6 Universal Design and Accessibility

Data visualization is a misnomer: it would no doubt be preferable to refer to the whole entreprise as **data perception** and/or **data representation**.

Indeed, were it not for the accident of evolution that gave such prominence to our sense of sight, we might be referring to it as data **sonification** (sound/music, text to speech), **physicalization** (texture-based), **olfactization** (odor/smell), **gustification** (taste), or other "*-ation*" terms related to various senses (or combination thereof).[1]

1: The first two of these, in fact, are active areas of research and implementation by practitioners.

But humans grow old, and the quality of their sight changes over time. Furthermore, a sizeable portion of any data visualization audience is subject to various conditions (not necessarily sight-related) that could make it difficult to get the most out of data presentations.

Designers must take this into account in order to produce **accessible** charts, dashboards, and infographics. Traditionally, the solution has been to translate text and tables into **Braille**.[2]

2: "A system of raised dots that can be read with the fingers by people who are blind or who have low vision. [...] Braille is not a language. Rather, it is a code by which many languages—such as English, Spanish, Arabic, Chinese, and dozens of others—may be written and read. As of 2016 the main code for reading material is *Unified English Braille*, a code used in [...] English-speaking countries [What is Braille?, *American Foundation for the Blind*]."

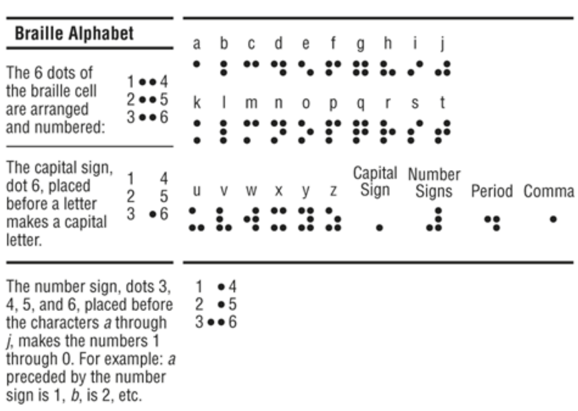


Figure 6.1: Braille symbols are formed with braille cell consisting of six raised dots arranged in two parallel columns each having three dots. Sixty-four combinations are possible using one or more of these six dots. A single cell can be used to represent an alphabet letter, number, punctuation mark, or even a whole word [59].

It is a clever system, whose readability can be improved through the use of various conventions, but it requires a medium which can be **embossed**. Summary tables can definitely be translated to Braille (although even the smallest of tables may end up taking up more canvas space than expected), but we cannot always do so for charts (presumably, the chart itself can be embossed into the medium, see data physicalization below).

How, then, do we make data visualizations accessible to non-sighted audiences? We could opt to **describe** the features and emerging structures in a visualization, assuming that these can be spotted in the first place.

This approach is tailor-made for **data storytelling**, where only a small number of charts is produced, but it is unlikely to be useful with **data exploration**, especially when chart generation is automatic and so many of them are produced that barely any of them are "visited" before being called up.

In data storytelling (as we see in Chapter 8, *Effective Storytelling Visuals*), **clarity** is key: we produce clear and meaningful visualizations that should stand on their own, but we must also describe what it is that we see in a fashion that allows all (including people for whom charts are akin to an alien script) to "see" the **insights**.

If we purposely steer away from attempting to describe all the insights (assuming that they can even all be "seen") in order to focus on a few highlights, sighted individuals will always have the ability to spot information and results that the communication team has elected to omit. That is not something that is available to non-sighted audiences.[3] There are, however, other options, which we discuss presently.

3: The same objections arise for **speech-to-text** tools.

6.1 Data Perception Alternatives

Sonifications

An intriguing approach to data representation is that provided by **data sonification**, using sounds (and music) to present and interpret data: clock chimes and Geiger counters, which produce a 'click' whenever a radioactive decay occur, offer early examples of such a process.

