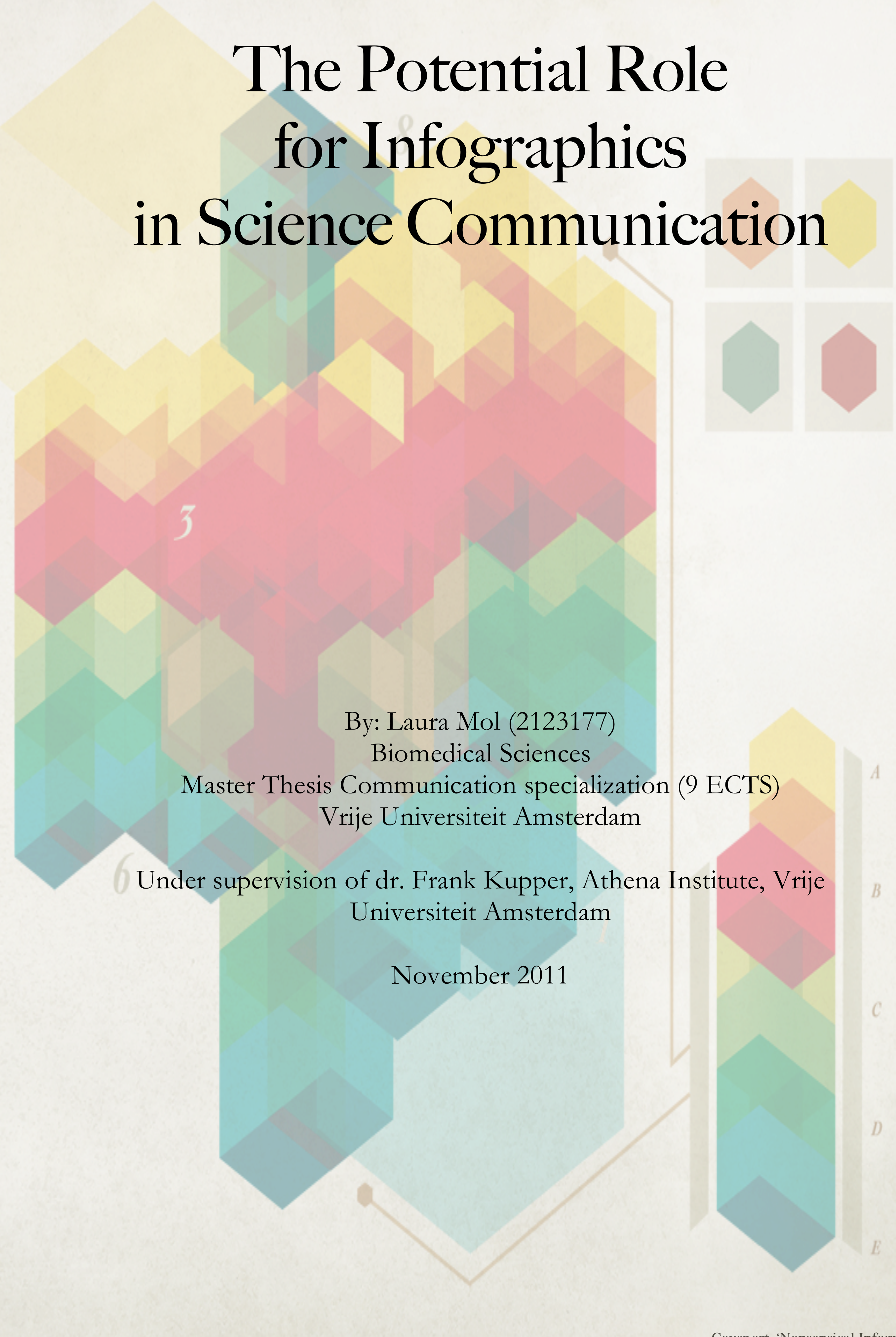

The Potential Role for Infographics in Science Communication

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"Tell me and I'll forget; show me and I may remember; involve me and I'll understand"

- Chinese proverb -

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Abstract

To explore the potential role infographics can have in science communication three core disciplines have to be considered. First of all: science communication and the main questions: What are the objectives or motives of science communication? What are the desired effects activities try to establish with the public?
Secondly, there is the field of infographics and the question what the purpose of an infographic is? Why is data visualized, what are the benefits over simply writing something down? Cognitive science is the interdisciplinary area of research that studies the mind and its processes, and can therefore provide an intellectual basis for data or information visualization.
Mapping the field of infographics showed that they aren't a novelty; in the past many people have used intricate combinations of diagrams and graphs to inform, persuade and convince the public. Most importantly one must realize that infographics are not mend to simplify but clarify data and information.
Transferring the data effectively can be done taking into account Edward Tufte's rules of graphical display of information. Key to a good infographic is creating salient visual stimuli, for example by utilizing the Gestalt principles on design and knowledge on color schemes effects. Eye-tracking technology is a way of testing the effect and success of an infographic.
Although I think infographics are suited best for mass media, such as newspapers, magazines and the Internet, they can be a tool in any science communication activity. Regardless of which intended effect the activities aim to have or which model or approach is used; all activities of SC have in common that at some point they have a transfer of knowledge. For enhancing the comprehension of information, knowledge and data, infographics are very effective.
In any form of science communication it is important to gain the attention of key publics that are not actively looking for science information. Infographics can help getting in the public's eye, because infographics are already very popular (especially on the web) and visuals are attractive.
They should, like any other science communication activity, contain quality trustworthy information and not be used in a purely ornamental fashion. In the end only good infographics are suited for science communication.

1. Introduction

“Do you want strawberries with dessert, or are they forbidden now?” “No, we can eat fruits, because they only have sugar in them, so no carbohydrates” Just a regular conversation between two girls, obviously on a low-carbohydrate diet, I overheard in the supermarket. They have no knowledge of basic biology or nutrition; otherwise they would know that sugars are carbohydrates. I’m also going to assume for the sake of the story that they think carbohydrates are bad for you and make you fat. With all the nutritional advice and ‘how-to-lose-weight-fast’ stories in women magazines, I don’t blame them. Carbohydrate deficient diets aren’t an ideal way to loose weight, because they are hard to maintain. They are popular nonetheless because of the Atkins and South Beach diet. These diets are based on the fact that the body starts to use stored fat for energy supplies in absence of sugars in the bloodstream. The opinions regarding low-carbohydrate diets vary greatly throughout the medical and nutritional science communities. Some say it will lead to impaired vitamin uptake and constipation, others argue low-carbohydrate diets result in general weakness or fatigue. A consensus among experts seems impossible (Taubes, 2002) and scientific research proves ‘something’ on this topic everyday, making it a whimsical as the weather in springtime.

I have a master’s degree in molecular nutrition and even I cannot keep up with what is good for you and what not. During my study I had people coming up to me all the time asking for nutritional advice. I tried to explain as best as possible some basic understandings of fats, sugars, proteins, macro and micronutrients. It was very difficult, my vocabulary was incomprehensible for them, and the cell or molecular level I was talking about too abstract. This was my first hand experience of the gap between a scientist and the ‘public’ or ‘lay men’. Explaining my field of expertise and how science works in general sparked my interest greatly. That’s why I commenced a science communication master and learned to look at science (the people, the research, the system) through the eyes of the public.

1.1 A short history of science communication

Science communication is a relatively new field of expertise, research on models and theories started in the 1950's in the US. The first attempts on communicating science to the public had a top-down approach, it consisted of scientists (or mediators) spreading of information among the public that suffered from a huge knowledge gap. It was known as the deficit model (Burns, 2003). That this knowledge gap existed was based on surveys in which the participants had to answer factual questions and ones about the process of science and the institutional place of science. The results showed that only 5 percent of the American public is scientifically literate, and only 20 percent are interested and informed in science. It was believed that filling the knowledge gap would lead to an improved 'scientific literacy'. This scientific literacy was needed to recruit science students. As well as to increase the acceptance and appreciation of the public of science and technique, and subsequently the large amount of money the United States government invested in it. At the time the Soviet Union (USSR) and the US were in a 'space race', a competition for supremacy in space exploration. When the USSR released the first artificial moon in the orbit, the US needed to act and did that by investing in scientific and technological research, especially aerospace engineering.

Many scholars criticized the presumption that informing the public and thereby filling the gap of knowledge would make 'everything better'; they mainly argued that there was no context. Furthermore, after nearly 25 years of gathering on the public understanding of science, and after many more years of active attempts to affect public knowledge, the numbers seem remarkably stable (Lewenstein, Models of public communication of science and technology, 2003).
An extension of the deficit model is the contextual model, which stresses there is not a 'general public', only specific groups that each have their need.
The contextual model acknowledges that individuals are not empty vessels ready to be filled with information, nor are they passive receivers. They process information according to social and psychological ideas that have been shaped by their previous experience cultural context, and personal circumstances.

However, also the contextual model has raised concerns because it is basically the deficit model that takes in account the personal context of the audience, however the goal might not be "understanding" but "acquiescence". Both the deficit and contextual model often assume a causal relationship between communication about science and the development of knowledge and understand, and subsequently to equate "public understanding of science" with "public appreciation of the benefits provided by science to society" (Lewenstein, The meaning of `public understanding of science' in the United States after World War II, 1992). However it has been shown in various studies that an increased level of knowledge can lead to feelings of uncertainty, criticism or even hostility among the public (Miller & Gregory, 1998).
Since the mid 1980s, researchers have stressed the importance of recognizing local and indigenous knowledge and commitments to political inclusion and participation. This led to two new models.

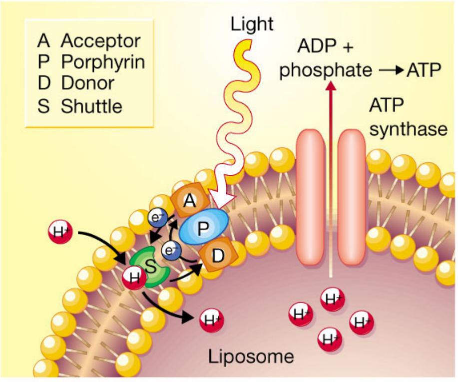
There is the public engagement model, in which the public participates in the policymaking and decision-making processes, by focusing on a series of activities intended to enhance public participation, hereby democratizing science and gain trust in science policy.
Lastly, Lewenstein says is the lay expertise model, which accepts the fact there are other knowledge resources besides scientific knowledge, such as the kind that comes from experience. The lay expertise model does not see scientists as the only people who can solve problems, but assumes that local knowledge may be just as important. Heavily influenced by social psychology, pedagogy and educational philosophy, its purpose is to involve the public to get to better knowledge building and understanding. Knowledge cannot simply be transferred, but at its best be shared. Knowledge evolves from interaction between people and their surroundings, and from that angle one can say that knowledge is not a firm fact but a social construct.

As a critique this model has been called 'anti-science', it favors the experience of laymen over verifiable knowledge about the natural world produced by the modern scientific system. Leading to critical questions such as: How can a model of public understanding based on lay expertise provide guidance for the general public? Both the public understanding model and lay expertise model have criticized for addressing politics and local community empowerment, not public understanding of science.

So there are two forms of communication between science and the public, one focused on transmission and the other on transaction. Currently there is a shift from the first to the latter; there is a growing interaction between the scientists and the laymen or the public. However, I feel that the majority of the people come more into contact with the classical informative model. That is because the interactive science communication activities are something you have to purposely look for. Debates, workshops, discussions, consensus conferences and stakeholder dialogues are examples of these activities. First of all, I think they are rare: you have to know when or where they are held, let alone know they exist. The part of the public who comes into contact with these events is small. Secondly, the part of the public that does come into contact is probably already interested in science.
More common forms of science communication are readings, lectures, conferences, and brochures, materials used for educational purposes, TV-programs, magazines, books and the science section in the newspapers. The chance of encountering one of these is apparent, for almost everyone in society.

1.2 Using images in science communication

Translating 'difficult' scientific content for a more general public is in a way a puzzle. As a science communicator you have to try different approaches, models and media, much like you attempt to put the pieces in the right place when making a puzzle. When using any model or approach in science communication one has to consider in what form communication takes place. The most obvious decision is to use text or images, or both.
A popular way of explaining scientific research is via images, because they have a certain appeal to the public. There is a saying that goes: "A picture is worth a thousand words'. Complex information can become more understandable through imagery. Scientist already know this, they often use figures and images to present mechanisms and systems. Take the image on the next page that explains the proton motive force, a bacterial system that generates energy.



When only words are used to describe this process, it would be a long paragraph that even experts might not understand.
However, showing this picture without any text would raise more questions than answers. A graphic visual representation of information, data or knowledge, often combined with text, is called an infographic. Infographics are becoming increasingly popular, not in the least bit because of the Internet and in particular social media like Twitter (Bradshaw, 2011). They are so ubiquitous, in magazines, newspapers and on the web, some already speak of an explosion of infographics or unenthusiastically 'the burst of the infographic bubble'. Infographics are at the nexus of journalism, design, communication and analysis. Therefore it requires great skill to make a good infographic, one has to be able critically look at data, make the right conclusion, see the relevance and working with designing software is critical. The infographic congress I attended in March 2011 revolved around the issue of the surfeit of aesthetically pleasing infographics lacking substance. One particular pessimistic speaker even said that 99% of the infographics out there was rubbish when it came to significance, but they were pleasing for the eye. Others pleaded for a data-police, because designers do not have the statistical analytical insight to use data correctly.

Because I see great potential, in this thesis I will explore the role infographics can have in science communication. Combining a literature study on infographics, visual language and knowledge building with my practical work on infographics at my internship.

2. Infographics

2.1 Introduction

As stated in the introduction, infographics are a visual representation of information, data or knowledge, often accompanied by text. They consist of signs, charts, maps, or diagrams that aid comprehension of a given text-based content. An official definition is hard to find, the field of infographics is relatively new. Literature and research on the topic is scarce. That is not to say that infographics are a novelty. To the contrary, they have been around for a very long time; some consider prehistorical cave paintings to be infographics. Infographics comparable to what is published nowadays, go back to the times of Leonardo Da Vinci. He drew the 'Vitruvian Man' in 1490 (as seen on the right), a study of the proportions of the male human body based on anatomical research he conducted himself. The drawing is explained in mirror writing.

