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INFORMATION VISUALISATION

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Definitions

01 Definitions

Alignment

Placement of every single graphic, text, heading, etc. to common axes or lines.

Axes

Lines that serve as boundaries for the space in which the data is displayed: 1) X-axis – horizontal; and 2) Y-axis – vertical.

Chart-junk

Graphical embellishments that do not represent data directly and are redundant elements in a chart or infographics. These are only used as decoration to make a graphic more interesting or memorable, but can be distracting (e.g. background) or distort the data (e.g. 3D charts).

Cognitive load of information

The mental effort that the user has to make when processing the information.

Colour

Hue – what we normally think of as colour, consisting of values such as blue, red, yellow, orange, brown, pink and so on.
Saturation – purity of the colour, ranging from pale versions to fully saturated versions.
Value – the range extending from black to white.

Data-ink-ratio

The proportion of ink that is used to present the data without redundancy, compared to the total amount of ink used in the whole visual display. The goal of data-ink ratio is that more ink (as close to 100% as possible) is used on the data, but making sure that no relevant information is excluded, which might be relevant for effective communication.

Data visualisation

Graphical or pictorial representation of data or information in a clear and effective manner. Its purpose is to assist in the understanding of data. Also referred to as 'information visualisation' or 'scientific visualisation' (the only difference being the audience). Examples of data visualisation can include charts, maps, infographics. It can be static or interactive.

02

Context

2.1 The need for visualisation

In an age of information-plenty, effective design and communication of information is an essential requirement. While progress and technological advances increase our access to knowledge, benefiting society in many different ways, information flow has increased exponentially (Dur, 2014). In the face of this challenge, information design is an essential tool. Infographics and data visualisation, in particular, have the power to take large chunks of information, present it in a visual, concise and accessible way; thereby reducing information load.

Infographics' popularity as a visual approach to communicate complex and dense messages has grown significantly in the last seven years (as evidenced in Google trends). This is due to the ability of infographics to encapsulate several details in one visual, while still being clear and precise (Smiciklas, 2012; Lamb, et al., 2014; Dunlapa and Lowenthalb, 2016).

However, despite this increased interest in the benefits of visual information, research studies on the effectiveness of information visualisation are scarce. Beyond a few academic papers, literature on infographic design and information visualisation is largely unscientific, and limited to a few books providing recommendations targeted at business or journalism. Moreover, these recommendations are essentially practice-based, i.e. they derive from tacit knowledge acquired through practical experience. When scientific studies are unavailable or do not give clear answers, design practice can aid our understanding of how design principles can be applied to produce effective design solutions (Lupton, 2004; Hartley et al, 2006; Lonsdale, 2017, 2014a, 2014b, 2016; Beier, 2012; Dyson, 2013; Beier and Dyson, 2014). However, we require empirical evidence to validate those design solutions, to ensure that they fulfil their goal of clear and accessible communication with the target audience.

The few research studies that are available are limited in scope. They test a limited number of visualisations, and/or the researchers often design the visualisations themselves, which compromises the reliability of the findings. They also test a limited number of participants, some of who are not always representative of the target user (Borkin et al., 2013).

The area with more research focusing on data visualisation is Medicine. Medical and health science journals display a variety of graphical representations of data, while infographics are used in public heath to inform about everything from outbreaks of malaria to global health worker shortage (Brigham, 2016).

In conclusion, there is clearly a great need for more studies on the effectiveness of infographics and data visualisation to communicate complex and/or large amounts of information (Dur, 2014).

2.2 The problem

More often than not, the presentation of information through infographics and data visualisation fails to communicate information clearly and efficiently. Most visualisations are difficult to interpret, are filled with irrelevant details, and sometimes are even misleading, prone to error and trigger bad decision-making (Few, 2004). As highlighted by Few (2005), "the damage done by bad graphics has reached epidemic proportions, but so far only a few voices are being raised in warning. Bad graphics act as a virus that stealthily destroys information with little notice"'.

Poorly designed visuals can create more confusion than clarity (Brigham, 2016). Typefaces, colours, clutter, disorganised information, random use of visual elements for decoration rather than function, lack of narrative; all can severely compromise the goal of a visual or infographic to communicate clearly and effectively. The fact that software and information technology have become more available and easier to use, does not help either. It is crucial for those visualising information to realise that visualisation and design require time, commitment and expertise (Few, 2004)

There is also an inaccurate perception that visualisation and infographics mainly entail aesthetics rather than function. Infographics does not mean data decoration (Few, 2004; Siricharoen and Siricharoen, 2015; Lievemaa, 2017). Naturally, appeal is intrinsic to well-visualised and organised information, and infographics do not need to look boring and simplistic to be functional, or extremely sophisticated to look beautiful (Mol, 2011). Both function and aesthetic form should co-exist.

The current situation, however, is that data analysts often create effective visualisations that fail to attract and engage the user, while designers often create gorgeous visualisations that fail to communicate effectively (Dur, 2012). More worryingly, there are cases where data analysts attempt to visualise data with little or no understanding of visual perception and information design principles. Another worrying trend is when designers attempt to interpret data on their own without the necessary skills to do so, resulting in inaccurate communication of data. There are also instances when people deliberately choose to create "pretty" visualisations, which do nothing but hide information, while appearing to do the opposite (Lankow, 2012; Gelman and Unwin, 2013).

Unfortunately, purveyors of information often spend long hours ensuring the highest standards of research and analysis, only to fall short in efforts to ensure the resulting data is presented in an engaging and effective fashion (Murray et al., 2017). Meanwhile, designers are used to working on the basis of intuition and experience, rather than explicit knowledge (Quispel and Maes, 2014). For effective visualisations to work, sound analysis and design knowledge must be combined.

Figure 1 is an example where theory, research-based principles and Gestalt principles were gathered by health experts and followed, only to result in a very poorly designed infographic. The infographic actually goes against some of the principles listed in its content. For example: it lists 'restrict colour', but colour is used excessively and in combinations that hinder legibility; it lists 'align elements', but most elements are misaligned including the sentence 'align elements'. On the other hand, we have Figure 2, an example of a beautiful infographic, with a harmonious colour palette and elegant graphic elements, but where the information is very difficult to interpret.

Figure 1 | How to make an engaging infographic for Healthcare

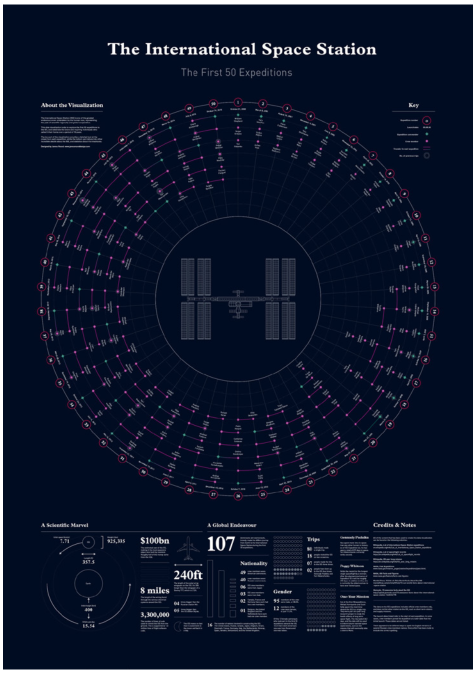
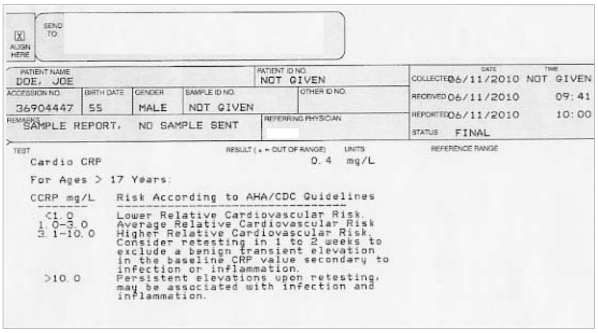


Figure 2 | The international space station

Figure 3b (bottom) is an example of an infographic developed through collaboration between stakeholders (in this case health professionals) and designers, with the users in mind, resulting in a clear and accessible design that also encapsulates and communicates the most relevant information to the user (Figure 3a, top, is the original document before redesign). This infographic is a redesign for a heart disease test (CRP), where originally no effort was made to explain the link between the test and actual heart disease. In the redesigned version, not just is the link explained (point 1 on the infographics), as context is given (point 2), risk of heart disease is personalised (point 3), and next steps to reduce risk are included (point 4). The only thing that is left to do is to test it with the target users (and adjust final design based on findings and feedback received) in order to validate it before implementation.


X ALIGN HERE
SEND TO

PATIENT NAME: DOE, JOE
PATIENT ID NO.: NOT GIVEN
ACCESSION NO.: 36904447
BIRTH DATE: 55
GENDER: MALE
SAMPLE ID NO.: NOT GIVEN
OTHER ID NO.:
REMARKS: SAMPLE REPORT. NO SAMPLE SENT
REFERRING PHYSICIAN:

	DATE	TIME
COLLECTED	06/11/2010	NOT GIVEN
RECEIVED	06/11/2010	09:41
REPORTED	06/11/2010	10:00
STATUS	FINAL	

TEST	RESULT (* = OUT OF RANGE)	UNITS	REFERENCE RANGE
Cardio CRP	0.4	mg/L	

For Ages > 17 Years:

CCRP mg/L	Risk According to AHA/CDC Guidelines
<1.0	Lower Relative Cardiovascular Risk.
1.0-3.0	Average Relative Cardiovascular Risk
3.1-10.0	Higher Relative Cardiovascular Risk. Consider retesting in 1 to 2 weeks to exclude a benign transient elevation in the baseline CRP value secondary to infection or inflammation.
>10.0	Persistent elevations upon retesting, may be associated with infection and inflammation.

Figure 3a | Original – The heart disease test

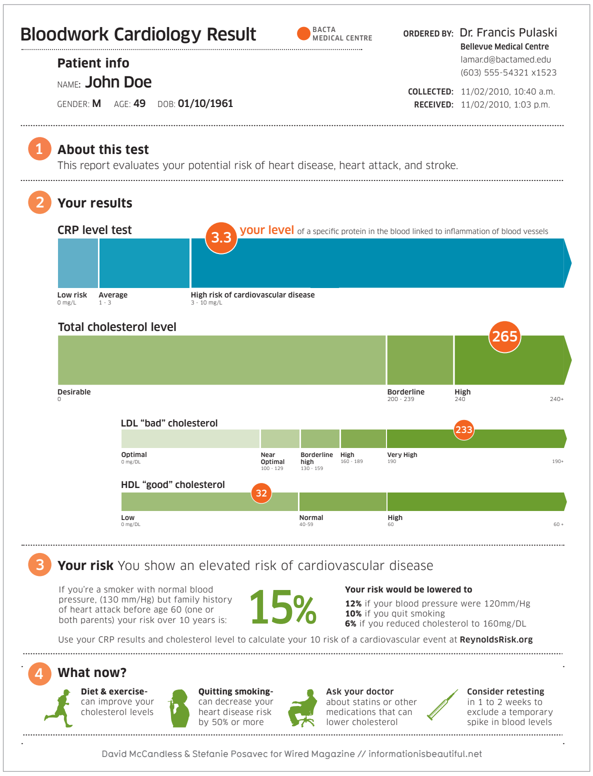


Figure 3b | Redesign – The heart disease test

2.3 Benefits of visualisation

Infographics and data visualisation are powerful tools to communicate information. As highlighted by Brigham (2016), the visualisation of information allows us to tell a story that otherwise would be buried in spreadsheets and large amounts of text. The benefits of information visualisation are many, with high impact on the user.

From a technical design perspective, visualisation improves information communication in a number of ways. First, visualisation communicates key aspects of complex information, data or concepts. It does so by visually representing huge amounts of data and lengthy reports in a concise and clear manner (Ware, 1999; Thomas & Cook, 2004; Mol, 2011; Brigham, 2016; Bursi-Amba et al., 2016).

Moreover, visualisation has the ability to present the shape of information and data totality within a single eye glance. This is extremely useful in situations of time-pressure and decision-making (Few, 2004a; Otten et al., 2015).

Visualisation presents complex data in a visual format that is compelling and engages the user's attention. For example, research has found that colour visuals can increase the willingness to read by 80% (Green, 1989; Otten et al., 2015; Bursi-Amba et al., 2016).

Storytelling is another benefit of visual information. Visualisation constructs a narrative supported by data, with the objective of providing insight and greater understanding of the information, even bringing to the surface information that was not anticipated. Visualisation can help the user identify cause and effect relationships, classify relationships among data, identify patterns, changes or trends in data, observe developing risk threats or risk uncertainty. Ideally, the narrative conveyed by visualisation will also include options for future action (Cleveland, 1994; Mol, 2011; Dur, 2012; Sancho, et al., 2014; Siricharoen and Siricharoen, 2015; Brigham, 2016).

Information visualisation can further assist with cognitive processing by providing context or metaphor. This is especially the case in those situations where users are unfamiliar with the data and/or concept, and do not have pre-existing knowledge to help make sense of new information (Dunlapa and Lowenthalb, 2016).

Most importantly, visuals increase comprehension and recall (Medina, 2008; Bursi-Amba et al., 2016). Research has shown that people are capable of recalling hundreds to thousands of pictures, even when having seen the pictures for only a few seconds (Zull, 2002). Furthermore, our ability to process and recall information is superior if learnt with visual inputs (Murray et al., 2017).

2.4 Infographics: the solution

When visualising information, the specific requirements of task, context and target audience are fundamental. For example, a busy manager required to make decisions under time pressure will need a different type of visualisation than a member of the public looking at information to plan a train journey (Brigham, 2016; Bursi-Amba et al., 2016). The amount of information and details, as well as the way information is introduced, must be designed according to the end users (Lievemaa, 2017).

In most instances, text is still required as an integral element of visualisation. Since human beings remember approximately 80% of what they see and do, and 30% of what they read, it seems logical to combine both text and visual elements, to maximise comprehension and recall (Lester, 2006). Moreover, while a few users might be comfortable with nothing more than graphics, other users are more comfortable with text and visual elements. Consequently, infographics is the best design approach precisely because they combine both visual and textual elements, making infographics more accessible across a wider range of uses.

For infographics to effectively enhance communication, they should be clear, accurate, relevant, actionable and visually pleasing. This can only be achieved when principles of perception and legibility are taken into account. Such an approach creates a balance and harmony between the various elements of an infographic (text, colour, graphics, layout). To increase decision maker receptivity to information, for example, infographics have to communicate most effectively the main points of interest and key judgements. In this way, an effective infographic will avoid clutter and 'chart-junk', whilst maintaining clarity and visual appeal. Complicated designs just make the information more complex than in its raw form (Dur, 2012).

As infographics encompass various visual elements on the same page, an accurate organisation of the content is imperative. Toward this end, the designer needs to: first, analyse the information thoroughly and understand it; classify it according to an order of importance; and finally associate it according to its meaning. This will serve to guide the user about where to focus, and in which order to read the flow of information. This process is even more important in situations of time pressure (Dur, 2012).

The optimal conditions for effective infographic design are a close cooperation amongst information/data analysts, designers, and subject matter experts from academia. The reason an academic background is important relates to the fact that academics deal with data on a regular basis, are rigorous and pay close attention to detail, and will therefore bring their own insight as users and producers of data. Such collaboration will produce information that is simplified but accurate, functional but compelling, and the content will not be sacrificed. Access to the target audience, to real materials, and the application of user-centred research methods, will also ensure that the infographics are adapted to the context and target audience needs.

2.5 The need for research-based guidelines

In conclusion, there is a need for guidelines that bring research and practice together and that take visual perception and cognition into account. Such guidelines are both necessary or useful when visualising information. Moreover, guidelines are open to interpretation and can be adjusted to the specific information context being dealt with. As argued by Berinato (2016) guidelines are for responding to context, not for setting it.

In this report, guidelines that emerged from a thorough and in-depth investigation are presented in a clear and efficient way, by dividing them into:

- **Guidelines from research** – This includes academic papers involving experimental testing, academic papers with a more theoretical focus, academic papers reviewing and discussing existing research, etc. When not presenting an experimental study, to be considered research, such academic papers also need to have a good set of academic references to support their analysis and discussion
- **Additional practice-based guidelines** – Several books, online articles, blogs, etc. were reviewed that give recommendations based on experience from practice. If any further recommendations, in addition to the ones given by research, are given, then these will be listed here, as a way to complement research.
- **Findings from research** – Relevant findings generated by the experimental studies reviewed are given here to reinforce and validate the guidelines, as well as to make them more user-centred.
- **Rationale** – At the end of each design feature, a rationale is given to explain further the meaning of certain guidelines and the need to follow them.

There are several terms used to define the visualisation of information and data. From infographics to information visualisation, from data visualisation to knowledge visualisation, from charts to graphs, etc. The review and set of guidelines here presented focus only on:

- **Underlying descriptive theories** – Include cognition (thinking) and visual perception (seeing) to explain how we see and process information before actually giving recommendations on how to visualise information.
- **Infographics** – Is a branch of the field of Information Design and in this review represents the visualisation of information combining graphics, text, colour and layout.
- **Data visualisation** – Is, in turn, a branch of infographics and in this review is limited to charts used to represent data in a visualised and objective form. This review is limited to the charts that are most established in practice and are the most researched, therefore proving a solid list of guidelines: bar charts (including stacked and divided bar charts), line charts, pie charts (including donut charts), and unit charts. A single section also reviews 'other charts' to include a few

other charts that, although to a much lesser extent, have been subject to some research. Tables are also addressed because, although not a visualised form *per se*, they are still important when communicating data, and they form part of many infographics. Newer and unusual chart types were not included at this stage of the research.

Important note: Guidelines are listed in the form of bullet points and small chunks of text. For this reason, and to avoid disrupting the reading flow with several in text citations within short chunks of text, all the references are given at the end of each section.

03

Underlying theories

3.1 Cognition (thinking)

3.1.1 Memory

There are three types of memory that process visual information in our brain: 1) iconic memory; 2) working memory; and 3) long-term memory.

Information usually remains in the iconic memory for less than a second before being forwarded to the working memory. Thus, at this first stage of memory, information is processed extremely quickly, and is nothing more than an automatic and unconscious perceptual processing – pre-attentive visual processing. Here, several features are detected such as: colour (hue and intensity); form (length, width, orientation, shape, size); and location of elements in a 2D space, making these the elements that stand out when we first look at information. Consequently, if something important needs to stand out in an infographic or chart, the information should be encoded using a pre-attentive attribute that has good contrast with the surrounding information. The same is true if a particular set of elements needs to be seen as a group, where a pre-attentive attribute can be assigned to such elements.

Information is then moved to the working memory, which is temporary and has limited storage capacity. At this second stage of memory, what our brains recognise as useful will be combined into meaningful chunks of information. According to the chunking principle, the cognitive load can be reduced if visualisations are presented in chunks. However, only three or four chunks of information can be stored at one time in our working memory. Nonetheless, these can contain a good amount of information. Therefore, for new information to be included into our working memory, something that is already there will be either forgotten or forwarded into our long-term memory. For example, in a learning context, when this working memory capacity is exceeded, learning is affected and cognitive processing becomes ineffective. In terms of data visualisation, if a legend for a chart contains a colour or symbol for 10 different sets of data, users will be forced to go back and forth between the chart and the legend because their working memory cannot take in more than three or four chunks of information. In terms of size, as long as a large amount of information is chunked coherently and consistently, the user will be able to hold more information in their working memory. An example of that is the fact that charts are able to communicate a large amount of information because it is perceived all at once and as a meaningful pattern, although it actually consists of hundreds and thousands of values. However, tables are only used to look information up; it would be impossible to take a series of numbers and chunk them together meaningfully to store in our working memory.

When we finally decide to store information for later use, we send chunks of information into our long-term memory. Long-term memory is extremely important to visual perception because it is where our ability to recognise visuals is held. In conclusion, in terms of visualising information, iconic memory and working memory is where we want to make sure that our information is perceived and processed adequately.

3.1.2 Cognitive elements

Both functional and cognitive elements need to be considered when developing effective visualisations that integrate different components of intelligence information. The goal when using visualised information is to reduce the cognitive load of information, i.e. the mental effort that the user has to make when processing the information. This is to allow users to easily interpret and assess large amounts of information and data with ease, and as quickly as possible. Infographics are particularly relevant in this context because the use of graphics together with text reduces the cognitive load. Moreover, an effective infographic allows users to spend more time focusing on the content, instead of trying to decode the way information is displayed.

The following guidelines should be taken into consideration in infographic design in terms of visual perception and reduction of cognitive load:

- **Information chunking** – Elements should be grouped together in a meaningful way. Users will treat meaningful units as one chunk of information (as opposed to separate bits of information), which will help them process and remember the information better.
- **Reminders** – Visual cues should be used to remind users about the information they are seeing when they need to make sense of more than one piece of information at the same time. For example, when users have to remember the type of data they are seeing while also finding patterns, labels and other supporting text elements can be used.
- **Familiar elements** – The way information is visualised should build on the knowledge that the user might have regarding symbols, colours, etc. If a symbol is likely to be unfamiliar, then a label can be added.
- **A limit of choices** – The number of choices given to the user should be limited. Although it might seem thoughtful to give various choices, the user will simply struggle to make a decision when faced with too many options.
- **A limit of visuals** – Although visualisation makes information more accessible and quicker to interpret, the number of graphic elements in each single section should be limited to avoid the user having to make an effort to determine which elements are relevant. Any unnecessary elements that are not important for the processing and understanding of the information should be removed (e.g. logos, decorative elements, junk such as unnecessary grid lines).
- **Order** – Information should be ordered so that the most relevant information comes first, as this will affect how users perceive the subsequent information.
- **Hierarchy** – A hierarchy should be presented in the order consumers are likely to use it (or that we would like them to use it). Information will be more readily processed if it is presented hierarchically in the order consumers are likely to use it. For example, what are the resources available, how should they be allocated, what are the benefits of allocating the resources, what are the risks of allocating the resources and how can they be avoided, and what should be done if the resources are not allocated properly?
- **Consistency** – Constant and common information across various infographics should be put in the same relative position. If users know where constant information will be found, locating the desired information will be a much easier and quicker process.

- **Emphasis** – Emphasis can be used to facilitate finding information, such as using different colours or sizes of typeface. This is particularly important for iconic memory, i.e. to grab the user's attention at a glance.

In summary, a well-designed infographic: 1) should engage and promote high-level cognitive functioning, i.e. to gain insight, reasoning, and understanding; 2) should attract the users to relevant information and minimise the possibility of users ignoring important information; 3) should promote chunking that provides strong retrieval cues that will then be passed onto long-term memory and support reasoning, thinking, and decision making.

Chunking should be achieved by using Gestalt principles of visual perception, as they promote grouping, as explained in the next section. Knowing how we perceive and interpret visual stimuli is equally important as understanding how we process and memorise information.

Guidelines: Bettman et al., 1986; Sweller, 1994; Few, 2004a and 2012; Let et al., 2013; Patterson et al., 2014; Lyra et al., 2016; Tetlan and Marschalek, 2016; Coyle et al., 2017; Majooni et al., 2017.

3.2 Gestalt Principles of visual perception (seeing)

Gestalt research was conducted to find out how we perceive pattern, form and organisation to make sense of what we see. In general, Gestalt principles show that we group graphical elements in particular ways to interpret them and build relationships between the various elements. These principles are essential to inform infographic design and enhance comprehension of information.

3.2.1 Principle of simplicity

We better perceive and interpret abstract and complex information when it is in the simplest form possible. For example, in Figure 4, the chart on the left requires less effort, and therefore is easier to interpret than the chart on the right, because our brains favour things that are clear, simple and ordered.

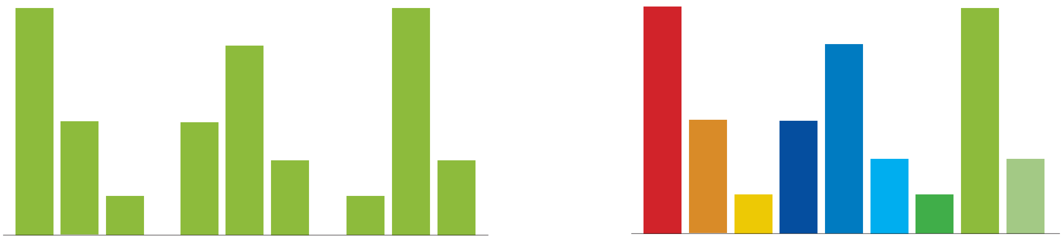


Figure 4 | Principle of simplicity

3.2.2 Principle of proximity

We perceive elements that are close together as belonging to a group. The manipulation of white space is a powerful tool when it comes to organising information and directing the viewers to particular information. For example, in bar charts, bars that are clustered will be seen as a group (Fig. 5).

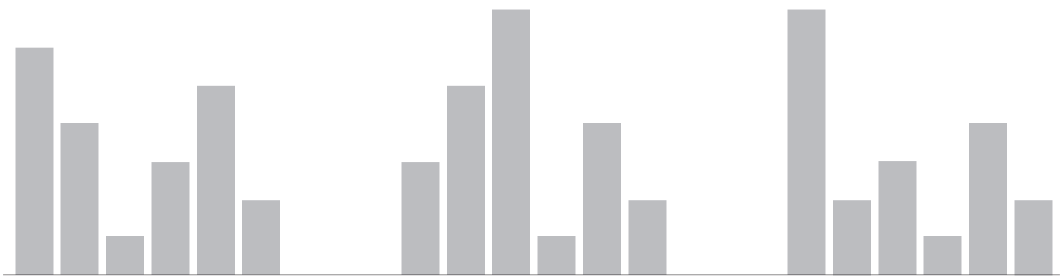


Figure 5 | Principle of proximity

3.2.3 Principle of similarity

We perceive elements that have the same typeface or are similar in size, shape, colour (both hue and intensity) or orientation, as being part of the same group. This principle works very effectively as long as the differences are only a few and clearly distinct from one another. For example, in a bar chart, if the bars are the same colour it will indicate to user that the bar values should be compared (Fig. 6, left). If different colours are used, it will impose extra cognitive load and may indicate that each bar belongs to a unique attribute, and therefore do not need to be compared (Fig. 6, right).

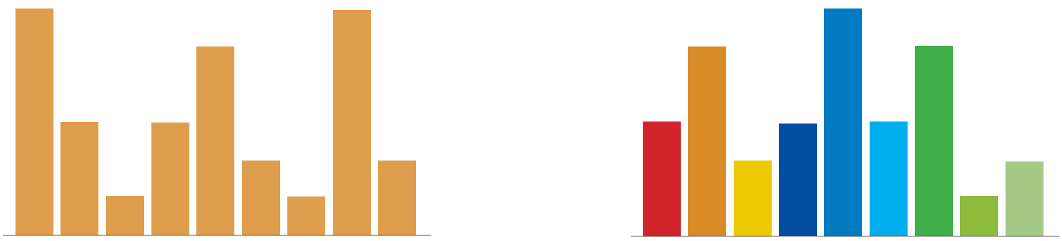


Figure 6 | Principle of similarity

3.2.4 Principle of enclosure

We perceive elements as belonging to the same group when they are enclosed in a way that it seems to create a boundary around them (e.g. border, common field of colour or shade) (Fig. 7). Enclosure is the strongest approach of visual perception to group elements.

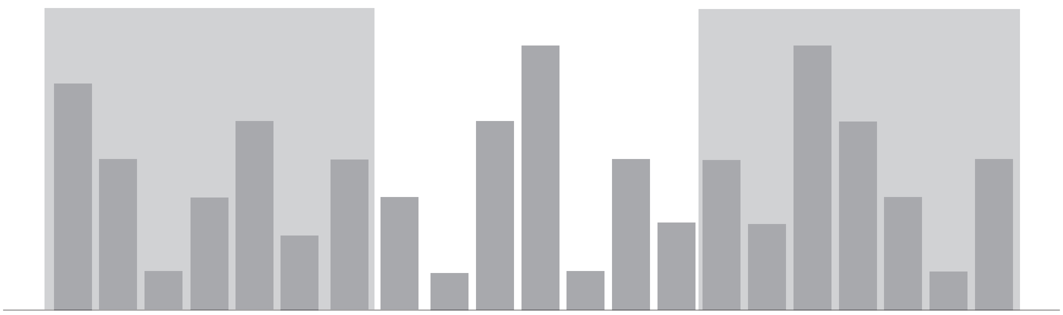


Figure 7 | Principle of enclosure

3.2.5 Principle of closure

We perceive open structures as closed, complete and regular if there is a way that allows us to reasonably interpret them as so. For example, in a chart we do not need complete borders to define a space. This is particularly relevant for the x- and y-axes, where it is actually preferable to define the area of the chart by using one single thin line (y-axis line on the left and x-axis line at the bottom), rather than with heavy lines around the entire area that will only create a boxed chart (Fig. 8)

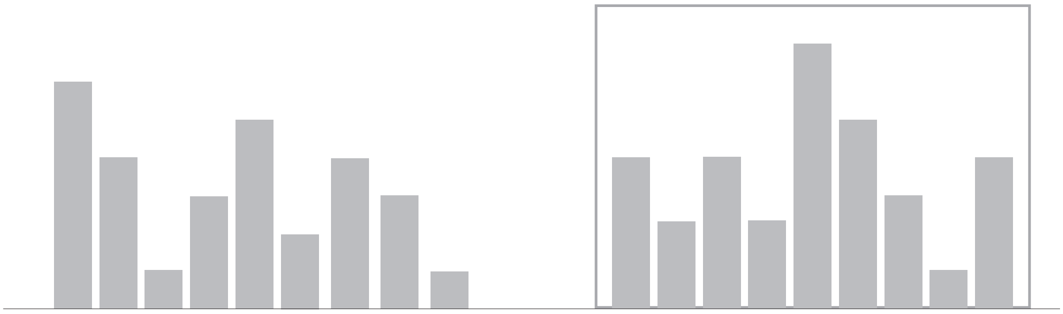


Figure 8 | Principle of closure

3.2.6 Principle of continuity

We perceive elements as part of a whole if they are aligned or seem to form a continuation of one another. For example, in a horizontal chart, aligning all the bars to the left, even without a line to indicate the y-axis, makes it obvious that they share the same baseline and are part of the same chart (Fig. 9).

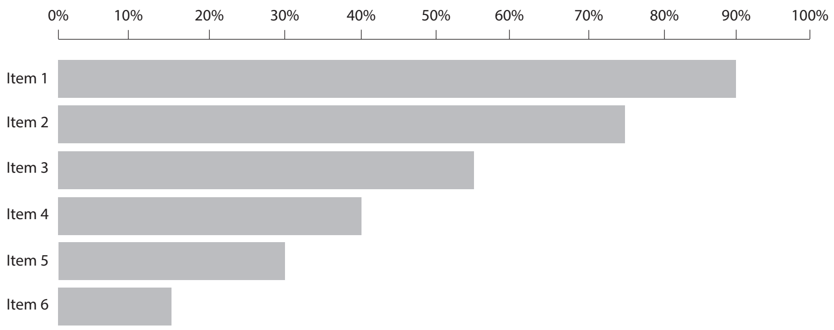


Figure 9 | Principle of continuity

3.2.7 Principle of connection

We perceive elements that are connected (e.g. by a line or point liner) as belonging to the same group. Connection is a stronger tactic than proximity or similarity (colour, size and shape). For example, using a line to connect points in a chart is an effective approach. It is very difficult for our eyes to connect points without lines (Fig. 10).

