

Information Visualization and Usability: Tools for Human Comprehension

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Information Visualization and Usability: Tools for Human Comprehension

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Abstract. This chapter makes a review on the progress of two growing areas in the field of communication: information visualization and usability. Information visualization has experimented a lot of changes during the last few years, especially with its arrival to the Internet and the development of different narrative forms by taking advantage of the main characteristics of the new environment. Something similar has occurred with the concept of usability. The following sections explore the significance of this young idea whose spread took place especially with the start of the Internet. With the objective of completing this theoretical framework, a small usability test was conducted with five renowned visualizations. The results of this test show that even the most salient journals do not fulfill many of the main usability recommendations. Hence, this area still has a considerable way to go regarding its appliance to information visualization.

Keywords: information visualization; usability; infographics; user-centered design

1 Milestones and development of information visualization

Information visualization has been one of the areas with a major development in the field of communication. Its main goal is the presentation of information and data in a comprehensive and orderly way (Uyan Dur 2014). Thus, this discipline can be defined as “the representation and presentation of both data and information that takes advantage of our visual capability in order to expand our knowledge” (Alcalde 2015: 20). Likewise, it is “the use of visual representations to explore, make sense of, and communicate data” (Few 2014: 2). As noted through these definitions, there have been many efforts to define and delimit the area, and most of them highlight the power of information visualization as a communicative tool for the knowledge enrichment (Olmeda-Gómez 2014).

When talking about information visualization we are analysing a booming area, especially in journalism. Thus, it is not a new area or an exclusive communicative tool of our days (Figueiras 2014). It is possible to find antecedents of this visual genre in books like William Playfair's *The Commercial and Political Atlas* and *Statistical Breviary* published in 1786 and 1801 respectively. As pointed out by Cairo (2008), these books contain the first examples of bar, line and pie charts. A few years later, in 1854, it is possible to find another great milestone in the development of information visualization. The British doctor John Snow showed the geographical spread of more than five hundred deaths due to cholera during ten days in the Soho district, London. Snow's map combines two datasets. First of all, the number and location of the cholera deaths and, secondly, the water sources location. Hence, thanks to this map it is possible to find out the relation among the deceases and the contamination of some water sources in the neighbourhood. Edward Tufte highlighted the importance John Snow's contribution by opening a new way of providing "direct and powerful testimony about a possible cause-effect relationship" (1997: 6).

Less than a decade later, the French engineer Charles Joseph Minard published one of the most iconic visualizations ever, a chart of the losses of Napoleon's army during its Russian Campaign (1812-1813). Minard's chart shows the development of different variables: "the size of the army, its location on a two-dimensional surface, the direction of the army's movement and temperature in various dates during the retreat from Moscow" (Tufte 2001: 40). All of that in a very visual chart which reflects the regression of Napoleon's army both during its advance towards Moscow first and its withdrawal then.

Although the examples previously noted are considered a key part of the development of information visualization, they were not published by the press, at least, initially. It exists a deep debate among some scholars about the start of press infographics. Thus, many of them consider that the description of Admiral Vernon's attack to Portobello's bay is the first example of infographics available in the printed press (Sullivan 1987 in Franco 2005). It was published by the *Daily Post* on the 29th of March 1740. However, it exists broad agreement among scholars in identifying the graphic published by the British diary *The Times* on the 7th of April 1806 about Isaac Blight's homicide as the first example of infographics in press (Peltzer 1991). This graphic contains a draw of the view of Mr. Blight's house as well as a plan of its inside with an explanation of the itinerary followed by its murders (Cairo 2008).

However, information visualization experts tend to coincide in highlighting the launching of the newspaper *USA Today* as one of the main milestones in the development of this field. Launched in September 1982, *USA Today* changed the way in which press journalism was produced by introducing a new design idea based on the use of colour instead black and white, an increase in the use of images and a clear commitment in the use of infographics (Lallana 1999). After the emergence of this journal, some global events like, for instance, the Gulf War and the difficulties for accessing audiovisual materials during its course, had a great influence in the development of this genre. The media tried to soft the shortage of videos and pictures of this conflict by using visualizations to explain both the development of the war as well as the weapons and materials used by the armies.

