

Visual perception

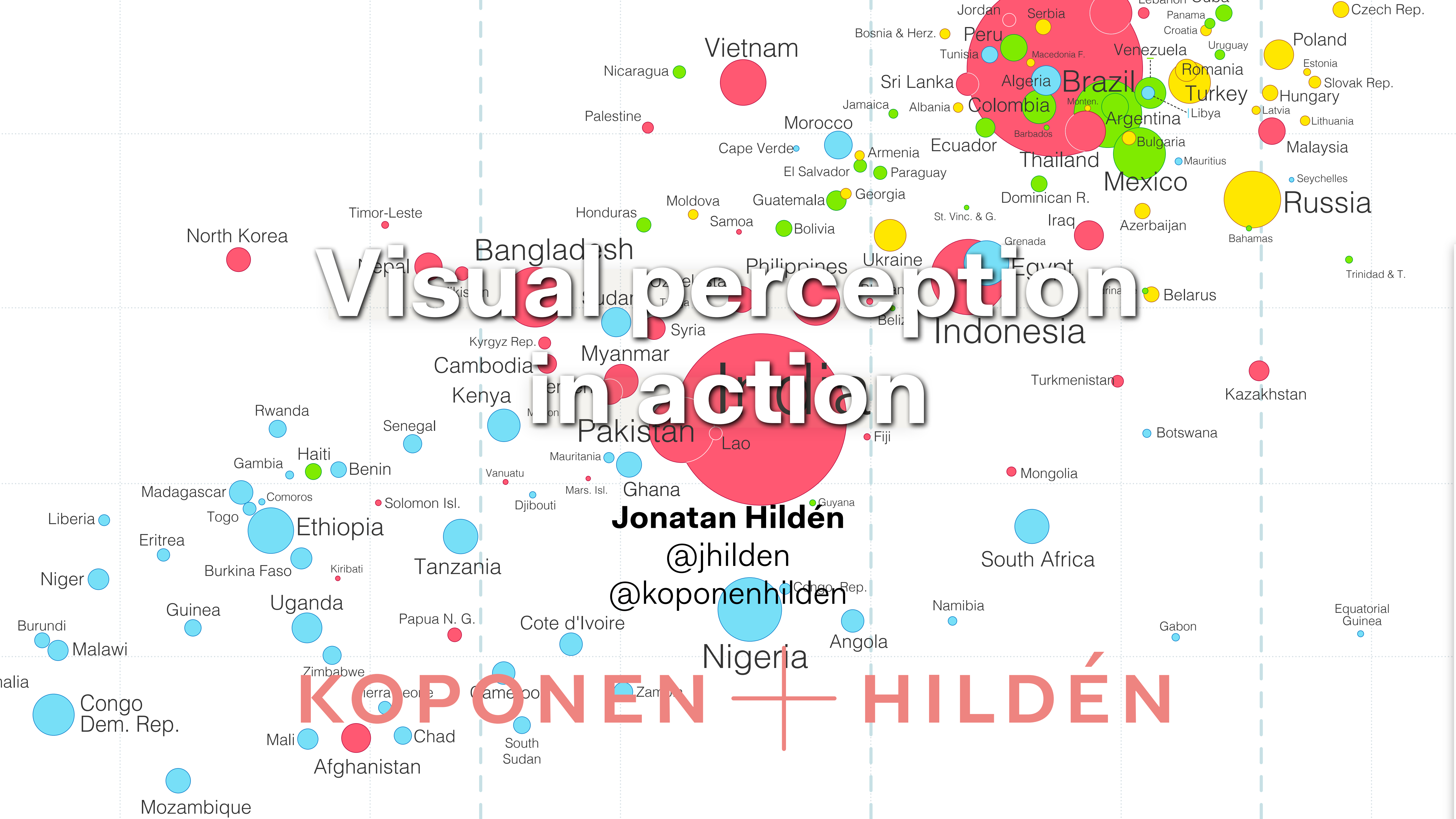
in action

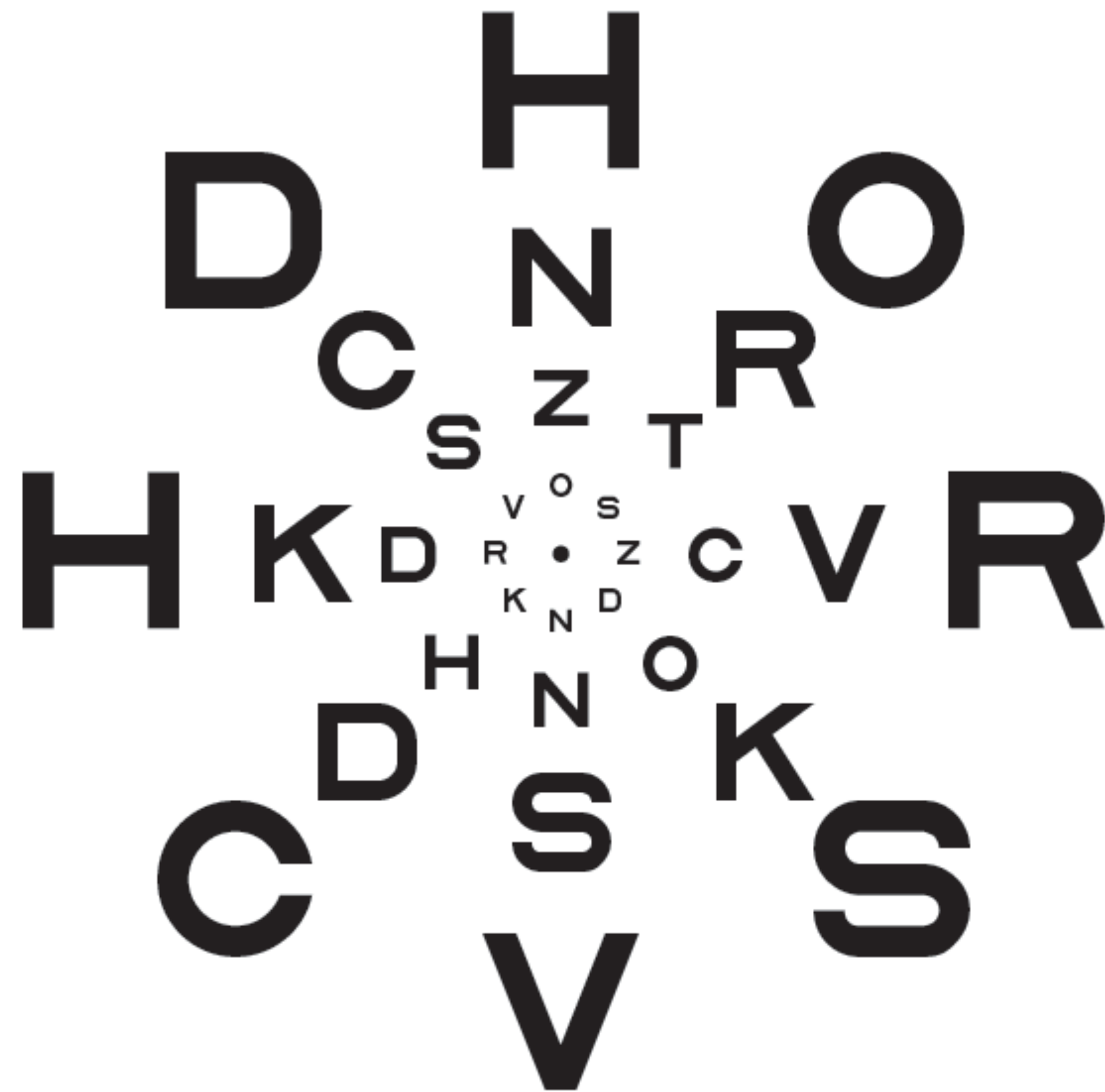
Jonatan Hildén

@jhilden

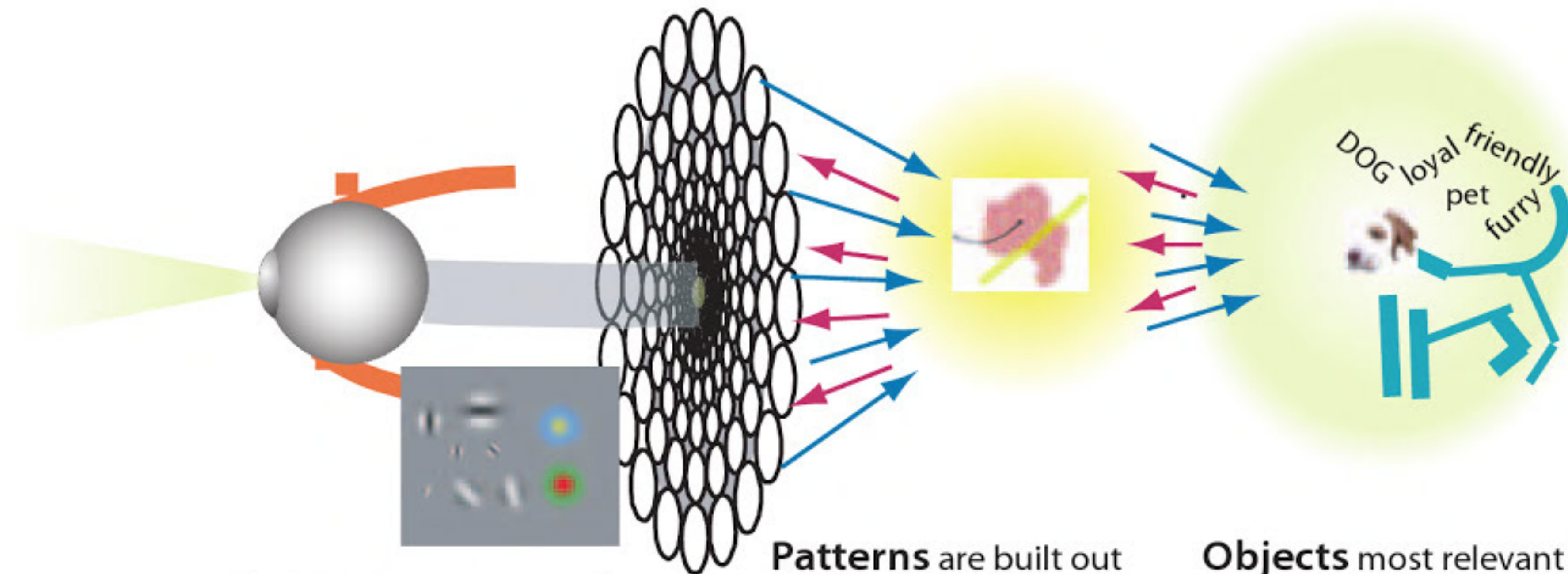
@koponenhilden

KOPONEN + HILDÉN





Anstis eye chart: each circle of letters is scaled to correspond to the decrease in acuity of vision towards the edge of the visual field



Features are processed in parallel from every part of the visual field. Millions of features are processed simultaneously.

Patterns are built out of features depending on attentional demands. Attentional tuning reinforces those most relevant.

Objects most relevant to the task at hand are held in Visual Working Memory. Only between one and three are held at any instant. Objects have both non-visual and visual attributes.

Bottom-up information drives pattern building

Top-down attentional processes reinforce relevant information

Conditions for effective visual searches

- 1. Tunable** or pop-out visual features , that our visual perception is specialized in picking out
- 2. The direction of attention** – what we see is dependent on what we are looking for.
- 3. The familiarity of the scene (*scene gist*)** – a familiar landscape or visualization is easier to read, since we know suitable search methods to use.

Attention affects what we see



Tunable (pop-out) features

SOME TUNEABLE FEATURES

SHAPE FEATURES

Shape

size



elongation



round/pointed



direction



filled shape



closure



Position and placement

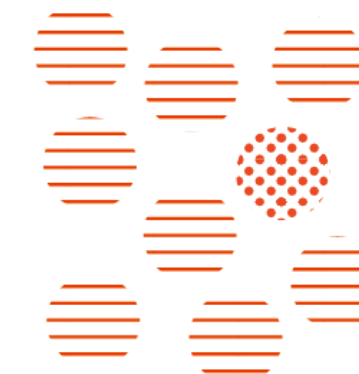
grouping, amount



density



texture



optical sharpness

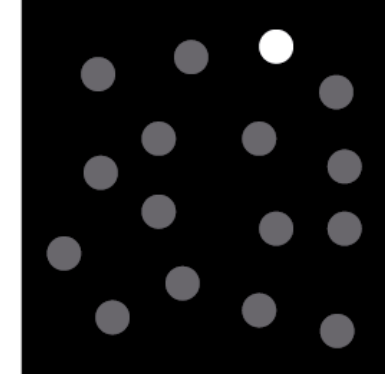


COLOR FEATURES

hue



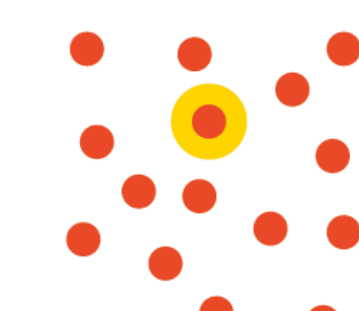
lightness/
darkness



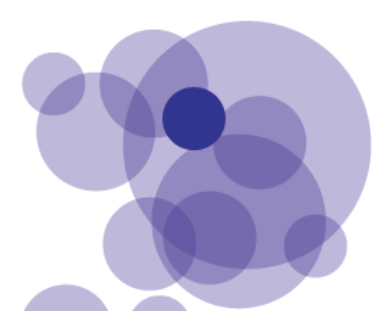
saturation



surrounding
color



transparency



MOVEMENT AND CHANGE

speed



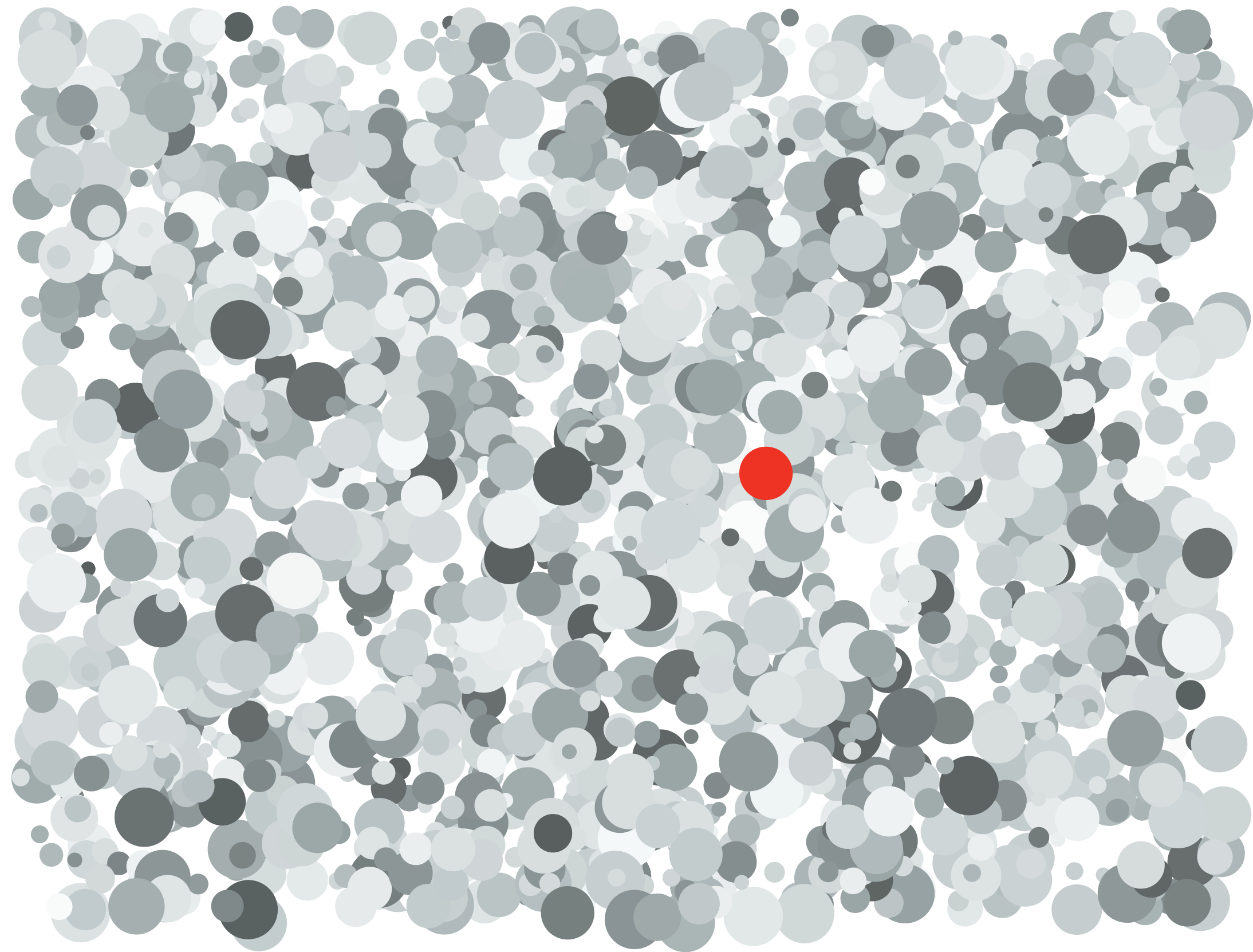
direction



vibration



The pop-out effect is relative and dependent on the visual context



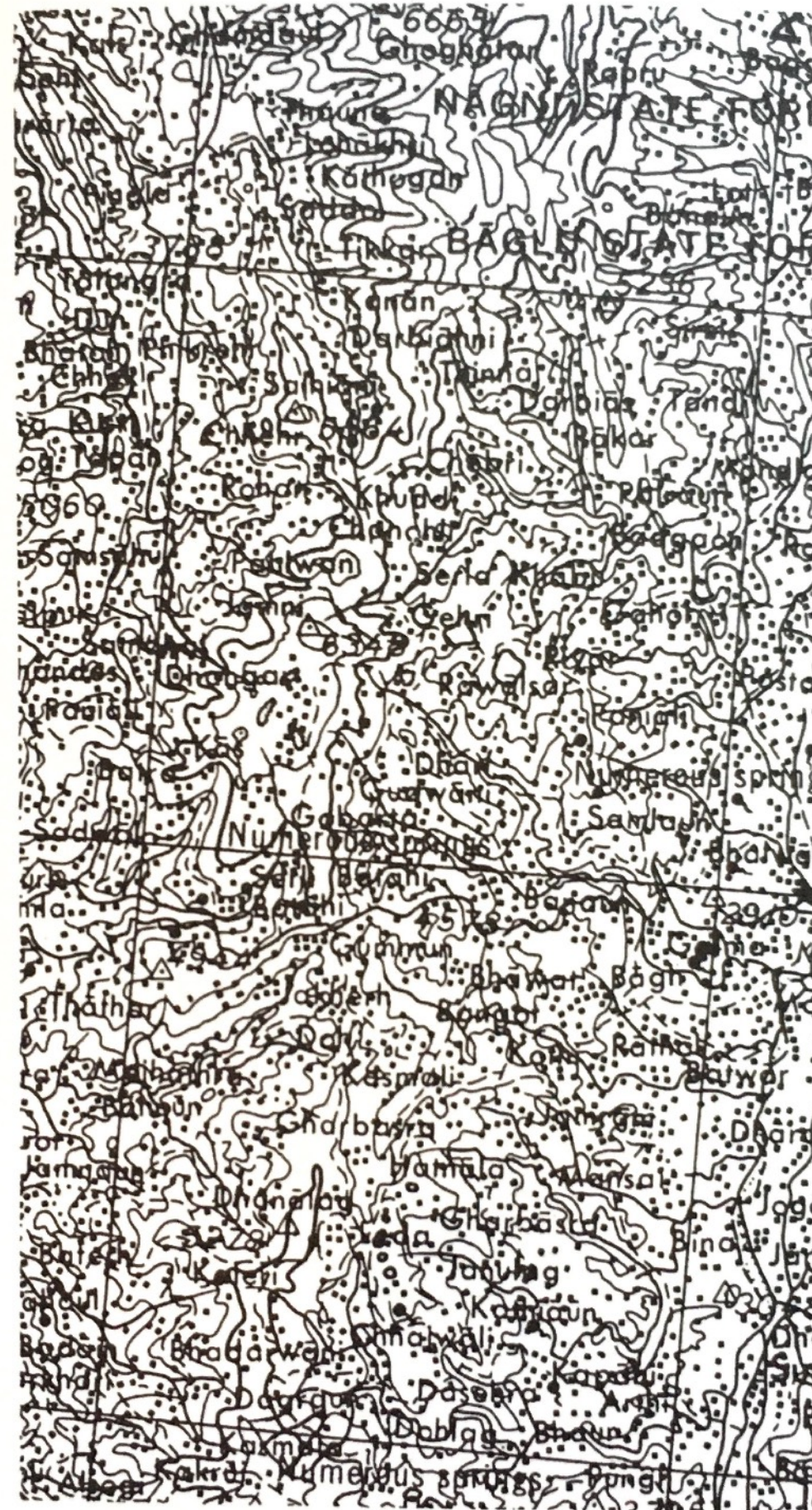
Tunable (pop-out) features

Difficult to find



Easy to find





Simla, India (U.S. Army map series U 502, NH 43-4, 1954), based on the Survey of India, 1921-1943.

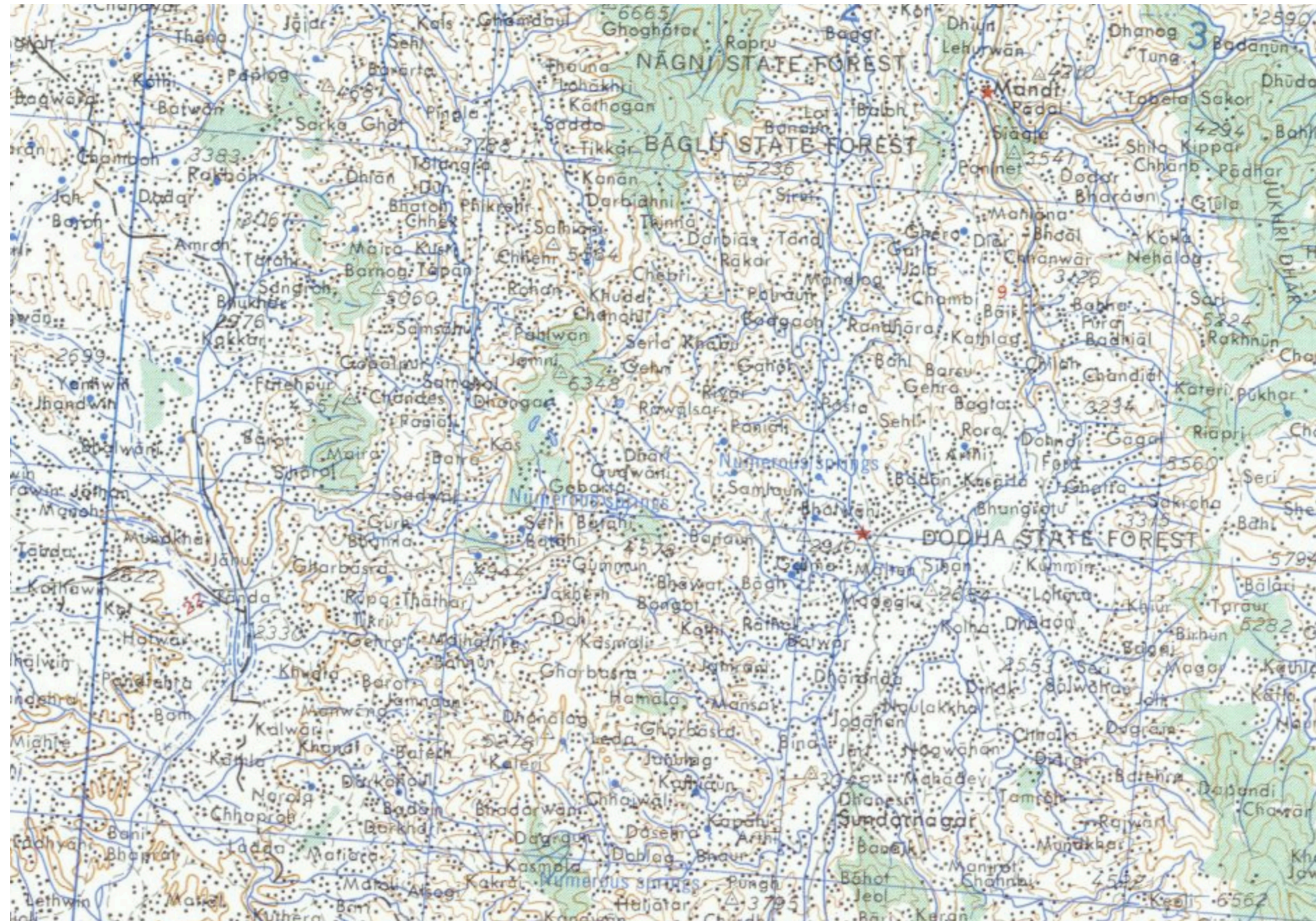
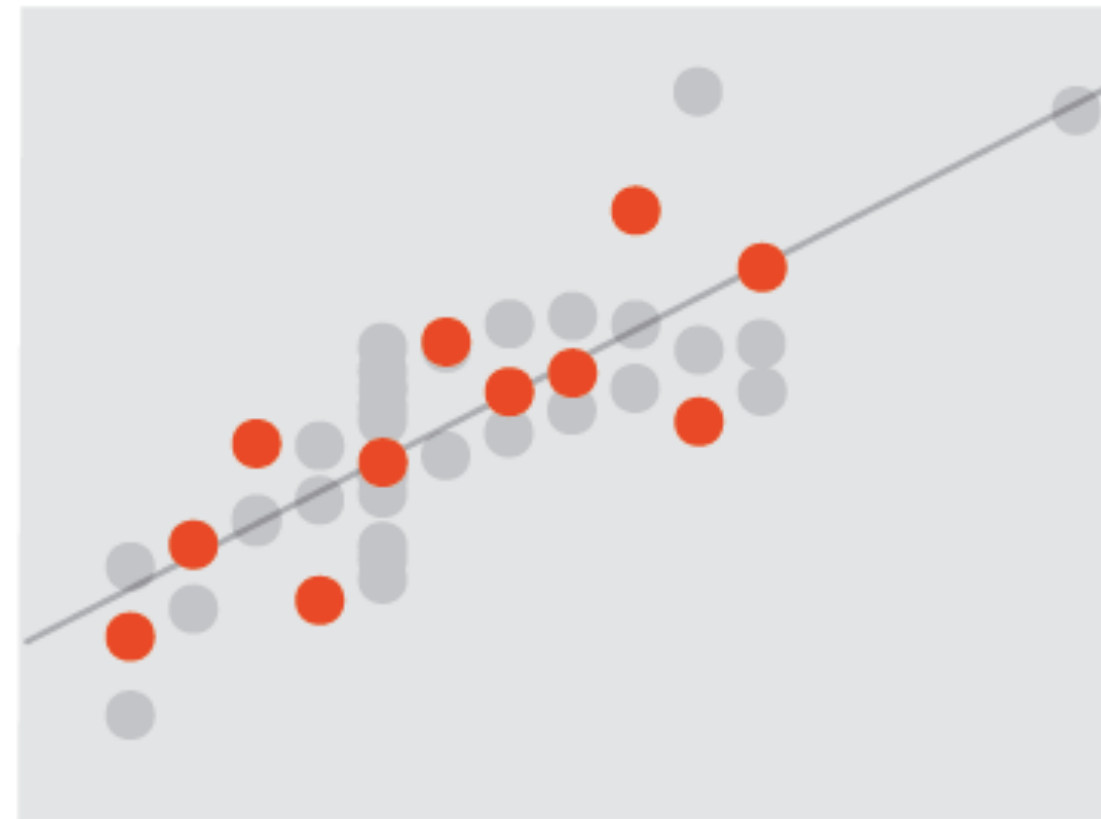


Figure and ground



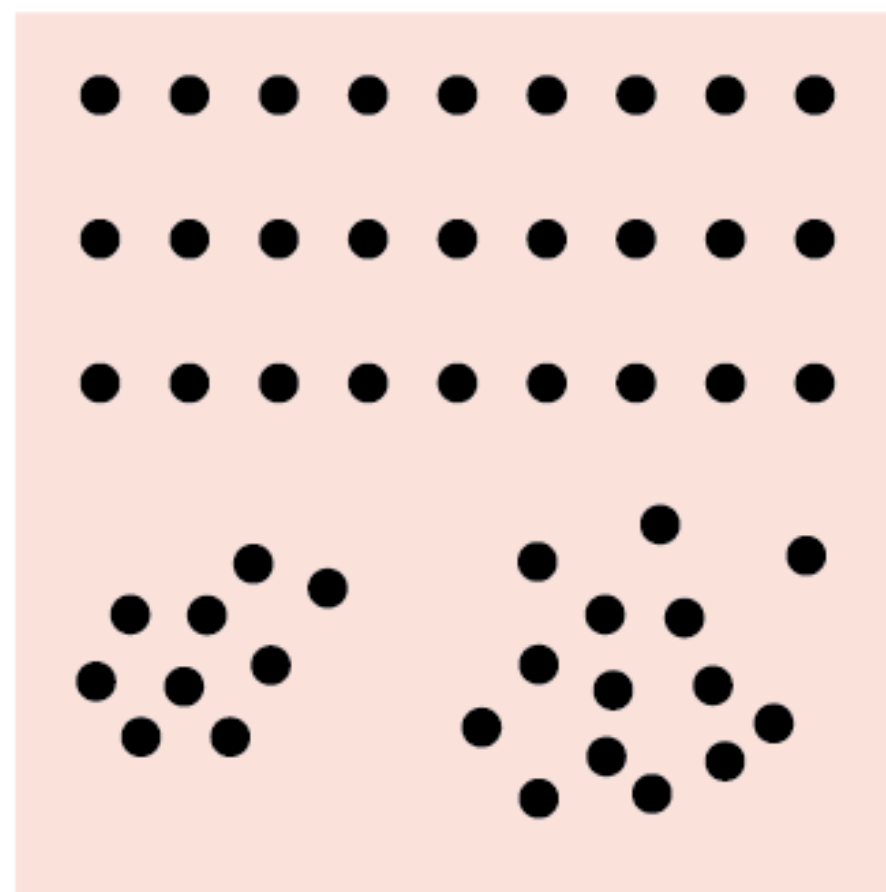
Good separation of figure and ground:
recognizable shape or clear hierarchy
of contrast and lightness.



