Data Visualization in the News Media: Trends and Challenges

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Abstract. Data visualization is applied intensively in the digital news media where it serves as an effective tool for storytelling and for facilitating explanations of complex or data-intensive information. However, research and theoretical studies of this type of narrative lag badly behind in terms of both their volume and importance. It is in response to this failure to keep pace that this chapter seeks to review academic and scientific production dedicated to understanding the news media, data visualization and, more specifically, information visualization, infographics, visual narratives, and visual storytelling. In so doing, our aims are to, first, delimit the state of the art of this discipline; second, describe emerging trends and the challenges faced when seeking to deploy data visualization, at the same time as identifying the technologies and protocols being employed to this end and, third, deter-mine the possibilities and limitations of its use for communication and journalism. We find that recent studies have focused primarily on infographics, data journalism, structured journalism, media literacy and the reader's interpretation of visual data, the exploitation of visualization in the digital media, and visual analytics. Studies of data visualization technologies and tools have shown an interest above all in the application of big data strategies within the news media, as well as in the development of software and tools of visual analysis. Finally, our scientific database revealed a number of studies dedicated to visual analytics, the specific challenges faced and the decision-making processes involved.

Keywords: Information Visualization, Data Visualization, Digital News Media.

1 Introduction

From the outset, the written news media have progressively incorporated a series of visual resources (essentially, infographics and graphics) to support and bolster their narrative function and so guarantee their communicative efficiency. Indeed, it was the specific task of the art departments of the traditional newspapers to design the graphics and infographics that accompanied the texts and which, to a large extent, served to

attract the attention of the reader at the same time as they acted as a source of information [1]. In short, data visualization in journalism has been gradually consolidated as a potent tool for storytelling, transforming news genres and opening up a new path for the reporting and consuming of news.

Yet, it has only been during the process of the digitization and transformation of the analogue media system to the digital media ecosystem that different ways of visually representing the news have taken center stage. Thus, in the digital news media today, we have been witnesses to a significant increase in the use of data visualization, to the point that it has become one of the principal strategies used by these media for telling their stories [2] [3] [4], as data sources are converted into visual information [5] [6].

Unlike a newspaper article in the traditional media where the text told the story and the graphics or visualizations supported what was being narrated, in the new digital media the latter no longer fulfil this merely secondary role. Indeed, thanks to their interactive nature, these visual products today occupy a prominent place in storytelling [7] [8].

But the value of visualization is much more than that associated with a simple narrative resource. Today, thanks to the resolution and size of the screens available to us and the gesture navigation of emerging devices, visual content can be truly captivating and play a key role in attracting an audience. And it is in these environments that offering free access to information visualization in the cybermedia plays a key role in marketing plans designed to attract users that consume other paid content. In short, information visualization, with its analytical and narrative power, can help attract and retain new users.

Although the digital news media today are characterized, among other attributes, by the intensive use they make of visualization for storytelling, theoretical studies conducted from within the academic community of this type of narrative have failed to keep up in terms of both their volume and importance. If we review the scientific literature on the subject of data analysis and data science, it is evident that just 0.5% of this production is dedicated to data storytelling and data journalism [9]. Moreover, most of this scarce production focuses its study of these strategies on the analysis of a limited number of cases or products or on the examination of the output of a specific country or city.

In short, in addition to the scarcity of scientific studies examining the field of visualization and communication, very little research has been dedicated to conducting indepth, systematic analyses of the nature, content, and contributions of this literature exploring the use of visual representation as a communication strategy in the digital news media.

In an effort to fill this gap, this chapter takes a systematic approach to the analysis of academic studies of data visualization in the news media. More specifically, the main goal of the study we conduct is to present the state of the art in this field. In addition to this general objective, we set ourselves the following specific objectives. We seek to, first, describe new trends and challenges in data visualization in the news media; second, identify the technologies being employed for its deployment; third, define the protocols used for data visualization in journalism, and, fourth, determine the possibilities and limitations of data visualization in the field of communication and journalism. To achieve these objectives, we apply the SALSA framework [10] [11] in order, first, to conduct a search and undertake an appraisal of academic articles and, second, to synthesize and analyze academic studies published on the following aspects related to journalism and the news media: information visualization, infographics, visual narratives, data visualization, and visual storytelling.

2 Theoretical framework

Data visualization in journalism is intensively employed as a tool for storytelling; however, as noted above, theoretical studies of this type of narrative lag badly behind in terms of both their volume and importance. In recent years, the main studies conducted on data visualization in journalism have focused primarily on a fairly limited set of subjects: infographics, data journalism, structured journalism, media literacy and the reader's interpretation of visual data, the exploitation of visualization in the cybermedia, and visual analytics.