1.1 From printed to interactive infographics

As pointed out before, information visualization has its origin in many works related with disciplines like economics or demographics. Then, the genre reached a new characterization with its adoption by the media and, more concretely, by the printed press. This integration resulted in the development of printed infographics, a particular way of informative communication which can be defined like “an informative contribution based on both iconic and typographic elements, which allows the comprehension of facts, actions or current topics or, at least, some of their main aspects by accompanying or replacing an informative text” (Valero-Sancho 2001: 21).

Following Cairo (2008), infographics are not an ornamental object with the objective of make the pages of the newspaper more light, dynamic or colourful. It has to work as a tool for the reality analysis improving readers’ comprehension.

Through these two definitions it is possible to assess two ideas. Firstly, the nature of infographics as a journalistic genre, similarly to others like reports or interviews. Secondly, the power of infographics as a vehicle for information transmission. Moreover, concerning its production, it has experimented an evolution during the last two decades. Nowadays infographics are increasingly the result of the work of journalists with design and data management abilities while, in the past, it was produced by artists who adapted its know-how to the needs of journalism (Cairo 2017).

The advance of infographics since the 90s has been continuous, as noted before. All of that thanks to the inclusion of new visual forms and technological tools which have allowed the adaptation and improvement of this genre. In addition, these changes have led into the birth of a new form of visualization, multimedia infographics, considered a completely new communicative form by many scholars (Arévalo 2009).

Wibke Weber, defines an interactive information graphic as “a visual representation of information that integrates different nodes into a coherent whole and offers at least one navigation option to control the graphic” (2013: 11). The youth of the use of this genre by the online media has provoked the emergence of a wide range of ways to name it. Thus, leveraging its characteristics –multimedia, hypertext, and interactivity–, a lot of nomenclatures have emerged. Some of them are, for instance: digital infographics (Pinto Rodrigues 2012), online infographics (Nogueira 2018), interactive infographics (Dick 2013), or multimedia infographics (Salaverría and Cores 2005). Another ones are data visualization (Iliinsky 2012) or information visualization (Anderson 2017). However, it exists a deep debate among scholars. While some of them consider that infographics are a subdiscipline of information visualization, others think that both infographics and information visualization are part of the same reality.

Despite these diverse ways to name it, which is undeniable is that multimedia infographics have experimented a huge advance in the last few years. This advance has its explanation in the fact that, while printed infographics do not rely on a close connection with technology, multimedia does. Thus, it is possible to notice different stages in the development of multimedia infographics which, following Gomes-Amaral (2010), are:

- *Content replication.* It was the initial stage of the publication of infographics online. Therein, newspapers replicated the same content published before on their printed version without any interactivity or multimedia capability.
- *Addition of certain interactivity.* The second stage was marked by the integration of a certain level of interactivity in the infographic pieces previously published in the printed edition of the media.
- *Inclusion and combination of multimedia elements.* The main characteristic of this third stage is the use of audio, video, text, images and hyperlinks in a product conceived for its publication online.

- *Data based infographics*. Visualizations linked to a database with real-time updating. This fourth stage allows the highest level of personalization and exploration for the reason that each individual use can refer to a specific part of the data in order to obtain an individual and exclusive experience.

Hence, when talking about infographics –both printed and multimedia– we are talking about a flexible and efficient journalistic genre and communicative tool which can be a complement for the information or present it autonomously (Zwinger and Zeiller 2016). In addition, infographics have demonstrated its capability to deal with data from many disciplines, and it is the reason why its use is becoming more frequent in disciplines like art (Li 2018) or economy (Gatto 2015).

Although the development of information visualization was steady during the last twenty years, further challenges have emerged during the last decade. The onset of new devices like mobile phones or tablets provoked new needs in the production of news graphics, especially the journalistic ones. Journalists, designers and programmers who carry out the task of data extraction and content production for these news products have now the need of adapting its visual appearance and its functions to these different ways of consumption. Hence, concepts like responsive design or usability play now a central role when producing information visualization.