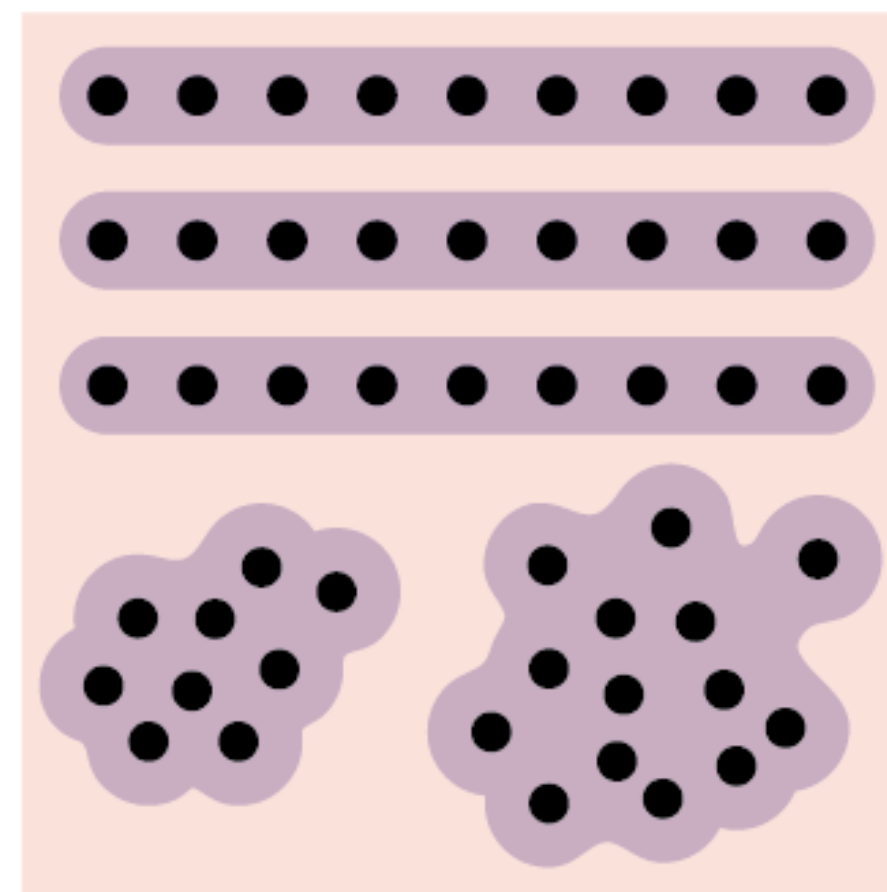
Multistable image:
Rubin's vase

Gestalt principles or laws: Proximity.

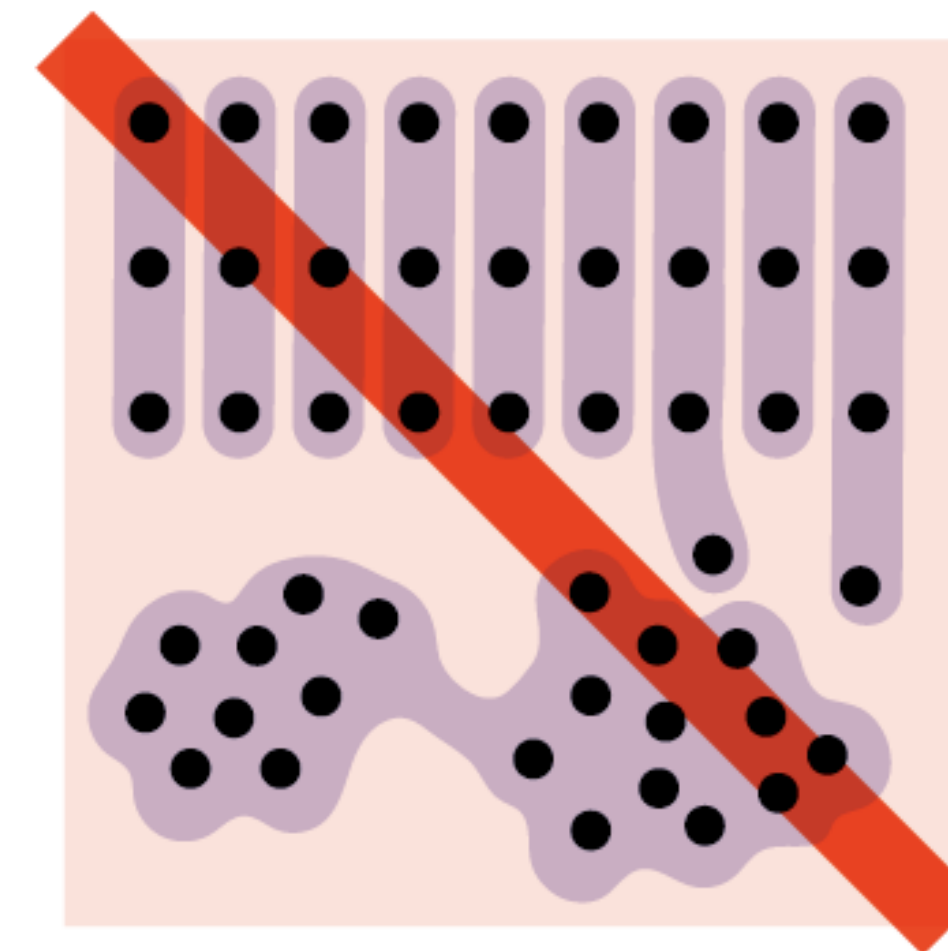
Objects close to each other are seen as forming groups



Pattern



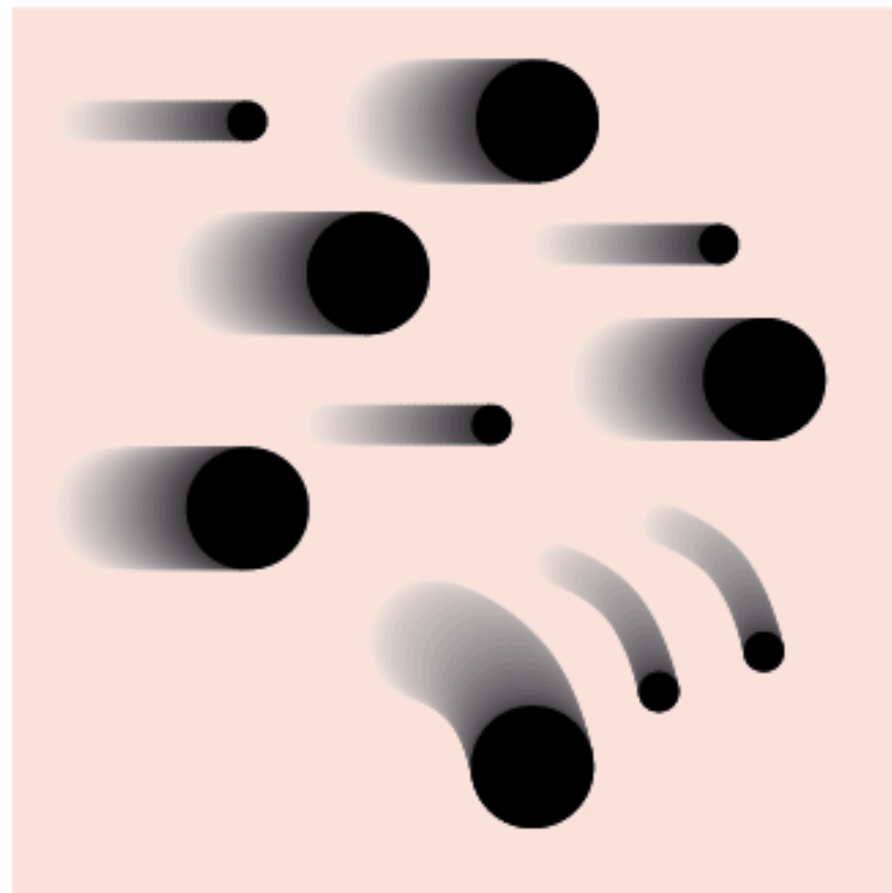
Interpretation according to the principle



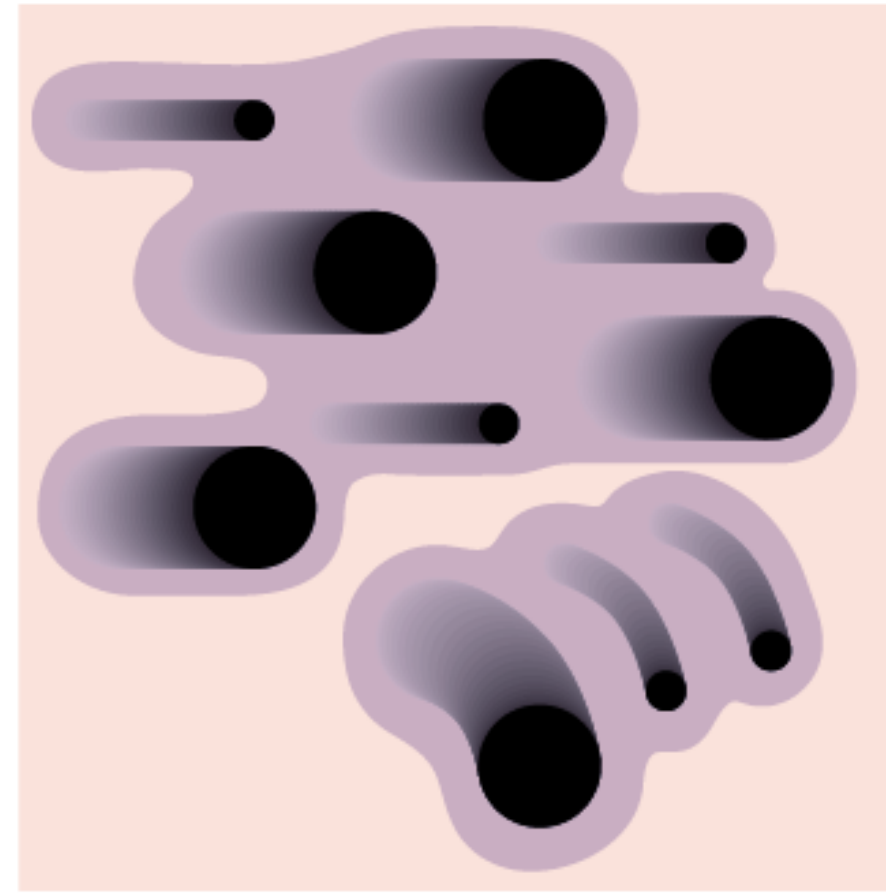
Contradictory or unlikely interpretation

Gestalt principles: Common fate

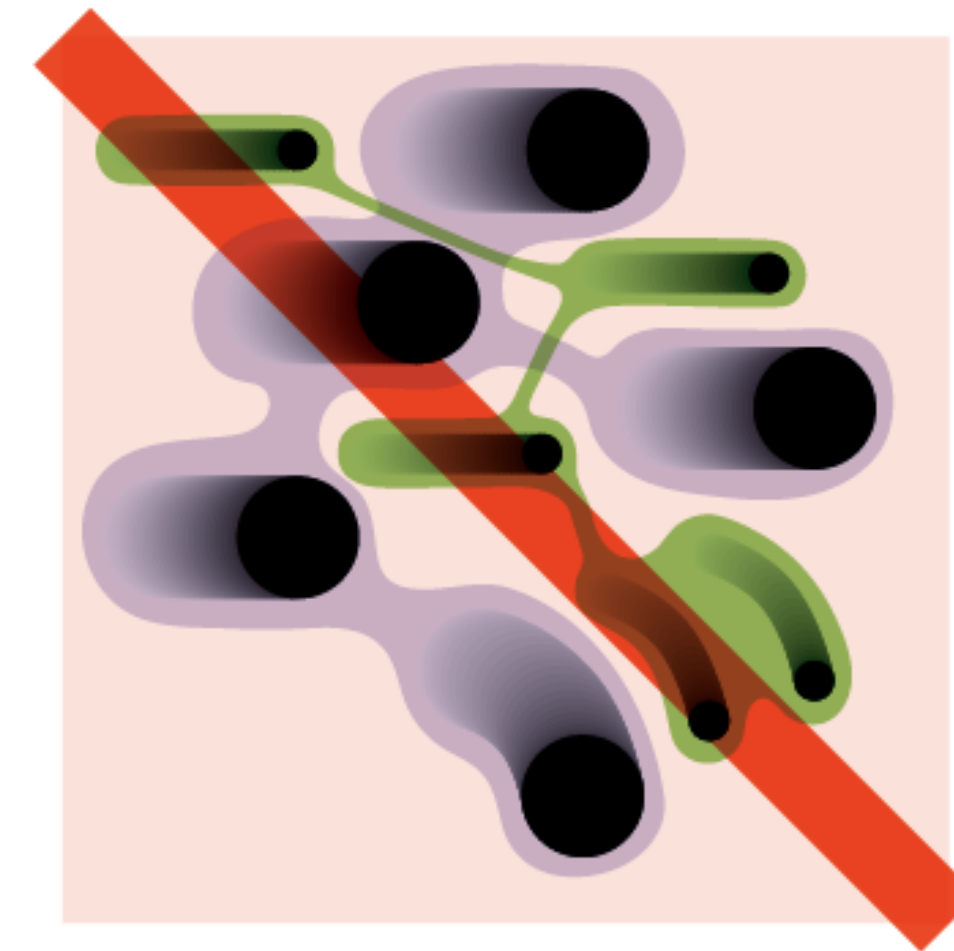
Objects moving together are seen as forming groups



Pattern



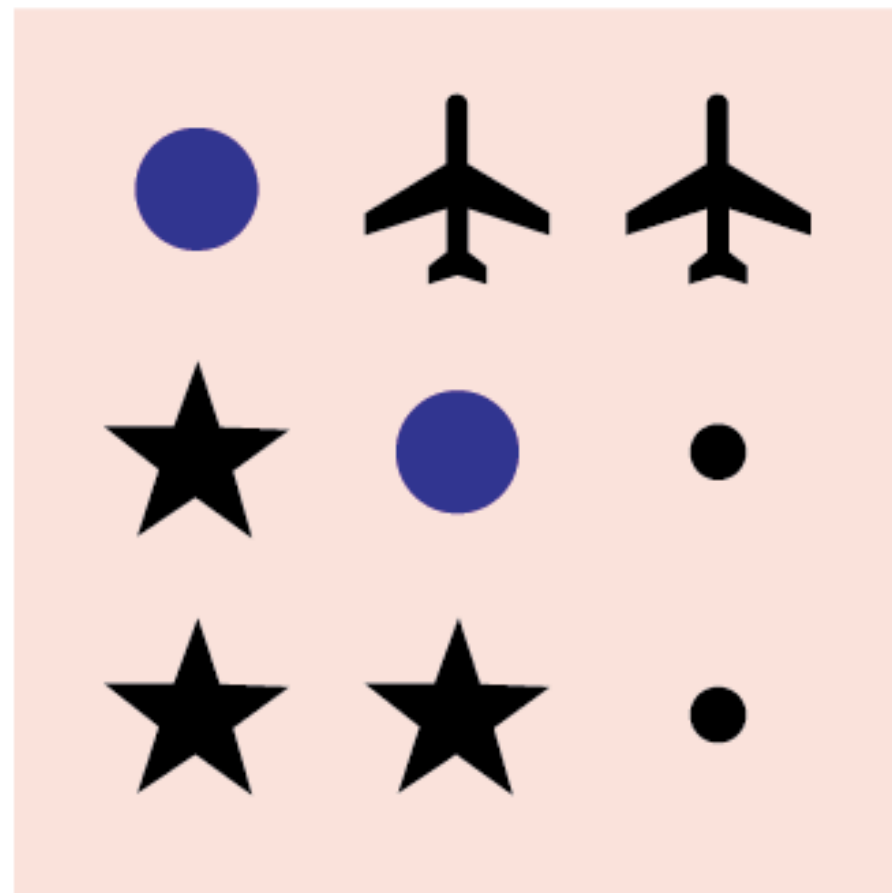
Interpretation according to the principle



Contradictory or unlikely interpretation

Gestalt principles: Similarity

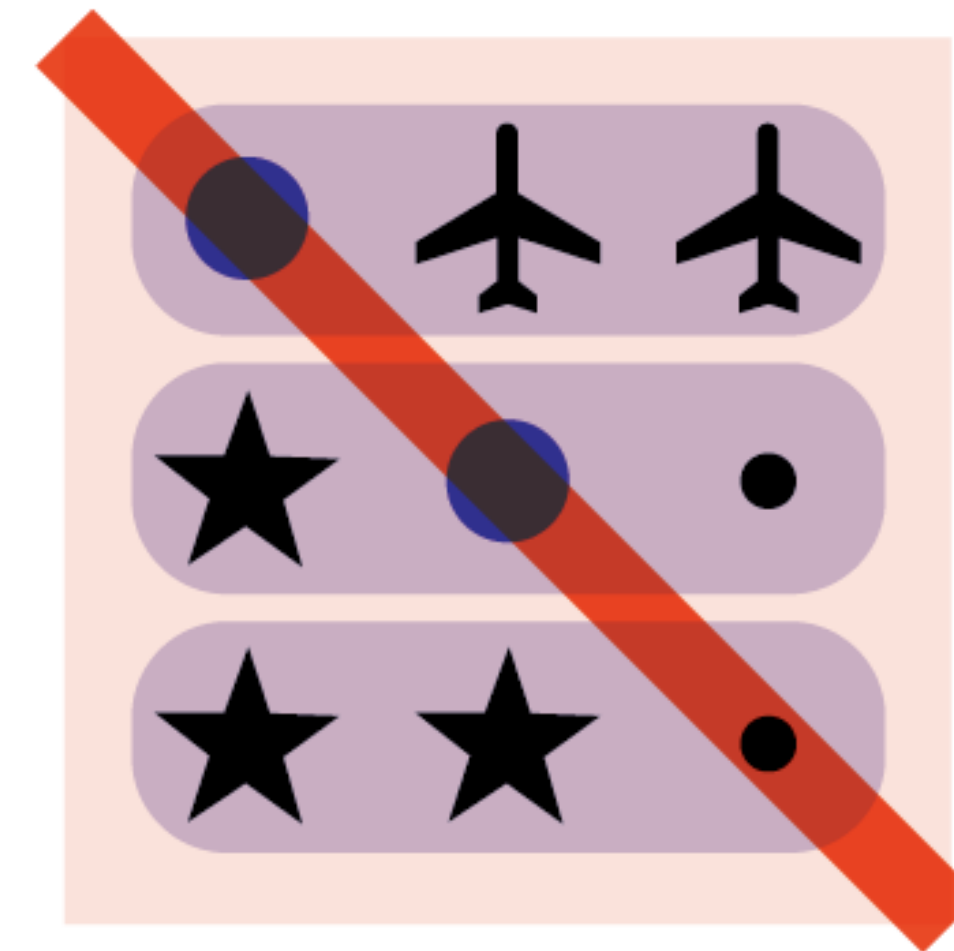
Objects resembling each other in shape, color or size are grouped together



Pattern



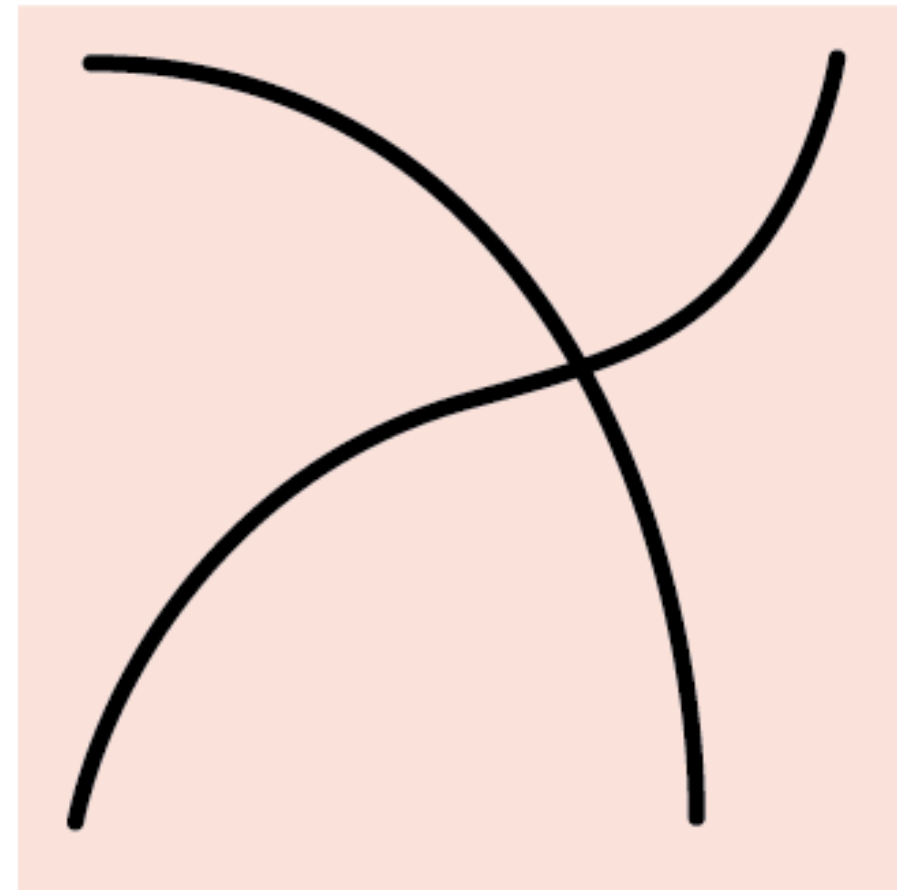
Interpretation according to the principle



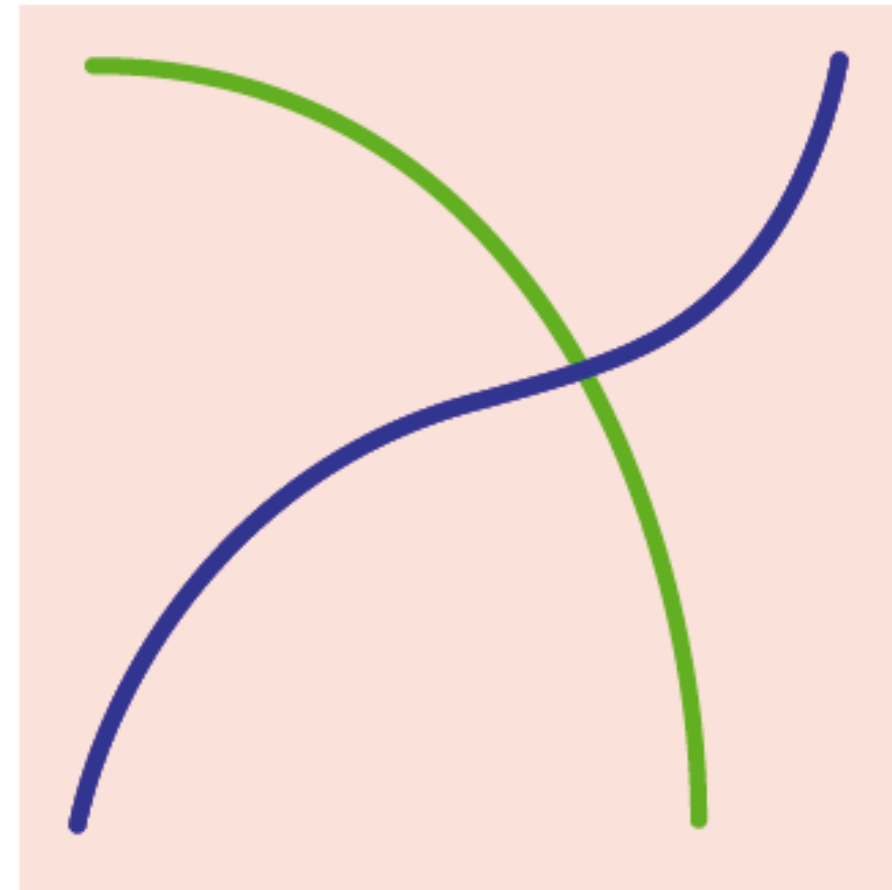
Contradictory or unlikely interpretation