In the following video, the planetary structure of the TRAPPIST-1 star system is represented with a song.

Figure 6.2: TRAPPIST Sounds : TRAPPIST-1 Planetary System Translated Directly Into Music (1:54), SYSTEM Sounds. The **frequencies** are associated to planetary transits in front of the star; the drum **hits** to conjunctions .

This is eerily reminescent of some early *Radiohead* songs.[4] The approach could be extended to use different instruments (**timbre**) for different planet types (perhaps brass for rocky planets and winds for gas giants, say); other elements that could be mapped to data features include **pitch**, **amplitude**, and **tempo**.

4: Amnesiac's Packt Like Sardines in a Crushd Tin Box , at a first listen.

It is also easy to imagine how this methodolgy could be applied to different stars (and their attending planets), leading potentially to different sonification "**styles**": stars that "sound" the same might have something in common which may be difficult to identify in the physical universe (which is to say, according to measurements such as luminosity, spectral type, etc.).

Another impressive experience is that of Lily Asquith, a non-sighted physicist at CERN. In the video below, she tells her audience how she tracks elementary particles in the *Large Hadron Collider*, which is traditionally done using particle diagrams, a sighted method.[5]

5: Possible data signature of a Higgs boson such as could be found at CERN's LHC [60]:

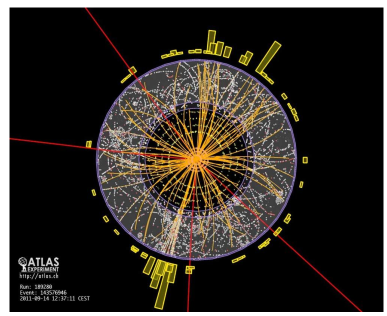


Figure 6.3: Listening to data from the Large Hadron Collider | Lily Asquith | TEDxZurich (17:44), TEDx Talks.

After visualization, sonification is probably the most mature data perception approach, as discussed by Carla Scaletti in her excellent ICAD 2017 keynote address: Why Data Sonification Is a Joke .

Additional examples can be found at:

- NASA's Sounds from Around the Milky Way and A New Cosmic Triad of Sound ;
- Andrea Polli's Atmospherics/Weather Works: A Spatialized Meteorological Data Sonification Project ;
- 400+ examples are showcased at the Data Sonification Archive (in categories ranging from architecture to war, and passing through climate change, gaming, politics, and sport, among others); the archive is a bit of time sink, but it is definitely worth your time.

We have been using data to represent our physical world for years; it is a happy coincidence that we can also use physical means to represent our data, as we now discuss.

Physicalizations

Data physicalizations have been pursued throughout history; artists and artisans, in particular, have been representing aspects of their worlds through a variety of media over the years.[6]

6: Although the resulting physical products are rarely expected to be "touched" by the general public. Physical representations have a distinctly **analog** aura (as opposed to **digital**, as discussed in The Analog/Digital Data Dichotomy [1]); **modern** uses can feel "gimmicky" *at times*, but there are plenty of "legitimate" approaches.

As is the case with visualization and sonification, the challenge is to find elements that can be mapped meaningfully to the data features (variables), to allow for comparisons, multivariate links, etc. (as in Sections 1.3, *Principles of Analytical Design*, and 2.3, *Representing Multivariate Observations*).

The Inca used **khipus** (strings and knots) as a physical data storage and representation device.[7]

7: It is believed that **colour**, the **relative knot positions**, **knot types**, and **rope lengths** were used to encode the variables.