2 The concept of usability and its relevance for information visualization

Usability has been defined by the International Organization for Standardization (ISO) as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” (International Organization for Standardization 2018: 15). Although this agency opens its definition to all products, the historical development of the concept has been centered mainly in computing tools in both software –computer programs, video games or, more recently, mobile apps–, and hardware sides–computers in its different variants, mobile phones or tablets among other devices–.

In 1993 Jakob Nielsen talked about the growing importance of user interfaces in the computing of that time. Nielsen pointed out that the changes in the use of computers – from specialized users to the popularization of these machines– lead to the need of “making life easier for the user” (Nielsen 1993: 8). Hence, in the last years the concept

of usability is more related with realities like the “learning agility and the ease of use of a product” (Rache et al. 2014: 180) and linked very closely to the idea of the user-centered design (UCD) where one of the main focus when producing a technological product is the capability to adapt it to the final user (Mayhew 1999). Regarding this idea, Nielsen (1993: 26) established five attributes to usability:

- *Learnability*. Systems should be easy to learn in order to make possible a quick adaptation of the user.
- *Efficiency*. This attribute refers to the ease of learning how the product works in order to increase users’ knowledge.
- *Memorability*. This characteristic points out the need of making systems whose use would be easy to remember. Thus, when users come back after a certain period of time without using it, it would not be necessary to learn how it works.
- *Low error rate*. Errors should not appear or, at least, their appearance should be scarce. Therefore, the system should be capable of recovering itself from an error.
- *Satisfaction*. Nielsen pointed out that systems should be pleasant to use, a feature that would lead the users to a major satisfaction.

As it is foreseeable, the major development of both the theory about this concept and the design of interfaces and devices with the most recommended usability criteria has been taking place from the beginning of the Internet, democratisation of computers and, in the last few years, mobile phones (Souza and Maciel 2018).

2.1 The challenges of usability evaluation

In the communicative context of our days, “users are surrounded by a broad range of networked interaction devices” (Yigitbas et al 2018: 231). This fact has provoked a lot of changes in the production of communicative products and tools. However, one of these changes stands out among the others: the user has become a central part in the designing process. This phenomenon is what experts call the user-centered design, “an iterative design process in which designers focus on the users and their needs in each phase of the design process” (Interaction Design Foundation 2019: 1). Hence, at the present time, those professionals who produce tools and products both in the area of communication or in other ones have to put the final users in the middle of their projects in order to provide them with efficient and attractive experiences.

In the course of this designing process as well as after its launching, both these teams and some outside bodies conduct different usability tests and experiments. These evaluations are used to assess the efficacy and the pertinence of both the products and the techniques employed in its production and can be performed in different ways.

For instance, Rache, Lespinet-Najib and Andre (2014) explained the existence of two types of methods for the evaluation of usability. First of all, there would be techniques where the presence and participation of the users are needed. These could be:

- *User testing*. In this method, the users are required to interact with the interface in both free and directed navigation.
- *Card sorting*. Researchers present different cards to the users. They are required to group them in different categories relevant for them for, finally, naming these categories.
- *Interviews*. These could be directed, semi-structured or non-directional. All these three types have the objective of knowing user's perceptions on the use of a product.
- *Questionnaire*. It exists some pre-determined and standardized questionnaires like the Website Analytics Measurement Inventory (WAMMI) or the Usability Measurement Inventory Software (SUMI).
- *Creativity methods*. Example of these techniques could be brainstorming or association of ideas, among others.
- *Critical incident*. Qualitative interview where the interviewed user identifies different events. The person highlights these events, how they evolved and their impact and consequences.
- *Observation*. In this method, researchers are observers of the normal performing of users' activities.

These authors noticed that another possibility is the use of techniques where the presence of the user is not required. These methods are performed only by researchers or experts which can notice the usability particularities of any product by using different procedures:

- *Heuristic analysis*. Inspection of the interface with the objective of detecting the positive and negative aspects of its usability.
- *Cognitive walk-through*. Simulation of the user's cognitive behaviour. The authors identified three phases in the implementation of this method: (1) definition of the

scenario and the aims of the study; (2) evaluation phase with questions for each task performed; (3) identification of any possible usability problem by using the answers given to the previous questions.