Figure 1: Vitruvian man

Infographics have come a long way since Da Vinci's illustrations, they were forgotten for the greater part of the 20th century but since the computer they have evolved quickly. Magazines and newspapers 20 years ago who wanted to decorate their pages with illustrations had to use pencils, photo's, scissors and glue. Then a revolution happened, because of the internet, technological innovations and increased communication possibilities. Today, many newspapers have special editors for infographics; the online version of the Volkskrant had a blog dedicated to infographics[1]. The New York Times has a site on learning with infographics[2]. The role the Internet has in the infographic revolution is undeniable and the Internet itself is a perfect tool to show the popularity of informative graphics. The use of the search term 'infographics' has exponentially grown since 2009, as Google Trends shows[3]. The revolution is continuing as I write this, because smartphones and tablets were introduced. People can download apps and subscribe to online versions of newspapers

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1 Volkskrant Blog
2 NY Times: Learning with infographics
3 Google Trends

and magazines. Therefore those media can offer online and interactive infographics, allowing the user to scroll through multiple layers in one infographic.

Although they often appear in newspapers, infographics do not necessarily have to be about current issues, such as the financial crisis or the Arabian Spring. Study books, popular-science magazines, scientific articles and encyclopedias also feature them. Instruction manuals from IKEA, safety instruction cards on airplanes and even the sign in the restaurant that tells you where the toilets are: all infographics. We interact with infographics on a daily basis.

2.2 History

In prehistory, early humans created the first information graphics: cave paintings and later maps. Throughout history, image and text have remained inextricably mixed. Some civilizations had images for an alphabet such as the Egyptians. Mapmaking started before writing and some of the earliest known maps go back to 7000 BC. (Meece, 2006). After that icons were used to keep records of cattle and stock. The Indians of Mesoamerica used imagery to depict the journeys of past generations. Illegible on their own, they served as a supportive element to memory and storytelling. Infographics are visual representations of data and the early ones are reminiscent of today's classical graphs, such as bar graphs and other charts.
In 1812 Napoleon's failed Russian campaign became well known because the French engineer, Charles Minard (1781-1870), illustrated the disastrous results. The graph titled '*Carte figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie*' shows the size of the army by the width of the band across the map of the campaign on its outward and return legs, with temperature on the retreat shown on the line graph at the bottom (see figure 2). He is considered one of the founders of the information graphics field and that one of best statistical graphics ever drawn (Tufte, The Visual Display of Quantitative Information, 2001) (Weiner, 1984).
Another pioneer is William Payfair (1759-1823), a Scottish engineer and political economist, generally viewed as the inventor of most of the common graphical forms used to display data: line plots, bar chart and pie chart. Playfair first published The Commercial and Political Atlas in London in 1786. It contained 43 time-series plots and one bar chart, a form apparently introduced in this work. It has been described as

the first major work to contain statistical graphs and one of the first people to use data not just to educate but also to persuade and convince (as is shown in figure 3).

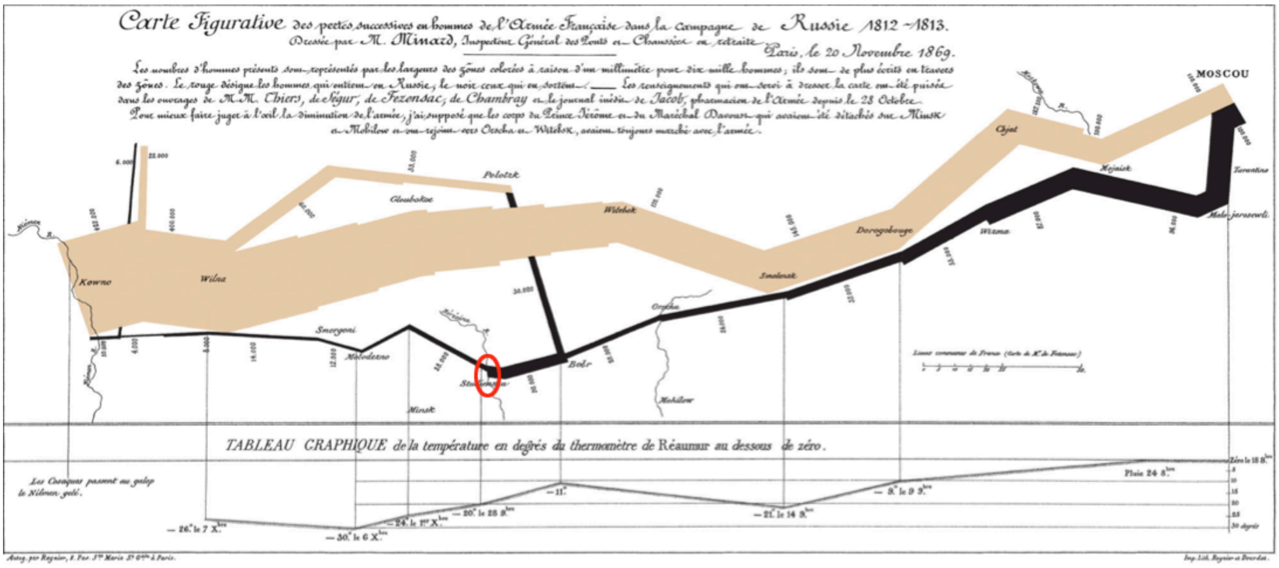

Figure 2: Charles Minard's flow map of Napoleon's march. Note the notorious crossing of the Berezina river (indicated with the red circle).

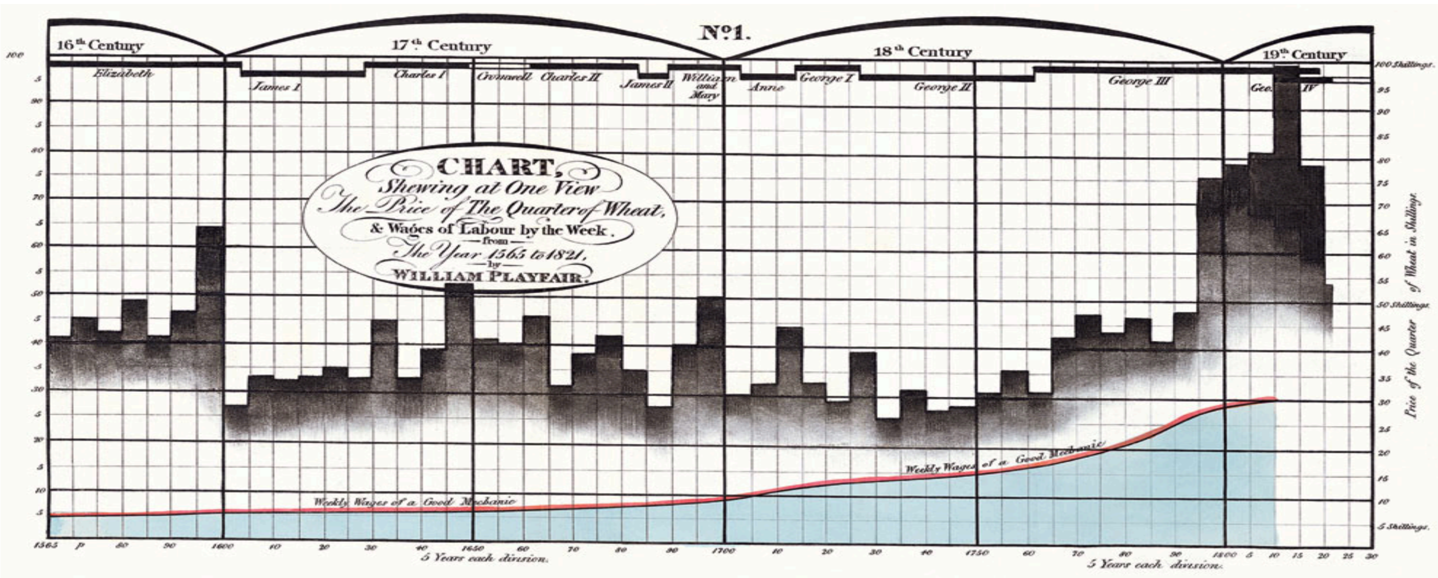

Figure 3: William Playfair 1821 chart comparing the "weekly wages of a good mechanic" and the "price of a quarter of wheat" over time

William Playfair in his days gave a good reason why we should employ data visualization: "As the eye is the best judge of proportion, being able to estimate it with more quickness and accuracy than any other of our organs, it follows, that wherever relative quantities are in question …[the Line Chart] … is peculiarly applicable; it gives a simple, accurate, and permanent idea, by giving form and shape to a number of separate ideas, which are otherwise abstract and unconnected".

Following the footsteps of Minard and Playfair was Florence Nightingale (1820-1910). Although mostly known for her work nursing wounded soldiers in the Crimean War, she also earned a place in history with her graphical methods to convey complex statistical information to a broad audience. After seeing the deplorable sanitary conditions in the war she wrote the influential text 'Notes on Matters Affecting the Health, Efficiency and Hospital Administration of the British Army'. To convince the British Queen, parliament members and civil servants, to improve the medical care facilities she added charts and diagram. Otherwise her audience would have been unlikely to read or understand traditional statistical reports. Her most famous work is the polar area diagram or Nightingale Rose diagram, equivalent to a modern circular histogram, in order to illustrate seasonal sources of patient mortality in the military field hospital she managed (see figure 4). The figure makes it abundantly clear that far more deaths were attributable to non-battle causes ("preventable causes") than to battle-related causes. Aside from its historical interest, Nightingale's Coxcomb is notable for its display of frequency by area, like the pie chart. But, unlike the pie chart, the Coxcomb keeps angles constant and varies radius (proportional to square-root (frequency))[4].
The importance of hygiene and the lack thereof proved to be a popular topic amongst the early infographic makers. Dr. John Snow made an epidemiological map, with deaths from a cholera outbreak in London, 1854, in relation to the locations of public water pumps (figure 5). Edward Tufte says in his book (Tufte, The Visual Display of Quantitative Information, 2001) about this: "Snow observed that cholera occurred almost entirely among those who lived near (and drank from) the Broad Street water pump. He had the handle of the contaminated pump removed, ending the neighborhood epidemic which had taken more than 500 lives."

[4] http://www.datavis.ca/gallery/historical.php

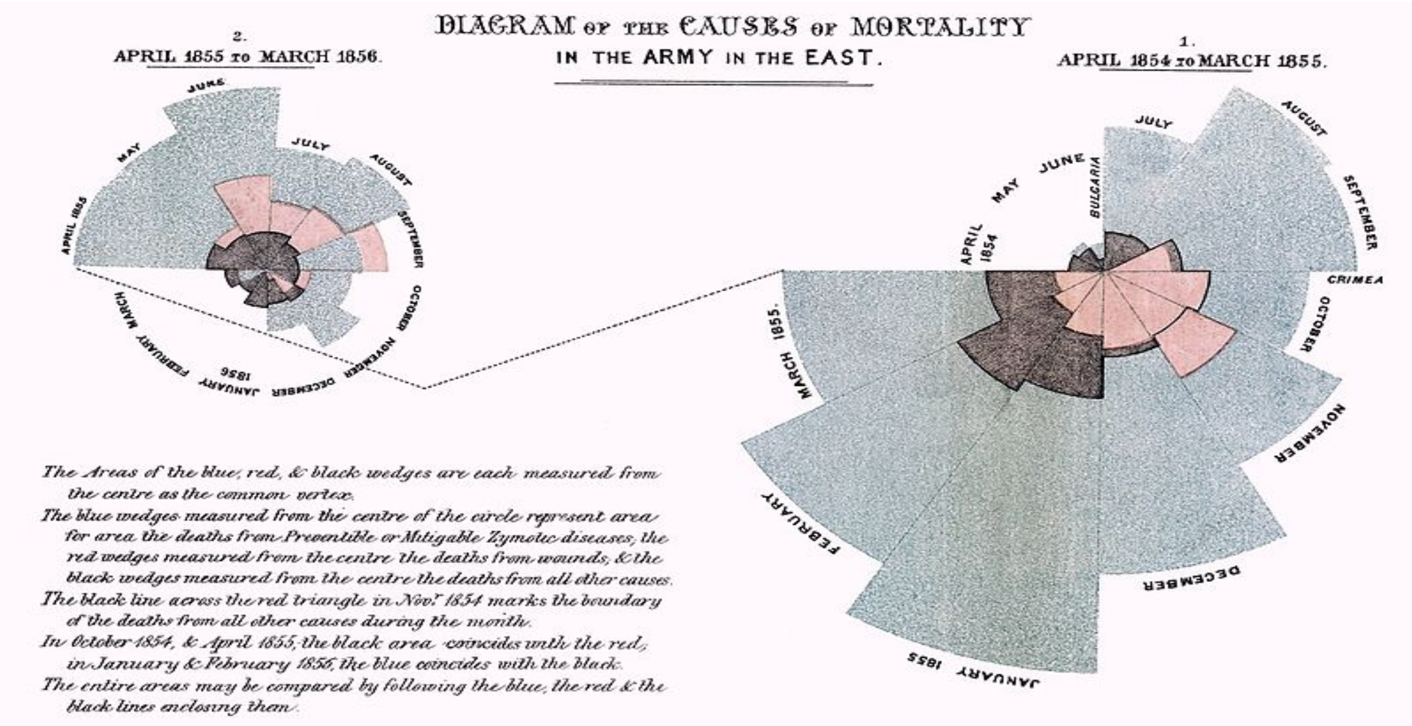

Figure 4: Florence Nightingale's Coxcomb chart

Figure 5: A low-res picture of the map, depicting London and the cholera cases by John Snow

By the end of the 19th century, as more statistical data became available, the limitations of 2 dimensions of the plane for the representation of data were becoming more ostensible. Several systems for representing 3D data were developed between 1869-1880. Figure 6 (showing the population of Sweden from 1750-1875 by age groups) by Luigi Perozzo, from the Annali di Statistica, 1879, is one of the first examples of a stereogram known (Deni, 2006). Perozzo's figure is also distinguished for being printed in color because it enhances the perception of depth.

