Accessible charts are part of the equation of accessible papers: a heuristic evaluation of the highest impact LIS Journals

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Abstract

Purpose

Statistical charts are an essential source of information in academic papers. Charts have an important role in conveying, clarifying and simplifying the research results provided by the authors, but they present some accessibility barriers for people with low vision. This article aims to evaluate the accessibility of the statistical charts published in the library and information science (LIS) journals with the greatest impact factor.

Design/methodology/approach

A list of heuristic indicators developed by the authors has been used to assess the accessibility of statistical charts for people with low vision. The heuristics have been applied to a sample of charts from 2019 issues of ten LIS journals with the highest impact factor according to the ranking of the JCR.

Findings

The current practices of image submission do not follow the basic recommended guidelines on accessibility like color contrast or the use of textual alternatives. On the other hand, some incongruities between the technical suggestions of image submission and their application in analyzed charts also emerged. The main problems identified are: poor text alternatives, insufficient contrast ratio between adjacent colors, and the inexistence of customization options. Authoring tools do not help authors to fulfill these requirements.

Research limitations

The sample is not very extensive; nonetheless, it is representative of common practices and the most frequent accessibility problems in this context.

Social implications

The heuristics proposed are a good starting point to generate guidelines for authors when preparing their papers for publication and to guide journal publishers in creating accessible documents. Low vision users, a highly prevalent condition, will benefit from the improvements.

Originality/value

The results of this research provide key insights into low vision accessibility barriers, not considered in previous literature and can be a starting point for their solution.

Keywords

Accessibility; low vision; color blindness; statistical charts; journals; scientific papers; heuristic evaluation

Paper type

Research paper

Introduction

Why the statistical charts accessibility matters

The inclusion of statistical charts in academic research papers is a widespread practice. They have an important role in conveying, clarifying and simplifying the research results provided by the authors (McCathieNevile and Koivunen, 2012). Charts can also save readers time and energy and reduce the word count of the papers (Franzblau and Chung, 2012)

On the other hand, other key sectors of society are also characterized by the extensive use of statistical charts as a tool to facilitate the understanding of information. This is the case, for example, of the news media. In this sense, the press has always used charts and infographics to represent data and statistics. The open data movement and the making available of large data sets in open access have only strengthened the so-called data journalism, multiplying this type of graphical representations in the media and increasing its interest among journalists, academics, computer scientists and designers (Meeks *et al*., 2019). Business intelligence is also another area in which statistical charts serve for exploration, analysis, and communication of data (Cairo, 2017). In the educational field, the knowledge about how to interpret and create statistical charts is present in different subjects and training levels, especially in the disciplines framed under the acronym STEM (Science, Technology, Engineering, and Mathematics), but also in other areas like social sciences or humanities. These are just some examples of key sectors of society that justify the need for accessible charts to guarantee access to information and knowledge for people with disabilities.

Visual representations enable communication of a wide variety of quantitative data, enabling readers to quickly and easily acquire and understand the nature of the underlying information (Gao *et al*., 2012). Although visual depictions are increasingly pervasive in science and social sciences, very little scientific literature is fully understandable because, as of now, critical graphical information is not directly accessible to visually impaired people (Gardner *et al*., 2009).

Why low vision people (Target group)

Low vision is the loss of sight that cannot be corrected in any form. It includes different degrees of sight loss, poor sensitivity to light or to contrast, color-blindness or color vision deficiency (CVD), night blindness, problems with glare, blurred vision, hazy vision, as well as almost complete loss of sight. There are multiple causes of low vision. Hereditary and congenital conditions are the most common causes of low vision and blindness among children worldwide, cataract among adults and elderly, and in countries in Africa, Asia and South America, infectious diseases such as trachoma and onchocerciasis are the main cause (Oduntan, 2005). Low vision is the visual impairment with the highest prevalence in the world, affecting approximately 217 million people (Bourne, *et al*. 2017), and this number will increase with the aging trend of the population. It must be emphasized that 86% of people with low vision and 61% of the population with presbyopia are 50 years or older (Bourne *et al*., 2017).

While the scientific literature published so far is mainly focused on the accessibility of statistical charts for blind people (Alcaraz *et al*., 2020a), only some of the aspects that improve the accessibility of statistical charts for this collective have benefits for people with low vision.

