Lecture 9
# Pre-attentive attributes, gestalt, illusions

Human visual perception

What happens when we look at the figure?

- The **light** from the screen / projector hits the retinas of our **eyes**
- Photoreceptor cells **transduce** (convert) this signal into nerve impulses
- In the brain:
  - detection of **basic features**
  - recognition of **patterns**
  - interpretation, assignment of **meaning**

Human visual perception
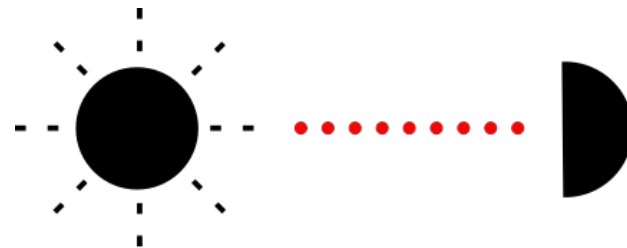
What happens when we look at the figure?

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Today: Detection of features and patterns, use for visualization

Note: Human visual perception is very good for detecting **motion** (danger/prey). This is relevant for animated visualization, but not covered today.

In which period of time was life expectancy higher in Slovakia than in Portugal?

country	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020
Slovak Republic	37.9	40.9	43.9	49.9	54.0	60.9	70.3	69.7	70.5	71.0	73.5	75.6	77.9
Portugal	35.6	35.6	35.6	40.9	51.5	58.6	64.3	67.2	71.5	74.1	76.7	80.0	82.0

In which period of time was life expectancy higher in Slovakia than in Portugal?
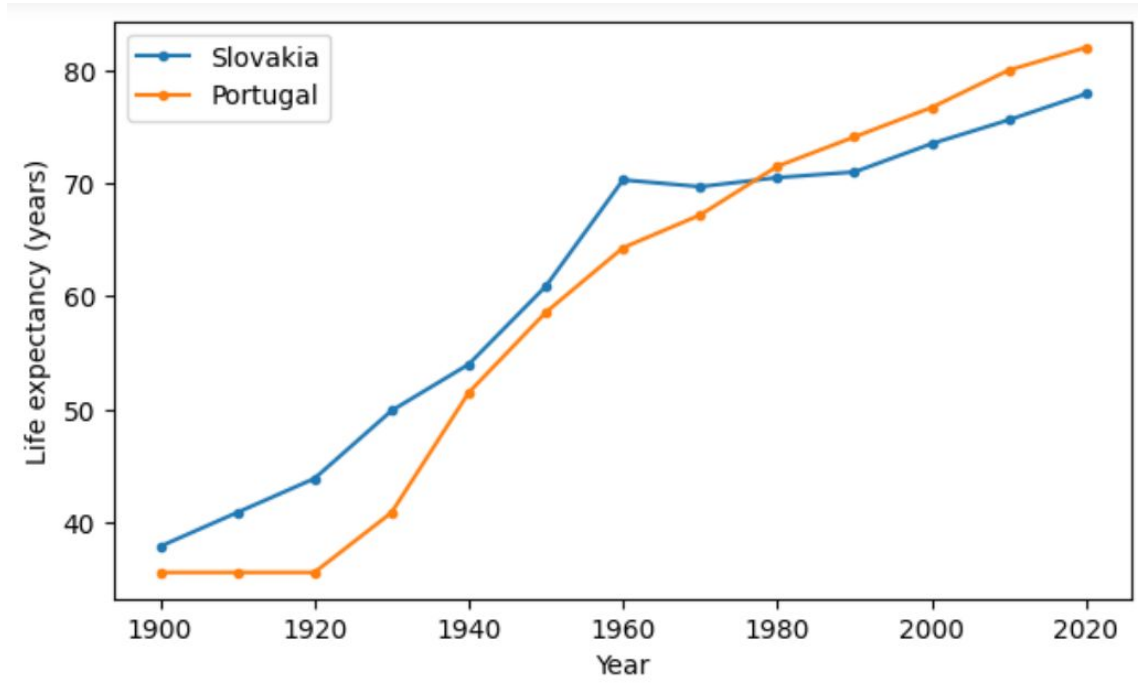
How many copies of digit six do you see?

1014508
2530653
6821550
3702967
8622988

What about now?

1014508

2530**6**53

6821550

37029**6**7

8**6**22988

What about Slovakia vs Portugal in this table?

	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020
Slovakia	**37.9**	**40.9**	**43.9**	**49.9**	**54.0**	**60.9**	**70.3**	**69.7**	70.5	71.0	73.5	75.6	77.9
Portugal	35.6	35.6	35.6	40.9	51.5	58.6	64.3	67.2	**71.5**	**74.1**	**76.7**	**80.0**	**82.0**

Pre-attentive attributes

- Features of the seen objects detected by our brain very **fast**
- Prior to and **without** the need of conscious **awareness**
- Brain uses them to **guide attention** / gaze to interesting parts of the scene
- Their correct use allows fast and effortless understanding of our visualizations

Next:

Examples of important pre-attentive attributes (form, color, position)
following Few 2009

See also https://www.csc2.ncsu.edu/faculty/healey/PP/

Pre-attentive attributes: form

We can quickly distinguish one object that differs from the rest
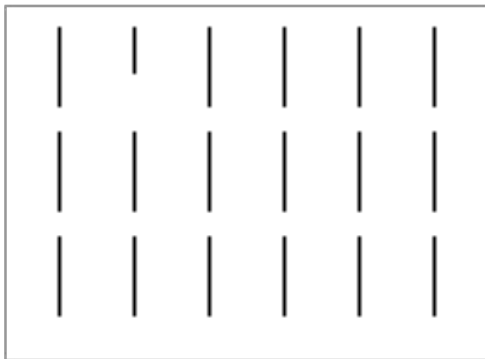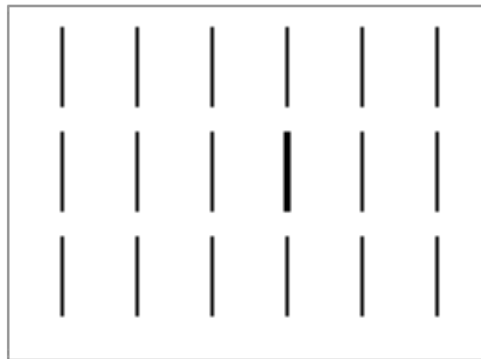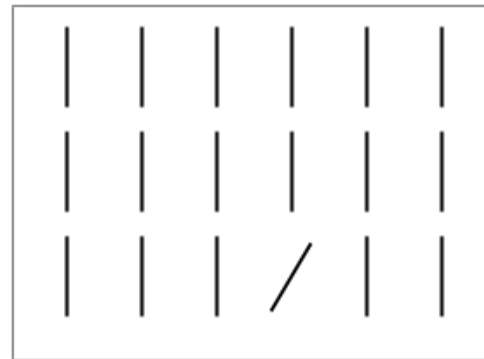
Length · Width · Orientation