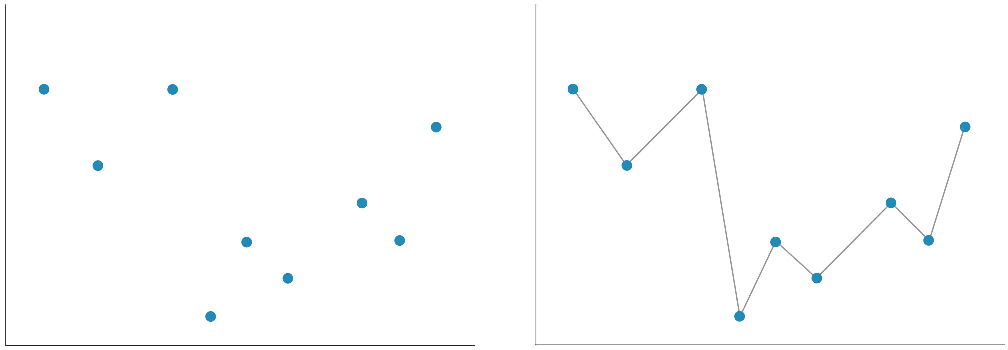


Figure 10 | Principle of connection

3.2.8 Principle of figure-ground

We perceive elements as either figure (the element in focus) or ground (the background on which the element rests). When dealing with information, and particularly in situations of time pressure where scanning might be used, it is crucial to be able to determine at a glance what is important (figure) and what is secondary (ground). Therefore, good contrast between the foreground and background should be ensured so that charts are more legible. In Figure 11, the chart on the right has additional cognitive load due to the lower contrast between the bars and background. This means that users will take longer to determine which elements are figures, i.e. that communicate data and need immediate attention; and which elements are ground, i.e. not as important and can be left to be interpreted later.

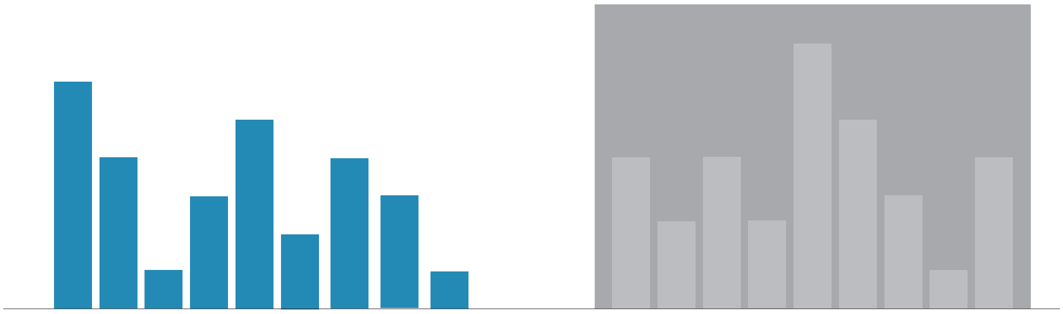


Figure 11 | Principle of figure-ground

3.2.9 Principle of focal point

Our attention will be grabbed by a point of interest, emphasis or difference. Therefore, distinct elements will be perceived as creating a focal point, and distinct features such as colour, size, and shape, can be used to highlight and create focal points. For example, in a bar chart, if only one bar is presented with a different shade or colour, the user's attention will be automatically directed to that bar first (Figure 12). This is a good technique to use when an important data value needs to be highlighted among the rest (e.g. a significant finding).

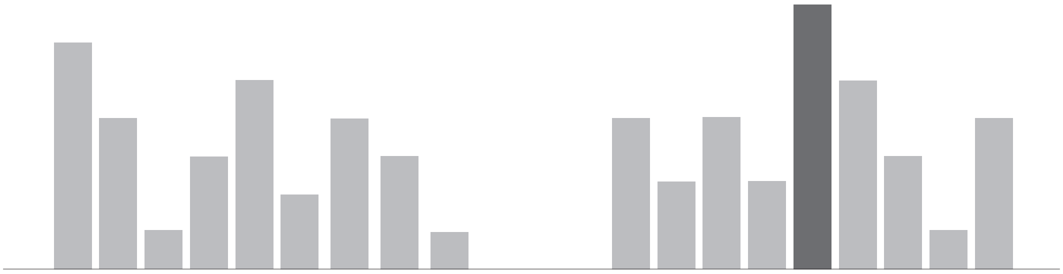


Figure 12 | Principle of focal point

3.2.10 Principle common fate

Lines that move in the same direction are perceived as belonging to the same group, i.e. they have a common fate. For example, in a line chart, lines trending in the same direction will be easily interpreted as belonging to the same or common data set (Fig. 13). Therefore, lines moving in opposite directions should only be used if the intention is to show exactly that, i.e. opposite trend.

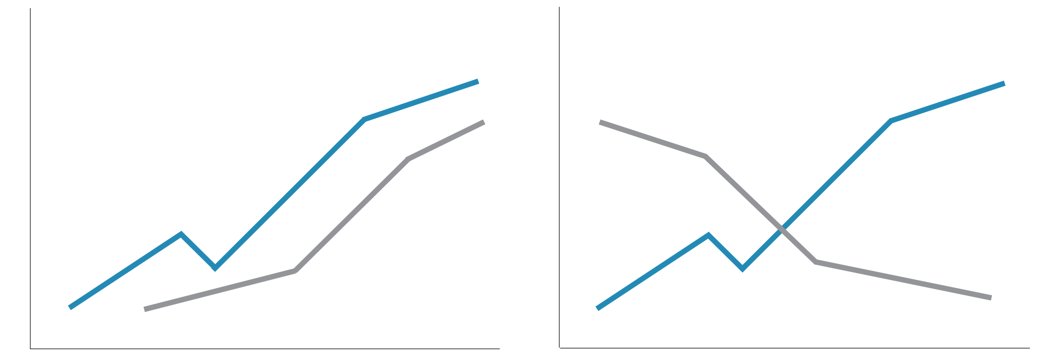


Figure 13 | Principle of common fate

Guidelines: Moore and Fitz, 1993; Lipton, 2007; Mol, 2011; Few, 2012; Ali and Peebles, 2013; Brower, 2014; Knaflic, 2005; Korpela, 2016b.

04

Infographics

04

Infographics

Infographics is the contraction of 'information graphics' and are used to communicate specific information to specific users. They are visual representations of information, data and knowledge and are designed with the goal of communicating intense and complex information in a clearer and more accessible manner than text, as well as creating attention and interest. The use of words, numbers, icons, colours, and graphics lend infographics the role of telling the story behind the information and data in a more focused, organised, intuitive and engaging way (Mol, 2011; Krum, 2013; Lyra et al., 2016).

All in all, effective infographics capture complex ideas, behaviours, or knowledge in an easily digestible visual format; deliver maximum information in a minimum amount of time and space; and combine visuals and words to increase consumer comprehension and retention (Niebaum et al., 2015). Moreover, an effective infographic is a self-contained and stand-alone document that does not require users to resort to external sources (Zhang, 2017).

4.1 General

Guidelines

1. Infographics should have a clear focus and purpose.
2. Infographics should communicate complex information quickly and clearly.
3. Infographics should communicate accurate, complete, and relevant content.
4. Infographics should be efficient, simple (but not simplistic) and concise (without leaving important information out).
5. Infographics should be included into one, maximum two, pages.
6. The reader should not be misled by the way information is visualised.
7. Design principles should be applied to infographics for successful communication of information.
8. Simple and plain infographics should be used when quick comprehension and decision-making are at stake.
9. For attention seeking, infographics can communicate simple messages with the help of visual elements, such as the use of bright colours and relevant images.
10. For wider appeal, embellished infographics can be used.
11. Infographics, however, should not be purely ornamental, but a way to enhance the comprehension of information.
12. The target audience should always be taken into account.
13. Considerable time should be spent on the design and evaluation of infographics to ensure that the message is communicated effectively and accurately.

Additional practice-based guidelines

14. The key message should be communicated in less than five seconds, and should be the first information users understand and remember after reading the infographic.
15. Visualisation should minimise text density as much as possible, otherwise infographics with too much text and numbers might look complicated and intimidating and might be skipped altogether.
16. When there is a lot of information to share, the infographic should be broken into several parts.
17. For clear and unbiased infographics (as is the case for academic and scientific infographics), the order of priority should be as follows: 1) Comprehension – the infographic should effectively provide knowledge that enables a clear understanding of the information; 2) Retention – the infographic should impart memorable knowledge." 3) Appeal – the infographic should engage a voluntary audience.
18. The user should be guided on how to interact with the information displayed in the infographic by making salient what is important, by eliminating distractions, and by creating a visual hierarchy of information through the use of text to label and explain.

19. All elements present in an infographic should convey the message, not describe the structure.
20. Ambiguity should be mitigated by ensuring that every element in the infographic has a specific purpose, which will not be misunderstood by the user.
21. Any conclusion that needs to be made can be stated in words, because not all users looking at the same infographic will draw the same conclusion.

Research Findings

- Infographics were found to facilitate a quick grasp of information, i.e. obtain useful information in little time and with little effort in situations of time pressure.
- Infographics were considered highly informative, practical, useful and valuable in decision-making and business operations. For example, historical data to help with decision-making, reports to help with strategy, and tips for better performance.
- The combination of text and graphics in a meaningful and calculated way (as is the case of infographics) was found to be very effective in a variety of learning, instructional, and persuasive tasks.
- Infographics within news stories were found to achieve longer viewing times than other images.
- Users were found to be more attracted by good visuals and small chunks of information, than by the one- or two-page in-depth stories.
- Infographics were considered by users to play a paramount role in technical documentation.
- Infographics were found to be intrinsically memorable, with consistency across various groups of people.
- The same information presented in different formats was found to result in different decisions.

Rationale

Presenting information with infographics can enhance understanding and learning, and influence decision-making, i.e. how quickly users can interpret information, but also how the information is interpreted and acted upon. It is therefore imperative to ensure that infographics are focused, accurate, accessible and clear.

Infographics also tell a story, even if just a simple data comparison. To this end, the most important elements of infographics are graphics, typography, colour and images. Consequently, choosing the wrong graphics, colour or typography may result in misunderstanding of the content/story. Moreover, the information needs to be filtered and synthesised, the relationship between the information and elements needs to be established, and patterns need to be represented in a simple way. Good design choices, simple communication of information, and the reduction of elements that distract from the message, require mastery. If these are not achieved, the result will be loss of information and production of incomplete and incoherent infographics.

Although appeal is important for attention grabbing, the main goal of an infographic should always be to communicate the information in order to facilitate comprehension and retention. The visual appeal of an infographic alone will not make up for poor design and content.

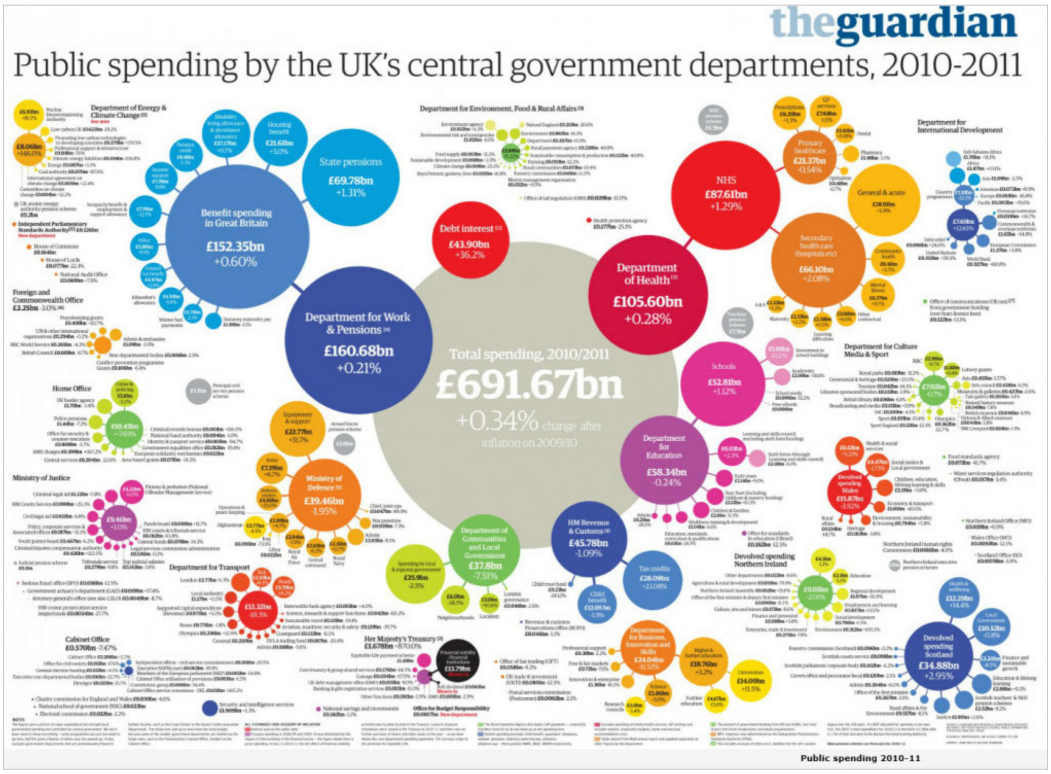
The way most users interact with infographics is by skimming, hence the need for the key message to be clear and straightforward. Moreover, keeping an infographic to one page ensures that all the elements contribute to the communication of the message at the same time, and that the infographic is easier to scan and then skim.

Therefore, taking into account the target audience and conducting frequent evaluations with users, are extremely important for the development of an infographic and its iterative and redesign process.

Guidelines: Mol, 2011; Lankow et al., 2012; Borkin et al., 2013; Krum, 2013; Knaflic, 2015; Mollerup, 2015; Stones and Gent, 2015; Berinato, 2016; Dikson, 2016; Dunlapa and Lowenthalb, 2016; Hassan, 2016; Yildirimi, 2017.

Research findings: Kendler, 2005.; Bettman, 1979; Payne, 1982; Winett et al., 1984; Bettman et al., 1986; Zacks et al., 2001; Holmqvist & Wartenberg, 2005; Mol, 2011; Bursi-Amba et al., 2016; Lyra et al., 2016; Zhang, 2017.

Rationale: White, 1991; Harris, 1996; Tufte, 2006; Mol, 2011; Spiegelhalter, 2011; Graves, 2013; Krum, 2013; Le et al., 2013; Arslan and Toy, 2015; Lazard and Atkinson, 2015; Otten et al., 2015; Bursi-Amba et al., 2016; Dunlapa and Lowenthalb, 2016; Lyra et al., 2016; Conley, 2017; Majooni et al., 2017; Murray et al., 2017.



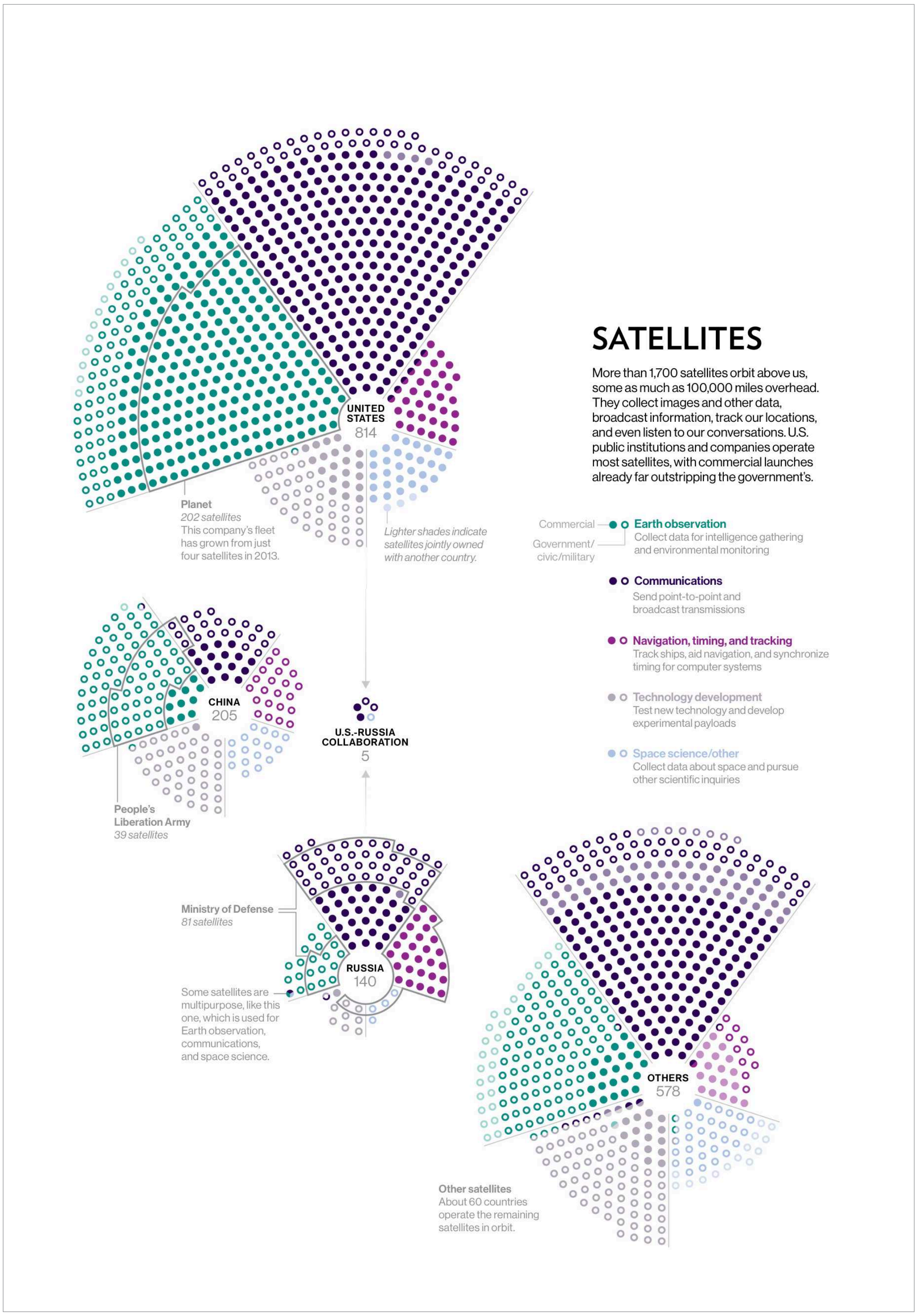


Figure 14. Government spending by department, 2010-11 (first) **| Figure 15.** Under surveillance – Satellites (second)

There is a clear contrast in terms of information overload between the two infographcis. In Figure 14 the amount of information is overwhelming, the page is too cluttered, there are too many text sections and too many colours. To process all this is exhausting and extremely arduous. In contrast, in Figure 15 the cognitive load is much lower. Our eyes can rest in the white space while making sense of the information, information is organised in chunks, and colours are much more subtle.

4.2 Text | Typography

Guidelines

1. Text in infographics should be transparent (i.e. not call attention to itself), easy to read and self-explanatory.
2. Typography should be chosen appropriately for their function, i.e. to convey the infographic message effectively and to fit with the purpose of the text and the infographic.
3. The number of typefaces should be limited to two (maximum three); otherwise they will only serve to distract the reader.
4. Type size, interlinear space and line length should be coordinated and chosen together.
5. Bold should be used over italic to emphasise text. Italic should be reserved for situations when a foreign word is used, or for short titles.
6. Because bold has different weights available (bold, semi- or demi-bold, black or ultra black), sufficient contrast should be used, because a slight difference in weight will be ineffective and will look like a print error.
7. All-capitals should be avoided whenever rapid reading is required.
8. Titles should be one of the most dominant elements in an infographic, and should quickly present the purpose of the content and the focus of message. When using a multiple display infographic (communicating various facts), the title should contain the topic of the infographic. When using a single display infographic, the title should communicate the main message (e.g. what was found).
9. The contrast between the title, headings and narrative text should be clear in terms of size differences and the features of the typeface (e.g. bold for the title and heading if the narrative text is regular).
10. When using white type on black, the amount of text should be small, and a sans serif type should be used in a slightly bigger size to avoid loss of legibility.
11. Text and its background must have good contrast to be legible.
12. Unsuitable backgrounds such as multi-coloured or gradient backgrounds should be avoided for text.
13. Black ink on dark red or purple paper should be avoided.
14. Large amounts of text should be left aligned rather than centralised. Centralised justification should be restricted to very small amounts of text or ttles/headings.
15. Orientating text should be included to help users understand the relevance of the infographic.
16. When infographics are embedded within other pages, other images will compete for attention. Therefore, the key message should be in large text to stand out.

Additional practice-based guidelines

17. Text in infographics should be kept short, simple, and powerful.
18. The typefaces selected should match the theme of the infographic

19. Typefaces with unusual features, typefaces that distract from the text content, and typefaces that have not been tested objectively, should be avoided
20. Bold can be used to emphasise one piece of information over another, and as a technique to thicken the characters when these are to be printed or seen on a dark and/or coloured background.
21. Both lowercase and uppercase letters should be used, where uppercase/capitals are used as initial letter of sentences, short titles and headings, and nouns.
22. Interletter space should not be too wide or too narrow, as this disrupts the normal reading flow.
23. Wide interword space and fully justified text should be avoided as they lead to "rivers" (vertical white spaces that look like rivers running down the page) that disrupt reading, as well as affecting the page texture.
24. Text should be set without rivers and without excessive hyphenation, which can be achieved by avoiding short line lengths and/or aligning text to the left.
25. For print material read at ordinary distances of approximately 300-350mm from the eyes (e.g. a book), arrangements between 9- and 12-point size, with a line length of 60 to 70 characters per line, and additional interlinear space of one to four points, should be used
26. For italic, body text and sans-serif type, an additional interlinear space of at least one point should be given in comparison to serif types.
27. Longer paragraphs should be denoted with a moderate indentation of one to four ems, or separated by one line space. Short paragraphs, however, should not be separated by one line space.
28. Generous margins around the infographic should be used for functional reasons, such as making notes, holding the page without covering any information, punch or clip copies for filing without damaging the text. In digital formats, margins allow the eyes to rest.
29. When normal paragraph headings are set heavier than the body type, they do not need to be in a larger size but just have blank line between them and the text.
30. The first line of the title and heading should be either longer or shorter than the second one, and no word breaks should be used.
31. When sans serif type is used for the main text, then only sans serif type should be used for titles and headings, either in the same weight or bolder.
32. Titles can be left aligned or centred, while headings should be aligned left.
33. A font palette should be created to establish what typefaces work together and what sizes, weights, and typefaces will be used throughout different parts of the infographic.
34. Having a font palette does not mean using several different typefaces. No more than two (maximum three), typeface families should be used. Instead, different weights and colours for different sections can be used, but should be kept consistent.
35. A font palette can be divided to reflect the structure of the infographic and include the following elements: main title, section title, headers, descriptors, body text.
36. If more than one typeface is used, there should be as maximum differentiation between them as possible (e.g. a serif and a sans serif type will have more contrast and will be better distinguished, than two serif typefaces).
37. For emphasis, a contrasting typeface or weight (e.g. bold) should be used, not both.

38. Each level of the hierarchy should be emphasised by one or more cues, such as spatial cues (e.g. indent, interlinear space, placement) or graphic cues (e.g. size, weight, style, colour).
39. Labels and captions should be designed to be clear.

Research Findings

- User focus was found to be greater for larger text summaries than for the graphic content or for small columns of text.
- Standard typefaces that are used in everyday reading situations have been found to be equally legible.
- No significant differences were found in speed of reading and comprehension between serif and sans serif type.
- No particular preference was found for either serif or sans serif type.
- Italic text was found to retard reading.
- Text in lowercase was found to be read quicker than all-capitals, and was also preferred.
- Black print on a white background was found to be much more legible than white print on a black background.
- Moderate text arrangements were found to be read faster than text in relatively long or short lines, smaller type sizes and with little or no interlinear space.
- Very short and very long lines, small type, and little interlinear space were disliked by users.
- Type sizes of 9-, 10-, 11-, and 12-pt with an interlinear space of one to four points were found to be the most legible (for print material read at ordinary distances of approximately 300-350mm from the eyes).
- Relative differences in sizes were found to be the best way to distinguish the hierarchy of headings.
- Centred headings were judged as most important, then left aligned headings, and embedded headings as least important.

Rationale

Infographics are used to communicate large amounts of information, and typography is inevitably one of the most important design tools to help towards that end. However, it is the combination and manipulation of various typographic features as a group that makes the text legible and perceived as easier to read. Each typographic feature should be selected in relation to the others.

Bad organisation of typographic information throughout the layout or infographics, can impair readability and legibility of information. Bad choice of type size, colour, and space between words and lines of text, can not only cause reading difficulties, but also affect the user's reading experience. Even titles, if set in italic, or in small typefaces, or set against a dark background, can be hard to spot and read. However, the title is a very important element of an infographic since it reveals the key message and is where most users start processing the information to quickly decide whether they will continue reading the infographic or not.

A few other relevant features that should be considered and understood in the context of infographic design, in order to facilitate efficient access of information, include the fact that: a) lowercase text takes less space on the page than all-capitals (about 35 per cent less, for text of the same body size), resulting in economy of space, which is crucial in infographics to reduce the amount of visual information on the page; b) very wide space between words creates vertical white spaces, called "rivers " (very apparent in newspapers due to short line length and fully justified text), which not only disrupt reading but also destroy the normal page texture; c) very narrow space between letters and words makes them join too close together leading to arduous reading, especially when the information has to be accessed in a quick glance; d) when text is set with very long line lengths it makes it more difficult for the eyes to make an accurate return sweep (i.e. a long movement to the left from the end of a given line to the beginning of the next line), which increases the number of return sweeps and eye fixations before the user finally finds the right text line to read next; e) too much interlinear (when text lines are too separated) will increase the time taken to get to the next line of text, i.e. it is more difficult for the eyes to make an accurate return sweep to the beginning of each new line of text.

Lastly, choosing typefaces and using them randomly in infographic design is bad practice. Contrastingly, creating a font palette can be fundamental to ensure a consistent design and improve the overall look of the infographic.

Guidelines: Simon, 1945; Tinker, 1963; Zachrisson, 1965; Poulton, 1967; Tschichold, 1967; Spencer, 1969; Becker et al, 1970; Hartley and Burnhill, 1977; Reynolds, 1978; Rehe; 1979; McLean, 1980; Glynn et al, 1985; Black, 1990; Bringhurst, 1992; Luna, 1992; Gilreath, 1993; Hartley, 1994 and 2004; Simmonds and Reynolds, 1994; Schriver; 1997; Wijnholds, 1997; Lipton, 2007; O'Grady and O'Grady, 2008; Lupton, 2010; Lankow, et al., 2012; Cousins, 2013; Davis and Quinn 2013; Coates and Ellison, 2014; Davidson 2014; Lamb and Johnson 2014; Lonsdale, 2014b; Strizver, 2014; Arslan and Toy, 2015; Stones and Gent, 2015; Dikson, 2016; Dunlapa and Lowenthalb, 2016; Mighty, 2017; Murray et al., 2017; Yildirimi, 2017; Carter et al, 2018.

Research findings: Pyke, 1926; Tinker and Paterson, 1928, 1931 and 1942; Paterson and Tinker, 1932 and 1940; Luckiesh and Moss, 1938; Simon, 1945; Tinker, 1955; Tinker, 1963; Poulton, 1965 and 1967; Moriarty and Scheiner, 1984; Williams and Spyridakis, 1992; Schriver, 1997; Lonsdale et al., 2006; Lonsdale 2007, 2014a, 2014b, 2016; Stones and Gent, 2015.

Rationale: Simon, 1945; Tinker 1963; Tschichold, 1967; Hartley and Burnhill, 1977; Rehe, 1979; Black, 1990; Bringhurst, 1992; Luna, 1992; Simmonds and Reynolds, 1994; Schriver, 1997; Wijnholds, 1997; Lonsdale et al., 2006; Lonsdale 2007, 2014a, 2014b, 2016; Arslan and Toy, 2015; Stones and Gent, 2015; Mighty, 2017; Carter et al., 2018.

continues

Total immigrants removed or returned, by presidential term
(1901-2016)
Removal Commonly understood to mean when US immigration authorities deport or exclude someone from America
Returns A specific immigration enforcement action, it refers to aliens apprehended at their own border while trying to enter the US illegally
Post-second world war years
TOTAL (includes removals and returns)
Beginning of Barack Obama's administration
People apprehended
Immigrants apprehended by border patrol sectors
(US Government fiscal years, 2009-2016)
UNITED STATES OF AMERICA
Deportations from the US
President-elect Donald Trump's tough talk on immigration was a central part of his campaign messsage. Last November he announced he wanted to deport up to three million undocumented immigrants. The data shows the number of foreigners removed from the United States has been increasing for several decades. Trump's hard-line stance might not be the fundamental shift in national policy as it first appears
Number of illegal aliens apprehended in the US since 1969
(in thousands)
The southern border patrol sectors
Immigrants removed due to their criminal status
(2009-2014)
By region
SOUTH AMERICA
AFRICA
ASIA
EUROPE
OCEANIA
NORTH AMERICA (2014 only)
Sources: U.S. Department of Homeland Security, GAO analysis of CBP data; Map Resources (map); U.S. Customs and Border Protection (fence).
SCMP Graphic: Marcelo Duhalde C.

