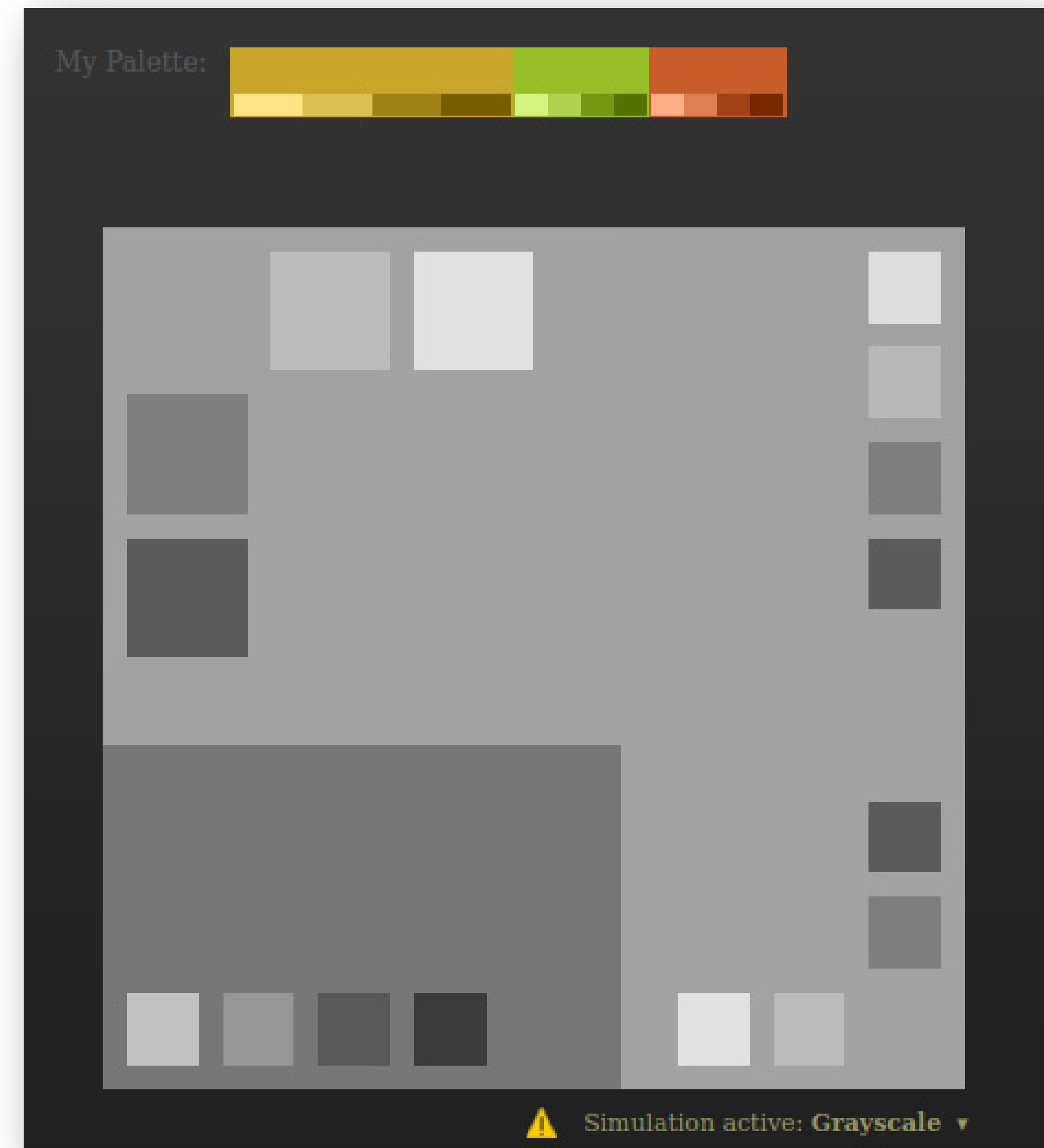