- *Personas*. Analysis of both the needs and profiles of the potential users of a product with the objective of creating fictional characters. Then, designers can refer to these profiles when producing a new interface.
- *Automated evaluation*. Use of algorithms for the automatic analysis of the quality of the presentation.
- *Evaluation by expertise*. Identification of any usability problem by an expert or a group of experts.
- *Analysis of documents and reports*. Review of documentation from diverse sources. With the use of this method, researchers can make their own judgements on different products.
- *Creativity methods*. As previously noted, this method involves the utilization of brainstorming or the association of ideas and it is valid for research in both the presence and the absence of the users.

3 Method

To complete the theoretical approach presented in this chapter with an empirical experience, a small heuristic usability test was conducted in order to see if some of the most recognized visualizations published in the last few years fulfill the main usability criteria set by different authors. To reach this objective, an analysis card used by de Oliveira and Guimarães (2017) adapted by selecting twenty of the items contained on it. It is necessary to point out that these authors reviewed previous research in order to set up this tool. It is necessary to note that there are different methods for usability evaluation as pointed out by Rache, Lespinet-Najib and Andre (2014). Then, five visualizations were chosen. These multimedia infographic examples were awarded in the Malofiej Awards' Best of Show – Online from 2015 to 2019. After its identification, the analysis card was applied to these items in an heuristic analysis in order to compare the presence of the chosen criteria in these renowned works. The twenty elements reviewed in this analysis card are listed in the Table 1 and were scored from 0 to 5 points. Thus, each visualization could obtain an overall score from 0 to 100 in fulfilling the established items.

Table 1. Usability criteria reviewed in the analysis card. Source: de Oliveira and Guimarães (2017).

Name	Questions about each topic
User control and freedom	Does the user have the freedom to control the visualization?
History	Does the visualization tell a story by itself?
User control	Is the user allowed to control the data?
Orientation and help	Does the visualization provide guidelines about its utilization?
Provide multiple levels of detail	Does the visualization offer the possibility to access multiple levels of detail for the information?
Details on demand	Does the information provide the possibility to ask for any further data?
Spatial organization	How good is the placement of the elements in the visualization?
Grouping and distinguishing items by format	Does the visualization distinguish items by its format?
Grouping and distinguishing items by location	Does the visualization distinguish items by its location?
Help and documentation	Does the visualization provide any documentation or context details about the topic?
Legibility	What is the ease to read the data in the visualization?
Aesthetic and minimalist design	Is the design minimalist?
Information density	What is the density of the provided data?

Cognitive complexity	Is this visualization difficult to understand to a medium user?
Multivariate explanation	Does the visualization use multiple variables for explaining the information?
Put the most data in the least space	Is the visualization efficient in using the space?
Formulate cause and effect	Does the visualization provide the cause and effect of the data or information showed?
Consider people with colour blindness	Does the visualization avoid colours like red and green?
Conciseness	Is the visualization concise by avoiding data redundancies?
Integrate text wherever relevant	Does the infographic use text only when necessary for extend the information?

The authors are aware that this experience is not representative about the development of the usability criteria or the user-centered design implementation. However, it will be very useful for pointing out some of the key strengths and weaknesses of five significant visualizations awarded by an international jury.

3.1 Selected works

In this section we will describe briefly the works which integrate our sample, five prize-winner visualizations at the Malofiej Awards, the most relevant recognition for infographics. Malofiej Awards take place at the University of Navarra every year since 1993, thanks to the joint effort of both the University of Navarra and the Spanish Chapter of the Society for News Design, one of the most important associations in the professional field of information visualization. For a few days, professionals and scholars from around the world share their experience in workshops and conferences. However, one of the main events is the awards ceremony where the most salient visualization examples in different

categories are recognized. For instance, in 2019 there were prizes for both digital and printed visualizations in categories like ‘Best of Show’, ‘Best Map’, ‘Climate Change and Environmental Commitment’, ‘Human Rights’, ‘Equality and Women’s Promotion’ as well as the classic ‘Gold’, ‘Silver’ and ‘Bronze’ qualifications for breaking news and features printed and online graphics.