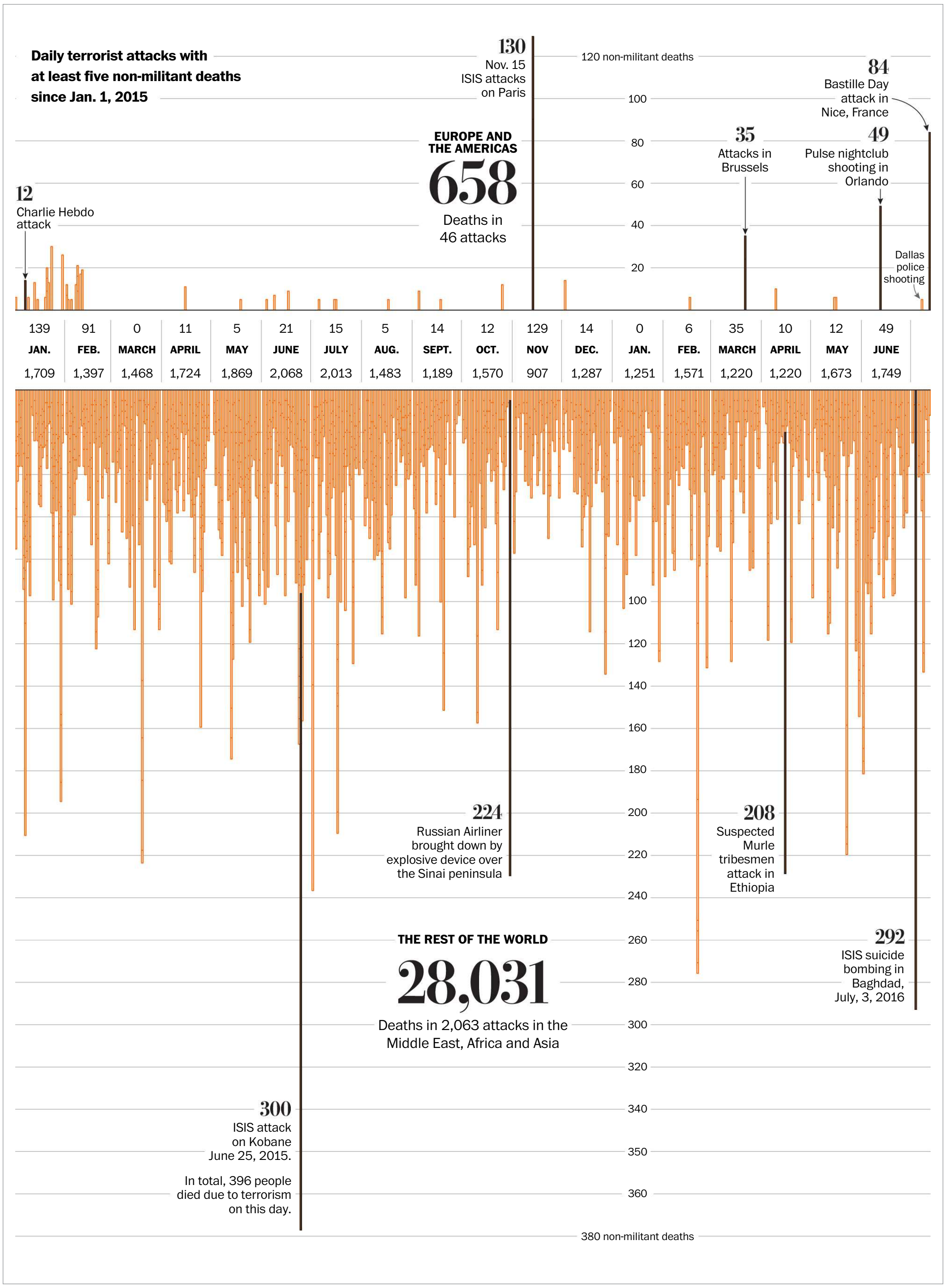


Figure 16. Deportation from the US (first) | **Figure 17.** How terrorism in the West compares to terrorism everywhere else – Washington post (second)

In Figure 16 the amount of colour distracts from the rest of the information. In terms of text, where it is placed on the colour background it is very dificult to read: small and light type, and when placed around the chart it is squeesed between lines as well as on an angle. All these features make accessing the information very difficult. In Figure 17, however, not just there is a good contrast between text and background, as there is a clear typographic hierarchy, where more important pieces on information are emphasised. Moreover, text has a clear supporting role to the complex bar chart that, without a well designed text, would be very difficult to interpret. It is a well balanced infographic overall.

4.3 Colour

Guidelines

1. Colour selection should not be subjective or based on personal preferences, but informed and deliberate to fulfil the specific needs and purposes of the infographic.
2. No more than four colours should be used in a single design, as using too many and incompatible colours overwhelms the user.
3. The same attention should be paid to both text and its background colour. If colour is used for the background, then contrasting colours should be used and dark elements should be set on a light background, and vice versa.
4. Colour can be used to focus user attention, clarify the meaning of the content, and ensure all the text is clear, readable and accessed quickly.
5. Colour can be used to help organise chunks of information and group pieces of relevant data together.
6. Colour can be used to emphasise words, make headings stand out, signal relationships within a document, show hierarchal levels, and provide structure and organisation in a document. All these will help the user to skim and navigate the information with ease. However, too much colour emphasises nothing.
7. Colour gradient effects should be avoided, as this makes the infographic busier.
8. Colour coding can be used to show levels of severity.
9. Colour can subtly affect mood and opinion. Therefore, it should be used harmoniously to support effective communication and make users comfortable with the colours used.
10. The meaning of colours in different cultures, regions and contexts must be taken into account to ensure the colours used do not offend or send the wrong messages to the target audience, and ultimately have negative consequences on a cross-cultural scale.

Additional practice-based guidelines

11. Colour should be used effectively to show differences in the information displayed, and therefore help the user to scan the information quickly, while still being able to isolate relevant chunks of information.
12. A three-color palette should be used for infographics. It should include the background colour, which should be the lightest colour of the three.
13. Three, maximum five colours, should also be the number for labelling and categorisation in a colour coding system, and they should be of equal strength and contrast.
14. Bright, highly saturated (primary) colours should be avoided, because they are visually too obtrusive and can create legibility problems.
15. Simultaneous contrast colour-pairings that create visual vibration when used together should be avoided.

16. Coloured text or symbols should not be placed on a coloured background. Either the text or the background should be black or white.
17. Only white, yellow, or a light cyan should be used for text on a black background (yellow should never be used for text or symbols on a white background). Other pastel colours, such as light green, may also be legible.
18. If text is coloured, then it should be bold.
19. Clear contrasts should be used, where a 70% contrast between an object and its background is advised.
20. To quickly check the contrast between values, the design should be printed in grey scale or the monitor should be turned to grey scale. If this shows that the different visual elements blend together, then the colours should be adjusted to create good contrast.
21. For colour to be memorable, only colours that the user is able to name should be used. Therefore, the basic six-colour palette should be considered.
22. Coloured text, coloured borders, coloured backgrounds, or coloured patterns should not be used solely for decoration.
23. Conventions and metaphors can be used to facilitate faster access to the information. For example, red for hot and blue for cold.

Research Findings

- Poor use of colour in infographics was found to compromise legibility.
- For search and identification tasks, colour coding was found to work better than variation in shape and size.
- Inconsistent application of colour schemes was identified as being a major design issue in infographics.
- The visual appeal of some infographics was found to be liked by users because of their simple and elegant colour combinations (e.g. blue, red and grey).
- Infographics with multiple bright colours and shades were considered busy and confusing.
- The use of colour in infographics was found to enhance memorability and influence users' retention.
- Colour infographics were found to be more effective than black and white infographics.

Rationale

Poor use of colour distracts users' perception, decreases their performance, increases difficulty when making sense of the information, and ultimately will send the wrong message to the user. Despite these potential risks of colour misuse, colour is a very powerful visual element that can greatly enhance communication of information. Therefore, to minimise potential risks, it is important to understand how colour can affect how information is processed, as well as how to make deliberate choices.

The ability of colour to grab attention is due to the fact that humans are more sensitive to chromatic variations and contrasts than light changes. Colour can also enhance memory and retention because it generates more working memory (important for reasoning and the guidance of decision-making and behaviour) and remains more significantly in the long-term memory. To nurture these cognitive abilities and assist the user to understand how colour is structured in an infographic, the relationship of hue, value and saturation needs to be considered and controlled.

It is also important to understand that we do not perceive colour in an absolute sense, but in relation to other colours. The same exact colour will be perceived differently, depending on the colours surrounding it. Although our eyes see colour in an absolute way, our brain, on the other hand, adjusts the colour according to its context.

In information design, the chaotic use of colour is particularly common in infographics. To avoid this, colour must be used with a function in mind. Colour can be used to label (colour as noun), to measure (colour as quantity), to represent or imitate reality (colour as representation), or to decorate (colour as beauty).

Furthermore, a harmonious and well thought through relationship between colour and text can significantly influence a document's effectiveness. When first looking at a document, users can easily distinguish levels of importance and decide what to read and look at first. Colour can help create a clear hierarchy in an infographic by enhancing the organisation of the information, distinguishing hierarchal levels in texts, and providing signal cues. Signal cues, if carefully considered, can also focus attention, group elements together, create specific points of information, and help users understand the relationships in an infographic.

For example, colour-coding enhances the users' capacity to distinguish between colours and associate each colour with a meaning. However, the eye only recognises a limited number of colours accurately and with confidence. More than three colours are difficult to recall. The less distinction between different colours, the more likely it is that the user will get confused, and will fail to distinguish the relative importance of specific colours. Therefore, if too many colours are used in a colour coding system, if contrast is not strong enough, or if the user does not know or understand the meaning to be associated with each colour represented in the system, colour will impair information extraction.

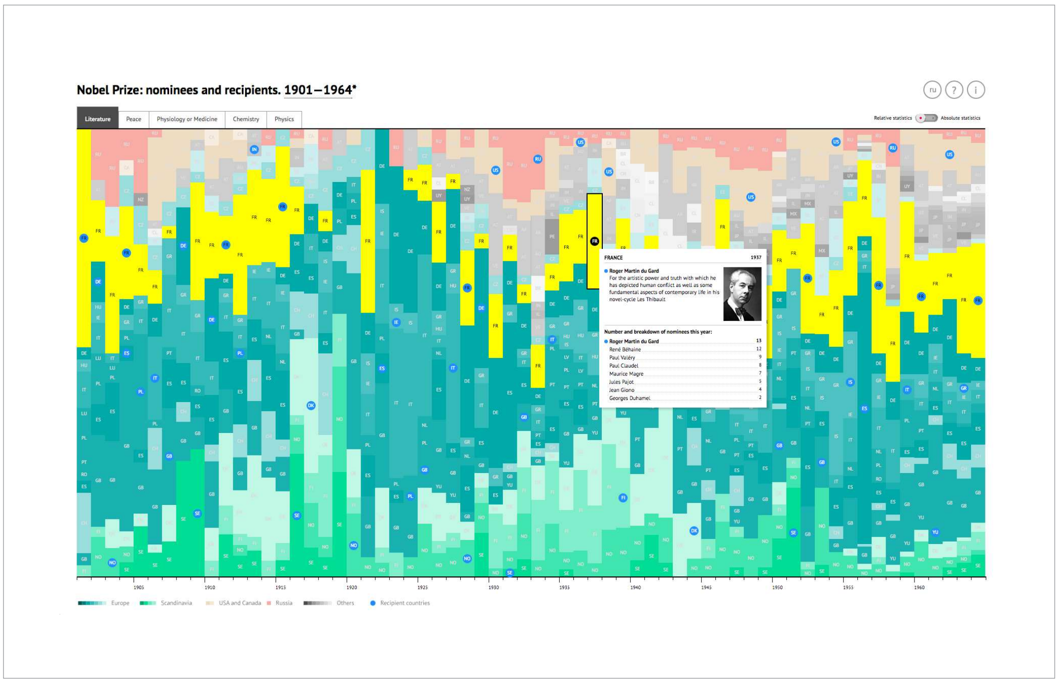
Using colour for decorative purposes can be considered colour misuse, as it adds complexity and may visually conflict or be confused with colours used with a function.

Guidelines: Travis, 1991; White, 1991; Keys 1993; Yantis & Gibson, 1994; Vanka and Klein 1995; Madden et al. 2000; Lipton, 2007; Kimball and Hawkins 2008; O'Grady and O'Grady, 2008; Stone, et al., 2008; Mackiewicz 2009; Baer, 2010; Balliette, 2011; Arnkil, 2013; Davis and Quinn, 2013; Coates and Ellison, 2014; Davidson 2014; Lamb and Johnson 2014; Arslan and Toy, 2015; Mollerup, 2015; Stones and Gent, 2015; Berinato, 2016; Dikson, 2016; Conley, 2017; Menezes and Pereira, 2017; Murray et al., 2017; Yildirimi, 2017.

Research findings: Christ, 1975; Hoadley, 1995; Dae-Young, 2010; Borkin et al., 2013; Stones and Gent, 2015; Bursi-Amba et al., 2016; Menezes and Pereira, 2017; Zhang, 2017.

Rationale: Tufte, 1990; White 1991; Keyes 1993; Magalhães, 1996; Few, 2005c; Puhalla, 2008; Stone et al., 2008; Mackiewicz 2009; Vazquez et al., 2010; Arnheim, 2011; Kostelnick and Roberts 2011; Coates and Ellison, 2014; Arslan and Toy, 2015; Stones and Gent, 2015; Bursi-Amba et al., 2016; Conley, 2017; Menezes and Pereira, 2017.


Beverage
Side
Main
Dessert
Snack
Ingredient
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER


Nobel Prize: nominees and recipients. 1901—1964*
Literature
Peace
Physiology or Medicine
Chemistry
Physics
Relative statistics
Absolute statistics
Europe
Scandinavia
USA and Canada
Russia
Others
Recipient countries

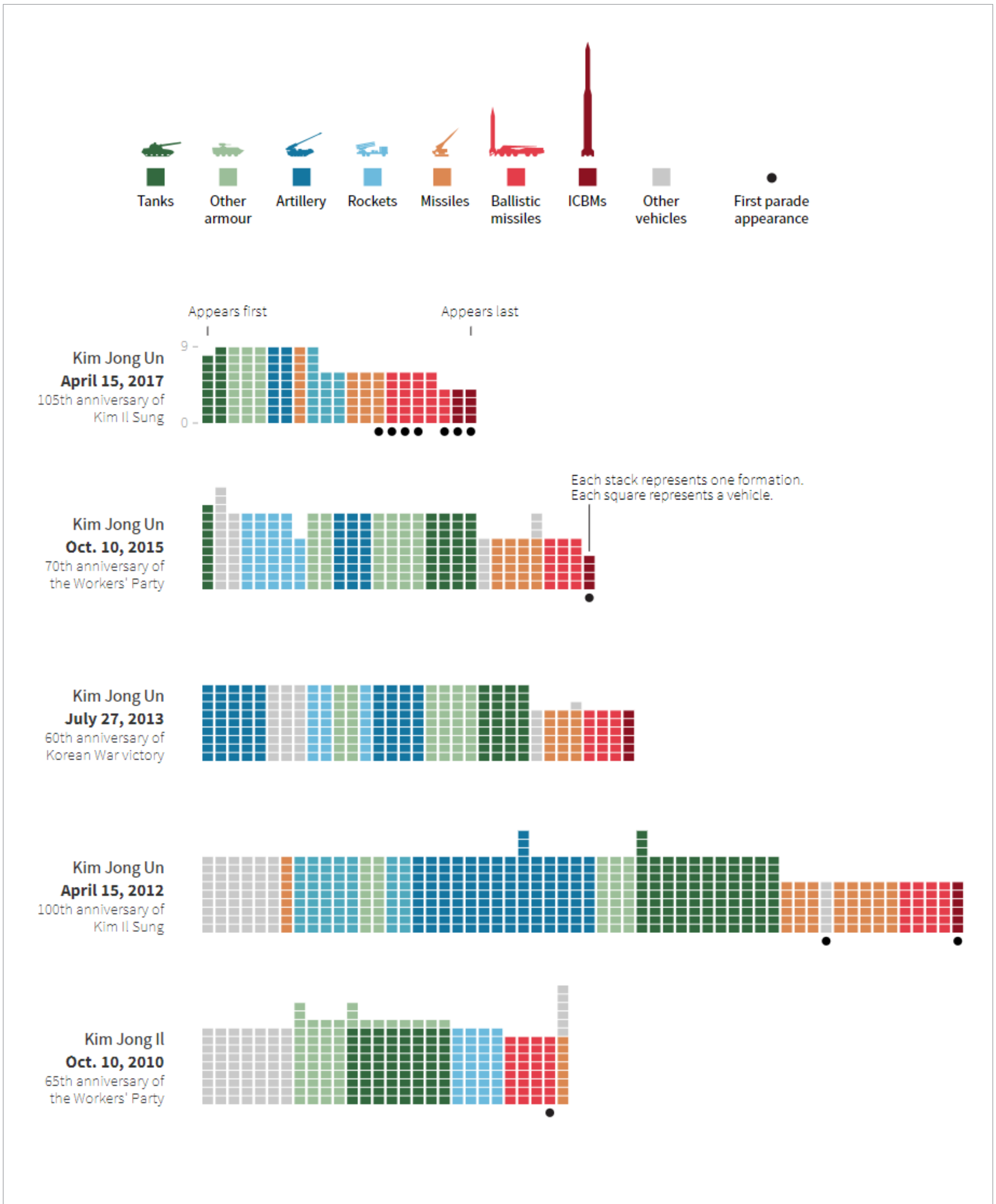


Figure 18a. All the National Food Days (first) **| Figure 18b.** Nobel Prize Nominees (second) **| Figure 19.** A show of force – North Korea's military parades (last)

Figures 18a and 18b are two examples of poor choice of colour palette. Despite colours not being too bright or saturated, they still fail to work harmoniously and end up being quite overwhelming. Figure 19, however, uses a wide range of colours but is successful in maintaining balance, contrast, clarity and aesthetics. Colour is used to represent North Korea's military parades in order to find out about the regime's capabilities and ambitions. This information was gathered though comprehensive research by watching full videos released by North Korea's state-run television KRT, Reuters images, images on military websites, etc. This is an interactive infographic worth looking at in detail (link provided in section 5 'Image credits').

4.4 Graphics | Visual elements

Guidelines

1. Visual elements should be consistent with the function, content and key message of the infographic, and determined early on in the design process.
2. All visual elements should be used effectively and arranged adequately within the infographic's structure.
3. All visual elements in an infographic should contribute to the communication of the message. If only decorative and unrelated to the subject matter, they should be removed as they can interfere with the function and clarity of the infographic.
4. Lines and arrows can be applied to guide users through the information.
5. Shapes that are simple and colourful can be used to emphasise information, and even make the data more personalised.
6. Pictograms can be used effectively for general representations of populations, and are easy to source.
7. Illustrations that resemble cartoon figures should be used carefully in more serious contexts such as health and security.
8. Pictures can be used to reflect the subject matter of the infographic. However, they should not distract, but rather assist the infographic in its purpose.

Additional practice-based guidelines

9. Visual elements of an Infographic should be able to tell the visualised story with little requirement for additional text explanations
10. Line, rules, bullet points and other graphic elements should have a function, such as to give direction and punctuation, not just to attract the eye.
11. To ensure that icons in an infographic are useful, a label or text should be used.
12. Icons in infographics, and the way they are paired with the text, should always add to the content, not distract users.
13. When pairing icons and typefaces, the typefaces should match the icons, and the style of both elements should have contrast and be consistent throughout (for example, for a bold icon a light typeface and vice versa).
14. To make icons clear, a background shape should be used (e.g. within a circle).
15. Size and colour choices should make icons noticeable and clear, not distracting.
16. Illustration should only be used to increase the quality of the infographics, not to distract.
17. Unique colours, pointers, labels and markers, can be used to draw the user's attention to important information.
18. To emphasise the main idea in the infographic, secondary elements should be de-emphasised by grouping them together, making them grey, etc.

Research Findings

- As a visual medium of communication, infographics were expected to contain more illustrations and images that can help the user understand a concept.
- Users were found to enjoy the visual and graphical nature of infographics.
- When viewing text-heavy infographics, user tendency was to glance at the texts, leaving them with the impression that they gain less insight with text-heavy infographics.
- Users were found to be aware that infographics cannot be completely without text. But they still preferred infographics to convey information without much help from words.
- A preference was found for restroom icons over other icon types.
- Users agreed that a higher quantity of graphics than text can make infographics easier to view on smartphone screens.
- The use of photography was seen as stronger than drawing, when the aim is to reflect reality closely.
- Pictures and graphs were considered more striking than text, and more capable of grabbing the immediate attention of the users.
- Long-term memory was found to increase when drawn pictures were used within and around the data, compared with using very plain graphs.
- Drawn illustration was preferred for positive statistics (e.g. about the benefits of exercise), but not for more serious statistics and risk information (e.g. the link between the negative risks of inactivity and smoking).

Rationale

Graphics-dense and text-light infographics seem to be most successful, but if decorative visual elements that distract the user are included, then they are perceived as less effective.

A coherent and well-structured layout is very important in guiding viewers from one section of the infographic to the other related section based on the flow of information and the underlying story. To that end, lines and arrows, for example, can be used to indicate a clear start and ensure that users process the information in the intended order, and that no information will be missed.

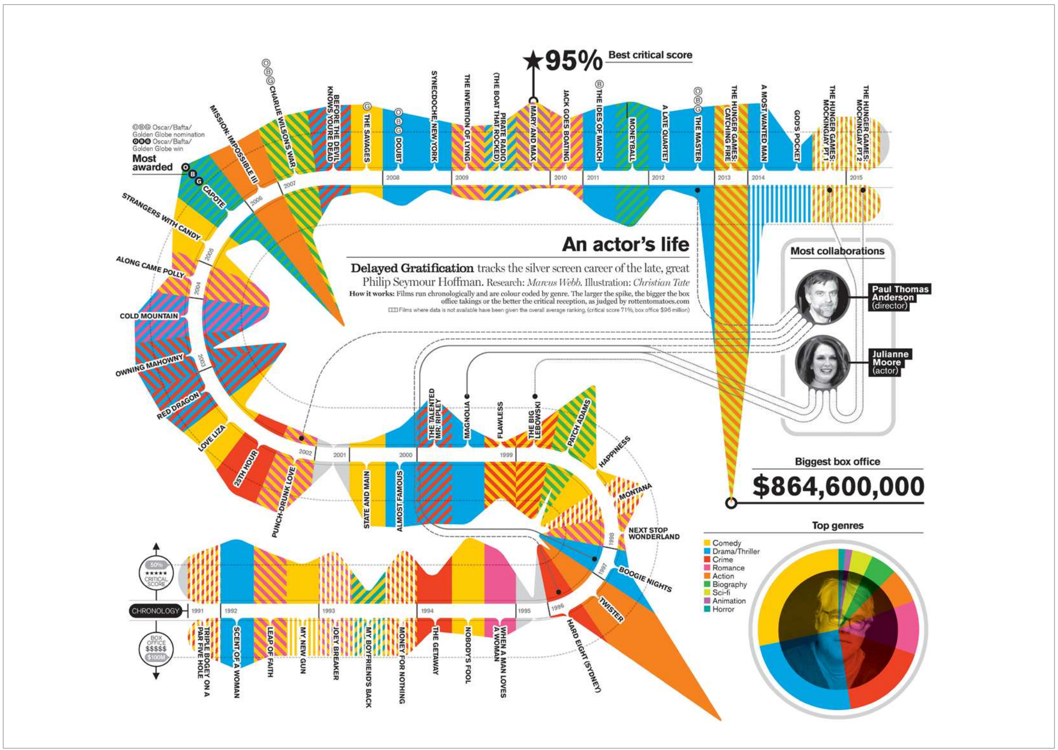
In terms of context, icons carry a more formal and objective tone than illustrations because they are usually made of simple shapes with minimum detail. However, understanding them might not be straightforward, and using a supporting label is what clarifies the context. Background shapes also help to make the icon clearer and more accessible, as they give a sense of order and organisation, and our eyes are also drawn to those shapes almost instantly.

Illustration, on the other hand, can work well in narrative infographics (e.g. editorial infographics) by helping to tell the story. However, they can be distracting in explorative infographics (e.g. data visualisation), and compromise the message being communicated. Illustration can also compromise the message if used improperly, if used to mislead, or if used to hide incomplete and meaningless messages.

Guidelines: Levin, 1981; Tufte 2006; Baer, 2010; Lankow et al., 2012; Davis and Quinn 2013; Davidson 2014; Lamb and Johnson 2014; Arslan and Toy, 2015; Stones and Gent, 2015; Berinato, 2016; Dunlapa and Lowenthalb, 2016; McCredy, 2016; Mighty, 2017; Moojin et al., 2017; Murray et al., 2017; Yildirimi, 2017.

Research findings: Larkin and Simon, 1987; Bateman et al. 2010; Zikmund-Fisher et al, 2014; Stones and Gent, 2015; Majooni et al., 2017; Zhang, 2017.

Rationale: Levin, 1981; Tufte 2006; Gillian and Sorensen, 2009; Lankow et al., 2012; Stones and Gent, 2015; Dunlapa and Lowenthalb, 2016; McCredy, 2016; Murray, et al., 2017; Majooni et al., 2017.



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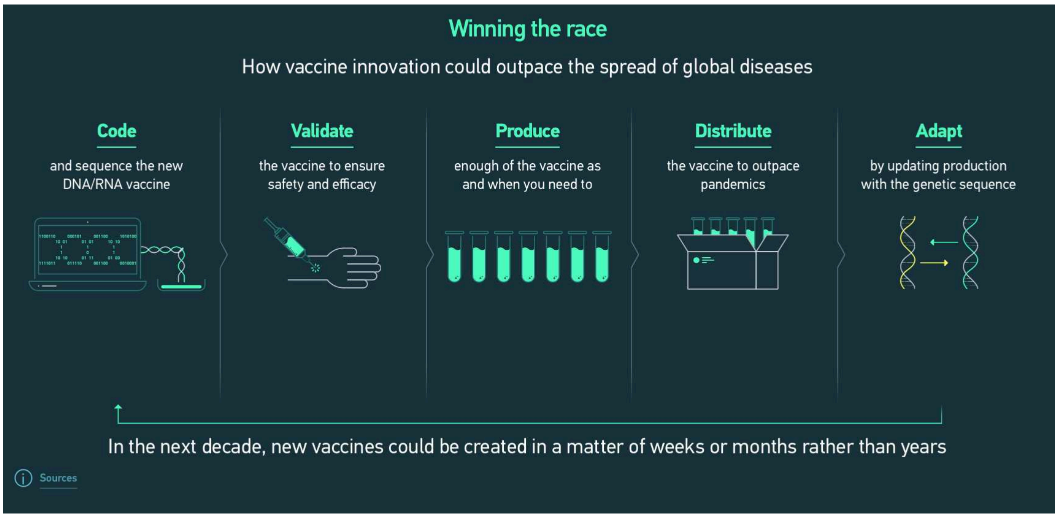


Figure 20. An actor's life (first) | **Figure 21a and 21b.** Outpacing pandemics (second and last)

Figure 20 is an example of over use of visual elements that have no real function. The combination of multiple patterns and saturated colours, together with other visual elements such as lines, increases cognitive overload. Moreover, it is very difficult to read the text in such a busy graphic display, plus the fact that the text is inclined to follow the data path. Figures 21a and 21b, on the other hand, use lines, dots and bars to display data about a sensitive issue, and do it in a very elegant way. And altough complementary colours are being used, they have just the right level of saturation to avoid vibration. Moreover, icons were created to communicate the importance of the research conducted, as well as future interventions. This is an interactive infographic worth looking at in detail (link provided in section 5 'Image credits').

4.5 Layout and structure

Guidelines

1. Our natural eye movements when looking at information, i.e. left-right and top-down, should be considered when designing the layout of infographics. A layout in zig-zag form should be favoured to increase comprehension.
2. The layout should also show a well-planned and clear hierarchical structure to help viewers locate the information.
3. Typefaces, shapes, colours, alignment and the space between elements should be consistent throughout the infographic layout.
4. Data visualisations, images and words should be balanced in an infographic layout. Text should be limited to titles, short annotations and bullet points, etc.
5. Text and relating images should be placed closely together in terms of perceptual proximity (and with the help of visual guides if appropriate) to direct the eye from the text to the images and back, and facilitate integration of information.
6. Good infographics should include an introduction, the key message and a conclusion.

Additional practice-based guidelines

7. Organising the information should be the first task when creating an infographic.
8. To organise information successfully, the following should be done: a) read carefully the information to be designed; b) identify the order the information needs to be presented; c) establish what the users need to see in terms of priority; d) decide how the different levels of information are going to be distinguished; e) consider elements such as typeface with a variety of weights, colour, scale, white space and other graphic elements that can successfully guide the user around the information.
9. After understanding and organising the information, the next step should be to create a grid to organise the content on the page and ensure visual clarity of the message through: a) organisation – a framework for text and visuals; b) movement – links between information sets and ability to move the eye through the content; c) grouping – connecting groups of content through proximity and alignment.
10. When developing a grid, the following should be decided: a) which pieces of information should be grouped together; b) what should be the size and format of the infographic; c) how text and graphics should work together; d) should captions be used; e) how should white space be used effectively to emphasise the information; f) how should consistency be kept; etc.
11. A graphic and information hierarchy should also be very clear in every infographic, and even more so when the information is complex.
12. Hierarchies should be assessed throughout the various stages of design development to avoid altering the order of information randomly and consequently affecting its meaning.

13. White space should be used generously, and in harmony with the grid to give users a "visual" break and help them focus on the relevant information.
14. To make sure elements are aligned adequately, the following should be checked: a) are headings aligned in the same vertical axis (left, right, centre)?; b) do headings, main text and sections have the same amount of space between them?; c) do lines start and end in the same proximity to the elements they are placed next to?
15. Elements should be aligned along as few horizontal and vertical lines as possible.
16. Weight and scale of the typographic elements, as well colour and type style, can be manipulated to signal the relevance and priority of certain information.

Research Findings

- Eyes were found to be clearly guided by a grid format, making fairly predictable eye movements from left-right and top-down.
- A predictable orientation of the chunks of information in a zig-zag model was found to help users follow the story of an Infographic more steadily and with less distraction.
- Eye-tracking data showed quantitative evidence that comprehension is high from a zig zag form of layout, and with a low imposed cognitive load.
- Coherence when designing a set of infographics can save users time, because users do not have to mentally adjust to a different style every time they see a new infographic.
- Eye-tracking shows that scanning paths are much more unpredictable and varied with infographic designs that do not use a clear grid.

Rationale

An easy-to-navigate layout should be used in infographics to clearly show where to begin looking at the information, and where to end. For example, taking account of our natural left-right/up-down eye movement when placing dominant visual elements in the layout of the infographic, can improve comprehension and speed of finding information. A clear hierarchy, with clearly connected elements, further helps the user navigate through complex information in a logical and accessible way, and consequently reduces information overload. Grouping by similarity, which strengthens the link between the various design elements, also reduces complexity of the infographic and increases the speed of finding information. Alignment is equally important as it ensures that all the pictures and text elements line up with each other along a series of invisible lines, making the information easy to follow.