Pre-attentive attributes: form

We can quickly distinguish one object that differs from the rest
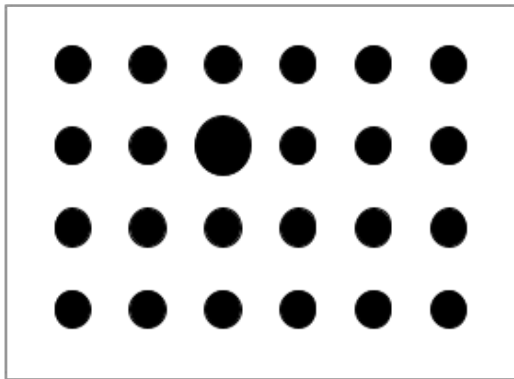
Size
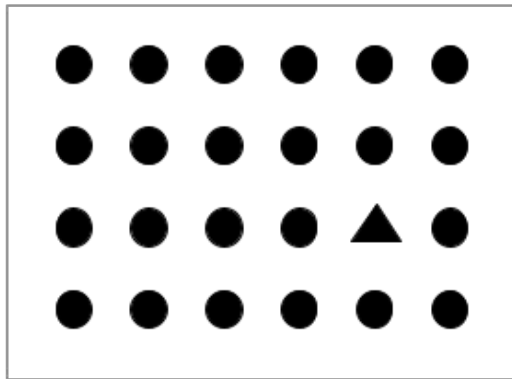
Shape

Pre-attentive attributes: color

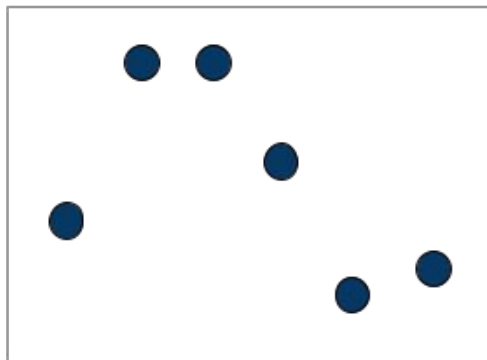We can quickly distinguish one object that differs from the rest
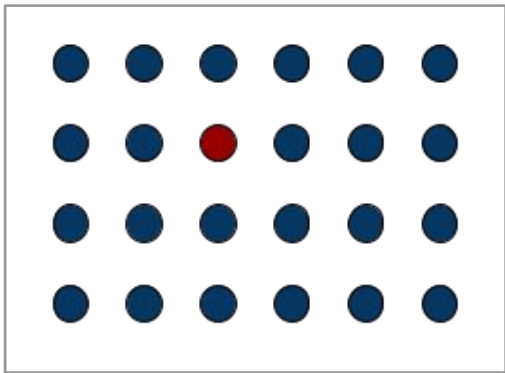
Hue
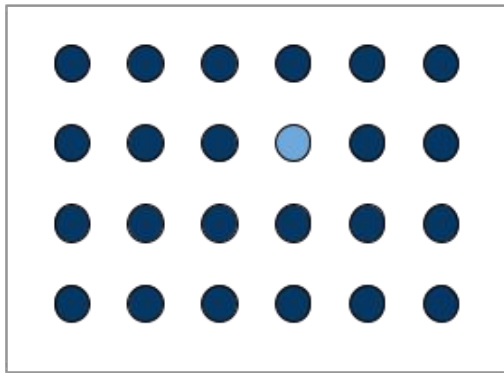
Lightness

# Pre-attentive attributes: position
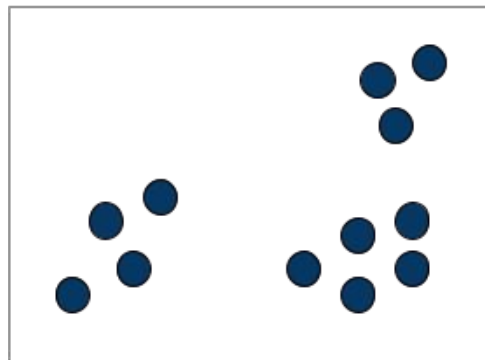
2D   Groups

Hierarchy of graph elements

Cleveland, McGill 1985

Experiments with volunteers of how well they **judge ratios** between values graphically encoded in different ways.

Not all pre-attentive attributes are equally good for **quantitative reasoning**.