Gestalt principles: Continuity

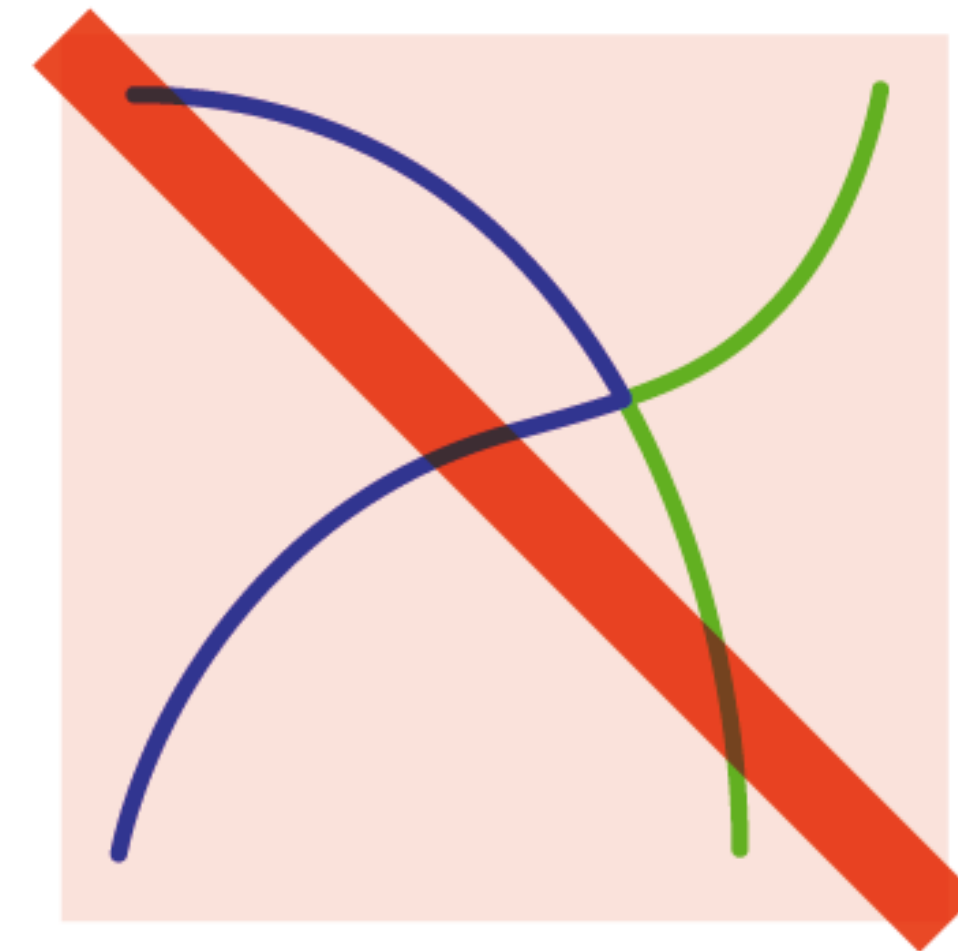
Crossing lines are interpreted as continuing smoothly, rather than making angled turns or as separate shapes



Pattern



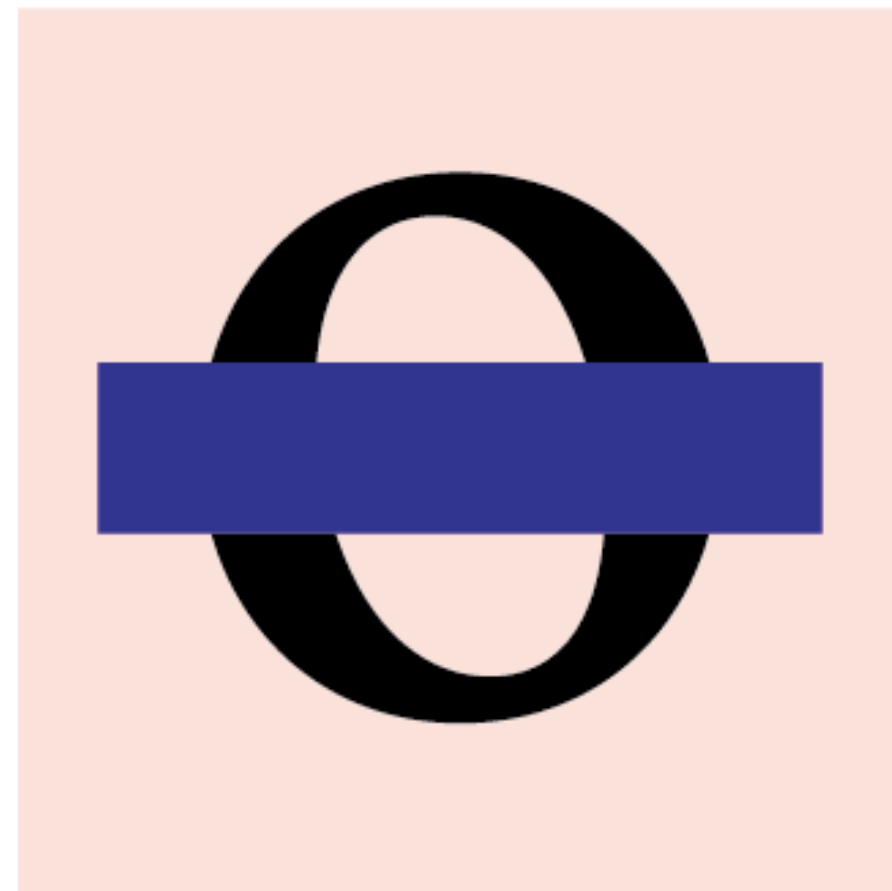
Interpretation according to the principle



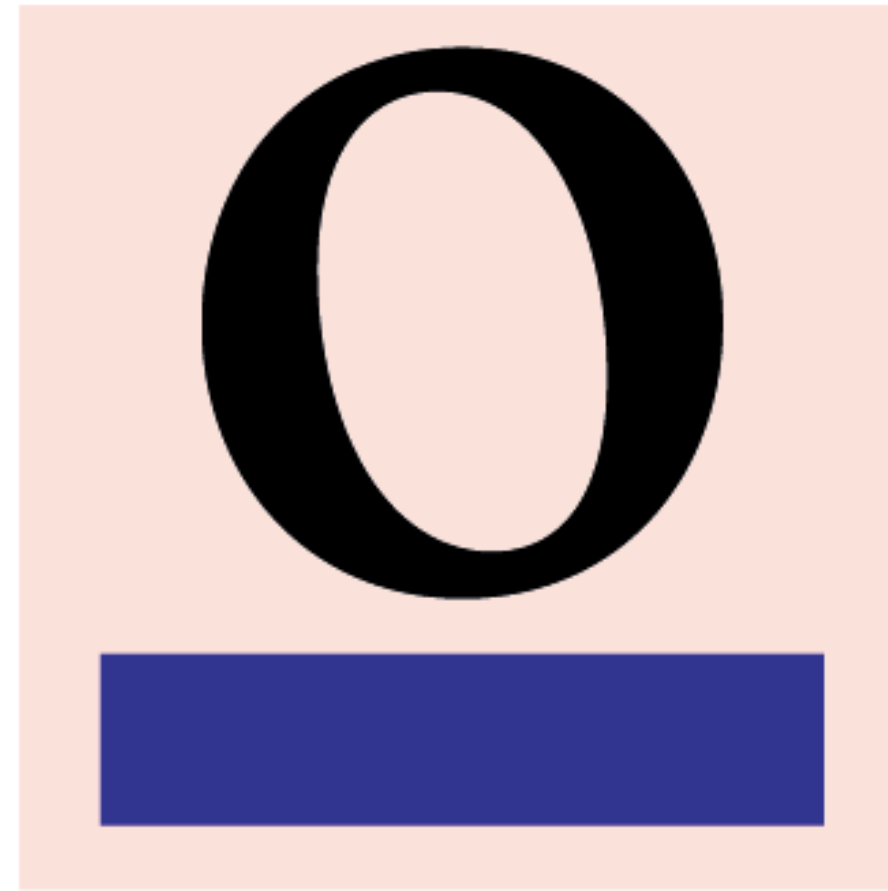
Contradictory or unlikely interpretation

Gestalt principles: Closure

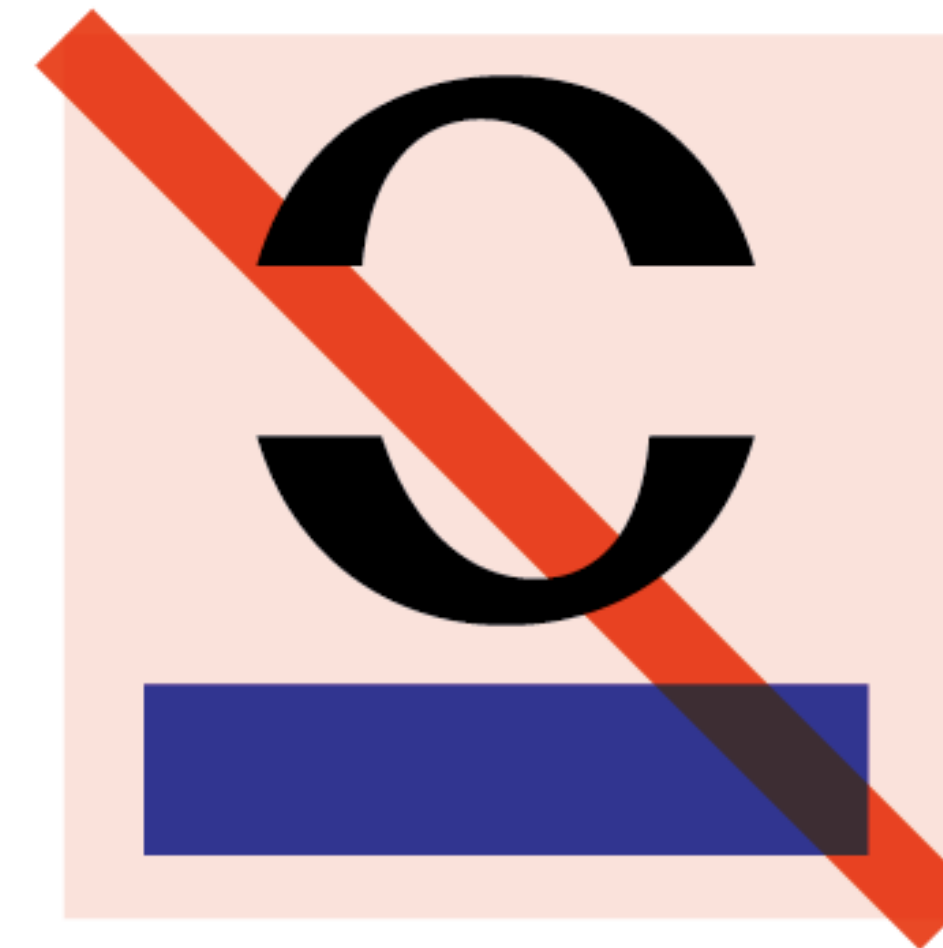
Elements are grouped together if they seem to form a closed shape. It is seen as whole even with parts missing



Pattern



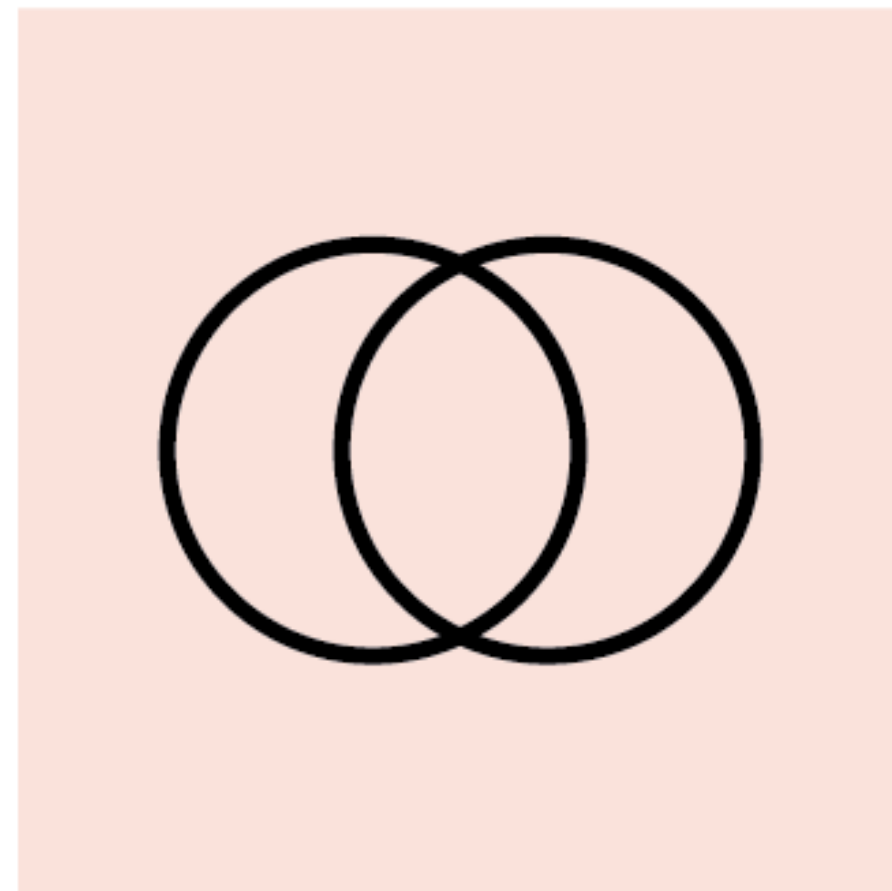
Interpretation according to the principle



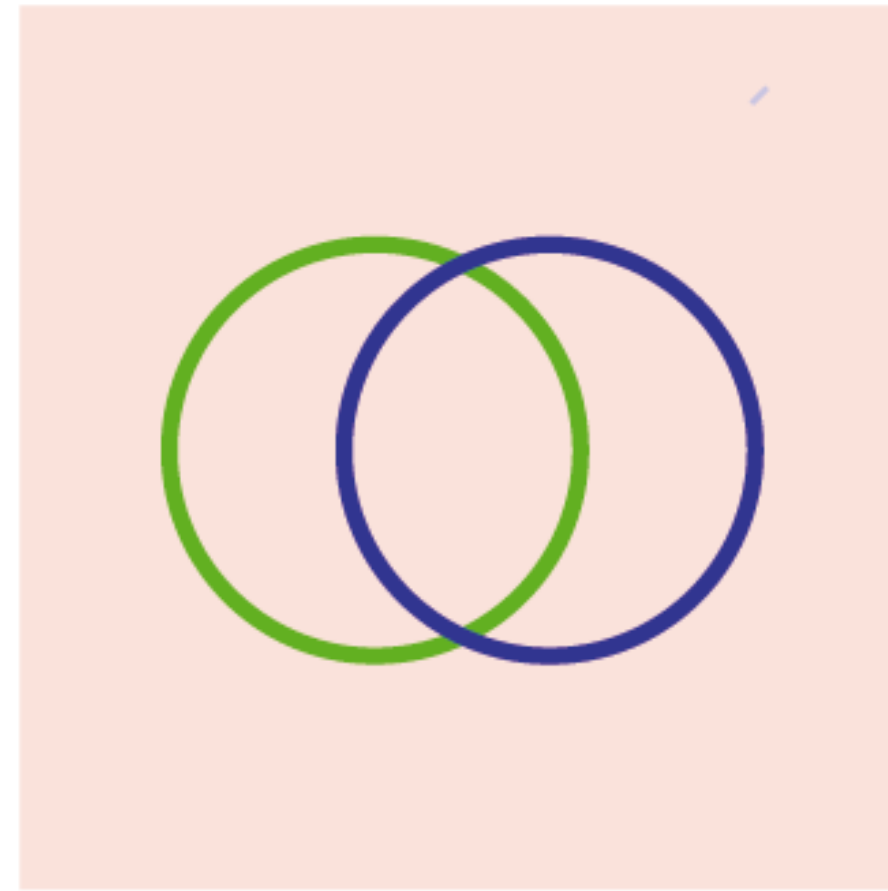
Contradictory or unlikely interpretation

Gestalt principles: Good gestalt

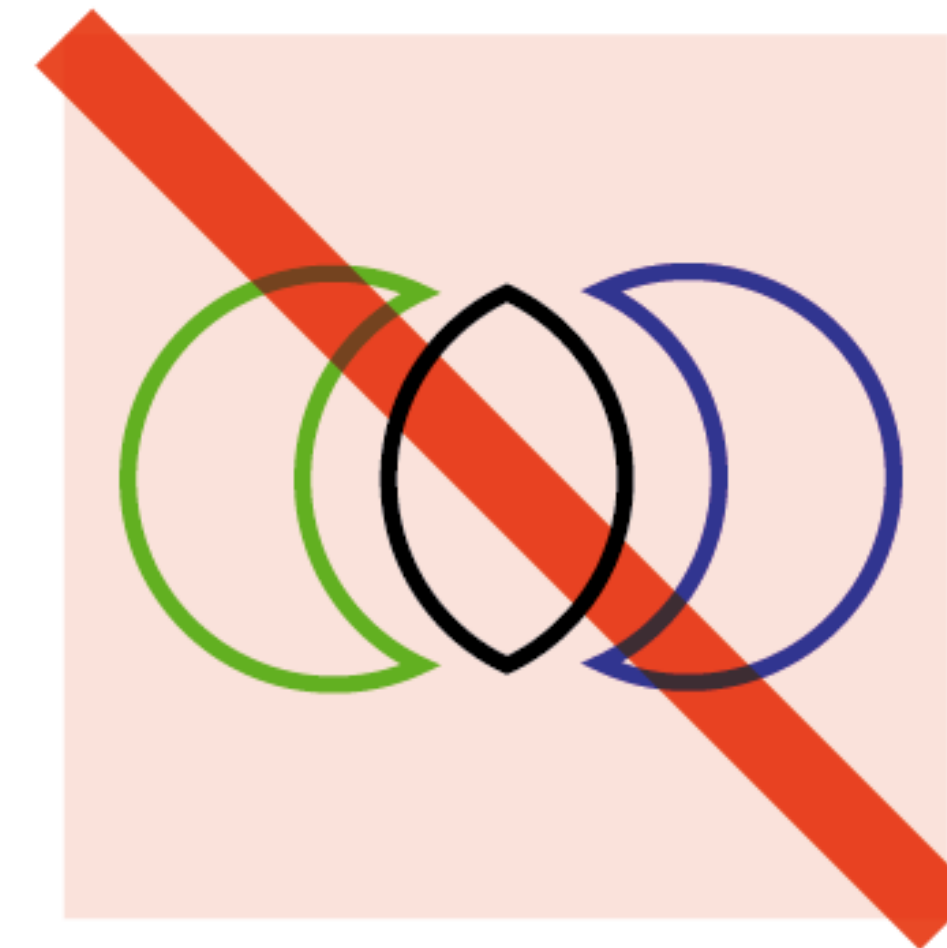
Elements tend to be grouped together if they are parts of a pattern which is as “simple” as possible



Pattern



Interpretation according to the principle

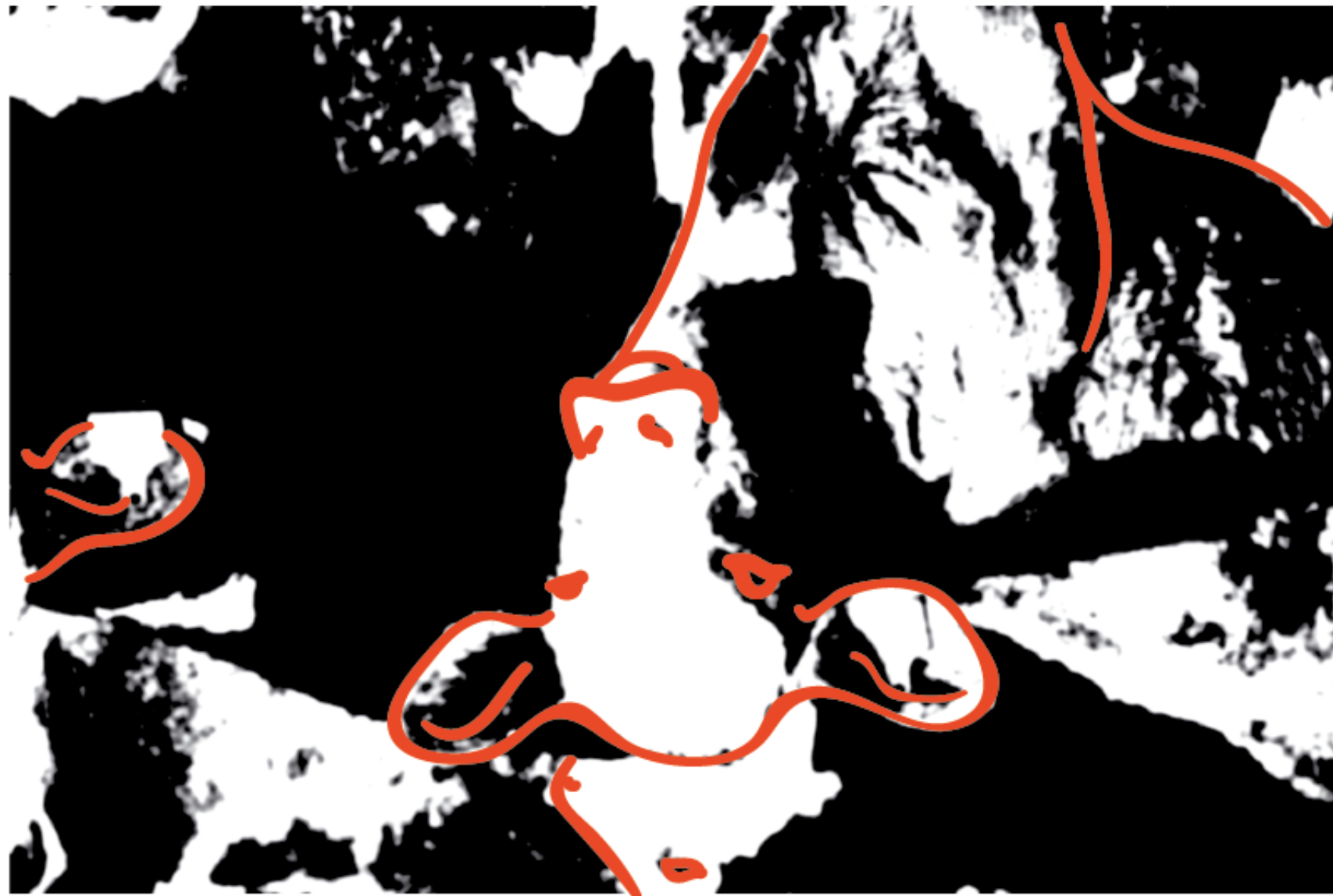


Contradictory or unlikely interpretation



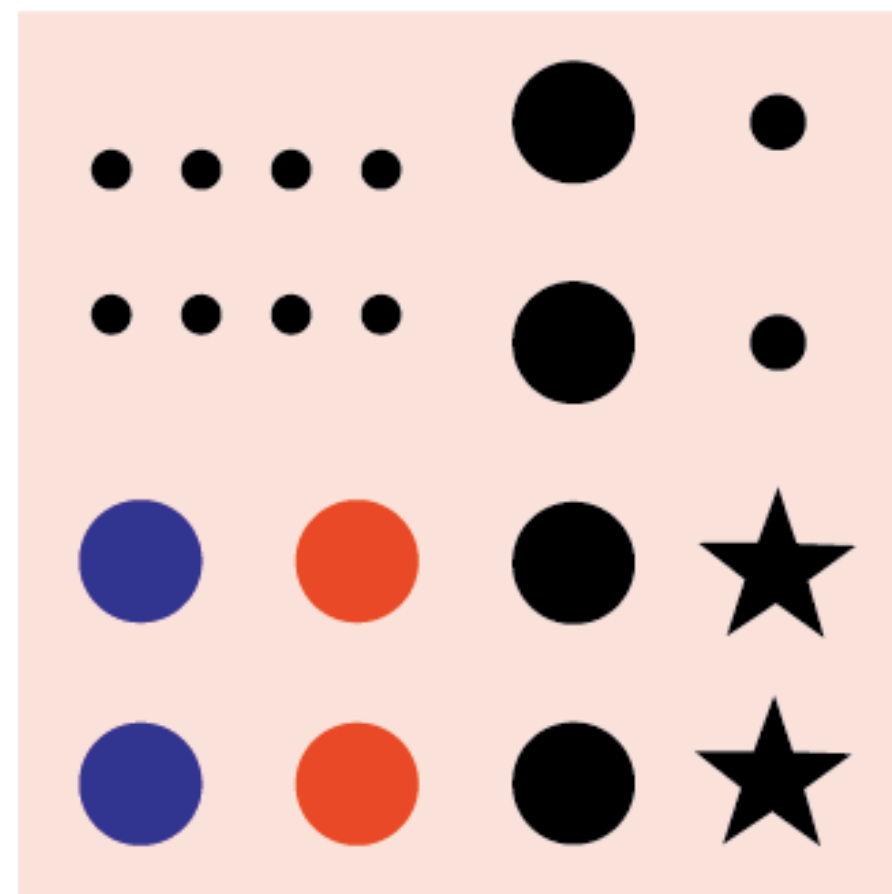
Gestalt principles: Past experience

Elements tend to be grouped together if they were together often in the past experience of the observer

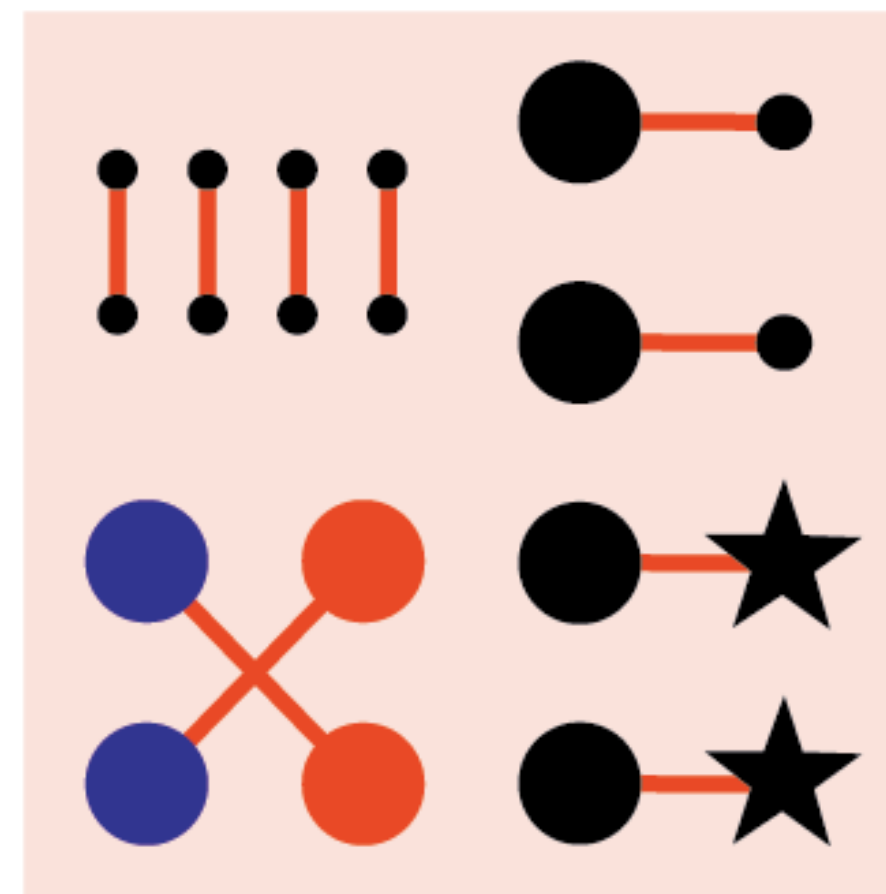


Connectedness and common region.

