Fachhochschule Kiel
University of Applied Sciences

Data Visualization and Visual Analytics
Perception and Visualization Design

Study Program Data Science
Prof. Dr. Tillmann Schwörer

Lecture Roadmap

Data Domains

Comparing Categories | Relationships | Geospatial | Time |
Part-to-whole | Distributions | Uncertainty | …

Storytelling

Perception + Visualization Design

Python + Tools

Interactive Visualization

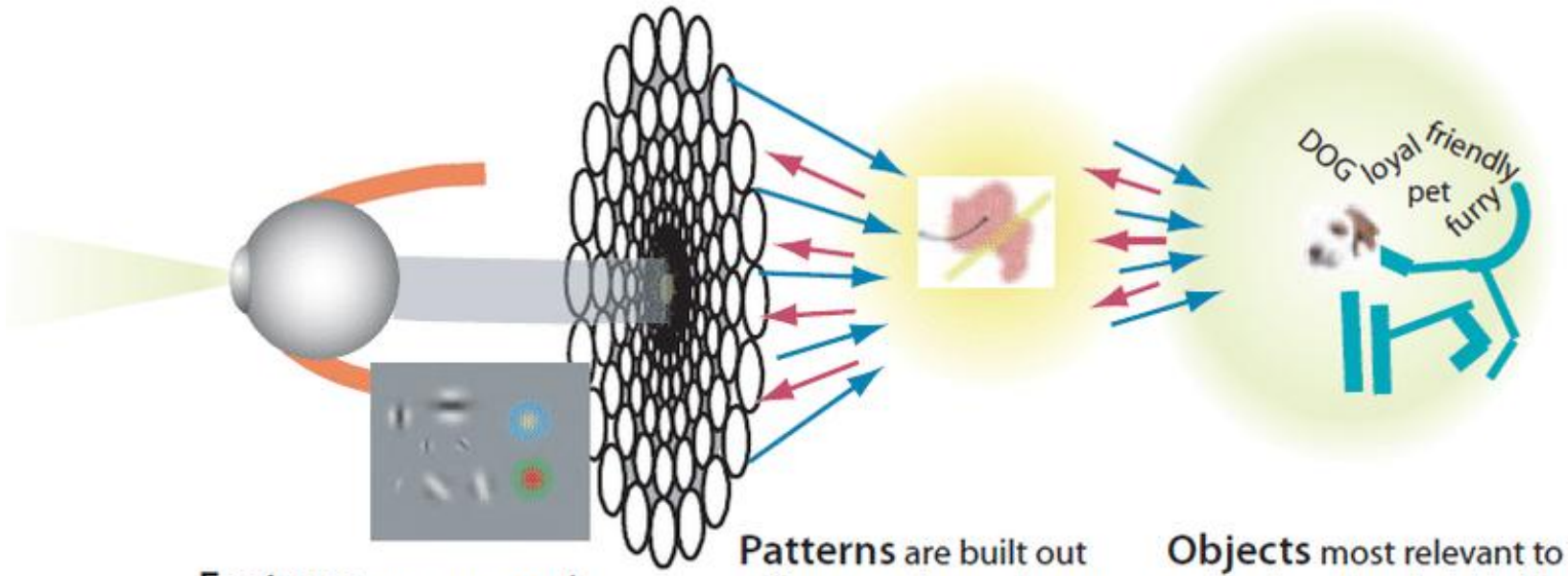
Our goal: align visualization design with perception

- **We want to create truthful, useful, and beautiful visualizations**
  - Draw the audience‘s attention
  - Represent data faithfully
  - Accurate and intuitive understanding
  - Make it memorable

- **How does the human brain process visual information?**
  - What makes the perception accurate (or biased)?
  - What makes the perception easy (or difficult)?
  - When do we perceive things as beautiful (or ugly)?

- **What does this imply for how we design visualizations?**

How our brain processes visual information



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.

1. Preattentive processing **2. Pattern Perception** **3. Cognitive Processing**

Bottom-up

Top-down

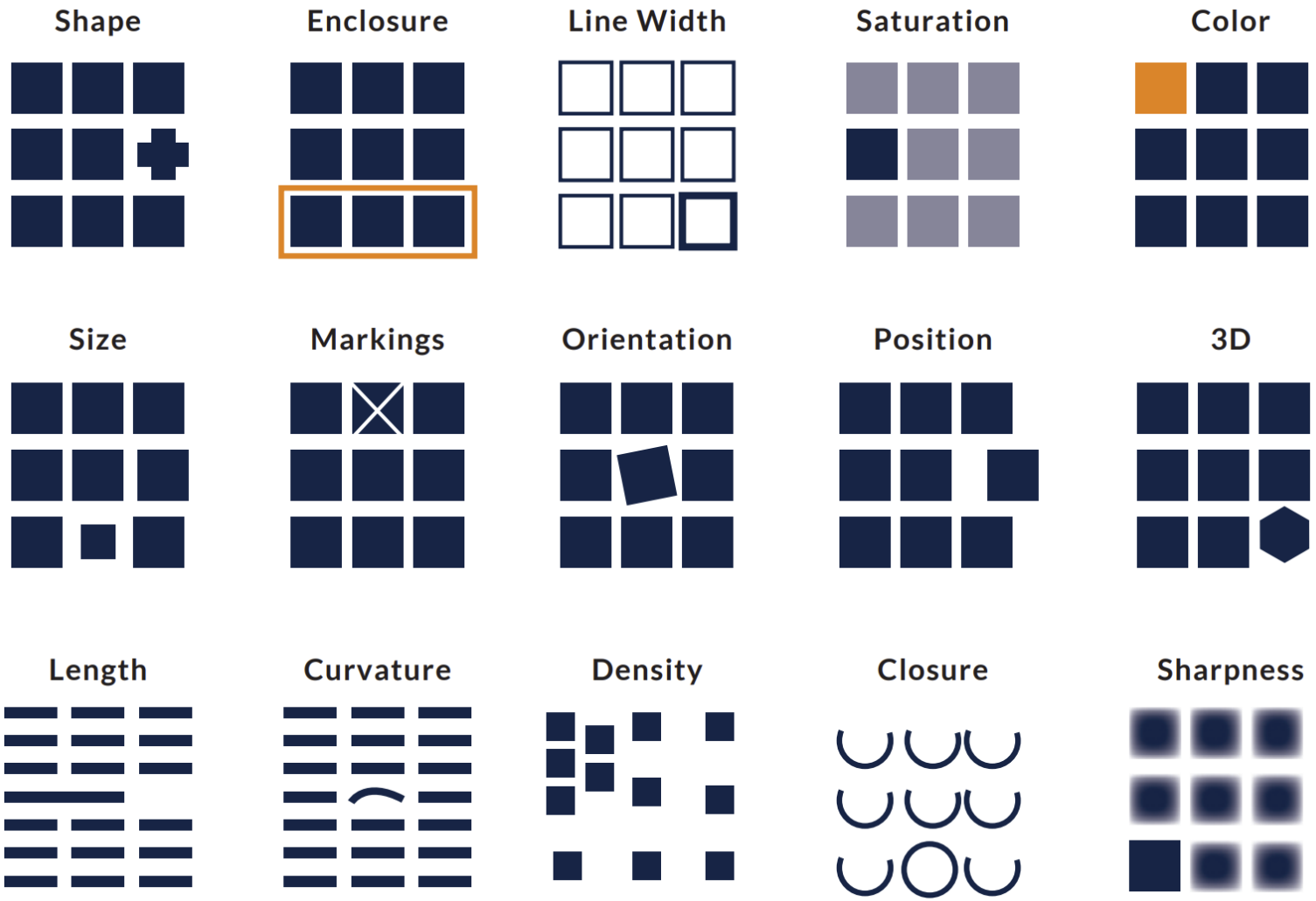
Phase 1: Preattentive Processing

- Occurs in the first 0.2 seconds – before attention kicks in: no scanning, no eye movements, no choices
- Happens automatically, without effort, in parallel
- You recognize “features” that pop out immediately

Preattentive feature: saturation

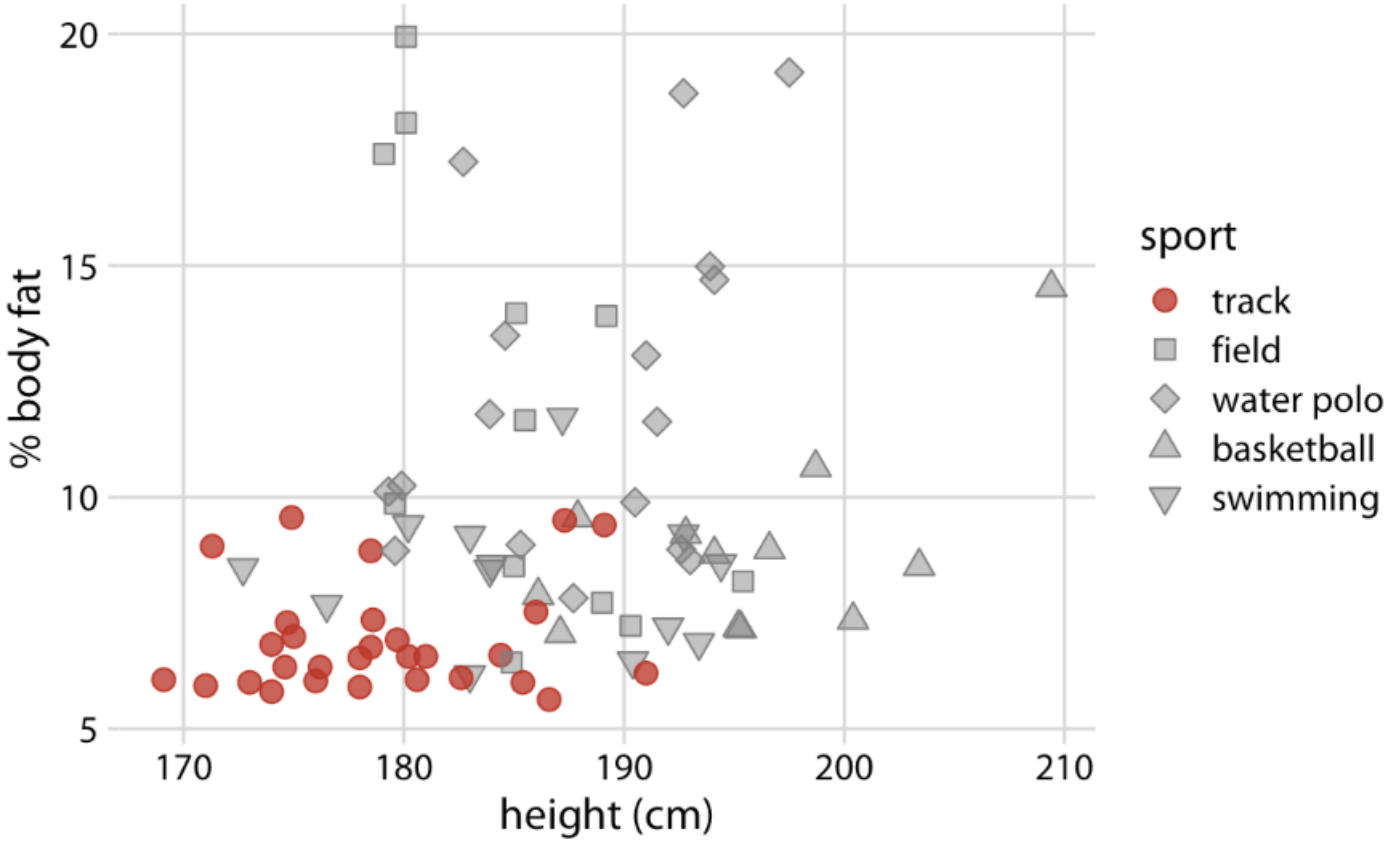
Count the 3s!