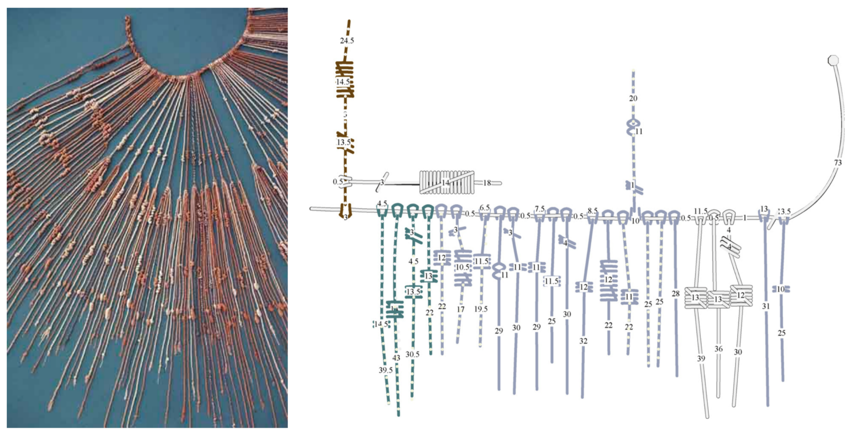


Figure 6.4: Traditional khipu [61] (left) and interpretation [62] (right).

More recently, **tactile infographics** have been created on **thermoform** (heated sheet of plastic sealed on a physical model) or swell paper.[8]

8: The tactile variables that can be used to represent data include: vibration, flutter, pressure, temperature, size, shape, texture, grain, orientation, and elevation.

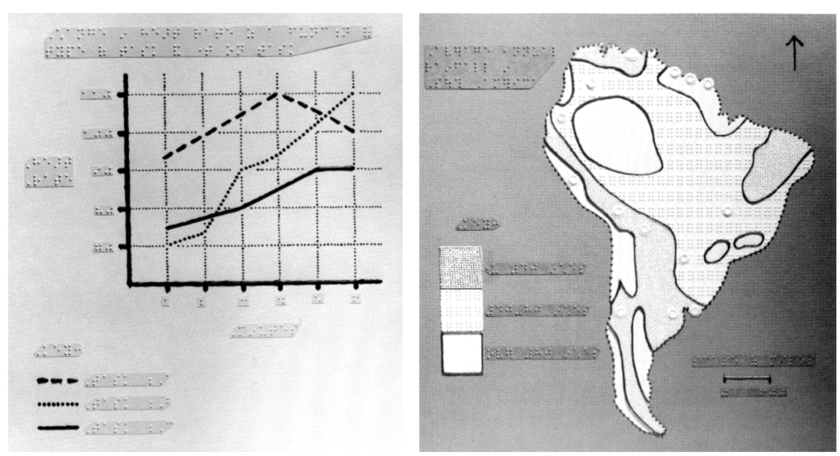


Figure 6.5: Thermoform representation of a line chart (change in heart rate as a function of type of task and time on task; left) and choropleth (average South America rainfall; right) [63].

Sonifications and physicalizations can unite in **audio tactile maps**, for instance: in this case, software with audio files is used to convey information as the user's fingers rolls over features or symbols of the tactile display.

Various other examples can be found at the Data Physicalization Wiki [9]

9: Another time sink that is worth a visit or three.