The solutions that focuses on alternatives other than graphical such as structured data tables, summaries or the use of sounds to communicate trends, do not have the same ability to efficiently show trends or comparisons between variables. They also require a greater use of short-term memory and a higher cognitive load when seeking to obtain answers or conclusions from tabulated data.

We must not forget that a significant percentage of users with low vision still have enough remaining vision to visualize the charts, either simply by resizing them, or by using the support of assistive technologies such as screen magnifiers, and that these people prefer to use their remaining visual capacity in their day to day (Szpiro *et al*., 2016), a condition that does not take into account the previous alternatives. According to their preferences, solutions such as the possibility to customize color or to increase the size of the chart or the text would better fit this user group and, regrettably, are not included in the current research literature.

In general, there is a significant lack of research focused on analyzing accessibility barriers and adequate technical solutions to guarantee accessibility for people with low vision (Moreno *et al*., 2020). The fact that many of these people can function independently despite certain limitations, without the help of white canes or guide dogs, makes them go unnoticed on a day-to-day basis. This has led to the description of low vision as an “invisible disability” (Shinohara and Wobbrock, 2011). An invisibility that has also been transferred to the scientific literature in a certain way.

Current situation

Splendiani and Ribera (2014) show a lack of common and clearly defined guidelines addressing accessibility issues related to figures in computer science journals, and a high variability in the application of recommendations related to accessibility features, like textual alternatives, the use of safe color palettes and sufficient contrast or the image format, resolution and dimensions. Similar cases are found in mathematics journals; the journals use vector images in most of the cases and yet they do not benefit from the possibilities for accessibility of this format (Splendiani *et al*., 2014) compared to bitmap images.

Among the publishers that have incorporated accessibility policies in recent years, Elsevier stands out. The publishing company has recently collaborated with the Highsoft Highcharts company in the creation of a JavaScript library with accessibility features to help improve the accessibility of its web chart library (Ted, 2018). The result is an accessibility chart JavaScript module with integrated screen reader and keyboard support. Moreover, Elsevier is undertaking some initiatives improving the accessibility of its collection, as for example in the journal *Research in developmental disabilities* (Nganji, 2015). The editorial is focusing the efforts on PDF files.

Related work

Several proposals exist for making statistical charts accessible to people with visual disabilities. However, most approaches focus on blind people or on people with severe low vision (Alcaraz *et al*., 2020a). Most of these proposals focus on one of the following four approaches: use of textual alternatives, sonification of data, generation of tactile alternatives and creation of multimodal alternatives. Regarding the use of textual alternatives, the Diagram Center (2015) has created guidelines on how to textually describe statistical charts and other types of complex images. Similarly, but oriented to a broader set of image types, the work of Splendiani (2015) focuses on how to textually describe non-text content for scientific articles. On the other hand, authors such as Corio and Lapalme (1999), Chester and Elzer (2005), Elzer *et al*. (2008), Ferres *et al*. (2010), Greenbacker (2011), Gao *et al*. (2012), Nazemi and Murray (2013), Kallimani et al. (2013) or De (2018) propose different methods for the automated generation of textual alternatives from the information available in a chart. For their part, authors such as Elzer *et al*., (2007), Agarwal and Yu (2009) or Yu *et al*. (2009) have studied the importance of captions for the understanding of a chart as “it often concisely summarizes a paper’s most important results” (Cohen *et al*., 2003). Regarding the use of data sonification, the mapping of charts to musical tones (Cohen *et al*., 2005) and vibrations (Evreinova *et al*., 2008) has been explored, as also has the use of sounds to communicate trends (Alty and Rigas, 2005) (Walker and Nees, 2005) or the use of volume, timbre and position, to represent quantitative and qualitative data (Franklin and Roberts, 2003) (Treviranus *et al*., 2018). The precision of these techniques has also been analyzed using different combinations of instruments (Brown and Brewster, 2003). For its part, the creation of tactile versions of charts and maps has an important tradition, and there are even specific guidelines for its design (Braille Authority of North America, 2012). In literature we also find different approaches for its semi-automated generation. The works of (Ina, 1996), (Ladner *et al*., 2005), (Miele and Marston, 2005) (Watanabe *et al*., 2014) are some examples. Finally, other authors opt for multimodality, combining haptic solutions with data sonification and other stimuli (Kennel, 1996) (Fritz and Barner, 1999) (Yu *et al*., 2000) (Roth *et al*., 2002) (Yu and Brewster, 2003) (Iglesias *et al*., 2004) (McGookin and Brewster, 2006) (Wall and Brewster, 2006) (Doush *et al*., 2009) (Goncu *et al*., 2010).