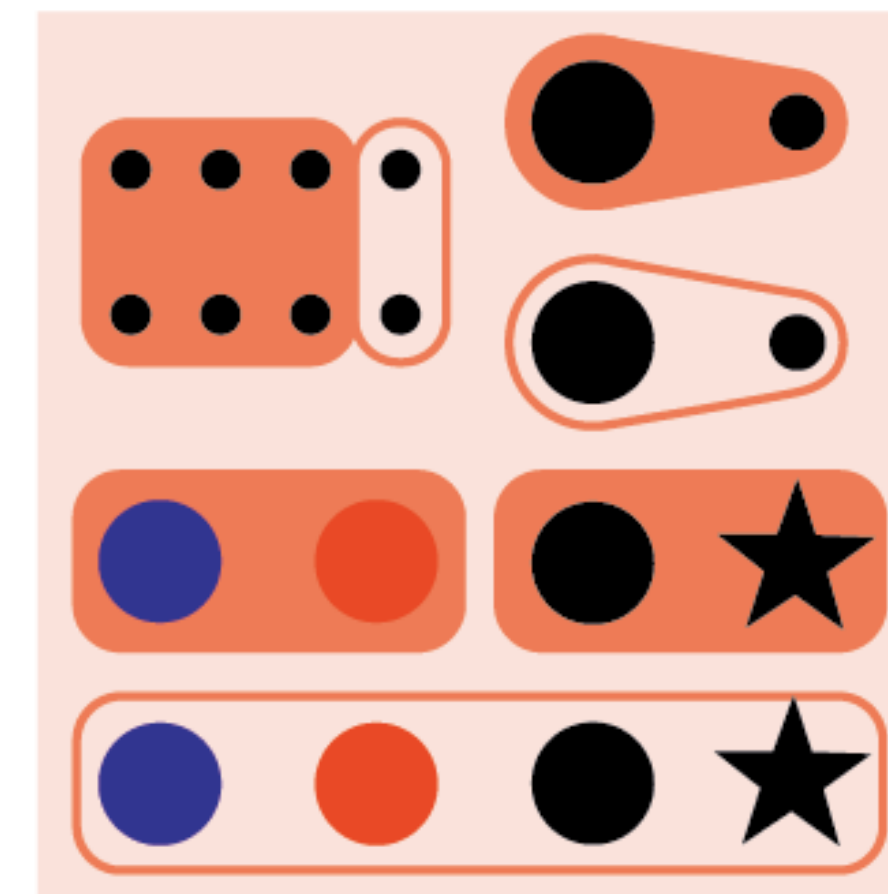
Visually connected elements or elements within the same contour tend to be grouped together, regardless of other features



Pattern

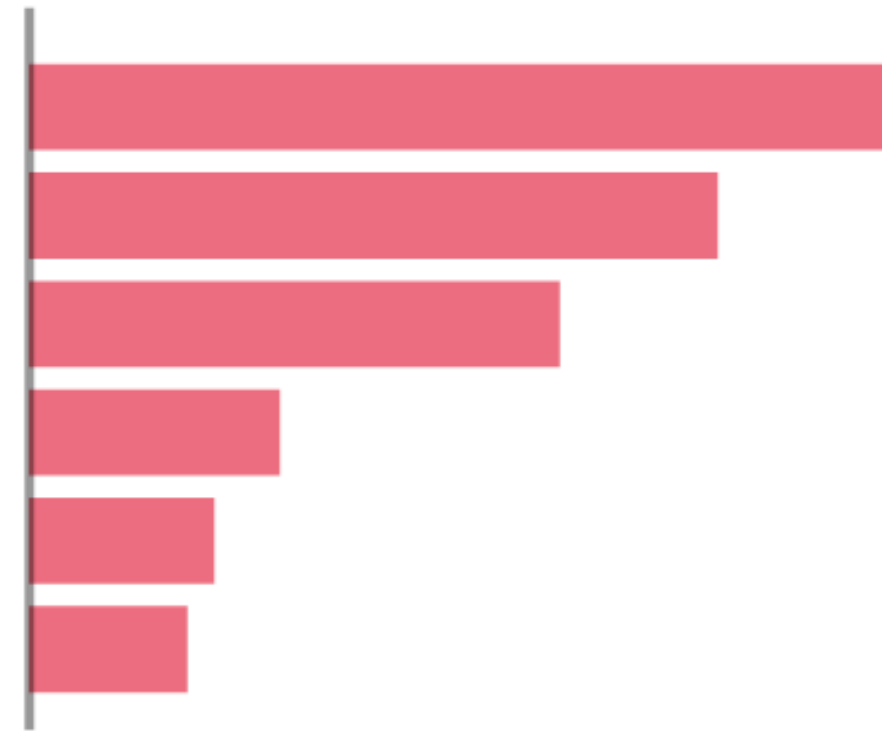


Connectedness
overrides other principles

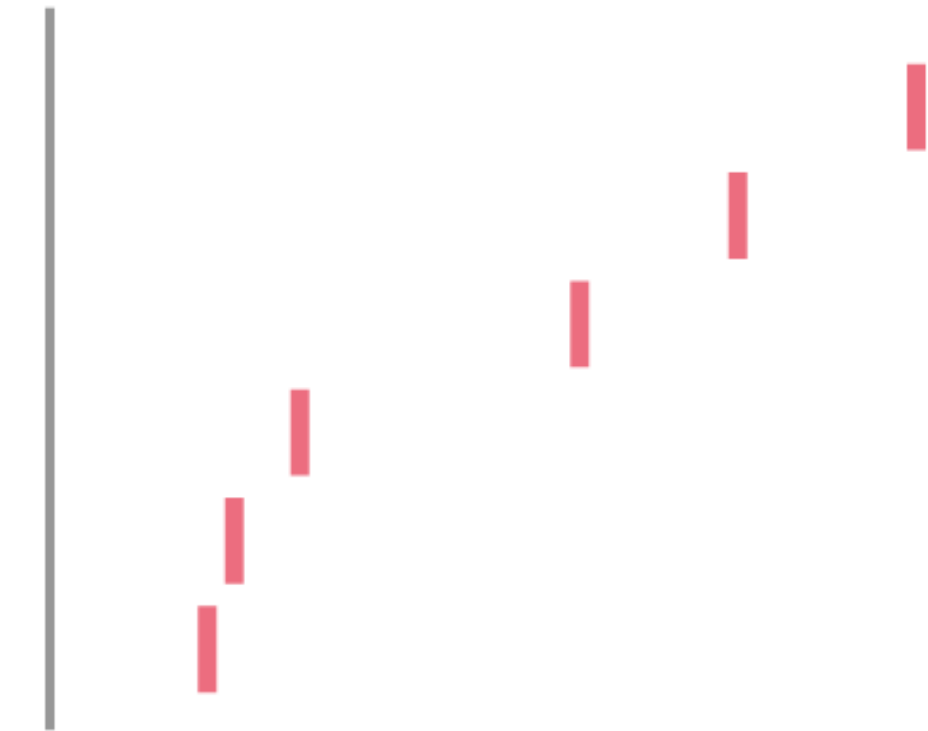


Common region
overrides other principles

Visual variables



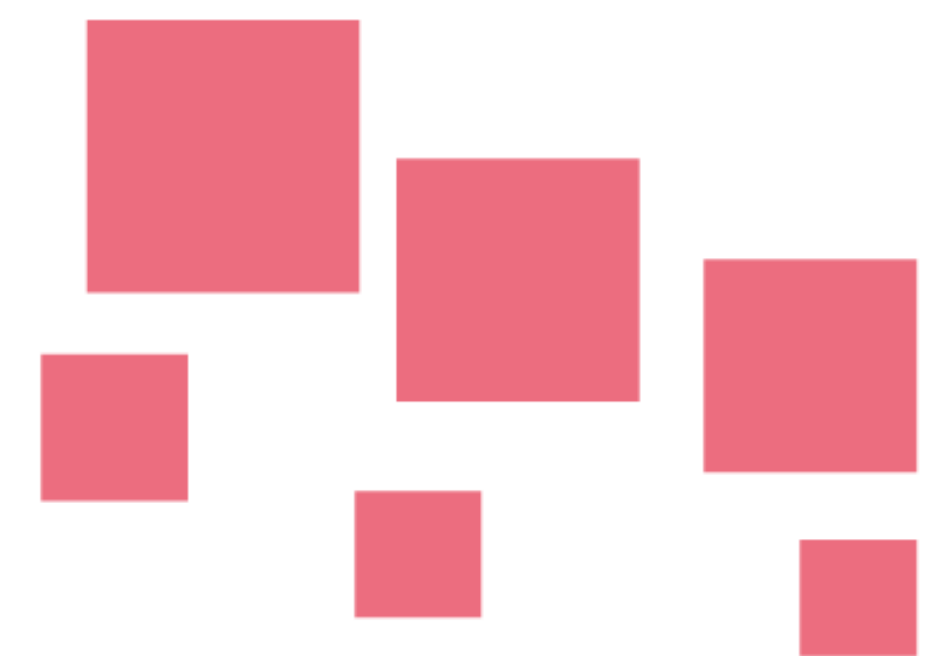
Position, length,
area



Only position



Only length



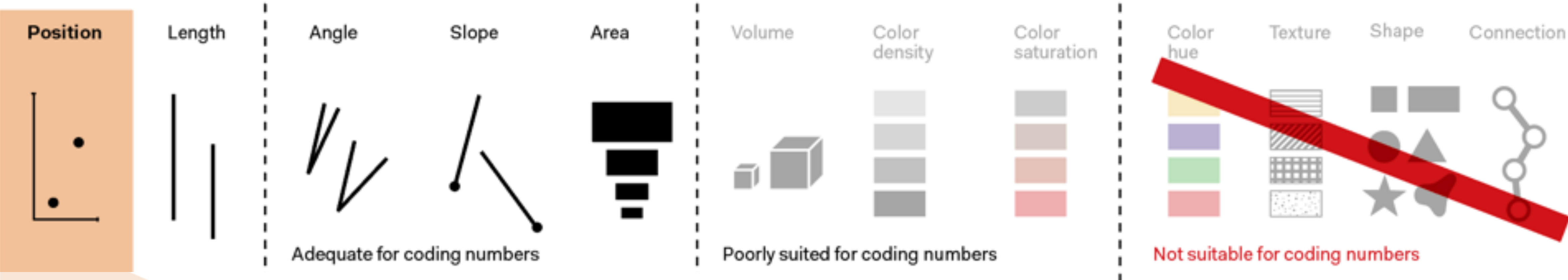
Only area

Visual variables

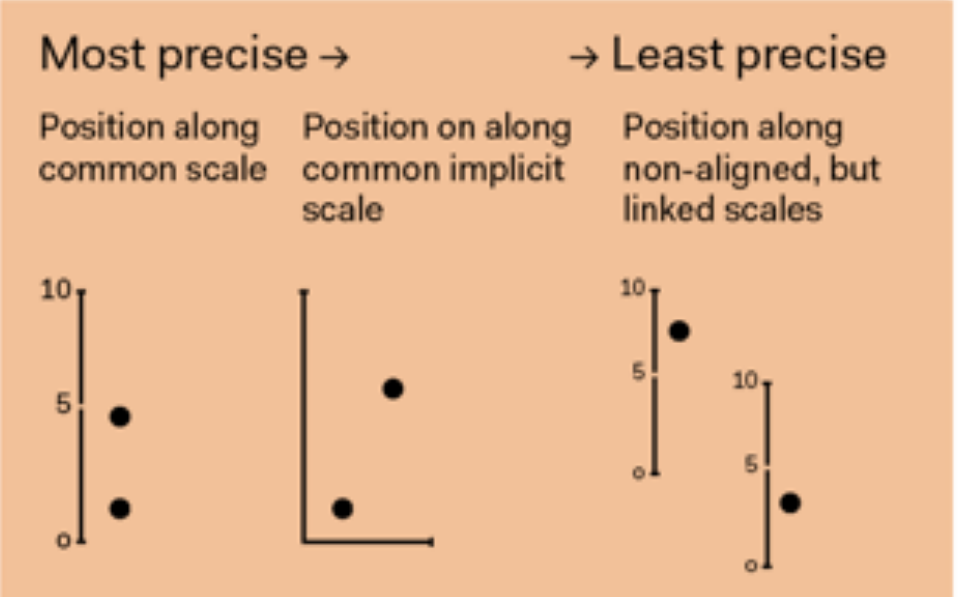
Numbers (ratio or interval scale)

Most precise →

→ Least precise



Using position for coding numbers



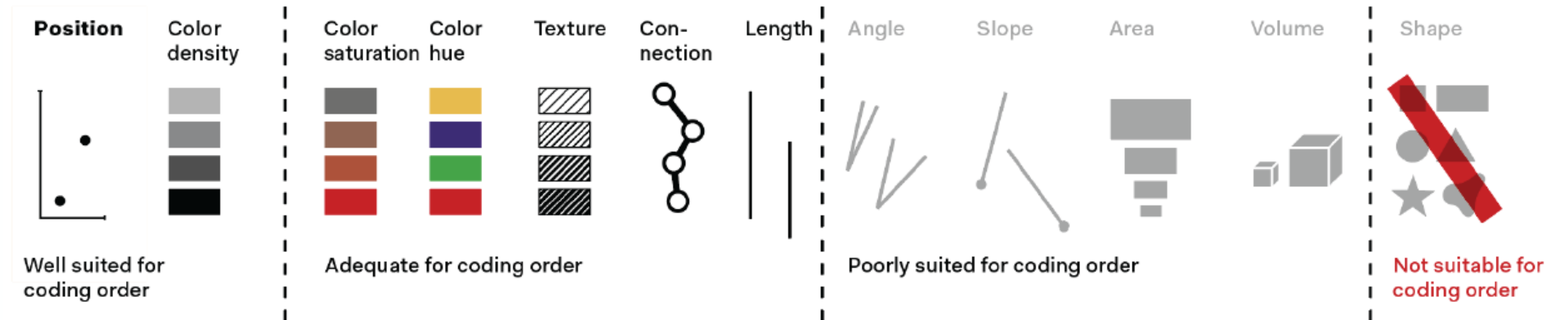
Jacques Bertin 1967, William Cleveland & Robert McGill 1984, Mark Monmonier 1993, Alan M. MacEahen 1994, Jock D. Mackinlay 1999, Juuso Koponen & Jonatan Hildén & Tapio Vapaasalo 2016

Visual variables

Order (ordinal scale)

Most precise →

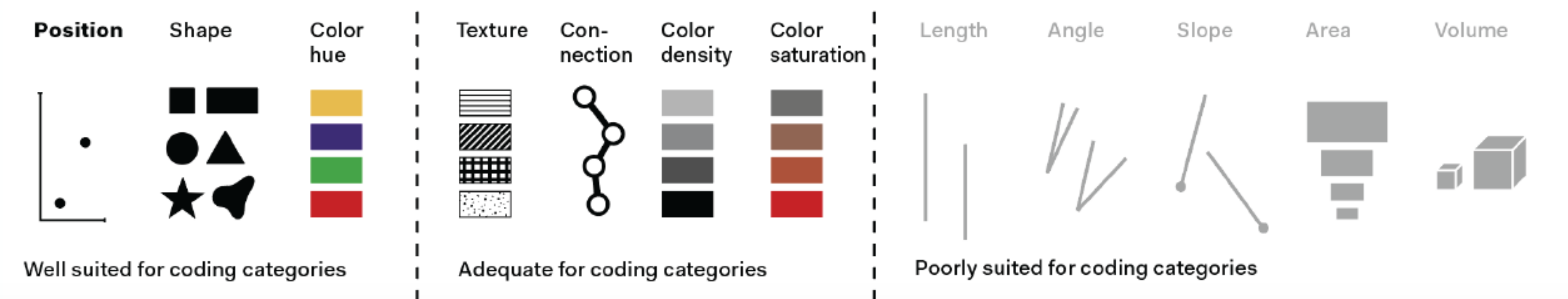
→ Least precise



Categories (nominal scale)

Most precise →

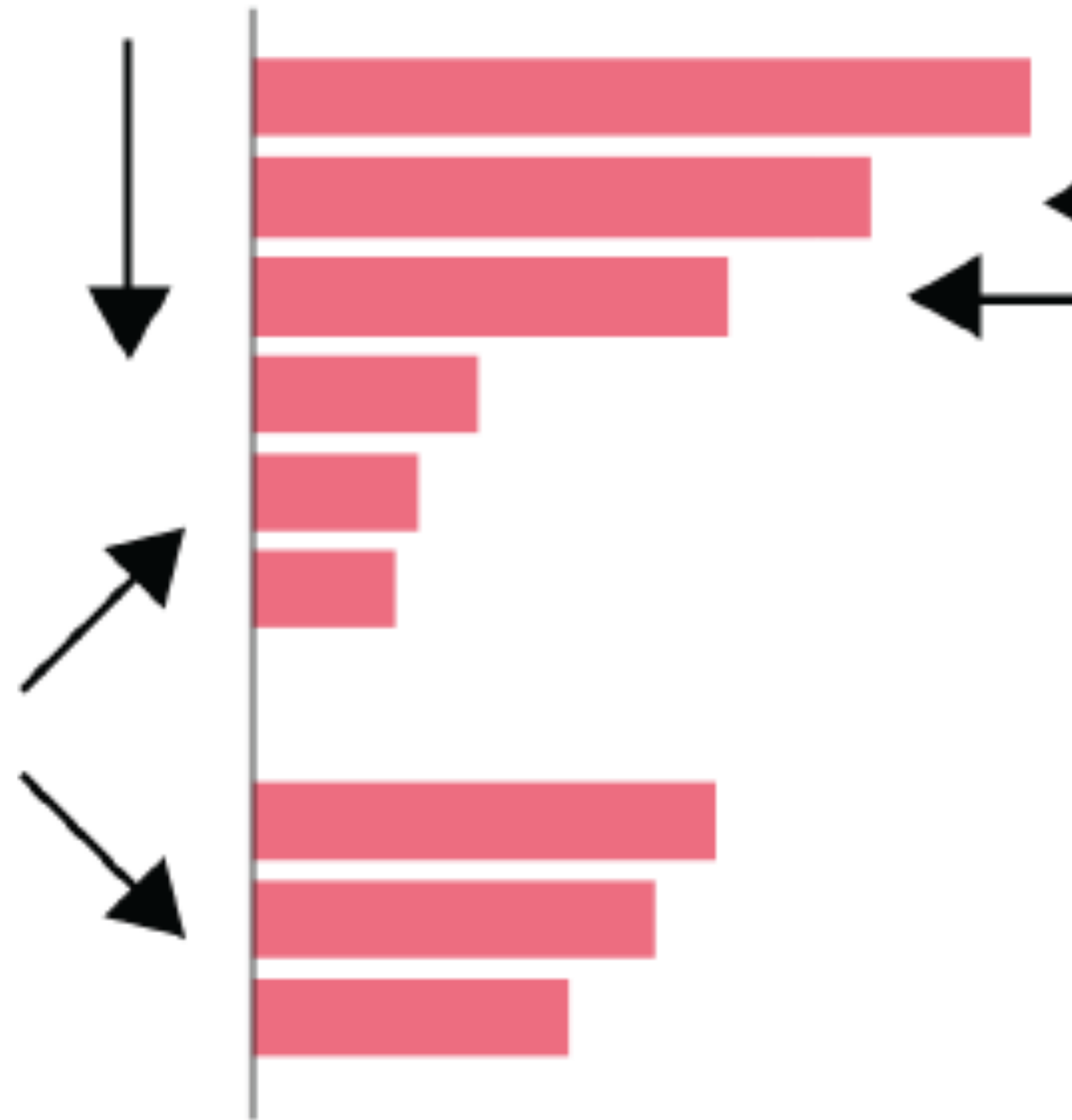
→ Least precise



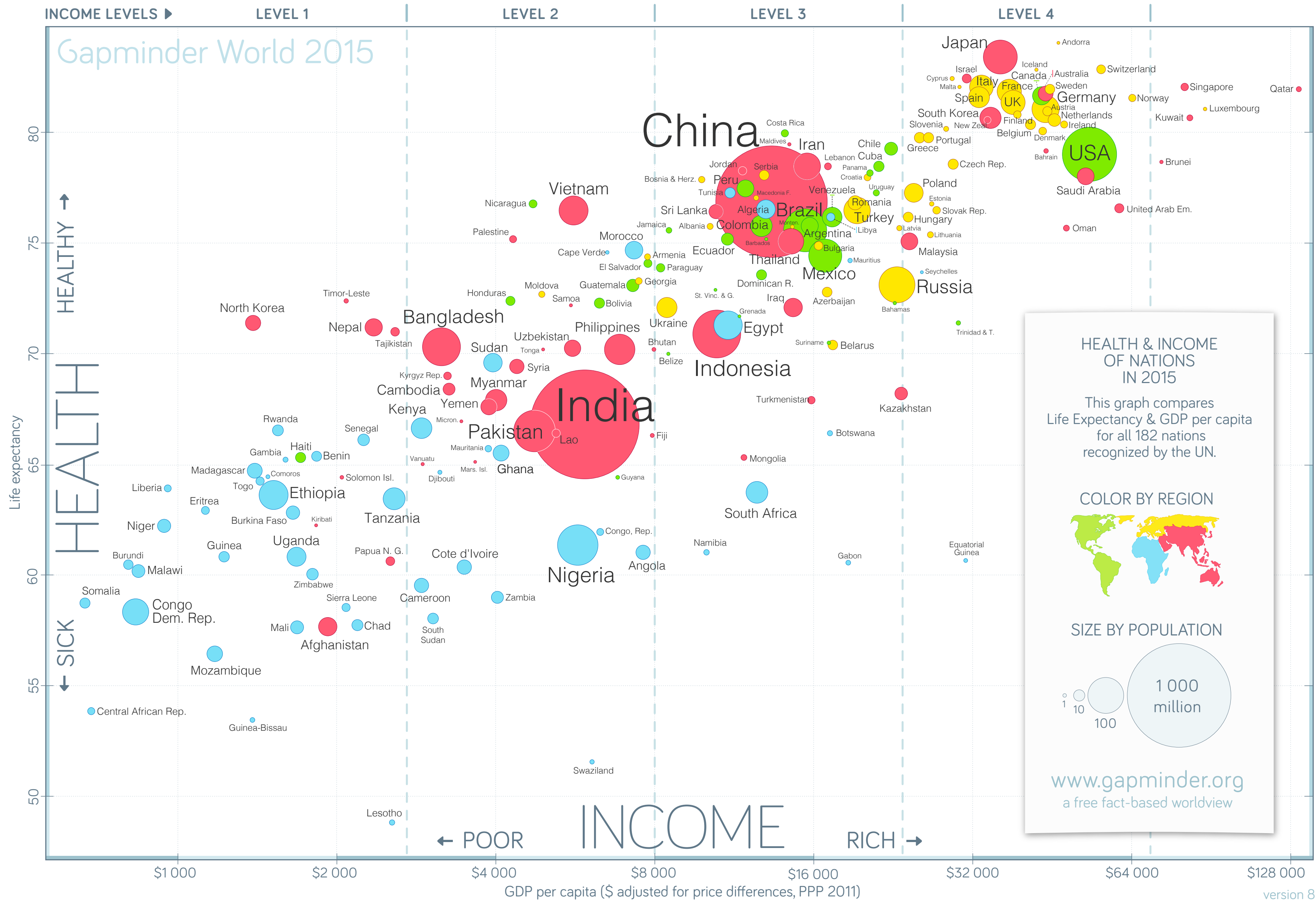
Visual variables

Position encodes
ordinal information:
ordering of bars

Position encodes
qualitative
information: two
separate groups
of bars

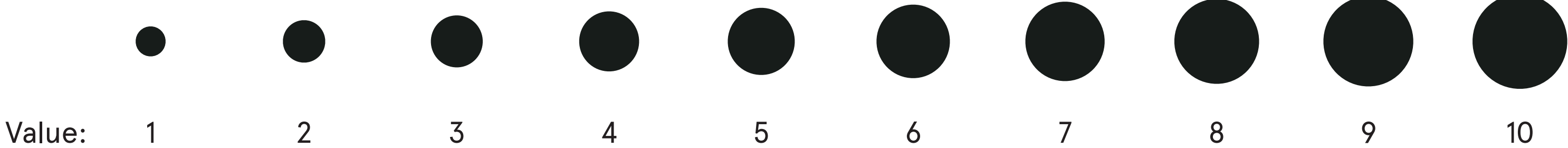


Position
encodes
numerical
information:
length of bars

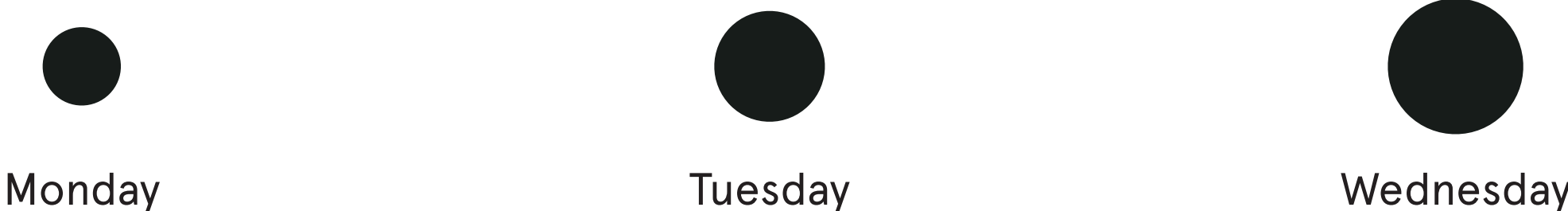


Strive for clear associations between variables and encodings

Area for encoding quantitative information – reasonable



Ordinal information – increasing risk of misreading



Nominal information (category) – implied value judgement



→ Preferably use colors / shapes to represent nominal information



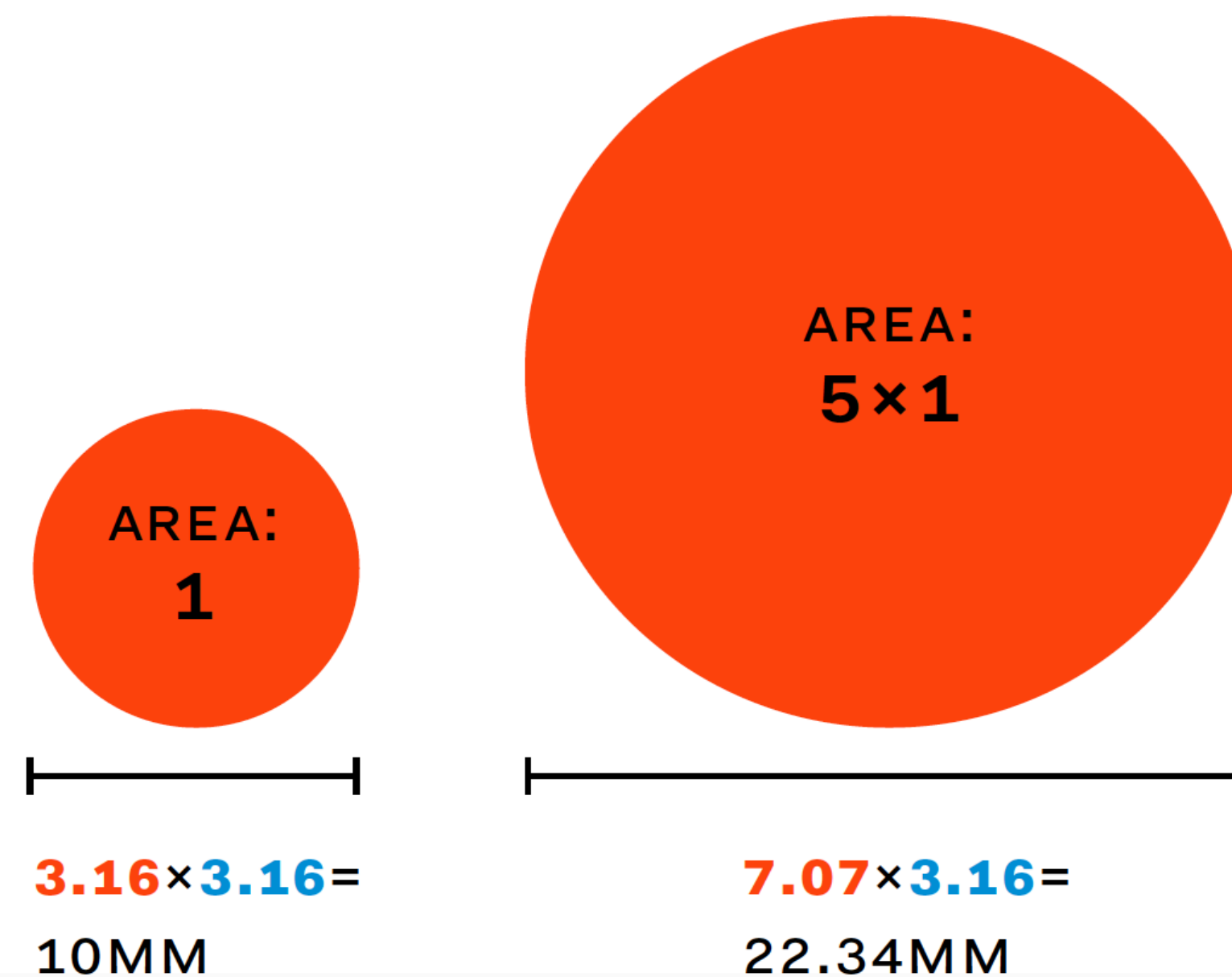
Always scale areas correctly with square roots (don't just input percentages!)