Prefer elements on the left side for accuracy

Based on https://paldhous.github.io/ucb/2015/dataviz/week2.htm
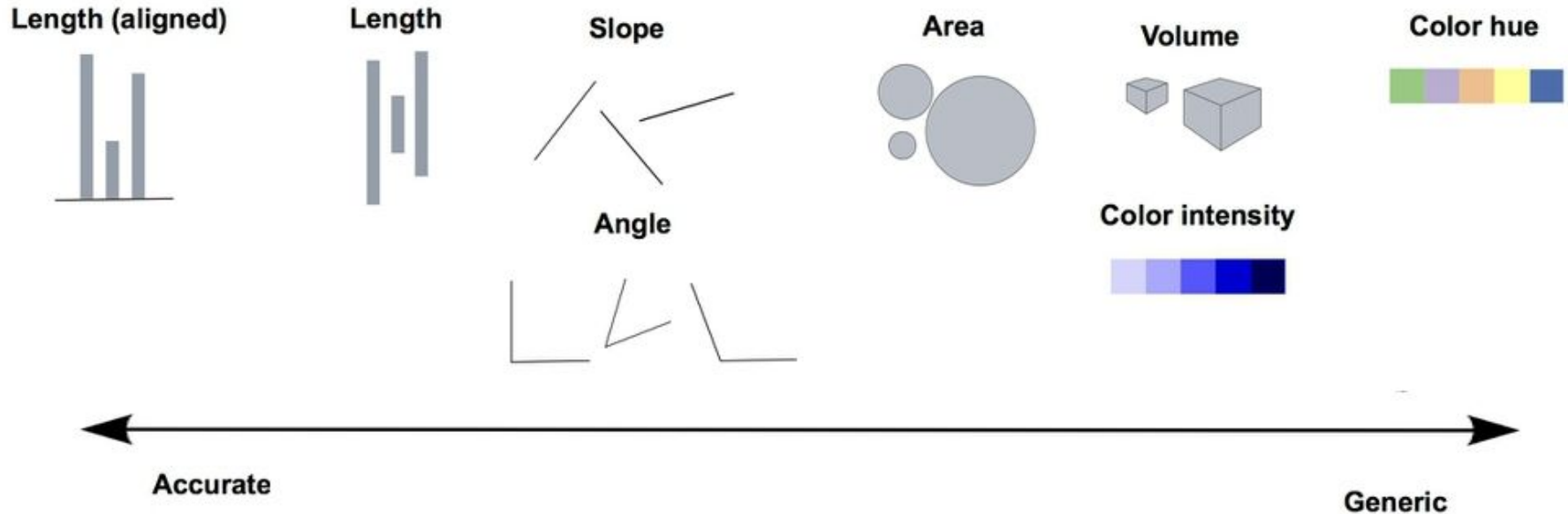
The same data with length vs. area
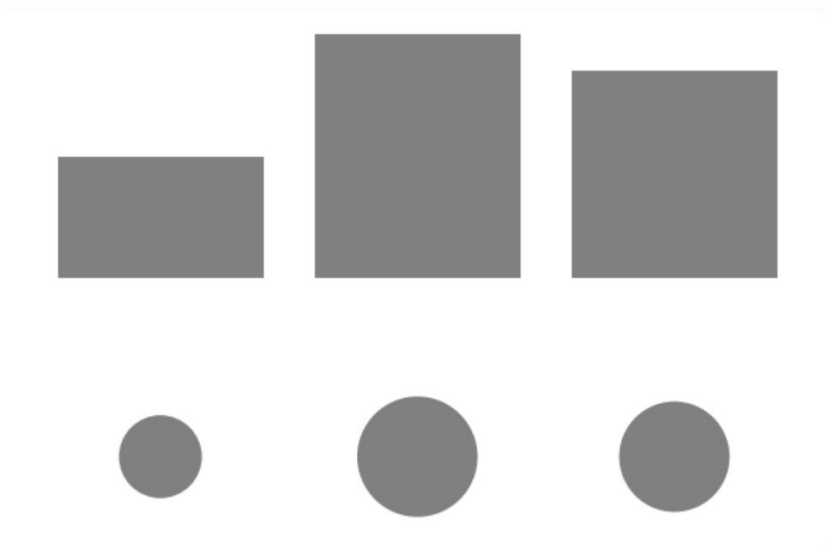
Chart selection tools

In lecture 3 and later, we have seen many types of graphs

Some websites list them based on variable type and purpose for easier selection:

- https://www.data-to-viz.com/
- https://extremepresentation.typepad.com/blog/2006/09/choosing_a_good.html

Let us look at some the suggestions from the first website in terms of the hierarchy of graph elements

From parts to the whole: gestalt

- Gestalt psychology (early 20th century, Austria and Germany)
- **Gestalt** means **pattern**
- Our brains group individual shapes into larger patterns
- The brain favors speed to precision (illusions, errors)
- It also favors symmetry and simplicity
- Several gestalt principles are relevant in data visualization

https://commons.wikimedia.org/wiki/File:Reification.svg
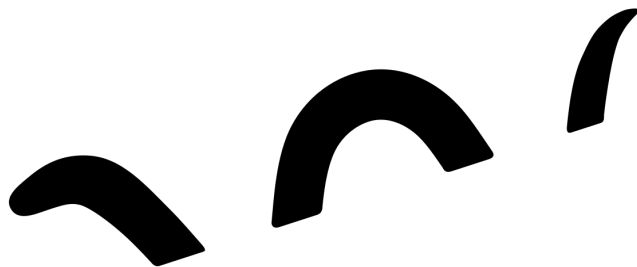
Principle of proximity

- Objects located close to each other are perceived as a group
- Good use of space in plots / tables / presentations can improve readability

https://commons.wikimedia.org/wiki/File:Gestalt_proximity.svg
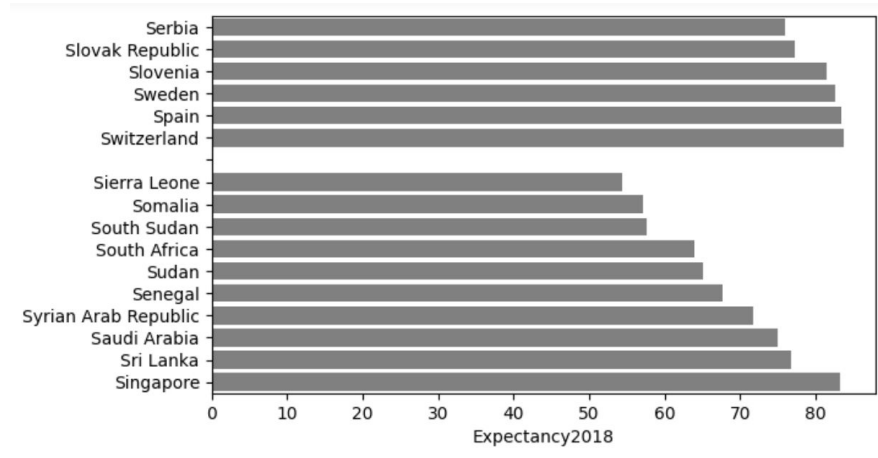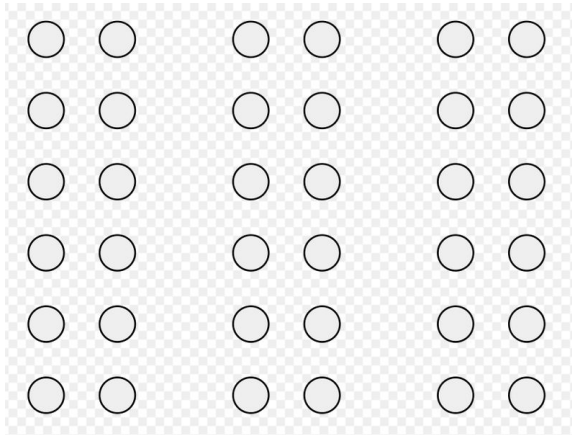
Principle of similarity