Among these sources, especially the ones that focus on evaluation, the main references are the *Web Content Accessibility Guidelines* (WCAG). The WCAG have been adopted by many countries as the minimum legal requirement for public —and in some cases even private— websites to comply. In the case of European countries, the WCAG 2.1 has been integrated into the *301 549: Accessibility requirements suitable for public procurement of ICT products and services in Europe v2.1.2* (ETSI, 2018) a reference standard determining the accessibility of websites and mobile applications of public sector organizations.

The WCAG are organized under four theoretical principles covering every aspect of accessibility: perceivable, operable, understandable and robust. Every principle is detailed in several specific guidelines, which in turn are translated to directly assessable criteria divided in three levels of conformity. The *WCAG 2.1* (W3C, 2018) have incorporated in their last update several success criteria relevant for low vision users. In the context of this article, new success criteria such as 1.4.10 Reflow (AA), 1.4.11 Non-Text Contrast (AA), 1.4.13 Content on Hover or Focus or 2.5.5 Target Size (AAA), are especially relevant.

From a business and marketing focused point of view Evergreen and Emery (2018) have created a data visualization checklist, relying on design principles collected by the same authors (2013), which covers many relevant aspects of its accessibility. The checklist has been rigorously tested by Sanjines (2018) and implemented as an online validator more recently (Evergreen, 2020).

On the other hand, in recent years other resources have also been published aimed at collecting accessibility requirements for people with low vision, including some relevant to statistical charts. This is the case of the accessibility requirements for people with low vision published by the Low Vision Task Force of the W3C (Allan *et al*., 2019), the compilation of adaptation techniques for this same user profile by Moreno *et al*. (2020) or van Achterberg (2019). In the same vein, but with a more practical orientation, Sorge (2020) has delved into the accessibility not only of statistical charts, but also of the remainder of STEM documents (Sorge *et al*., 2020) due to its importance in guaranteeing students' access to these subjects under equal conditions.

Finally, in the field of big data and data visualization techniques, Sathi and Sadhasivan (2020) have explored solutions to enable visually impaired users to access the Big data analysis results using Tableau Desktop software. For its part, Snaprud and Velazquez (2020) outline related practices and approaches to accessibility improvements and propose a way to evaluate and compare accessibility aspects of data visualizations based on the WCAG 2.1 guidelines and WCAG-EM 1.0 methodology. Similarly, Lundgard *et al*. (2019) analyze a set of sociotechnical considerations in the design of data visualizations for people with visual disabilities, focused on the analysis of the case study of an inclusive design workshop held in collaboration with the Perkins School for the Blind.

Regarding the field of scientific publication, Simon *et al*. (2019) results show that the most common accessibility problems with charts and figures in the proceedings published by the Innovation and Technology in Computer Science Education (ITiCSE) are captions that do not adequately describe the figure and the use of font sizes too small to be readable. Our hypothesis is that there are many other accessibility problems present in scientific journal papers. Furthermore, a wide range of barriers to access statistical charts are experienced by the different low vision profiles. These barriers can be overcome by including textual alternatives, high contrast images or with the use of patterns and textures as an alternative to the use of colors, among others, but they are not always required to the authors, or reviewed in sufficient detail by the publishers of these journals before publication.

To fill in the existing low-vision gap for this type of content, this paper aims to evaluate the accessibility for people with low vision of statistical charts in a sample of ten library and information science (LIS) representative science journals through a heuristic evaluation. Artwork submission policies are also reviewed. The results should confirm our hypothesis that there is a significant number of accessibility barriers for people with low vision in articles in scientific journals beyond those detected in other works published by other authors, making it difficult or impossible for this group to access research results presented as statistical charts.