The correct way to scale up or down dimensions when using areas to show values: use a *scale factor* to multiply the square root of the *value*

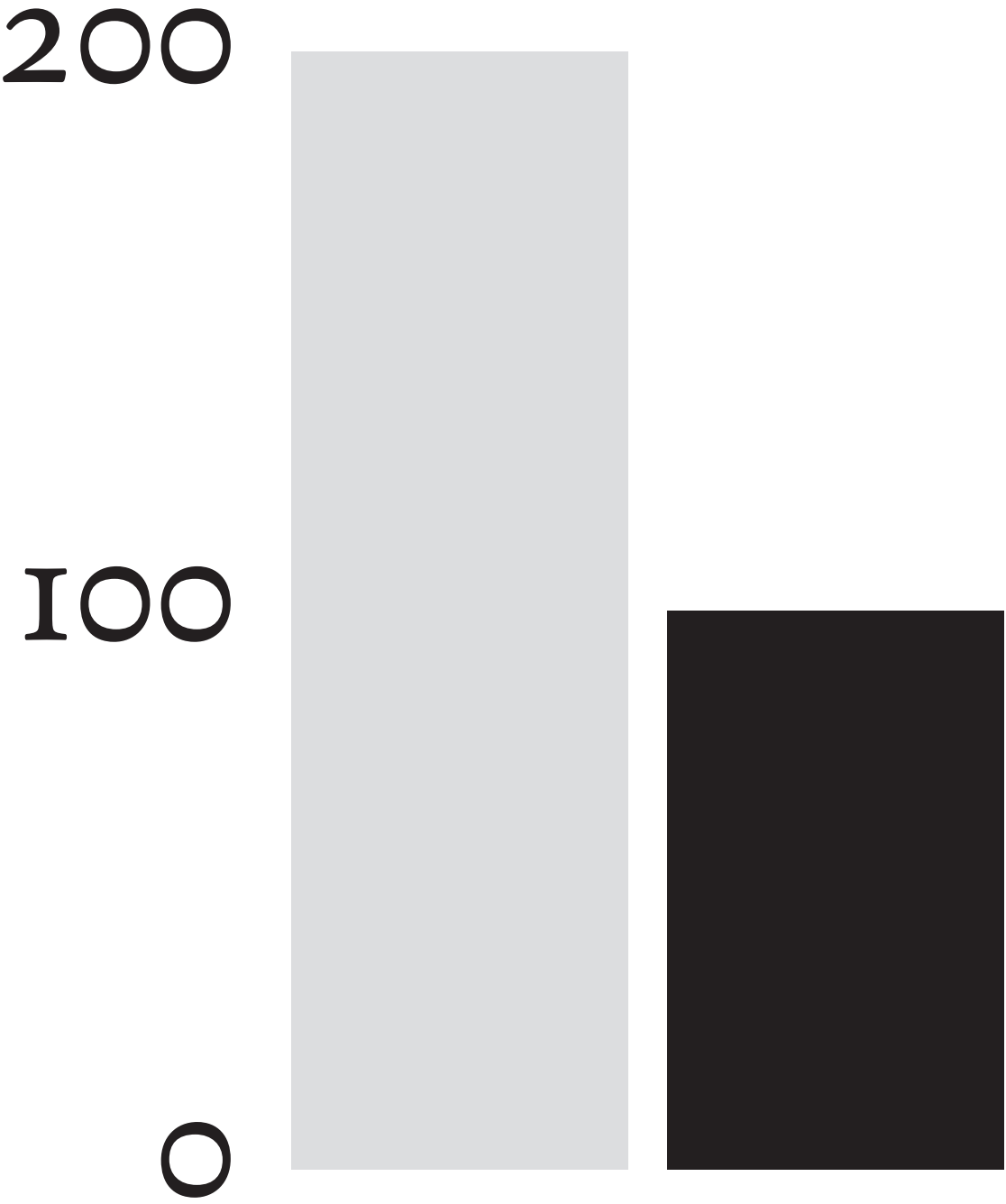
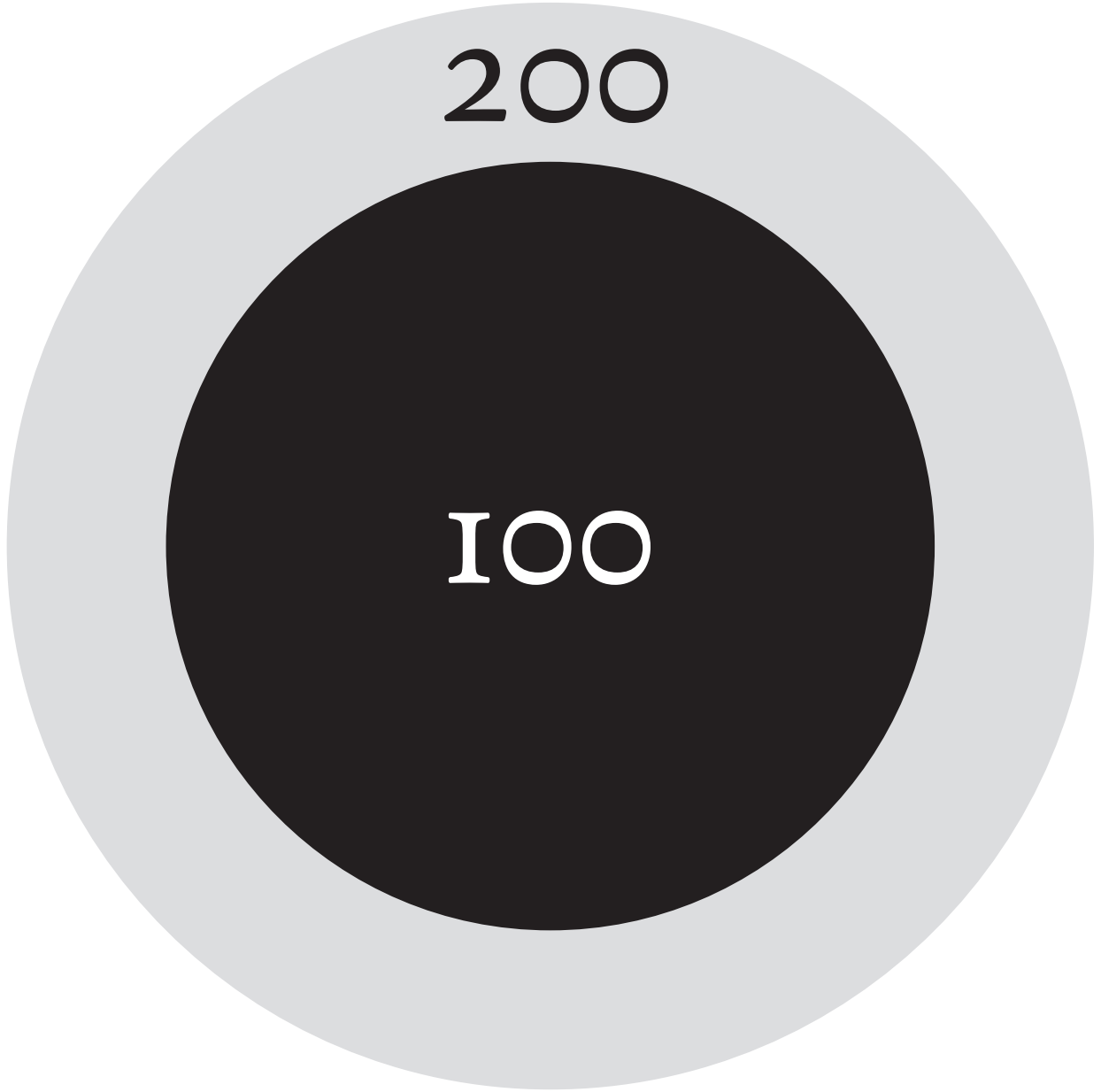
$$\text{width} = \sqrt{\text{value}} \times \text{scale factor}$$

VALUE: 10

VALUE: 50



**Area differences
are hard to gauge
visually, especially
with superimposed
shapes**

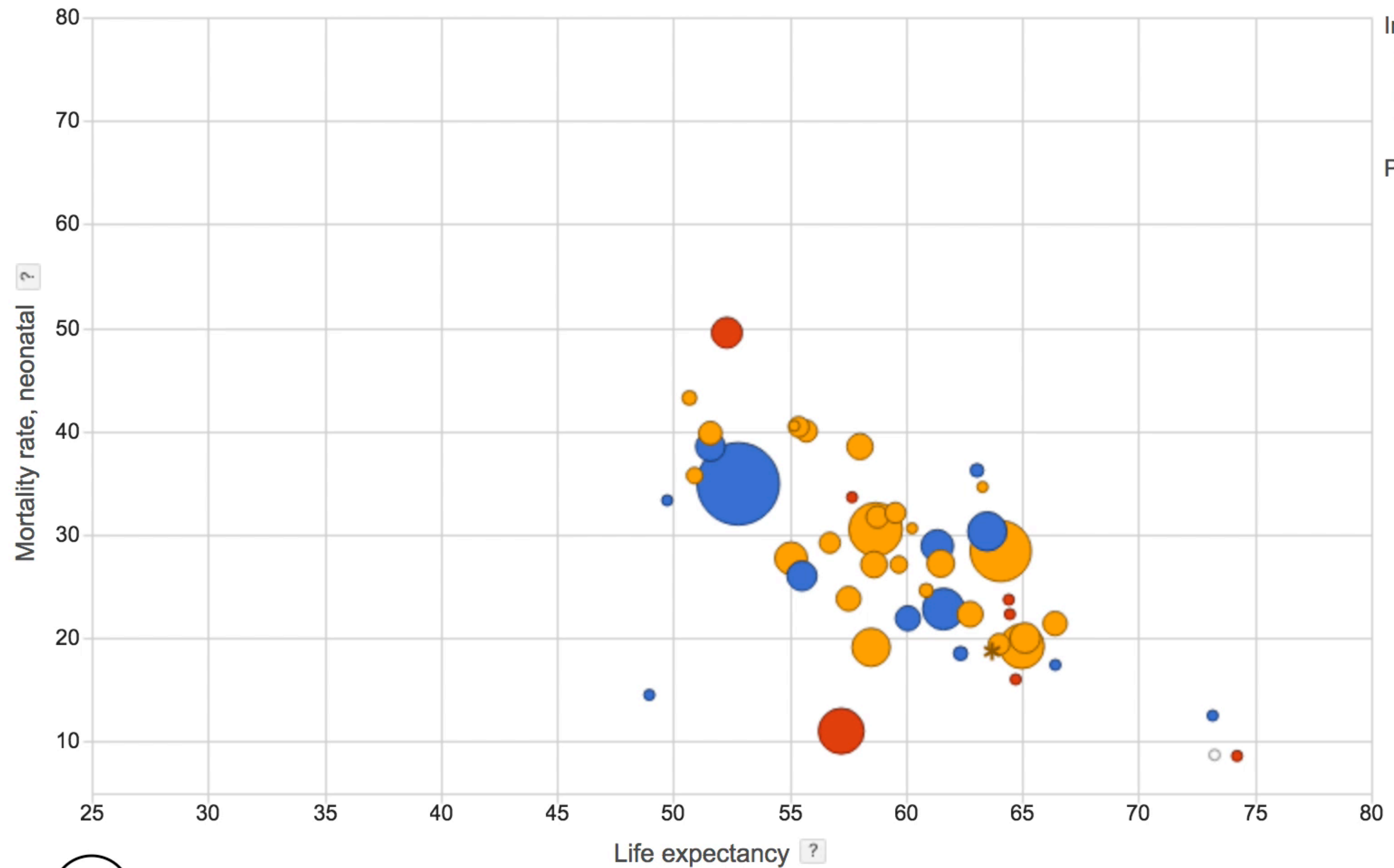


Motion is a powerful visual variable, but there isn't much research on the topic

06:29



Countries, Sub-Saharan Africa ?



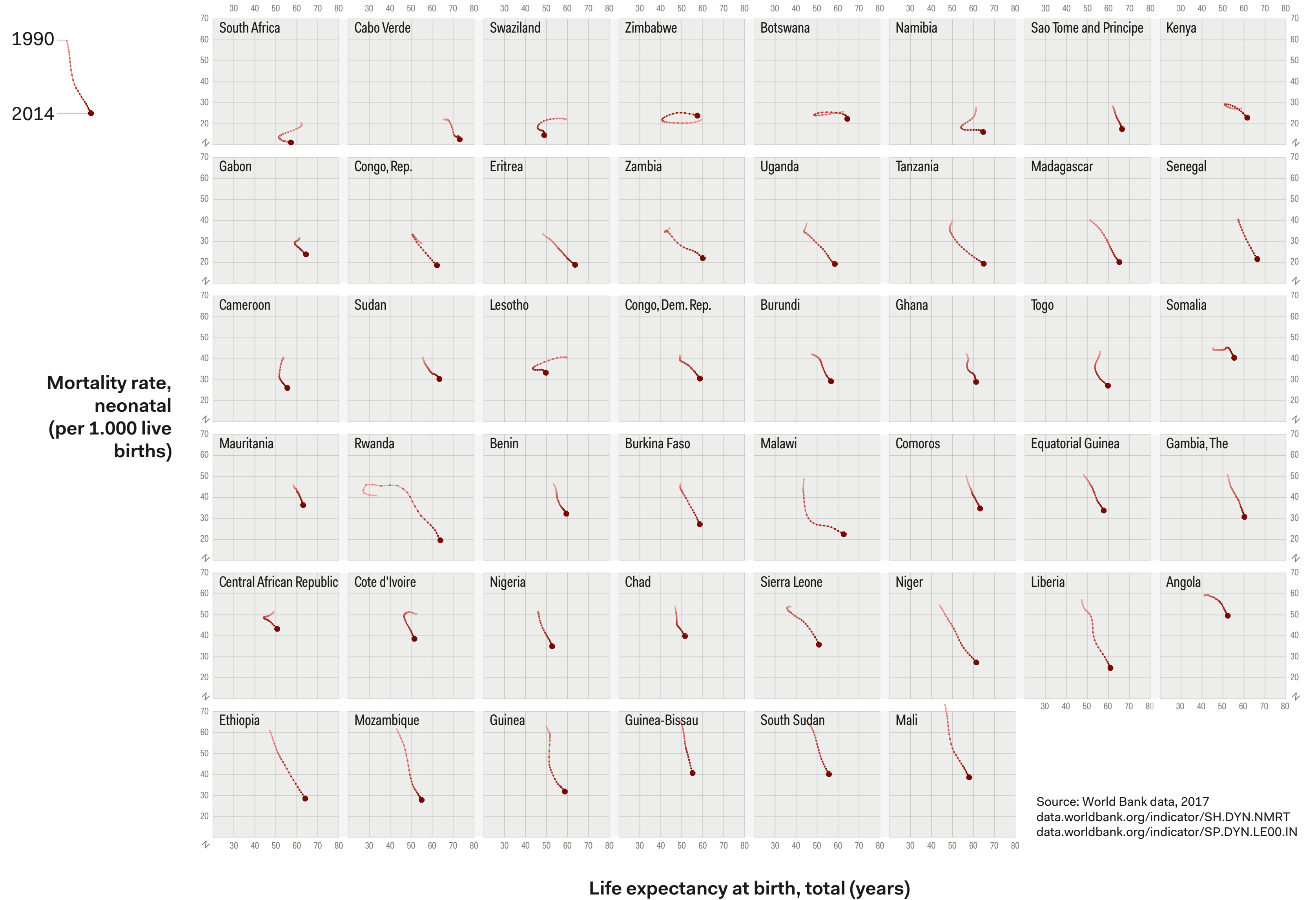
2014

Data from [World Bank](#) Last updated: Feb 6, 2017

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Neonatal mortality rate compared to life expectancy in countries of Sub-Saharan Africa, 1990–2014

Countries sorted in rows left to right from lowest to highest recorded neonatal mortality rate. 2014 values emphasized.



The components of color perception

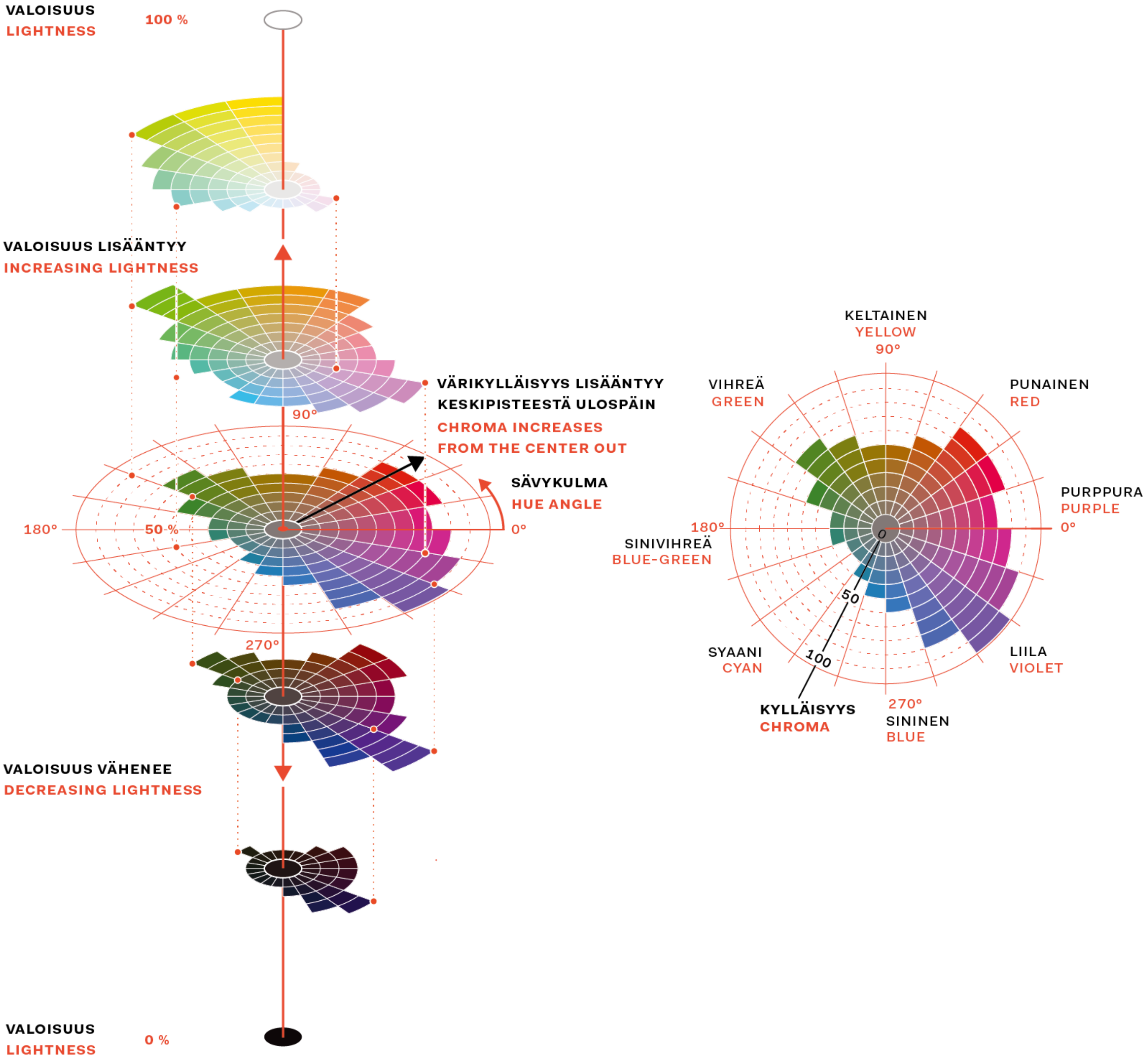
Hue – the perceived color, e.g. blue, red, yellow.

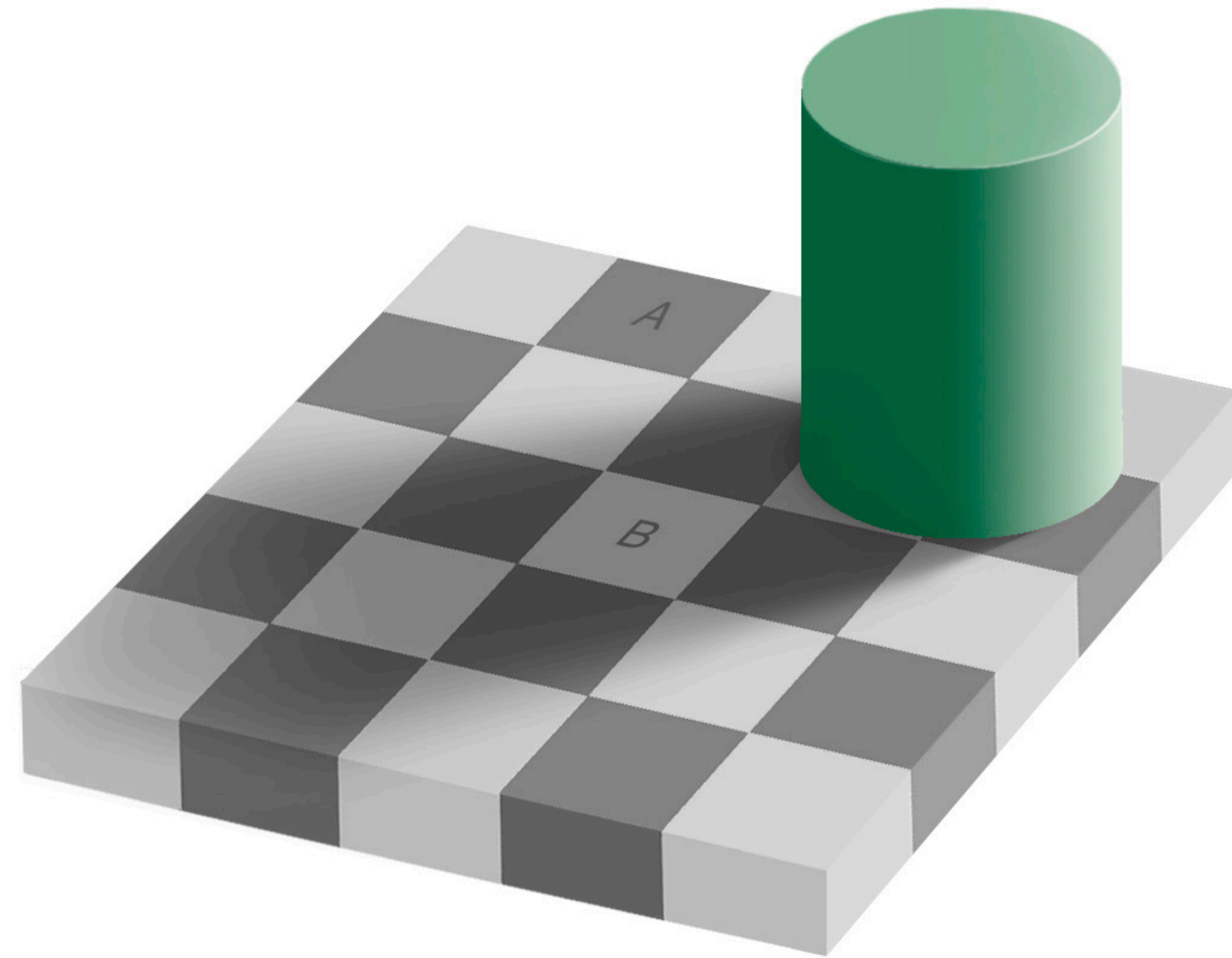
Dependent on the wavelength of the light