More preattentive features



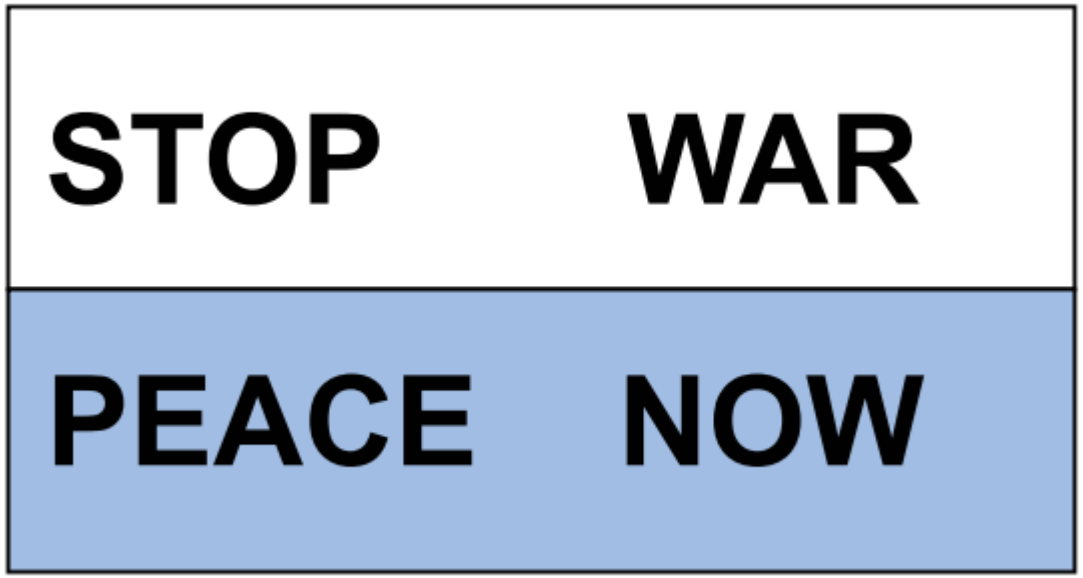
Takeaway 1

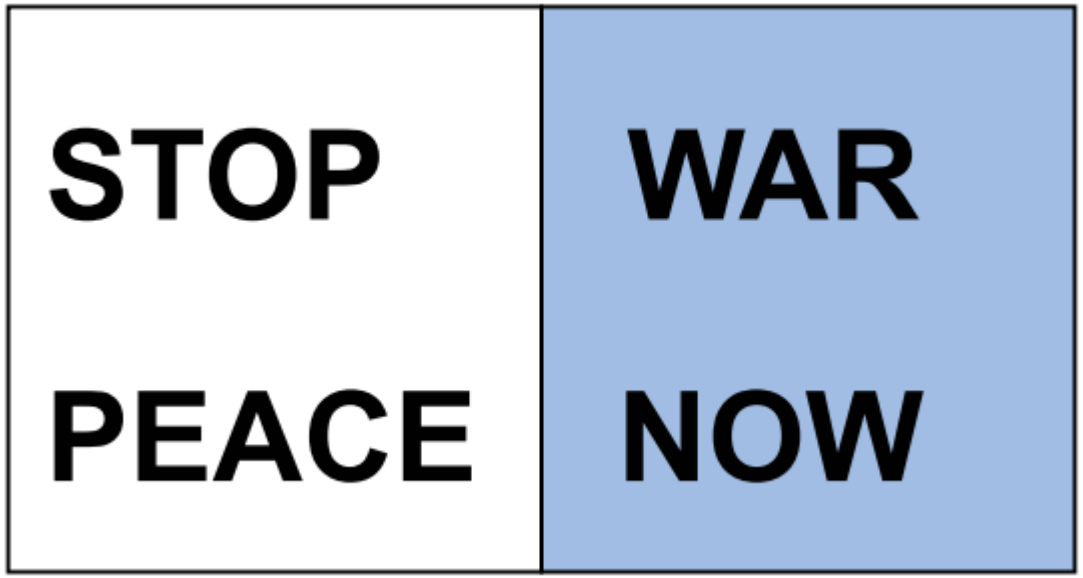
Use preattentive features (like color, size, or shape) to immediately draw the audience's attention to the most important information



Phase 2: Pattern Perception

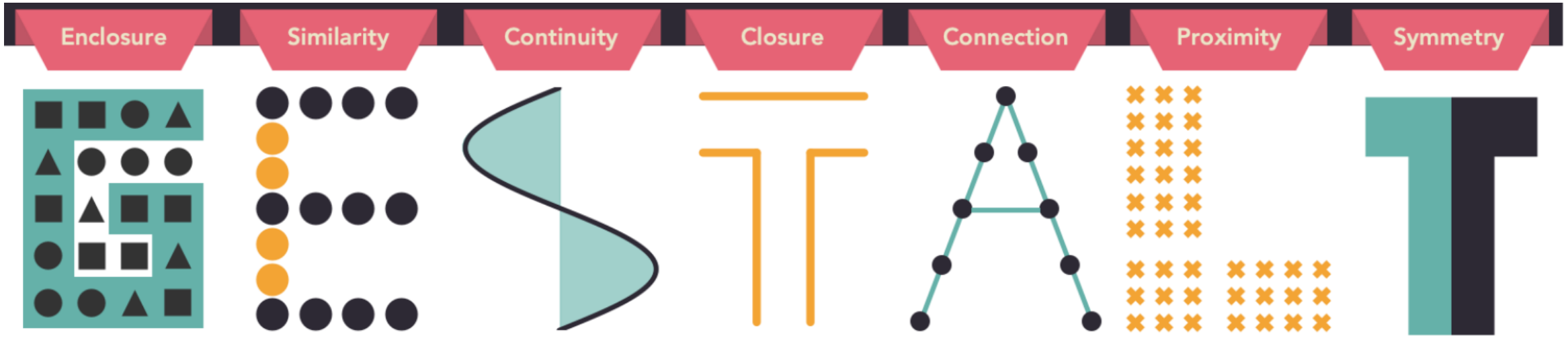
- Occurs after basic feature detection
- Also, takes little time
- Basic features are grouped into patterns: clusters, shapes, figure-ground distinction
- We perceive structure, but don‘t yet interpret meaning





What guides the perception of patterns?

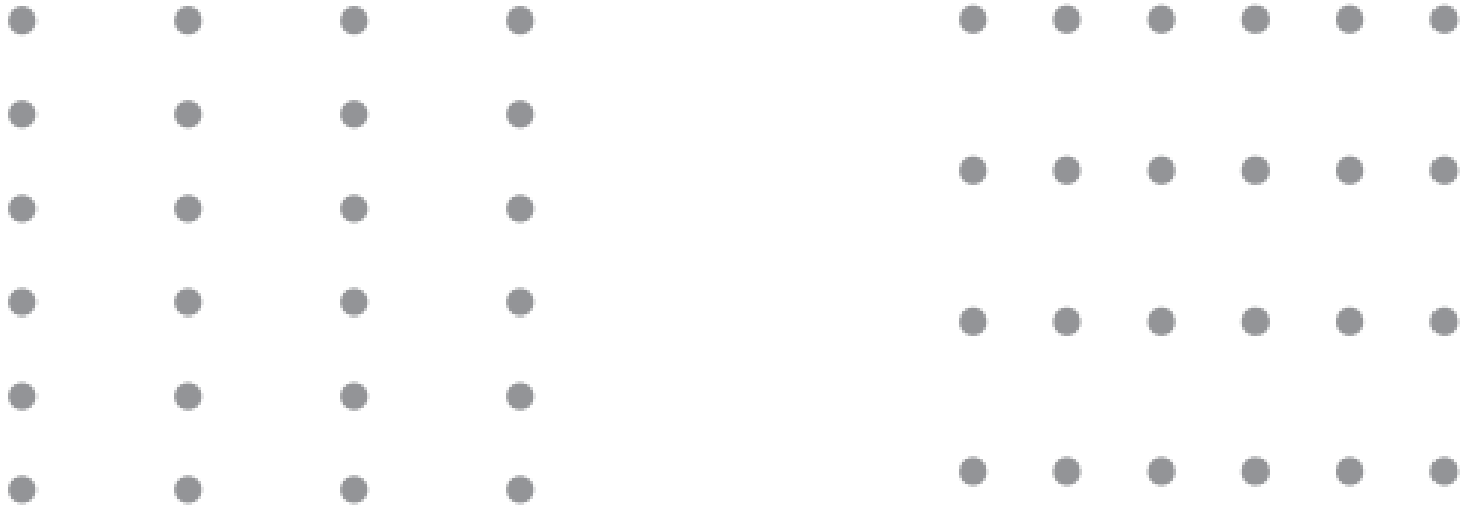
This has been formalised in **“<u>Gestalt Theory</u>”** (a school of psychology): we perceive patterns (rather than just individual elements), based on the following **<u>Gestalt Principles</u>**



Source: https://vizzendata.com/2020/07/06/utilizing-gestalt-principles-to-improve-your-data-visualization-design/

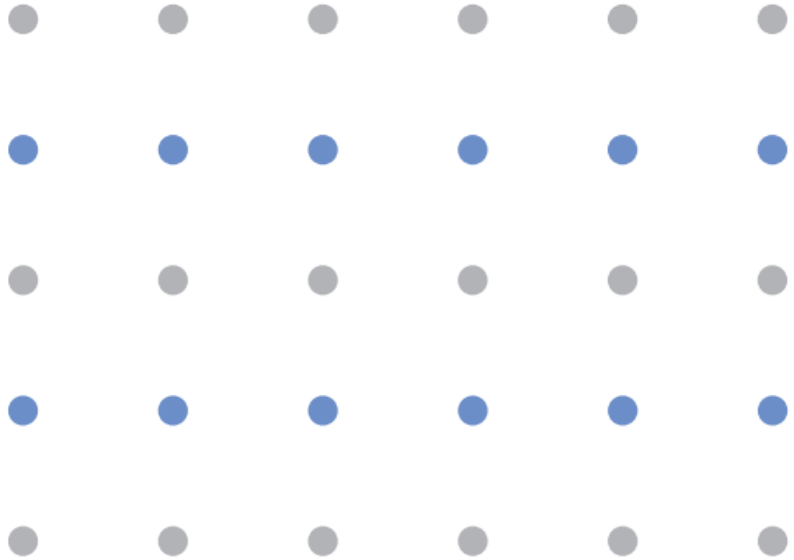
Proximity

Objects that are close to another are perceived as a single group



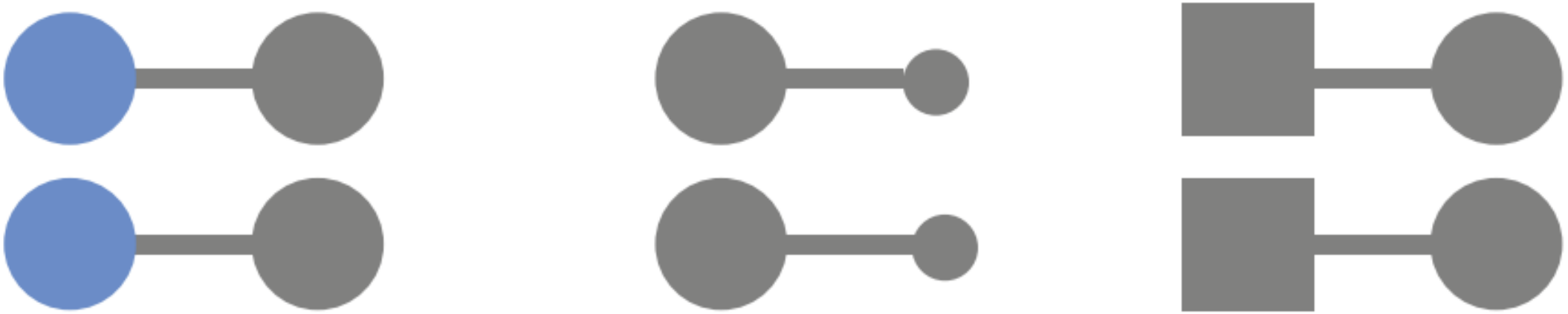
Similarity

Objects that look similar (color, shape, size, font, …) are perceived as a single group