For example, research conducted into the use of infographics has tended to be concerned essentially with its typology, use, characteristics, and evolution in the news media [12] [13] [14]; the informative treatment afforded scientific infographics [15] [16] [17] [18]; and the analysis of different case studies employing infographics, including a study by Castañeda [19] of the Jihadist terrorist attacks in Barcelona and the work of Simakova & Ivandaeva [20] who compared the infographics of the New York Times and the Russian Reporter.

In the case of research focused on visualization as applied to data journalism and structured journalism, we find a number of highly insightful studies, including, most notably, Chen and Guo [4] who conduct an analysis of the Global Data Journalism Awards. Equally noteworthy are studies by Pentzold and Fechner [6], who examine how journalists exploit data to exploit a news story's prospective probabilities, and Weber et al. [21], who analyze the genre of data stories and journalistic storytelling. Of interest here also are studies by Ojo and Heravi [9], who seek to determine the characteristics of a good data story and how such stories should be created, Kalatzi et al. [8], who examine the specific facets of data journalism and its potential from a theoretical approach, and Freixa et al. [22], who focus, among other things, on offering a definition of structured journalism and its characterization.

A number of interesting studies have been made of data visualization technologies and tools and, in particular, of the relationship between big data and the news media [23], the software used to interpret Twitter analytics and news events [24], data visualization devices [25] and the creation of visual analysis tools [26].

One of the aspects that has attracted most research interest within the field of data visualization is that of media literacy, understood as the way of teaching and learning about the news media. Here, two works stand out: first, Cairo [27] thanks to his analysis of the way in which the reader interprets the visualization of data in the news, and, second, Engebretsen [28] who undertakes this interpretation from the point of view of young students.

Studies have also been made of data visualization practices in newsrooms. These include studies of productive routines [29] [30], proposals for data visualization in cybermedia [31] [32], visualization design [33] [34], and interaction techniques [35].

Finally, studies have been undertaken of visual analytics, the specific challenges faced and the decision-making processes involved. For example, Segel & Heer [2] reviewed the design of data stories and identified different genres of narrative visualization, while an early study conducted by Keim et al. [36] was something of a precursor in its reflections on visual analytics, its elements and functions.

2.1 Methodologies employed by data visualization

A review of the literature dedicated to the methodology employed by studies concerned with understanding the relationship between data visualization and journalism reveals a preference for the following techniques: case studies, interviews, bibliographic analyses, and content analyses.

The case studies published in recent years have tended to focus primarily on analyzing items of journalism that appear in specific areas of the news media. In what follows, we describe, in chronological order, some of the most representative of these studies.

Segel and Heer [2] analyzed narrative visualizations in online journalism, blogs, instructional videos, and visualization research and reported five case studies that highlight a range of different design strategies. Later, Catalan-Matamoros et al. [17] conducted a content analysis by undertaking a retrospective review of the use of images in articles about Ebola vaccines and vaccination in all issues of the Spanish newspapers, El País and El Mundo, over a five-year period. In a similar vein, López-del-Ramo and Montes-Vozmediano [13] analyzed 33 infographic reports that received awards in the Malofiej Competition and Castañeda [19] analyzed 36 infographics by applying the method developed by Valero Sancho, in which journalistic infographics are awarded a quality index using a numerical formula of zeroes and ones.

More recently, Ojo and Heravi [9] categorized the patterns employed by 44 outstanding data stories that had been winners of the Global Editors Network's Data Journalism Awards between 2013 and 2016; Sjafiie et al. [37] analyzed the changes in the way news events are illustrated using text and image narrations and their evolution towards infographics in the Suara Merdeka newspaper in Indonesia; and Araújo [29] analyzed the coverage of women on the 7, 8, and 9 March 2017 in three of the most important news media websites in Brazil: Folha de S. Paulo, O Globo and Estadão. Alonso-Plazas [25] undertook a study of 116 visualizations produced between 2010 and 2012, all of them previous winners in the online category of the Malofiej Awards of the Society for News Design; and Simakova and Ivandaeva [20] studied various classifications of infographics and analyzed the emotional and aesthetic load of different infographics published by the Russian Reporter and the New York Times.

Finally, Jacob [15] identified and analyzed infographics related to the COVID-19 pandemic as used in The Hindu and The Times of India. That same year, Chen and Guo [4] analyzed and classified the interactions in works of data journalism receiving prizes in the Global Data Journalism Awards 2012–2019; and Pentzold and Fechner [6] conducted a case study centered on an extensive list of four different source types for data

journalism – namely, directories of data journalism projects, award schemes, websites, and blogs that monitor data journalism projects – and specifically identified 70 media outlets.