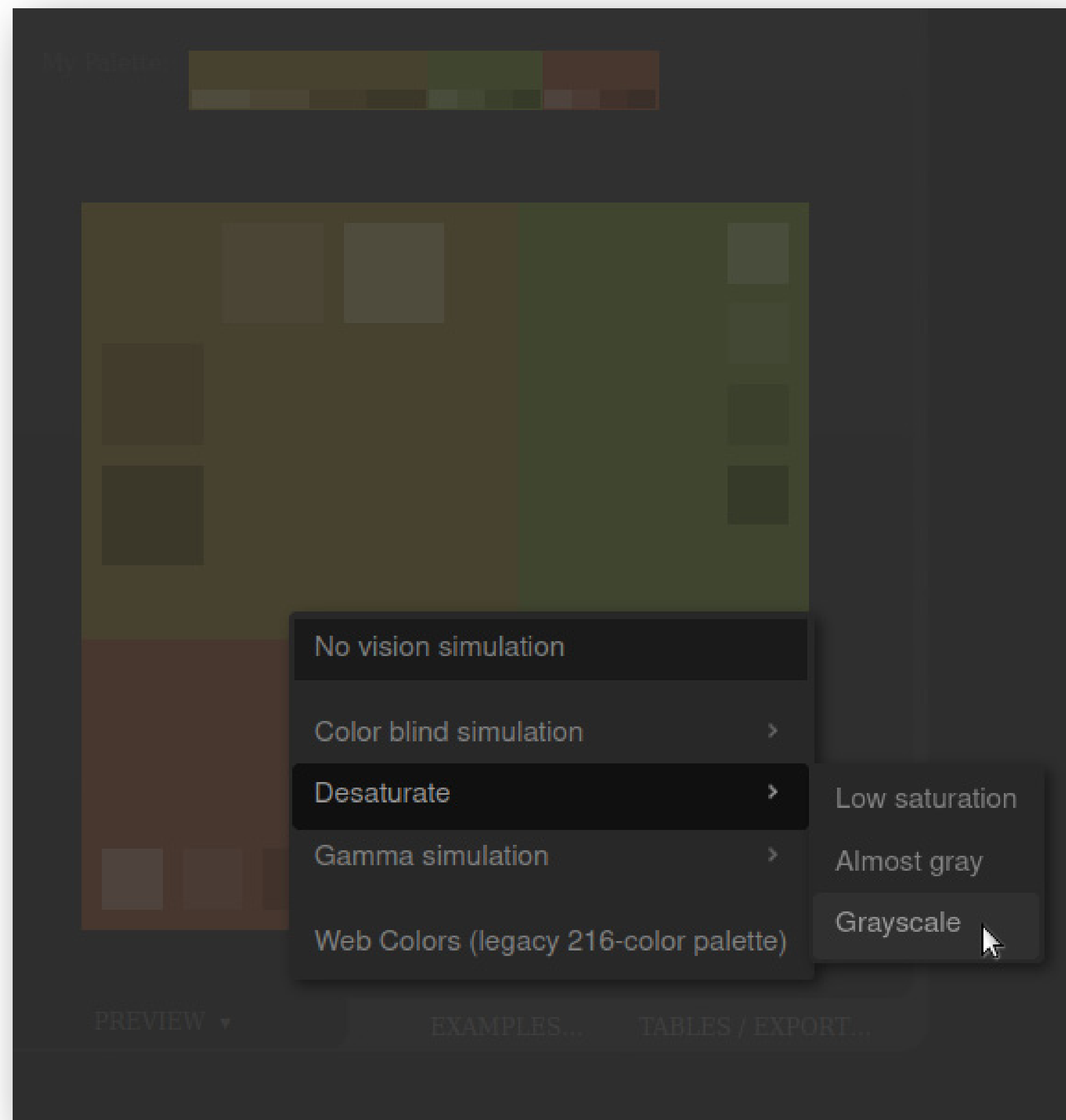
<https://paletton.com/>