- Similar objects are perceived as a group even of not close by
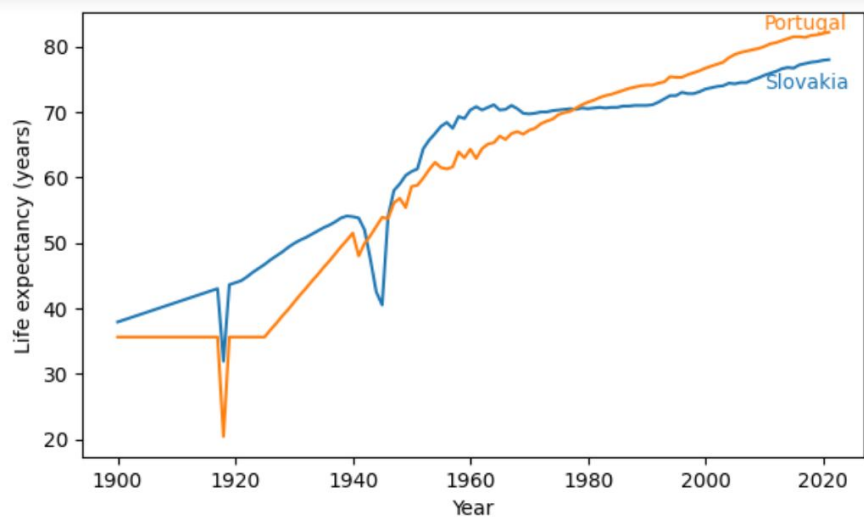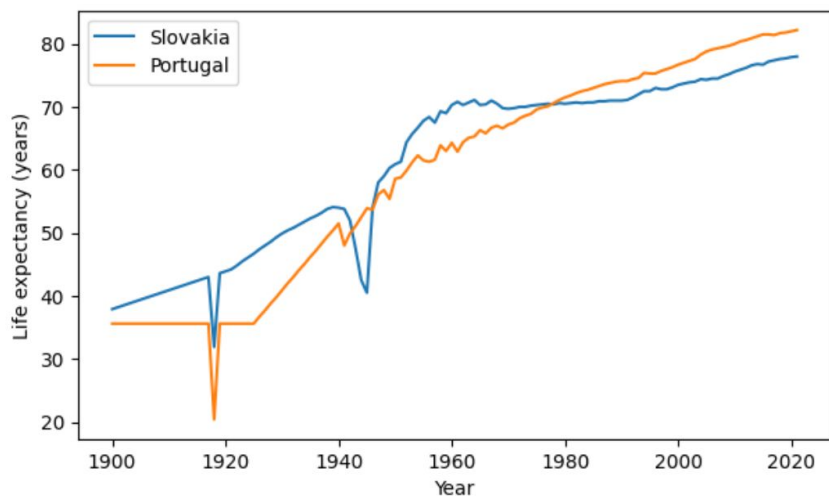- Various plots use color / shape to distinguish groups

PCA colored by gender
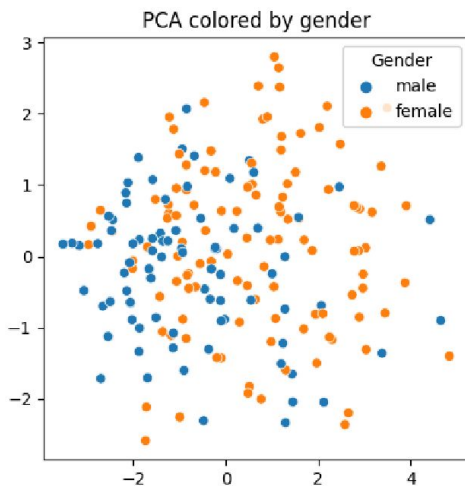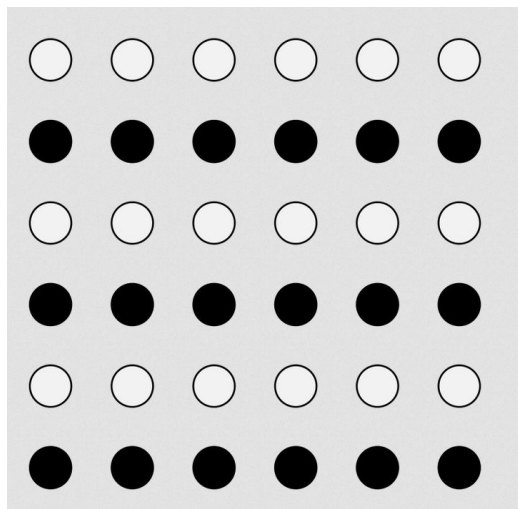
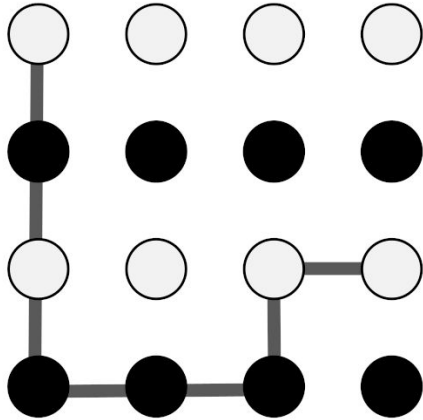# How are both principles used here?
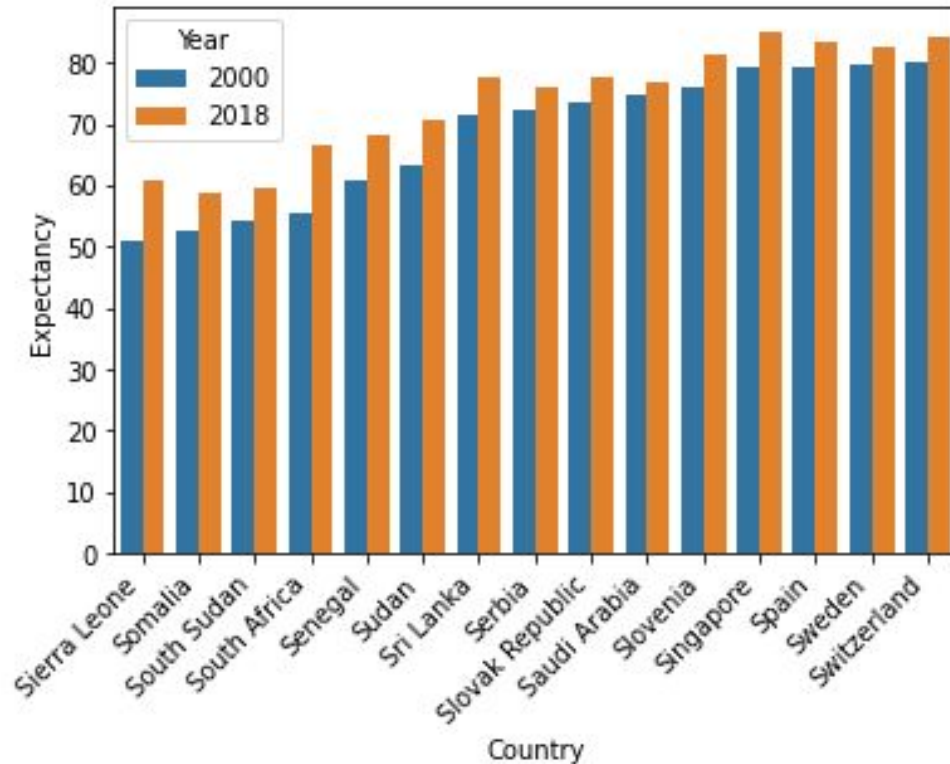
Example