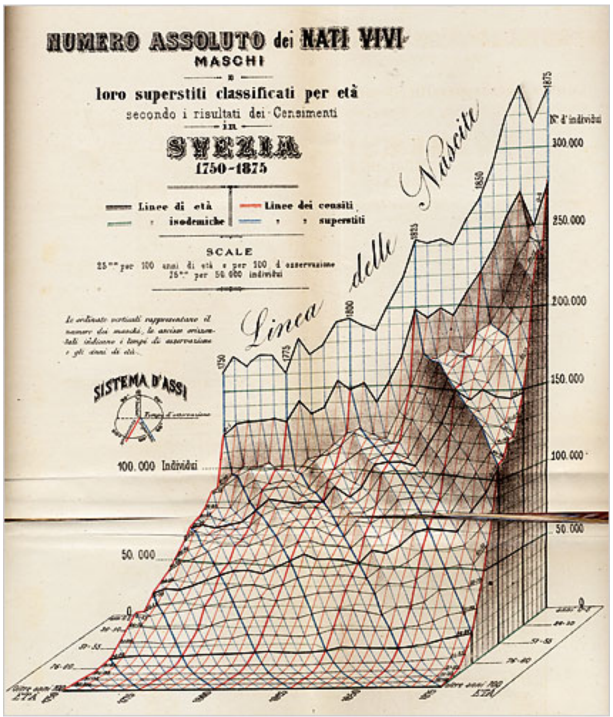

Figure 6: Stereogram of the Swedish census for the years 1750 to 1875 shows the number of male births each year in relation to the number of survivors.

The rise of infographics as seen nowadays is mostly due to the developments in computer and printing technology, and the Internet. However, it started when shortly after the First World War, Otto Neurath, an Austrian philosopher with a team of artists and data specialists, created the first symbolic pictorial language for conveying information. It was called Isotype (International System of Typographic Picture Education), the first abstract and visual representation of data, designed so that it was easy to understand. Isotype proved that when information is portrayed with human perception in mind, complex data can be more effectively and efficiently communicated to a wider audience.

As computers became more powerful and widely used across different disciplines, applications and programming languages were developed to streamline computations and mathematical analysis. This provided opportunities to analyze and visualize spatial data and to produce interactive visualizations on computers (Brunelli, 2010).

The introduction of color to the world of newspapers was another important step and can be traced to the 1982 debut of USA Today. Considered by some as a revival of newspaper popularity and the solidification of graphics as a vital part of news communication, the first issue contained a full-page color weather map created by George Rorick. This weather graphic turned the usually tedious weather statistic into an interesting and accessible information graphic that appealed to a wider audience (Rajamanickam, 2007).

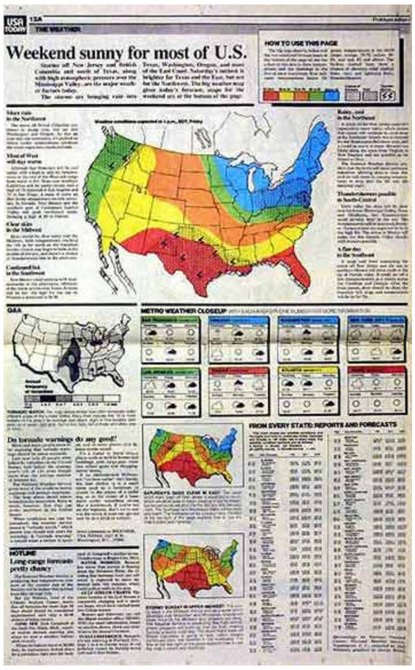
Weekend sunny for most of U.S.

Figure 7: Weather forecast in the USA Today in 1992

In the early 2000's a new trend on the Internet emerged and was coined 'web 2.0': web applications that facilitate participatory information sharing, interoperability, user-centered design and collaboration[5]. Specifically a merging of technologies and social paradigm shifts has allowed the Internet to develop into the medium it is today, a source for information, social interaction, artistic expression and unlimited amounts of data. Technologies such as Adobe's Flash enabled artistic and graphically designed interfaces to create a new layer of interaction between users and web pages. All of this combined makes the Internet the number one source of infographics and although there are many professionals out there, the field is largely dominated by amateur designers and office workers. With tutorials, open source and freeware programs for graphic design everybody can learn how to make infographics. Social media and blogging sites like Twitter, Facebook, Flickr, Reddit and Tumblr make it easy to show work to anybody interested and make it go viral. This is how infographics with titles such as 'What Kind of Geek Are You?' 'A Detailed Look at Sex Injuries' and 'FarmVille vs. Real Farms' became the most popular ones[6]. The infographic (on the growth of the Internet) on the next page is a perfect example of what popular infographics look like these days, combining a large amount of data and different element such as bar graphs and pie charts with attractive color schemes[7].

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[5] Wikipedia definition.

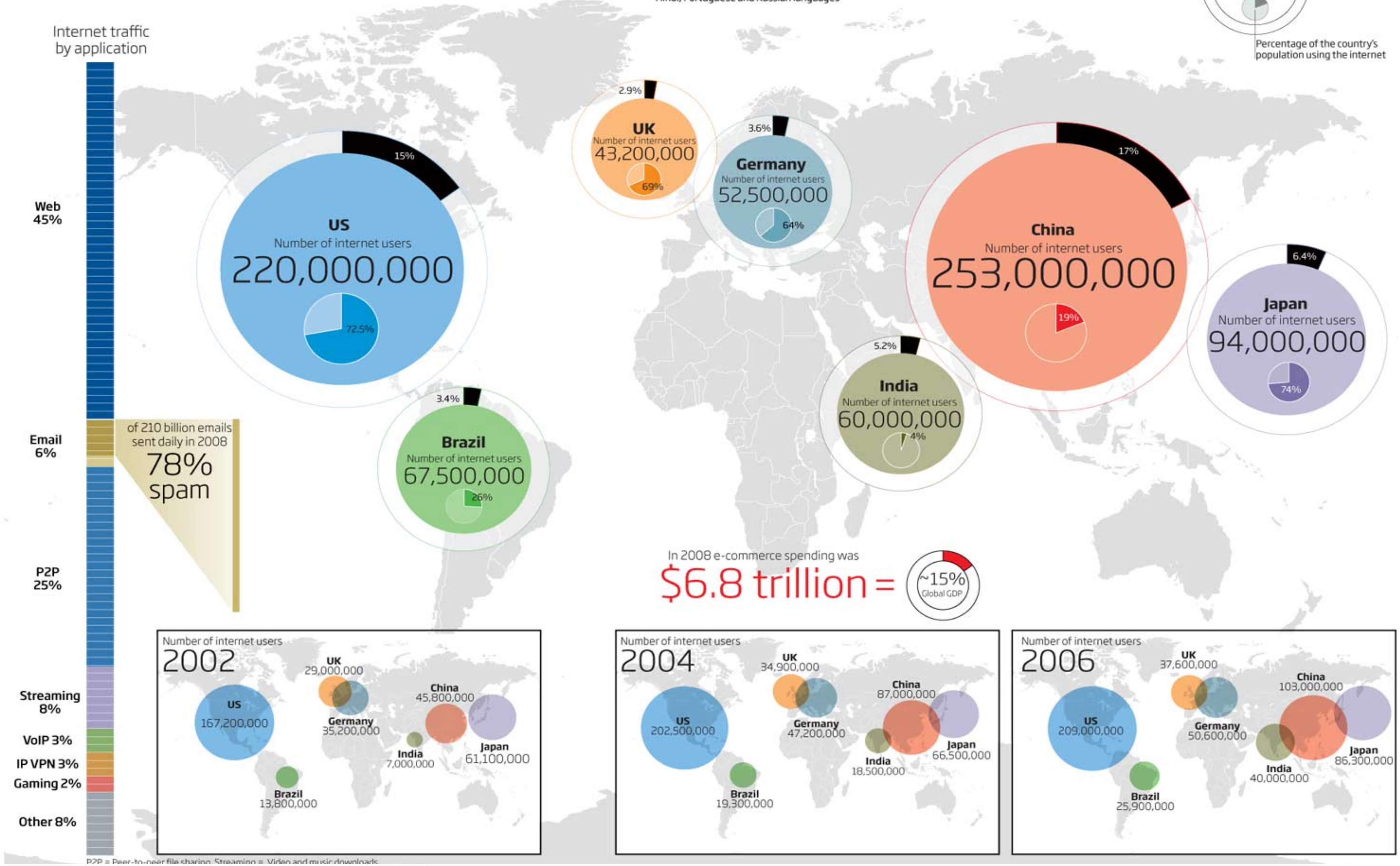
[6] Most popular infographics of 2010

[7] 'The exploding internet' infographic

The exploding internet
2008

Internet traffic is growing by about 50 per cent annually, with video and music streaming rising fastest. At the same time, the web is becoming divided along language lines

By 2012, Asian web surfers, including about 490 million Chinese, will outnumber North Americans by 3 to 1 and Indians will become the third-largest group online. Tomorrow's web will probably be dominated by a mixture of the English, Mandarin, Hindi, Portuguese and Russian languages



P2P = Peer-to-peer file sharing. Streaming = Video and music downloads

2.3 Different Elements

A cross-section of infographics available on the Internet has been surveyed to establish the most used elements of infographics. There are a number of entities that can be considered as the elements of infographics. The basic and key material of an informative graphic is the data, information, or knowledge that the graphic presents with limited resources. The data can be visualized in the form of lines, boxes, arrows, and various symbols and pictograms. Many infographic use various forms together. They often feature a key that defines and explains the visual elements in plain text and numbers, a scale and labels are well known examples. In general three categories are distinguishable: text, images (drawings or photo's or a combination) and image elements (dots, lines, arrows and shapes). Arrows indicate a direction (such as 'this follows out of that' or 'start reading here and go there afterwards) and lines can point something.

2.4 Purpose

As said before, the birth of infographics as seen today, came with the USA Today in 1982. Many market studies done prior to the launch of the paper demonstrated that readers were more and more attracted by good visuals and small packets of information, rather than by the one-page or two-page in-depth stories that were common in dailies at that time (Cairo, The Elements of Infographics: What information graphics are and are not, 2007). The infographics made by USA Today were intended to condense big amounts of information in a small space. This is a goal that is still held today, because there is no better way to display large sets of data than with a good statistical chart, or to provide geographical context to a story than with a map for example. There were downsides to the original purpose of using an infographic. The first one is that it is really easy to unconsciously cross the boundary between being concise and being simplistic. And, related to that: if infographics are regarded as devices for making pages (on the web, or in newspapers and magazines) more attractive it is tempting to start treating them as sheer space-fillers in absence of a photograph. They should not be purely ornamental, but a way to enhance the comprehension of information. The adagio when making infographics is, according to infographics legend Nigel Holmes: "We're not trying to simplify things, but to clarify". How pretty the infographic looks at the end is a secondary issue, because appeal is a by-product of well-organized information. A well-designed infographic can summarize tons of figures and display them in an ordered and meaningful way but a chart should not necessarily be easy to read. There are cases in which this is not a realistic or desirable goal. The depiction of Napoleons travel through Russia was not a simple chart; to truly understand the content (and how ingenious the work is) a quick glance is not sufficient. On an abstract level, an information graphic is an aid to thinking and understanding. A good infographic makes patterns arise, discovers trends, condenses enormous amounts of information in a very small space, but does not leave out important facts.

Sometimes infographics accompany an article; sometimes they are a medium of their own, because a good infographic is able to tell a story and show facts that would be hard to show otherwise. Then it should answer the basic five W's (and the H) of journalism. 'The what', 'the where', 'the why', 'the who', 'the when' and 'the how' of a story. In the end it is important that the infographic does not leave the user with more questions than it gives answers.

2.5 Interactive Infographics

There are many different types of infographics, such as geographical infographics or cartograms. Often used to display spatial en topographical information, such as spending patterns and land use. A form coming from the Isotype language, are pictograms, where pictures of specific sizes and numbers represent statistical data. Sometimes used in newspapers to elaborate or explain financial news. There are the classic forms that can easily be produced with Excel: bar graphs, pie charts and scatterplots. More complicated are the axonometric projections, a type of parallel projection, more specifically a type of orthographic projection, used to create a pictorial drawing of an object, where the object is rotated along one or more of its axes relative to the plane of projection (Bertoline, 2002). It is a 3D drawing of a building for example, that be viewed from different angles. They are very popular in traveling and architectural magazines.

An example is figure 8, made by John Grimwade, director of information graphics at Condé Nast's Traveler and Portfolio. He was a guest speaker at the Infographics congress in March 2011 were he stated that his company is now focusing on interactive infographics. Instigated by the rise of multimedia tablets such as the Apple iPad. The projection of Central Station can become interactive when it's made for the iPad (or a computer), so that user can virtually walk trough it.

Figure 8: Axonometrical projection of Grand Central Station in New York by John Grimwade

Interactivity in infographics means in essence: exchange of information between a reader and an artificial system, the reader evaluates the possibilities of the application (which is explored by his or her manipulation), performs an operation and the system returns a response.