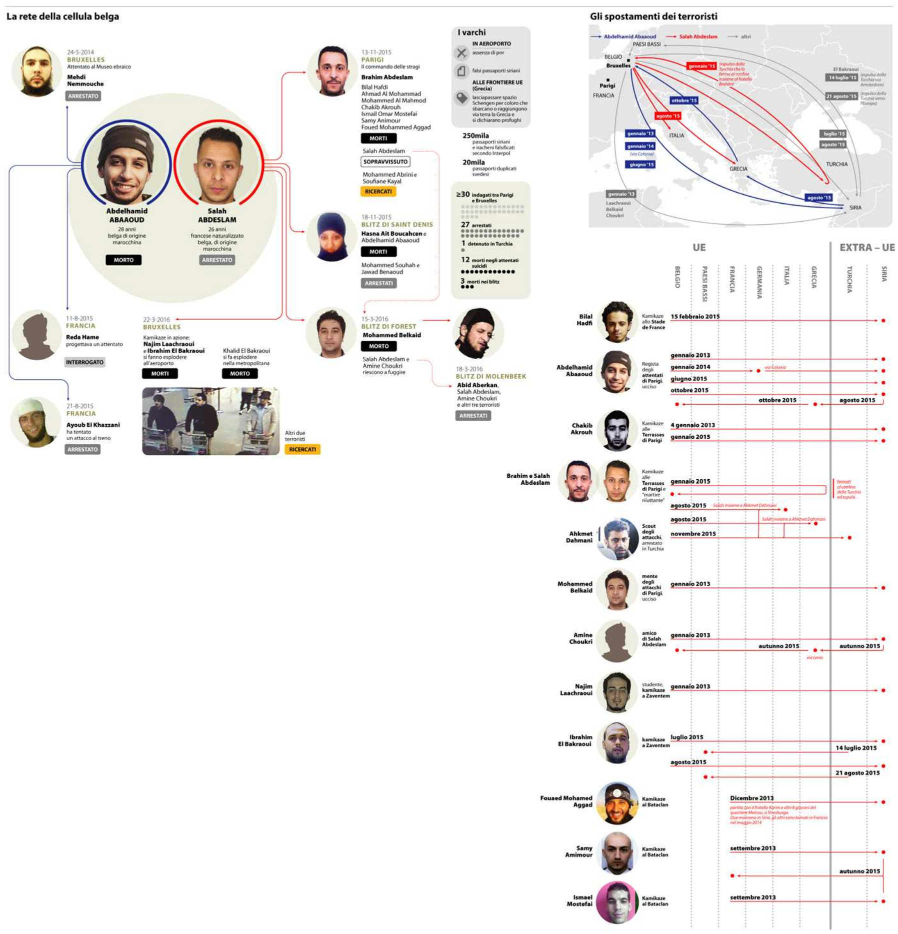
These are all features that should be used consistently in infographic design. Having a consistent and coherent design across a set of infographics does not mean, however, that all infographics should look the same. Every infographic should have a specific design to fit the content, but some design elements should be standardised and used consistently. It is a process similar to creating a style guide for consistency in technical and business documents.

Furthermore, a well-structured infographic delivers more than accessible information. It delivers harmonious, balanced and aesthetically pleasing information.

Guidelines: Wickens and Carswell, 1995; Lipton, 2007; O'Grady and O'Grady, 2008; Holsanova, 2009; Baer, 2010; Davis and Quinn 2013; Coates and Ellison, 2014; Davidson 2014; Lamb and Johnson 2014; Arslan and Toy, 2015; Stones and Gent, 2015; Berinato, 2016; Dikson, 2016; Mighty, 2017; Majooni et al, 2017; Murray, et al., 2017; Yildirimi, 2017; Zhang, 2017.

Research findings: Stones and Gent, 2015; Majooni et al, 2017; Zhang, 2017.

Rationale: Lidwell, et al., 2003; Lipton, 2007; O'Grady and O'Grady, 2008; Baer, 2010; Moere and Purchase, 2011; Arslan and Toy, 2015; Stones and Gent, 2015; Majooni et al, 2017; Menezes and Pereira, 2017; Zhang, 2017.



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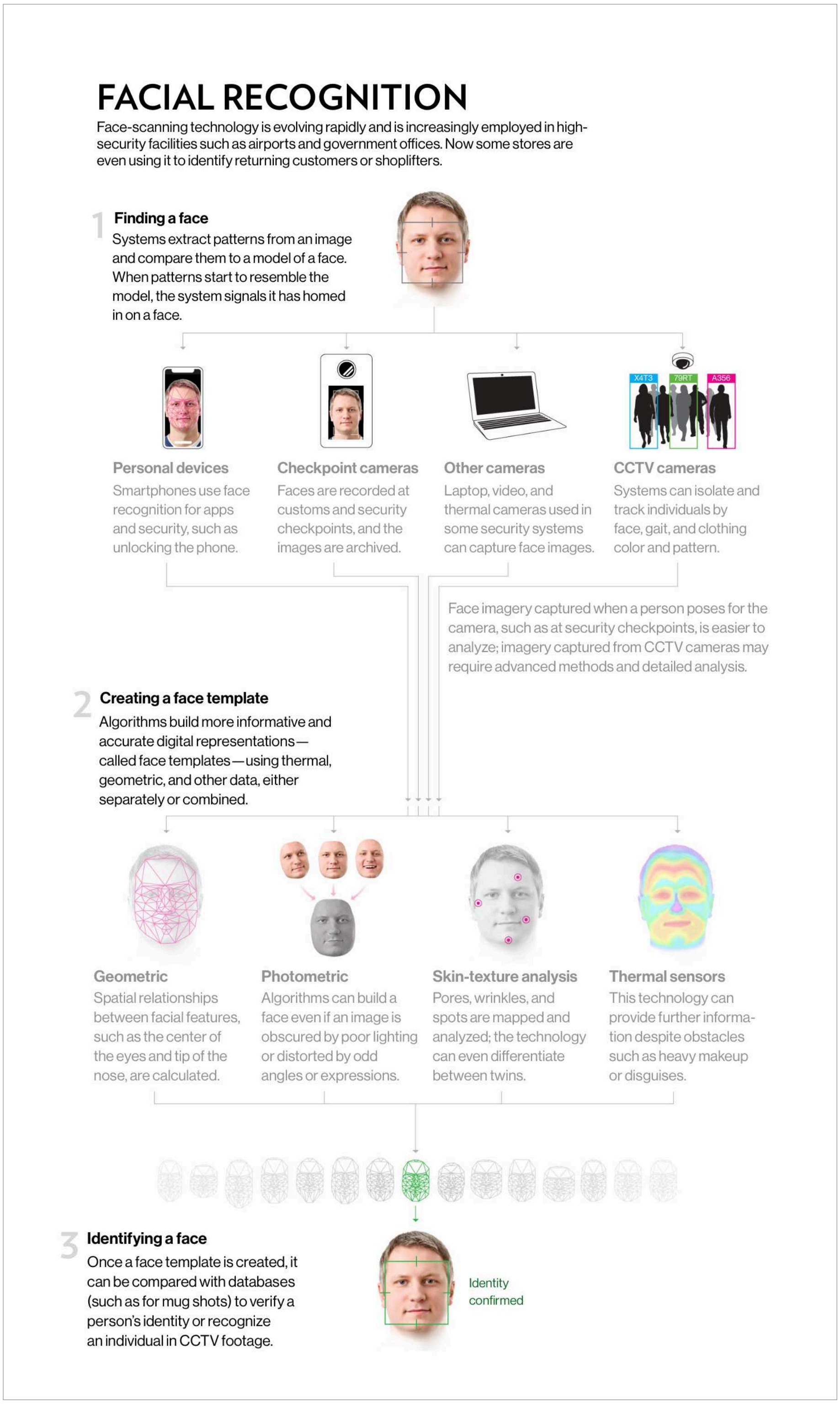


Figure 22. The net of terror (first) | **Figure 23.** Under surveillance – Facial recognition (second)

Information in Figure 22 is badly organised. Despite a logical sequence and link between the information, everything is squashed and pushed to one side. There is no good use of white space, which actually leads to an unbalanced page. In figure 23 there is a clear balance, good hierarchy and order of information, and all other elements (lines, figures, etc.) work well together in a harmonious and elegant way.

05

Data visualisation

05

Data visualisation

Data visualisations are not infographics, but are featured within infographics (Krum, 2014). Data visualisation is the visualisation of numeric values with charts, tables and graphics by transforming raw and intense data into visual presentations. Most of all, it includes clear information based on measurable statistical data (Dur, 2014).

Data visualisation and infographics, however, exist on a continuum (Cairo, 2013). Of the elements used in infographics, data visualisation is among the strongest one, if not the strongest. First, because it summarises hundreds and thousands of numbers into a digested visual form, but also because it has direct effect on the credibility and persuasiveness of infographics (Tanyoung and DiSalvo, 2010).

5.1 General

Guidelines

1. Data visualisation should be kept simple and display information in an accessible and readily understandable way.
2. Data visualisation should be used for comparison, not for individual amounts.
3. A suitable chart format and design, one that requires as little perceptual and cognitive processing as possible, should be selected for the specific context and data that needs to be communicated.
4. Multiple data visualisation formats should be considered, to suit the type of data to be communicated and the target audience in question.
5. The content of a chart should be organised by: a) analysing the data thoroughly; b) classifying it in order of relevance; c) associating it according to its meaning.
6. Visual attributes should be used in data visualisation to help: a) group information into meaningful sections; b) prioritise information in order of importance; c) sequence the information according to the order in which it should be read.
7. Data quality and simplicity should be ensured by: a) keeping symbols, colours, text and metrics consistent; b) carefully selecting a few visual cues to help clarify the meaning of the data; c) creating clear captions, titles, and annotations on how to interpret the visualisation (in particular when less familiar formats are used); d) ordering the information by rank and relevance; e) clarifying uncertainty (e.g. clearly labelling associations, comparisons, etc.); f) avoiding using shadows and truncated scales; g) using the same scale for comparison.
8. Chartjunk and cluttering should be minimised by avoiding: distracting patterns, overbearing colours, shading, 3D, unnecessary grids, etc.
9. A simple and straightforward design with a richness of data should be used instead by: reducing the need for inferences, making clear and explicit comparisons, providing optional additional detail.
10. Information density can be accepted in certain instances, as long as the information can be visually extracted from the chart.
11. Data-ink ratio should be optimised by reserving the use of visuals (data ink) to communicate important data, and not for presenting redundant information.
12. Extra visuals (extra ink) can be used at times to facilitate cognitive processing and help the user to perform a task with ease.
13. Data should have a narrative quality, i.e. a story to tell about the data to provide a context and give more meaning to the data.
14. To communicate complex data effectively and in a more intuitive way, a balance between functionality and aesthetics should be established.
15. Words, numbers, and drawings should be combined to make complex data more accessible and support the reader in interpreting the data accurately.
16. The focus of the whole visualisation should be on two or three key messages, which are then depicted using different visual aids.
17. Data transparency and integrity is imperative – displaying the data accurately and in context, avoiding distortion and bias.

18. The limitations, quality and relevance of the information should be acknowledged. When needed and appropriate, communicating a restricted part of a whole picture should be an option.
19. Data should be visualised in a manner that facilitates analysis.
20. The needs and expectations of the audience should be considered at all times.
21. Data visualisations should be validated by feedback from the target audience and by conducting usability studies that include cognitive process tracing (e.g. eye tracking, verbal protocols, etc.).
22. The target audience should be involved in the design, evaluation, and dissemination of data visualisations.

Additional practice-based guidelines

23. Visualisation of information should start with a clear understanding of the message that needs to be communicated.
24. Data visualisation should not be used if a simple sentence is sufficient to communicate the information clearly, or when only a number or two need to be communicated (a chart for such little data will only take space).
25. When considering aesthetics in data visualisation, things to take into account are: a) be smart with colour – colour should always be used with an intention and used sparingly to highlight relevant parts; b) pay attention to alignment – elements should be organised in clean vertical and horizontal lines to achieve a sense of unity and cohesion; c) maximise the use of white space – margins should be preserved by not including unnecessary elements simply because there is space.
26. Four elements should be included in all charts: title (about 12% of the visualisation); subtitle (8%); visual field (75%); source line (5%).
27. Within the visual field, axes, labels, and sometimes captions and legends can be included.

Research Findings

- Charts designed according to principles of perceptual and cognitive processes of chart reading, were found to improve performance
- Statistical charts were found to encourage viewing in comparison to articles and numerical tables.
- A preference was also found for charts that visualise statistical information.
- An even stronger preference was found for charts that allow direct visual comparisons of statistical data and reaching a conclusion quickly.
- A preference was found for simple visual displays that allow access to more data.

Rationale

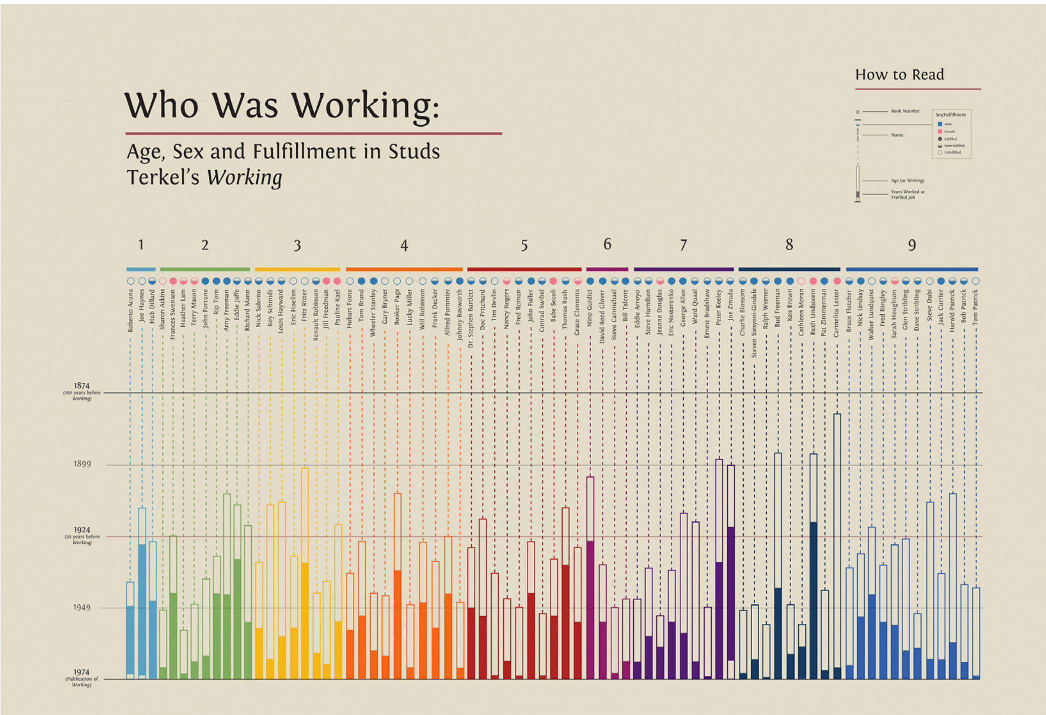
The essence of good data visualisation is simply to facilitate data communication in a quick and effective way. Therefore, simple, straightforward and familiar data visualisations are often more powerful than complex ones. Combining words, numbers and images (what we currently define as an infographic) is a sound design strategy that should be used to make complex data more accessible. Moreover, infographics present a story about the data, and because storytelling engages the user with the data, this will result in the user spending more time interpreting the data and, consequently, better data processing and understanding.

Above all, data needs to be communicated accurately. This can be further supported through an effective encoding of the data within an accurate organisation of the information on the page. This guides the user about where to focus and in which order to read the flow of information. Designs that are more aesthetic, are also perceived as easier to use, are better accepted, and foster problem solving. However, the correct balance between form and function needs to be ensured for effective communication of data. The use of colour, arrangement of elements on the page, and manipulation of white space, for example, should all be invisible components in a visual display. If these elements are noticed, the design is poor and will only create visual discomfort, and may even be seen as disrespectful to the data, as well as to the user accessing the data.

Guidelines: Gillan and Neary, 1992; Gillan and Lewis, 1994, Gillan and Richman, 1994; Gillan and Callahan, 2000; Gillan, 1995, 2000; Lipkus and Hollands, 1999; Shah and Hoeffner, 2002; Few, 2004a, 2004c, 2012; Hesse and Shneiderman, 2007; Friedman, 2008; Gillian and Sorensen, 2009; Hildon et al., 2011; Mol, 2011; Spiegelhalter et al., 2011; Dur, 2012; Trevena et al., 2012; Woller-Carter et al., 2012; Gelman and Unwin, 2013; Krum, 2013; Knaflic, 2015; Berinato, 2016; Okan et al., 2016; Asada et al., 2017; Garcia-Retamero and Cokely, 2017.

Research findings: Gillan and Callahan, 2000; Gillian and Sorensen, 2009; Le et al., 2013; Zhang, 2017.

Rationale: Friedman, 2008; Mol, 2011; Dur, 2012; Knaflic, 2015; Coyle et al., 2017.



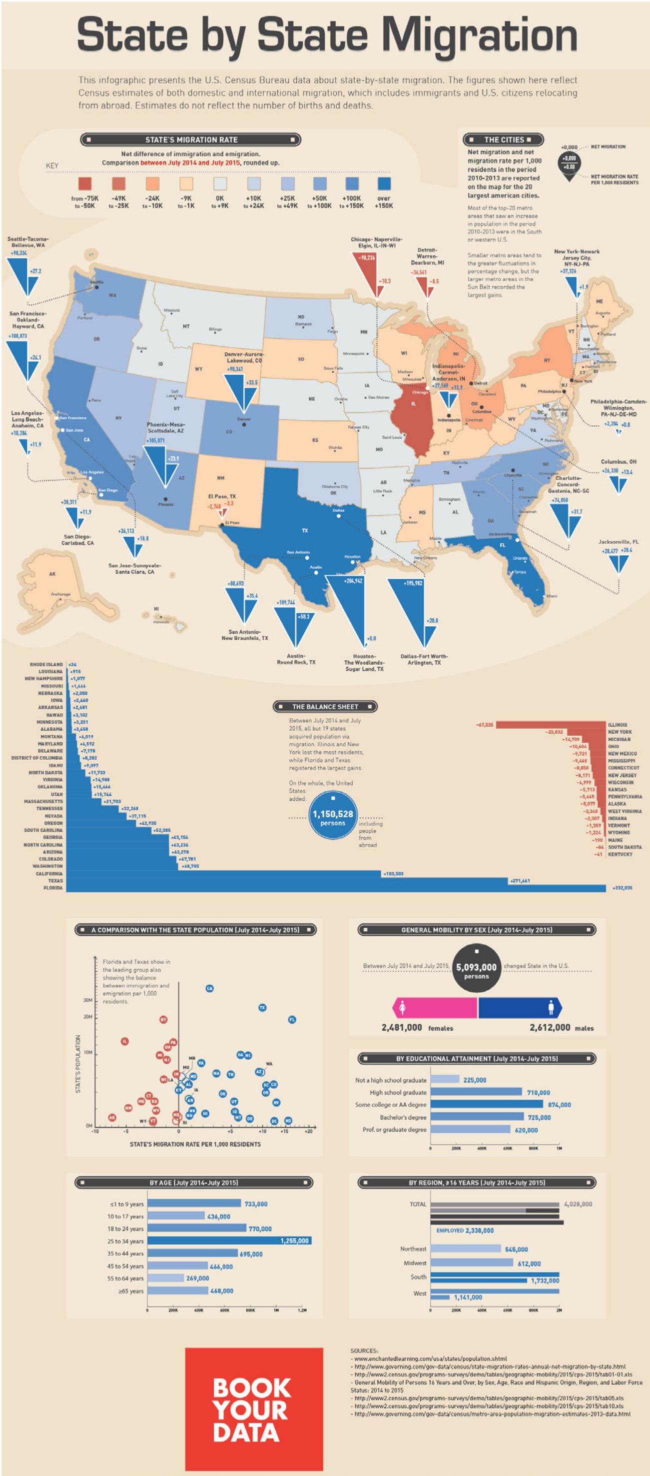


Figure 24. State by state migration (first) | **Figure 25.** Who was working (second)

At a first glance, the information in Figure 24 does not seem as overwhelming as when actually analysing it. For each single item of the approximately 70 items displayed, the user needs to interpret: name, book number, age, gender, fulfillment, age at writing, years at work. All this in a chart where bars are multicoloured and very close together. There is just too much information to discern and process at one glance. In contrast, the infographic in Figure 25 organises data in different chunks, where colour helps to distinguish relevant information, as well as group related information. This decreases cognitive overload.

5.2 Text | Typography

Guidelines

1. Typographic design principles should be applied to any visualisation that includes text.
2. No more than two typefaces should be used in the same visual display.
3. Type sizes should be appropriate for the size of the chart and the chart area.
4. Sans serif type should be used for digital content and at smaller sizes.
5. Both serif and sans serif typefaces can be used in combination to create a visual hierarchy and still maintain legibility. For example, using a sans serif typeface for headings and a serif typeface for paragraph text creates contrast and helps the user navigate the data and identify which text should receive attention first.
6. Type weight (e.g. bold) and size can also be used to create contrast and hierarchy.
7. Consistent use of type should be used throughout the data visualisation(s) to convey a cohesive story.
8. Left-justified alignment should be used for bigger chunks of text, as the vertical edge on the left facilitates readability.
9. Left-alignment should also be used consistently to reduce visual clutter.
10. Important numerical and textual information should be added to the visualisation to increase accuracy.
11. Titles/headings should be clear and informative.
12. All supporting text (labels, legends, etc.) should be positioned to help the user interpret the chart, not to distract or confuse.
13. Labels should be used to provide detailed information on the data, and excluded if redundant or if making the chart look cluttered.
14. Labels should be used with segmented data, with a wide range of data, and with data areas (especially when volume is used to represent size).
15. Labels should not be used when the task is only to understand general trends (rather than specific data points), or to compare one data element to another (unless the data points are close to one another).
16. Horizontal labels extending beyond the chart should be avoided.
17. Legends should be written to make the chart self-explanatory.
18. Legends should be placed around the chart, or built into the chart, rather than perceived as separated from the chart.
19. Legends of similar charts should emphasise their different features.
20. Legends should have the same order as the corresponding content elements on the chart.
21. Borders around legends should be used only when necessary.
22. Self-explanatory symbols could be used in certain contexts instead of a legend, but all abbreviations and symbols should be clearly defined.
23. Captions should be used to highlight important aspects of charts, but they are often too general and do not capture a chart's intended message. Therefore, verbs and adjectives in a caption could be used to suggest the general category of the chart's message (e.g. the word 'declining' can suggest a falling or a change-trend).

24. Charts and text should be consistent in format.
25. Big typefaces to make numbers stand out should not be used as a form of visualisation, as they are still numbers.

Additional practice-based guidelines

26. Typography should not oppress the data.
27. Typefaces that are well established, well researched and familiar to the user should be used.
28. Type style should be simple, independently of being serif or sans serif.
29. Upper and lowercase should be used instead of all-capitals for narrative text.
30. For short word sequences (e.g. titles, labels, keywords) all-capitals could be used.
31. Type should not be set too small or too condensed.
32. Type should not be set at an angle.
33. Hyphenation should be avoided.
34. Wide interletter space should be avoided.
35. Interlinear space should be about 2 points higher than the type size for comfortable reading.
36. Bold, and sometimes italic, can be used to emphasise and differentiate elements such as titles, labels, captions, or within short word sequences, but should not be used at the same time.
37. Headlines can be bold or a couple of sizes bigger than the main text.
38. Bold should be favoured over italics and underlining as it adds less noise to the design while still highlighting elements clearly.
39. Bold should be used to increase legibility on a coloured or shaded background.
40. Bold should not be used for the numbers on a scale.
41. Bold should not be used for a large amount of text because by emphasising everything, nothing gets emphasised.
42. Bold can be used to emphasise the main point of the message.
43. Italic should be avoided because it does not stand out much and is not very legible.
44. Underlining should be avoided because it adds quite a bit of noise and compromises legibility.
45. Different typefaces should not be used for emphasis, not only because it makes reading more arduous, it also disrupts aesthetics.
46. Variation in size can also be used to emphasise important information and grab the user's attention.
47. Inversing element (e.g. white text on a black background) should be used sparingly because, although it might grab attention, it adds considerable noise to the information and compromises legibility.
48. One form of emphasis per element should be enough.
49. Direct labelling (i.e. directly on the chart and/or in close proximity to what it is describing) should be used to help process the data, such as to explain nuances in the data, highlight important things, or describe external factors that are considered relevant. For example, lines in a line chart should be labelled directly to allow quick identification, unless the space between lines is tight.
50. A pointer (a thin line from the label to the data element) can be used to assist labels that are adjacent instead of direct.

51. Labels should be concise, and care should be taken not use large blocks of text (especially under a line in a line chart).
52. Axis labels should be centred and parallel to its axis.
53. Titles should be centred and placed over or under the visual display.
54. Users looking at the same data visualisation will not draw the same conclusion. Hence the need to state in words any conclusion that needs to be made.
55. For high legibility a good contrast between text, colour and background should be maintained.

Research Findings

- Users were found to pay attention to the title of a chart when the title is close and aligned to the other data elements within a simple chart.
- When looking at a chart, a higher number of fixations were found to occur around the legend area and the data area.
- Users are also of the opinion that looking at the legend and the data area helps them to complete the task quicker.
- Users were found to pay more attention to legends in plain charts, but paid more attention to data areas in 3D charts.

Rationale

Text in charts helps to make data visualisation accessible and can play a number of roles in communicating with data, such as to label, to introduce, to explain, to reinforce, to highlight, to recommend, and to tell a story. However, neglecting typographic design principles and using the wrong typography can impair comprehension of the content and even disrupt the flow of information. Hence the need to apply typographic design principles to all text in a data visualisation.

Moreover, both design and the location of text in a chart, as well as its spatial relationship to the data area, are extremely important in determining a chart's usability. Chart legends, for example, can make users work very hard to understand the chart because it requires a lot of eye movements when swapping back and forth between the chart and the colour legend.

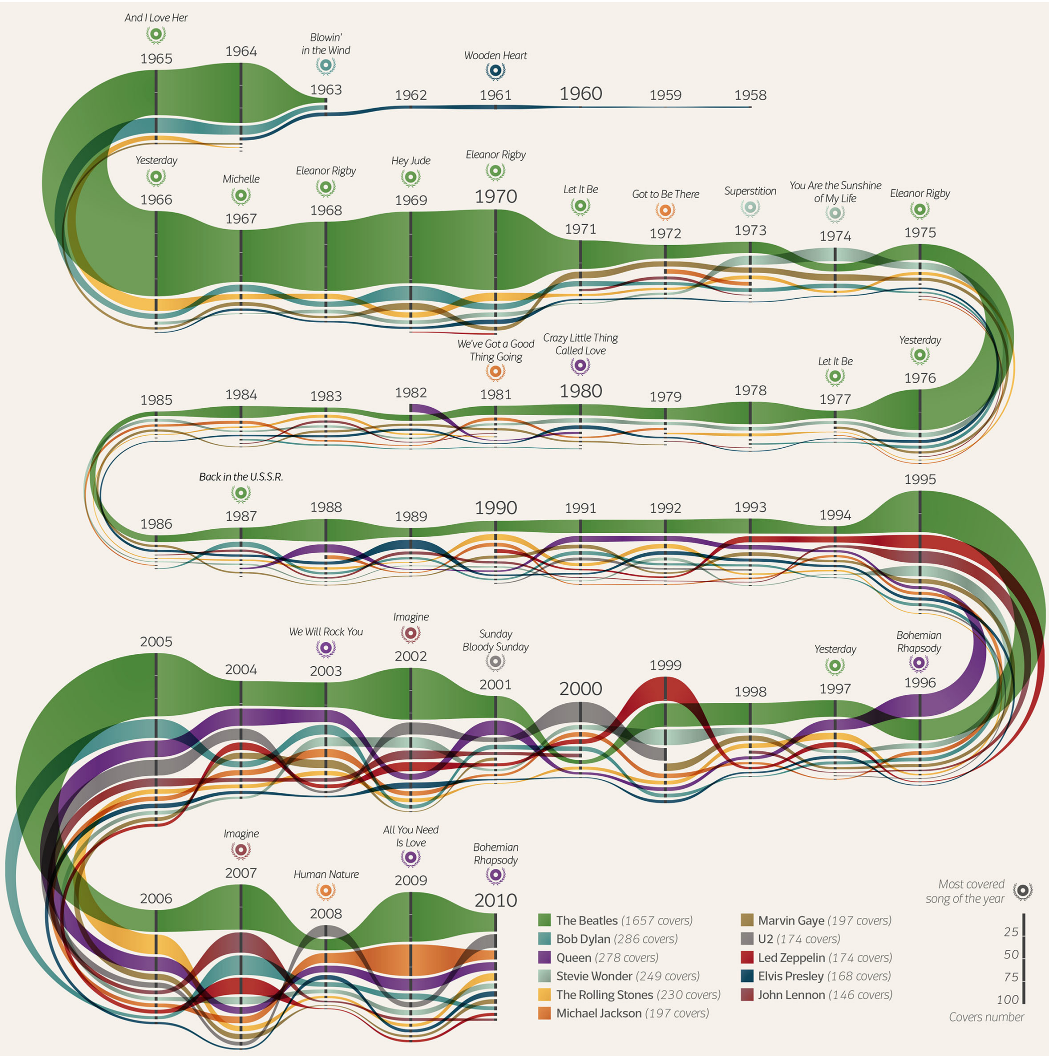
Text in data visualisation should be always transparent, i.e. the data should be the main focus, not the text. The text's role is simply to describe the chart clearly and to present the information effectively, not to trigger emotion, nor to deviate the user's attention from the data.

A simple test for legibility is to reduce the chart (photocopy, for example) to an acceptable small size, and if the typography is still legible, then it was designed adequately.

Guidelines: Lipkus and Hollands, 1999; Shah and Hoeffner, 2002; Watzman 2002; Kosslyn, 2006; Wu et al., 2017; Balliette, 2011; Ali et al. 2013; Borkin et al, 2013; Krum, 2013; Wong, 2013; Lonsdale, 2014b; Hamstra et al., 2015; Knaflic, 2015; Mollerup, 2015; Okan et al., 2015; Stones and Gent, 2015; Berinato, 2016; Asada et al., 2017; Coyle et al., 2017; Garcia-Retamero and Cokely, 2017.

Research findings: Renshaw et al., 2004; Stones and Gent, 2015.

Rationale: Renshaw et al., 2004; Krum, 2013; Wong, 2013; Knaflic, 2015; Coyle et al., 2017.