separate legend vs marking lines with text in the same color

- using principles of proximity and similarity

Principle of connection

- Connected objects are perceived to form a group
- Stronger than proximity and similarity
- Consider carefully when to use line graph vs. scatter plot
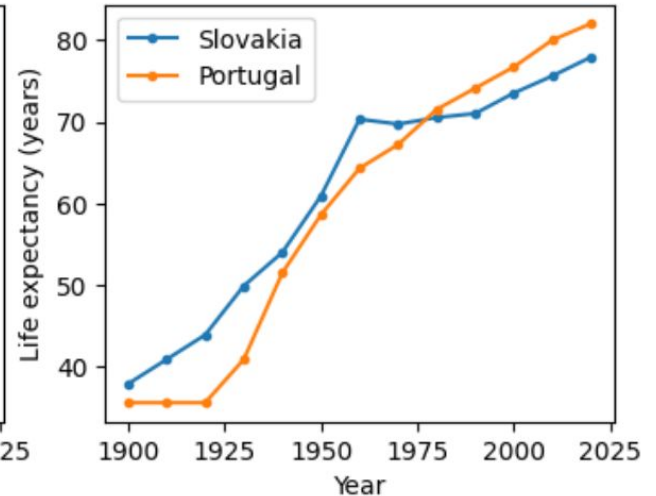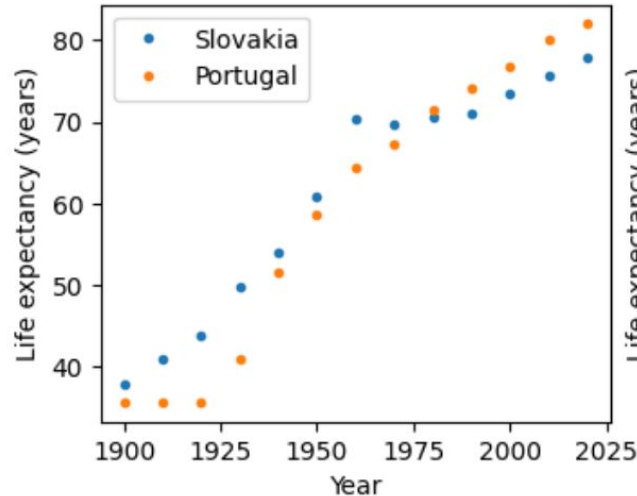
Principle of enclosure