According to Alberto Cairo, founder of the website Visualopolis[8] there are three kinds of online interaction: instruction, manipulation and exploration (Cairo, Interactividad: la nueva frontera de la visualización de información en prensa, 2008). Instruction is the simplest form of interaction between a reader and a computer graphic, the handling of buttons that control a linear narrative. A huge percentage of computer graphics journalistic follow this model. In the second category, the manipulation, are infographics that have a higher degree of control by the user. In these cases, there is more to it than a simple push of a button, it allows the user to modify the entire configuration of computer graphics.
A highlight of this form is the graphic on the origin of donations from major Democratic and Republican candidates as seen in figure 9 [9]. The user first gets an overall picture (via a map) and is then able to navigate in different ways: first, you can

[8] http://www.visualopolis.com/

[9] NY Times Infographic

adjust the time range shown, and second, you can set up an animation showing the evolution of donations the successful candidate, third: each circle on the map is a button to reveal specific information. The user can also search for donors by postal district. The graph summarizing the results of the primaries has great depth, not only showing the results in each state, but in many cases, also in each county. The most notable of this example is not its technical brilliance, but that the foundations are not limited to presenting data, but allow the reader to explore. This creates new patterns of data guided by curiosity and engagement with the story, though is on a very elementary level by providing information.

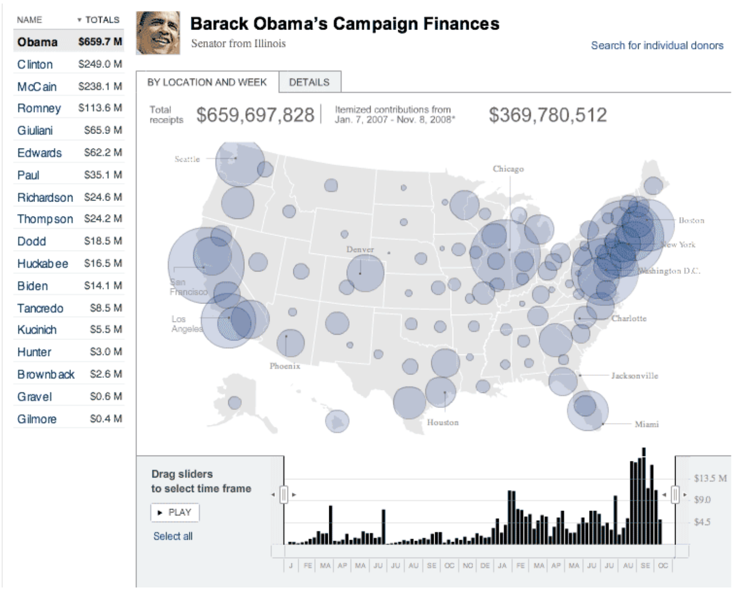


Figure 9: Screenshot of the campaign finance interactive map

The exploration form of online interaction is mostly found in videogames but can be applied to infographics as well. Popular videogames such as World of Warcraft can teach the field of infographics a great deal. The learning curve is smooth: the dynamic of learning during the game is to complete tasks ("quests") of increasing complexity. It can provide a feeling of immersion in the content (Cairo, Interactividad: la nueva frontera de la visualización de información en prensa, 2008). Also here it must be stated that although the visuals can be very attractive in interactive infographics, the norm remains: the quality of content determines the excellence and usability of the infographic.

3. Information visualization

3.1 Introduction

Infographics are part of information visualization. It is a research field that aims to amplify cognition of patterns and trends in abstract datasets, by developing effective mapping techniques for representing values in visual forms. It can help answer the question why visualizing data and information is helpful in understanding it. Additionally it can aid designing infographics, in such a way that they have maximal effect.

The field of information visualization is an interdisciplinary one, combining concepts from computer science, data mining, cognitive science and graphic design, each solving an isolated part of the specific problem to more adequately transfer information. This is relevant as the ability to collect, store, and manage data is increasing quickly, our ability to understand it remains relatively constant. Information visualization presumes that "visual representations and interaction techniques take advantage of the human eye's broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once. Information visualization focused on the creation of approaches for conveying abstract information in intuitive ways" (Thomas & Cook, 2004). It also describes why representing data visually is desirable (Ware, 1999):

- Visualization provides an ability to comprehend huge amounts of data. The important information from a large number of measurements is immediately available.
- Visualization allows the perception of emergent properties that were not anticipated.
- Visualization often enables to see if anything is wrong with the data itself, such as outliers, or the way data was collected
- Visualization facilitates understanding of both large-scale and small-scale features of the data.

According to Ware (Ware, 1999) there a four stages in data visualization, presented in figure 10:

- The collection and storage of data itself
- The preprocessing designed to transform the data into something we can understand
- The display hardware and the graphics algorithms that produce an image on the screen
- The human perceptual and cognitive system (the perceiver or reader of the picture)

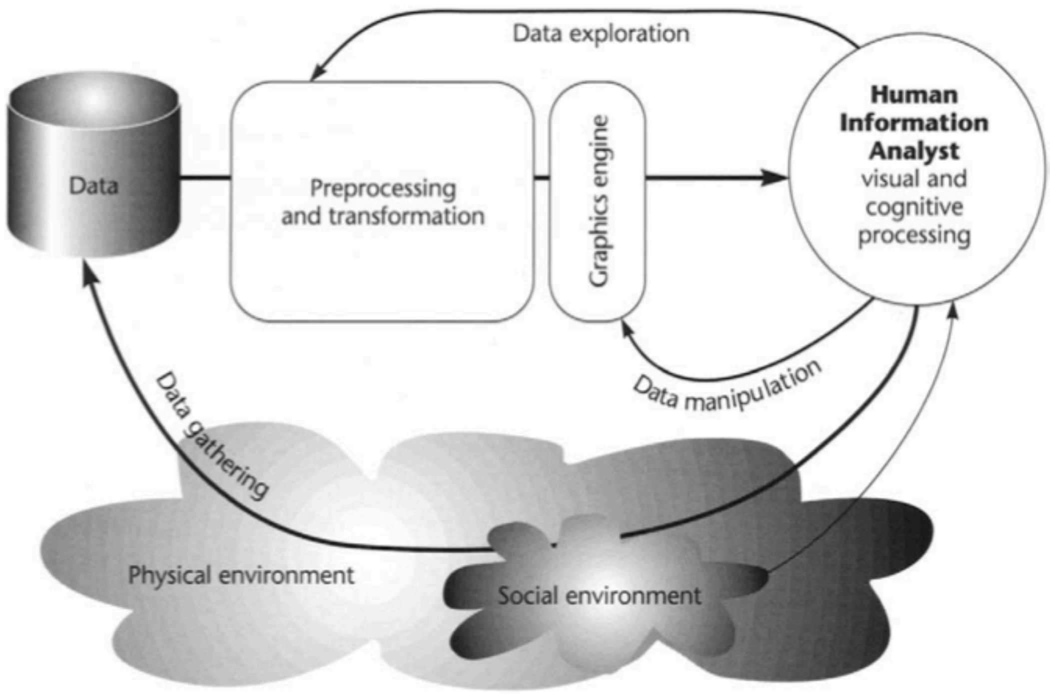


Figure 10: Schematic diagram of the four stages in data visualization

Notice the different feedback loops in the figure, the longest running from 'human information analyst' or receiver to the data collection. The person who collects or seeks the data, such as a journalist or scientist, looks for patterns or interesting leads and might look for more.

A real life example of how the process of data visualization works comes from Peter Aldhous, the San Francisco Bureau Chief for New Scientist magazine. He noticed how the earthquake that struck near the Haitian capital, Port-au-Prince, on 12 January 2010, was unremarkable in seismic terms, but was one of the most deadly earthquakes in the past four decades. He downloaded freely available data about earthquakes and fatalities: from searches at the U.S. Geological Survey for quake magnitudes and locations and The International Disaster Database for earthquake fatality data. Then he used software to turn the data into the format needed to make the graphics. With Adobe Illustrator and Adobe Flash he made the (interactive) animations[10].

The final image showed that the scope of these disasters is defined not by the Richter scale, but by location. Urban areas characterized by overpopulation and poorly build houses are the real cause of the high fatality rates. This example perfectly illustrates how data visualization can uncover information that otherwise may have gone unnoticed.

Both the physical environment and the social environment are involved in the data-gathering loop. The physical environment is a source of data, while the social environment determines in subtle and complex ways what is collected and how it is interpreted. The critical question is how best to transform the data into something that people can understand for optimal effect.

3.2 Effectively transforming the data

It has been said that the infographics by Minard and Playfair were excellent, but what accounts for the quality of graphics? According to Edward Tufte, there are two key elements in good design: simplicity of design and complexity of the data.

Tufte is an American statistician and professor emeritus of political science, statistics, and computer science at Yale University.

[10] Creating an infographic

He is famous for his writings on information design, regarded as a pioneer in the field of data visualization and an expert on infographics[11]. He has written many books on theory and practice of designing graphs, charts and maps[12]. According to him excellence in visualizing data consists of complex ideas communicated clarity, precision and accuracy.

Therefore he made set of rules that graphical displays of statistical information should follow, but many of them can be used for designing infographics in general:

- Fundamental of good data visualization is to show the data.
  How to show the data, depends on the data, audience and medium.
- Induce the viewer to think about the substance rather than the methodology, graphic design, the technology used or something else. This seems very logical but especially designers with an artistic education tend to focus more on the beauty than the content. Therefore they should avoid 'chartjunk' as Tufte calls this. Distracting patterns, overbearing colors, use of shading or 3D and even unnecessary grids and outlines are just some of the elements of chartjunk. Getting rid of this leads to design transparency.
- Avoid "fooling around with data" and use a simple and straightforward design with a richness of data. The success of visualization is based on understanding the data and care about the substance. Tufte says: "There is a place for art, and there is a place for visualization. Mixing the two is difficult and dangerous, and often leads to things that are neither"[13].
- Utilize data-ink. Many graphs or bars or other elements in data display provide little or no information, when that is compared to the amount of space they use (ink) one can say that the data-ink ration is skewed. To get a high data-ink ratio Tufte suggests using small multiples. A single design repeated several times within the eye span, each example showing a different value of the independent variable(s).

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11 'The information sage' by Edward Tufte

12 Edward Tufte bibliography

13 'The Visualization Cargo Cult'

"Comparison must be enforced within the scope of the eye span: a task at which small multiples excel. For a wide range of problems in data presentation, small multiples are the best design solution. At the heart of quantitative reasoning is a single question: Compared to what? Small multiple designs, multivariate and data bountiful, answer directly by visually enforcing comparisons of changes, of the differences among objects, of the scope of alternatives." (Tufte, Envisioning Information, 1990)

Many visualizations today are descriptive rather than comparative, but with no context the meaning is often lost.

Figure 11: A well-known example of small multiples is the weather forecast

- Choose a proper format and design.
  This is a very broad rule and encompasses everything there is to be designed about the infographic. First of all the lay out, is the infographic wider than it is long, is the image vertical or horizontal. Are there many colors or is it black and white. These properties largely depend on the medium that displays the infographic. Then there is the data, do you present it with graphs or bars or just images? If it is a story or data that has to do with events or facts placed in the context of time, a time line is appropriate. Using a circular form suggests a cycle or a continuous event; these are rhetoric meanings that have to be taken into account.

- Tell the truth

  It is fairly easy to lie with visual representations of data, especially when using tables, graphs and bars. Graphical integrity is ensured when the data is shown in context

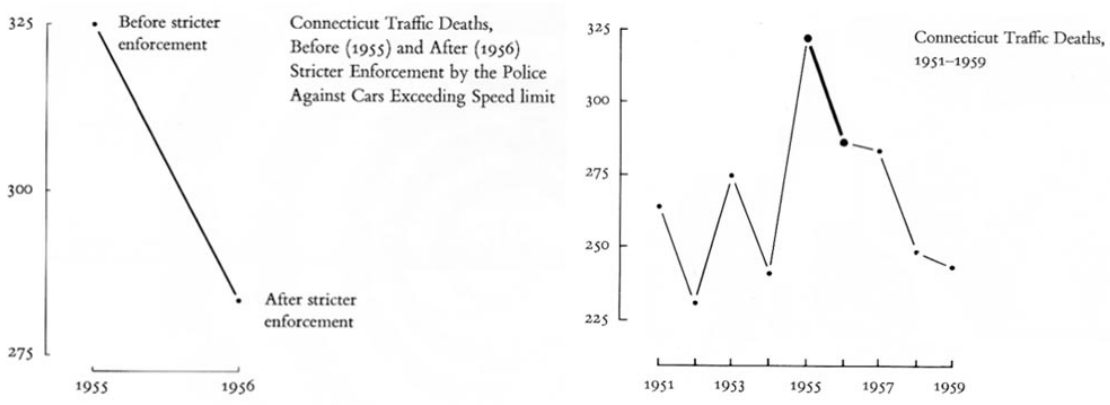

Figure 12: Compare the graph on the left with the picture on the right and see what an enormous difference it makes.

- Use words, numbers, and drawings combined

  This combination is what defines an infographic. Tufte states that combining words, number and images makes complex data more accessible. Often a picture alone is not enough and leaves space for interpretation, which is unwanted if something needs to be explained correctly. Viewers need the help words can provide. It is necessary that the words and graphics that belong together are placed on the paper that way and not segregated, which will lead to confusion.

  Additionally, he makes a clear distinction between graphics that function to communicate or illustrate a certain finding and graphics that serve as an exploration of a data set. In the first case words tell the user what the data is, what it represents, the meaning of the graphic. In the latter case it tells the user how to read the data, not what to read in terms of content.
- It should have a narrative quality, a story to tell about the data. Narrative focuses on “time” and “space” to tell its story, which provides context and gives

more meaning to the information. Presenting a story also draws the user of the infographic in.

Edward Tufte has very strict rules when it comes to presenting data. Almost everything that has some playfulness to it, by his standards is considered chartjunk. Color, using figures for bars and more lively fonts is not done, however many designers consider that this is something that draws attention. Not all infographics display statistical information, which is why his work is only applicable to them to a certain extent.

3.3 The human perceptual and cognitive system

Data visualization also looks at the role visualizations have in human cognitive processes, it is about finding an intellectual basis for visualization. Why and how should communication take place via images? How can the effect of the images be maximized? The point of data visualization (and thus infographics) is that the information must be understood and preferably that the user gains knowledge and learns something. There are a number of ways humans can learn; for example non-associative learning, associative learning, classical conditioning and imprinting. Benjamin Bloom (1913-1999), was an American educational psychologist, suggested three domains of learning:

- Cognitive - To recall, calculate, discuss, analyze, problem solve, etc.
- Psychomotor – To dance, swim, ski, dive, drive a car, ride a bike, etc.
- Affective – To like something or someone, love, appreciate, fear, hate, worship, etc.