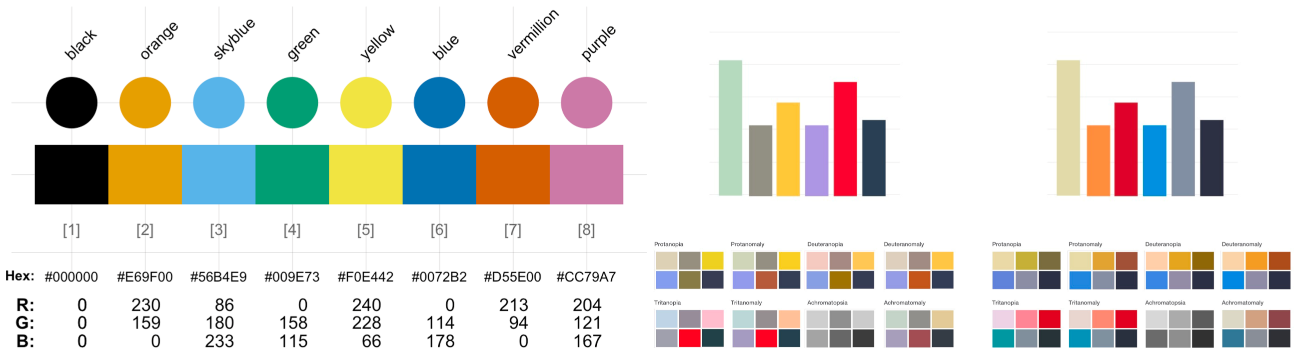


Figure 6.8: Two colourblind-friendly colour scales (left: [66], right: [67]).

6.2 Colourblindness

In Figure 4.17, the focal point is indicated by a change in colour (a dark yellow bar). Aesthetically, this is a pleasing choice, but would you agree that the pink bar in the chart on the right of Figure 6.6 might be easier to spot?[10]

10: Or not... what do you think?

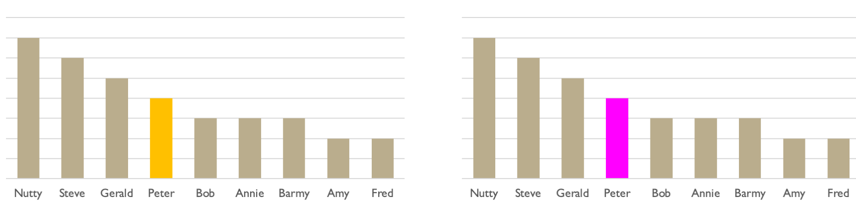


Figure 6.6: The focal point directs the reader's eyes (reprise).

A sizeable proportion of the population (~4% in North America) is **colourblind** to some degree, due to a genetic defect affecting one (or more) of the eye's **cones** (red, green, blue) [64].

Charts that rely solely on colours might fail to convey the full extent of the data story to a significant proportion of the audience: the primary and secondary colours, for instance, might not be as easily differentiable as one would hope, depending on the cone defect.

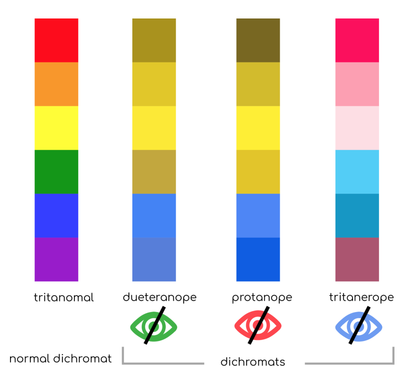


Figure 6.7: The effects of various colourblind afflictions [65].

Part of the solution is to consider using **contrast-friendly** colour palettes for charts, and to support the signals conveyed by colours with other design elements (shapes, size, annotations, etc.), as in the palettes shown below.

It can be difficult to guess what our colour choices will look like to colorblind individuals; uploading charts to simulators (such as Coblis) provide an idea of how they will be perceived in the various colourblind spaces.[11]