As previously stated, the five online visualizations awarded as the ‘Best of Show’ from 2015 to 2019 were selected. They will be briefly described before displaying the main findings of our small heuristic usability test.

*Areas Under Isis Control*¹ This visual story, whose last update was on the 28th December of 2015, describes the advance of both the Iraqi Army and the ISIS militants in their fight for the lands of Iraq, Syria and Jordan. The user only has to scroll down in order to find a great variety of maps —up to thirty—, charts and pictures of the conflict zone. Although the content does not show any interactivity, *The New York Times* visualization team tried to tell the whole story with the use of charts, maps, text and images.

*Unaffordable Country*² allows the user two possibilities. First, it is possible to reach historical information from 1995 to 2014 about the house price in every single region of the United Kingdom. It is possible to find out the highest, lowest and median price of a house in the chosen area. Then, the users have the option of entering their salary in order to check how affordable could be buying a house with their current earns. All of that in an interactive choropleth map where a chromatic scale from blue to red shows the price of the housing.

*Olympic Races Social Series*³. The Olympic Races Social Series were a set of visualizations published by *The New York Times* during the 2016 Rio de Janeiro’s Olympic Games in order to give an account of the development of the athletics or swimming races among others. There were explanations about the most successful

¹ Published by *The New York Times* in 2014 and awarded in 2015. Available at <https://www.nytimes.com/interactive/2014/06/12/world/middleeast/the-iraq-isis-conflict-in-maps-photos-and-video.html>

² Published by *The Guardian* in 2015 and awarded in 2016. Available at <https://www.theguardian.com/society/ng-interactive/2015/sep/02/unaffordable-country-where-can-you-afford-to-buy-a-house>

³ Published by *The New York Times* in 2016 and awarded in 2017. Available at <https://www.nytimes.com/2016/08/15/sports/olympics/usain-bolt-100-meters-justin-gatlin-results.html?smid=pl-share>

countries in each discipline. All the visualizations followed very similar patterns. They were built-in news stories as an animated content that the users could play. Then, a simple and lineal representation of the swimming pool or the running track was presented with an iconic draw of the athletes and its distance and position during the course of the races. At the end, the visualization showed which athlete won the gold, silver and bronze medal as well as the distance between the first competitor and the rest of the participants. The main point of these items is that they were shared as GIFs through *The New York Times*' social media accounts, being a very visual content whose simplicity and clarity could attract more readers to the whole information, which was completed with text, images and, sometimes, other graphic examples.

Although the whole series were awarded, the authors selected one example of this set, the news piece about Usain Bolt's victory in the 100 metres race published on the 14th of August 2016.

*The Science of Hummingbirds*⁴. This visualization has the objective of explaining the particularities of hummingbirds, one of the smallest bird species. In this work, the user can access a lot of information about these birds like their speed, comparisons about their size, the particularities of their tongue or their brain. All of that with a combination of real images, draws, text, and charts in order to provide a lot of information on these creatures.

*A Window into Delhi's Deadly Pollution*⁵. This visualization is the result of the placement of a camera in the top of a building in Delhi in order to advert the pollution levels in the city. The resulting story was composed by a map with the location of the camera and the presentation of hundreds of images from that point. The user has to scroll down the piece to make a journey across the pollution levels between the 29th of October and the 8th of November 2018. The story offers comparisons between different hours of the day as well as charts with data collected from pollution measure stations in the city.

⁴ Published by *National Geographic* in 2017 and awarded in 2018. Available at <https://www.nationalgeographic.com/magazine/2017/07/the-science-of-hummingbirds/>

⁵ Published by Reuters in 2018 and awarded in 2019. Available at <https://graphics.reuters.com/INDIA-POLLUTION/01008173281/index.html>

4 Findings of the usability test

As explained in the method section, five renowned visualizations were reviewed in order to find how they apply some of the most common usability characteristics. Thus, in this section the main strengths and weaknesses of each visualization will be highlighted by pointing out those areas where each work is salient as well as noting those ones were not. Therefore, before explaining the singularities of each visualization regarding its usability patterns, the final score of each test will be showed in the Table 2. It is necessary to note that due to the smallness of the sample this will serve just for monitoring some trends and especially for making a slight comparison among different visualizations which obtained the same award.