Research method

The research is based on the heuristic evaluation method, one of the most efficient usability evaluation techniques without users. Streamlined, the heuristic evaluation is a usability engineering method to find the usability problems in a user interface design. It involves having a small set of evaluators examining the interface and judging its compliance with recognized usability principles (the "heuristics") (González *et al*., 2001). This technique has its origin in the work of Johnson *et al*. (1989) and was widely promoted in the seminal work of Nielsen and Molich (1990). Heuristic evaluations are very widespread in the field of usability and accessibility. On the basis of these works other authors have made methodological proposals for the preparation of new lists of heuristics for the evaluation of both general aspects related to usability, accessibility or user experience, known as “domain heuristics”, leading to the emergence of specific and rigorous methodologies focused on how to create new domain heuristics (Rusu *et al*., 2011; Van Greunen *et al*., 2011; Hermawati and Lawson, 2015; Jiménez *et al*., 2017; Quiñones *et al*., 2018).

In our research, we follow the method by Quiñones *et al*. (2018), adapted for the creation of a list of heuristic indicators to evaluate the accessibility of statistical charts considering the needs of low vision and CVD users (Alcaraz *et al*., 2021). The heuristic indicators set proposed is made up of 18 indicators that cover aspects related to the information transmitted by the chart (title, axes, text alternatives, caption...), its visual display (typeface, colors, contrast...) and the behavior and functionalities they offer (personalization, visible focus indicator...).

In some cases, non-compliance to the heuristic affects the user experience of the chart, mildly compromising its accessibility. However, there are cases where the consequences of not complying with the heuristic results in one or more user profiles having serious difficulties to perceive the chart or being unable to do it, completely compromising its accessibility. For that reason, each heuristic has been weighed according to the criteria established in table 1.

The complete list of heuristic indicators is shown in table 2. However, some of the heuristic indicators in the initial list were implemented differently in scientific journal articles compared to news media (Alcaraz *et al*., 2020b), in particular, it is worth mentioning:

- H1 'Title' versus H3 'Caption': most articles do not provide a title but instead they provide a caption. Following the initial evaluation criteria, H1 should be scored with 0 in almost all the charts. After a review, the evaluators decided not to take H1 into account, as not including the title responds to common practices of scientific articles.
- H6 'Data source': most articles presented charts with data from the article itself, thus not explicitly mentioning the source of the plotted numbers. In this case, again, the evaluators decided not to include this indicator on the final score.
- H15 'Without disturbing elements": after evaluating the charts in previous research, the evaluators discovered ads and watermarks for copyright purposes hindering important information from the charts and created an indicator to penalize it; but in the current research such practice is not common at all and the evaluators did not include this indicator in the final evaluation either.

Table 1. Weighing criteria.

Criteria	Weight
If the chart fails the heuristic, one or more user profiles will not have a satisfactory user experience with the chart, mildly compromising its accessibility. If the chart succeeds at the heuristic the chart's accessibility slightly improves.	x1
If the chart fails the heuristic, one or more user profiles will have serious difficulties to perceive the chart information, severely compromising its accessibility. If the chart succeeds at the heuristic the chart's accessibility considerably improves.	x2
If the chart fails the heuristic, one or more user profiles will not be able to perceive the chart information, totally compromising its accessibility. This heuristic is key to provide access to the chart for one or more user profiles.	x3

Table 2. Heuristic indicators set.

ID	Heuristic	Weight
H1	Does the chart have a brief and descriptive title that helps users identify it among others appearing on the same page, as well as navigate between them? *(not included in the final score)*	x1
H2	If the chart uses shapes, color or patterns encodings is there a legend to decodify them?	x1
H3	If the chart needs axes, are they visible and have appropriate, concise and clear labels and titles?	x1
H4	Does the chart have a caption helping understand it?	x1
H5	Are all the abbreviations in the chart expanded?	x1

ID	Heuristic	Weight
H6	Does the chart include information about its source (institution, date and URL of dataset)? *(not included in the final score)*	x1
H7	Is there an optimized version for printing available?	x1
H8	Does the chart provide a text alternative that briefly informs about its contents and helps users decide if they want more information?	x1
H9	In case the text alternative does not adequately convey the information provided by the chart, does the chart provide a textual long description containing complete and structured information about the data?	x3
H10	If the chart uses colors to provide information, is the color scheme safe for the different types of color vision deficiencies, including achromatopsia (total absence of color vision)?	x3
H11	Does the visual presentation of text and background have a contrast ratio of at least 4.5:1, and the non-text elements of the chart a contrast ratio of at least 3:1?	x3
H12	Is the text included in the chart legible (sans-serif font, font size of at least 16px or 12pt, line spacing of at least 1.5, no abuse of capital letters, bold or italics)?	x2
H13	If the chart is provided as a bitmap image, does the image have sufficient quality for a clear visualization and does it support a zoom of at least 200% without blurring or pixelation?	x3
H14	Can the chart be zoomed up to 200% without an assistive tool and without loss of content or functionality?	x2
H15	Does the chart have any disturbing element like watermarks that hinder the visibility of the chart? *(not included in the final score)*	x3