- Enclosed objects are perceived as a member of the group
- Stronger than proximity and similarity
- Useful for highlighting in plots; little is enough (e.g. light background)
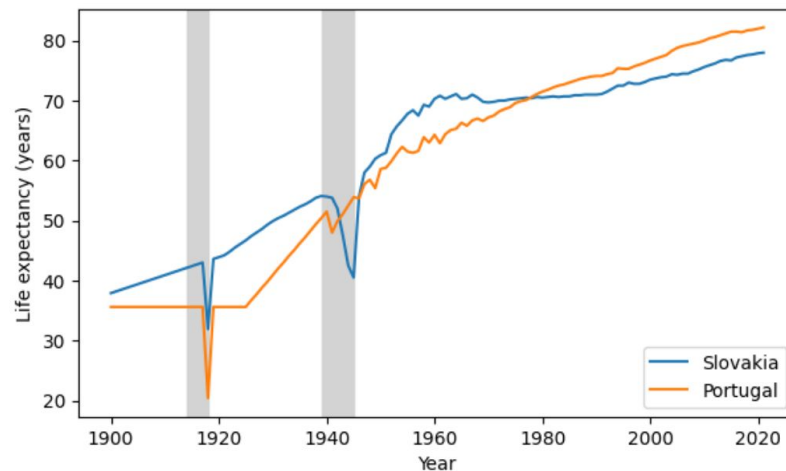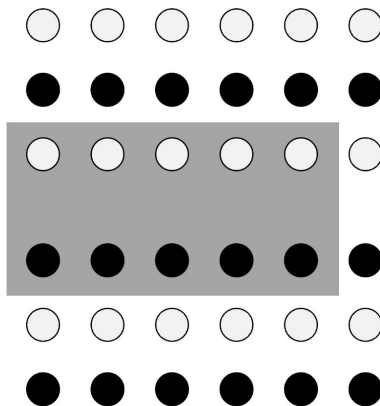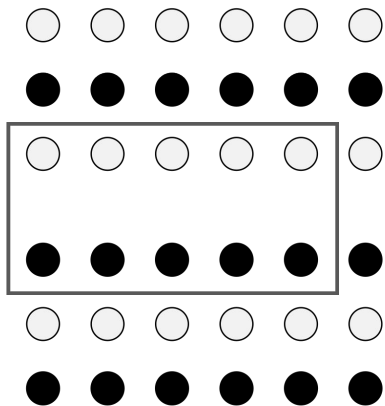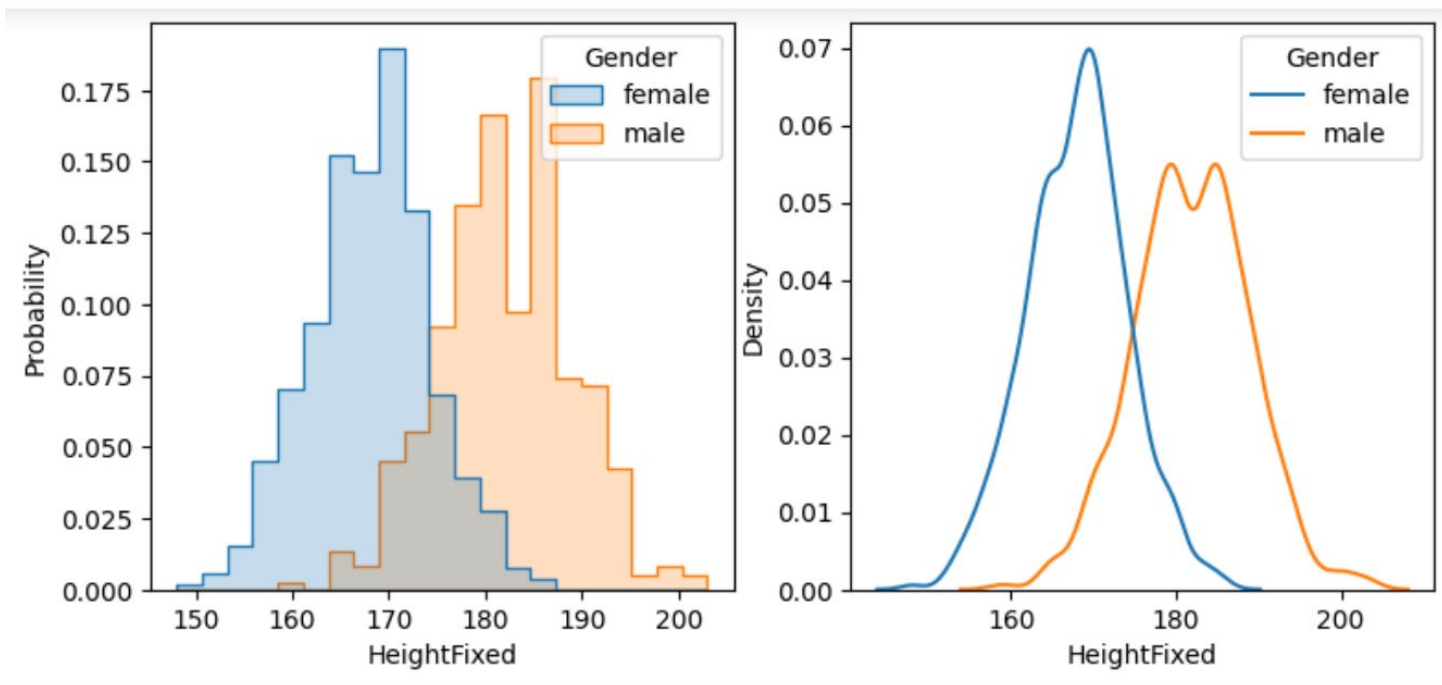
Principle of closure

- Our brain fills gaps in figures, connects interrupted lines
- Useful / dangerous when interruptions by design
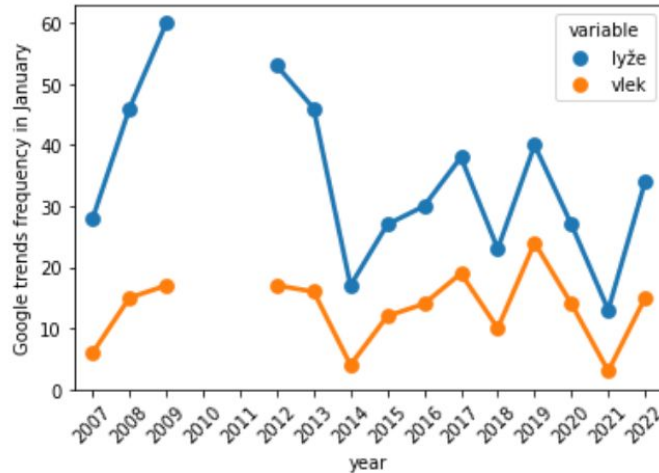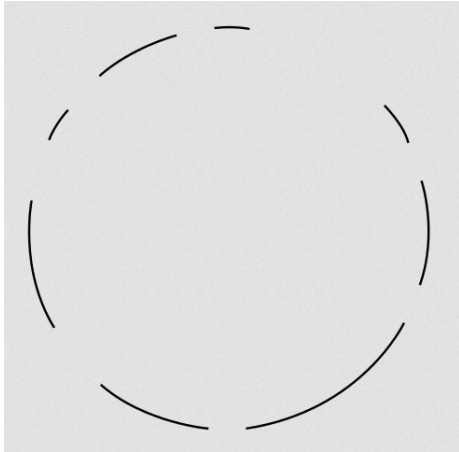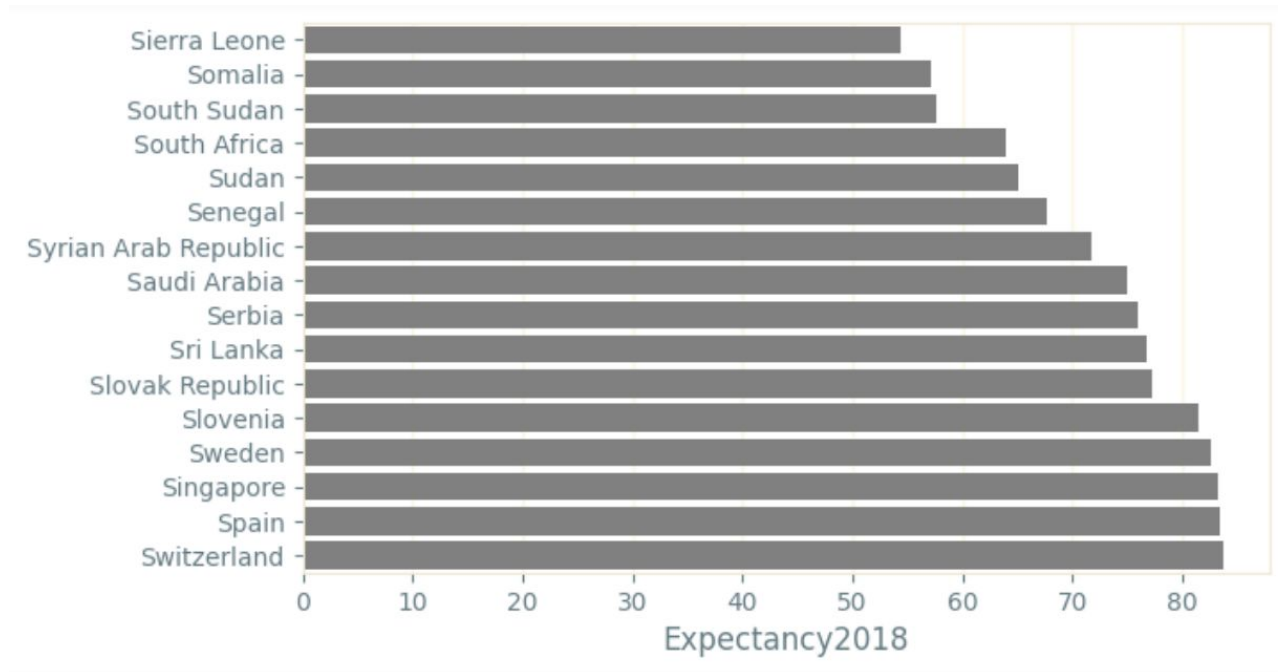
Principle of continuity