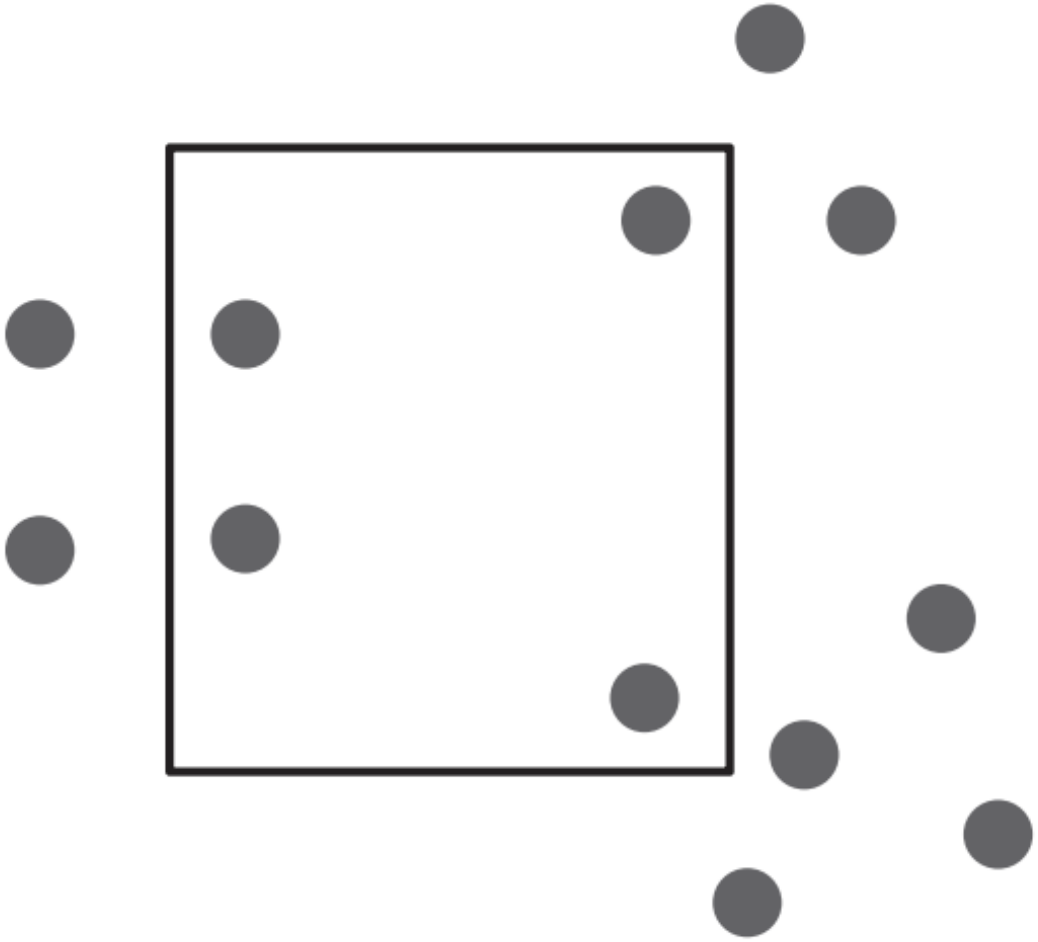
Connectedness

Connected objects are perceived as a single group



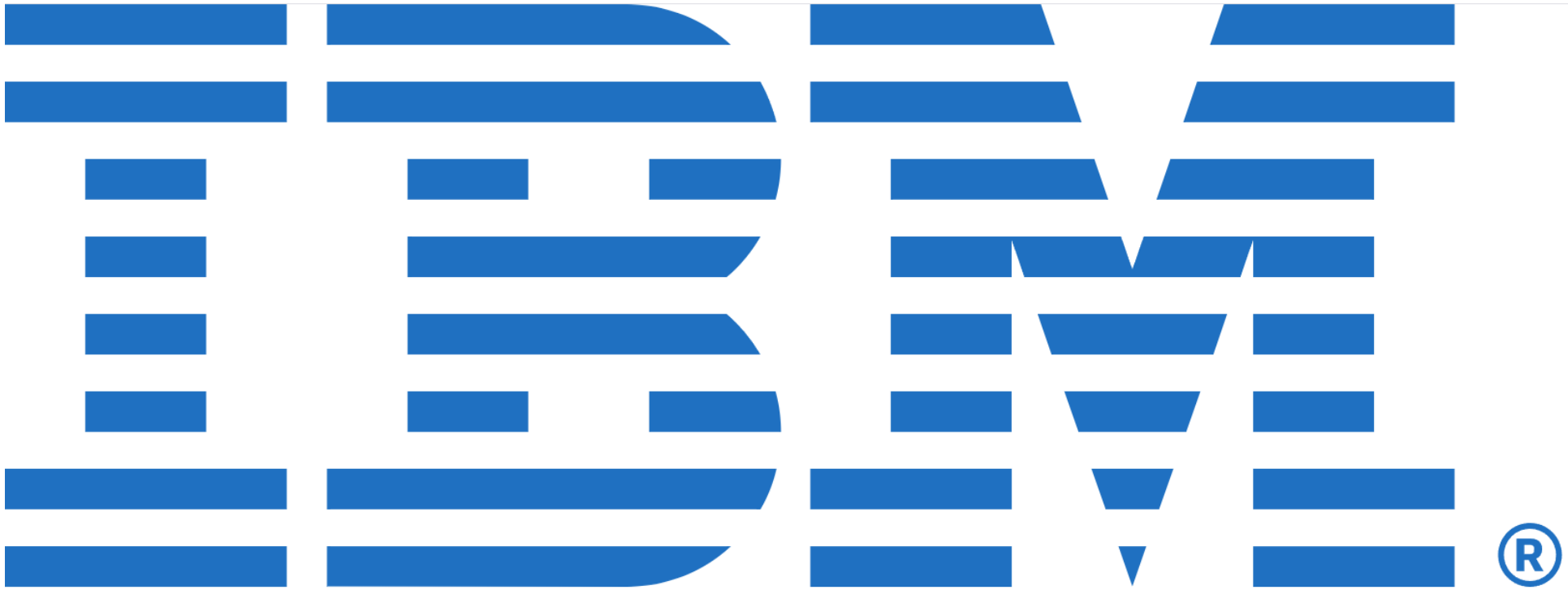
Enclosure

Enclosed objects are perceived as a single group



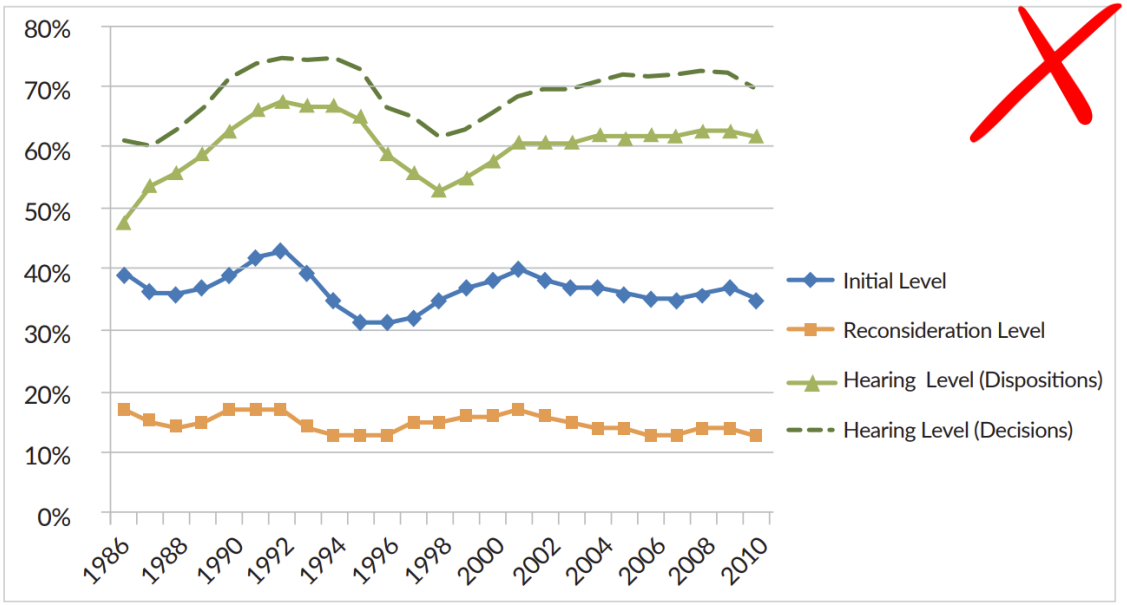
Closure

The mind fills gaps to create a complete object

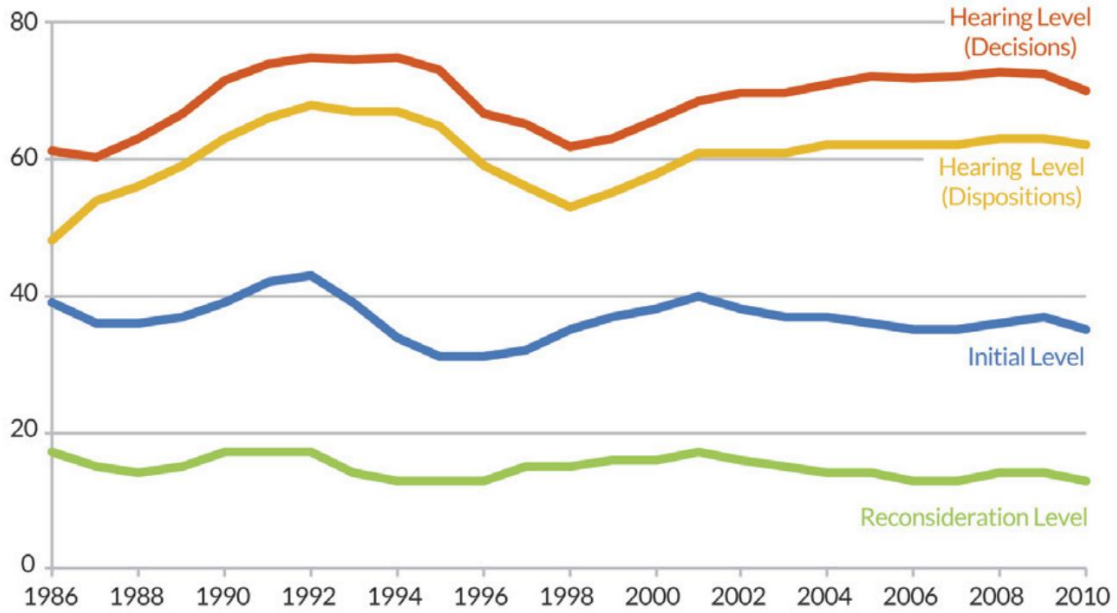


Takeaway 2

Place related elements near each other to signal their connection. (→ **Proximity**)



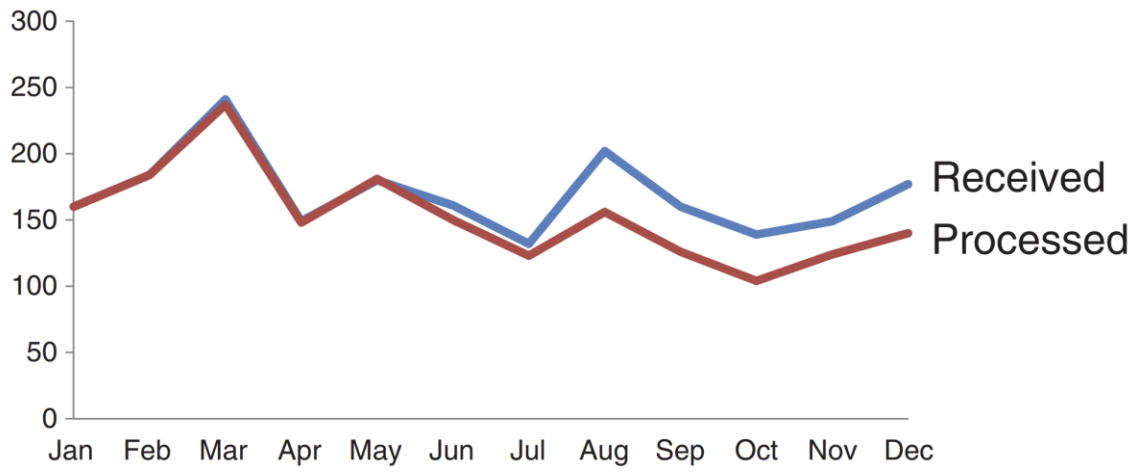
Legend is far off and in wrong order.