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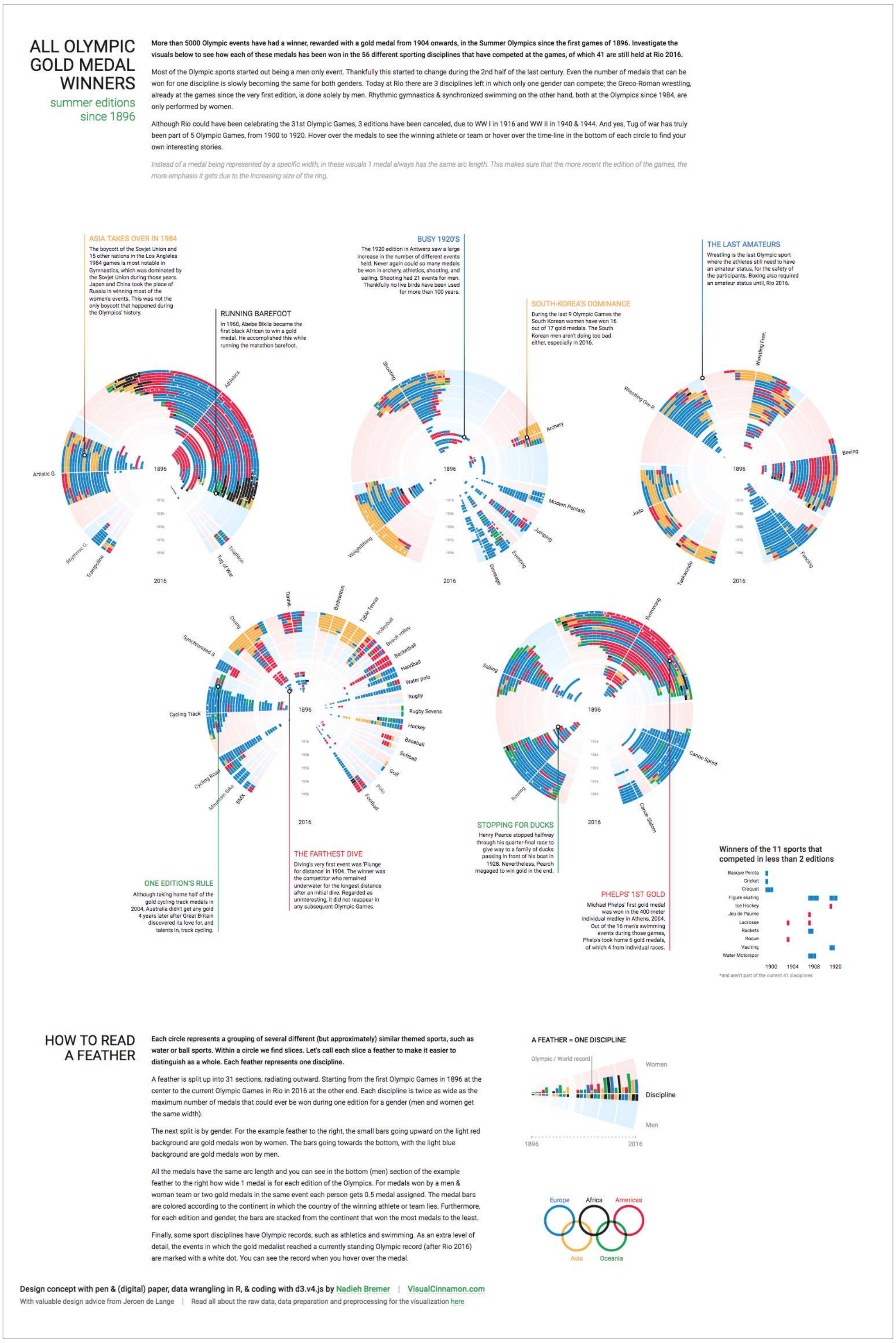


Figure 26. Cover mania (first) **| Figure 27.** Olympic Feathers - Visualizing all gold medal winners since 1896 (second)

For such a complex data infographic as the one in Figure 26, the text is doing very little to support the user in interpreting the data. In Figure 27, however, although still complex data, the text directly links to those areas of most relevance, and a full explanation is further given (left) on how to interpret the data and read each feather.

5.3 Colour

Guidelines

1. Colour can be used effectively to enhance chart reading accuracy, if selected and used carefully to fit with the type of data and context, and with the intended meaning and overall story to be told.
2. Colours should be used sparingly, with the function to convey information in charts, rather than as decoration.
3. A chart colour palette should be selected, and the use of a colour outside that palette should be avoided.
4. For categorical information, colours that are well separated in the colour wheel should be used.
5. For continuous data, saturation or darkness of the same colours should be used.
6. Colours adjacent to each other on the colour wheel should be avoided as they produce little contrast when used together. If used together, then their brightness needs to be different enough to create a clear contrast.
7. Background colours should also provide sufficient contrast.
8. Colour meaning and the meaning of colour combinations should be considered.
9. Colours should be kept consistent across charts for all chart elements.
10. Colour coding can be used in charts to help users interpret data.
11. Colour saturation should be used as an additional element to represent differences in quantitative information in bar charts, pie charts, etc.

Additional practice-based guidelines

12. Colours should be chosen strategically, because each colour will convey a different piece of information or add a layer of data.
13. The information presented in charts should dictate what colours are needed.
14. The colour palette should be restricted to two or three colours, and variation in saturation should be used to create distinguishably different colours within the same colour palette.
15. Soft colours should be used in charts, instead of colours from the opposite side of the colour wheel (which are high in contrast).
16. When allowed by the software, a colour palette could be created that includes a set of relatively soft but distinct colours for general use, and another set with dark and bright colours for emphasis.
17. A single and neutral colour should be used for the background.
18. Contrast between colours should be used for legibility, and different values within the same colour can also be used to define layers of attention.
19. High luminance contrast should be used to make the edge between one shape and another more legible.
20. When using colour scales/gradient in charts with more than one colour, the shades for the first colour should go from dark to light, and then for the second

colour from light to dark. Otherwise, the eyes cannot make a meaningful comparison if they have to suddenly jump from a light to a dark shade.

21. Multiple colours should not be used to represent the same type of data (e.g. different colours for each bar chart under the same category). Graduating shades of one colour should be used instead.
22. A darker or lighter shade, or a different colour, can be used to emphasise a specific point or data value.
23. Multiple colours could be used when conveying different meanings or "labelling", i.e. distinguishing one element from another.
24. Multiple background colours or even a colour gradient (ranging from light to dark) should be avoided because it makes some elements look different than others, when they should look exactly the same.
25. Contrasting (i.e. different) colours should be used to draw attention, and analogous (i.e. similar) colours to group elements.
26. Grey should be used for contextual and second-level information, as well as for structural elements such as grid lines.
27. Thematic representations of colours in charts should be avoided (e.g. red and green to show Christmas sales).
28. Red should not be used for positive numbers in a bar chart, as it is strongly associated with loss, but can be used effectively for negative values.
29. Colour can be used to set a tone. For example, deep blue for conservative and bright colours for cheerful things.
30. Warm colours should be used for elements that need to be in the foreground, because warm colours such as red and orange are perceived as being in front of a cooler colour such as green and blue and black.
31. Deeper saturations and greater intensities should be used to indicate greater amounts.

Research Findings

- Colour was found to reduce the number of eye movements needed to extract relevant information.
- Chart comprehension accuracy was found to be similar for colour and black and white charts, but users respond more quickly to charts with colour information.
- When multi-colour charts were presented to users, decision-making was made more quickly and accurately.
- Some highly saturated colours were found to cause overestimations of size for geographic regions.

Rationale

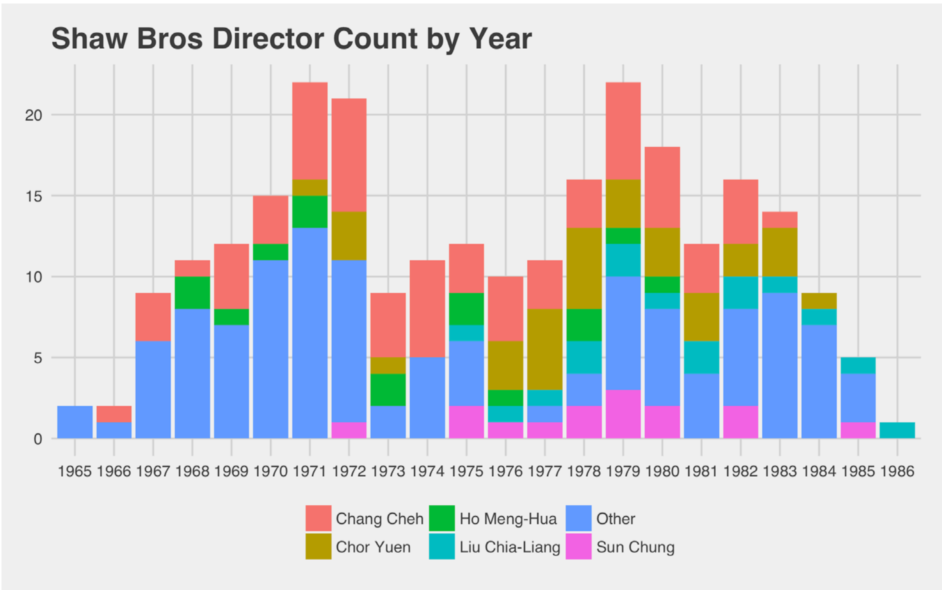
The first rule of using colour in data visualisation is to avoid chaos and do no harm. Colour misuse is commonly found in data visualisation due to using too many colours, using too much of one colour, and using colour in all the available white space. Overall, poor use of colour distracts, obscures and confuses the user.

Although there is a natural aesthetic component associated with colour, in data visualisation using colour is primarily about function. When a chart contains multiple variables, the use of colour can help reduce cognitive load, as it helps the user to discriminate more easily between different variables. When using paler and more soothing colours to encode data (e.g. the colours of bars, lines and points), charts can be analysed more comfortably and with less distraction. When using colours that are darker and greyer, or more pastel (closer to white), the design will look more sophisticated. This will then allow the use of more intense colours for emphasis. When using colour to organise information, colour can help to group related items and guide user attention in proportion to importance. When using a limited palette of two or three colours, with saturation variations within these colours, the data visualisation will look both functional and aesthetically pleasing. Above all, it minimises visual clutter and unnecessary effort from the user to make sense of the information.

Guidelines: Kosslyn, 1994, 1996 and 2004; Shah and Hoeffner, 2002; Few, 2005c; Stone, 2006; Stewart et al., 2009; Ali and Peebles, 2013; Gelman and Unwin, 2013; Wong, 2013; Mollerup, 2015; Stones and Gent, 2015; Berinato, 2016 Asada et al., 2017; Coyle et al., 2017.

Research findings: Cleveland, 1984; Cleveland and McGill, 1984; Benbasat and Dexter, 1985; Stewart et al., 2009.

Rationale: Tufte, 1990; Few, 2005c; Kosslyn, 2006; Stone, 2006; Stewart et al., 2009; Wong, 2013; Coyle et al., 2017.



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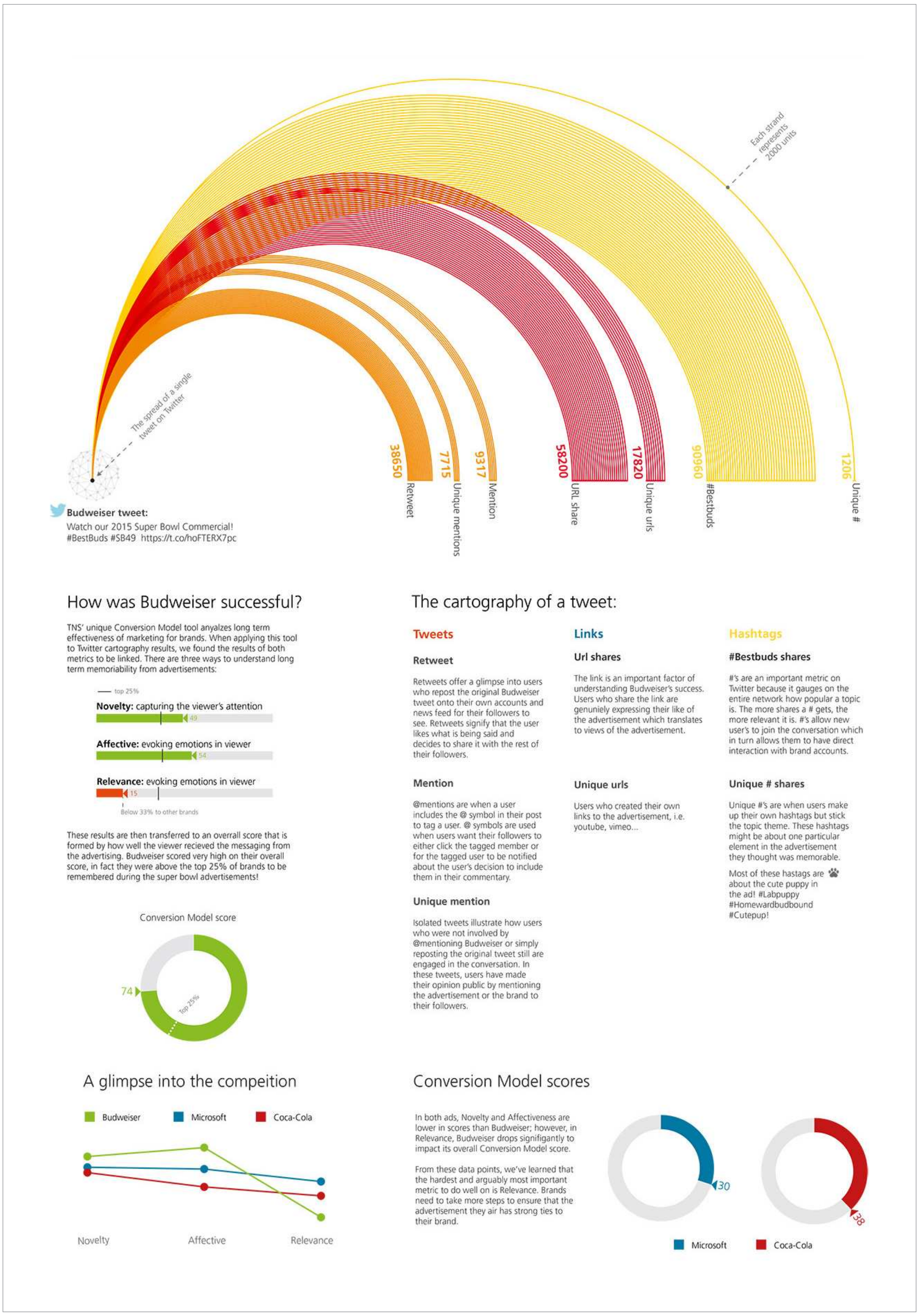


Figure 28. A Data Driven Exploration of Kung Fu Films (first) | **Figure 29.** Twitterography Mapping an ad on Twitter (second)

The colour palette used in Figure 28 lacks harmony and the colour contrast gives the sensation of vibration. This, in addition to stacked bar charts, makes information very difficult to access. In Figure 29, although various colours are also used, they are used more sparingly, tastefully and in a balanced way that does not distract form the information.

5.4 Graphics | Visual elements

Guidelines

1. Symbols, bars, and lines can be used to increase discriminability among data, but should be used consistently when used across similar charts.
2. Overlapping data symbols should be avoided.
3. White space is a powerful element that can be used effectively to draw attention to the chart.
4. Meaningful axis ranges should be selected.
5. A zero baseline should be used, especially with bar charts. With time-series plots, scatter plots, etc., a nonzero baseline can be used but the user must be alerted so that such detail is not missed.
6. The same axis scales and ranges should be applied to charts that are being used for comparison.
7. The aspect ratio (relative height and width) and data density (chart size) should be carefully selected to avoid misrepresenting the data.
8. Backgrounds should be used to make the chart salient, not to compete with it. Therefore, background elements should not resemble, or group with, the content elements.
9. Grid lines can be used as a structural element and only to facilitate accurate analysis. However, these should be secondary lines that are lighter in weight, colour, or style.
10. A secondary y-axis (i.e. another vertical axis on the right-hand side of a chart) might be appropriate in certain situations, but generally should be used with caution or avoided altogether.
11. Visual explanatory cues (e.g. icons) can be used to explain the data better.
12. Tick marks should be placed at regular intervals and extended inside the axis.
13. Larger tick marks should be placed where the axis labels are and halfway between the labels.

Additional practice-based guidelines

14. Points can be used effectively to identify a specific location on a chart, due to their unstated shape and presence. When only a single set of values needs to be encoded (requiring only a single shape), dots should be used because of their visual simplicity.
15. Lines can be used to show trends and patterns of change, and to show values according to their location in relation to the scales along the axes.
16. Points and lines are also a good option to facilitate comparison between individual values at particular points in time.
17. Reference lines can be used to mark meaningful and critical instances.
18. Bars can be used to show quantitative values in two ways: at the bar's endpoint and through the bar's length.

19. The zero baseline should be slightly thicker than the grid line.
20. Inner grid lines should pass behind the lines or bars.
21. Interval scales should be used with caution to avoid altering the data and misinforming the user.
22. Y-axis increments should be simple and reflect the natural way we count, such as 0, 5, 10, 15, 20, etc.
23. If two y-axes are used, different colours or patterns can be used to distinguish the data that corresponds to each axis.
24. Instead of using a secondary y-axis, an alternative approach should be used. For example: a) data points that belong on the secondary y-axis should be labelled directly; b) the charts should be pulled apart vertically, with each having a separate y-axis along the left, but still having the same x-axis for both; c) the y-axis should be linked to the data by using colour (for example, using a blue title and having the matching bars in blue as well).
25. The height-to-width ratio of the axes should be large enough to allow the user to easily discriminate differences in the data.

Research Findings

- Background pictures were found to give some kind of advantage in data visualisation and in certain conditions. The conclusion from the findings was, however, that this does not support the use of unnecessary decoration.
- An example of using extra visuals (extra ink) to improve performance under conditions in which perceptual and cognitive processes are required, was shown in Neisser (1964) and Treisman and Gelade's (1980) research. They observed that when a search target (circle) and background elements (squares) had different features, the target was especially easy to find.

Rationale

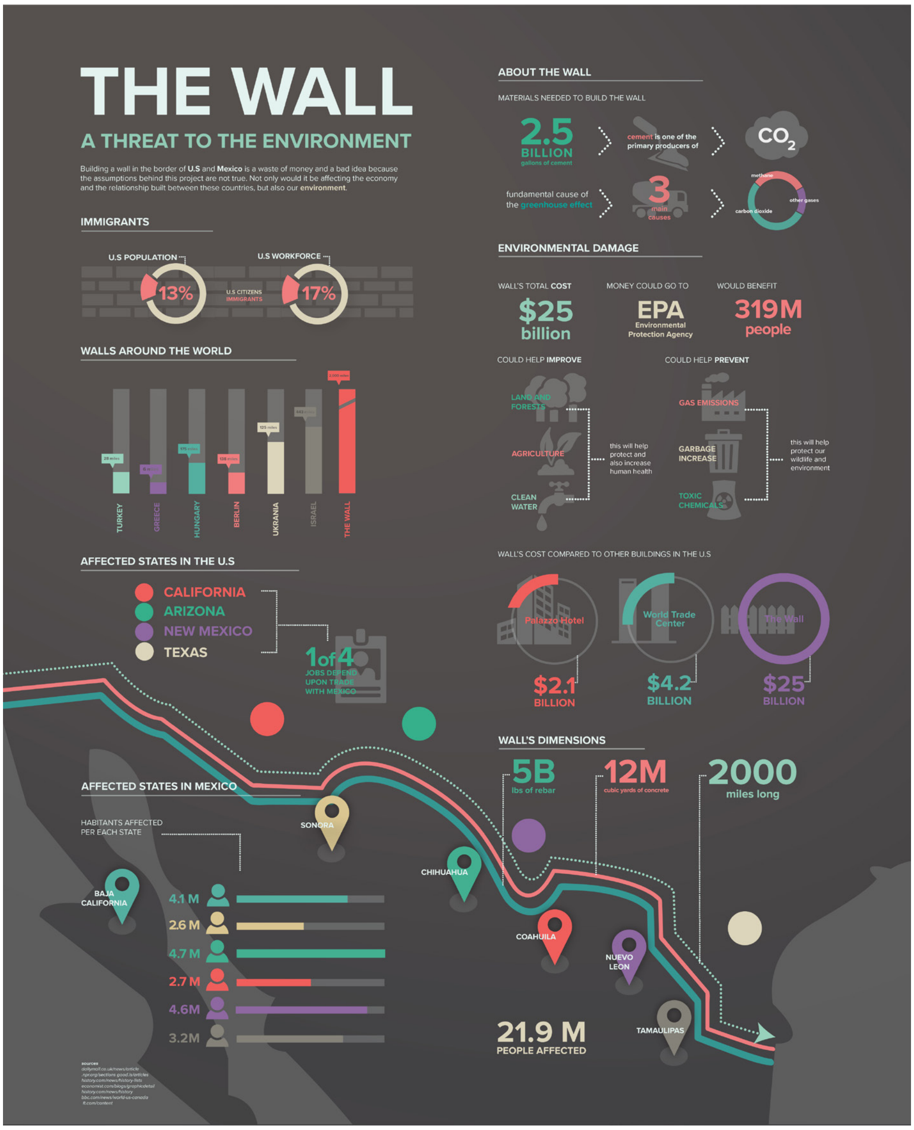
The three visual elements that work most effectively to encode quantitative values are points, lines, and bars. Each element is suitable to communicate particular quantitative messages. Scatter plots is one of the very few circumstances when points can be used by themselves (i.e. without a line) to encode quantitative values based on a horizontal and vertical location. When it comes to lines, only the ends of each segment of a line marks the locations of values. As for bars, compared to points and lines, these are visually the most dense of the three elements.

Size and colour are much less effective than points, lines and bars. It is easy to see that one circle is bigger than another, or darker than another, but it is very difficult to clearly see by how much. In terms of background, research has shown that if distinctly different features are used sparingly, it can help the user remember the chart or engage the user, but should be used with caution and with enough contrast for the data to stand out. Grid lines are almost always considered chart junk because users can usually perceive approximate values without the help of grid lines. Therefore, more often than not they only distract from the real data and should be avoided.

Guidelines: Pasternak and Utt, 1990; Hibbard et al. 2002; Few, 2004b, 2005b, 2006 and 2012; Kosslyn, 2006; Gerteis et al. 2007; Hildon et al., 2011; Wong, 2013; Knaflic, 2015; Berinato, 2016; Asada et al., 2017; Coyle et al., 2017.

Research findings: Sorensen, 1993; Gillian and Sorensen, 2009.

Rationale: Few, 2004b, 2005b, 2006; Sorensen, 1993; Gillian and Sorensen, 2009.



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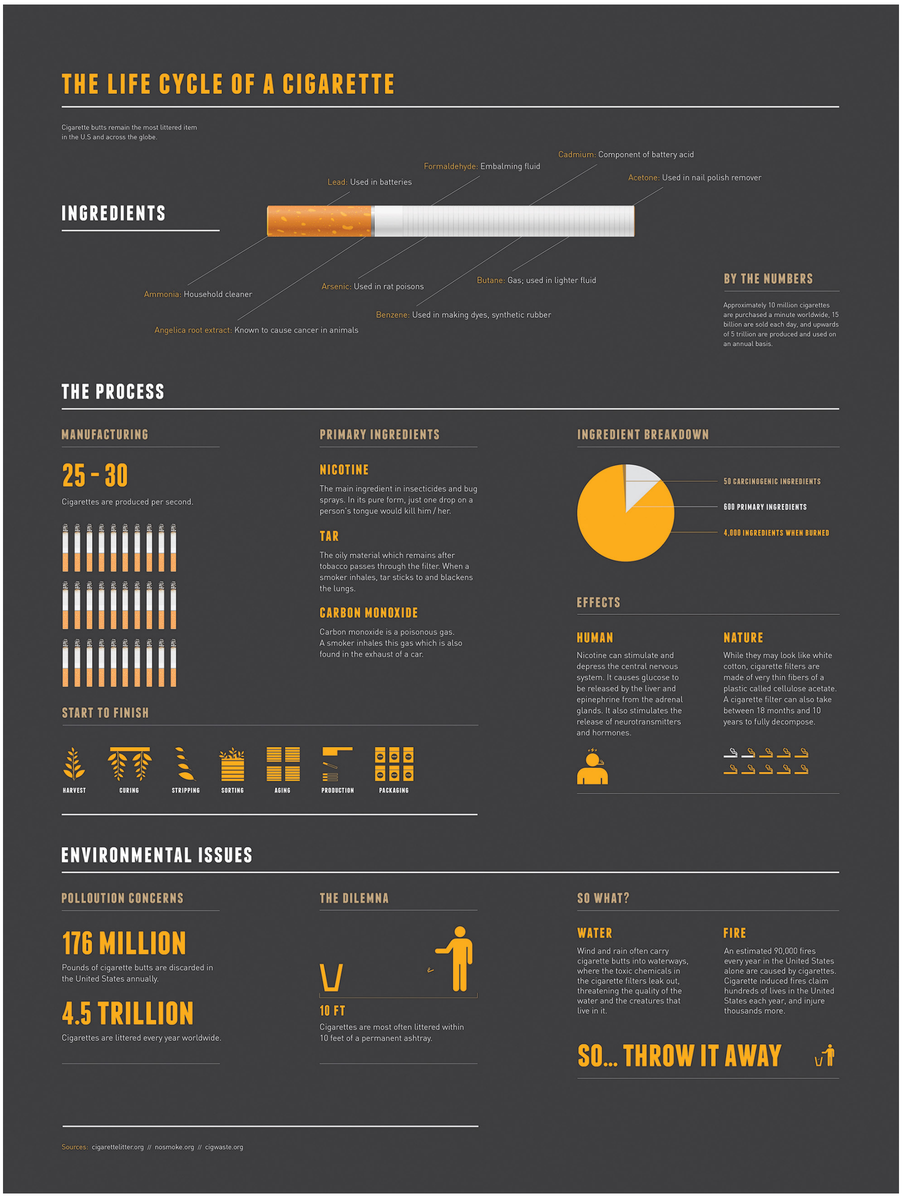

Figure 30. The Wall: A Threat to the Environment (first) **| Figure 31.** Throw It Away- Lifecycle of a Cigarette (second)

In Figure 30, graphic elements such as icons, are actually hidden and highly de-emphasised by all the other high contrast elements that simply take over the entire infographic. However, even de-emphasied, they still manage to interfere with the legibility of the information, and the text in particular. In Figure 31, icons are given more prominence, and therefore contribute in equal terms as the other elements to the communication of the information. Using just one colour for emphasis also makes the infographic more balanced and clearer overall.

5.5 Chart junk

Guidelines

1. Once the primary function of communicating the information and data is achieved, then aesthetics can be considered.
2. Embellishment (which goes a bit further than aesthetics and works more like decoration) is a possibility when recall is required, but is never necessary.
3. Embellishment should only be used when adequately selected and designed, and only with the purpose to give meaning to information.
4. Narratives, images, and metaphors that are sufficiently vivid could be considered to grab and retain the user's attention, but care should be taken not to distract and stimulate unnecessary emotion.
5. The higher the amounts of data and complexity, the lower the number of embellishments should be.

Additional practice-based guidelines

6. Care should be taken in particular with software that makes it too easy to decorate the message with distracting visual content.
7. Unnecessary, extraneous, decorative, or irrelevant items or information in a chart should be eliminated, while maintaining the meaning.
8. Every element in a chart should be necessary and designed as simple as possible.
9. When detail is not needed, the information should be summarised.
10. Necessary elements that do not clearly have an impact on the message, should be de-emphasised by pushing them to the background (for example, using light grey, as opposed to black).

Research Findings

- Embellished charts were not found to have an effect on accuracy or speed of comprehension when compared to a plain version.
- When testing a series of embellished bar charts, none performed better at communication the data than standard bar charts.
- Users were found to pay more attention to the data areas when plain charts were used than when embellished charts were used.
- Embellished charts with a good degree of legibility were found to have an effect on long term rather than short term recall memory. After a long-term gap of 2-3 weeks, recall of both the chart topic and the details was significantly better for embellished charts than for plain charts.
- Charts with a degree of embellishment, rather than being purely plain, were cited as most preferred.

- When adding icons to a bar chart, three times more users remembered the chart and the gist of the data. This embellished version was also found to be more appealing than the plain bar chart version.

Rationale

The main question when it comes to discussing chart junk, is whether embellishments assist the data, or simply serve to distract from it, or even distort the data. Embellishments that are not data in themselves, can assist effectively in the communication of data: a) when wanting to engage the interest of the user and ensure that the user reads the message b) when wanting to draw the user's attention to particular elements that should be noticed to make sense of the information c) when there is a need to make the message more memorable.

The way that chart junk seems to improve retention is that it forces the user to make cognitive effort to understand the chart, consequently increasing their knowledge and understanding of the data. However, chart junk is not the only factor that can influence the user's interpretation and recall of the visualisation. Type, colour, structure, and layout, have as much influence on our cognitive workload and retention. Moreover, with over-embellished charts, users might focus on particular areas only, while ignoring more meaningful areas of the visualisation. Chart junk may result in beautiful data visualisations, but fail to communicate information effectively.

Overall, data visualisation can be used successfully to attract attention, stimulate interest and even persuade, but should never be used if information needs to be worked hard to be accessed and perceived. Embellishment in particular is certainly not a replacement for good data organisation and clear presentation of ideas.

Guidelines: Few, 2004a; Spiegelhalter et al., 2011; Borkin et al., 2013; Wong, 2013; Knaflic, 2015; Stones and Gent, 2015; Berinato, 2016; Burgio and Moretti, 2017.

Research findings: Inbar et al., 2007; Bateman et al., 2010; Borkin et al., 2013; Li and Moacdieh, 2014; Skau, et al., 2015; Stones and Gent, 2015.

Rationale: Friedman, 2008; Bateman et al., 2010; Few, 2011; Hulman, et al., 2011; Borgo et al., 2012; Dur, 2012; Moere, et al., 2012; Borkin et al., 2013; Wong, 2013; Gelman and Unwin, 2013; Li and Moacdieh, 2014; Stones and Gent, 2015.