As mentioned above, another of the most typical methodologies employed in the study of data visualization and its media applications is that of the interview. A good example of this is the collaborative study undertaken by Engebretsen et al. [30] in which the authors conducted qualitative interviews with professionals working in newsrooms in Norway, Sweden and Denmark. More recently, Engebretsen [28] interviewed 10 students to learn how the informants read, interpreted, and responded emotionally to data visualizations, including visual metaphors, interactivity, and animation. Tuñez-López and Nogueira [14] included in-depth interviews using a structured questionnaire, in a methodological triangulation that followed up responses to an initial survey, with four infographic designers working for The Guardian, The Times and National Geographic. And finally, Weber et al. [21] interviewed editorial leaders, journalists, developers and designers from 26 leading news organizations in Europe.

Another of the most frequently employed methodologies applied to the study of data visualization in cybermedia is that of the systematic review of academic articles. Here, we find analyses dedicated specifically to the tools of data visualization, including the use of NodeXL [24], infographics in the media [12], structured journalism, interaction and data visualization [22], data journalism and its visualization [8], interaction and coding in data visualization [35] [34] [33] and visual analytics [36].

Finally, a number of data visualization studies have focused on reporting content analyses, above all in relation to the use of infographics [16], images that accompany the text [17] and data graphics [32].

3 Materials and methods

Having outlined the theoretical framework that affords us with an overview of data visualization in journalism, we turn now to describe the methodology employed in undertaking this study. In what follows, we explain in detail how the systematic review was conducted, how the academic articles were selected and what steps were followed in the procedure adopted.

Systematic reviews can be considered research studies in their own right given that the evidence base is derived from the documents selected and, moreover, the method employed comprises the search procedures, while the outcomes obtained are a synthesis of the references identified [38].

To conduct the systematic review [10] [11], we employed an adapted form of the SALSA Framework, where SALSA is the acronym for:

• Search: The search phase involves defining the project to be carried out, the design of the search equations, their application to what are principally academic databases and the selection of references taking into consideration various exclusion and inclusion criteria [39].

- AppraisaL: This evaluation phase is carried out by re-reviewing the inclusion and exclusion criteria for each reference, including its main topic, date of publication, object of study, and, finally, the quality of the specific article identified [39].
- Synthesis: In this phase, structured summaries are drafted, centered around the main parameters of each study: that is, the object of study, objectives, most significant results, etc. Diagrams or concept maps can then be incorporated [40].
- Analysis: In this phase, data and information of value concerning the aspects to be studied are extracted systematically [40].

To select the corpus for analysis, a series of keywords and search equations are first chosen and applied to the core collections of Scopus and Web of Science between the dates of 1 January 2016 and 31 December 2020. We opted to use these databases on the grounds that they are widely considered to be two of the most important and because they are used by academics around the world. In addition, we stipulated that the documents selected had to be written in English and/or Spanish, that they be academic articles and published in open access.

The search equations employed are designed to consider essential elements of data visualization in the news media and, as such, are as follows

- "Information Visualization" AND (journalism OR newspaper* OR "digital news media")
- "Infographics" AND (journalism OR newspaper* OR "digital news media")
- "Visual Narrative" AND (journalism OR newspaper* OR "digital news media")
- "Data Visualization" AND (journalism OR newspaper* OR "digital news media")
- "Visual Storytelling" AND (journalism OR newspaper* OR "digital news media")
- The exclusion criteria employed are shown below:
- Articles in languages other than those indicated.
- Articles resulting from false coordination of keywords.
- Articles on journalistic formats that fail to mention the analytical methodology employed.

Additionally, the battery of articles includes:

- Gray literature [41].
- Seminal and/or reference articles in the field.

Once we had obtained the corpus of articles, we double-checked the references, with one of the authors providing summaries of the academic articles and the others checking and auditing them.

The results of this systematic review allowed us to establish and sustain the theoretical framework and to identify the emerging trends and challenges associated with data visualization in the news media.

 Table 1. Adapted format of the SALSA Framework

Application of the SALSA Framework

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| Phase | Criterion |
|-----------|---|
| Search | Database: Scopus, Web of Science and gray literature (Google) Search equations: |
| | "Information Visualization" AND (journalism OR newspaper* OR "digital news media") "Infographics" AND (journalism OR newspaper* OR "digital news media") "Visual Narrative" AND (journalism OR newspaper* OR "digital news media") "Data Visualization" AND (journalism OR newspaper* OR "digital news media") Visual Storytelling" AND (journalism OR newspaper* OR "digital news media") Visual Storytelling" AND (journalism OR newspaper* OR "digital news media") Visual Storytelling" AND (journalism OR newspaper* OR "digital news media") Visual Storytelling" AND (journalism OR newspaper* OR "digital news media") |
| AppraisaL | Initial number of documents: 127 Final number (N) after applying inclusion/exclusion criteria: 31 Inclusion/exclusion criteria: elimination of false positives, arti- cles with IMR&D or similar structure (methodology explicit and reporting of results), seminal and reference articles, both academic and professional (gray literature). |
| Synthesis | Narrative synthesis and data tables derived from the analyses performed |
| Analysis | Components: • Object of study • Objectives • Questions/Problems/Hypotheses • Methodology • Results |