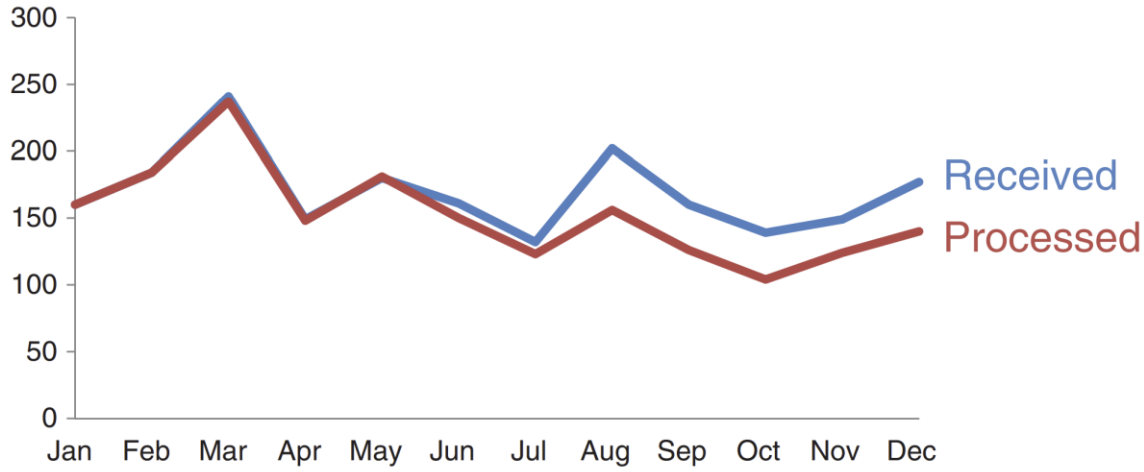


Label your data directly!

Takeaway 3

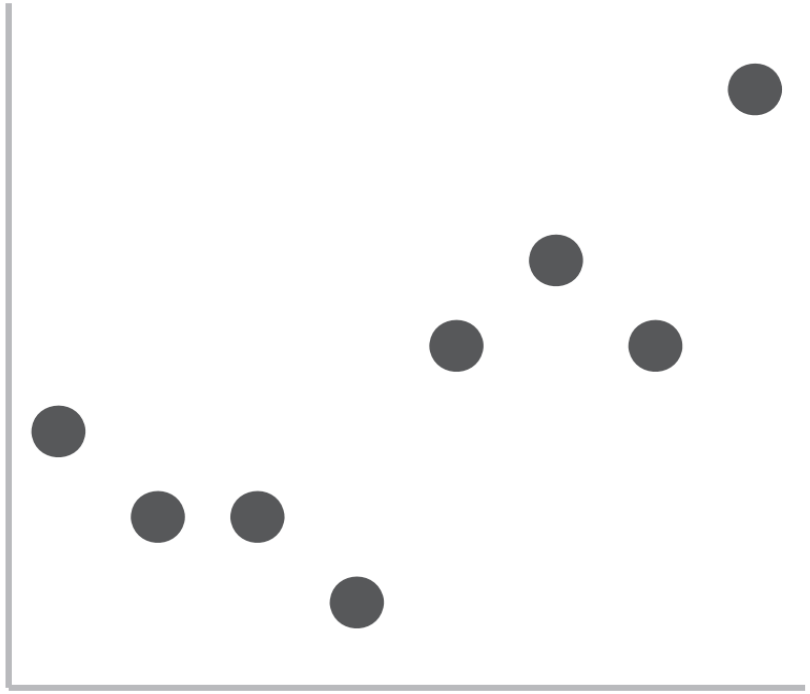
Use the same shapes, colors, or sizes to highlight group membership. (→ **Similarity**)

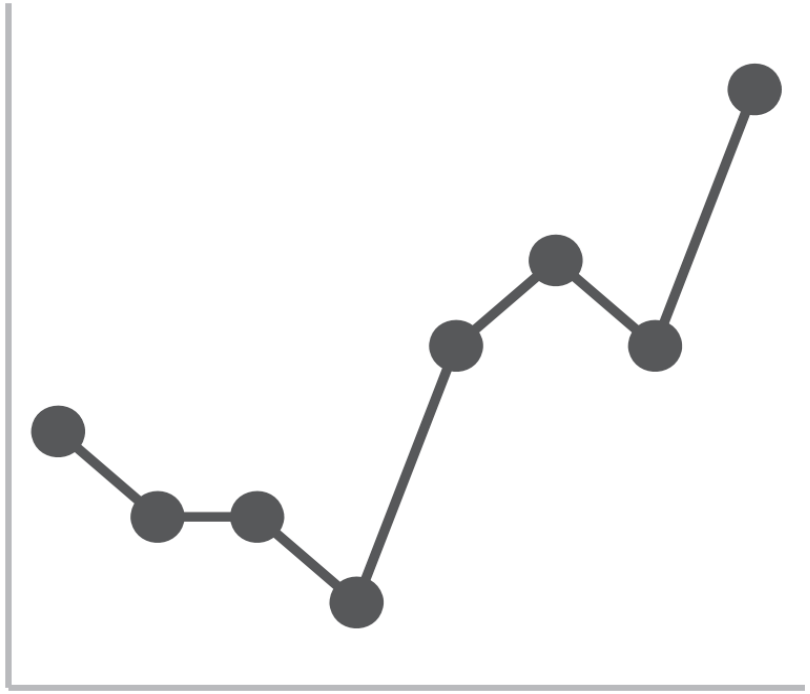




Takeaway 4

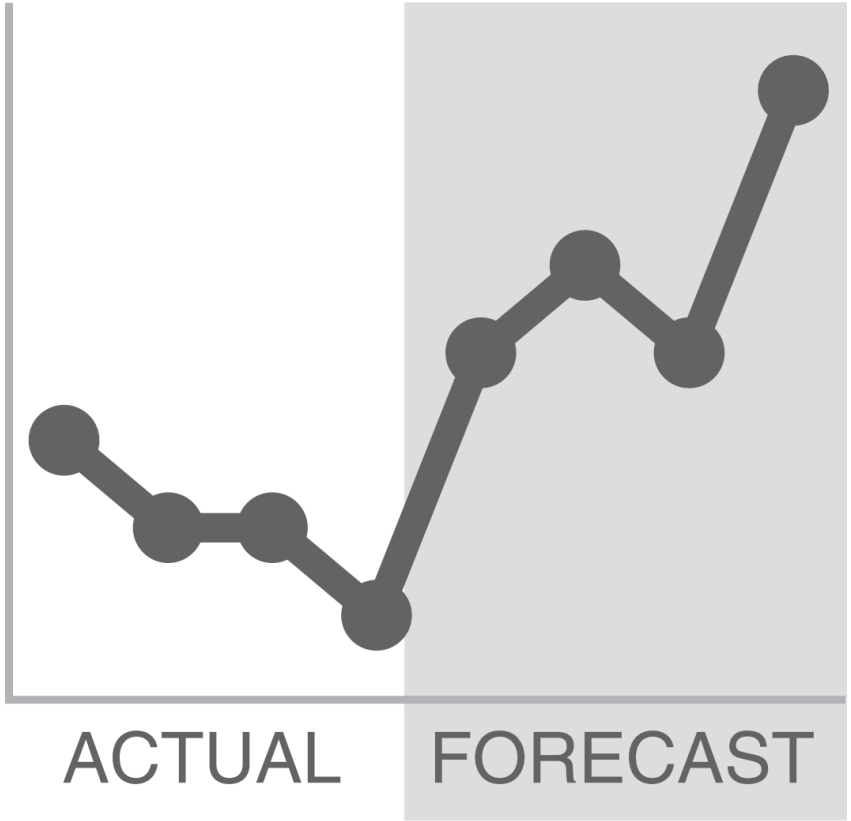
Use lines to signal connection, e.g. through time (→ **connectedness**)





Takeaway 5

Use shapes or backgrounds to draw the attention to data that belong together
(→ **Enclosure**)



Takeaway 6

We can simplify shapes (→ **Closure**)

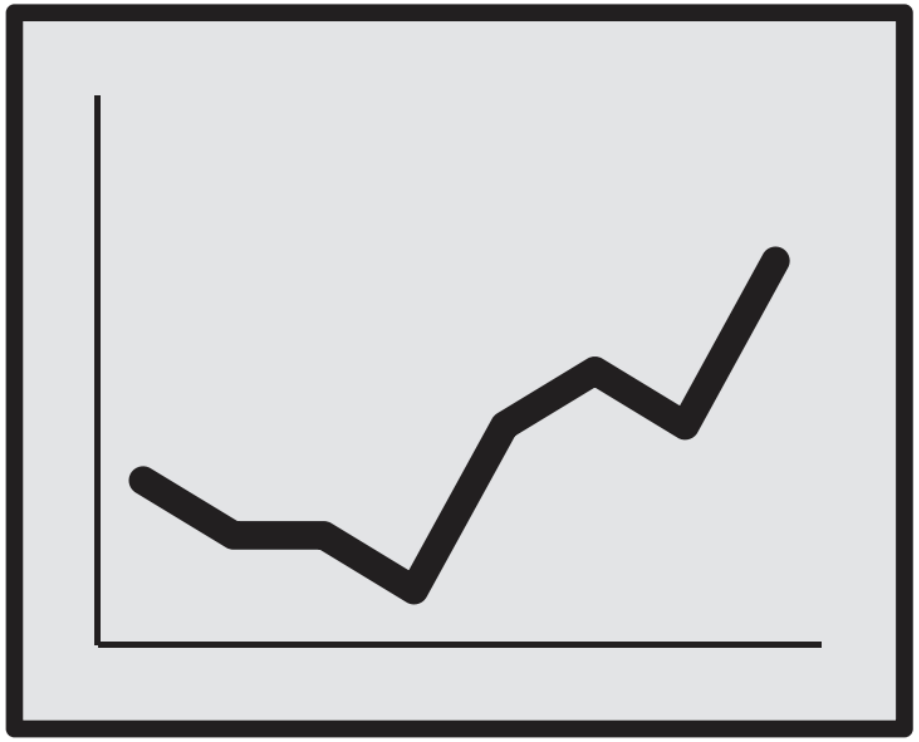


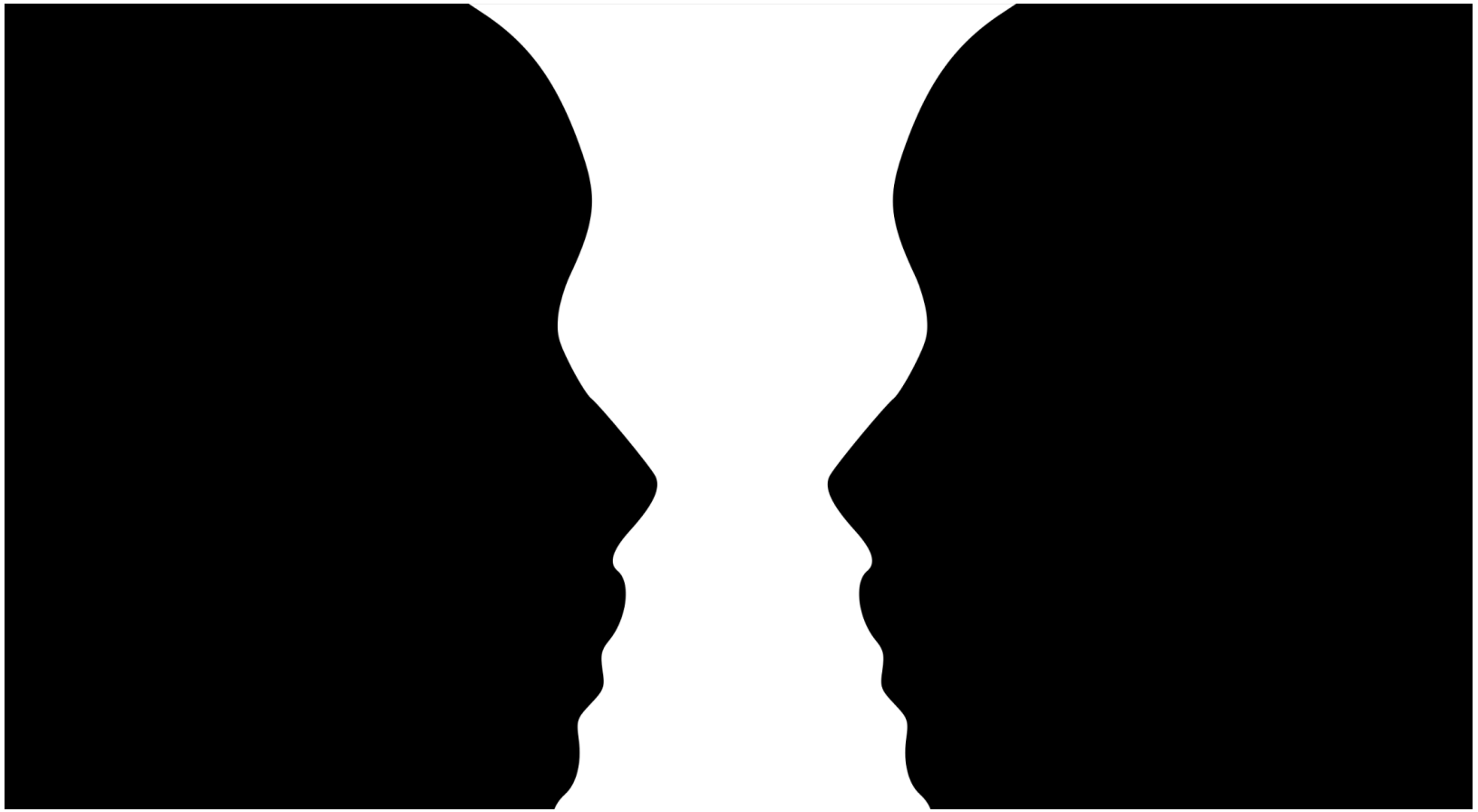
Chart borders and background shading are not necessary