ID	Heuristic	Weight
H16	When an element of the chart (lines, bars, points...) receives the focus, is there a visual indication of it?	x1
H17	Is it possible to navigate between the marks and elements of the chart with keyboard, mouse and gestures?	x3
H18	Is it possible to customize the chart (color scheme, contrast, typography...) with assistive technologies or with a resource-specific customization system?	x2

With the aim of achieving quantitative results that would later make it possible to compare the means or the level of accessibility with respect to a maximum score, a Likert scale of four points was used for the calculation of the level of compliance of each indicator. The range goes from 0 (worst possible score) to 4 (best possible score). Additionally, the options “Not applicable” and “It is not a problem” have been added, for those cases in which the question is not pertinent, or in which not complying with the indicator does not lead to an accessibility problem, respectively. The Likert scale is shown in table 3.

Table 3. Likert scale.

Score	Level of compliance
-	Not Applicable (NA)
-	Failure is not a problem (NP)
0	No compliance
1	Low compliance
2	Acceptable compliance
3	High compliance
4	Excellent compliance

The score in the Likert scale is multiplied by the weight resulting in a weighed value, for every indicator. The final value is multiplied by 10. In parallel, the maximum weighed value of the overall chart is calculated, considering that the maximum score for the “Not Applicable” and “Failure is not a problem” indicators is 0, and 4 for all the other indicators. Finally, the maximum weighed value is used to divide the obtained weighed value. The score formula is shown below:

$$\frac{(\sum_{i=1}^{n} assigned\ score\ x\ weight) * 10}{\sum_{i=1}^{n} maximum\ score\ x\ weight}$$

In a previous stage of our research (Alcaraz *et al*., 2020b), we used our heuristic indicators set to evaluate the accessibility of statistical charts in the digital newspaper for people with low vision. This evaluation has also been used to validate the efficiency of the proposed indicators (Jiménez *et al*. 2018), with 14 WCAG 2.1 success criteria selected as control heuristics (Appendix B). The efficiency was measured through the following metrics:

– **Ratio of unique problems**. The relation of unique problems identified by the new set of heuristics in comparison to the control heuristics.

– **Ratio of problem dispersion**. The distribution of problems identified by each heuristic in the new set of heuristics in comparison to the control heuristics.

– **Ratio of severity**. The severity of problems identified with the new set of heuristics in comparison to the control heuristics.

– **Ratio of specificity**. The specificity of problems identified with the new set of heuristics in comparison to the control heuristics.

If the ratios are bigger than 1 then it can be stated that the heuristic indicators set identifies more unique problems.

The results were as follows: ratio of unique problems: 2.54, ratio of problem dispersion: 1.52, ratio of severity: 1.07, and ratio of specificity: 1.27. Demonstrating that the proposed heuristics find more unique problems, the problems are better distributed, more severe and specific than in the control set, and therefore the new set of heuristics is much more suitable for evaluating the accessibility of statistical charts than WCAG 2.1.

Analysis undertaken and sample of charts

The sample of charts to be evaluated (see Table 4) was taken from under these considerations:

1) Samples were taken from the ten library and information science journals with the highest impact factor according to the ranking of the Journal Citation Report (Science Edition 2018, 6 April 2020).
2) For each journal, 2019 issues were considered, 5 charts for each, among basic charts: bar charts, line charts, scatterplots and pie charts. Issues were reviewed from January to December, only one chart per issue was included (except in the *Journal of computer-mediated communication*, where 2 charts from the same issue had to be included because there were no more charts available). Preferably, charts that appear alone, not combined with other charts in the same figure, were selected in order to guarantee that the caption, alternative text… refer to the analyzed chart. In the case of the *Journal of the American Medical Informatics Association* only open access issues were considered due to access restrictions during the COVID-19 Pandemic. In the *Journal of Computer-Mediated Communication*, only 2 charts fulfilling the requirements were identified, so in this case only 2 out of the 5 planned charts were included in the sample
3) Once selected, we observed that many journals offer the figures in several formats: embedded in the PDF, as a JPEG or PNG graphic in the HTML file, or as a separate high-resolution image or PowerPoint. As the user can select any of these alternatives, the best option possible was considered for evaluation purposes, often the high-resolution image, sometimes the PowerPoint slide… there is an exception to this rule: in the case of the *MIS Quarterly* journal, and due to COVID restrictions, the authors were only able to access the PDF version, so in this case no other formats were considered.