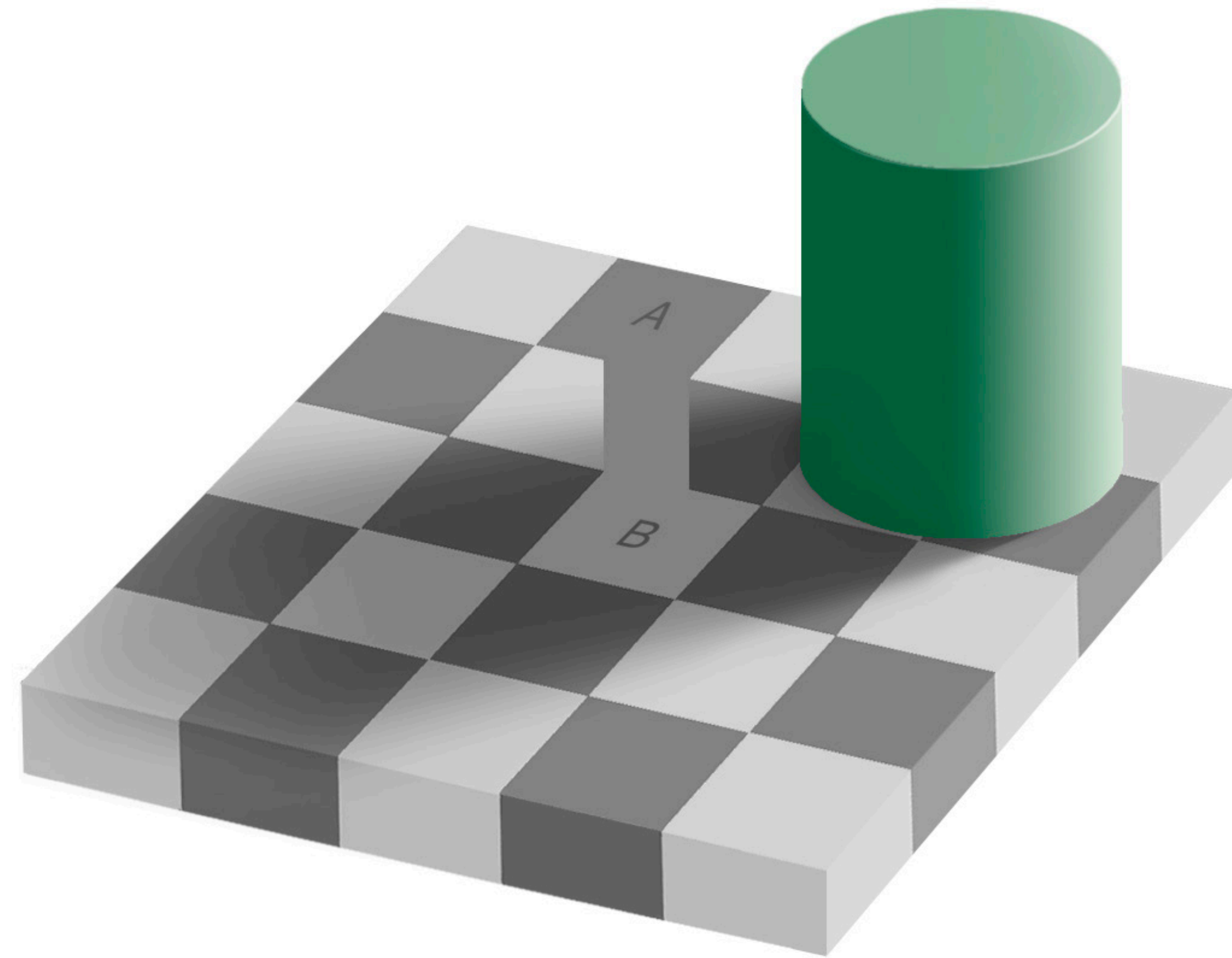
Chroma (or saturation) – how intense the color appears as compared to a neutral hue

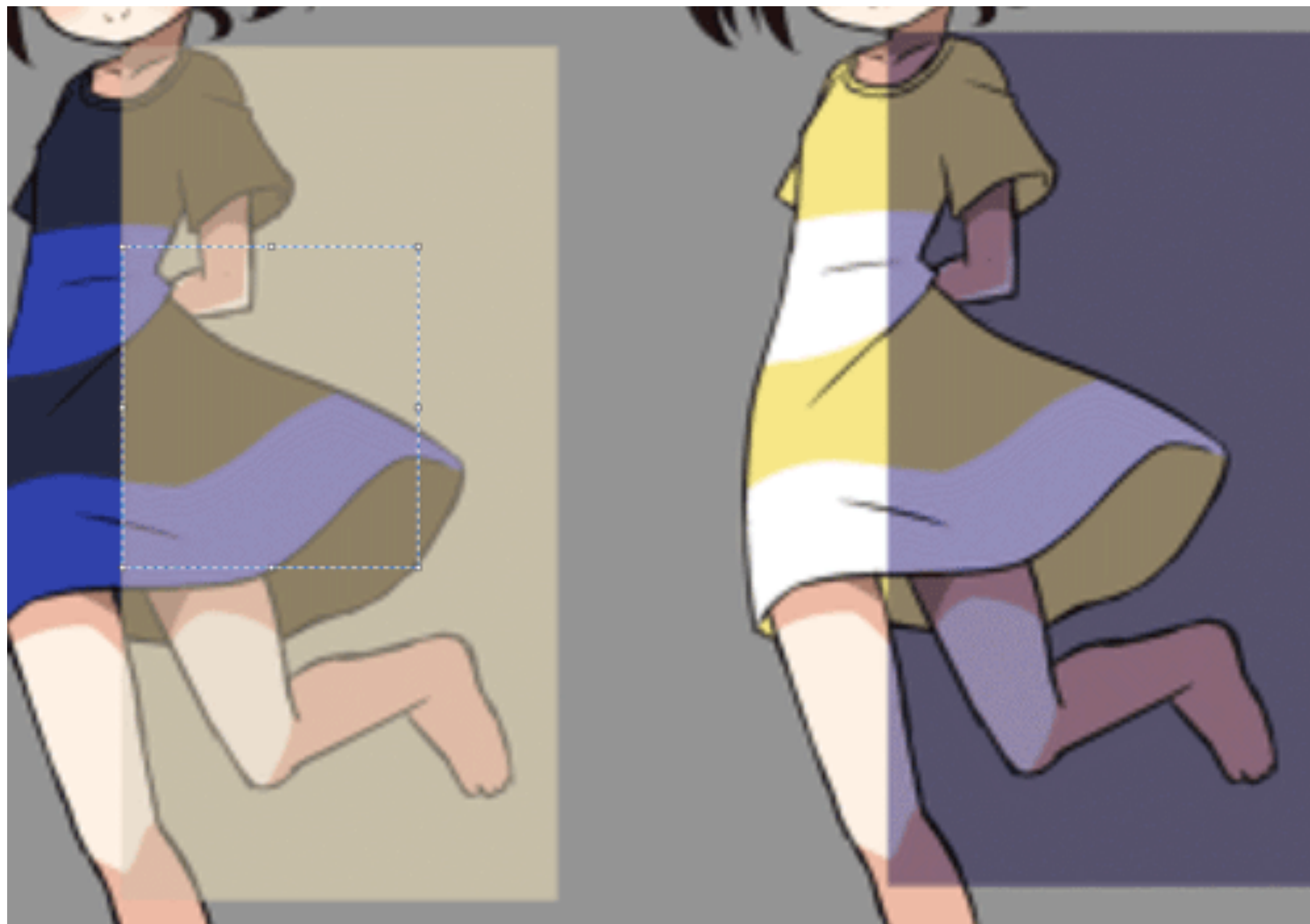
Lightness (or luminosity) – visual system's interpretation of the reflectivity of a surface or brightness of a light source

The HCL color space

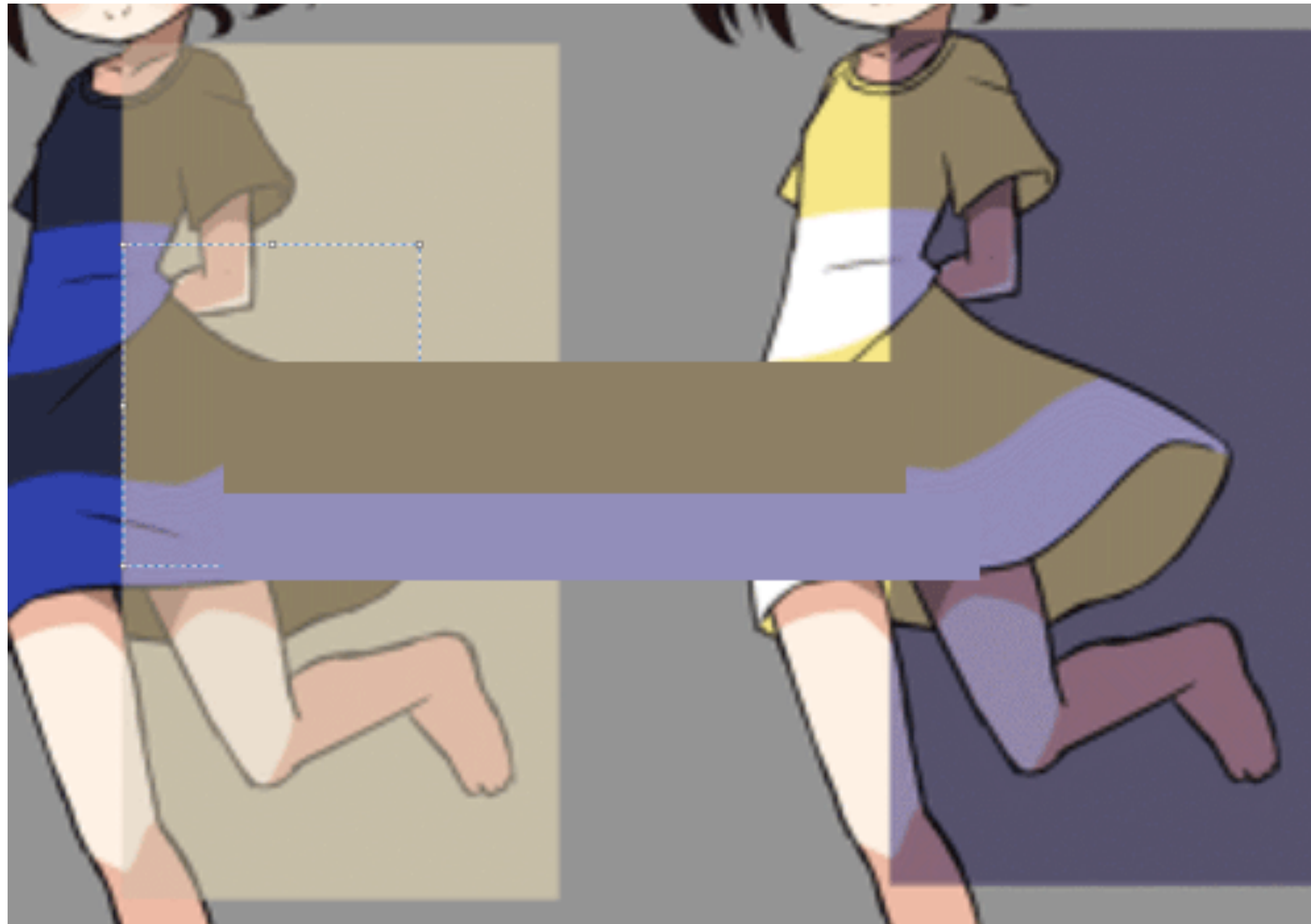




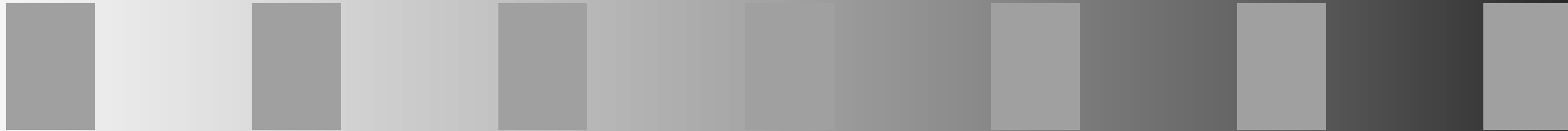


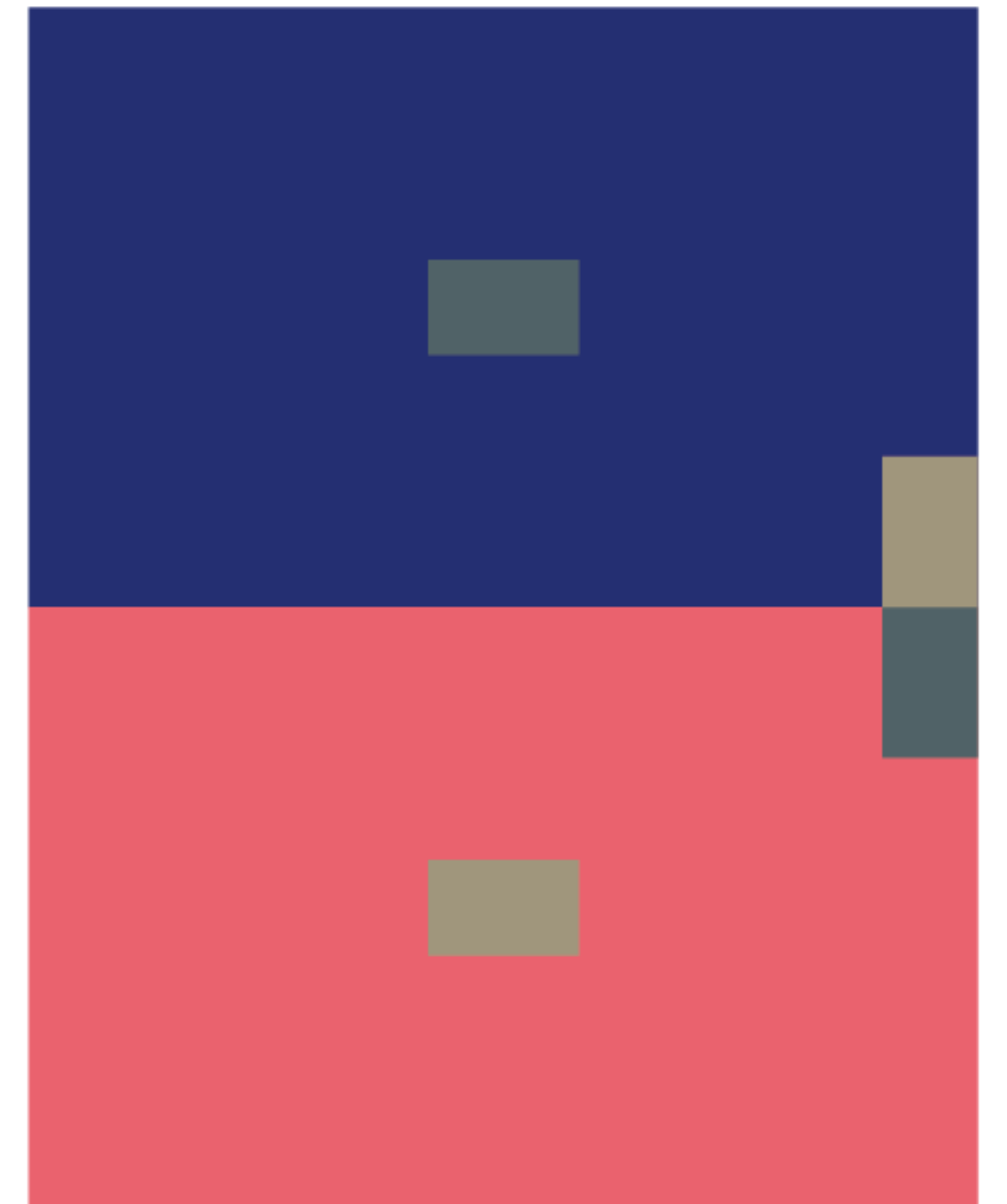


KOPONEN + HILDÉN

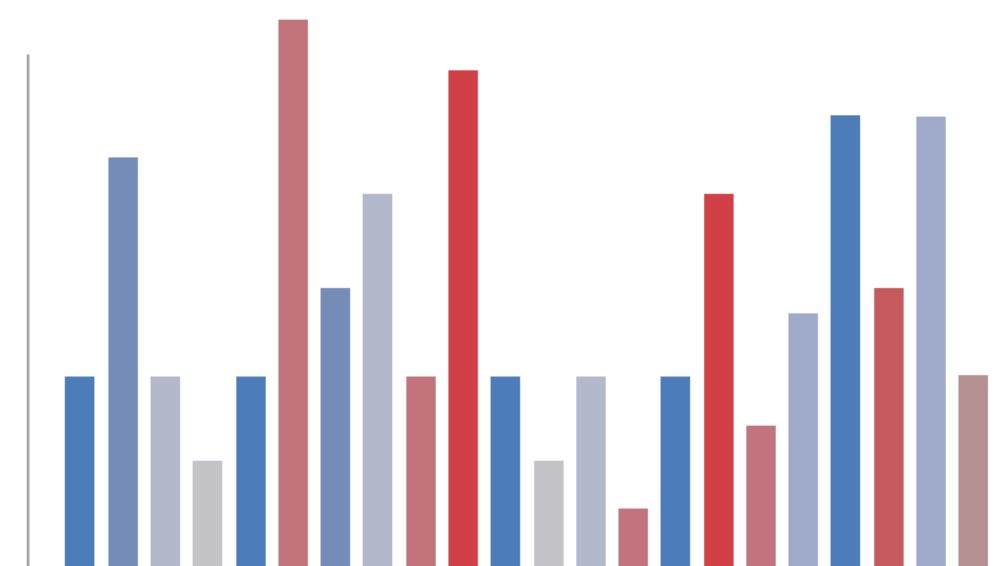
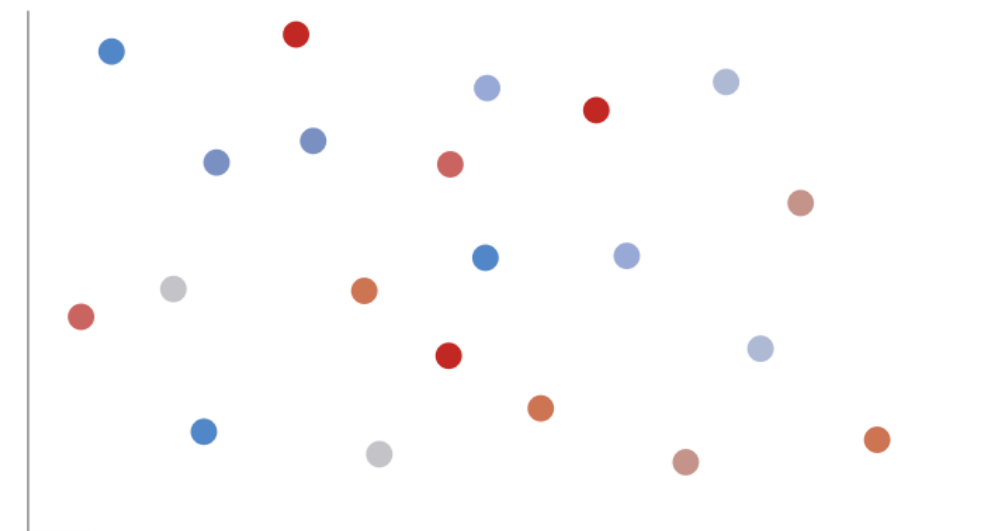


Simultaneous contrast

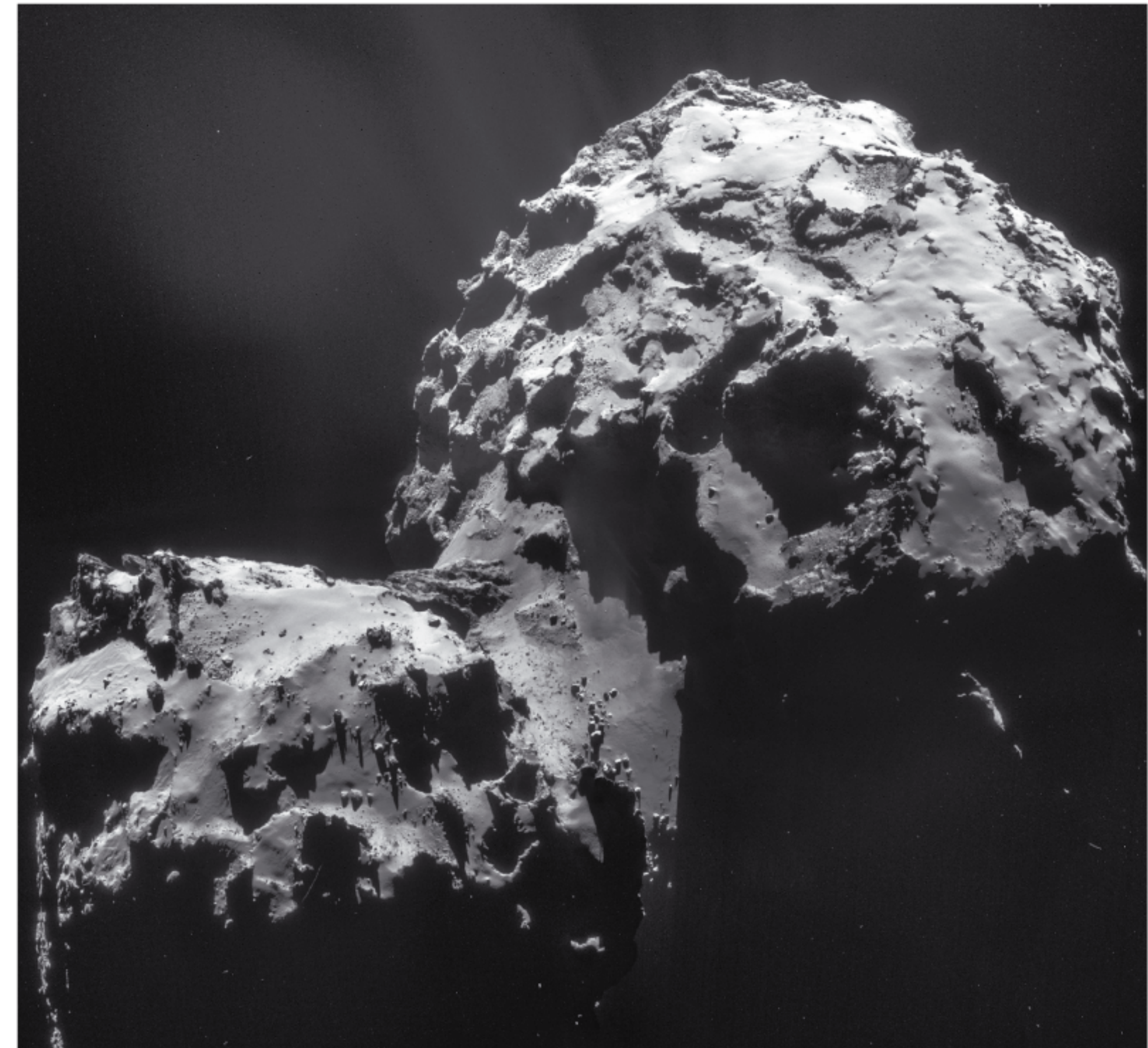
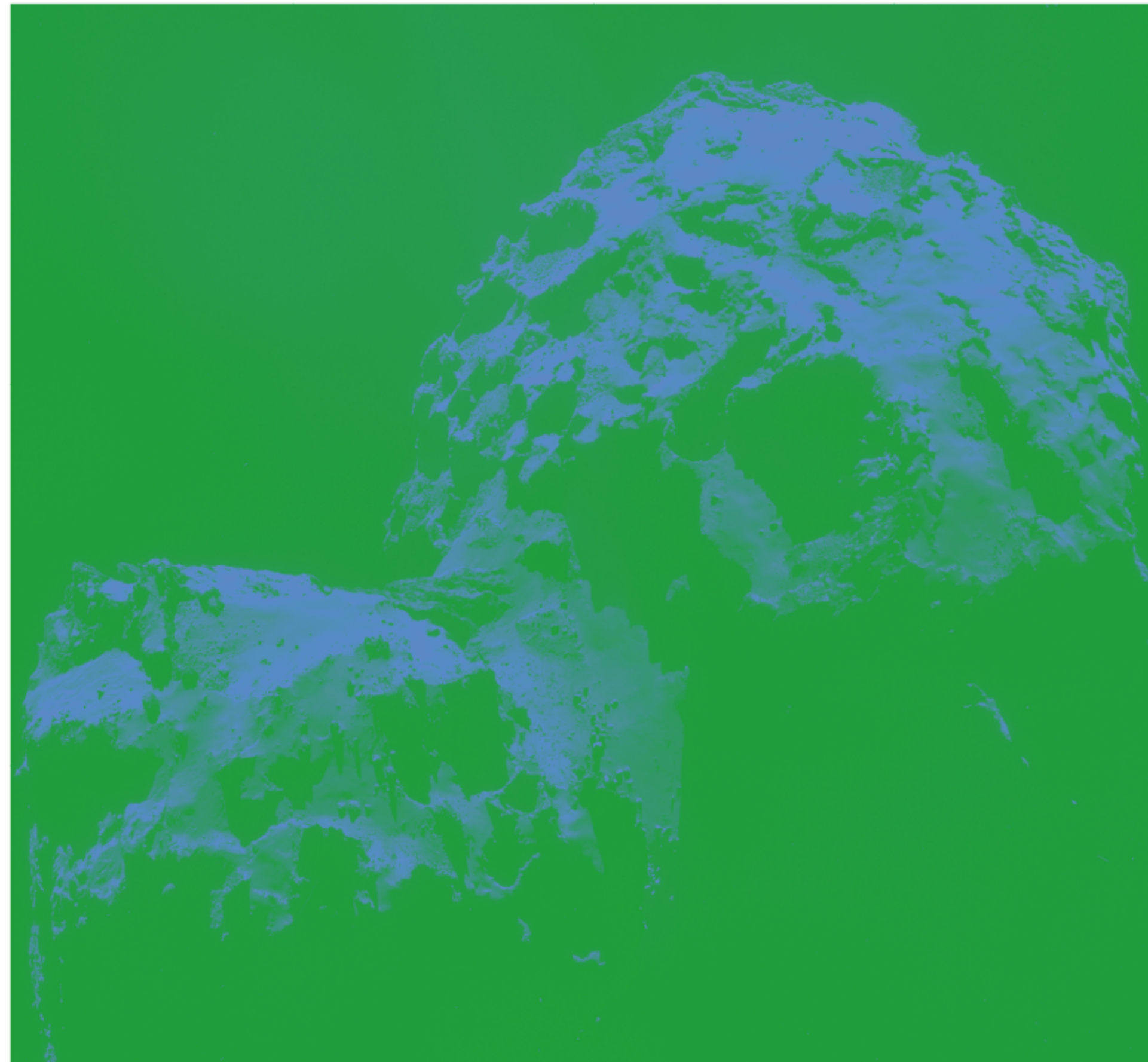