The mind fills gaps to create a complete object

Figure-ground organization

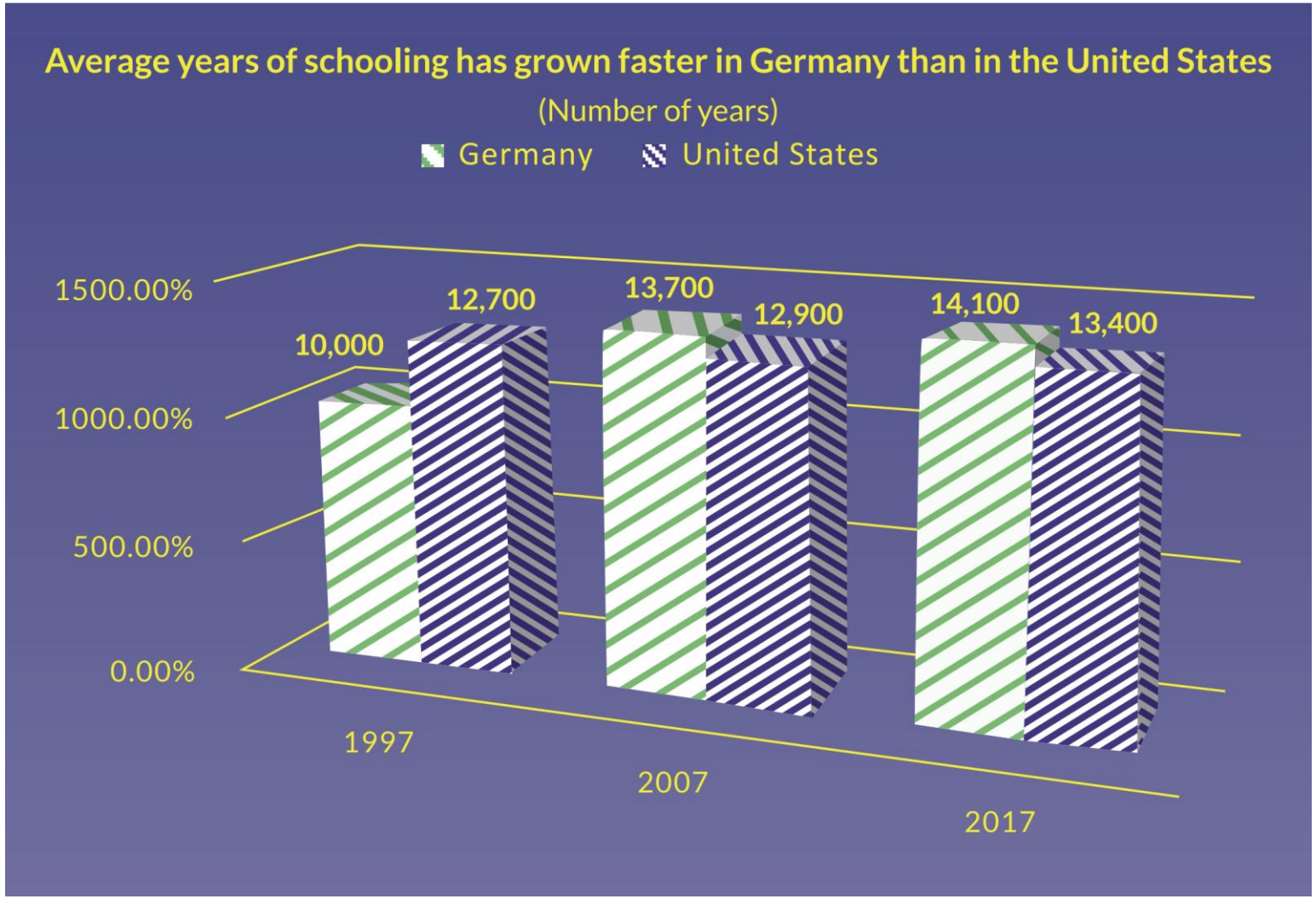
During the pattern perception phase, the brain also separates **figure** from **ground**

→ What do we want our eye and brain to focus on?



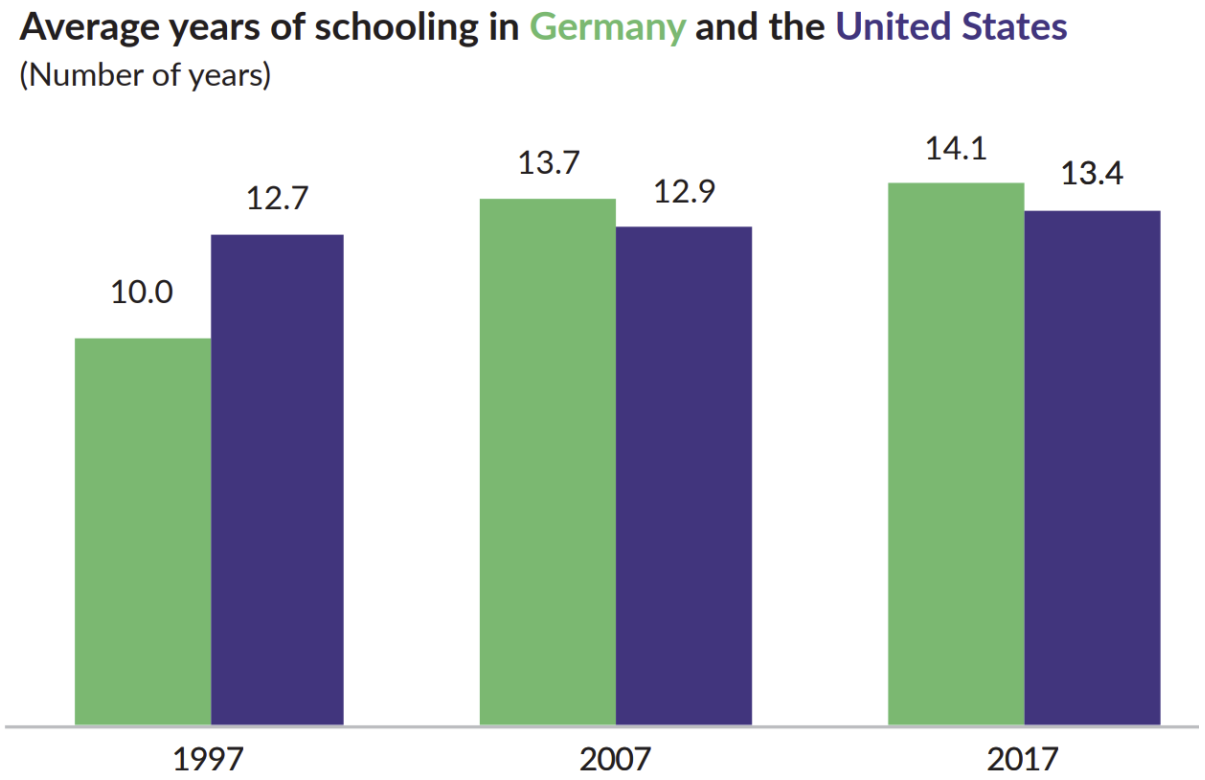
When do we perceive something as figure?

- Smaller size
- Enclosed parts
- Stronger light weight
- Darker
- Distinctive colors
- …



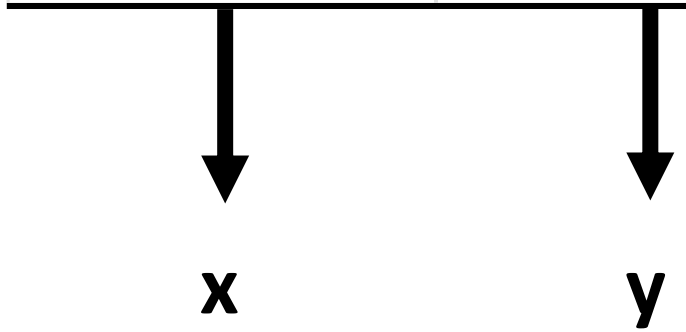
Takeaway 7

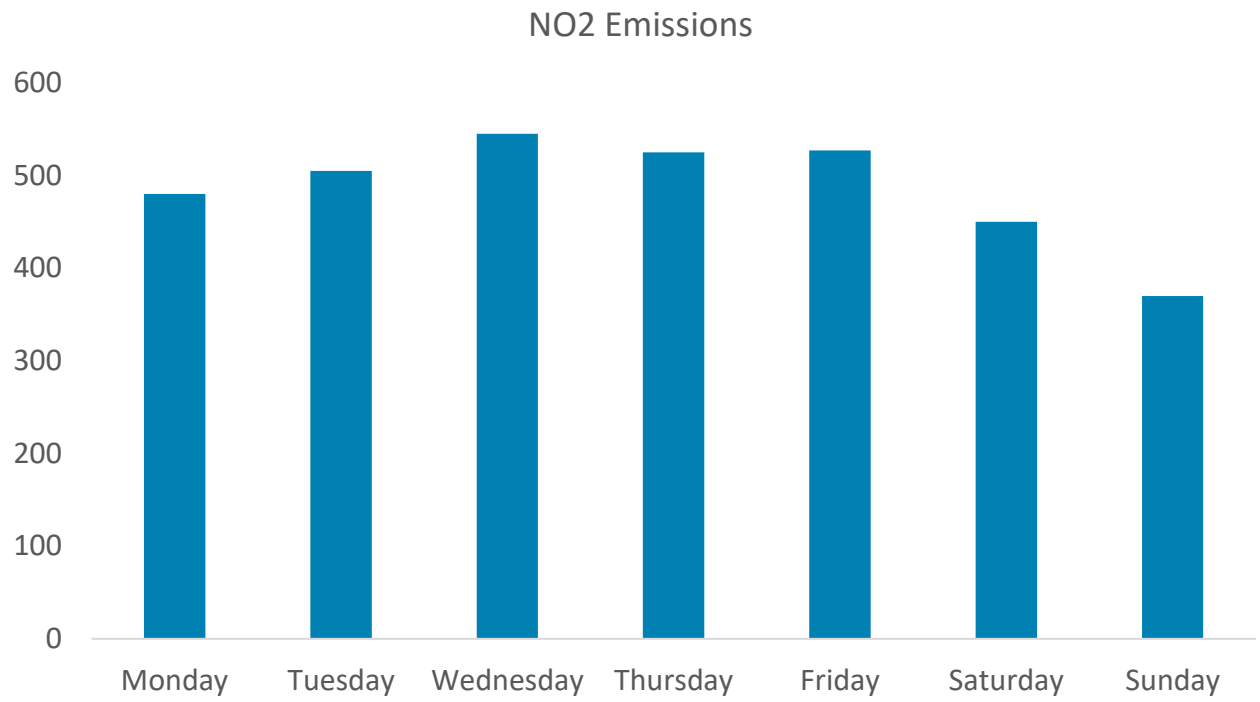
Let the data stand out (→ **Figure-ground separation**)



How should we encode data values visually?