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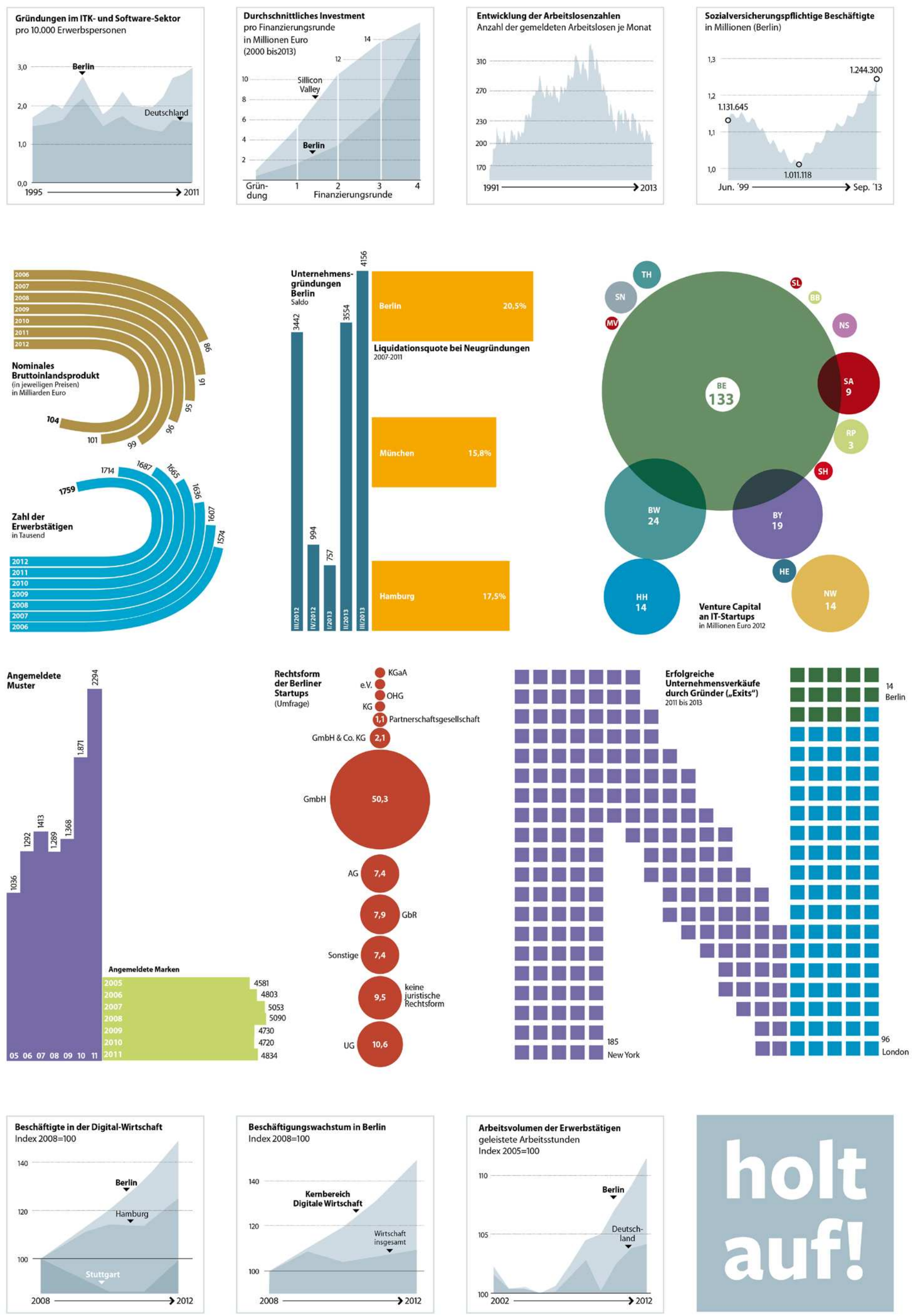

BM Infografik Christian Schlippes, Heike Assmann

Quellen: IBB, BA, Patentamt, BITKOM, Mc Kinsey, questfox.com, Müller, B. (2012): Hightech-Gründungen, VBKI, Volkswirt. Gesamtrechnung der Länder, einige Werte gerundet

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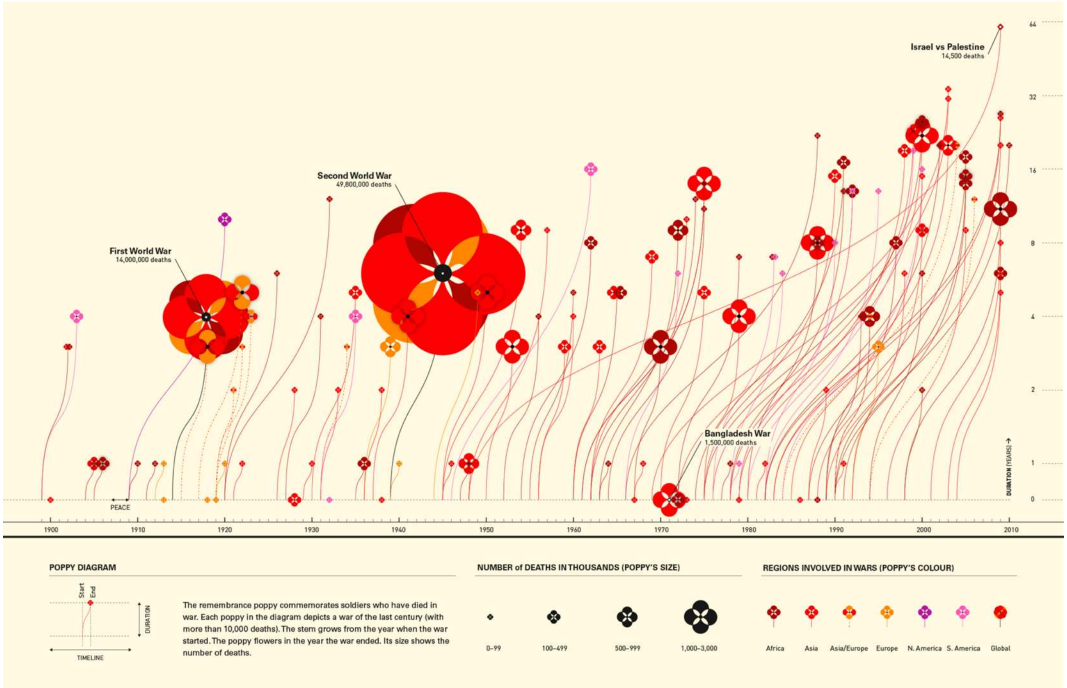
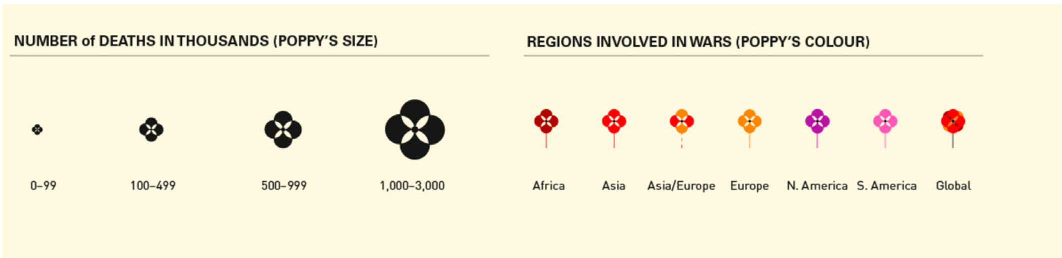




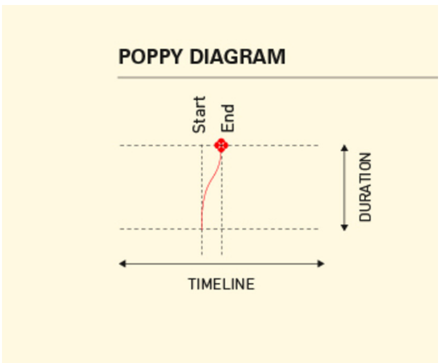


Figure 32. Berlin Startups (first) | **Figure 33.** Field of Commemoration (second)

Although displaying a balanced layout, the infographic in Figure 32 uses data with the primary purpose of embellishment, which ends up distracting from the information and making it difficult to interpret the data. The infographic in Figure 33, however, despite using embellishment, uses it with the purpose of reinforcing the message, in this case the link to the poppies used to remember those killed in war. Moreover, the legend given is very comprehensive, leaving no doubts as to how to interpret the data. All in all, this is a beautiful infographic that, despite its embellishment, achieves its core message.

5.6 Tables

Guidelines

1. Tables should be used for tasks requiring looking up numbers, to compare individual values; when values involve multiple units of measure; when precise values are required.
2. Tables should fade into the background so that the data stands out. To that end, heavy borders or heavy shading should be avoided and white space should be used instead.
3. If white space alone cannot be used, then light borders, light rules or subtle filling colours should be used instead to set apart elements of the table.
4. Grids in tables should be avoided.
5. To emphasise, distinguish or mix the detail in a table, visual cues such as heat maps can be used. That is, in addition to the numbers, cells can be coloured to show the relative magnitude of the numbers.
6. Alternating grey background, or using grid lines for every entry in a table, should be avoided because our eyes can easily follow numbers across a table.
7. Thin rules, however, can be used after every three to five entries (three entries if the table is wide) to help follow the numbers across the table. Moreover, if the table only has two columns, then there is no need for lines.
8. Shading can be used if a column of relevant numbers needs to be highlighted (e.g. the one with the main message).
9. Entries in a table should be ordered in a logical manner.
10. Whole numbers should be flushed right, but if the numbers are small (1 or 2 digits), then they can be centred.
11. Decimal numbers should be aligned on the decimal point, and the decimals should be rounded-off.
12. The unit (such as the % or £/$ sign) should only be displayed with the first entry.

Research Findings

- Tables were cited as being better than charts for point reading and recall.
- Tables were found to be a more accurate choice than charts for people with poorer perception ability.
- Tables containing icons, words or numbers were found to be sometimes easier to understand than bar charts.
- In some studies users were found to react favourably to tables, or prefer them over other data formats.

Rationale

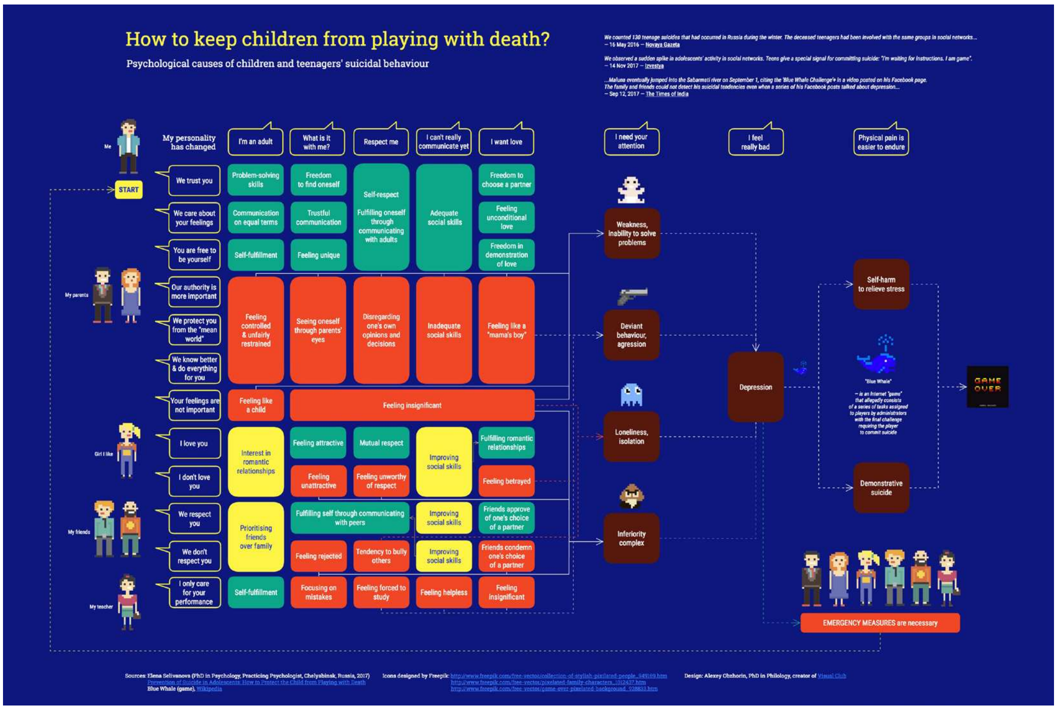
Tables are a good option when communicating to a mixed audience to allow each user to look for their particular row or column of interest. Tables are equally good when communicating multiple different units of measure.

When looking at a table, users scan across rows and down columns to see which numbers are high or low and mentally rank them. Therefore, it is essential to de-emphasise those elements that are only being used to structure the data. However, using colour saturation to organise the data within cells can help to decrease this arduous mental processing by providing visual cues and helping to access and understand the data more quickly.

Guidelines: Few, 2004a and 2012; Gelman and Unwin, 2013; Wong, 2013; Knaflic, 2015

Research findings: Vessey 1991; Brown, 1992; Elting et al., 1999; Gerteis et al., 2007; Hawley et al., 2008; Hildon et al., 2011.

Rationale: Knaflic, 2015.



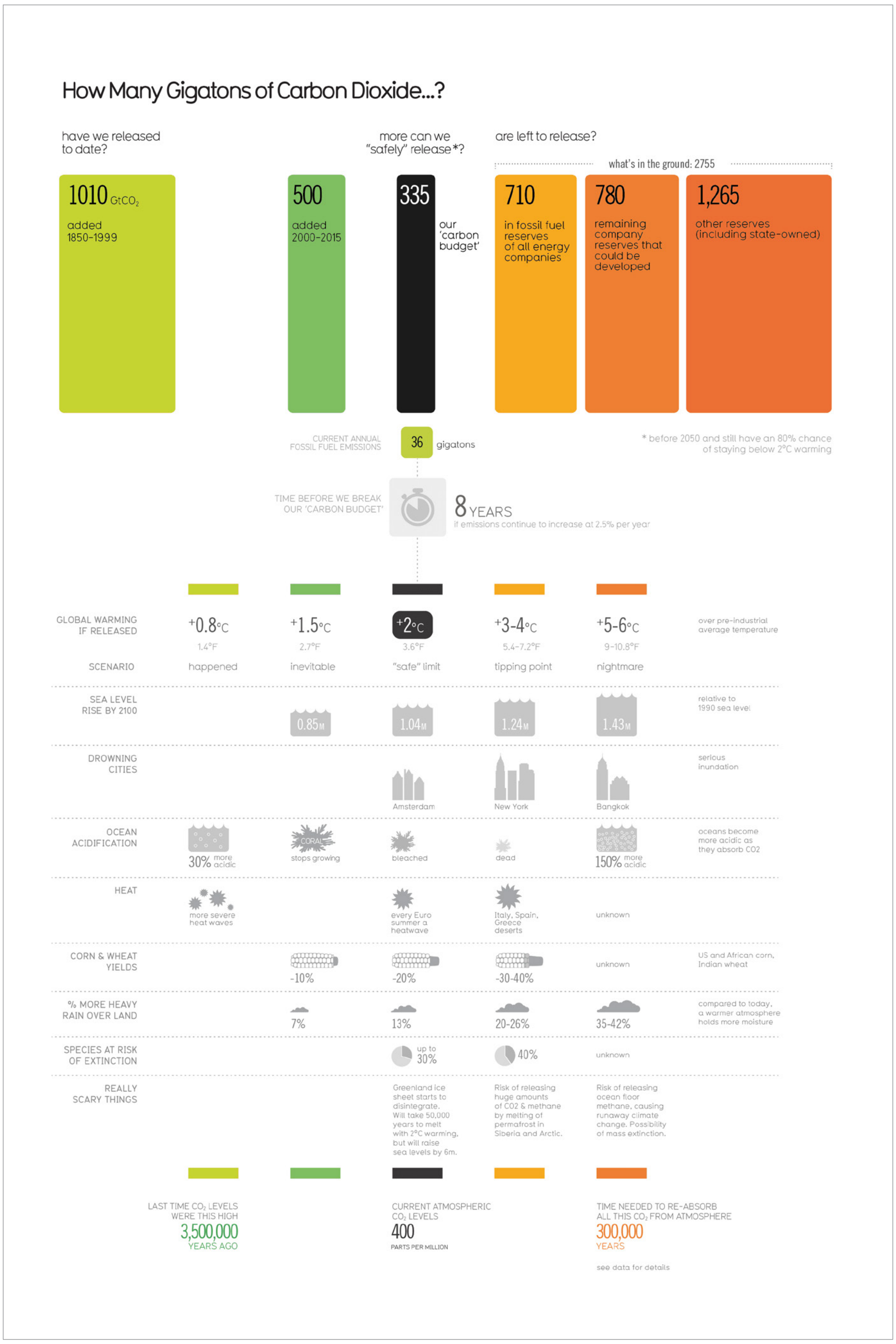


Figure 34. How can we keep children from playing with death? (first) | **Figure 35.** How many gigatons of carbon dioxide? (second)

The infographic in Figure 34 uses the concept of gaming to address, in a lighter way, a sensitive issue such as the causes of children and teenagers suicidal thoughts. However, the visual tone contradicts that, as it presents a very heavy piece of information. Colours are overwhelming, the text is just squashed within boxes, etc. Figure 35 is the antithesis of that. The chart is light, well organised, with some icons to appeal to a broader audience, a well balanced colour palette where colour is not used in excess. Moreover, secondary information and graphic elements are de-emphasised and pushed to the background, while still legible and with a function.

5.7 Charts in general

Guidelines

1. The primarily purpose of chart design should be to present relevant data precisely and effectively. After this is achieved, design should be used make the chart more attractive and interesting.
2. Charts should be simple, and visual clutter should be avoided at all costs.
3. Care should be taken not to over-embellish data-rich charts.
4. The choice of display format should be sensitive to the task at hand and the message to be communicated.
5. More bespoke, unusual and visually compelling chart formats should be used with caution and tested to ensure understanding
6. Cognitive load should be reduced by minimising the amount of information conveyed in any individual chart, but also by using meaningful colours, symbols, direct labelling lines or bars, instead of relying on legends.
7. The eye should be encouraged to compare different pieces of data, but comparison of different denominators (e.g. 1 in 100, 1 in 1000) should be avoided.
8. For less mathematically proficient users (low in quantitative numeracy) numerical information could be presented in frequencies instead of percentages for better understanding.
9. Statistical reports with the aid of tables and charts should be used instead of narrative-only reports, as with the latter the reaction from readers was found to be more positive.
10. Context or conclusions adjacent to the charts should be provided when needed.
11. The number of data dimensions shown in each chart should be limited.

Additional practice-based guidelines

12. When choosing a visual display for the data, the following questions should be asked: What does the user need to find out? What is the best chart for the specific need? Is this chart the easiest for the user to interpret?
13. To help the user process information within complex charts, a clear visual hierarchy should be in place whereby important elements are highlighted, distractions are eliminated, and visual order is established.
14. Once the chart has been selected and designed, it should be tested by showing it to users, and ascertain: where the user focuses; what the user sees; what observations the user makes; what questions does the user have. This will confirm whether the right chart is being used, or inform what changes need to be made.
15. Super-categories can be used effectively to organise the data and give the user a construct to help interpret and process the data. For example, 20 different demographic breakdowns can be organised and clearly labelled into groups or super-categories such as age, race, income level, and education.

Research Findings

- Visual clutter was found to increase fixation time.
- Comprehension of charts was found to depend on the task to be performed, and that each chart can help to fulfil a different and specific goal.
- Tables, charts and the combination of tables and charts, when compared to narrative only data, were found to decrease the amount of reading time.
- Adding icon arrays and bar charts to numerical information was found to lead to an increase in reading accuracy.
- Users were found to like consistency and being helped to interpret and bring information together through visual explanatory cues.
- The use of visual cues (icons and words) was found to help clarify the meaning of the data and assist in making the right choice.
- Unique visualisation types (pictorial, grid/matrix, trees and networks, and diagrams) were found to have significantly higher memorability scores than common charts (circles, area, points, bars, and line charts).
- Men were found to react more favourably to statistical reports that incorporated more charts. Overall, females were found to react more positively than men to various data visualisation formats, with reports that include tables having the most favourable reaction.
- When asked "Which of the following numbers represents the biggest risk of getting a disease? 1 in 100, 1 in 1000, or 1 in 10?", 25% of U.S. users and 28% of German users answered incorrectly. This was due to some users only looking at the biggest number out of either the numerator or denominator.
- Numerical information in the form of frequencies rather than percentages was found to be more easily grasped by people low in quantitative numeracy.
- For comparison of the relative size of two categories, judgment was found to be most accurate along a common scale (simple bar chart), was of intermediate accuracy when assessing length (divided or stacked bar charts), and was the least accurate when assessing angles (pie charts).
- For estimating the absolute size of proportions, bar charts showed similar results to pie charts. Comprehension based on divided bar charts was found to be worse than bar charts and pie charts. Tables were also found to take longer to read, but were more accurate and faster than line charts. When axes and scales on bar charts were not provided, estimating proportions was found to be easier with pie charts than with bar charts.
- For estimating differences, a bar chart was found to be more accurate than a pie chart in a population of cancer patients but not in a population of students.
- For judging which of two categories was bigger, tables and bar charts were found to be similar in terms of accuracy, while pie charts were found to perform worse than bar charts. It was also found that providing a scale for this type of task improved accuracy, and providing the numerical value in addition reduced the time needed to complete the task. Moreover, under time pressure, tables performed worse than the other charts.
- For judging which of two sums of proportions are greater, pie charts were found to be more accurate than bar charts because neighbouring cells are visually easy to sum.
- For identifying trends and patterns, charts were found to be more accurate than tables.

Rationale

Charts are compelling as they assist the user in understanding better the story behind the data. Charts are also perceived as a simpler form of information. Care should be taken, however, when using different formats of charts. As tempting as it might be to use more unusual charts due to their attractiveness, some formats do not give relevant, clear, or any, information, and only serve to confuse the user.

Supporting text can play a vital role in data interpretation. For example, using text to describe the main point of a chart, by highlighting the data in the text or caption, and making sure the text has a format consistent with the chart, can be extremely useful to guide users to better interpret the data. This is also important when targeting novice chart users, as they are usually influenced by their own prior knowledge. When it comes to statistical reports, a brief description of the visualisation and other relevant information (e.g. conclusions, interactions and patterns found, and even recommend next steps) can also help to better relay the story and make a statistical report more accessible and more digestible.

One particular factor to be cautious with when selecting charts is the number of data dimensions (a data dimension conveys a single level of measurement and categorisation). The higher the number of data dimensions in a chart, the more arduous it is for the user to understand patterns in each individual data dimension. For example, a time-series plot displays only two dimensions of data: one along the y-axis, and another across the x-axis that represents time. A bubble chart, on the other hand, can display as many as five dimensions of data: the x-axis, the y-axis, the size of each bubble, the colours of grouped bubbles, and the animated dimension of time, which is very arduous for the user to interpret and process. Three dimensions charts, for example 3D bar charts, also lack precision and are misleading, as it is difficult for the user to understand which data point to consider, i.e. the front side of the bar or the far side of the bar.

Guidelines: Peterson, 1983; Shah and Hoeffner, 2002; Renshaw et al., 2004; Stewart et al., 2009; Goldberg and Helfman, 2010; Schonlau and Peters, 2012; Woller-Carter et al., 2012; Gelman and Unwin, 2013; Wong, 2013; Li and Moacdieh, 2014; Knaflic, 2015; Stones and Gent, 2015; Asada et al., 2017; Coyle et al., 2017; Pjesivac et al., 2017.

Research findings: Cleveland and McGill 1984, 1985; Simkin and Hastie 1987; Peterson, 1983; Spence, 1990; Spence, et al. 1991; Vessey 1991; Meyer et al., 1997; Hollands and Spence, 1998; Meyer et al., 1999; Feldman-Stewart et al., 2000; Hibbard et al. 2002; Renshaw et al, 2004; Gerteis et al. 2007; Fasolo et al., 2010; Heer and Bostock 2010; Garcia-Retamero and Galesic, 2010; Galesic and Garcia-Retamero, 2011; Hildon et al., 2011; Schonlau and Peters, 2012; Borkin et al., 2013; Stones and Gent, 2015; Pjesivac et al., 2017.

Rationale: Pasternak and Utt, 1990; Shah and Hoeffner, 2002; Stones and Gent, 2015; Coyle et al., 2017.

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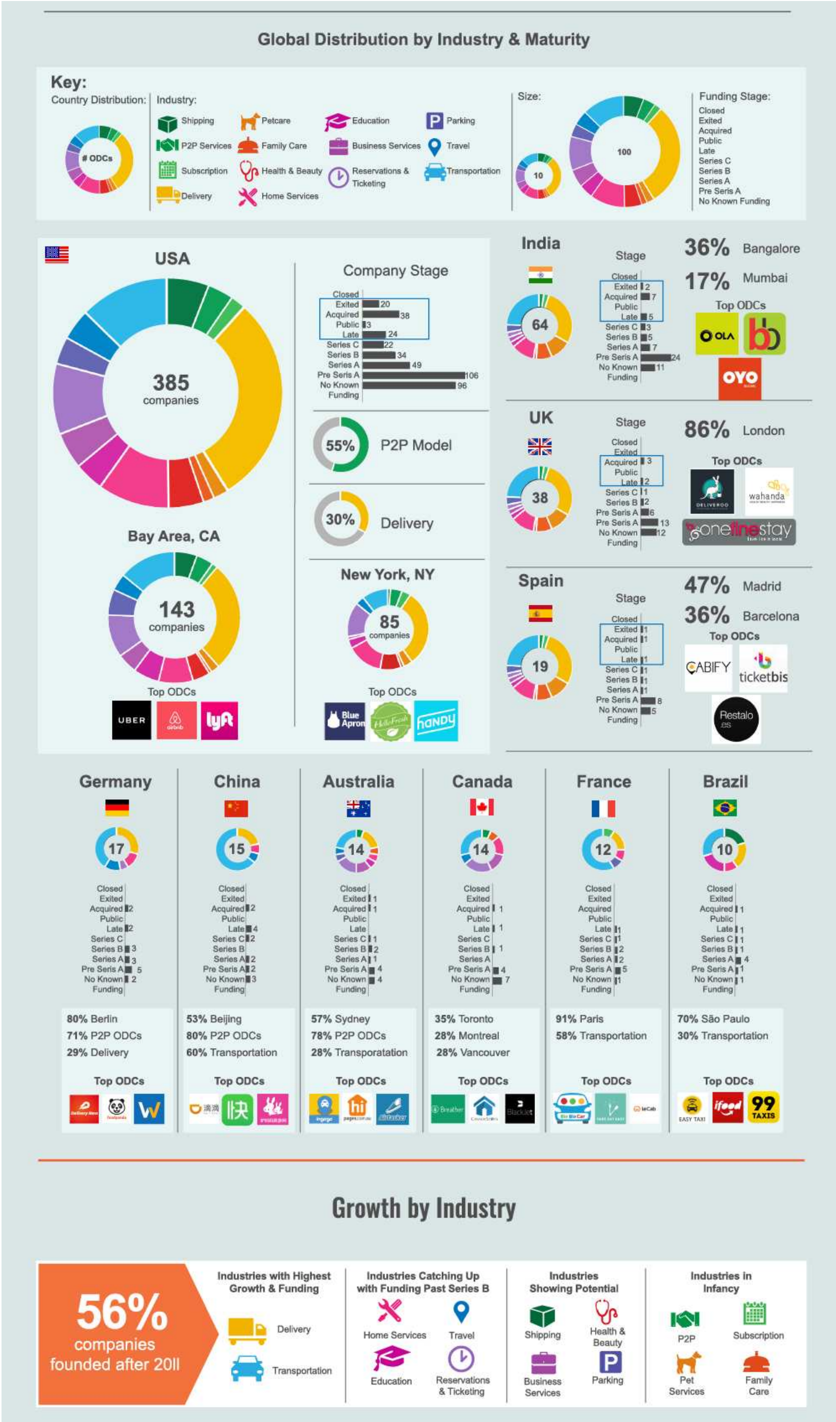
Global Distribution by Industry & Maturity
Key:
Country Distribution:
ODCs
Industry:
Shipping
Petcare
Education
Parking
P2P Services
Family Care
Business Services
Travel
Subscription
Health & Beauty
Reservations & Ticketing
Transportation
Delivery
Home Services
Size:
100
10
Funding Stage:
Closed
Exited
Acquired
Public
Late
Series C
Series B
Series A
Pre Seris A
No Known Funding
USA
385
companies
Company Stage
55% P2P Model
30% Delivery
Bay Area, CA
143
companies
Top ODCs
New York, NY
85
companies
Top ODCs
India
64
Stage
36% Bangalore
17% Mumbai
Top ODCs
UK
38
Stage
86% London
Top ODCs
Spain
19
Stage
47% Madrid
36% Barcelona
Top ODCs
Germany
17
80% Berlin
71% P2P ODCs
29% Delivery
Top ODCs
China
15
53% Beijing
80% P2P ODCs
60% Transportation
Top ODCs
Australia
14
57% Sydney
78% P2P ODCs
28% Transporatation
Top ODCs
Canada
14
35% Toronto
28% Montreal
28% Vancouver
Top ODCs
France
12
91% Paris
58% Transportation
Top ODCs
Brazil
10
70% São Paulo
30% Transportation
Top ODCs
Growth by Industry
56%
companies
founded after 20ll
Industries with Highest Growth & Funding
Delivery
Transportation
Industries Catching Up with Funding Past Series B
Home Services
Travel
Education
Reservations & Ticketing
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Shipping
Health & Beauty
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Subscription
Pet Services
Family Care

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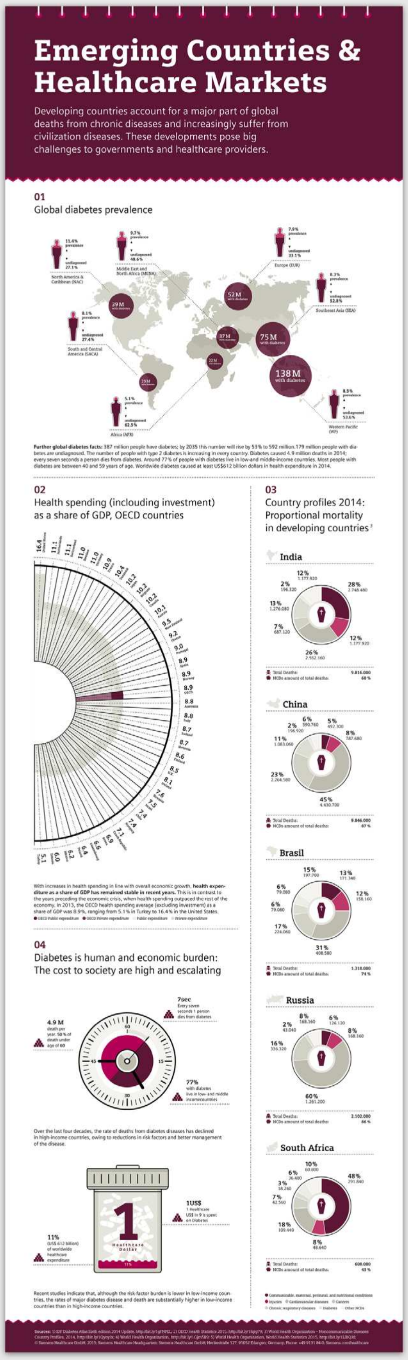


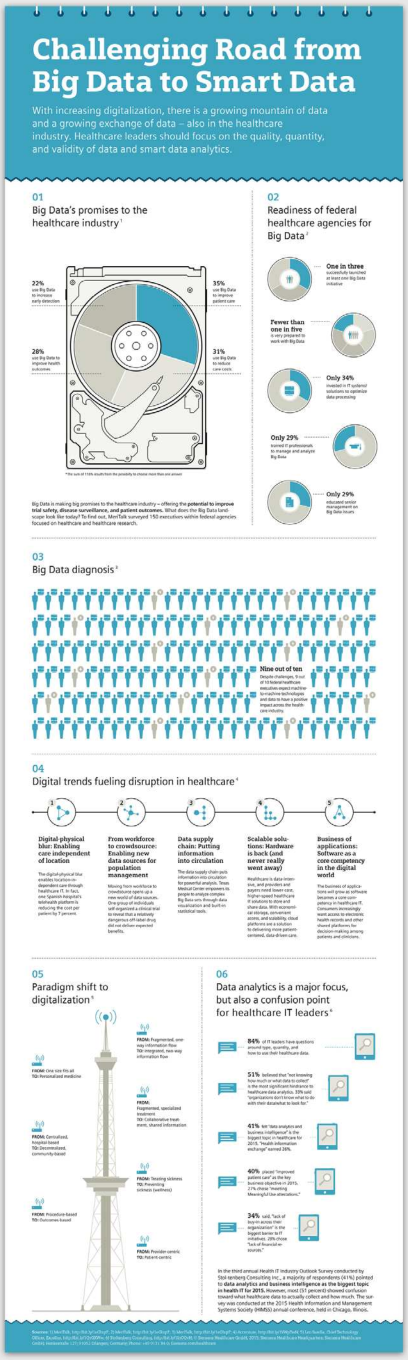


Figure 36. The on-demand economy (first) | **Figure 37.** Global Trends in Healthcare (second)

The many multi-coloured donut charts presented in Figure 36 make the infographic too busy, while the many fragments per chart with very little direct labelling make it very arduous to access and interpret the data. This is further aggravated by the inclusion of many other coloured icons and brand logos. In Figure 37, where only one colour plus shades of grey are used in the infographic, cognitive load is reduced. Although there are still a few donut charts to interpret, they are less overwhelming and have plenty of direct labelling presented in a coherent, balanced and legible way.