The size of the marks has a strong effect on perceived color differences

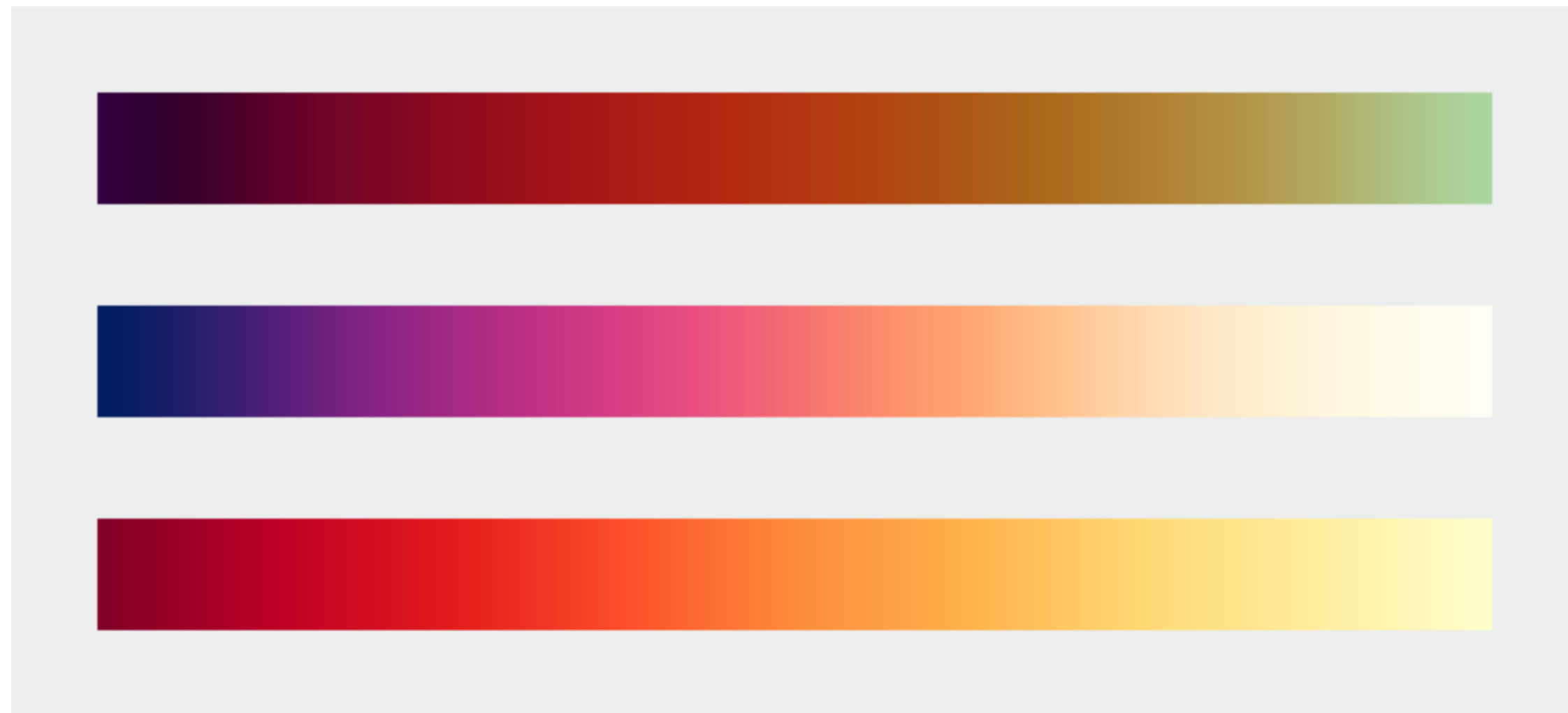


Seeing shapes is based on luminosity



Palettes that combine a continuous change in lightness with a shift in hue often work best in visualizations

Sequential palettes



Diverging palettes

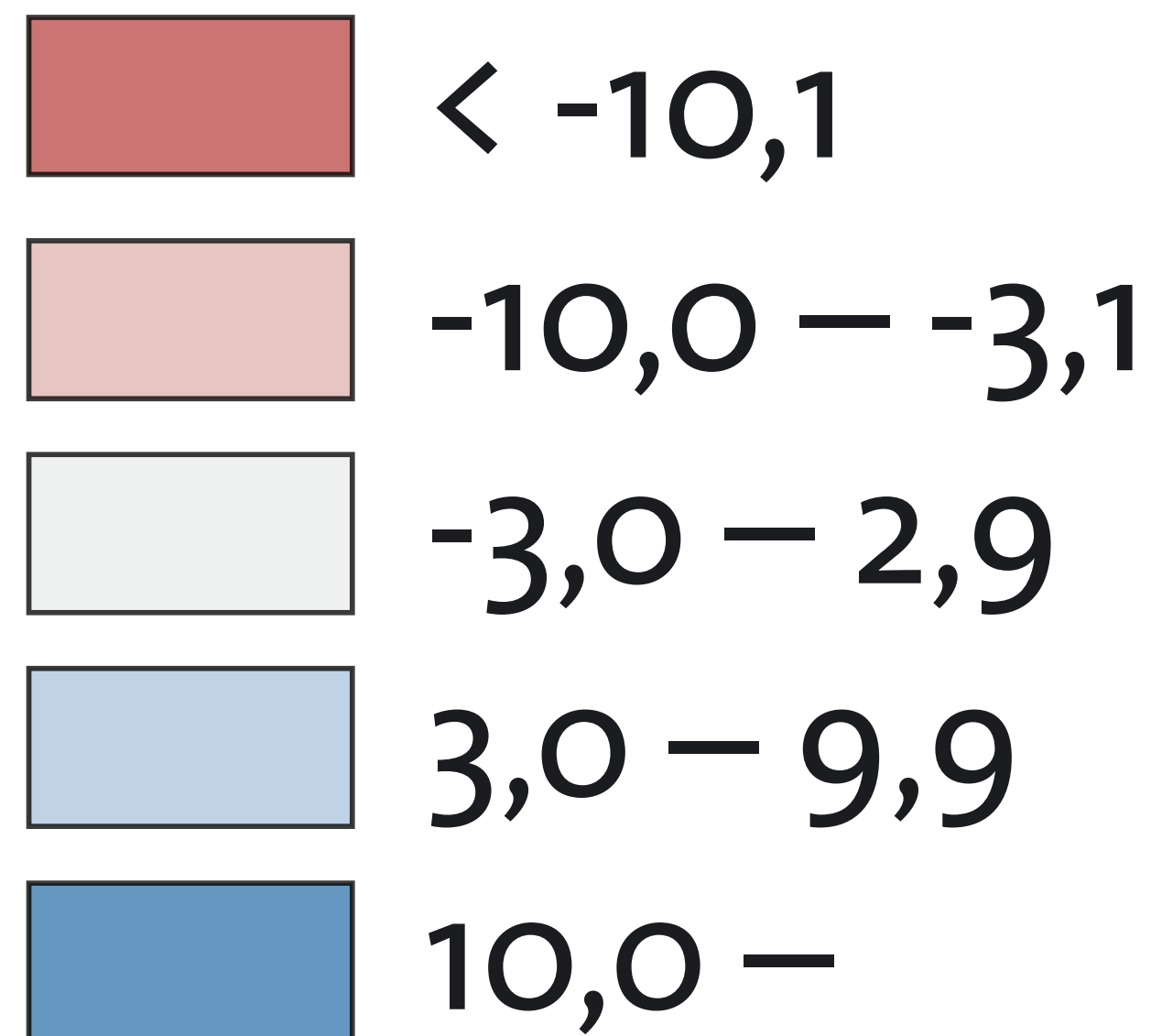


<http://earthobservatory.nasa.gov/blogs/elegantfigures/2013/08/06/subtleties-of-color-part-2-of-6/>

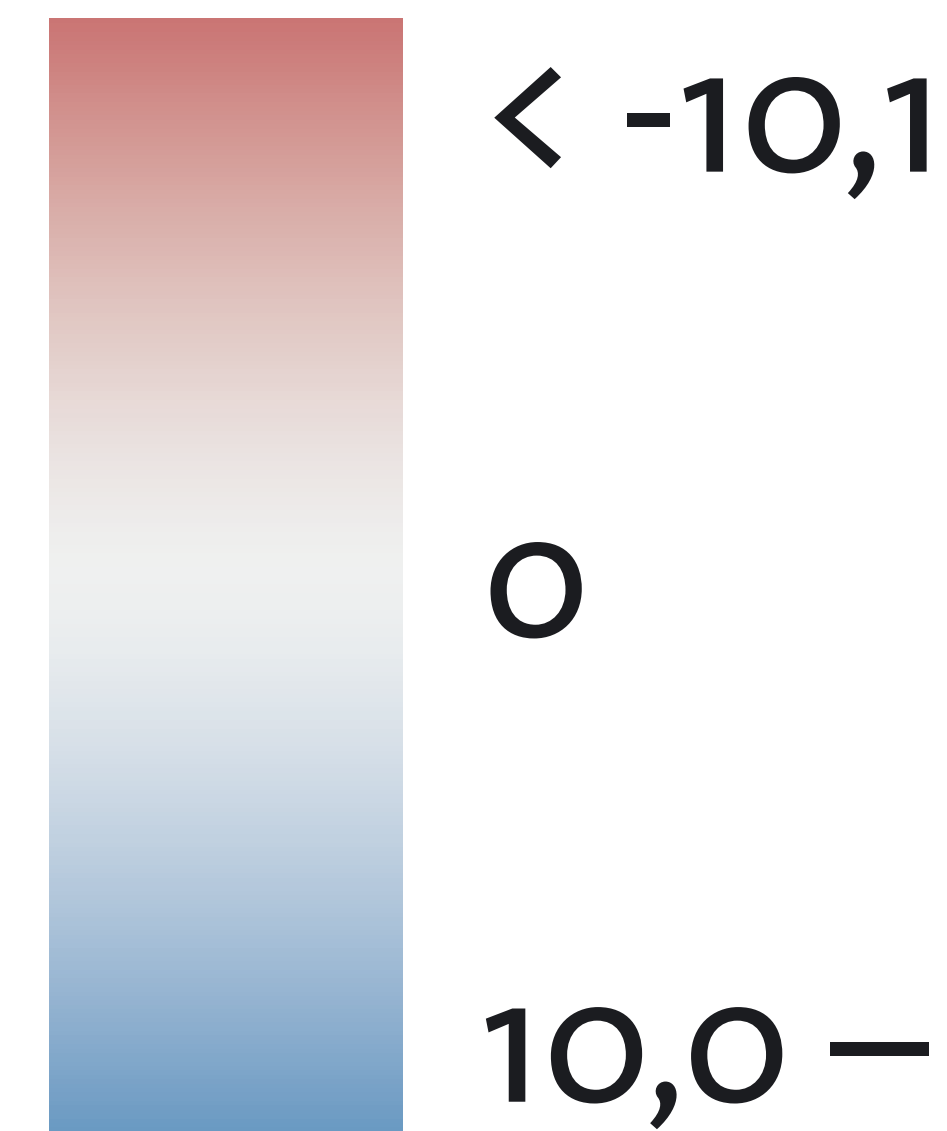
<https://blog.datawrapper.de/colorguide/>

Color scales with discrete steps sacrifice accuracy, but are generally easier to read than continuous scales

Migration, persons per 1 000 inhabitants

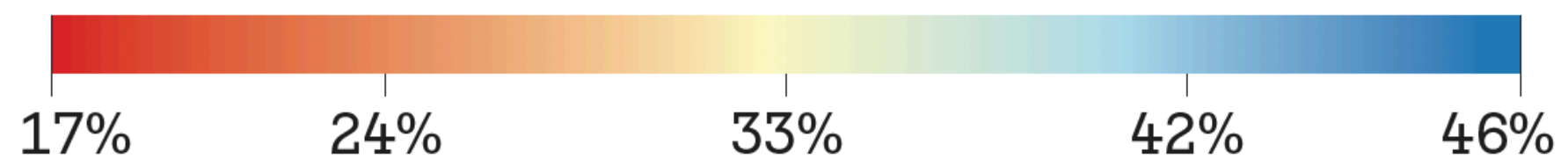
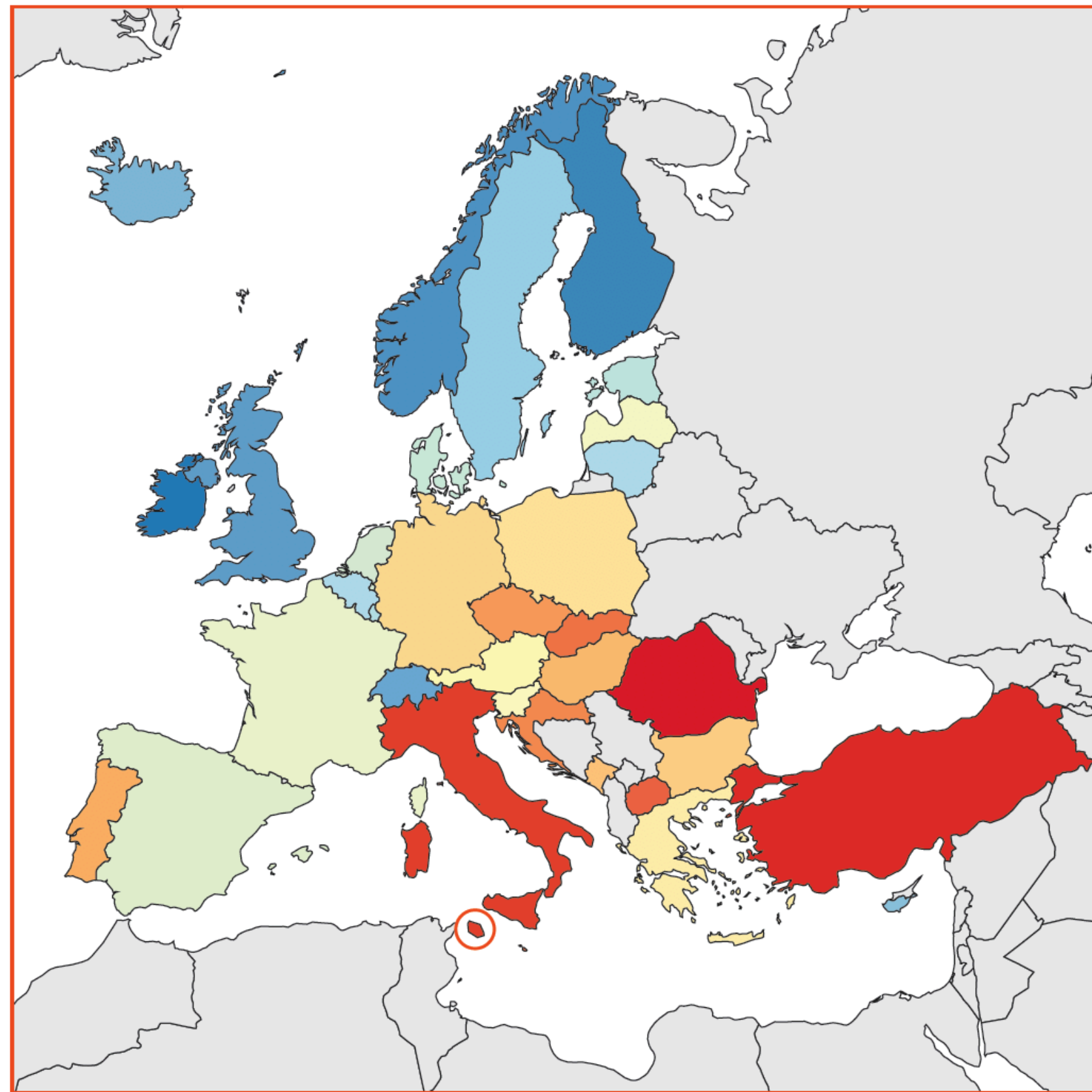


Migration, persons per 1 000 inhabitants



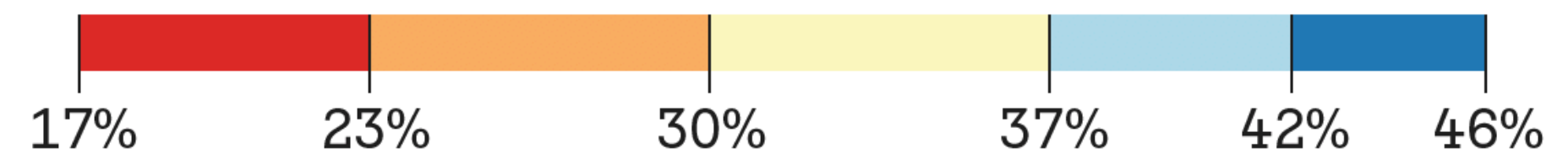
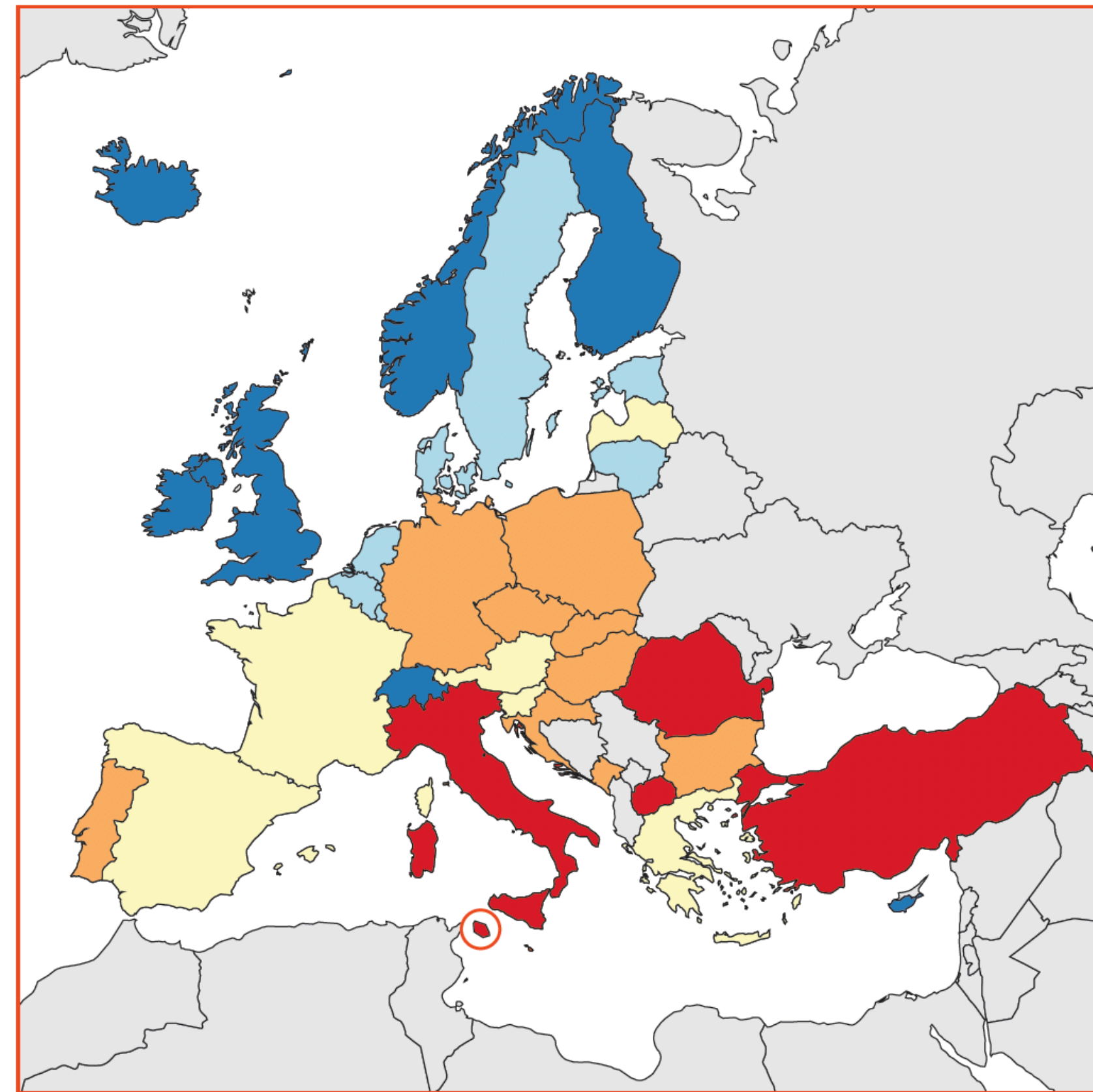
Percentage of population with tertiary education in Europe, ages 25–64

CONTINUOUS SCALE



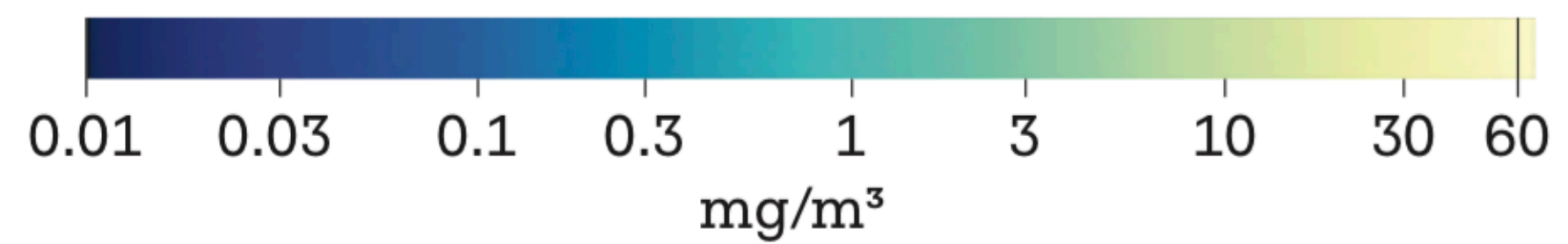
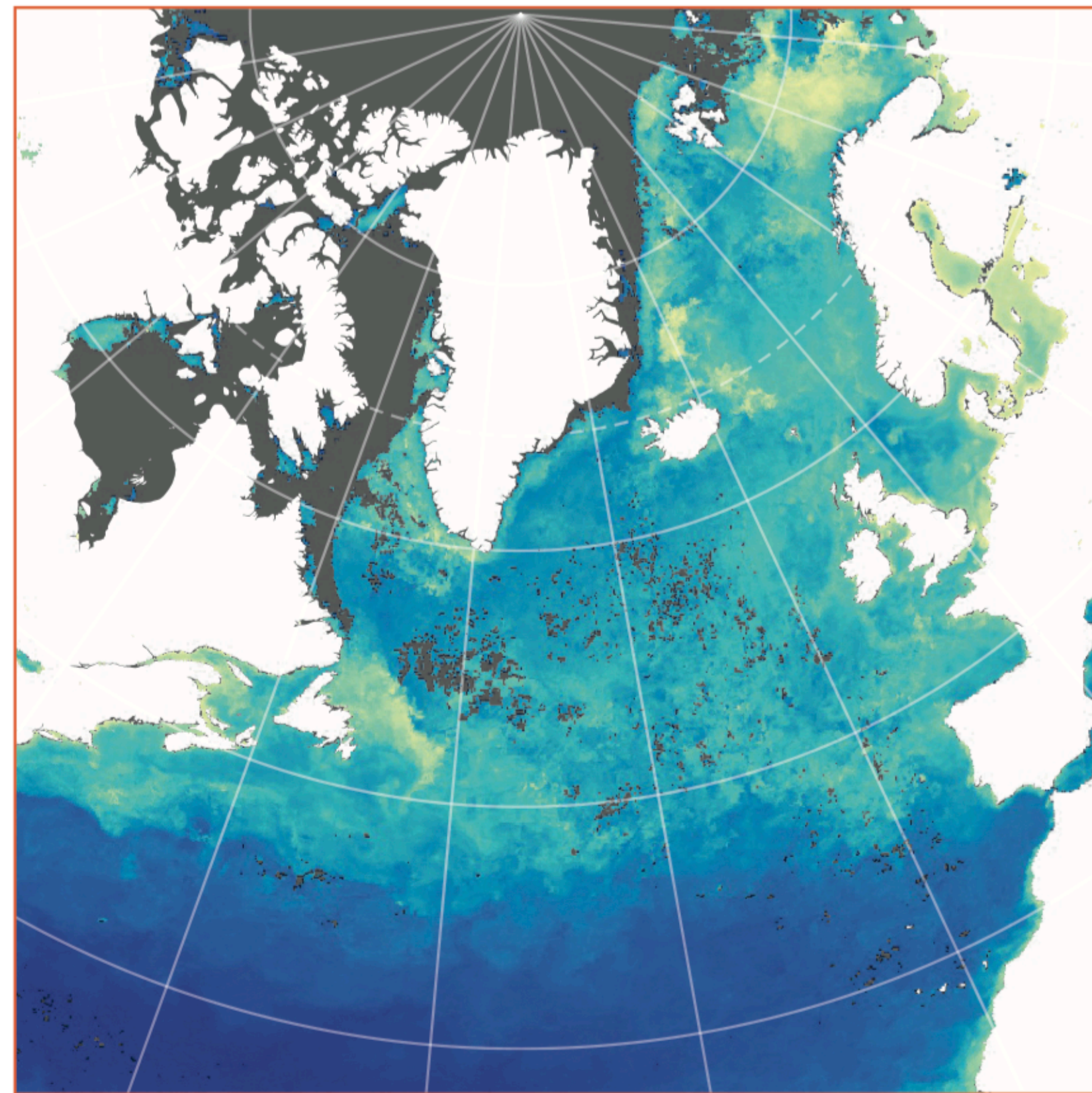
No data

CLASSIFIED SCALE



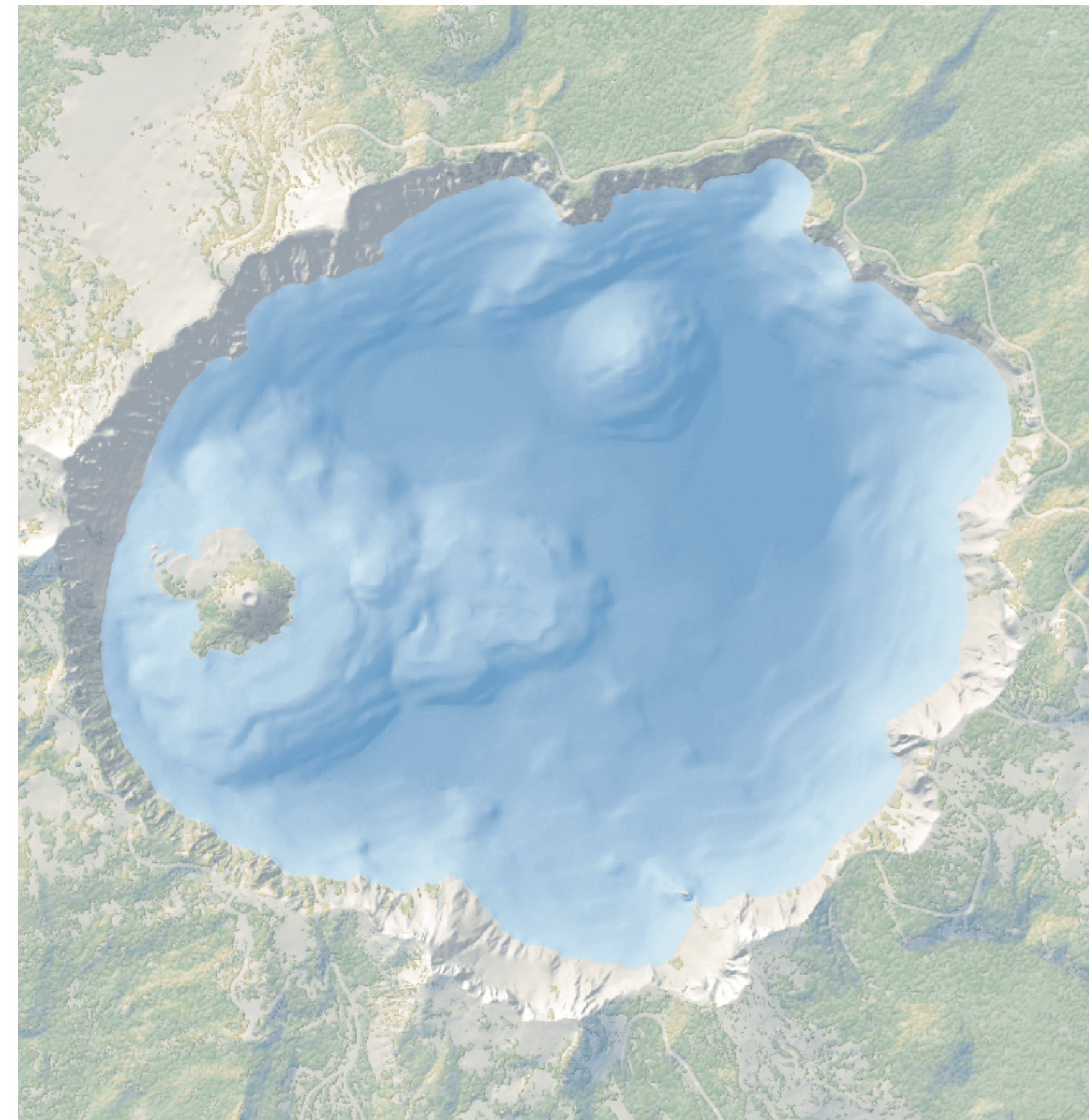
Source: Eurostat 2018. edat_lfse_04

Chlorophyll concentration in the North Atlantic
Visualization based on data from the MODIS sensor
aboard NASA's Aqua satellite, May 2018