4 **Results**

If we combine the results of the two databases (WoS and Scopus), the search equation that yielded the highest number of results was the equation ["Information Visualization" AND (journalism OR newspaper * OR "digital news media")]. Thus, as Table II shows, the highest number of publications was found when studies on information visualization and journalism, newspapers and online news media are combined. The topic with the second highest number of scholarly publications is data visualization and journalism, followed by studies of infographics and visual storytelling and, finally, research on visual narrative and journalism.

Table 2. Number of search results in Scopus and Web of Science

| | Search Results | |
|-------------------|---|---------------------|
| Database | Equation | N° of ar- ticles |
| Scopus | "Information Visualization" AND (journalism OR news- paper* OR "digital news media") | 35 |
| | "Infographics" AND (journalism OR newspaper* OR "digital news media") | 17 |
| | "Visual Narrative" AND (journalism OR newspaper* OR "digital news media") | 5 |
| | "Data Visualization" AND (journalism OR newspaper* | 27 |
| | "Visual Storytelling" AND (journalism OR newspaper* OR "digital news media") | 9 |
| Web of Science | "Information Visualization" AND (journalism OR news- | 10 |
| Science | "Infographics" AND (journalism OR newspaper* OR "digital news media") | 2 |
| | "Visual Narrative" AND (journalism OR newspaper* OR "digital news media") | 10 |
| | "Data Visualization" AND (journalism OR newspaper* | 2 |
| | "Visual Storytelling" AND (journalism OR newspaper* OR "digital news media") | 10 |

By adopting this methodology, we are able to obtain an overview of academic publications in the field of data visualization and journalism. More specifically, our results show that more articles in this field can be found in Scopus than in Web of Science.

Below, we provide a summary of the results obtained. First, we include a table showing the titles and authors of the articles extracted from the search in Scopus and Web of Science; and, second, we include a further table showing the articles extracted from the gray literature and reference documents.

Once the documents in Scopus and Web of Science had been identified, they were screened, and any false positives and duplicate documents were eliminated, leaving us with a corpus of 22 documents.

Table 3. References obtained from the search conducted in Scopus and Web of Science

| | Corpus of final documents |
|---------|--|
| ID | References |
| 1 | Jacob, R. (2020) Visualising global pandemic: A content analysis of infographics on COVID-19 |
| 2 | Chen, Z. & Guo, W. (2020) Innovative Research on the Improvement of Visual Quality of Data Journalism in China: Visual Language and Interaction Design |
| 3 | Yang, J. & Jin, H. (2020) Application of Big Data Analysis and Visualization Tech- nology in News Communication |
| 4 | Montes-Rojas, M. L.; García-Gil. J. & Leija-Román, D. A. (2020) Visualización mediática de la ciencia: tipología de la infografía científica de prensa |
| 5 | Ahmed, W. & Lugovic, S. (2018) Social media analytics: analysis and visualisation of news diffusion using NodeXL |
| 6 | Day coverage on the sites of three major Brazilian newspapers |
| 7 | periodística online Ivars-Nicolás, B. (2019) La infografía periodística en España: definición v tipología |
| 8 | de uso Sjafiie, S;. Hastjarjo, S.; Muktiyo, W. & Pawito (2018) Graphic Visualization in |
| 9 10 | Printed Media: How Does the Use of Technology Influence Journalism Culture Engebretsen, M.; Kennedy, H. & Weber, W. (2018) Data Visualization in Scandi- |
| 10 | navian Newsrooms Emerging Trends in Journalistic Visualization Practices Freixa, P.; Pérez-Montoro, M. & Codina, L. (2017) Interacción y visualización de |
| 12 | datos en el periodismo estructurado Cairo, A. (2017) Visualización de datos: una imagen puede valer más que mil nú- |
| 13 | Pentzold, C. & Fechner, D. (2020) Data journalism's many futures: Diagrammatic displays and prospective probabilities in data-driven news predictions |
| 14 | Catalan-Matamoros, D.; Guzmán, B. & Langbecker, A. (2014) El contenido visual publicado en prensa durante una crisis sanitaria: El caso del Ébola |
| 15 | Catalan-Matamoros, D. & Peñafiel-Saiz, C. (2019) A visual content analysis of vac- cine coverage in the print media |
| 16 | López-del-Ramo, J. & Montes-Vozmediano, M. (2018) Construcción comunicativa del reportaje infográfico online de calidad |
| 17 | los diarios del País Vasco sobre los atentados del 17-A (17-VIII-2017) Túñez-Lopez M & Nogueira A G (2017) Infographics as a mnemonic structure: |
| 18 | Analysis of the informative and identity components of infographic online com- positions in Iberic newspapers |
| 19 | Engebretsen, M. (2020) From Decoding a Graph to Processing a Multimodal Mes- sage Interacting with data visualisation in the news media |
| 20 | Weber, W.; Engebretsen, M. & Kennedy, H. (2018) Data stories. Rethinking jour- nalistic storytelling in the context of data journalism |
| 21 | Bounegru, L.; Venturini, T.; Gray, J. & Jacomy, M. (2017) Narrating networks: Exploring the affordances of networks as storytelling devices in journalism |
| 22 | Simakova, S. & Ivandaeva, E. (2019) National features of infographics |