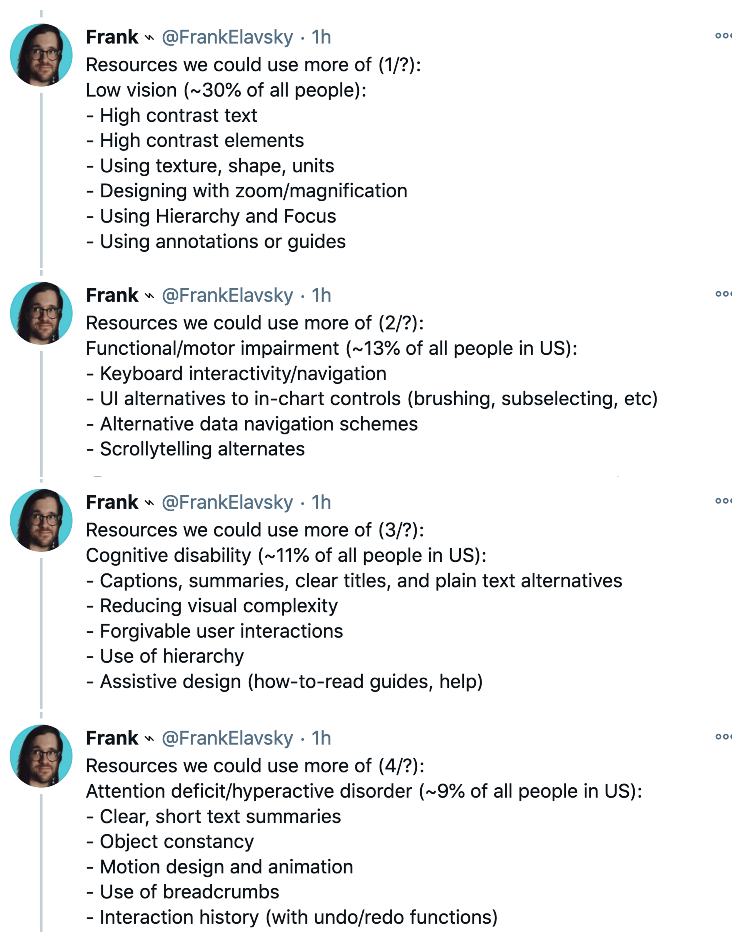
11: This is what the images of page 86 would look like under various colorblindness conditions.

6.3 General Resources

Colourblindness is not the only accessibility issue related to data charts, but it is one of the most visible. Exactly why that should be the case is hotly debated: some commentators believe that it solely because it is a condition that disproportionately affect biological males.*

While we believe this may indeed play a role, we point out that the focus on colourblindness could also be partly explained by **convenience**: of all accessibility solutions, changing colours is probably the easiest to implement.

In a short twitter thread, F. Elavsky lists additional **accessibility resources**:



Frank @FrankElavsky · 1h
Resources we could use more of (1/?):
Low vision (~30% of all people):
- High contrast text
- High contrast elements
- Using texture, shape, units
- Designing with zoom/magnification
- Using Hierarchy and Focus
- Using annotations or guides

Frank @FrankElavsky · 1h
Resources we could use more of (2/?):
Functional/motor impairment (~13% of all people in US):
- Keyboard interactivity/navigation
- UI alternatives to in-chart controls (brushing, subselecting, etc)
- Alternative data navigation schemes
- Scrollytelling alternates

Frank @FrankElavsky · 1h
Resources we could use more of (3/?):
Cognitive disability (~11% of all people in US):
- Captions, summaries, clear titles, and plain text alternatives
- Reducing visual complexity
- Forgivable user interactions
- Use of hierarchy
- Assistive design (how-to-read guides, help)

Frank @FrankElavsky · 1h
Resources we could use more of (4/?):
Attention deficit/hyperactive disorder (~9% of all people in US):
- Clear, short text summaries
- Object constancy
- Motion design and animation
- Use of breadcrumbs
- Interaction history (with undo/redo functions)

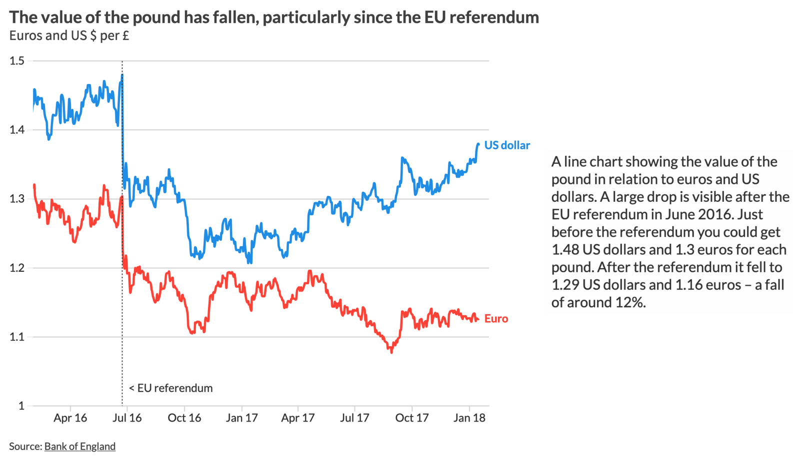
Note that producing **high contrast** charts seems to solve a sizable number of accessibility issues.