<https://colorbrewer2.org/>

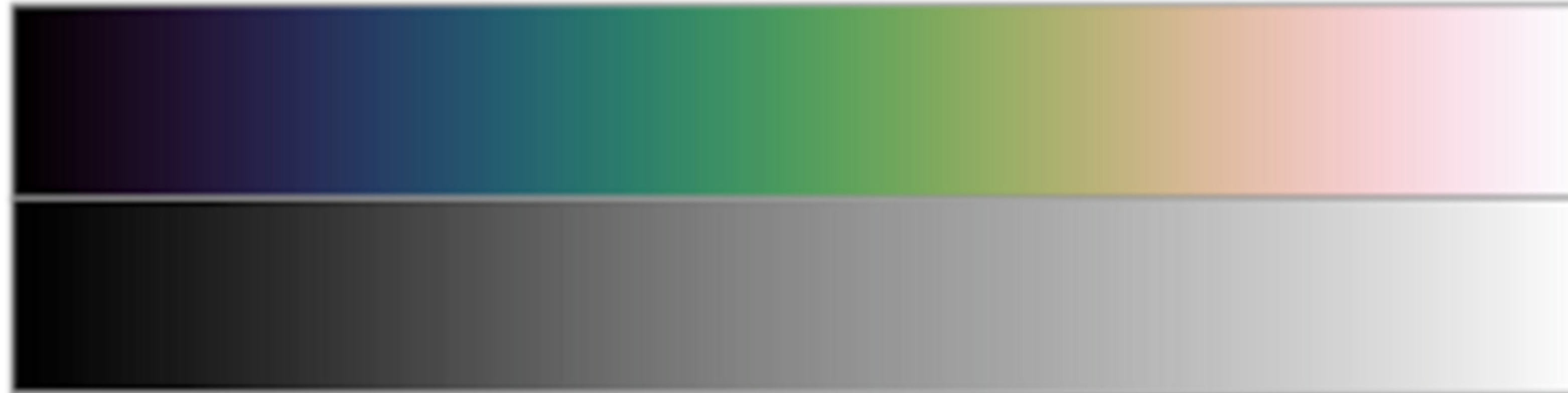


Example: Paletton.com



Optimize colors for brightness, not hue!