5.8 Bar charts

Guidelines

1. Bar charts can be used for discrete data comparison and absolute or relative frequencies where the bars are closely positioned.
2. Bar charts should be kept simple.
3. The amount of data should be limited, and no more than 12 bars should be used in a single bar chart.
4. Multiple-bar charts should be avoided. If used, they should have a plain design.
5. When dealing with various categories, consideration should be given to filter and arrange the categories into larger, more comprehensive groups, as this will limit the number of bars.
6. Grouping bars should be done with care, as it will influence the way data is communicated and interpreted.
7. With grouped bars, a hierarchy can be used so that the user is able to look at each bar and get a better understanding of the story.
8. Stacked bar charts can be used to show both absolute and percentage data.
9. Stacked bar charts should generally be avoided, as they are complex. If used, consideration should be given to providing helpful interpretations of the data.
10. Adding embellishments to stacked bar charts should be avoided.
11. Colour, simple textures, or simple shapes might be ok for simple bar charts in order to help recall and make it more appealing to the user.

Additional practice-based guidelines

12. Bar charts can be used for single series, two series, or multiple series.
13. Bars should only be used with a quantitative scale that begins at zero. This is because with bar charts our eyes compare the relative end points of the bars. Having a zero baseline is necessary for an accurate comparison, as it will give context for the entire bar (not just the top of the bar).
14. The scale of a bar chart should not be changed to manipulate or distort the data, as this is unethical.
15. Bars should not extend beyond the end of the scale.
16. Multiple-bar charts should not have more than four categories (i.e. no more than four bars in each group), as it is difficult for users to compare too many bars.
17. Corresponding bars should be visualised and arranged in the same way.
18. Emphasising/colouring individual bars should be deliberate.
19. Outliers (i.e. outstanding values) capture attention, but if there is no space for them, then a clearly marked broken bar can be used instead.
20. Bars should not be overlapped.
21. If bars are overlapped, care is needed so that they do not look like stacked bars.
22. The space between the bars should be narrower than the bars. About half the width.

23. Bars, however, should not be too wide, as it will lead the user to compare areas instead of length.
24. With multiple-bar charts, visual grouping should be defined by manipulating the space between the bars within each group (less space), as well as between each group of bars (more space).
25. Colour should not be used to distinguish multiple bars, as rainbow colour bars are even more arduous to follow.
26. If fill colours are used, these should be clearly distinct, and more intense colours can be used to emphasise particular values.
27. Shading bars should be done from lightest to darkest for easy comparison.
28. Shadows should not be created behind the bars.
29. When all the bars measure the same variable, the colours or shades inside the bars should be the same to avoid confusing and distracting the user.
30. A darker or lighter shade bar can be used to distinguish projections/expectations/estimates from actual values.
31. A grey background can be used when a negative area of a bar chart needs to be identified (i.e. below zero).
32. Fill patterns should be avoided in bar charts (horizontal, vertical, diagonal lines).
33. Borders around bars should only be used if the colour does not contrast with the background, or if one bar needs to be emphasised against the other bars. In such cases, a light grey line can be used.
34. Direct labelling (i.e. data labels inside the bar, or right next to them) should be used to reduce clutter and can be also used for multiple-bar charts with two categories.
35. Labels with type at an angle (e.g. on a 45-degree slant) placed on the x-axis should not be used for vertical bar charts. A horizontal bar chart with labels on the left-hand side should be used instead.
36. The y-axis labels in bar charts should be placed on the left-hand side, so that the user sees how to interpret the data before getting to the actual data.
37. On certain occasions, to reduce clutter further, the y-axis might be deemphasised by making it grey, or eliminated entirely and only the data labels are shown within the bars and close to the data points (still making sure that the axis begins at zero, even if not visible).
38. Values that are too small to be shown by a bar can be shown by a number only.
39. A legend should be used for multiple-bar charts with three or four categories.
40. When a legend is used, the order of elements in the legend should follow the same sequence as the bars.
41. Legends are key to the understanding of information, and therefore should not be placed below the chart.
42. Divided bar charts can be used, so long each column adds to 100%.
43. Labels that identify single segments in a divided vertical bar chart (and percentages, if necessary), can be positioned on the right of the bar.
44. If a scale is needed, and only one bar is being displayed, then the scale should be positioned on the left-hand side.
45. As divided bar charts can also show accumulated percentages, these should be shown on the left-hand side of the bar.
46. A divided bar chart should not have more than five or six parts. This is even more important if several stacked bar charts are compared. If needed, as in a pie chart, the smallest parts can be grouped together to reduce the number of parts.

47. When using a 100% divided vertical bar chart, it should be considered whether the absolute numbers for each category total should also be included to facilitate interpretation of the data and comprehension (by direct labelling or in a footnote).
48. Showing divided bar charts side by side for comparison introduces another variable. Such variable can be shown along the x-axis with a label under each bar.
49. In multiple divided vertical bar charts the segments that change the least amount should be placed at the bottom.
50. Stacked vertical bar charts can be used to show absolute numbers (not percentages), compare totals across categories, and also see the subcomponent pieces within a given category.
51. Stacked bar charts are visually overwhelming, and even more so when a varied colour scheme is used.
52. Labelling and position of the segments can follow the same guidelines as for divided bar charts.
53. Horizontal bar charts (i.e. a vertical bar chart flipped on its side) should be considered because they are extremely easy to process, especially considering our way of processing information in zigzag shapes.
54. Horizontal bar charts should be used instead of vertical bar charts if the category names are long.
55. When precise reading is important, direct labelling can be used to show the exact value of each bar directly on the bar or at the end of the bar, which then makes the scale on the x-axis unnecessary.
56. Horizontal bars should never be used for time-series values.
57. Ordering of categories should take into account the zigzag shape of information processing. This is because users will look at the top of the chart first. Therefore, it makes sense to put the biggest or most important category first, and the remaining categories in decreasing numerical order or in decreasing order of importance. If, however, what needs to be emphasised is the smallest category, then that category should be put first and the remaining in ascending order.
58. Horizontal bar charts can be used to rank items by value (e.g. age groups) or by alphabetical order.
59. If plotting horizontal bars over a period of time, the bars should be ordered from the most recent data point at the top, and go downwards and back in time.
60. If there is no natural ranking order, then data should be ordered in the way that will make the most sense to the users.
61. For very long lists of horizontal bars, specific data points flushed right should be included and thin rules should be used to separate the bars in groups of three to five bars to help the users read across.
62. Vertical grid lines and scale should be avoided in horizontal bar charts, because it makes it even more difficult to distinguish the relative length of the bars. Instead, direct labelling should be used.
63. If most of the values are negative, then a vertical bar chart should be used unless the labels are too long and cannot be placed underneath the bars.
64. If a horizontal bar chart needs to plot only negative values, these should never be plotted on the right-hand side of the zero line.
65. Labels for horizontal bar charts with negative and positive values should be positioned on either side of the baseline, respectively, or all flushed left.
66. Bars with negative values can be shaded darker to distinguish them from the positive ones.

67. Stacked horizontal bar charts can be used successfully to visualise portions of a whole on a scale from negative to positive (e.g. for Likert scale, which ranges from Strongly Disagree to Strongly Agree).
68. Two-way bar charts should be avoided (e.g. demographic charts plotting the number of males on one side and females on the other).
69. To compare two sets of bars on opposite sides, it is better to use two data series as a multiple-bar chart.
70. If a two-way bar chart is used, the x-axis should be marked using the same scale on both sides of the y-axis.
71. In two-way bar charts the bars should be ordered to emphasise interactions.
72. Pairs of bars (i.e. across both sides of the two-way bar chart) should be labelled on one side only, and preferably on the left-hand side because it is our natural way of processing information.
73. 3D bar charts must be avoided, as they add no information.

Research Findings

- Simple bar charts with one or two variables were found to work well.
- Vertical bar charts were found to be better understood when compared with horizontal bar charts or pie charts.
- Stacked bar charts were found to perform less well than simple formats.
- Comprehension for stacked bar charts was found to be worse, except with the easiest tasks.

Rationale

Bar charts are very easy to interpret because it simply involves comparing the end points of the bars, assessing which category is biggest or smallest, and understanding the incremental difference between the categories. Bar charts, however, are sometimes neglected because they are more common. Instead, this should be seen as a benefit, because faced with a more common format, the user will spend less time and effort to understand the chart. That time can instead be spent making sense of the visual information.

Horizontal bar charts in particular, with category names on the left-hand side, are extremely useful and legible because the text is written from left to right, and this is how English native speakers (and most users) process information. Moreover, when there are no other visual cues, we typically process information in the shape of a Z, i.e. we start at the top left and then move our eyes across zigzagging in "Z" shapes. This means that our eyes will see the category names before the data. Therefore, when we access the data in a horizontal bar chart, we already know what it means, and do not have to go back and forth between the category names and the data (like we do in a vertical bar chart).

There are other variations of bar charts, however, that are not as simple for our eyes to read. For example, stacked bar charts cause confusion, are too complex and unnecessary. With stacked vertical bar charts, once the user goes beyond the bottom series (the one directly next to the x-axis), it is very difficult to compare the remaining subcomponents because the baseline used for comparison is no longer consistent for all bars. This is an arduous comparison to make.

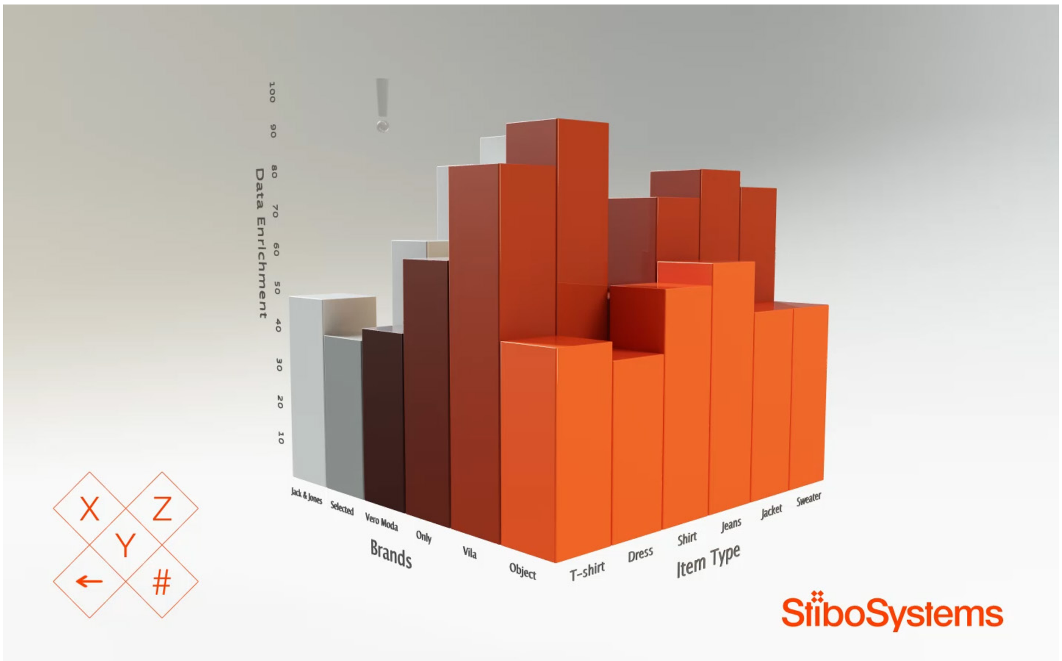
3D bar charts are also difficult and misleading, and only add unnecessary and distracting elements to the bar chart, such as side and floor panels. More importantly, 3D skews numbers because it creates a lower front end point and a higher back end point, confusing the user as to which one to consider.

In terms of visual elements, colour is the one to be most cautious with. Unnecessary use of different colours in bar charts when the bars are part of the same data, will only make it difficult for the user to see all the bars as a single related data set. It will also make it difficult to see the relationships among the bars as they range from the largest value to the smallest.

Guidelines: Simkin and Hastie, 1986; Carswell and Wickens, 1987; Kosslyn, 1994 and 2006; Shah et al., 1999; Zacks and Tversky, 1999; Shah and Hoeffner, 2002; Few, 2004c, 2006 and 2012; Schonlau and Peters, 2012; Wong, 2013; Knaflic, 2015; Mollerup, 2015; Siricharoen and Siricharoen, 2015; Stones and Gent, 2015; Kirk, 2016; Asada et al., 2017; Coyle et al., 2017.

Research findings: Feldman-Stewart et al., 2000; Hibbard et al., 2002; Hildon et al., 2011; Schonlau and Peters, 2012; Stones and Gent, 2015.

Rationale: Few, 2004c; Schonlau and Peters, 2012; Wong, 2013; Knaflic, 2015; Stones and Gent, 2015.



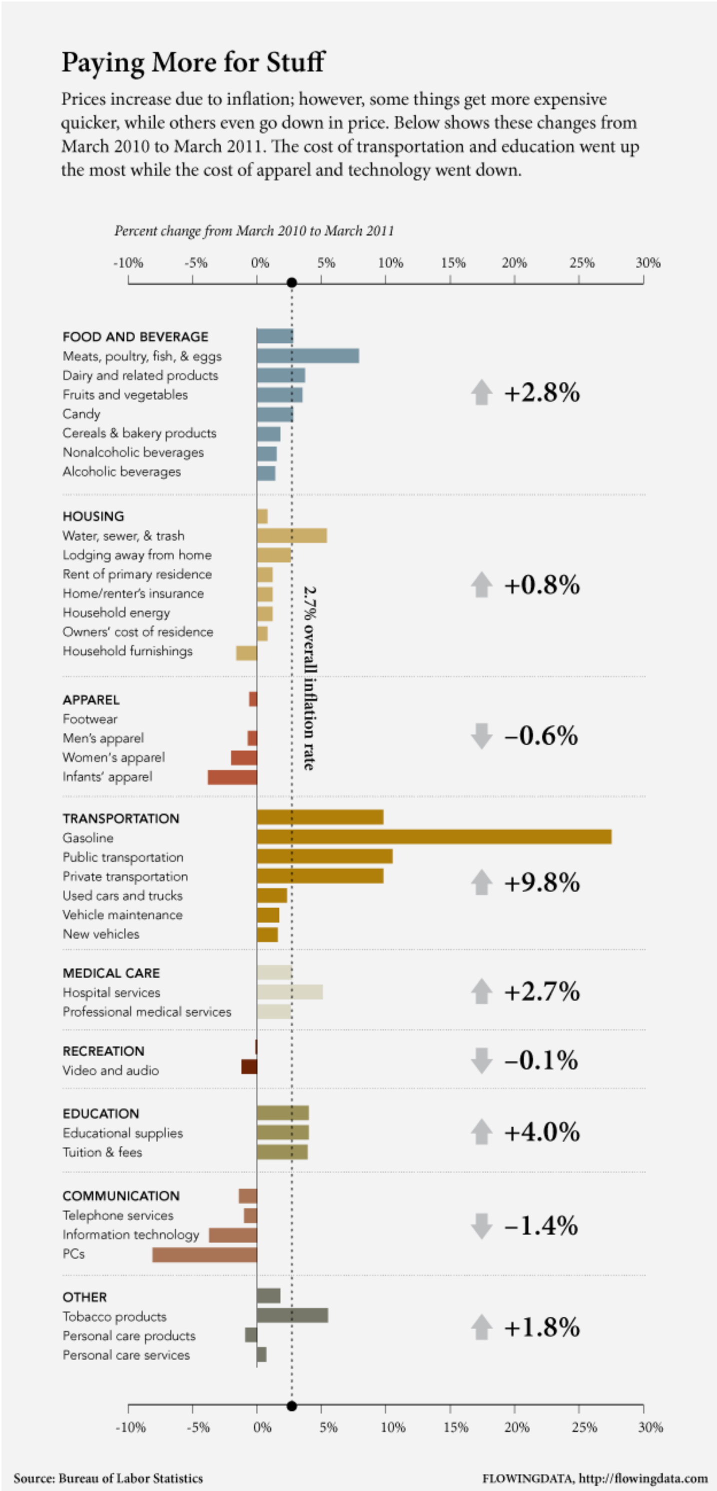


Figure 38. Data Enrichment Visualization (first) | **Figure 39.** Paying more for stuff (second)

Figure 38 is a good example of how 3D bar charts, even with a balanced colour palette, are very difficult to interpret and lack precision of data. Figure 39 shows a good example of using horizontal bar charts for long labels, as well as a good approach for cases where several bars need to be displayed that relate to different categories of data. All in all, it is a well balanced chart with clear text and a soft colour palette that does not distract from the information and data.

5.9 Line charts

Guidelines

1. Line charts can be used to emphasise x–y trends, represent quantities in terms of spatial extent, and communicate trends in data and time series, i.e. to show development over a period of time.
2. In line charts, simple designs should be chosen, direct labelling of lines should be used, and including too many variables should be avoided.

Additional practice-based guidelines

3. A zero baseline is not needed for line charts, but this decision should be made with caution, and a baseline still needs to be clearly marked.
4. If a zero baseline is not used, it should be made clear to the user. Moreover, the context should be also taken into account so that the data is not over-zoomed and minor changes or differences do not appear significant when they are not.
5. In line charts, care should be taken not to choose a y-axis scale that makes the line too flat, nor a y-axis scale that creates an overly exaggerated line that does not represent the data fairly.
6. No more than three or four lines should be used in a single chart (four if the lines are not intersecting).
7. With more than three data series, a set of individual charts should be used instead.
8. Very thin or very thick trend lines should be avoided.
9. A thick line or a line in a different colour or texture can be used, however, for distinction or to emphasise importance.
10. In a multiple-line chart, if black and white is used, then the most important data series should be represented by the darkest line; if colour is used, then the most important data series should be one full colour, and the other lines should be shades of a second colour.
11. A line with warm colours should always be in front of cold colours (e.g. red or orange over blue or green).
12. The area below a line in a chart, or between two lines, should never be shaded because it will turn it into an area chart.
13. When multiple trend lines need to be communicated, then each line should be in a separate chart with its own axis and displayed as a panel of charts where the most important panel appears first.
14. If the lines are too close together, a legend should be used instead of direct labelling, and its order should match the ranking of the end points because they are the most current data points.
15. When some data is missing in a line chart, a label can be used to explain the gap.
16. If a line goes from negative to positive numbers, a grey tone can be used to distinguish the area that is below the zero baseline.
17. Data points can be emphasised with dots.

18. When lines connect discrete points, these should be made at least twice as thick as the line and discriminable enough.
19. An annotated line chart can be used to show various important incidents through a period of time, where direct labels are placed close to those incidents.

Research Findings

- Line charts were found to be more effective than bar charts, and users were more likely to describe x–y trends (e.g., as x increases, y decreases) when viewing line charts than when viewing bar charts.

Rationale

Plotting various lines on the same chart leads to confusion and fails to achieve the aim of a chart, which is to communicate and help interpret data. Therefore, line charts should be considered only if the benefits of showing many trend lines side by side outweighs the cost of increased difficulty in interpreting the data. This complexity is further aggravated when using multi coloured lines. The suggestion would be, however, to have a set of different charts when more than three data series need to be conveyed. Keeping the clarity of each single line facilitates comparison and processing.

If line charts are to be used, understanding can be improved by emphasising certain elements. For example, by annotating a point on a line chart with a value or a piece of text, to draw attention to the fact that such a point has an important role in the message being communicated. Or, by referencing the point with a noun in the caption. Certain parts of a line chart, however, will be naturally emphasised without having to do anything. This applies, for example, to sudden large rises or falls in a line and segments at the end of a line chart (as they show the end of the quantitative changes).

Guidelines: Carswell and Wickens, 1987; Carpenter and Shah, 1998; Lipkus and Hollands, 1999; Shah et al., 1999; Zacks and Tversky, 1999; Shah and Hoeffner, 2002; Kosslyn, 2006; Few, 2012; Wong, 2013; Knaflic, 2015; Mollerup, 2015; Kirk, 2016; Asada et al., 2017.

Research findings: Carswell et al., 1993; Shah et al., 1999; Zacks and Tversky, 1999; Shah and Hoeffner, 2002..

Rationale: Wu et al., 2010; Wong, 2013; Coyle et al., 2017.

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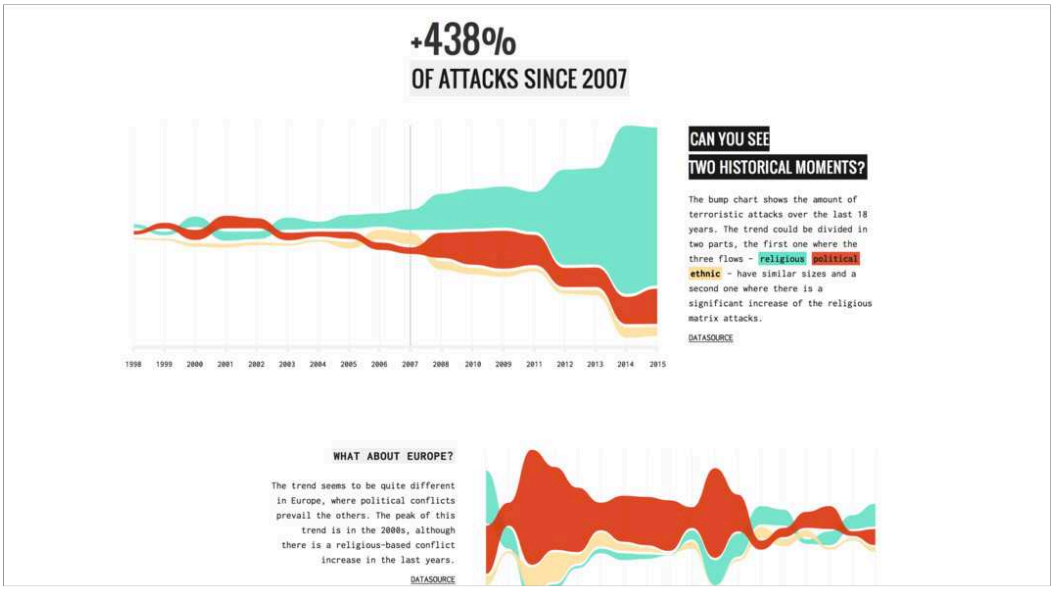


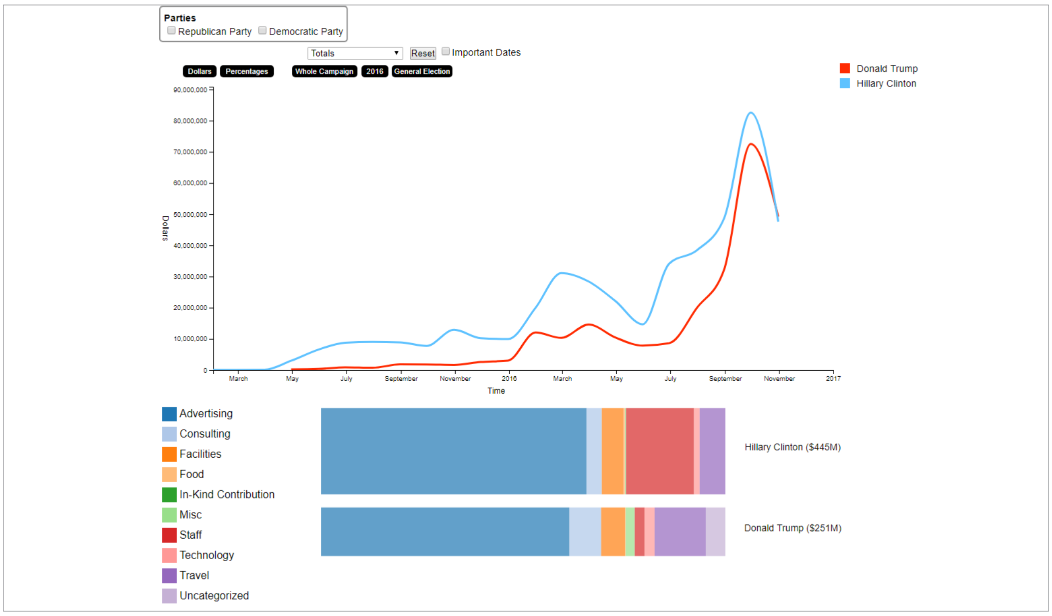


Figure 40. It's not so ISIS (first) | **Figure 41.** 2016 US Campaign Expenses (second)

The line chart in Figure 40 is an example of how filling the space between lines creates an area, which should be carefully considered. However, in this case serves its purpose of not just quantifying the occurance of attacks through a timeline, but also the amount of attacks throughout that period. The line chart in Figure 41 is very simple in nature, which makes it clear and accessible. This line chart is also well complemented by the divided horizontal bar chart giving extra information on the type of expenses (it is a shame, however, that no direct labelling is given for the bar chart to increase understanding and precision of information).

5.10 Pie charts

Guidelines

1. Pie Charts can be used for part-whole assessment, but not for representation of exact numbers.
2. Pie charts can be used for percentage data and relative proportions.
3. Pie charts can be used to represent quantities in terms of area or angle size.
4. Pie charts should be accompanied by text that clarifies the main message.
5. Direct labelling should be used for segments of pie charts to give the exact number/portion
6. Multiple pie charts should be avoided because they do not convey information clearly.
7. The centre of the pie chart should not be obscured. Therefore, donut charts should be avoided, as they are even more difficult to interpret than pie charts.

Additional practice-based guidelines

8. Generally, pie charts should be avoided because they are hard to interpret. This is even more the case with colour, exploded, donut and 3D pie charts.
9. Pie charts can be used to illustrate simple, but not complex relationships among many segments.
10. The sum of the parts, the full pie should represent a whole, i.e. 100%.
11. Absolute numbers should not be used in pie charts as users expect to see percentages.
12. Pie charts should not contain more than five slices, and if there are more than five, then the smaller and less significant segments should be combined and labelled 'other' to create the fifth slice.
13. In case there are too many segments, and these need to be displayed separately, then a stacked segmented bar chart should be used.
14. Segments in a pie-chart should be displayed clockwise: a) when the slices are close in value, the largest slice should be at 12 o'clock on the right and go clockwise from largest to smallest; b) when there is a much bigger slice that will take over half of the pie, the largest segment should be at 12 o'clock on the right; the second biggest slice should be at the 12 o'clock on the left; and the rest would follow counter-clockwise (the smallest slice would therefore fall near the bottom of the chart, which should be the least significant position).
15. Pie charts with three slices, 'Yes', 'No, and 'Don't know', should be organised in that precise order.
16. Further segmenting within a slice should not be done. Instead, an additional bar chart should be used, not a new pie chart.
17. Different shading can be used to highlight relevant segments, and the highlighted segment does not need to be the largest slice. If a smaller slice is highlighted, the elements should not be reordered.

18. To highlight a segment, only one technique should be used instead of two or more (e.g. shade and pulling out the slice should not be used together).
19. If the wedges of the pie chart are too small, then instead of direct labelling, the label should be placed outside, but right next to the wedge.
20. Exploded pie charts should be avoided, but if used for emphasis, only twenty-five per cent of the wedges should be exploded, otherwise nothing is emphasised.
21. A donut pie chart could be used to show the total value of the pie inside the chart.

Research Findings

- Although pie charts were not found to assist comprehension, they often did not significantly impair comprehension either.
- When a small number of users were tested, pie charts were found to be an effective way of communicating proportion in both plain and embellished styles.
- When a large number of users were tested, pie charts were found to perform the least well for accurate verbatim knowledge (i.e., the ability to correctly read numbers from charts) when compared to tables, unit charts and bar charts. But, pie charts were found to perform the best for gist knowledge (i.e., the ability to identify the essential point of the information presented).
- Some users were found to struggle to read percentages from a pie chart.
- Donut charts were found to generate the most variability in opinions, with users confused with the labelling of the rings within the donut. However, the simplicity of the display appealed to some participants.
- Donut charts were found to be no worse than pie charts.
- Nested donuts (and radial bar charts) were found to be problematic because they require comparison of circles of different radius and area. However, the area and arc length are important for effective comparison.
- Arc length was found to be important. Changing the radius (based on data or just for aesthetic reasons) was found to interfere with the ability to read the chart.
- Bar charts and line charts were found to be more effective at comparing values than pie charts.

Rationale

Pie charts are helpful in the sense that they have introduced millions of users to data by providing a tangible sense of numerical relationships where the data are parts of a whole. However, overall, pie charts are problematic because it is difficult to compare categories within a pie chart.

The rationale is that it requires users to examine angles and discern an exact number, which humans cannot achieve with precision. For example, if the segments are close in size it is extremely difficult to discern which one is bigger. If segments are not close in size, then the only thing we can see is that one is bigger than the other, but cannot really tell by how much. Moreover, angle judgments tend to be bias because acute angles are usually underestimated, while obtuse angles are usually overestimated. One suggestion to overcome such problems is to provide direct labelling to help the user to interpret individual segments and make comparisons between segments.

More elaborated pie charts, such as 3D pie charts, exploding pie charts, and donut charts, make data processing even more difficult and should be avoided. Donut pie charts, for example, are very appealing, but less accurate than the other two formats. This is because the hole in the middle makes the areas become smaller and the angles practically non-existent. Therefore, to make sense of a donut chart the user is faced with the arduous task of comparing the areas of the donut sections or the distances along the inner and outer edges.