Having analyzed the 22 documents, we identified the sector's seminal articles and references in the gray literature.

 Table 4. References obtained from the search conducted in the gray literature and seminal articles

| Corpus of final documents | | |
|---------------------------|--|--|
| ID | References | |
| 1 | Brüggemann, V., Bludau, M. & Dörk, M (2020) The Fold: Rethinking Inter- activity in Data Visualization | |
| 2 | Kalatzi, O.; Bratsas, C. & Veglis, A. (2018) The Principles, Features and Techniques of Data Journalism | |
| 3 | Ojo, A. & Heravi, B. (2018) Patterns in Award Winning Data Storytelling | |
| 4 | Keim, D.; Andrienko, G.; Fekete, J.; Görg, C.; Kohlhammer, J. & Melançon, G. (2008) Visual Analytics: Definition, Process, and Challenges | |
| 5 | Elmqvist, N., Vande-Moere, A., Jetter, H.C., Cernea, D., Reiterer, H., Jankun-Kelly, T.J. (2011) Fluid Interaction for Information Visualization | |
| 6 | Heer, J. & Robertson, G. G. (2007) Animated Transition in Statistical Data Graphics | |
| 7 | Heer, J. & Shneiderman, B. (2012) Interactive Dynamics for Visual Analy- sis: A taxonomy of tools that support the fluent and flexible use of visualiza- tions | |
| 8 | Segel, E. & Heer, J. (2010) Narrative Visualization: Telling Stories with Data | |
| 9 | Yi, J. Soo, J., Kang, Y., Stasko, J. (2007) Towards a Deeper Understanding of the Role of Interaction in Information Visualization. | |

In what follows, we report our global findings with regard to the corpus of publications analyzed and outline the state of the art as regards data visualization in journalism, the challenges faced, the technologies applied and the application protocols employed in the field.

4.1 Corpus of publications

We start by addressing the findings that can be extracted from an initial formal analysis of the articles making up the corpus of 31 publications as selected following the methodology described above. Specifically, we present a brief analysis of the quantitative data describing the authors, the organizations to which they are affiliated and their geographical location.

In the case of the authorship of the studies, a total of 499 names are included in the text and bibliographies of the works included in our corpus. Among these, the names of the vast majority (n=489) appear in fewer than five articles and of these 361 appear in just one document.

An analysis of the ten most prolific authors reveals that the top places in this ranking are occupied by authors of seminal works or articles of reference in the field or discipline of data visualization – e.g. Cairo, Heer, Tufte, and Shneiderman (see Figure 1). Top of the leader's board is Cairo with 12 documents, while Bederson props up the top ten with just five documents.



Fig. 1. Ranking of the ten most prolific authors in the corpus of publications.

Turning to focus on the organizations involved in these publications, our data show a total of 411 names included in the text and bibliographies of the works included in our corpus. Among these, the names of the vast majority (n=400) appear in fewer than five articles and of these 311 appear in just one document.

An analysis of the ten most prolific organizations reveals that the top places in this ranking are occupied by tech firms, publishers, scientific associations and prestigious universities, all of them with direct ties to the field or discipline of data visualization (Figure 2). Top of the leader's board is Google with 12 documents, while Stanford University props up the top ten with just six documents.



Fig. 2. Ranking of the ten most prolific organizations in the corpus of publications

Finally, in the case of the geographical locations associated with these publications, our data show a total of 501 place names included in the text and bibliographies of the works included in our corpus. Among these, the names of the majority (n=400) appear in fewer than five articles and of these 368 appear in just one document.

An analysis of the top ten locations reveals that the top places in this ranking are occupied by countries (and some cities) in which most of the scientific production in the field or discipline of data visualization is conducted and where the main work in data journalism is also produced (Figure 3). Top of the leader's board is the United States with 23 documents, while Canada props up the top ten with just eight documents.



Fig. 3. Ranking of the ten most prolific locations associated with publications in our corpus.