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

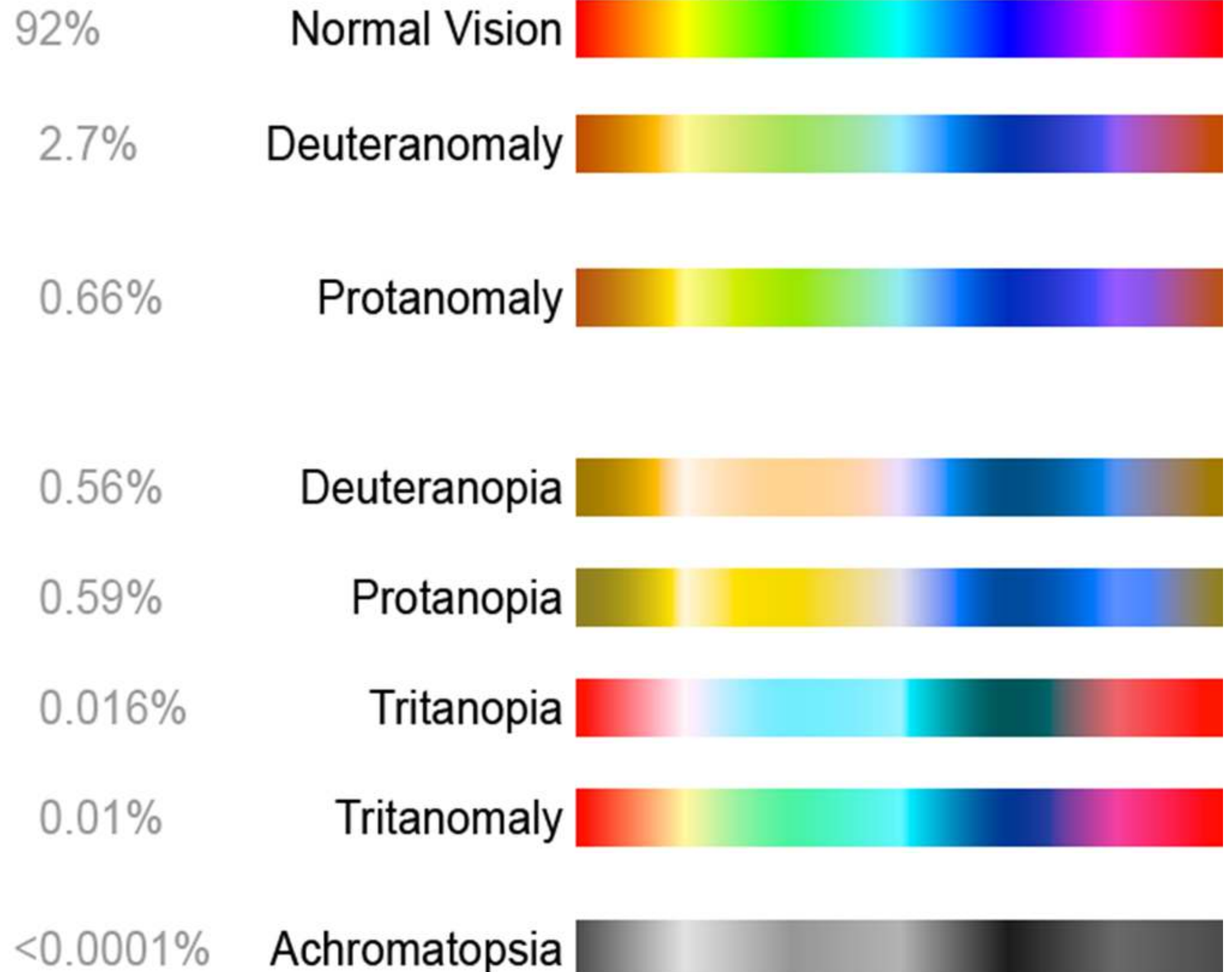


The „rainbow“ scale would be inefficient for gradual differences when viewed in grayscale!