The term cognition (Latin: cognoscere, "to know", "to conceptualize" or "to recognize") refers to the processing of information, applying knowledge, and changing preferences. Cognitive science is the interdisciplinary scientific study of minds as information processors. It includes research on how information is processed (in faculties such as perception, language, reasoning, and emotion), represented, and transformed in a (human or other animal) nervous system or machine (e.g., computer). Memory formation also falls under the scope of cognitive science.

3.3.1 Memory formation

Important is to realize that there are several ways environmental stimuli can enter the brain, via sight, hearing, taste, smell, and touch. Sensory information is taken in by sensory receptors and processed by the nervous system. Sensory memory (SM) allows individuals to retain impressions of sensory information after the original stimulus has ceased. However, every individual encounters so many stimuli that storing everything might lead to information overload. Therefore stimuli are filtered and only a few make lasting impressions. Stimuli must stand out to be noticed and memorized.

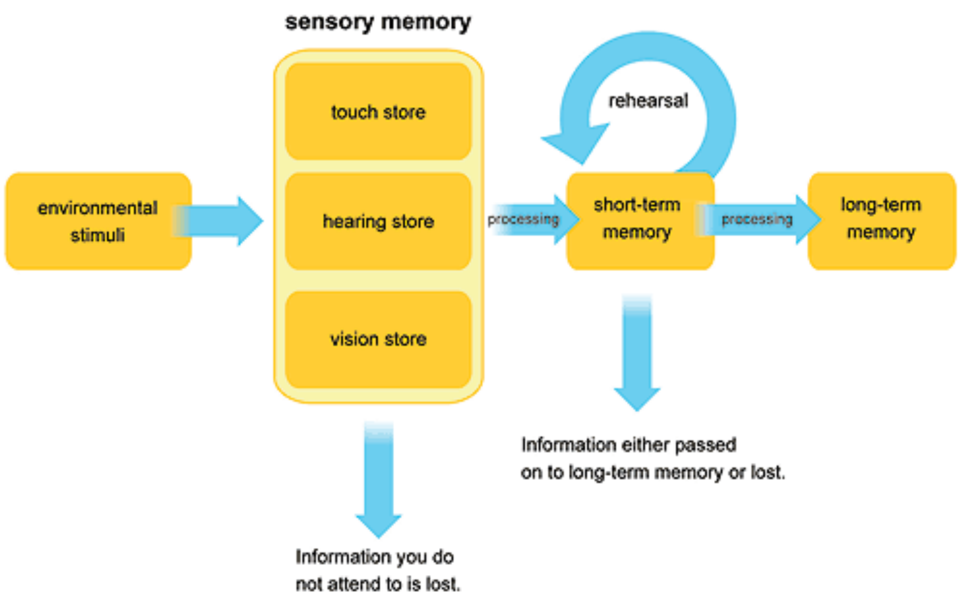

Figure 13: A schematic view of memory formation.

Iconic memory is the visual sensory memory register pertaining to the visual domain. Visual input travels to the visual working memory (or visual buffer), which can hold information in the mind needed to do complex tasks such as reasoning, comprehension and learning. Is the input impressive enough or is much effort done to memorize it, than it will travel to the long-term memory. That last step between the buffer and the long-term is a two-way interaction (Kosslyn S. , 1999), because when we see an object and have seen it before we can recognize that because the long-term memory has stored what that object looks like. This is called associative memory. We learn by seeing everyday, because part of what we see is stored in the long-term memory. Many of our experiences and memories are stored as images in our visual cortex, or more precisely as mental imagery (Kosslyn S. , 1996). We use this also during our thinking processes. For example if you don't know where your keys are, you can trace back the steps you made from the moment you know you still had them. You can remember or mentally recreate getting out of your car, opening the door of your house and immediately going upstairs to change clothes because it was raining. The keys are still in the pants you had on before you changed! Mental imagery is also crucial in perception, as shown by mistaken or illusive perceptions (imagining, for instance, that the sweater hanging in the darkness of your room is an intruder), and various types of non-deceptive seeing (such as imagining a cloud to have the shape of a heart). A notorious example is the duck-rabbit figure where you can see a duck or a rabbit, literally depending on what you have in mind. However, there are some philosophers, such as Sartre and Wittgenstein, who draw a distinction between imagery and perception. They argue that our imagination, unlike our perception, is under the control of our will (and experienced as such). Provided I know what an elephant looks like, I can choose to imagine one wherever and whenever I want to, but I cannot choose to see an elephant unless one actually happens to be present. By contrast, if an elephant is present before my open eyes, I cannot help but see it, whether I want to or not.

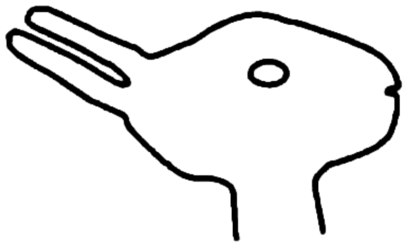

Figure 14: The duck-rabbit

How accustomed we are to visual mental imagery is shown by various idiomatic ways in the English language of referring to it: 'visualizing,' 'seeing in the mind's eye,' 'having a picture in one's head,' 'picturing,' 'having/seeing a mental image/picture,' and so on. Of course we do not actually have images in our head, they are merely a pattern of neuron activation.

3.3.2 Creating salient visual stimuli

Our eyes are constantly scanning the surroundings with rapid eye movements called saccades, looking for something new, uncommon or potentially dangerous. If something is out of the ordinary, for example it has bright colors or movements, the eyes will naturally focus on that. Designers can incorporate these elements in their work to capture the viewer's attention, by framing something in a black square or make something bright red while everything else has shades of grey. That's the reason why it is a good idea to use a restrained color palette rather than a very varied one, and one color for emphasis. Too many different intense, bright tones and the eyes of the viewer will start to wander around looking for a focal point to the graphic. Research on why and how certain objects will pop up has been done by the Gestalt school of psychology, a German group that was founded in the first decade of the 20th century. They helped understand how the early stages of visual perception work.

3.3.3 Gestalt theory of perception

Gestalt means when parts identified individually have different characteristics to the whole (Gestalt means "organized whole"). Despite that almost a century has passed since those rules were defined, they still are of great help for designers and visual journalists. Gestalt principles are often misunderstood because they are usually discussed as a list. This might lead to thinking that they can act independently. Rather, at any instant that our eyes are open many of these rules are applied simultaneously. When working with visual language and images it is important to keep the gestalt principles in mind with each design. It tells you something about how the design is perceived and can therefore have a different effect than intended. Here is a small selection of the gestalt principles; many of the images come from unpublished but excellent work by Alberto Cairo[14].

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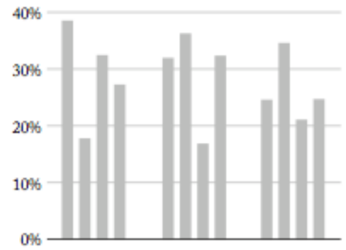
[14] http://www.albertocairo.com/imagenes/2007/noticias/4041.pdf

1. Proximity

One of the most important rules for infographics, especially for visual display of statistical information and maps. Objects that are displayed close to each other will be perceived as natural groups. In the example it is hard not to see groups in the bars that are clustered. It also seems clear that the central set of numbers is organized into rows, whereas the one on the right is organized into columns. Viewing each bar or each number, as an individual entity is almost impossible. This rule is also imperative when designing a book or an infographic, because it explains why a pictures and the text that belongs to it should always be close.



4 3 6 7 9 8 1 2 5 5 1 1 8

1 5 3 4 5 1 1 5 2 5 1 3 1

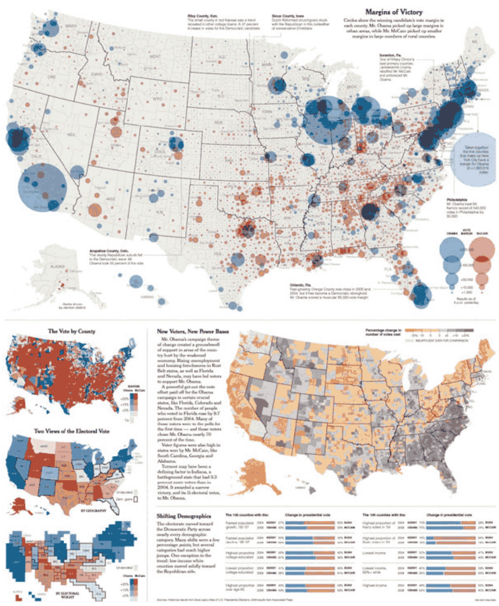
1 4 1 8 1 9 5 1 2 8 1 9 9

3 1 2 5 1 1 6 1 5 3 1 8 1

4	6	9	1	5	1	8
4	6	9	1	5	1	8
1	3	5	1	2	1	1
5	1	1	6	2	1	1
1	1	1	5	2	1	9
2	1	1	1	2	4	5
3	2	1	6	5	1	1

2. Similarity

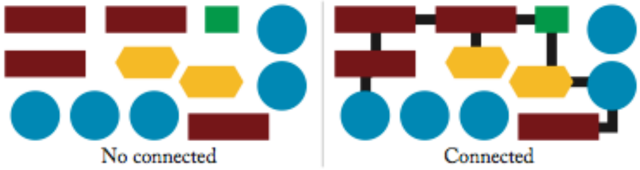
This principle is easy to explain: objects that look alike will be perceived as parts of the same group. There are many kinds of similarity such as shape, color, orientation, size, texture and value. In the infographic here the red and blue areas on the maps tend to stand out and be perceived as relevant information. The red and blue also comes back in the bars indicating that the information is related. The circles in the upper map have different color but are related and can probably be compared.



3. Connectedness

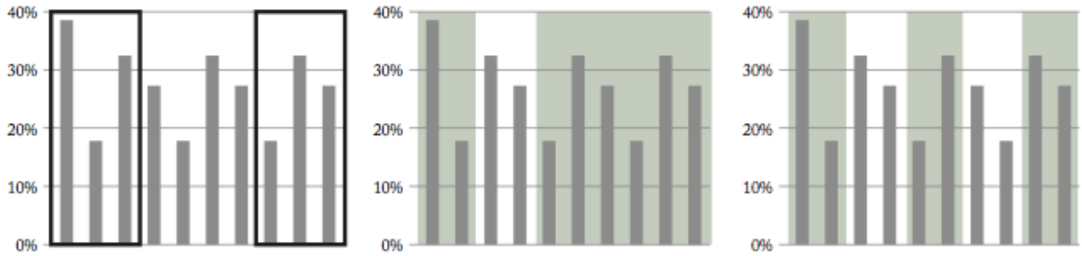
This is a very important rule because it can prevail other principles, such as proximity or similarity, when they act simultaneously during early stages of visual perception.

Using connecting lines or arrows can make groups of elements that have nothing in common not the color or the shape, nor a they close to each other.



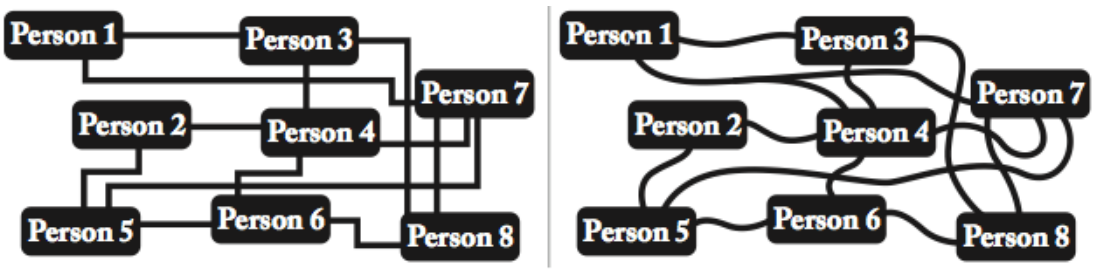
4. Enclosure

Objects that lie within an area whose borders are sharp and clear will appear to belong to the same group. In the picture below the spatial distribution of the bars remains the same, yet they seem to be grouped in different sets. It leaves the viewer with the question what those enclosed areas represent: different categories, different years?



5. Continuity

This principle states that it is likely that object will be noticed without effort when it has smooth and continuous edges rather than when its boundaries are straight and have sudden changes of direction. Curvy shapes are more natural, it does not necessary look better (it is less organized) but it is easier to interpret for the eye-brain system.



The smooth lines are part of preattentive processing. Preattentive processing of visual information is performed automatically on the entire visual field detecting basic features of objects in the display. Such basic features include colors, closure, line ends, contrast, tilt, curvature and size. These simple features are extracted from the visual display in the preattentive system and later joined in the focused attention system into coherent objects. Preattentive processing is done quickly, effortlessly and in parallel without any attention being focused on the display (Treisman, 1985). This is important for design of visualizations, because it gives information on what can be perceived immediately, what properties are good discriminators and what can mislead viewers.

3.3.4 Seeing in color

Another fundamental role in the design of information is the use of color, because a suitable color palette can be a very powerful tool for organizing infographics and making them both more understandable, and pleasant to the eyes. As stated previously bright colors can capture the eyes quite effectively.