4.2 Trends in data visualization

To examine current trends in the study of data visualization, we have opted to divide these emerging approaches into three main blocks: those related to the use of data, those that address advances in design and interaction, and those that address one of the topics – that of health – in which the visual analysis of information plays a central role in guaranteeing efficient communication.

In the case of emerging trends in the use of data journalism, Freixa et al. [22] confirm that a system of structured journalism is constituted by a set of three levels – encoded data, layers of information and an interface. Yet, Araújo [29] concludes that the use of data in traditional newsrooms has not attracted any more attention than that attracted by other commonly employed journalistic techniques.

Likewise, Pentzold and Fechner's [6] study of the creation of news based on data for predictive purposes recognizes the incipient nature of the field and acknowledges that, for the time being at least, its potential has yet to be fully developed. Most of the stories these authors analyzed are concerned with problems rather than events and present analyses of current political or economic questions or environmental or social issues, but offer few insights that might help anticipate future trends.

However, the bulk of contributions analyzing trends focus on questions of design and interaction in journalistic developments of this type. For example, Engebretsen et al. [30] confirm that the boom in the consumption of news from small screens (with the mobile leading the way) favors the simplicity and linearity of visual design. Similarly, López-del-Ramo and Montes-Vozmediano's [13] study of the characteristics of infographic reports reveals similarities of style and focus with more traditional or classic reports. However, the infographic reports examined by the authors are characterized by being structurally and functionally simple, autonomous stories that make a limited use of animation and other iconic and textual elements.

Bounegru et al. [31] claim that telling stories based on network graphics exploits a much more multimodal approach. The interaction between these modes (static, dy-namic or animated diagrams, written language, photographs, design, and pictograms) characterizes the specificity of this composite form of narration. Meanwhile, Simakova and Ivandaeva [20] analyze a number of specific cases and identify similar characteristics in the infographics of the Russian Reporter and the New York Times, highlighting the fact that statistics are provided in the form of different 'subspecies' of diagrams, that infographics are usually static, and that they are created in order to provide readers with visual information without requiring any additional effort on their part to obtain that information.

Finally, in relation to questions of design, it is worth highlighting the analytical and classificatory proposals provided by journalistic products of this type. For example, Yi et al. [35] propose seven different categories of interaction techniques based on user intent. According to the authors, this categorization captures more effectively the ways in which interaction techniques are used, while at the same time it provides a more useful common vocabulary to apply to specific information visualization projects. In a similar vein, Segel and Heer [2] describe seven genres of narrative visualization: magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and

video. They show that these genres can be combined with interactivity and messaging to produce varying balances of both author- and reader-driven experiences. Finally, Ojo and Heravi [9] propose a typology of data stories from a journalistic perspective. Following a study of 44 outstanding data storytelling practices, the authors identify seven types of data story and they classify a quarter of the stories as stories that explain a phenomenon to afford a deeper understanding, followed by stories that reveal anomalies or deficiencies in systems.

Trends in the visual treatment of health-related data have also attracted the attention of researchers, with many – unsurprisingly – analyzing this treatment with respect to news items concerning the COVID-19 pandemic. For example, Jacob's [15] study of data visualization and COVID-19 in The Hindu and The Times of India confirms that the message of the infographics focused mainly on the severity of the virus by reporting the number of COVID-19 cases detected in India and globally, while less attention was given to preventive strategies to avoid infection. Likewise, Catalan-Matamoros and Peñafiel-Saiz [18] analyzed visual imagery in the media coverage of vaccines in the written press and found that images are commonly used in the print media, appearing in 56% of articles about vaccines. Each article included, on average, one image and 76% of the visual resources were photographs.

But the current pandemic has not been the only subject of study. Catalan-Matamoros et al. [17] report the results of their examination of the coverage of the Ebola crisis in Spain and confirm that photography was the most frequently employed resource in newsrooms (69.2%), followed by graphics (9.2%) and infographics (8.8%).

4.3 Challenges faced by use of data visualization in the digital news media

The challenges faced by the use of data visualization in the news media is another of the topics found to emerge from our analysis of the corpus. These challenges concentrate primarily in the area of training needs, the evolution of journalistic discourse, and the problems associated with the perception of data journalism by information professionals.

In the case of the challenges related to the continuous training needs of information professionals, Chen and Guo [4] confirm that data treatment by professionals must be based on information content, data logic, and presentation purpose and that the data mapping process should be standardized and unified. They also recognize that these professionals should aim to enhance the level of interaction by exploiting the tools of interactive technology, given that this is the way to ensure a better reader-computer interaction experience. In a similar vein, Yang and Jin [23] recommend that visualized news should use a newer data visualization design to improve the user experience. They stress that the visualization of news on television is a complex process, which requires journalists to enhance their literacy in this field and to broaden their understanding of data and its visualization.