Weekday	NO2 Emissions
Monday	480
Tuesday	505
Wednesday	545
Thursday	525
Friday	527
Saturday	450
Sunday	370





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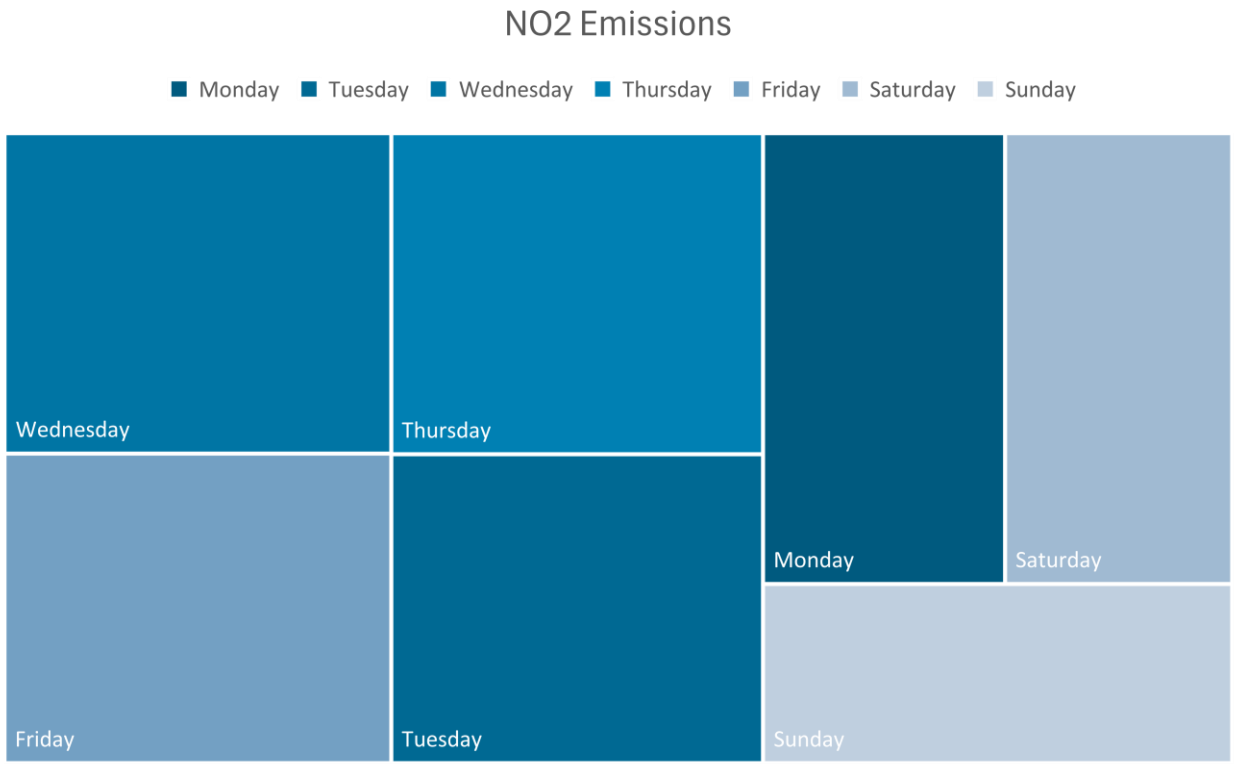
color **area**



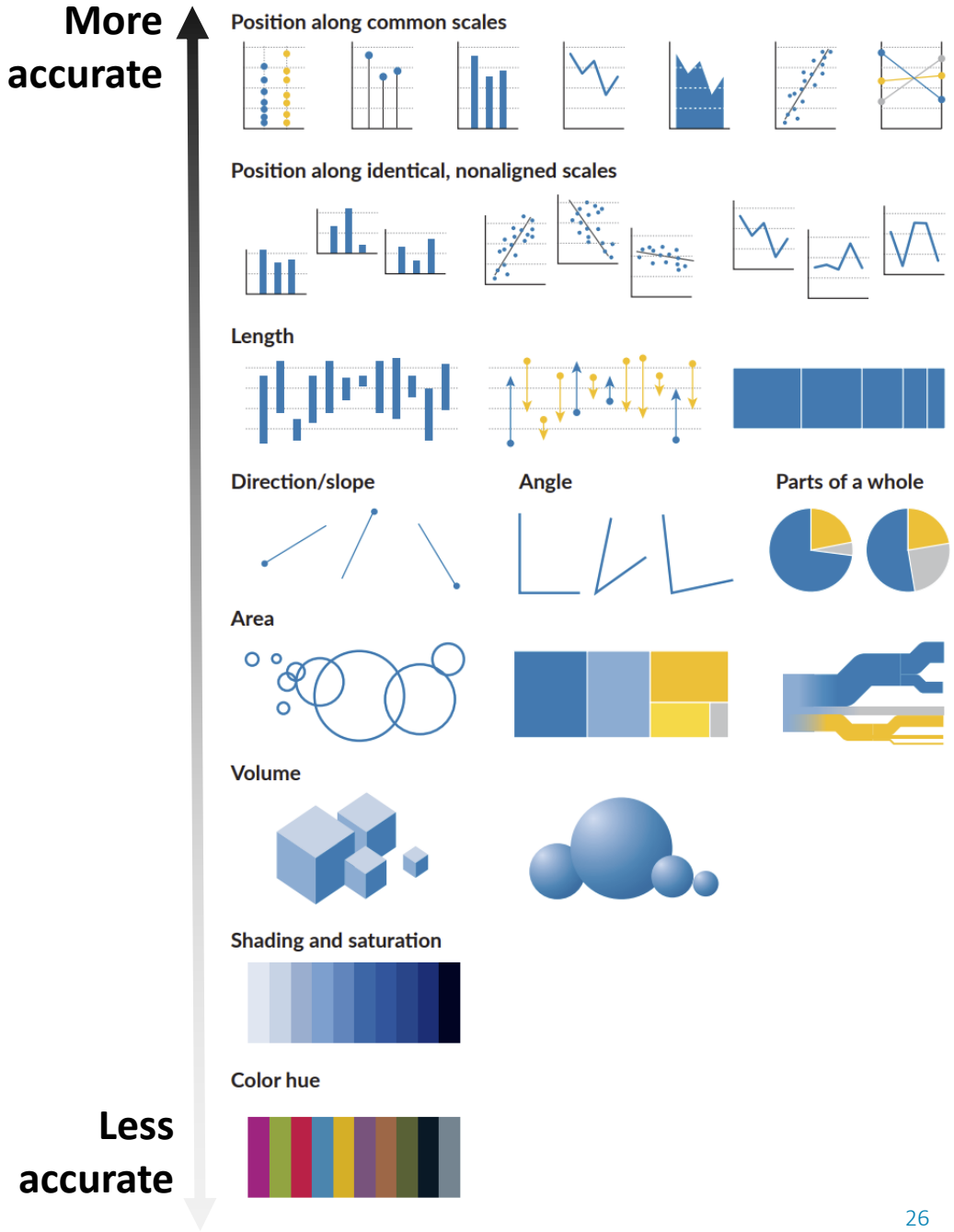
Takeaway 8

Choose encodings that are perceived accurately (→ **encoding effectiveness**)

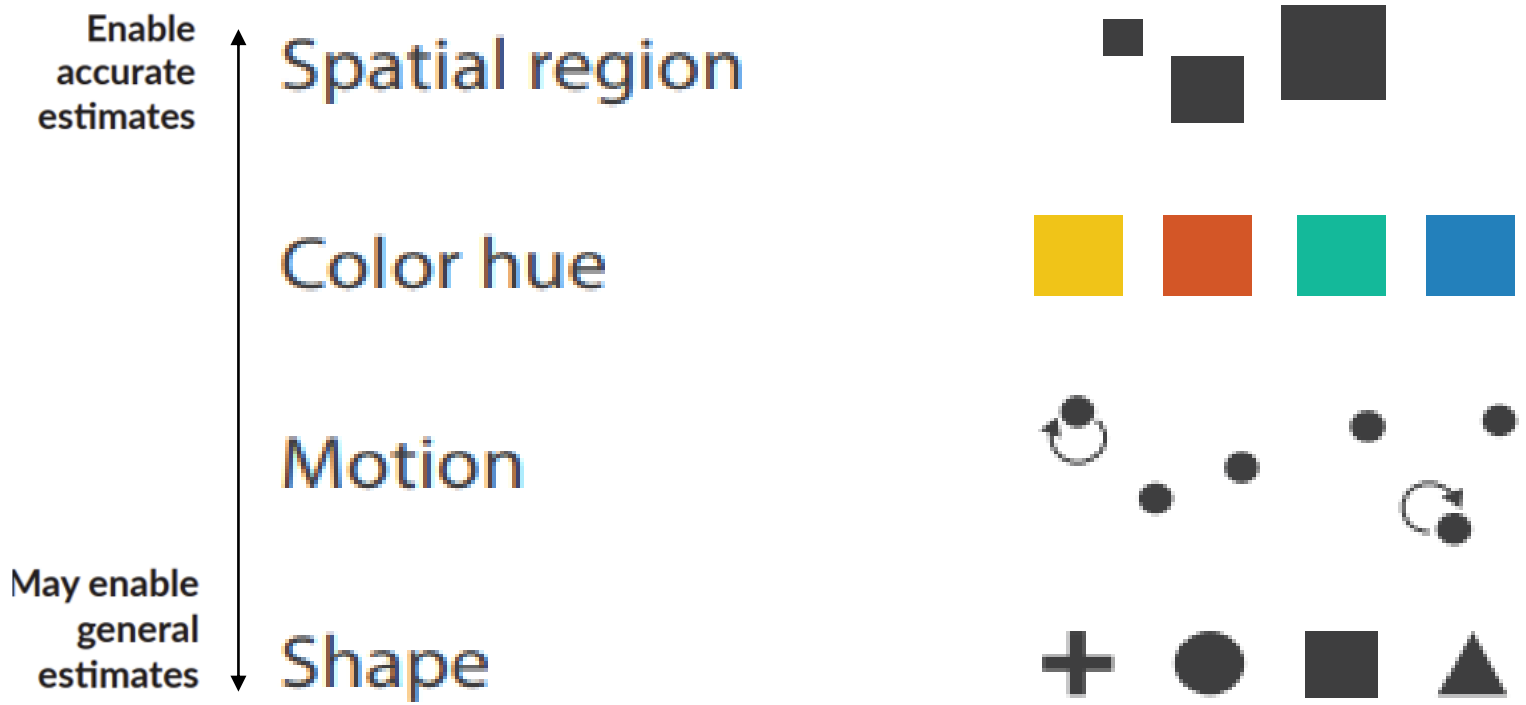
The brain tries to decode back, e.g.:

- Longer bar → higher value (easy)
- Larger area → higher value (difficult!)

For numeric data the standard bar, line, scatter plots are often the best choices!