Light consists of waves of electromagnetic energy (or of particles called photons). Eyes can detect only a small range of the electromagnetic spectrum. Long-wavelength light (infrared) or short-wavelength (ultraviolet) lights lie below and above the threshold that can be perceived. When light hits objects, some of the wavelengths are absorbed and some are reflected, depending on the materials in the object. The reflected wavelengths are what we perceive as the object's color.
The ability of the eye to distinguish colors is based upon the varying sensitivity of different cells in the retina to light of different wavelengths. As mentioned earlier there a two types of photoreceptor cells in the retina, cones and rods. Cones can be divided into three subgroups:

- Cones that absorb long-wavelength light (red)
- Cones that absorb middle-wavelength light (green)
- Cones that absorb short-wavelength light (blue)

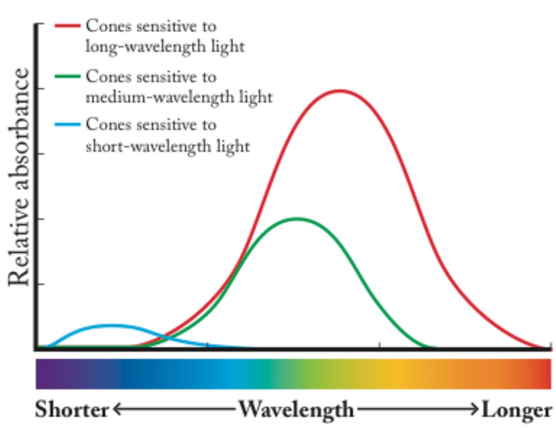


Figure 15: graph displaying the different sensitivities of the cones

The sensitivity of the cones to the different colors in the visible spectrum varies. Some cones are more sensitive to green, others to blue or red. Seeing color happens because of the unequal activition of different colors. As figure 15 shows the human eye is more sensitive to long wavelenght light. Short wave length light, such as ultraviolet, can easily damage the eye and cannot be perceived. Red, on the other hand is very easily seen because it is long-wavelenght light and is therefore the standard accent color in visual displays. Warning signs and traffic lights are red, and if a designer wants to accentuate a feature it is often red. During aging the acuity of short-wave length lights diminishes (Sternberg, 2002). The different acuities to color tell that subtle shade differences are crucial for understanding the information; age plays a big role in color perception. Older people have trouble identifying subtle shades differences in blue, red colors are more appropriate. Children like very bright colors, but adults prefer pastel oriented color schemes. A principle derived from how color is perceived is that, as the brain tends to group areas or objects of the same nature, on any statistical map of other form of infographic, data with the same color belongs together and different colors mean different phenomena.

In general very bright color should not be used in infographics. A saturated color scheme confuses the user because it is impossible to separate the information based on importance. Using colors (non saturated brown, greens and blues) that are common in nature should be standard colors, whereas bright colors can function as accents to highlight significant information.

3.4 Eye tracking

Eye tracking is recording the human eye movement, it used in research on the visual system, in psychology, in cognitive linguistics and in product design. Tracking eye movement is following the path of attention deployed by the observer. This can give insight into what he or she found interesting and what captured the attention. It can even give some insight into how the scene (it can be text, images or a combination) was perceived (Duchowski, 2007).

For example: the eye reads a line of text in discrete pieces by making a series of fixations and saccades. A fixation is a brief moment, around 250 ms, where the eye is paused on a word or word group, and the brain processes the visual information. The saccade is a fast eye movement; usually goes forward in the text around 8-12 characters, to take in the next section of text. A regression is a backwards motion in the text, and it indicates confusion. The eye tracking parameters reveal much about the reader's cognitive state as well as the nature of the reading material. For instance, more difficult passages of text will yield longer fixations, shorter saccades, and a higher regression rate, because the reader has to go back and forth for better understanding (Beymer, 2007).

In recent years, the increased sophistication and accessibility of eye tracking technologies have led the commercial sector to use it for product testing. In general, commercial eye tracking studies function by presenting a target stimulus to a sample of consumers while an eye tracker is used to record the activity of the eye. Examples of target stimuli may include websites and newspapers, the studies yield interesting data and give information about how to maximize the effect of a website or newspaper via design.

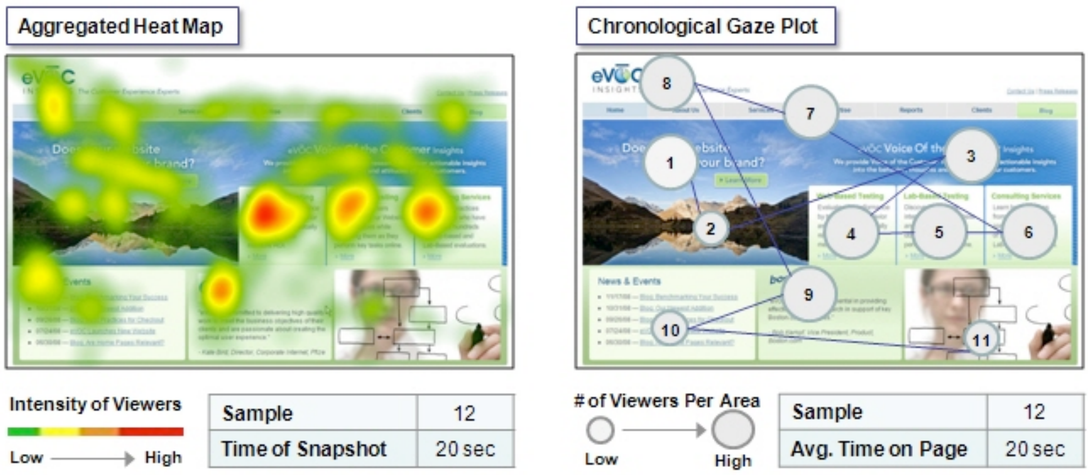


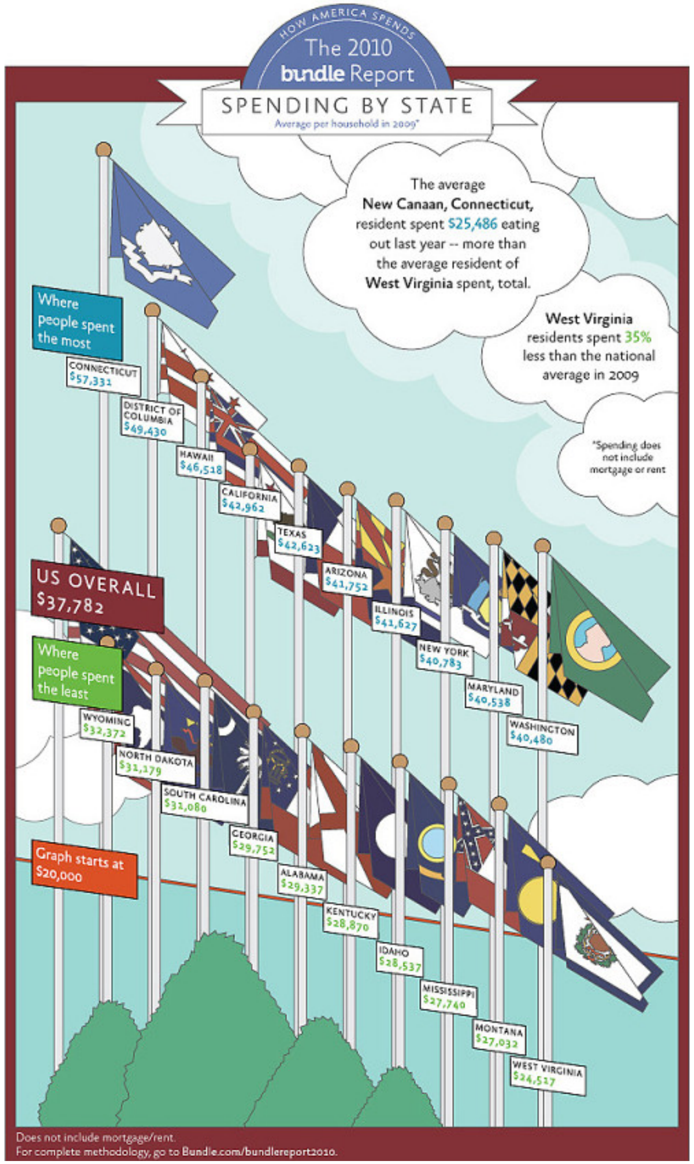
Figure 3: The data of eye-tracking research on a website visually quantified

3.4.1 Eye tracking infographics

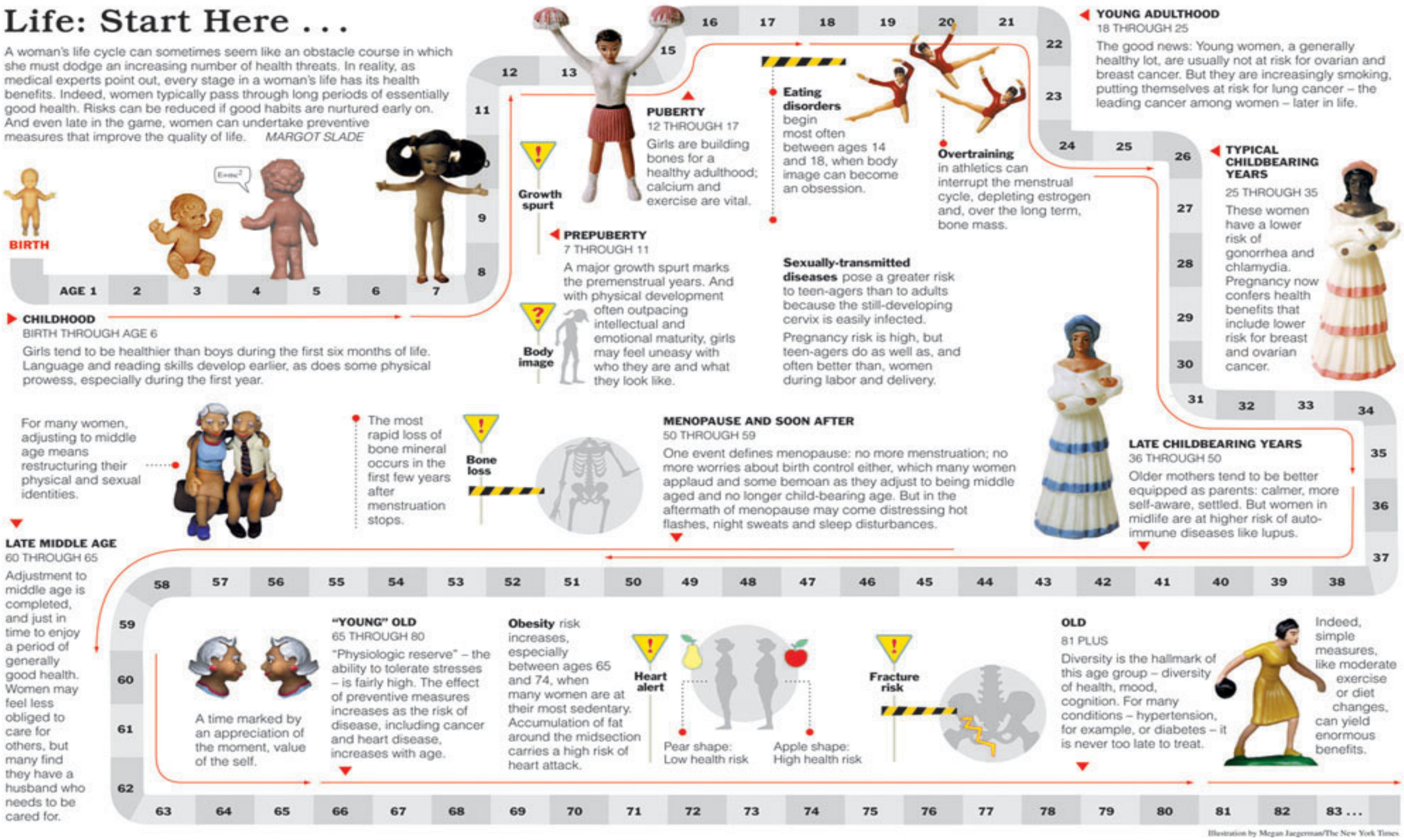
Since 1991 the Poynter Institute, one of the most important centers for training journalists in the United States, has conducted a study called '*Eyetrack*' that analyzes and records the way that readers see and navigate through the pages of newspaper. This helps identifying entry points to the page and which elements attract attention and motivate them to read the text of the information. The study conducted in 2007 provided specific eye tracking information on infographics. It showed that infographics and photos on news pages essentially attracted equal attention, however infographics were the most impressive element to enter a page. It also revealed that 87% of the people who saw an infographic also read the accompanying text, whereas only 41% read the text of an 'ordinary' page containing a heading and text (Quinn & Stark, 2007).