In relation to the challenges faced by the evolution of journalistic discourse, Montes-Rojas et al. [16] recommend that the information treatment of scientific infographics in the press should adopt detailed characteristics and patterns in order to visualize and communicate science and technology more effectively. However, these authors observed that the journalistic approach seems to lean more towards the analysis, representation, and visualization of scientific data than other approaches. Alonso-Plazas [25] identifies six modes of visualization – namely of events, of hidden problems, of places, of narratives, of subjectivities, and of convergences. This author's study confirms that the visualization of narratives is the mode that is most impermeable to the incorporation of an environment that facilitates exploration or experimentation with the data. Finally, he confirms that each mode responds to the paradigms of specific trends in the discourse of data journalism and information visualization.

Túñez-Lopez and Nogueira [14] also report that cybermedia infographics are typified by their low level of interactivity and poor exploitation of multimedia; however, great efforts are made to improve their narrative mode. Moreover, the study recognizes that infographics in the cybermedia are usually limited by their low visibility. And, in a complementary fashion, Engebretsen [28] recognizes that one of the greatest challenges to be faced by data visualization is that of its reception and interpretation. Among his most interesting findings is the variation in the responses of student participants to the metaphorical and figurative forms of data visualization. Some informants paid attention to the symbolic value of figurative shapes without losing focus on the abstract, non-naturalistic coding orientation of the expression. Others, in contrast, focused mainly on the figurative nature of the forms and interpreted them exclusively according to a naturalistic coding orientation. This strategy was open to subjective, and even misleading, associations in the interpretation of some data visualization products.

Finally, a series of challenges emerges in relation to problems experienced by information professionals in their perception of data journalism. For example, Kalatzi et al. [8] report that there is still some confusion and skepticism around data journalism with respect to its exact role and value. They identify two problems: the first is that many journalists are still somewhat hesitant when it comes to working with data, statistics and programming, and the second is that many media outlets operating on tight budgets fail to adopt data journalism as it has no obvious business model to support it and it has yet to be shown to generate significant income. Segel and Heer [2], in their study of narrative visualization, emphasize certain concerns about its application and design, specifically as regards the balance between author-driven elements, which provide narrative structure and messaging, and reader-driven elements which enable interactive exploration and social sharing. Finally, Sjafiie et al. [37] highlight that, in the future, the function and role of infographics in the media will become more important and that its intensity and form, along with understanding, will all improve thanks to the evolving technology.

4.4 Technologies employed in data visualization

The technologies employed in data visualization is another of the topics addressed in the scientific literature, which shows a concern for its typologies and the central place they occupy within the development of data journalism.

For example, Ahmed and Lugovic [24] recognize the importance of using NodeXL in a range of fields, including the media, above all as a tool for measuring and mapping

emerging news events on Twitter. Similarly, Ojo and Heravi [9] also identify the core technologies and tools that can be deemed fundamental for good data journalism practices. They recognize that web development and publishing, data analysis, and data visualization are among the most important core technologies for creating compelling data stories.

Keim et al. [36] report that technology must be able to provide answers to the following issues: the relevance of specific information for a given task, the adequacy of data processing methods and the validity of results for that task, and the acceptability of the presentation of those results. Sjafiie et al. [37] agree that the development of infographics in the print media is highly influenced by the technology used in other media platforms and Engebretsen et al. [30] recognize that software development is a critical factor in the evolution of data visualization practices.

4.5 Protocols for the application of data visualization in journalism

The application protocols for data visualization and data journalism is another topic addressed by the literature. For example, Ivars-Nicolás [12] offers a definition of infographics for the print media and outlines their three specific goals – namely, to describe, to locate, and to compare. The author stresses that infographics, in the main, accompany informative text and are used primarily with graphics and maps, but that they are rarely employed as illustrations to provide detailed accounts or descriptions.

Sjafiie et al. [37] recommend that in order for data to be transformed into attractive infographics, journalists, editors and art designers need to cooperate and work together. Engebretsen et al. [30] confirm that creating groups of expert staff specialized in data visualization and journalism favors innovation in this field. In addition, they recommend that users, their behavior and user feedback be taken into account since they are key factors for the development of data visualization in the news media.

Additionally, Weber et al. [21] identify different characteristics that help define data stories in journalism – namely, that the data shape the core of the story to be told, that the story should have a specific communicative function, that it should combine textual and visual elements to enrich the story being told, and that it should break from traditional text-based storytelling structures in the news with interactivity being given a central role. Similarly, Brüggemann et al. [33] propose the philosophical notion of the 'fold' as a productive way of jointly considering interaction and visual encoding in data visualization. These authors formulate a critical framework for interactive data visualization and characterize the fold's operations and qualities and identify principles and questions for the design and interpretation of data visualizations.