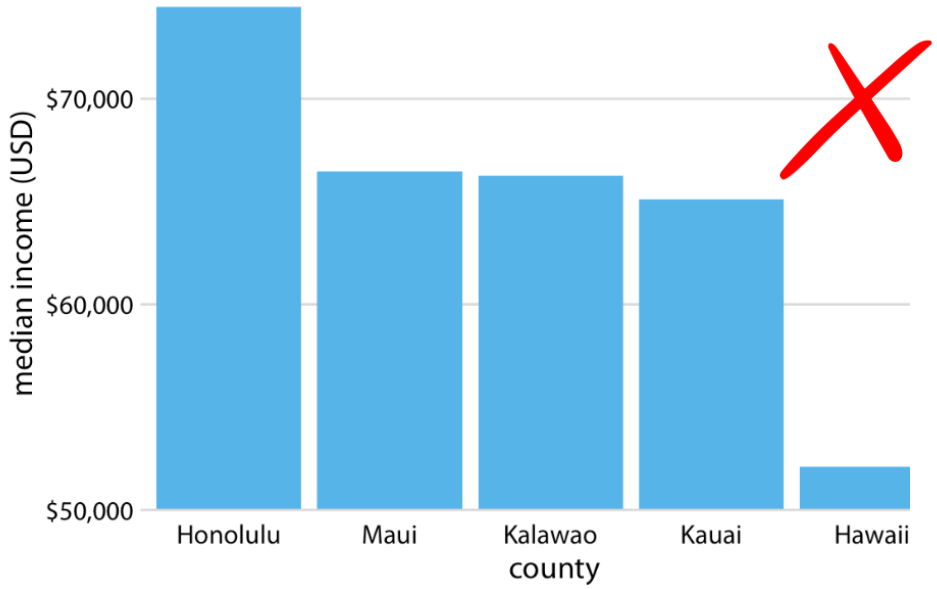
Perceptual ranking of categorical data

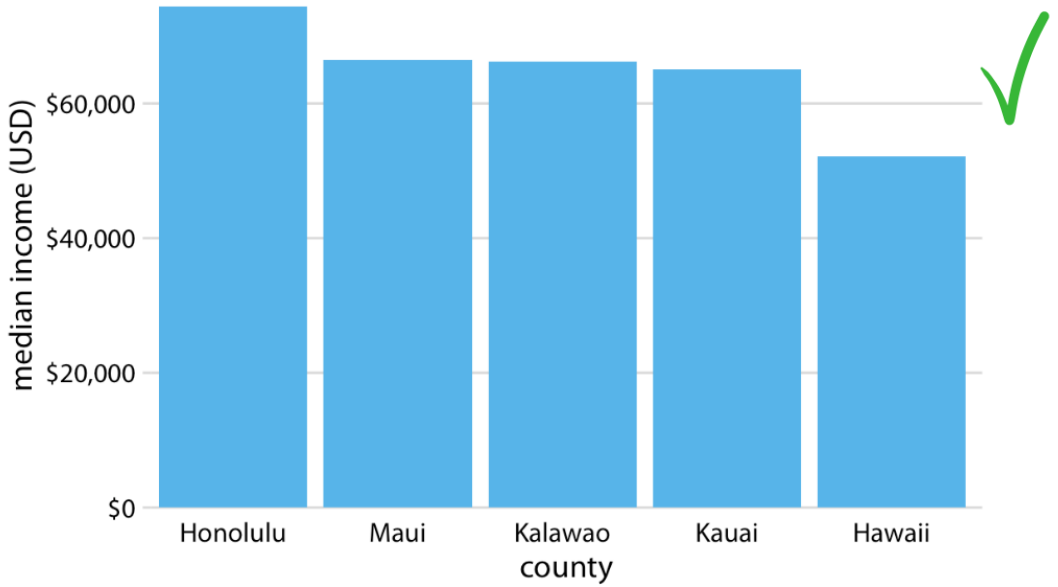


Principle of Proportional Ink

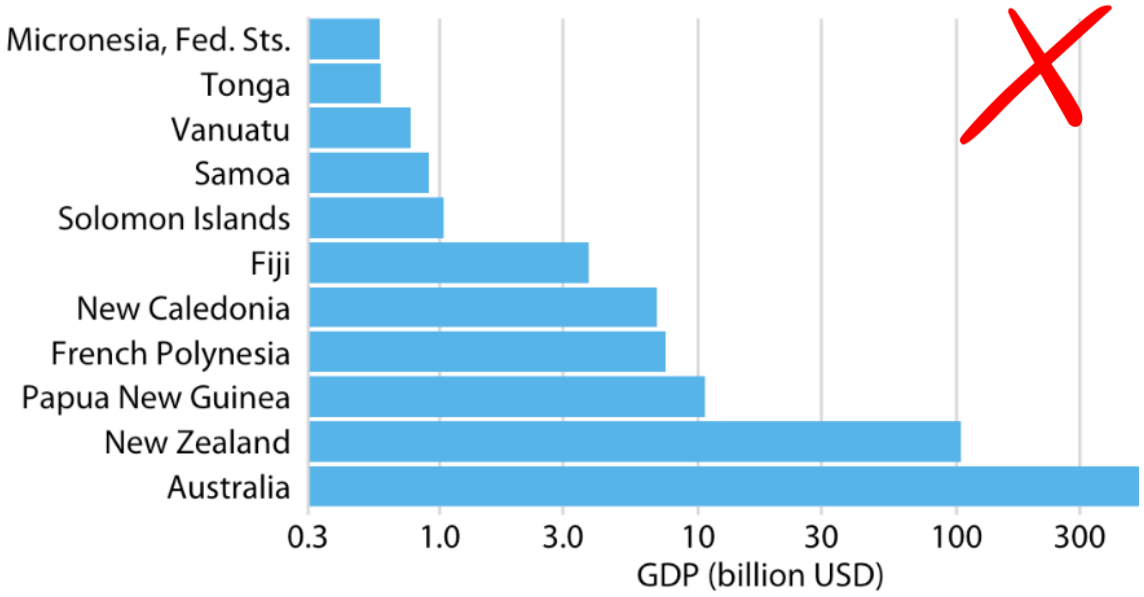
Takeaway 9

The amount of ink used should be proportional to the value that it represents.

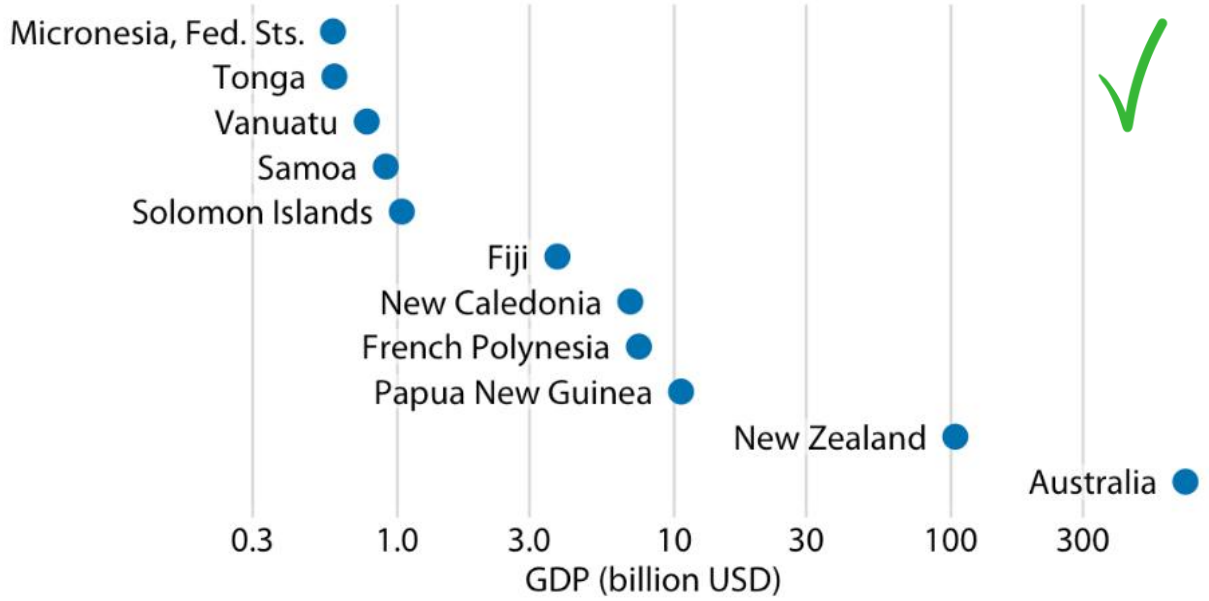




Example: can I use log scaling?



Don’t use log scaling for bar charts

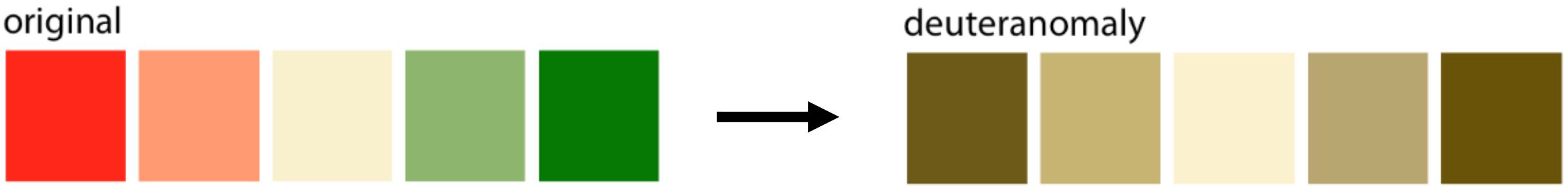


Log scaling can be acceptable for scatterplots

Color blindness

8% of men and 0.5% of women are color blind

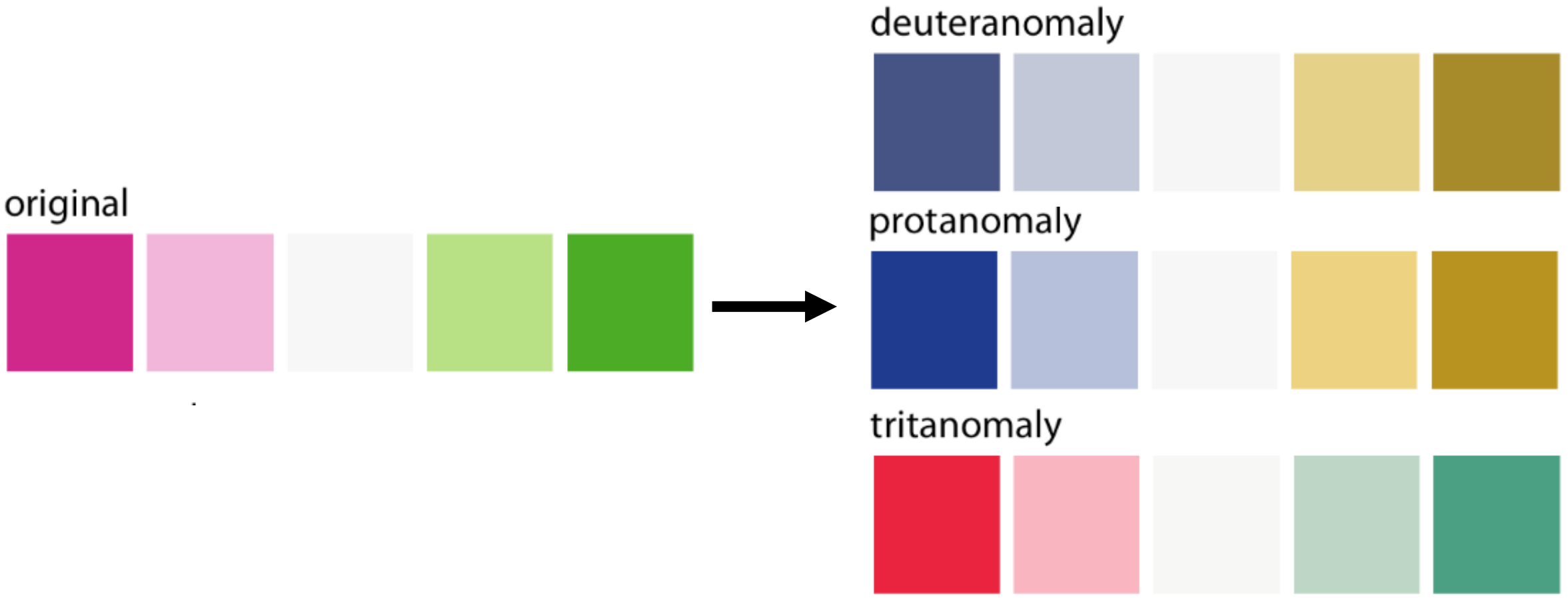
- Deuteranomalia (red-green): 6% men, 0.40% women
- Protanomalia (red-green): 2% men, 0.04% women
- Tritanomalia (blue-yellow): very rare