4. Case Studies

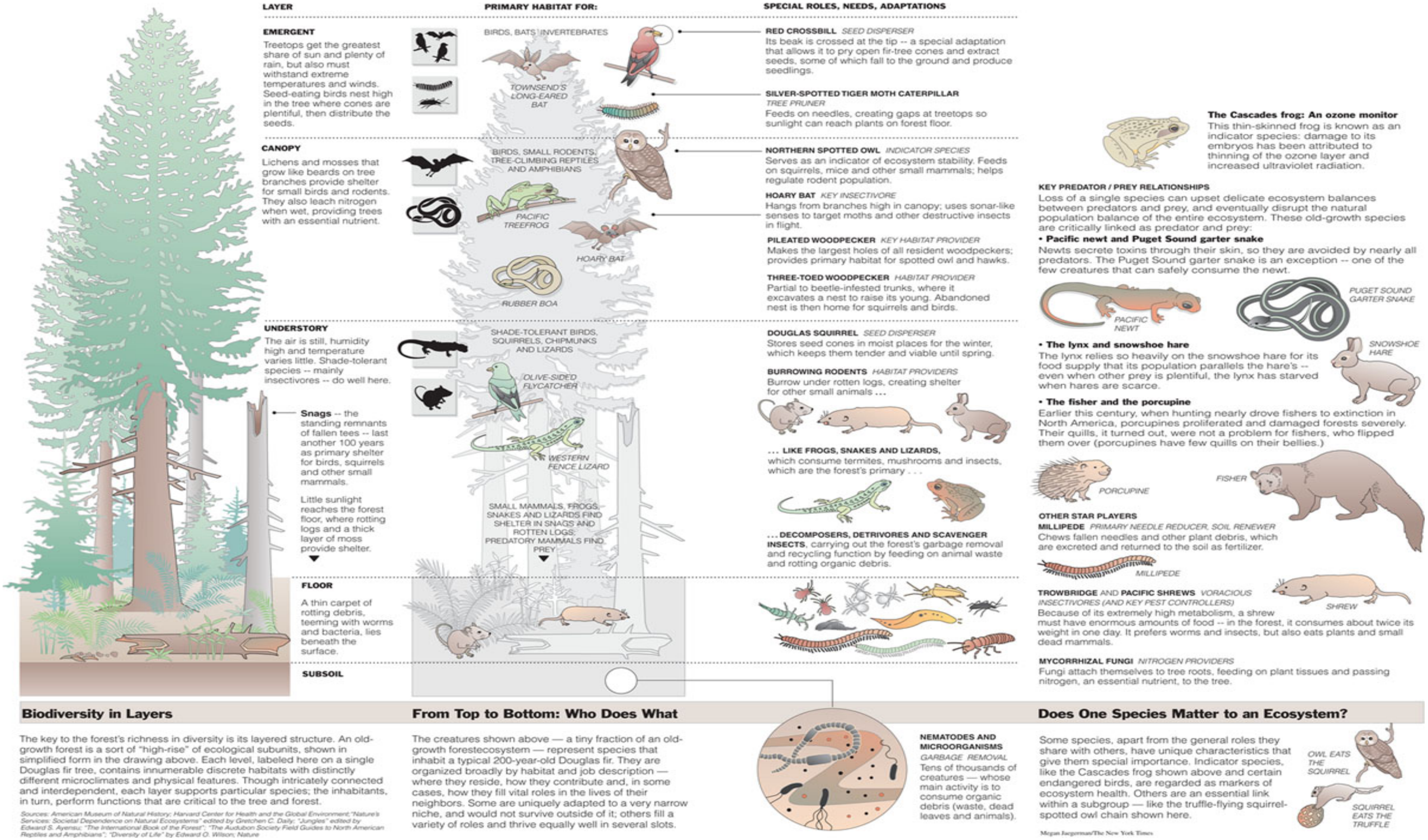
After establishing what makes data visualization good and what makes it bad, it is time to look at the practical implications. I have taken some infographics that were floating around on the Internet and critically looked at them. Taking in account the information gather from background literature I decided whether the work was good or not and what can be changed.



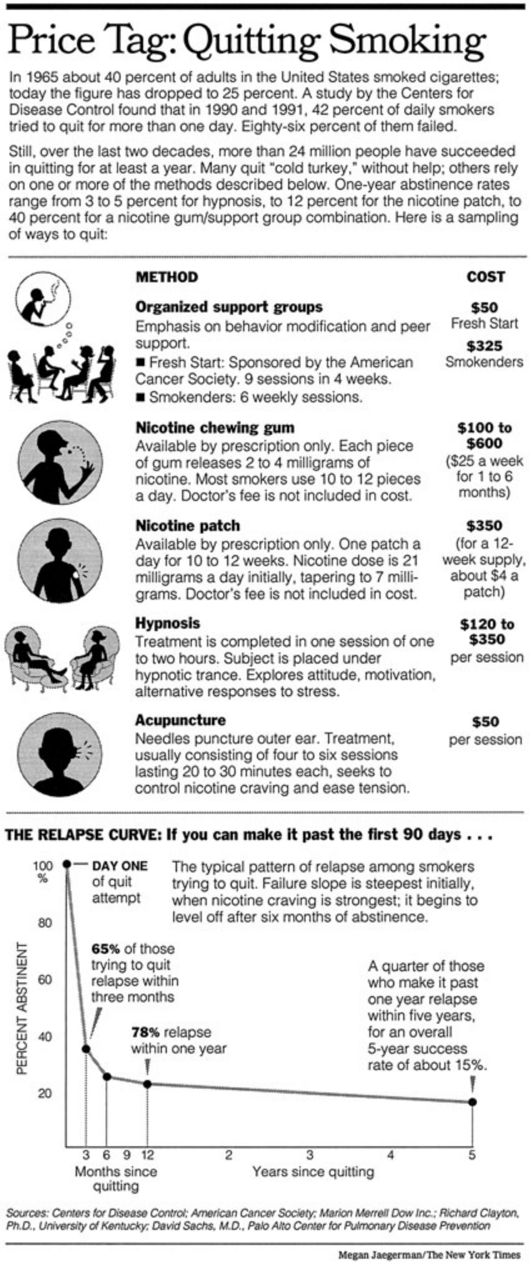
This graph shows the spending pattern in the US. The graph itself is very cluttered making it difficult to see what it is about. The designer made flagpoles that presumably resemble a bar, like in a bar graph. They make a curve, however you can see two curves, one made from the labels (with the state name and amount of money on it) and one made of flagpole tops. Compare Washington with California and see what an immense difference it makes when the user reads the label or the flagpole curve. Absence of a grid or axis is another pitfall here. The graph literally says in a label at the left that it starts at $20,000. Is the bottom of the page $20,000? Or is it the red line? This is a clear example of a bad infographic. The designer did not use the proper design or format, a table or bar graph is much more appropriate. Instead he or she opted for a more aesthetic approach using flagpoles, thereby complicating the data. Leaving the user with more questions than answers.



This infographic is a perfect example of story telling, the picture itself reminds the user of a board game or a lifeline. Therefore the design chosen by the maker is very fitting since it is a lifecycle. The numbers indicate the years and where the user must start reading, the arrows indicate the path to follow. The color palette in general is quiet, but color red is employed to accentuate important information. Icons such as exclamation marks are additionally used to capture attention, as are the black yellow bars that are widely known as a warning sign. It is a playful graph, but informs the user thoroughly about serious matters such as proper diet and health complications in females.

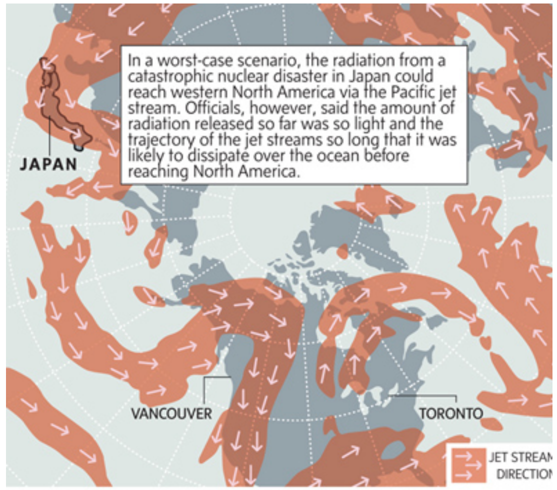


This is a complicated field guide of biological species found in forests. Most field guides isolate each animal or plant; here many animals and plants are placed in their natural context along with the fully integrated explanatory text. The pictures show what the animals look like, while the text (properly placed next to the figure it explains) gives in depth information. Natural colors are used and therefore the scene is easy on the eye, also appropriate considering the topic.

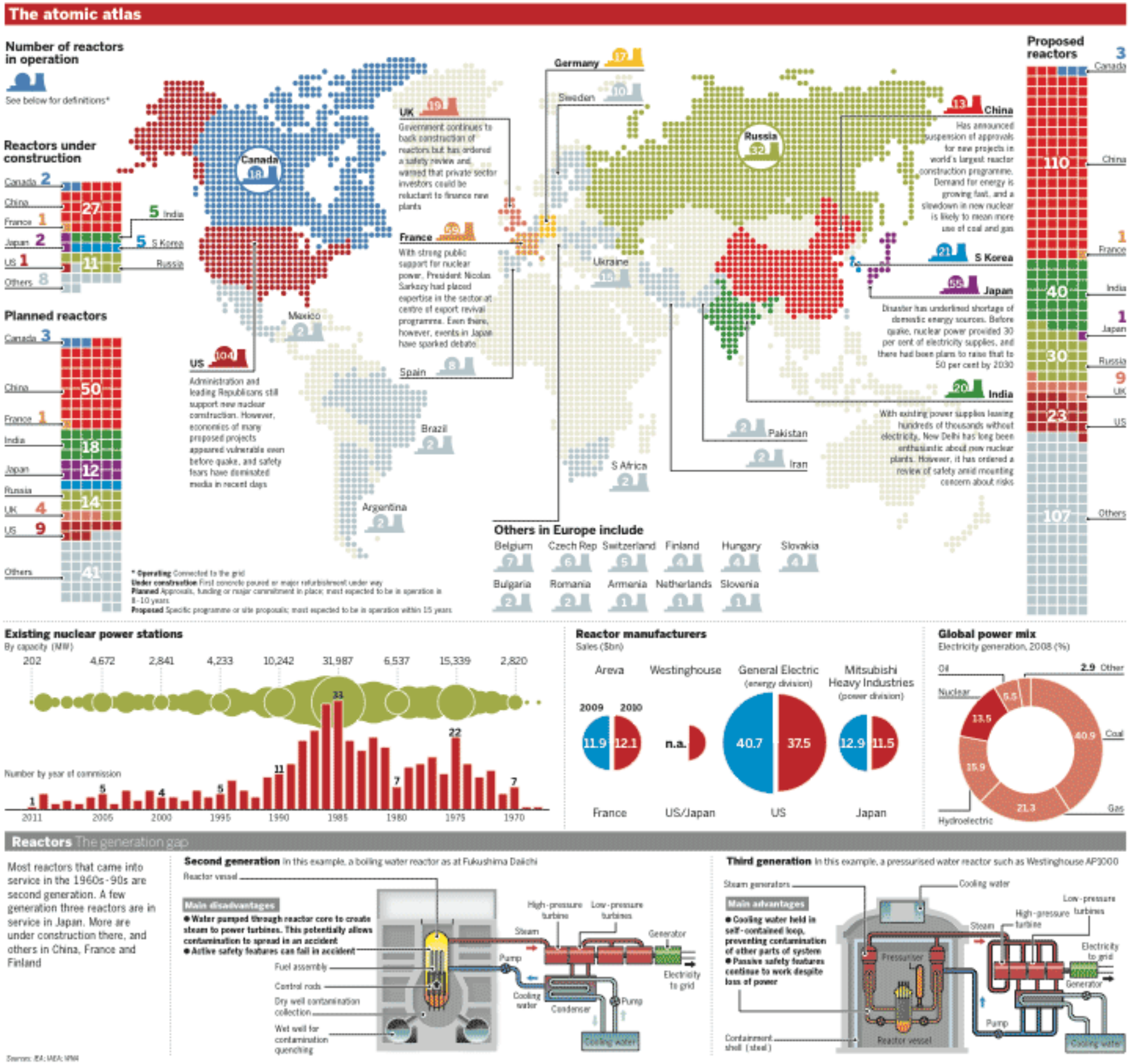


The graph on quitting smoking combines tables, images and text - whatever it takes to explain the content. This is a fine example of a content-driven infographic, with no segregation of information by its mode of production. There is no chart junk, no unnecessary colors or grids in the table. The pictures are small but give the text and numbers something extra. Something that will draw the reader of the newspaper (it was published in the New York Times) to the page it is printed on.

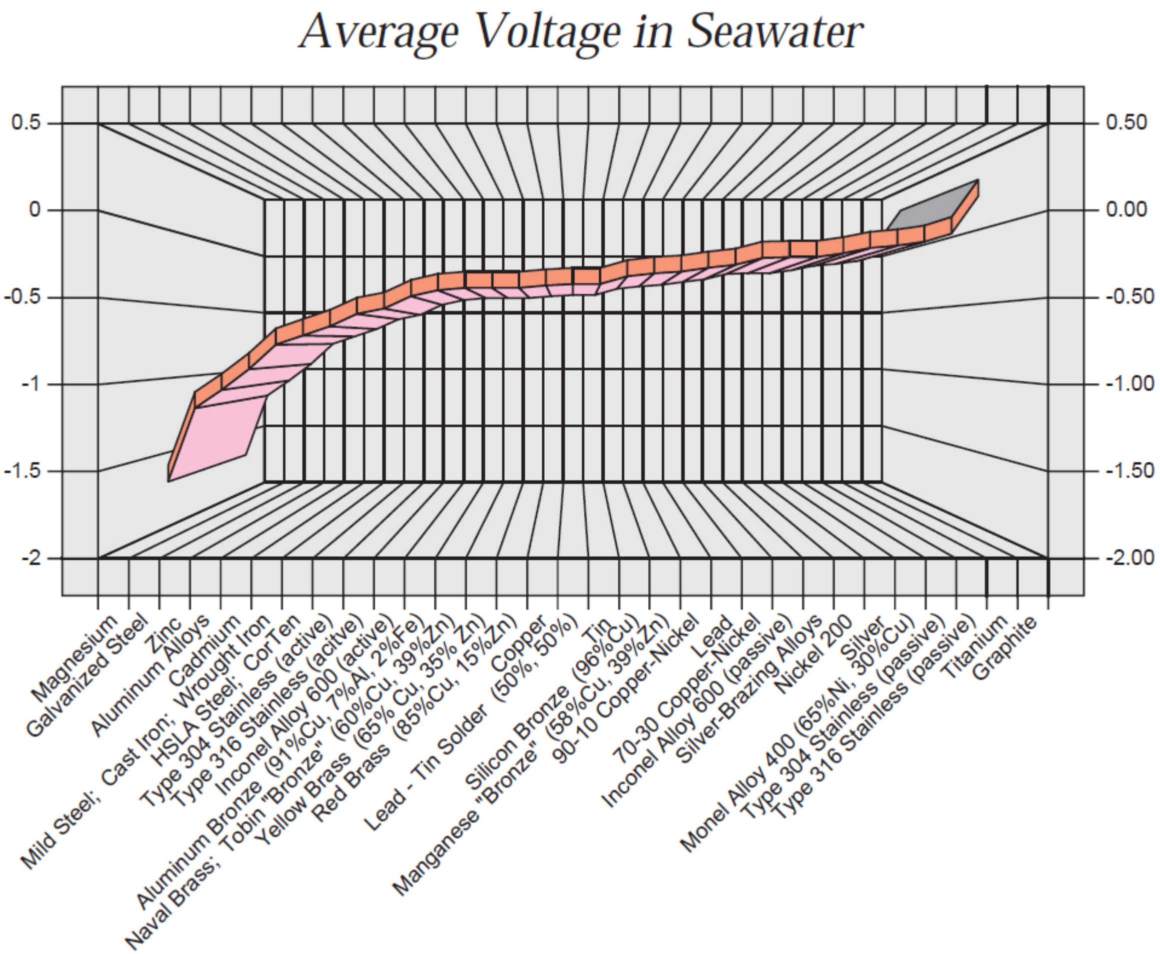
After the earthquake in Japan in March 2011, many newspapers and magazines did stories and editorials on the event. The magnitude of the earthquake and the subsequent economic issues inspired many designers to make infographics and visualized data to tell the story, from tsunami to the nuclear power explosions. The small picture on the right is a simple infographic explaining how jet streams could carry radiation to North America. However, the caption somewhat undermines all of that by saying the radiation is likely to dissipate over the ocean before reaching North America. One can wonder why they have made this in the first place. Is there any news or information in that? It is important not to make infographics for infographics sake. The second infographic (displayed on the next page) is a very large one from The Financial Times. It is so full of information, that the used will definitely learn something. However, for some people it might be too full. Therefore, it is maybe more appropriate for a scientific magazine than for a newspaper for they have a different target audience.