Color Blindness

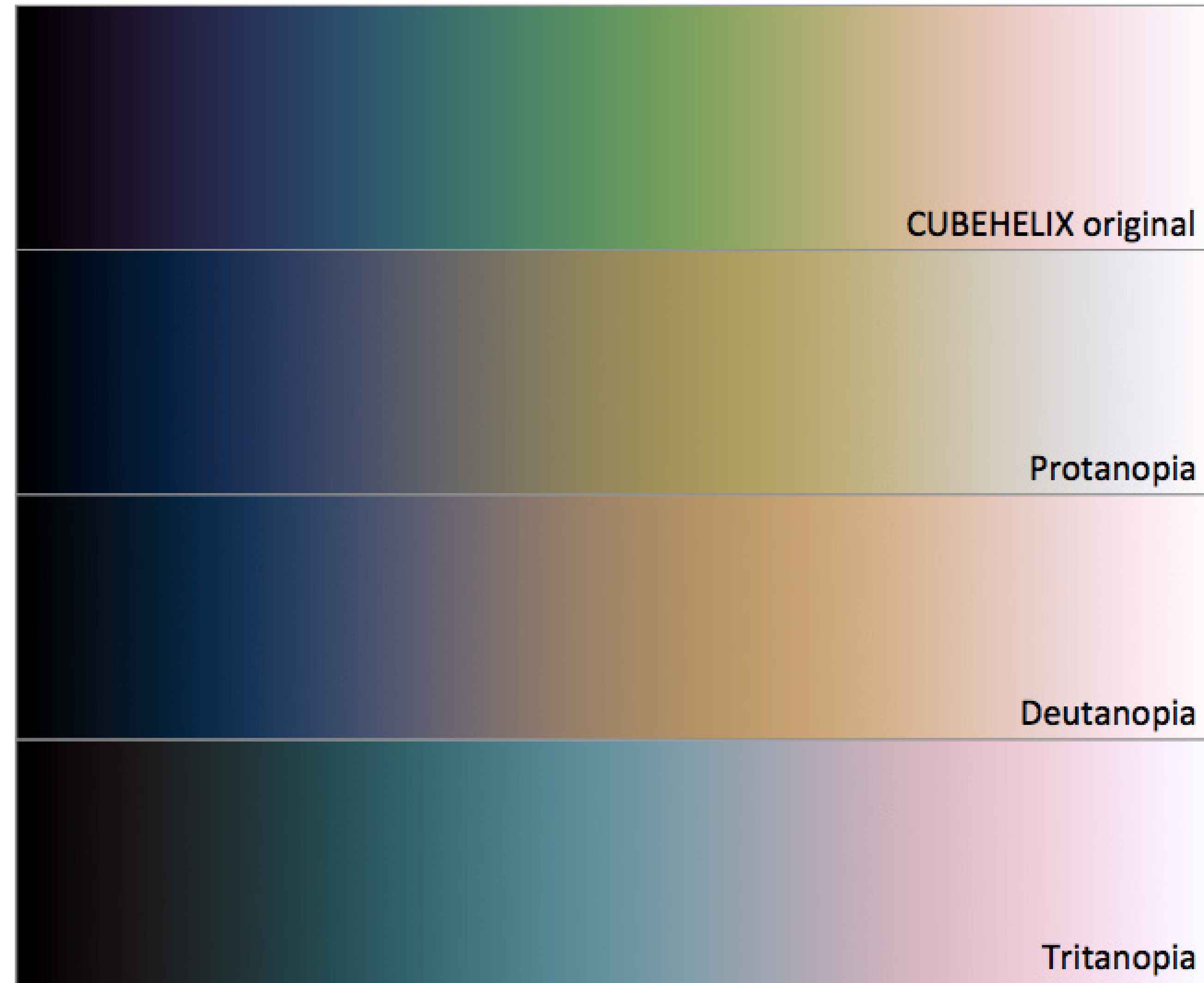
Decreased ability to see color or differences in color

- 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.