This is how people with Deuteranomalia perceive the original colors

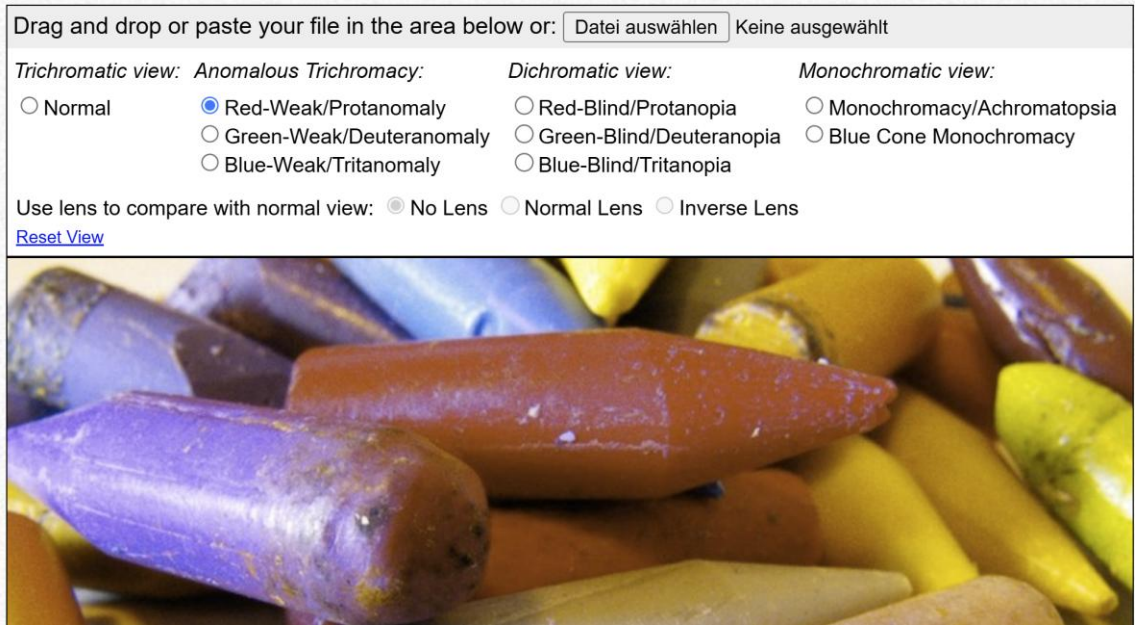
Takeaway 10

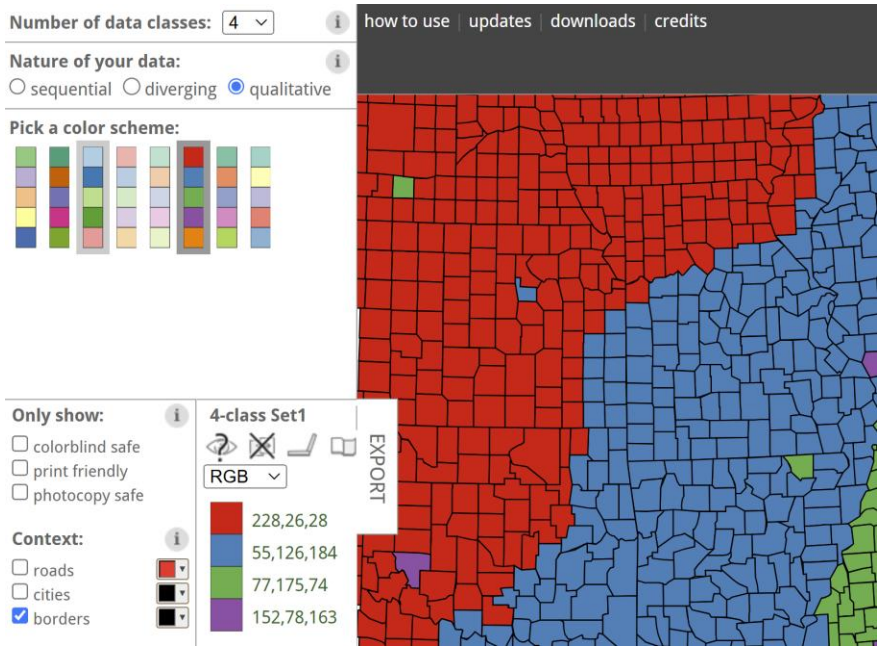
Choose **color-blindness** aware color palettes



Color blindness tools

- https://www.color-blindness.com/coblis-color-blindness-simulator/
- https://daltonlens.org/colorblindness-simulator
- https://colororacle.org
- https://colorbrewer2.org





Takeaways – in one slide

	Short name	Description
1	**Preattentive attributes**	Use preattentive features (like color, size, or shape) to immediately draw the audience's attention to the most important information
2	**Proximity**	Place related elements near each other to signal their connection
3	**Similarity**	Use the same shapes, colors, or sizes to highlight group membership.
4	**Connectedness**	Use lines to signal connection, e.g. through time
5	**Enclosure**	Use shapes or backgrounds to draw the attention to data that belong together
6	**Closure**	Simplify shapes
7	**Figure-ground separation**	Let the data stand out
8	**Encoding effectiveness**	Choose encodings that are perceived accurately
9	**Principal of proportional ink**	The amount of ink used should be proportional to the value that it represents.
10	**Color blindness**	Choose color-blindness aware color palettes

Practical methods to make good design choices

Example

GERTRUDE'S PIANO BAR

STARTERS:

GERTRUDE'S FAMOUS ONION LOAF - 8
SUMMER GARDEN TOMATO SALAD - 8
SLICED VINE-RIPENED YELLOW AND RED TOMATOES WITH FRESH MOZZARELLA AND BASIL BALSAMIC VINAIGRETTE
HAMLET'S CHOPPED SALAD - 7
CUBED CUCUMBERS, AVOCADO, TOMATOES, JARLSBERG CHEESE, AND ROMAINE LEAVES TOSSED IN A LIGHT LEMON VINAIGRETTE
CARIBBEAN CEVICHE - 9
LIME-MARINATED BABY SCALLOPS WITH RED PEPPER, ONIONS, CILANTRO, JALAPENOS, AND ORANGE JUICE
SHRIMP COCKTAIL - 14
FIVE LARGE SHRIMP WITH HOUSE-MADE COCKTAIL SAUCE

ENTREES:

NEW YORK STEAK, 16 OZ - 27
ROTISSERIE CHICKEN - 17
NEW ORLEANS LUMP CRAB CAKES WITH WARM VEGETABLE COLESLAW, MASHED POTATOES, SPINACH AND ROMESCO SAUCE - 18
GRILLED PORTOBELLO MUSHROOM STUFFED WITH RICOTTA CHEESE, GARLIC, ONIONS AND SPINACH, SERVED OVER MASHED POTATOES - 18
NEW ZEALAND RACK OF LAMB - 26
BARBEQUED BABY BACK RIBS - 24
AUSTRALIAN LOBSTER TAIL, 10 OZ - MARKET PRICE
SURF & TURF
AUSTRALIAN LOBSTER & 8OZ FILET - MARKET PRICE

Gertrude's Piano Bar

Starters

Gertrude's Famous Onion Loaf - 8

Summer Garden Tomato Salad - 8
sliced vine-ripened yellow and red tomatoes with fresh mozzarella and basil Balsamic vinaigrette

Hamlet's Chopped Salad - 7
cubed cucumbers, avocado, tomatoes, Jarlsberg cheese, and romaine leaves tossed in a light lemon vinaigrette

Caribbean Ceviche - 9
lime-marinated baby scallops with red pepper, onions, cilantro, jalapenos, and orange juice

Shrimp Cocktail - 14
[illegible]ve large shrimp with house-made cocktail sauce

Entrees

New York steak, 16 ounce - 27

Rotisserie Chicken - 17

New Orleans Lump Crab Cakes - 18
with warm vegetable coleslaw, mashed potatoes, spinach, and Romesco sauce

Grilled Portobello Mushroom - 18
stuffed with Ricotta cheese, garlic, onions and spinach, served over mashed potatoes

New Zealand Rack of Lamb - 26

Barbequed Baby Back Ribs - 24

Australian Lobster Tail, 10 ounce - Market Price

Surf & Turf
Australian Lobster & 8 ounce Filet - Market Price

Gertrude's Piano Bar

Starters

Gertrude's Famous Onion Loaf 8

Summer Garden Tomato Salad 8
sliced vine-ripened yellow and red tomatoes, fresh mozzarella, and basil Balsamic vinaigrette

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cubed cucumbers, scallions, avocado, tomatoes, jarlsberg cheese, and romaine leaves tossed in a light lemon vinaigrette

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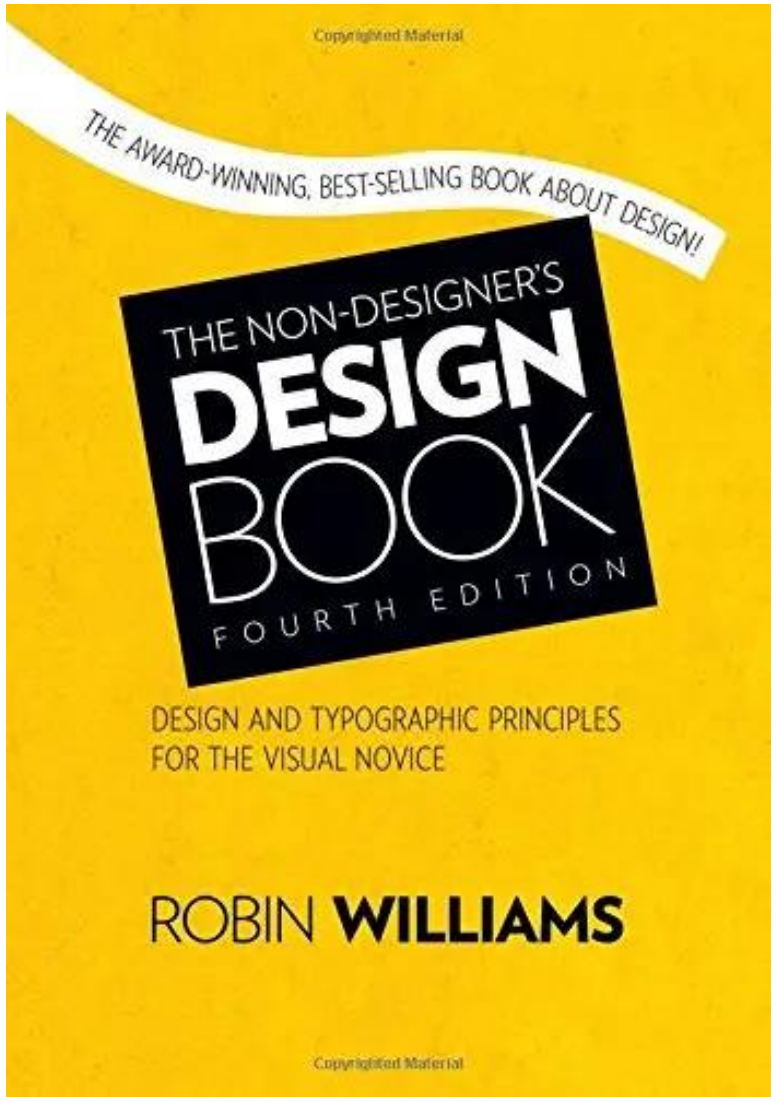
Australian Lobster Tail, 10 oz. Market Price

Surf & Turf Market Price
Australian Rock Lobster and 8-ounce Filet

CRAP Design Principles



Contrast: avoid elements that are merely similar. If the elements (type, color, size, line thickness, shape, space, etc.) are not the same, then make them very different.

Repeat visual elements (colors, shapes, line thicknesses, fonts, sizes, etc.) throughout the piece

Align: Nothing should be placed on the page arbitrarily. Every element should have some visual connection with other elements.

Proximity: When several items are in close proximity to each other, they become one visual unit rather than several separate units.

Maximize the signal-to-noise ratio

- Signal is the information we want to communicate
- Noise are all elements that don't add to/destract from our message

Every single element of our visualization takes up cognitive load of the audience … As designers of information, we want to be smart about how we use our audience's brain power (see Nussbaumer Knaflic, 2015)