THE GLOBE AND MAIL » SOURCES: SAN FRANCISCO STATE UNIVERSITY



The infographic contains a wealth of information on various topics all related to the catastrophe in Japan. The use of colors is appropriate and serves a function. It combines bar graphs with pie charts, it uses small multiples and pictograms. In itself the work is very well done, however you can argue that the maker overestimates the user (in this case the newspaper reader).



This graph is an example of how not to present statistical information. First of all the use of 3D is out of place, for the designer there is no need to use it other than to show that you can do it. Additionally there is an undesirable optical effect of the gridlines. This is a clear case of chartjunk and how adding extra grid leads to a distorted data/ink ratio. The display of the data as a series of connected boxes is incorrect. The item labels are misaligned with the tick marks, and taking up far too much of the graphic display area. I would imagine this is Edward Tufte's nightmare.

5. Conclusion

To explore the potential role infographics can have in science communication there are three core disciplines that have to be considered. First of all: science communication and the main questions: What are the objectives or motives of science communication? What are the desired effects activities try to establish with the public?

Secondly, there is the field of infographics and the question what the purpose of an infographic is? Why is data visualized, what are the benefits over simply writing something down?

Cognitive science is the interdisciplinary area of research that studies the mind and its processes, and can therefore provide an intellectual basis for data or information visualization.

In the end of this chapter I want to elaborate on the future of science communication in general. I will focus critically on the relationship between science communication and the Internet, and what role infographics can play in that.

Where do science communication and infographics meet?

Science communication can be defined as the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science (Burns, 2003):

- Awareness, including familiarity with new aspects of science.
- Enjoyment or other affective responses, e.g. appreciating science as entertainment or art.
- Interest, as evidenced by voluntary involvement with science or its communication.
- Opinions, the forming, reforming, or confirming of science-related attitudes.
- Understanding of science, its content, processes, and social factors.

Science communication may involve science practitioners, mediators, and other members of the general public, either peer-to-peer or between groups

There are various activities associated with SC, which aim for different effects among the public. They can create a better understanding of science; they can raise awareness, they want to engage the public or let the public participate in science using their knowledge. Regardless of which intended effect the activities aim to have or which model is used; all activities of SC have in common that at some point they have a transfer of knowledge, regardless of the approach used. There is always a scientific discovery or other scientific knowledge that flows from the scientist to the public. This can take place via a text, a poster, a flyer, a news article, a background story in a magazine etc. I think this is where infographics can play a major role in SC, because in whatever medium is used infographics can be applied.

Infographics are generally used to:

- To transmit or communicate a message.
- To present large amounts of information in a compact and easy to understand way.
- To reveal the data. Discovering cause-effect relations, to know what is happening.
- To periodically monitor the evolution of certain parameters.

Here it is made clear that there is a distinction between graphics that function to communicate or illustrate a certain finding and graphics that serve as an exploration of a data set. In SC science in the broadest form (beta, alpha and gamma sciences) is communicated. The results of scientific research, the process of the research, the methodology, and the consequence and implications for society such as pro's, con's, uncertainties or risk, should all be addressed. Infographics can function in all this. Additionally the exploration type graphics are suited for the scientists themselves or when you are dealing with a more informed public.

In general infographics fall in the category of classical one-way communication, the user views the infographic and the effect is often unknown. Studies that directly measured the learning and thus the cognitive effect of infographics do not exist.

There have been a number of eye tracking studies that have measured the learning effect of words and graphics (i.e. multimedia learning) (Mayer, 2010). Multiple studies found that learners spend more time looking at relevant areas of an animation when relevant features are highlighted. Others found that participants learned more after instruction. However, a serious challenge for eye-tracking researchers is to find the sometimes-missing link between eye-fixation measures and learning outcome (or cognitive performance) measures.
Moreover, infographics are not only helpful to readers. They also compel people to think about their message and how they structure information.
In my opinion infographics can function as a communication device in various forms and stages in science communication.

Why prefer infographics to a plain text?

After the literature study I found that there is a myriad of reasons for data visualization and infographics. First of all visual information is attractive, drawings and colors grab the attention of the eye. Eye-tracking research among readers of news websites showed that infographics and photos on news pages essentially attracted equal attention. It also revealed that 87% of the people who saw an infographic also read the accompanying text, whereas only 41% read the text of an 'ordinary' page containing a heading and text. This study was contradicted by another eye tracking study that tried to determine how design influence information recall of Internet news. They found that text alone or text with photos is best in presenting news online based on recall, it revealed nothing on user preference because the participants weren't ask any questions about this (Pipps & Walter, 2009).

Based on visualization studies infographic are favorable to text because they are capable of making complex processes and large amounts of data and information understandable. Again based on cognitive science, it has been proven that humans simply learn better and understand more, if the tools are well designed and are aesthetically pleasing to the eye.

Infographics use symbols, colors, graphics, and other design methods to present information in a way that is visual and easy for our brains to interpret. In addition to the information being easy to interpret, a specific piece of information can be found due to the shapes, symbols, and colors that facilitate the display of information. Compare that to reading an article where your brain has to stay focused on reading the information in a certain order, remembering all that information in order to continue through the rest of the article. Not to mention if you need to reread a specific piece of information and you have to find a word or phrase in an elaborate text.

Some visualizations need not only adequately represent information; their presentation needs also to be effective, leading to a behavior change in the user. Therefore infographics sometimes have to capture the heart. Neuroscientific evidence points out that whereas cognitive thinking leads to conclusions, emotions are the base for behavioral change. Therefore the truth needs not only be adequately represented it also needs to be effective. The aim of the fields of rhetoric and persuasion is behavior modification, or to make the truth more effective. Past empirical studies have shown that arguments presented using metaphors have a persuasive advantage over similar ones presented in prose. This advantage is not limited to metaphors and the advantage is especially strong when they are presented visually. (Lengler & Vande Moere, 2009). Al Gore's work 'An Inconvenient Truth' is a good example of how effective the truth of global warming (of course *truth* is a very loaded term in science, because there are also people who dispute the notion of global warming) can become when information visualization techniques are combined with visual rhetorical figures. He showed a visual antithesis (a glacier now and seventy years ago), a juxtaposition stimulating the viewer to imagine a third picture. In general are rhetorical figures, such metaphors, in infographics especially befitting topics that can evoke emotional responses among the public such as nanotechnology, the financial crisis or cloning. Using these specific elements in infographic does require skilled designers.

What are the difficulties when using infographics?

As Tufte stated: “Graphical competence demands three quite different skills: the substantive, statistical, and artistic. Visualization competence requires no less” Regardless what the topic of the infographic is, the data must be correct and the designer has to completely understand it before turning it into an infographic. Transforming the data is the second step; hereby the designer has to find an appropriate format and design to display the data. Using the right elements, the correct colors such as a natural color scheme as a standard with bright colors to accentuate. It is important to keep in mind several rules such as Gestalt principles and the rules of Edward Tufte. These rules and principles are not mandatory, but definitely a guideline to create a good infographic. Where Tufte stated that aesthetic features only distract attention from the message, others find that beauty in an infographic is a way to draw the user in.
Designing an infographics means that you have to know what the target audience and the medium are, not only for design purposes only (color schemes, high definition graphics etc.) but also to determine what the level of content should be. Here a parallel with science communication can be drawn. The target group or public should be known before designing the infographic. The public is heterogeneous and based on SC literature we can roughly divided them into three groups (Burns, 2003):

- General public: scientists, mediators, decision makers plus other sectors and interest groups. For example, school children and charity workers.
- Attentive public: the part of the general community already interested in (and reasonably well-informed about) science and scientific activities.”
- Interested public: is composed of people who are interested in but not necessarily well informed about science and technology.

The instruments used in the infographic field and in SC are also partially overlapping. Infographics are often found in magazines, newspapers and books; classical transmission-based SC activities are lectures, brochures, seminaries, presentations, or informing the public via mass media such newspapers, magazines, Internet and television. Infographics are often displayed on the Internet and are suited for use on computers. When infographics are digitally used, interactive infographics should be considered, they are not limited to presenting data, but allow the user to explore.

Infographics in digital form, that is on the web, on the computer (for example in e-learning modules) and on tablets (such as the iPad) can be interactive. However, the since the 'tablet revolution' has only recently started this is idea of interactive infographics is still in its infancy. There are many struggles, for example that the sizes of the files are big so that the download time is extensive. Online-graphics in a normal browser is far superior to iPad-graphics in every way. Probably the biggest issue when it comes to interactive graphics: not enough customers to pay the innovation-costs – and not enough innovation to attract the customers.
Infographics in the newspapers have already proven to attract readers; therefore they are very well suited to appear in the science section. Again, the on-line version of the paper can make use of interactive infographic. Some already do, like the NY Times (known for their excellent infographics) such as this one on child brain development or this one on options for reconstructive breast surgery.
The full effect of infographics can be determined using eye-tracking studies in the future. It offers a unique path to testing aspects of theories of multimedia learning, particularly concerning perceptual processing during learning. This might give newer insights in the role they can play for science communication.

The future of science communication

The SC field is an interaction continuum, which continuously gives society and the public an increasingly important role and the level of interaction gradually grows. On one side is the one-way communication, with the sole purpose of informing the public. On the other side are science and the public that are engaged in a dialogue. They interact very actively.

A challenge for the future is to find a better balance between the different interaction modi between science and society. Transmission centered SC is not better than transaction based SC, or they other way around. Which approach . As Van der Auweraert & Van Woerkum stated "all four approaches (PUS, PAS, PES, PPS) should get enough attention so that they can develop. Science communicators must use activities from the entire interaction continuum, to create a sustainable relationship between science and society".

In my opinion social media and the internet will be a very important medium for science communication in the future. With the proliferation of the internet it has become a major source of information for scientists as well as for the public, changing science communication fundamentally.

The scientific community (the source of the knowledge) controls the stream of information that flows to the public (Bucchi, 2008). Web-based science communication often consists of this one-way communication, with websites providing information comparable to newspapers or magazines.

As stated earlier in the more recent years this view has been challenged by the public and science communicators leading to models of science–public relations with emphasis on public engagement and dialogue (Irwin, 2008). The participatory web (web 2.0) claims to be a more dialogic form, with forums and services that aim to enhance user-driven content, like Wikipedia.

These forums can be found on science blogs, which are ubiqutious. A recent article estimates there are between 1000 and 1200 active, serious science blogs, "written by graduate students, postdocs and young faculty, a few by undergraduates and tenured faculty, several by science teachers, and just a few by professional journalists" (Bonetta, 2007). These can be general or specific like a virology blog, where active and heated discussion between patients and experts takes place on controversial diseases (CFS) allegedly caused by viruses (XMRV)[15]. This is why one can argue that dialogue is an integrated part of science communication on the internet. There is

[15] Virology blog discussion

communication but is this always between the scientist and the public or just between a blogger and its devoted readers, the people who are already interested in science? Besides, anyone can say anything relying on the anonimity of the Internet; shouting something in a comment section is not equivalent to dialogue.

Not all information on the internet comes from scientist bloggers or mainstream media who (usually) have reliable references for their content. There is plenty of space for 'lay journalism', which is cultivated by the web 2.0 because of the user-driven content websites (Minol, 2007).
Additionally, many websites that offer information pertaining to health care or biotechnology are of dubious quality and are sometimes funded by companies trying to sell their product or services, such as nutrigenomic testing services[16]. I wonder how the public must discern valid and valuable information in the noisy overload of information that is inherent to the Internet. There are more people producing science news than there are people who can justifiably define themselves as science journalists, thereby altering the quality of scientific news.
In general the availability of credible sources online does not mean the public will use it. One of the greatest challenges for science communication (online) still remains reaching the public. Even more than with traditional media, people can easily ignore science content on the internet if they have no interest in it (Bubela & Nisbet , 2009).

In any type of science communication it is important to gain the attention of key publics that are not actively looking for science information. On the web infographics can help getting in the publics eye, because infographics are already very popular and because visuals are attractive. When you are using the Internet for SC infographics are a way to get people to visit the website. A good infographic also has search engine optimization (SEO) benefits. Many infographics have an embed code (similar to YouTube videos). As soon as websites include infographics it improves SEO ranking. I think infographics can play a role in science communication if they comply with the rule of a good infographic. Because the popularity is increasing, especially on the web,

[16] United States Government Accountability Office, 2006

they provide opportunities to reach new audiences. Using the web for science communication offers possibilities but also has disadvantages (Trench). The biggest obstacle for Internet user looking for science related news is making distinctions between validated and non-validated information and between journalists and non- or near-journalists. When using infographics the user has to make another judgment: is this infographic good and trustworthy or not?

And in the end only good infographics are suited for science communication.

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