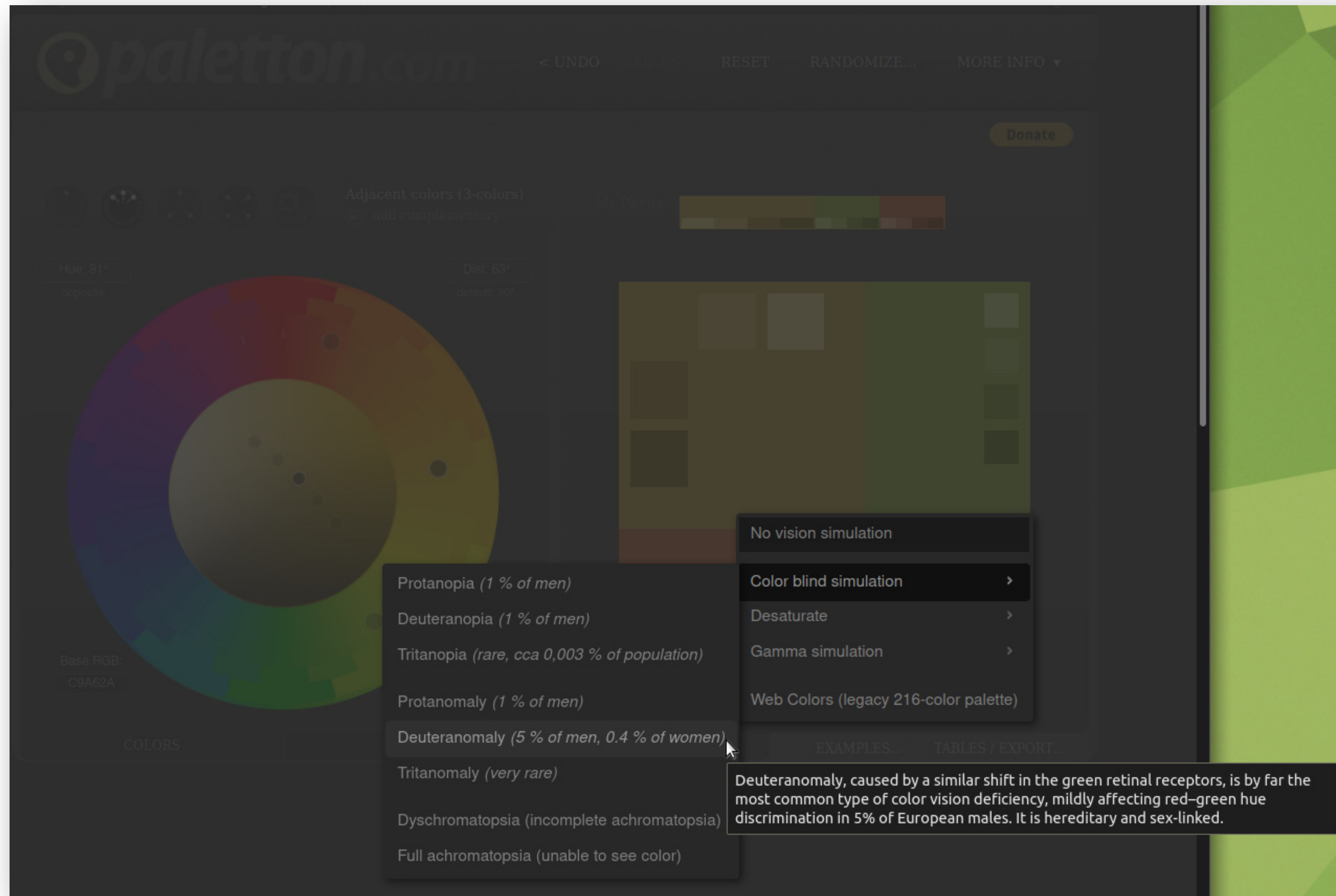


Color Scheme for Color Blindness

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



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

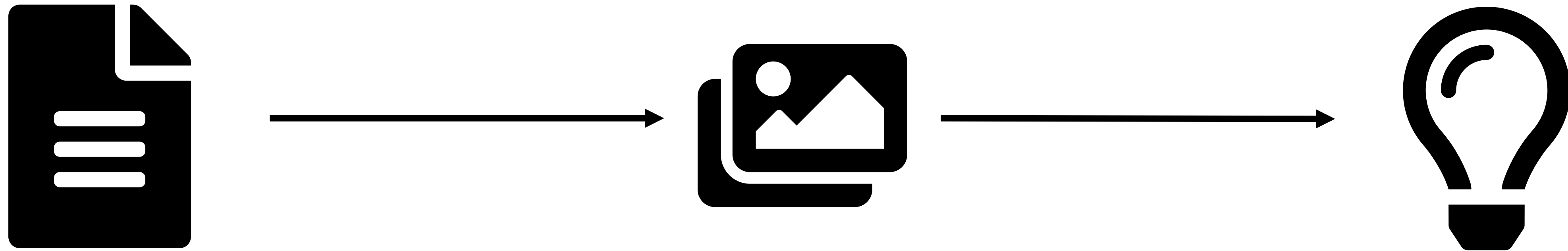
the least ink in the smallest space

is nearly always multivariate

requires telling the truth about the data

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

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.

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