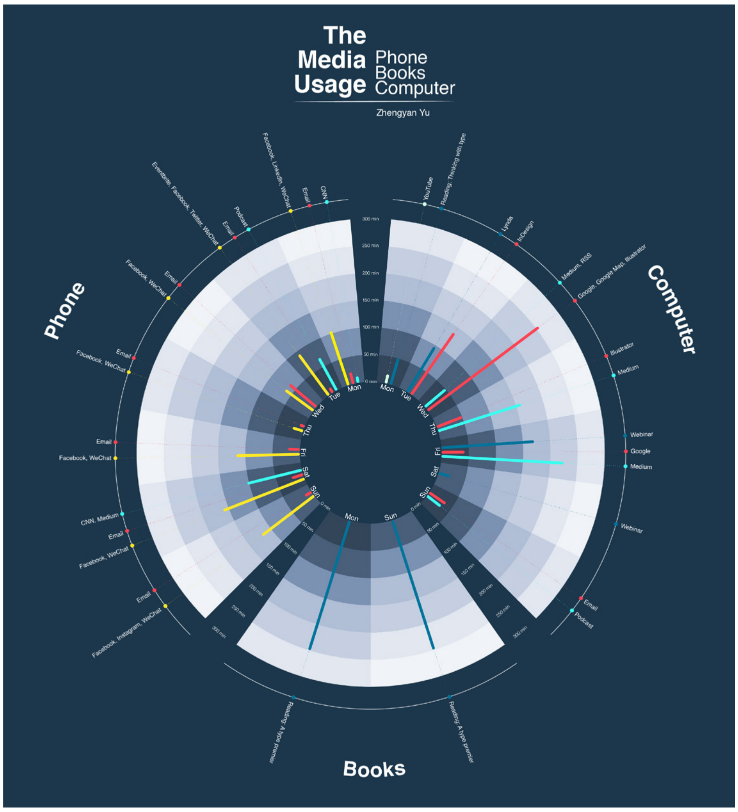
Multiple pie charts can also be very appealing with all of their colours, circles, and dimensions, but they are not efficient in conveying information clearly either.

Overall, comparison involving angles is more difficult than comparison along scales, as is the case with bar charts.

Guidelines: Lipkus and Hollands, 1999; Shah and Hoeffner, 2002; Kosslyn, 2006; Few, 2012; Wong, 2013; Knaflic, 2015; Kozak et al., 2015; Mollerup, 2015; Stones and Gent, 2015; Kirk, 2016.

Research findings: Hawley et al., 2008; Galesic and Garcia-Retamero, 2011; Schonlau and Peters, 2012; Le et al., 2013; Skau, et al., 2015; Stones and Gent, 2015; Skau and Kosara, 2016.

Rationale: Cleveland and McGill, 1984; Cleveland, et al. 1984; Few, 2012; Schonlau and Peters, 2012; Gelman and Unwin, 2013; Le et al., 2013; Wong, 2013; Knaflic, 2015; Kozak et al., 2015; Mollerup, 2015; Stones and Gent, 2015; Coyle et al., 2017.



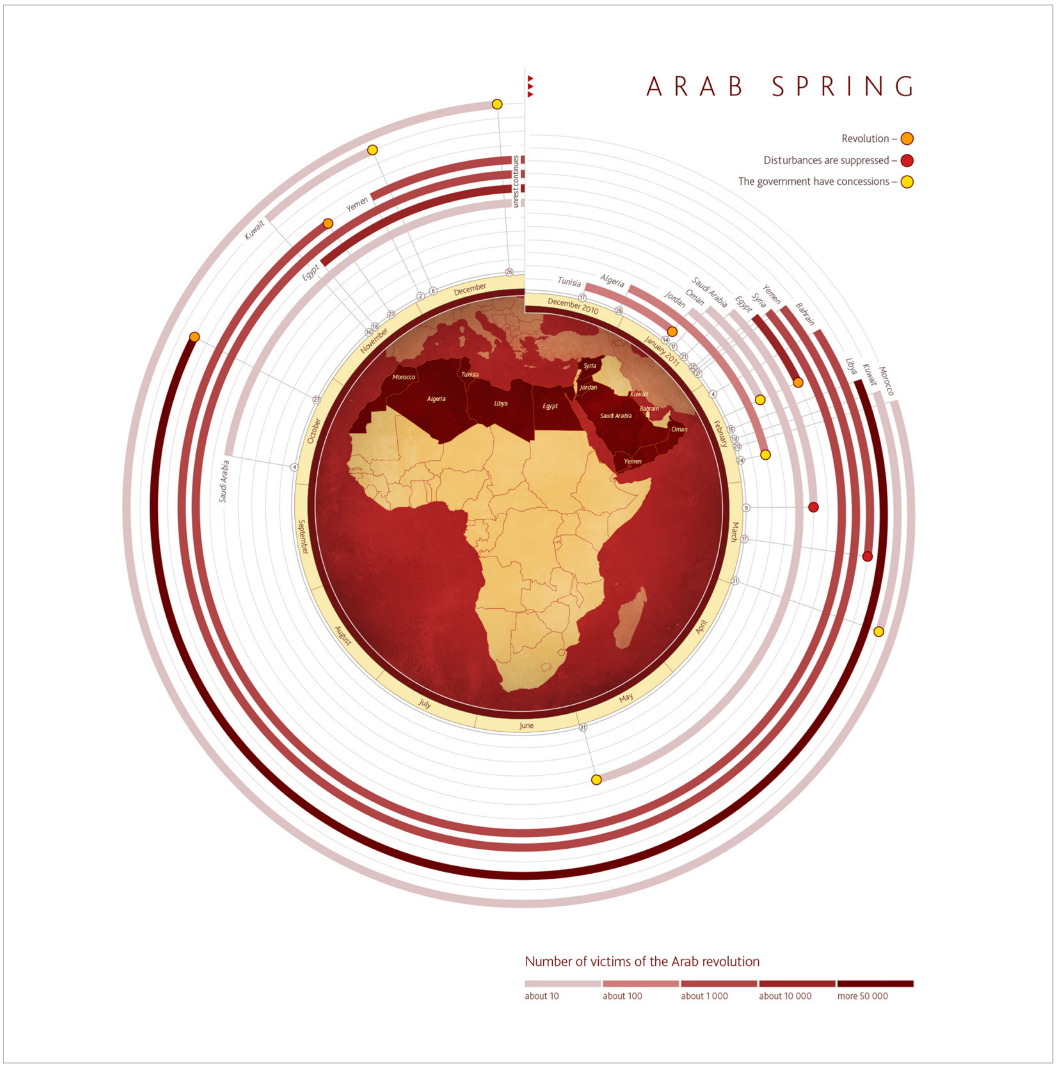


Figure 42. The media usage (first) | **Figure 43.** Arab Spring (second)

Both pie/donut bar charts in Figure 42 and 43 display information in a more complex way than a bar chart would. However, while in Figure 42 it is very difficult to ascertain the content and precision of the data, this is not so much the case in Figure 43. In Figure 43, direct labelling, the legend, the colour palette, and even the grid, all help to make information more accessible and easier to interpret.

5.11 Unit charts

Guidelines

1. Unit charts (also known as pictographs or icon arrays) can be used for part-to-whole data.
2. Although engaging, unit charts should be used only to compare a few simple data series, otherwise bar charts should be used instead.
3. In unit charts, strong contrasting colours should be used, and the quantity that needs to be emphasised should be positioned on the left.
4. Mixing up the icons or randomly positioning them, should be avoided.
5. Icons used in unit charts should be simple to present the data in an attractive and efficient manner, as well as maintain a clear picture even if used in multiples.
6. Icons should also be compatible with the data content.
7. To represent variables, one symbol only should be used, and then different shades can represent those different variables.
8. Partial icons should not be used as they just add confusion. The only exception is squares, because even just a small part of the square can be interpreted.
9. There should be enough of a gap between the rows to increase legibility and distinction of clusters of shapes.
10. The categorical sorting should be meaningful.

Research Findings

- Comprehension of unit charts was found to be generally good, and users rated unit charts favourably.
- A unit chart was found to lead to a lower comprehension when compared to a vertical bar chart (with a single slice).
- Unit charts were found to be adequate for both verbatim and gist knowledge.
- Unit charts were trusted over other formats such as tables and bar charts.
- Unit charts were found to be successful when users were asked to recognise frequencies (e.g. 1 in 10).
- Unit charts with scattered icons were found to perform worse than those which icons that are systematically arranged, and were also rated as the least preferred information format.
- Adding numerical and textual information to describe data in unit charts was found to improve performance.
- Person like unit charts were found to be the most preferred information format.
- Users were found to recognise proportions fairly easily with part-to-whole sequential unit charts.

Rationale

Unit charts are visual displays that contain rows of repeated picture symbols. Most unit charts are scaled where each picture symbol represents several real-word units (100, 1000, 1 million, etc.). When unit charts are not scaled, then each symbol represents one single real-world unit.

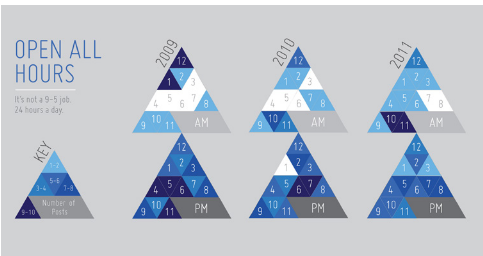
Unit charts are not faster to read than numbers. Even if neatly organised in rows of equal length, it is time-consuming to make a simple calculation of counting the number of symbols, then the number of rows, and then multiply them. This becomes even more complex when irregular numbers of columns, rows or items within them are displayed.

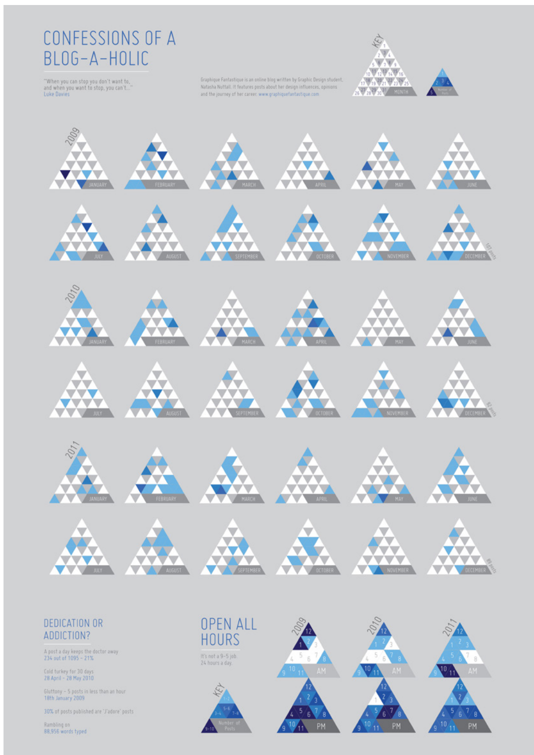
Therefore, unit charts are mostly an engaging and attractive visual display that grabs attention and is easier to recall. It is also a good strategy to project a strong rhetorical argument (e.g. 250 black crosses are more powerful to show number of deaths and to shock, than the number 250 itself).

Guidelines: Kosslyn, 2006; Few, 2012; Wong, 2013; Stones and Gent, 2015; Kirk, 2016.

Research findings: Hawley et al., 1998; Fuller et al., 2001 and 2002; Feldman-Stewart, et al. 2007; Price et al., 2007; Hawley, et al., 2008; Ancker, et al., 2011; Hildon et al., 2011; Schonlau and Peters, 2012; Zikmund-Fisher et al., 2012; Hamstra et al., 2015; Stones and Gent, 2015; Garcia-Retamero and Cokely, 2017.

Rationale: Few, 2012; Mollerup, 2015.





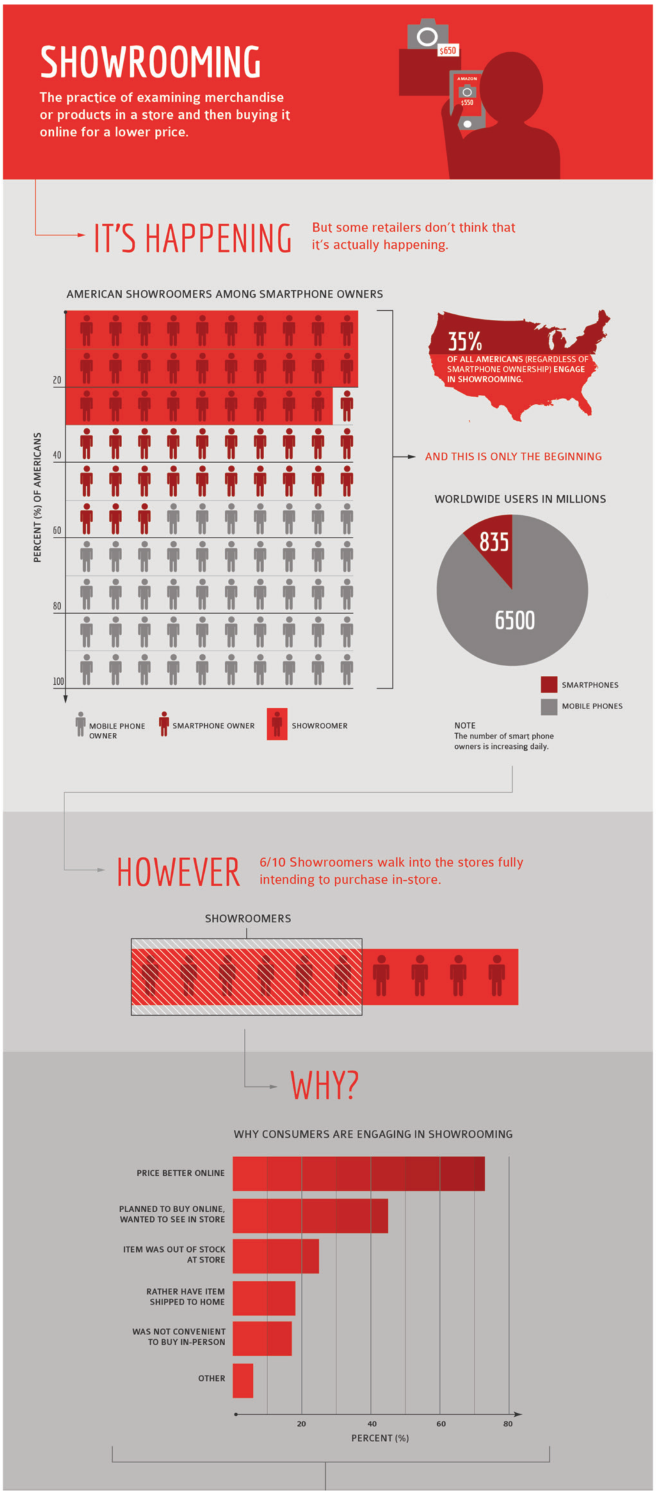


Figure 44. Confessions of a blog-a-holic (first) | **Figure 45.** Showrooming (second)

The triangle structure of the unit chart in Figure 44 makes it very difficult to interpret the data. The legend/key given does not provide much more help either. In Figure 45, however, despite using a more complex shape than a triangle, because of its structure and organisation, the unit chart is a lot easier to access and understand. Moreover, it has a clear legend and is supported well by other charts that contribute to the precision and understanding of the information.

5.12 Other formats

3D charts

- 3D charts should be avoided when the user needs to extract precise information, the overall meaning of graphed information, or complex information. This is because they were found to decrease comprehension and accuracy when compared to 2D charts.
- 3D charts might be acceptable to use when it is important to integrate information (not when precise metric is needed). 3D colour charts in particular were found appealing.
- Adding a third dimension for purely aesthetic reasons should be avoided, because it does not provide meaningful information about the variables. It only adds extraneous information.

Bubble charts

- Although more visually appealing, bubble charts should be used with caution because they are more difficult to read with precision. For example, compared to bar charts, a bubble is more difficult to compare than the height of a vertical bar.
- Bubble charts can be used to obtain a general sense and compare different values of a small number of items.
- Bubble charts should be used with caution because they are misleading due to a distortion in data. This is because the visualisation of numbers is not proportional to the real data.
- The difficulty of reading bubble charts can be minimised by using labels with values, although it will make the display more cluttered.
- Bubble charts can be used for other purposes beyond comparisons, such as in distribution maps.
- Direct labelling in bubble charts is difficult, especially when several points are joined together, making the chart very busy. In this case only those bubbles that are more important to distinguish should be labelled.
- Colours for each category must be clearly distinct, and because bubbles will overlap, using semi-transparent colours or only the outline of the bubble, can be an effective solution.
- Geometric accuracy of the circle size must be calculated to avoid distorting the data. Even then, users will interpret the bubbles differently. Some users take into account their area, while some users take into account their diameter, and some their rays.
- 3D spheres should not be used, as this no longer represents quantitative values through the size of a geometric area mark.

Heat map tables

- Heat map tables can assist the user in quickly spotting relevant areas and patterns, where strong colours represent high or outstanding values and weak colours represent low or normal values.
- A legend to indicate colour associations should be included in heat maps.

Mapping

- Mapping should not be used to compare quantities or volumes, unless geography is important to convey the message.
- In mapping, solid shades should be used to highlight an area, not patterns.
- The outlines of a map are not the message. Therefore, they should be simple and understated, with the only function being framing the information (like grid lines should be de-emphasised in a line chart).

Multiple charts

- Using multiple charts to communicate the same data, allows each chart to make a different and additional contribution to the overall story, which might not be possible with just one format (e.g. a table to help understand exact quantities, and a line chart to communicate a trend).
- Multiple charts in a series should be arranged in the most logical and easiest way to compare values, and should be consistently designed (apart from the labels, titles and legends which do not need to appear in every single chart of the series).
- Rules or grids should only be used in a multiple chart series if the charts are very close together and the white space is not enough to clearly delineate them.
- Multiple charts, whether in the same series/format or not, should be considered when sets of related data need to be communicated. For example, when several outcomes are affected by a single factor (how smoking affects lung cancer, heart disease, stroke, etc.). In such situations, the relationship between successively viewed charts should be well thought through.

Scatter plots

- Scatter plots can be used to show association between a pair of variables, to show a distribution of data, and to show the relationship among data points.
- If points are not clear enough, they should be enlarged, or a more visually distinct point shape should be used.
- If the points overlap and some are not visible, the chart should be enlarged, or the size of the point should be reduced, or the fill colour should be removed. Overlapping points should not be identified with different symbols.
- Points can take any simple shape, including dots, squares, triangles, diamonds, x's, plus signs, and dashes. Dots, however, are to be favoured.

- To show the trend, a line can be used through the oblong pattern in a scatter plot when there is a correlation.

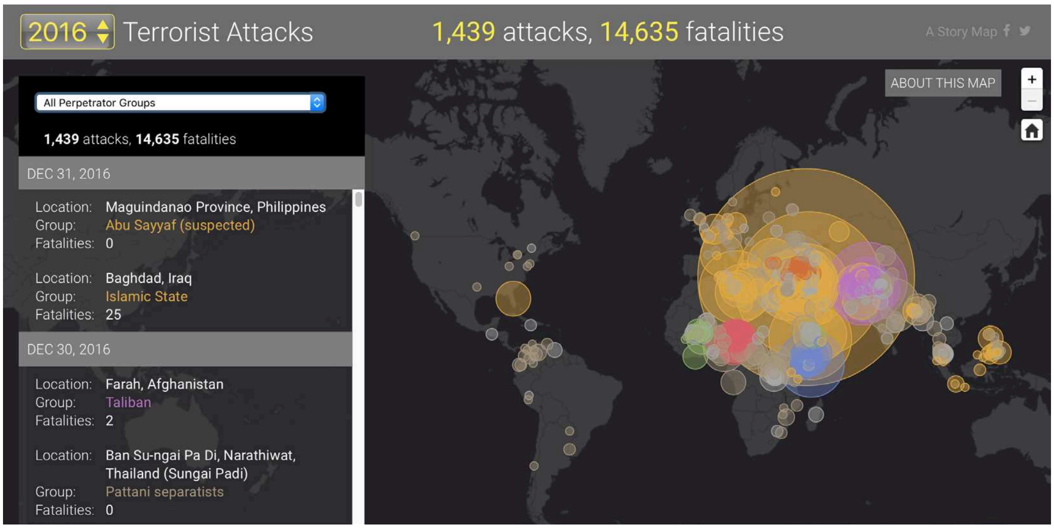
Spider/radar charts

- Spider/radar charts that require circular scan should be used with caution, as they were found to be harder to scan and led to different and unpredictable scan strategies. This is because positions along a quantitative scale are much more difficult to compare when they are not displayed linearly along a single vertical or horizontal scale. Moreover, it is difficult to discern where the information starts and ends, in which direction to read, etc.
- If used, although the axes are angled, it is important to ensure that all labels are readable, i.e. not at an angle or upside down
- A radar/spider chart could be used with caution to show similar data questions as a bar chart, with the added feature that the polar form of the radar projects a sense of wholeness and allows for cyclical data to be included, such as hours, days and months.

Stacked layer charts

- Layer charts should be avoided, as they are harder to read than some of the other types because humans can only compare areas as rough estimates. Moreover, because layer charts are similar to line graphs, we tend to read them as a line graph, which is the wrong procedure to analyse the data.
- Layer charts can be used to show a total where line charts are stacked on top of each other.
- Layer charts should not have more than four or five layers.
- The layers in layer charts should be clearly distinguished to help make it obvious that the layers are stacked on top of each other.
- Direct labelling is preferred for layer charts.
- When there is no natural order in a layer chart, the layers with the least variation should be positioned at the bottom.
- For better data interpretation, a layer chart can be split into a panel of individual line charts where the most important chart is put first (although, this split will not give a total, if that is the intention of using the layer chart).

Guidelines and research findings: Zacks et al., 1998; Lipkus and Hollands, 1999; Few, 2006 and 2012; Kosslyn, 2006; Shah and Hoeffner, 2002; Stewart et al., 2009; Goldberg and Helfman, 2010; Cairo, 2013; Schonlau and Peters, 2012; Gelman and Unwin, 2013; Wong, 2013; Knaflic, 2015; Mollerup, 2015; Siricharoen and Siricharoen, 2015; Berinato, 2016; Kirk, 2016; Asada et al., 2017; Burgio and Moretti, 2017.



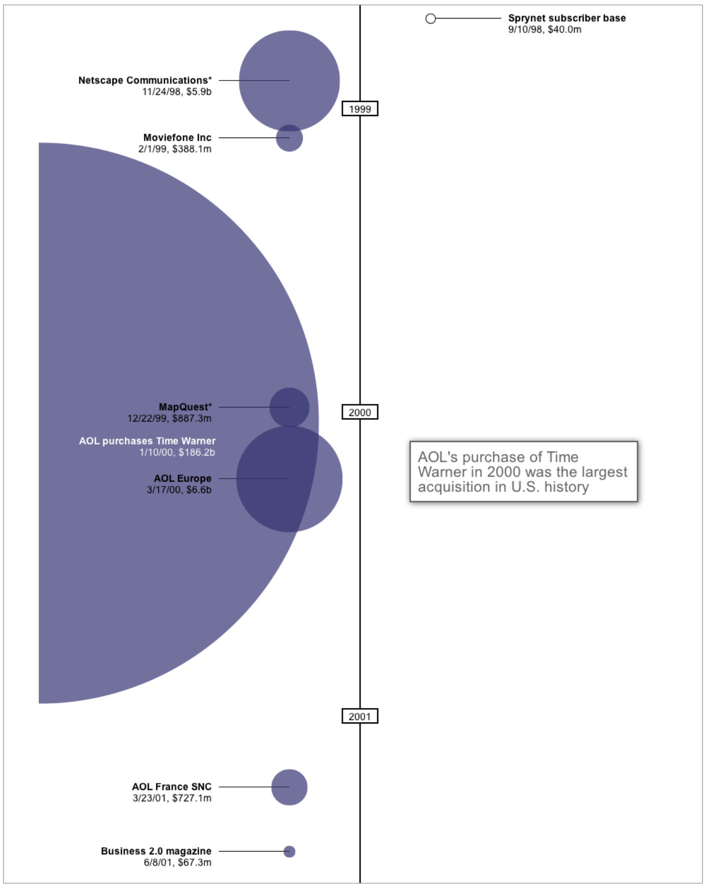


Figure 46. Terrorist attacks 2016 (first) | **Figure 47.** Time Warner evolution (second)

Bubble charts with so many bubbles, as in the infographic presented in Figure 46, are very difficult to interpret with precision and only serve to get a general sense about the data. Figure 46 is an interactive infographic that provides a very long and not that easy to access legend. However, it makes good use of semi-transparent bubbles to support interpretation. Figure 47 is an example of another interactive infographic where text and lines are cleverly used as direct labelling, which supports information processing.

06
Image credits

06 Image credits

All the figures and charts not included in this list were designed by the researchers exclusively for this report.

Figure 1 | How to make an engaging infographic for Healthcare
http://bjsm.bmj.com/content/51/16/1183

Figure 2 | The international space station
http://www.jamesrounddesign.com/space-station-data-visualization/

Figure 3 | The heart disease test
https://www.wired.com/2010/11/ff_bloodwork/3/

Figure 14 | Government spending by department, 2010-11
https://www.theguardian.com/news/datablog/2011/oct/26/government-spending-department-2010-11

Figure 15 | Under surveillance – Satellites
https://www.nationalgeographic.com/magazine/2018/02/surveillance-watching-you/

Figure 16 | Deportation from the US
https://www.informationisbeautifulawards.com/showcase/1865-deportations-from-the-us

Figure 17 | How terrorism in the West compares to terrorism everywhere
https://www.washingtonpost.com/graphics/world/the-scale-of-terrorist-attacks-around-the-world/
https://www.informationisbeautifulawards.com/showcase/1859-how-terrorism-in-the-west-compares-to-terrorism-everywhere-else

Figure 18a | All the National Food Days
https://www.informationisbeautifulawards.com/showcase/1432-all-the-national-food-days

Figure 18b | Nobel Prize Nominees
https://ria.ru/infografika/20151210/1339535142.html?lang=en
https://www.informationisbeautifulawards.com/showcase/1701-nobel-prize-nominees

Figure 19 | A show of force – North Korea's military parades
http://fingfx.thomsonreuters.com/gfx/rngs/NORTHKOREA-USA-PARADES/010040R41MB/index.htm
https://www.informationisbeautifulawards.com/showcase/1963-a-show-of-force

Figure 20 | An actor's life
https://www.informationisbeautifulawards.com/showcase/574-an-actor-s-life
https://www.slow-journalism.com/infographics/culture/philip-seymour-hoffman-infographic

Figure 21 | Outpacing pandemics
https://www.informationisbeautifulawards.com/showcase/1888-outpacing-pandemics
https://mosaicscience.com/story/outpacing-pandemics-epidemics-vaccines-infectious-disease/

Figure 22 | The net of terror
https://www.informationisbeautifulawards.com/showcase/1472-the-net-of-terror
https://iibawards-prod.s3.amazonaws.com/uploads%2F1473276921686-xv8tdw1k2ksk987n-bbe8d5ef4126c2dbb4753 2ffea9e3e5e%2FLa+rete+della+cellula+belga.jpg

Figure 23 | Under surveillance – Facial recognition
https://www.nationalgeographic.com/magazine/2018/02/surveillance-watching-you/

Figure 24| State by state migration
https://www.informationisbeautifulawards.com/showcase/2535-state-by-state-migration
https://www.bookyourdata.com/email-list-database/state-by-state-migration

Figure 25 | Who was working
https://www.informationisbeautifulawards.com/showcase/588-who-was-working

Figure 26 | Cover mania
https://www.informationisbeautifulawards.com/showcase/436-cover-mania

Figure 27 | Olympic Feathers - Visualizing all gold medal winners since 1896
https://www.informationisbeautifulawards.com/showcase/1698-olympic-feathers-visualizing-all-gold-medal-winners-since-1896
https://nbremer.github.io/olympicfeathers/

Figure 28 | A Data Driven Exploration of Kung Fu Films
http://vallandingham.me/shaw_bros_analysis.html

Figure 29 | Twitterography Mapping an ad on Twitter
https://www.informationisbeautifulawards.com/showcase/1066-twitterography-mapping-an-ad-on-twitter

Figure 30 | The Wall: A Threat to the Environment
https://www.informationisbeautifulawards.com/showcase/2534-the-wall-a-threat-to-the-environment

Figure 31 | Throw It Away- Lifecycle of a Cigarette
https://www.informationisbeautifulawards.com/showcase/16-throw-it-away-lifecycle-of-a-cigarette

Figure 32 | Berlin Startups
https://www.informationisbeautifulawards.com/showcase/487-berlin-startups

Figure 33 | Field of Commemoration
https://www.informationisbeautifulawards.com/showcase/375-field-of-commemoration

Figure 34 | How can we keep children from playing with death?
https://www.informationisbeautifulawards.com/showcase/2458-how-can-we-keep-children-from-playing-with-death

Figure 35 | How many gigatons of carbon dioxide?
https://informationisbeautiful.net/visualizations/how-many-gigatons-of-co2/

Figure 36 | The on-demand economy
https://www.informationisbeautifulawards.com/showcase/1671-the-on-demand-economy

Figure 37 | Global Trends in Healthcare
https://www.informationisbeautifulawards.com/showcase/2370-global-trends-in-healthcare-5-part-infographic-for-siemens-healthcare

Figure 38 | Data Enrichment Visualization
https://www.informationisbeautifulawards.com/showcase/615-data-enrichment-visualization

Figure 39 | Paying more for stuff
https://flowingdata.com/2011/04/27/how-much-more-we-pay-for-stuff-now-than-we-did-last-year/

Figure 40 | It's not so ISIS
https://www.informationisbeautifulawards.com/showcase/2478-it-s-not-so-isis

Figure 41 | 2016 US Campaign Expense
http://zhaoanna.me/ElectionExpenses/
https://www.informationisbeautifulawards.com/showcase/2008-2016-us-campaign-expenses

Figure 42 | My media usage
https://www.informationisbeautifulawards.com/showcase/2226-my-media-usage

Figure 43 | Arab Spring
https://www.informationisbeautifulawards.com/showcase/76-arab-spring

Figure 44 | Confessions of a blog-a-holic
https://www.informationisbeautifulawards.com/showcase/23-confessions-of-a-blog-a-holic
http://cargocollective.com/natashanuttall/Confessions-of-a-Blog-a-holic

Figure 45 | Showrooming
https://www.informationisbeautifulawards.com/showcase/120-showrooming

Figure 46 | Terrorist attacks 2016
https://storymaps.esri.com/stories/terrorist-attacks/?year=2016
https://www.informationisbeautifulawards.com/showcase/1977-2017-terrorist-attacks

Figure 47 | Time Warner evolution
https://www.bloomberg.com/graphics/infographics/time-warner-evolution.html
https://www.informationisbeautifulawards.com/showcase/513-time-warner-evolution

07

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07 Bibliography

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