Table 2. Final results of the usability test. Own elaboration.

Title	Publication	Year	Final score
<i>Unaffordable Country</i>	<i>The Guardian</i>	2016	83/100
<i>Areas Under ISIS Control</i>	<i>The New York Times</i>	2015	77/100
<i>The Science of Hummingbirds</i>	<i>National Geographic</i>	2018	75/100
<i>A Window into Delhi's Deadly Pollution</i>	<i>Reuters</i>	2019	70/100
<i>Olympic Races Social Series</i>	<i>The New York Times</i>	2017	49/100

As shown in Table 2, *The Guardian's Unaffordable Country* reached the highest score in our usability test. This visualization obtained the maximum rating of five points in the following categories: user control and freedom, user control, details on demand, spatial organization and formulate cause and effect. Compared with the other four examples, the user can control which data are displayed and it offers the highest possibilities when looking for the data of a particular area. It is a good example of spatial organization because the map is optimized for an efficient displaying in any screen without any infill material. The lowest scores for this work were the three points obtained in both history

and cognitive complexity. Compared with the rest of visualizations reviewed, the story narrated in this one is not as evident as the other ones. Something similar occurs with its cognitive complexity. A certain level of literacy in the use of interactive maps is needed for navigating through this work.

The highest values for *Areas Under ISIS Control* were reached in the following items: history, provide multiple levels of detail, grouping and distinguishing items by location, and formulate cause and effect. Due to the extent of this example and as in contrast with the previous one, the narration of a whole history in this visualization is a good example of how this journalistic genre can be combined with elements like images, videos or text in order to narrate complex data and facts. Thus, in this case, *The New York Times* used a cascade of maps and charts that, together with text and images, completes a whole story which formulates the causes and effects of the described scenario by itself. In sum, these materials are correctly grouped both by its format and its location, which simplifies the ease of its read. However, the lowest values for this example were given in areas like its informative density –it constitutes an in-depth visualization with a lot of information– or the lowest possibilities for its control by the user. Moreover, this visualization does not have any interactive possibility at all.

National Geographic's The Science of Hummingbirds obtained a very similar qualification if compared with the previous example. This is thanks to its salience in criteria like the fact that it narrates a whole story by itself –history– or different qualities related to its design. For instance, this visualization uses text only wherever it is relevant, considers people with colour blindness and puts the most data in the least space. However, it obtained a score of two points in areas like control possibilities for the user or the existence of the possibility of obtaining data on demand.

A Window into Delhi's Deadly Pollution had a score of 70 points. This visualization combines the highest score obtained in fields like the integration of text wherever it is relevant or its conciseness with the fact that users do not have any control possibility, or they do not have the opportunity of obtaining details on demand. It is a good example of what some experts call 'scrollytelling'. Scroll is the main action that users are allowed to perform in this visualization without any other exploration possibilities apart from those ones established by the designers.

Finally, *The New York Times' Olympic Races Social Series* obtained the lowest qualification in our study. This is due to the nature of the visualizations, designed for being played without any possibility of interaction. Therefore, although this example

reached the highest rates in areas like considering people with colour blindness or the ease of its comprehension by any user, all those categories related with the level of details provided or the control options available for users had low scores. Then, watching these results, it is possible to notice that this visualization was envisaged with a supplementary and visual function, not as the main way for displaying the information.

5 Conclusions

In sum, the aim of this chapter was to highlight the growing importance of usability in the present context of information visualization. As noted in the previous sections, information visualization has been one of the journalistic genres with a major development since the 1990s decade. Especially with the arrival of the Internet, this way of communication has explored new narrative forms and capabilities.

However, in this context, usability and efficiency criteria play now a central role. As stated, information visualization teams have to pay more attention than ever to this side of the development. Here, journalists, designers and programmers try to make visualizations where efficiency, attractive and informative relevance have to be present in one single product.

To prove how important is following usability patterns in nowadays' journalism, a small usability test was conducted. This brief experiment has allowed us to appreciate some of the weaknesses and strengths of high-renowned visualization works in order to highlight the importance of considering as much usability criteria as possible when producing informative pieces like these.

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