* A reverse situation arises among biological females linking deficiencies in the eye's cones with issues of depth perception.

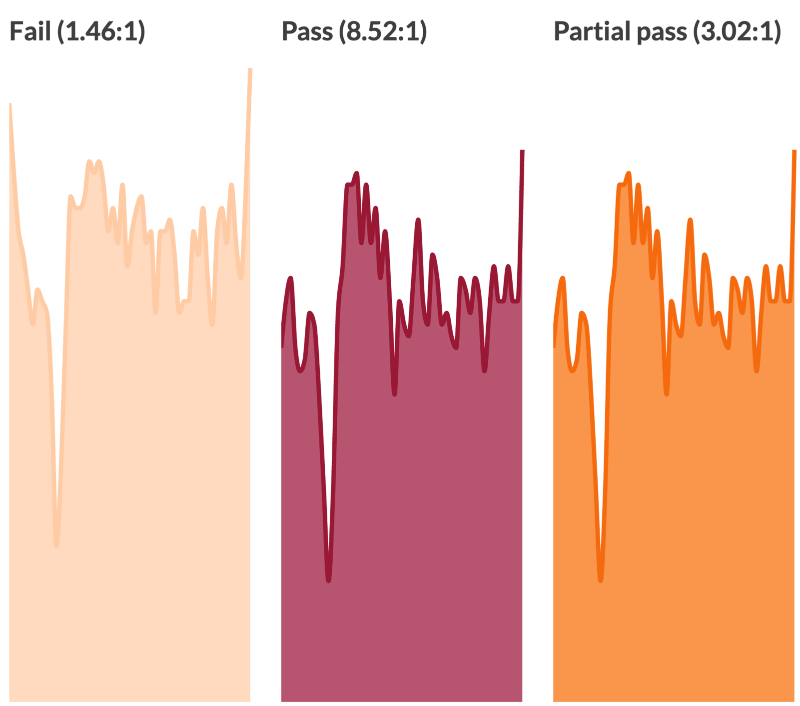
6.4 Practical Suggestions

What does all of this translate to, practically-speaking? Lyndsey Pereira-Brereton and Luisa Bider suggest that data charts can be made more accessible by [68] (the examples are from the same source):

- **adding text descriptions** to the charts (which represents an early form of storytelling with data, see Chapter 8);



- **using colours that are bold and clear** enough for individuals to perceive both text and graphical elements;[12]



- **minimizing the number of colours** used in charts, such as going from 4 (1 per graph) to 2 (1 per chart pattern) in the example at the top of page 108;

12: Web Content Accessibility Guidelines (WCAG) suggest meeting the WCAG AA requirements. To check if font colour and size choices are AA accessible, we can use a contrast checker website. For colours to be AA accessible they need to have a contrast ratio of at least 3:1 for graphical elements, and 4.5:1 for normal text.