- Smooth lines are easier to follow than angular and sharp

Frames not necessary, gestalt principles fills them in
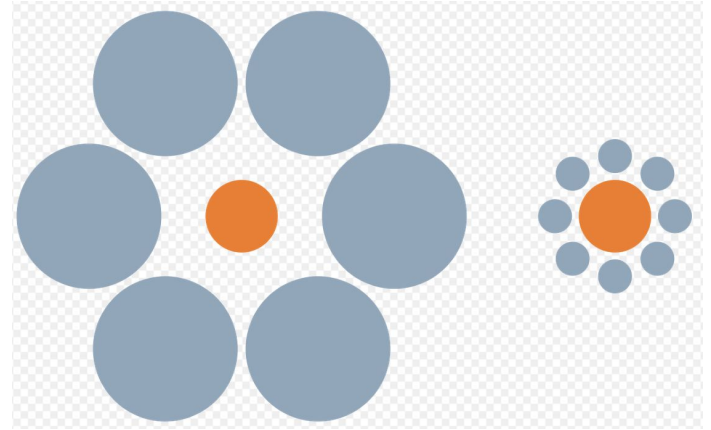
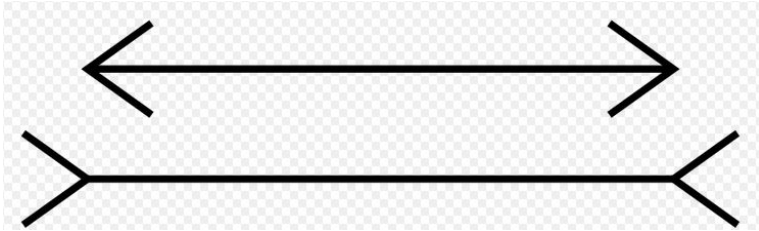- Principles of closure and continuity

Illusions

- Fast visual processing leads to errors
- These are demonstrated by many optical illusions
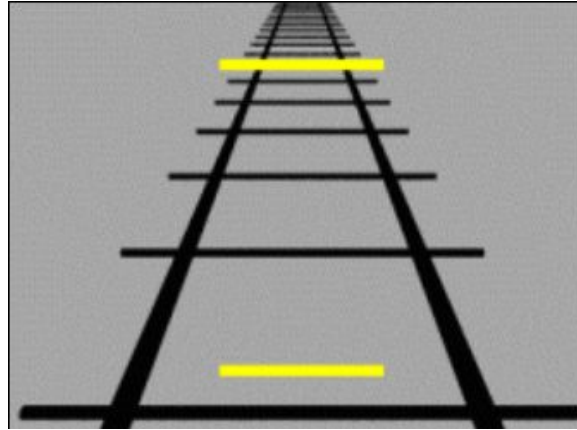- Beware not to create illusions in your plots
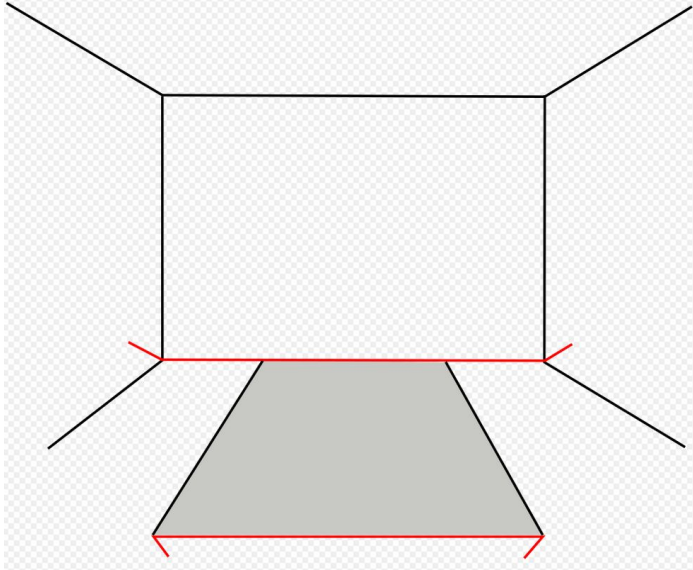
Illusions: length and size