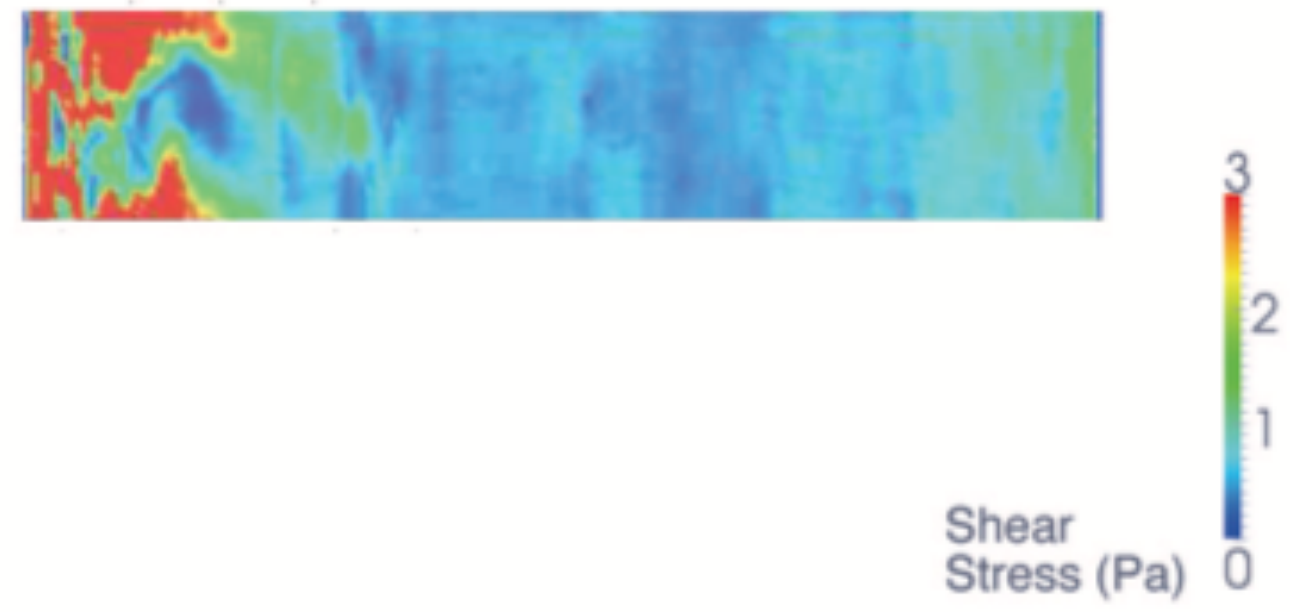
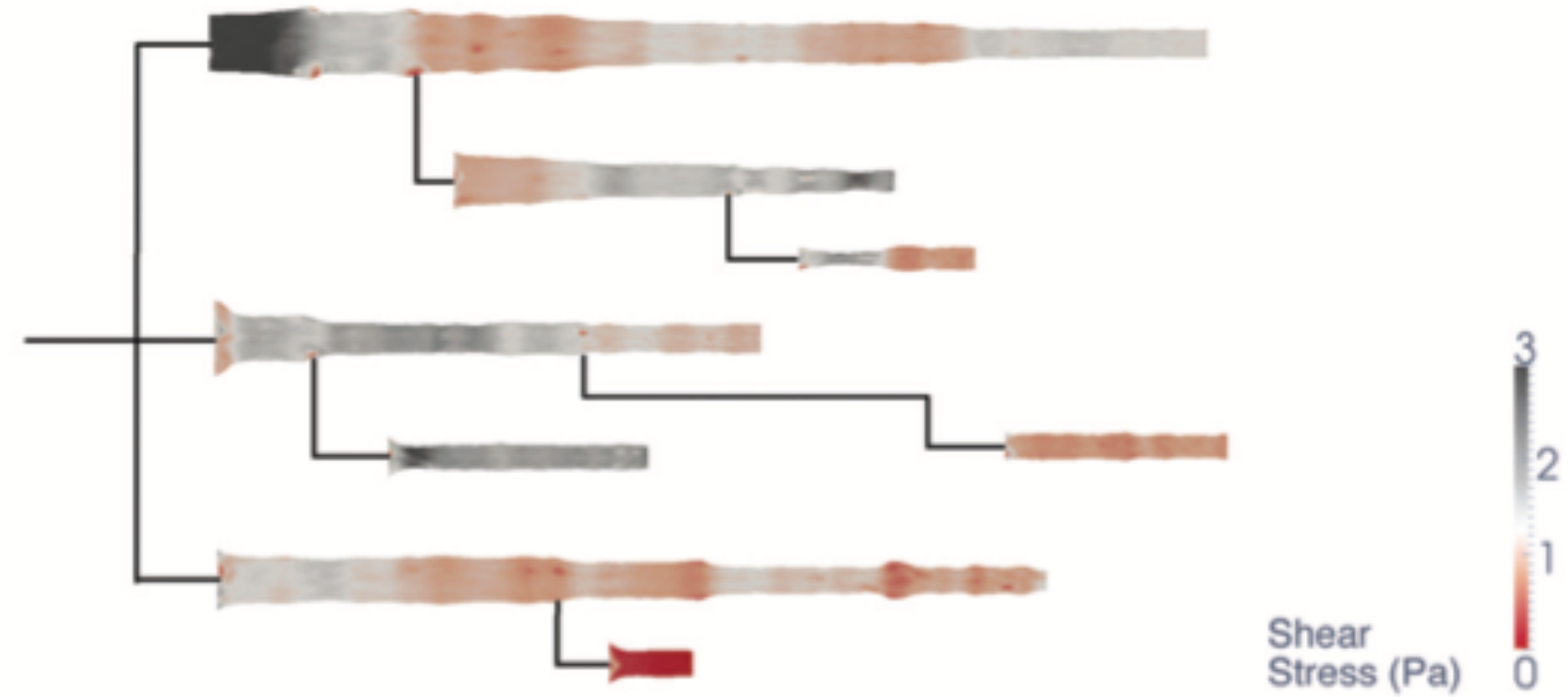
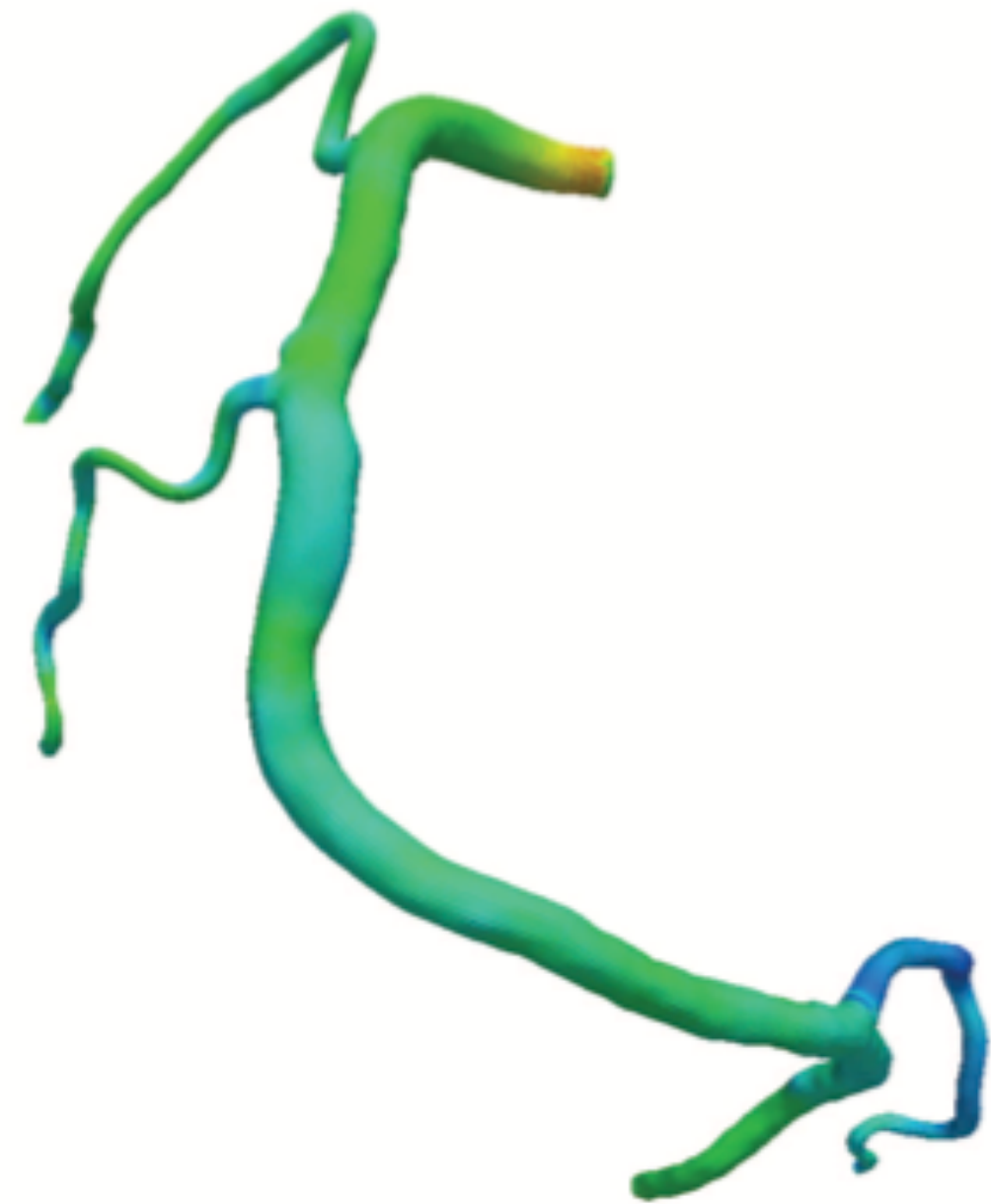
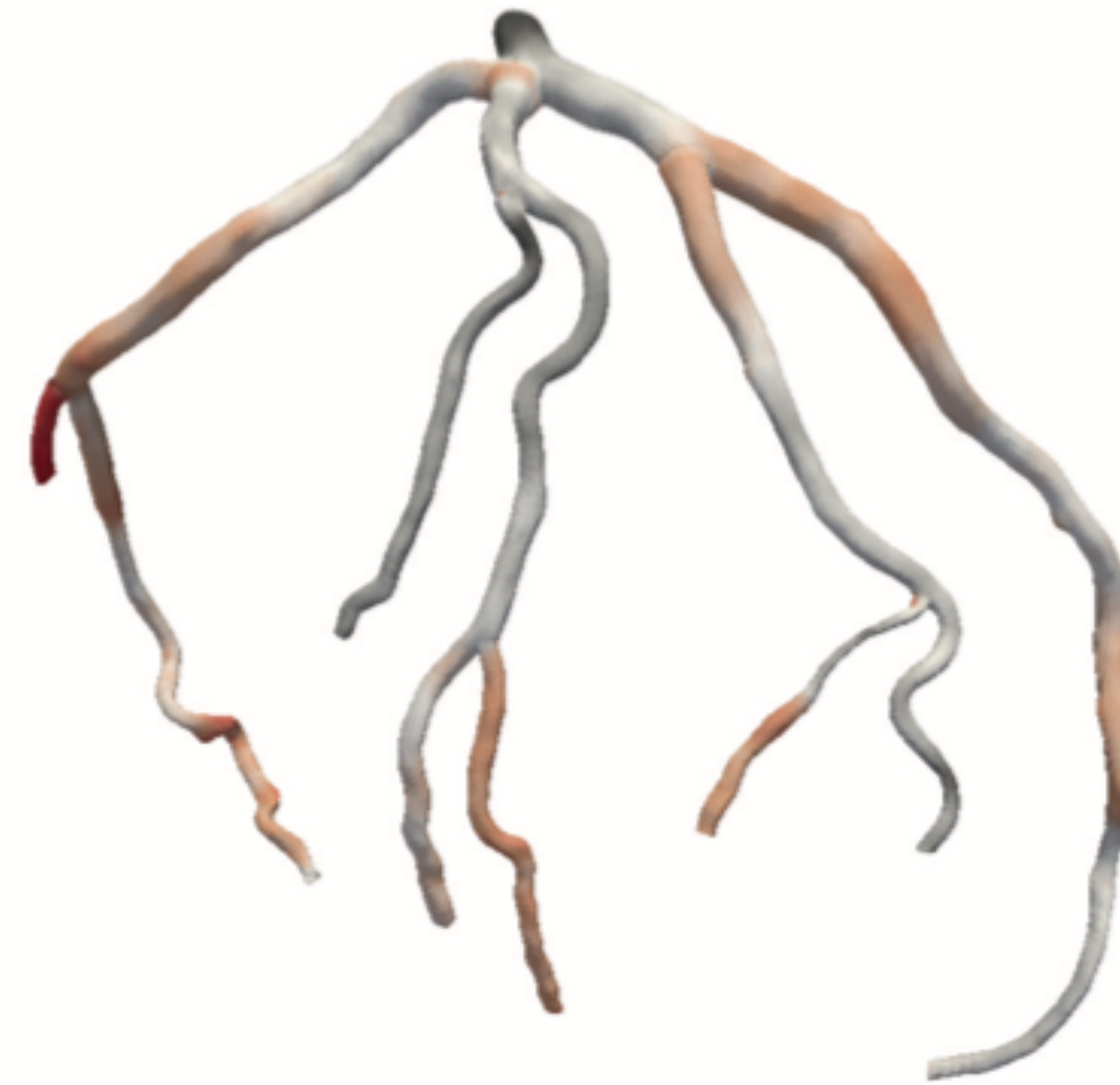
■ No data

Source: the Earth Observatory Group in coordination
with Gene Feldman and Norman Kuring,
NASA Goddard Ocean Color Group



8% of men and 0.5% of women have some form of hereditary color vision deficiency!

That means: **Never use
rainbow scales!**

A**B****C****D**

“Gold standard” palettes

“Viridis”
scheme



“Cividis”
scheme



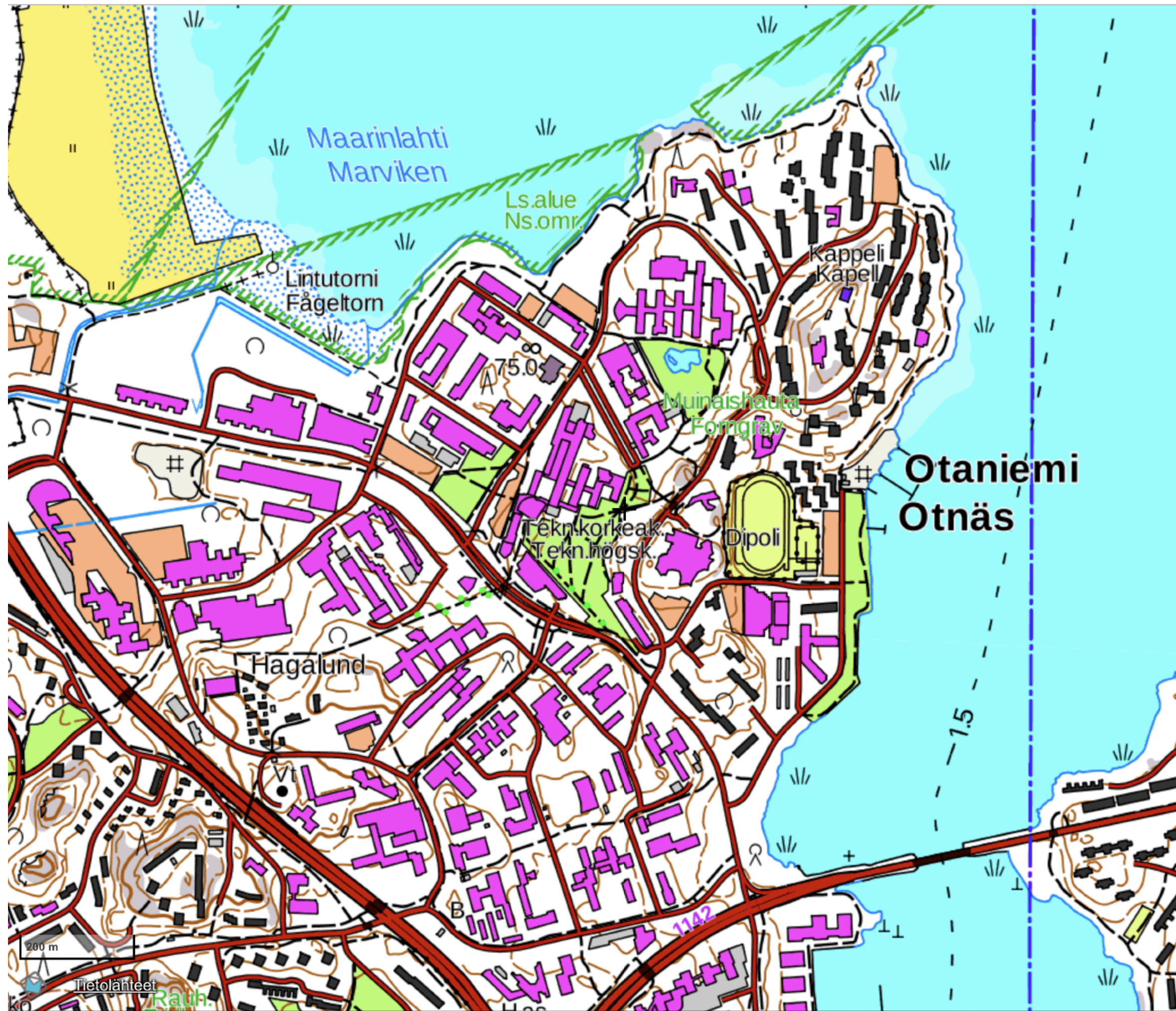
“Plasma”
scheme

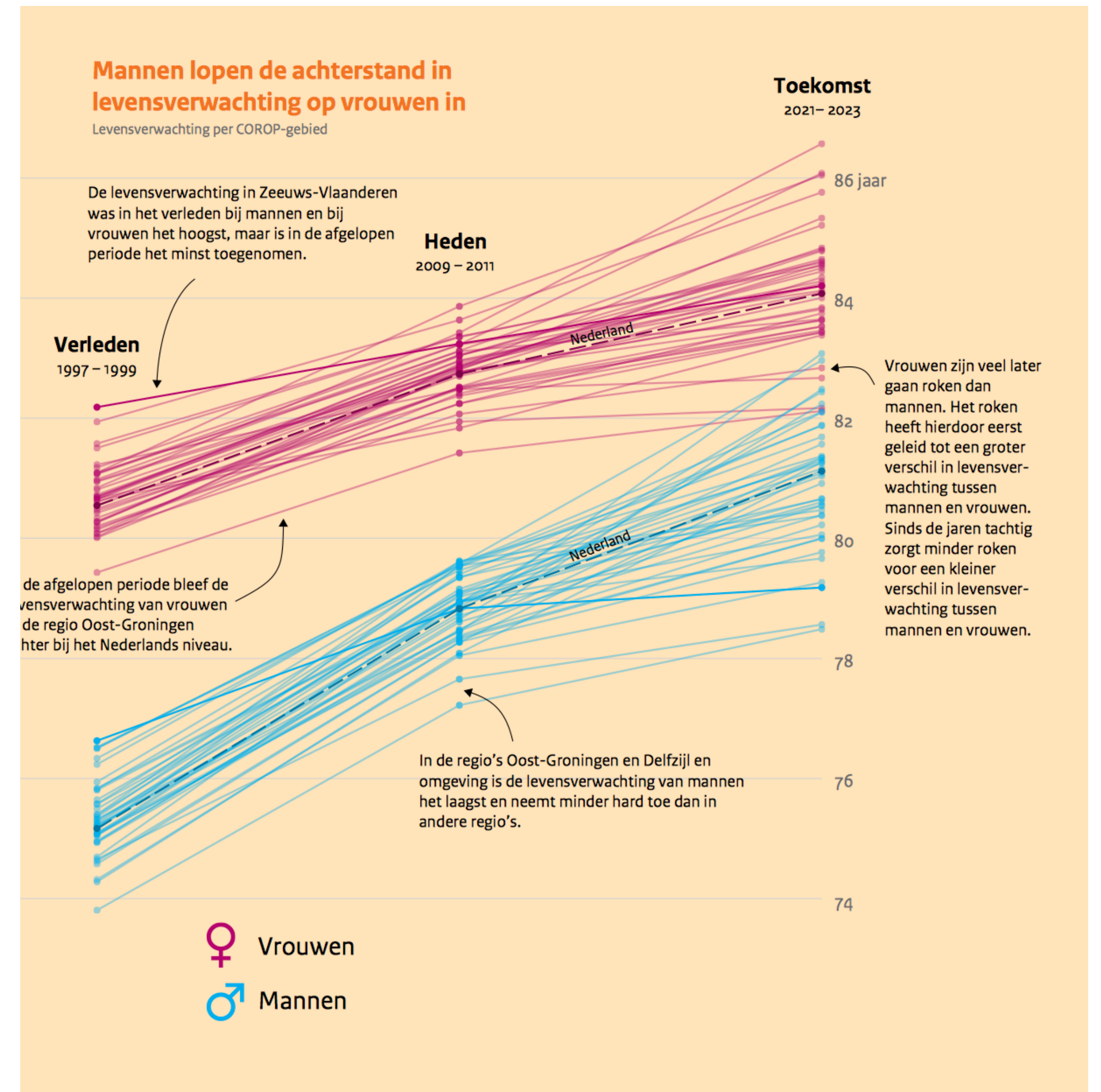
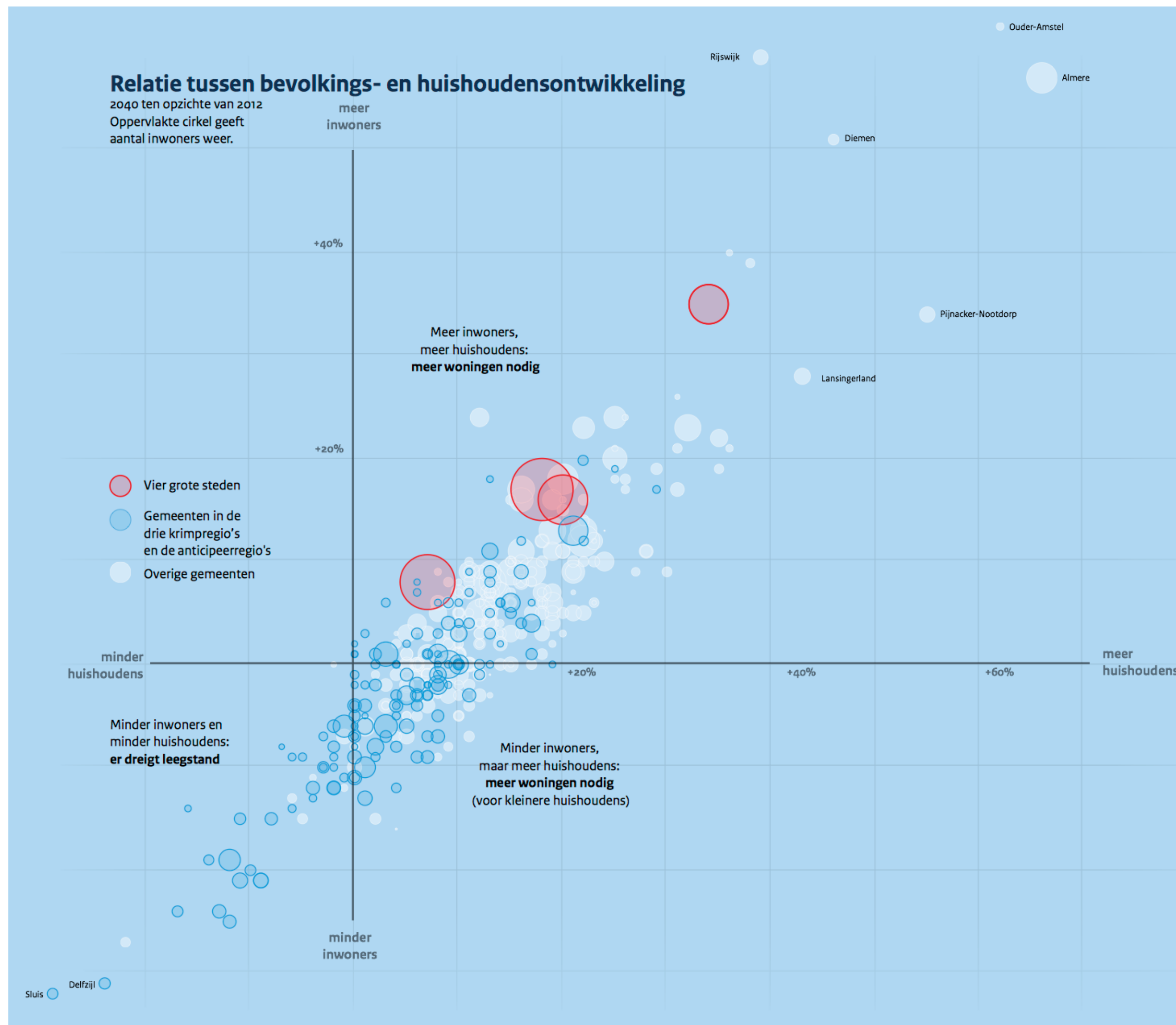


Most distinct qualitative colors

	RGB values			HCL values		
	R	G	B	H	C	L
	0–255	0–255	0–255	0–360	0–100	0–100
Vermillion	213	94	0	55.6	76.7	54.2
Bluish green	0	158	115	164.4	47.5	57.7
Blue	0	114	178	266.2	41.5	46.0
Yellow	240	228	66	100.0	76.6	89.1
Black	0	0	0	–	0.0	0.0
White	255	255	255	–	0.0	100.0
Orange	230	159	0	77.6	76.5	70.6
Sky blue	86	180	233	250.9	36.8	69.8
Reddish purple	204	121	167	344.6	40.0	61.0

It's hard to add emphasis if background colors are intense!





The golden rule of visualization

Choose the method of presentation based on the clarity of the result.

Thank you.

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