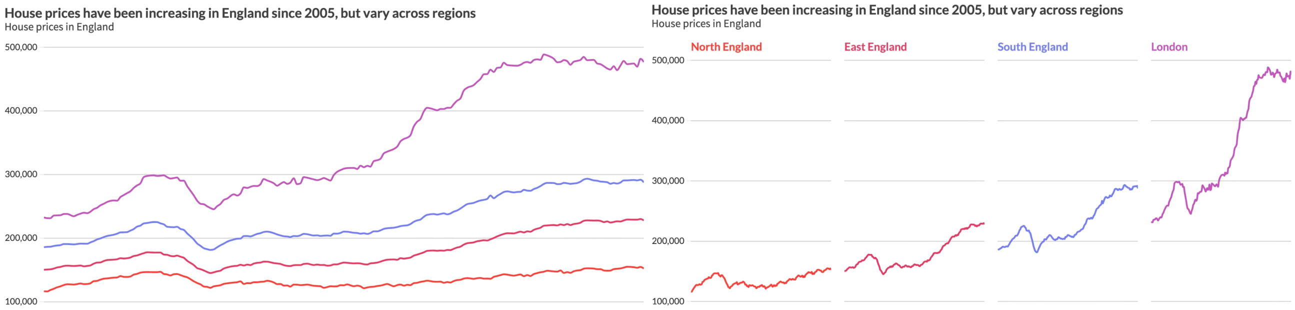
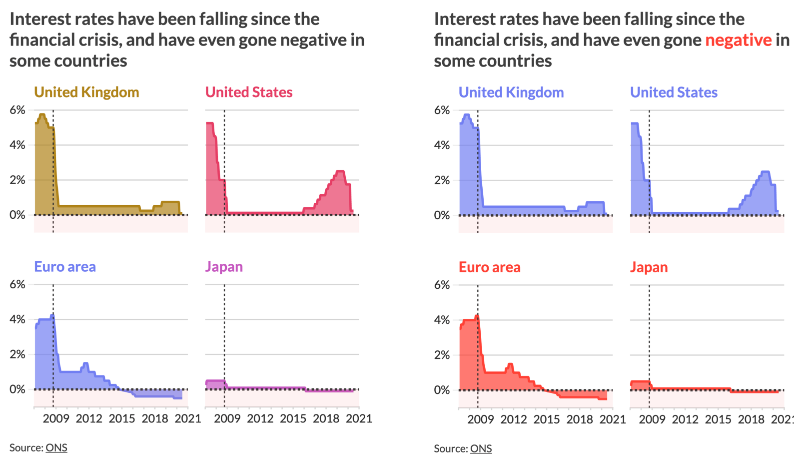
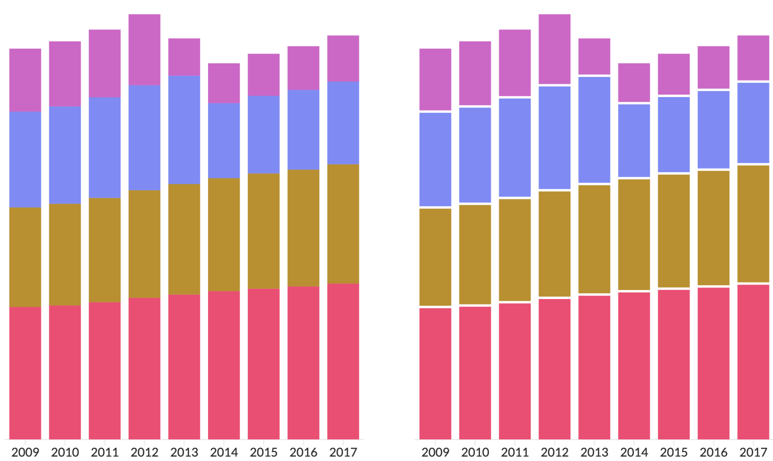


Figure 6.9: Short graphs vs wide graphs [68].



- **using white separators to increase the contrast** between various chart elements (according to the corresponding Gestalt principles, see Section 4.2);



- **favouring the use of "short" graphs over "wide" graphs** to reduce issues associated with attention deficits (compare the two charts in Figure 6.9).

Making data charts accessible is difficult, but it is worth the effort: accessible charts benefit all audience members and are likely to continue driving technological breakthroughs in the field.