Müller-Lyer and Ebbinghaus illusions

Illusions: length, perspective, spatial compensation
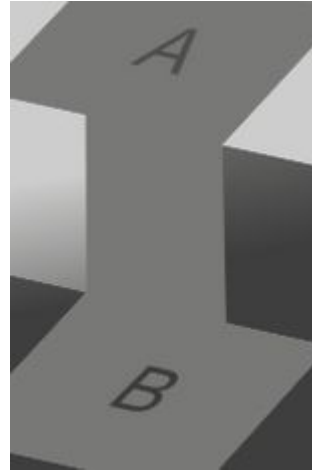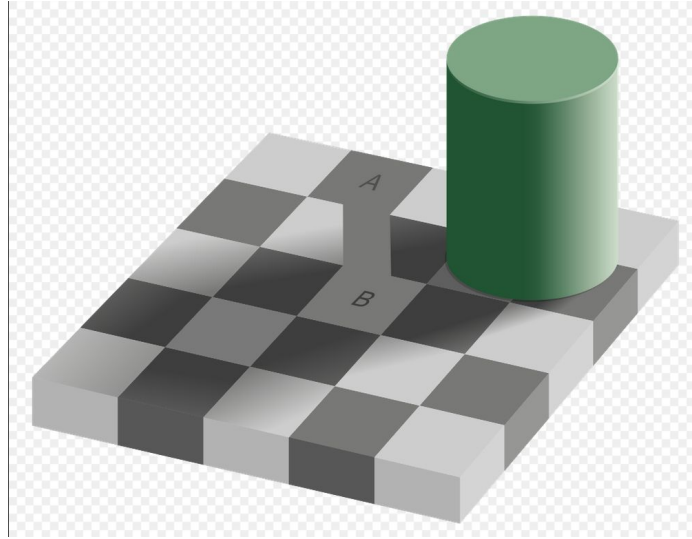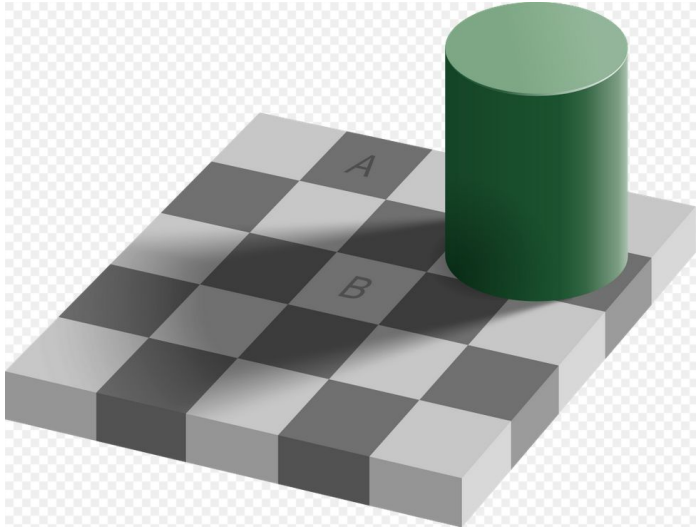
Illusions: color

Illusions: color

Mach bands: when bands touch, the edge effect exaggerates their difference

https://commons.wikimedia.org/wiki/File:Mach_bands_-_animation.gif

Working memory

- **Iconic memory:** extremely short-term (<1s), simple pre-attentive processing
- **Visual short-term memory:** many seconds, but very small capacity (only 3-5 items)
- **Long-term memory:** store and recall selected information

Since working memory is small, looking at a plot with many colors requires back-and-forth between legend and plot
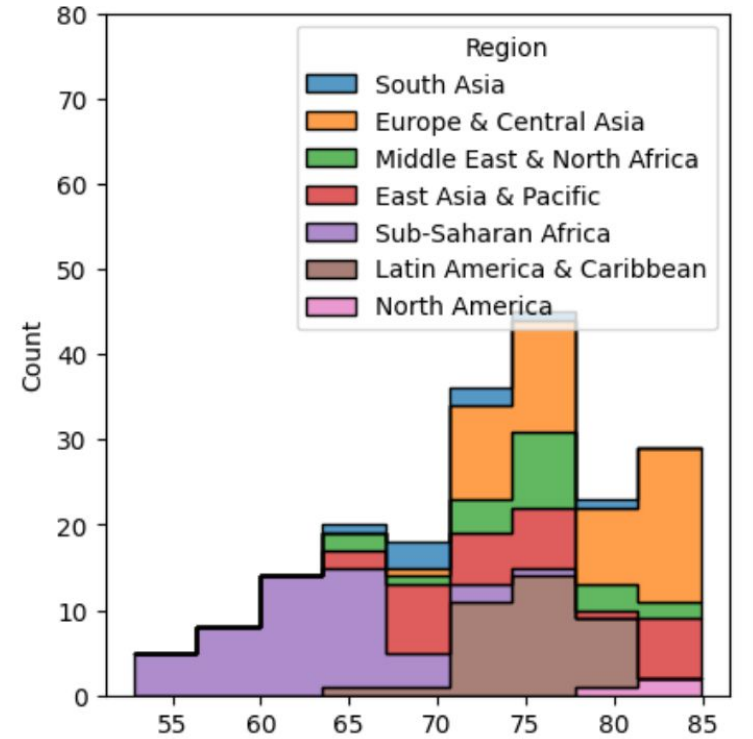
Chart and table junk

- **Chart junk**: elements of plots not necessary to convey information
- They unhelpfully catch our attention through pre-attentive attributes
- Most visualization can be improved by simplification
- Some redundancy can be useful

Nice visualizations of the simplification process:

- https://www.darkhorseanalytics.com/blog/data-looks-better-naked
- Also tables, maps and the unpopular pie charts

Summary

- **Pre-attentive attributes** are processed by our brains very fast
- Choosing the right attributes from the **hierarchy** allows accurate quantification
- Principles of **gestalt** describe how the brain connects part to the whole
- The brain can also make errors in visual processing as seen in **illusions**
- Removing **chart junk** concentrates our attention to the important elements

Additional sources

- [Utilizing Gestalt Principles to Improve Your Data Visualization Design](#)
- http://daydreamingnumbers.com/blog/gestalt-laws-data-visualization/
- Albert Cairo: The Functional Art
- C.N. Knaflic: Storytelling with Data
- Stephen Few: Now You See it