In a similar vein, Elmqvist et al. [34] outline eight specific guidelines for designing and constructing effective information visualizations that support 'fluid' interaction: (1) use smooth animated transitions, (2) provide immediate visual feedback on interaction, (3) minimize indirection in the interface, (4) integrate user interface components into the visual representation, (5) encourage user interaction creating a dialogue between user and the visualization, (6) ensure the interaction never ends (7), reinforce a clear conceptual model so that the user has a clear idea of the state of the visualization, and (8) avoid explicit mode changes. Finally, Heer and Robertson [32] identify that by employing a set of design principles animated transitions can significantly improve the graphical perception of changes when transitioning between statistical data graphics. A few years later, Heer and Shneiderman [26] created a taxonomy on multiple fronts related to data visualization that is of use to (1) students, as it provides them with a high-level, orientative introduction to interactive concerns guaranteeing successful visual analysis; (2) developers, as it functions as a checklist of items to consider when creating new analytic tools; and (3) researchers, as it helps highlight critical areas that would benefit from further investigation.

5 Discussion

We have been able to confirm that the field of visualization and communication is characterized by a number of emerging trends and fresh challenges that the media must face in their efforts to engage with data visualization. The main challenges that we identify in our systematic review of the literature concern ways to improve the percentage coverage of infographics [15], their integrity and credibility as a tool for information transfer [20], and the type of content that is typically included and worked on in the news media [14] [13] [16].

Moreover, the literature concerns itself with how open data, both public and private, can be used to structure news stories and encode content based on data visualizations [29] and how digital numerical information and algorithmic analyses can be exploited to anticipate and draft these stories [6].

The trends that emerge in the use of data visualization take different paths. However, the main ones appear to be the use made of such visualizations by the news media according to data and, more specifically, big data applications [23], according to how a newsworthy event progresses [17], according to its configuration from the point of view of journalistic narration [31], and according to its application in different genres such as data journalism [8] [9] and structured journalism [22], among others. All of these emerging trends leads to a rethinking of journalistic stories [30] and how readers receive them [28].

Likewise, the literature reveals the existence of certain frameworks and taxonomies – specifically in relation to interaction and data visualization [35], narrative visualization [2] and its effectiveness [25], and the presentation of the data itself [4], among others – that can help standardize good practices for the design of effective visualizations in the news media [9].

What is evident is that technological developments have changed the value and practice of journalism in relation to graphic visualization [37], in fact software development has been a critical factor in the evolution of data visualization practices [30]. In this regard, several studies report on the technologies that can be used for the development of data visualization in the news media, including NodeXL [24], among others.

These particular practices and the use of specific tools are gradually becoming part of the productive routines of those journalists dedicated to data visualization, and as such they are generating a series of needs, possibilities and limitations that have to be given careful consideration. For example, today, routines need to consider when infographics should be used to communicate information [12], what the key characteristics of journalistic data stories are as seen from the newsrooms [21], how to design interaction to ensure good journalistic visualization projects [34], and how to apply animated transitions in the graphical perception of changes when transitioning between related data graphics [32], among others.

6 Conclusions

In the light of the objectives established at the beginning of this chapter, we turn now to highlight relevant conclusions. We end with proposals for further research. The following general conclusions can be drawn:

- 1. Thanks to the systematic review undertaken here, we can confirm that various studies have been published on the use of data visualization in the news media that attach considerable importance to emerging trends, challenges, protocols and informational and communicative possibilities in this field.
- 2. Likewise, thanks to this review, we can identify the leading studies undertaken in relation to data visualization and journalism in recent years, the case studies analyzed, and their results regarding the application of data visualization, the type of technologies applied, good practices and strategies of use to guarantee greater support for enriched storytelling.
- 3. Further, the identification of these studies helps us to identify and appraise the recommendations made for the application of data visualization and to consider its possibilities and limitations as employed in the field of communication and journalism.

Data visualization has become a highly valuable tool for complementing news stories and information, making it necessary to study how it works, what its impact is and how it can be applied from a range of different perspectives.

To determine how it works, future studies can usefully undertake analyses of information visualization products, data storytelling, and infographics as applied to different journalistic formats, from the most traditional (i.e. news stories and reports) to the most innovative (i.e. data journalism and structured journalism, among others). To determine its impact on news consumption and how it is perceived by the audience, applied research should focus its analyses on products designed by different news media platforms and associated user response, taking into consideration different types of reader (that is, conducting analyses by age, by country, by cultural level, etc.).

And, finally, studies of data visualization applications could be undertaken from different angles, including, for example, from the perspective of interaction or its application in newsrooms, as well as form the perspective afforded by different recurring topics, such as health, the environment and human rights, or from that of methodological strategies used in evaluating data visualization as a journalistic product, among others.

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