Despite the limitations on the sample, the final set of charts could be considered a representation of what is found in scientific publications in the field, and the analysis can give a precise insight of common practices.

Table 4. List of library and information science journals selected ordered by the impact factor.

Journal	Categories	Impact Factor
International journal of information management	Information Science & Library Science	5.063
Journal of computer-mediated communication	Communication; Information Science & Library Science	4.896
Journal of knowledge management	Management; Information Science & Library Science	4.604
MIS quarterly	Management; Information Science & Library Science; Computer Science, Information Systems	4.373
Government information quarterly	Information Science & Library Science	4.311
Journal of the American Medical Informatics Association	Medical Informatics; Health Care Sciences & Services; Information Science & Library Science; Computer Science, Information Systems; Computer Science, Interdisciplinary Applications	4.292
Information & management	Management; Information Science & Library Science; Computer Science, Information Systems	4.120
Journal of strategic information systems	Management; Information Science & Library Science; Computer Science, Information Systems	4.000
Information processing & management	Information Science & Library Science; Computer Science, Information Systems	3.892
Journal of informetrics	Information Science & Library Science; Computer Science, Interdisciplinary Applications	3.879

The complete list of the analyzed charts is included in appendix A.

Additionally, to complement the information gathered from actual charts in each journal, the researchers reviewed their submission policy (as of May 10 2020), regarding general guidelines for authors and specific guidelines on figures, as stated in the journal website and on the publisher's website (often more complete). The analysis focused on recommendations related to the proposed indicators for heuristic evaluation.

Finally, researchers also applied the heuristics to charts created by default by one of the most common authoring tools: MS Excel, used in many of the analyzed charts. The version used for the analysis was Microsoft Excel Office 365 for macOS operating system, which does not differ much from other current versions of this Office Suite. With this tool, one of the authors reproduced a bar chart, a line chart, a pie chart and a stacked bar chart from the sample (in particular charts numbered as 4, 14, 21 and 30) with default options and he tested the heuristics upon them, not taking into account those that depend exclusively on the author (such as title semantics -- H1 -- for example). He also recorded whether there was an option to change default settings in order to fulfill accessibility requirements. The logic behind this last step is that authoring tools play a key role in terms of the final accessibility of a chart, since it cannot be expected that authors know all the requirements of users and the tool should provide good defaults; in order to grant accessibility to a large scale, the charts created by a tool must meet the accessibility guidelines and the requirements of different users.

Evaluators team

Four experienced evaluators assessed the charts using the heuristic evaluation methodology described previously. All of them followed the recommendations in the guide of the scoring methodology which thoroughly explained the scope of each principle and showed examples of possible scores prepared by the first author; this was valued very helpful in obtaining consistent evaluations. The evaluation process took place between April 22 and May 3, 2020. Three of the evaluators had previous experience with the methodology used, having applied it in a previous work (Alcaraz *et al*., 2020b). Each evaluator performed his or her evaluations independently and a final meeting was held to review all the results, especially the discrepancies. Ideally there should not be any discrepancy between the evaluators, because they agree on the severity of the problems and they fully understand the heuristic principles. However, due to subjectivity affecting the scoring process, and to mitigate its effects, the standard deviation between the different evaluators’ score is calculated and a threshold is set. If the standard deviation is higher than this threshold then, the scores are discussed jointly, to better understand the identified problem and the applied heuristic, until the different evaluators’ scores are more coherent. After the scores are coherent, the final evaluation given is the average of the different evaluators' scores.

On this research, of the 705 indicators analyzed (15 heuristics for each of the 47 charts evaluated), only in 37 cases (5.248%) the scores differed with a standard deviation greater than 1, and only in 2 cases (0.283%) the different scores presented a standard deviation greater than 2. The threshold was set at 2. These results show a great coherence between the different evaluators’ score and they can be perceived as a display of the quality of the heuristic indicators. When deviations higher to 2 were found, the evaluators discussed in depth the specific criteria used to score, and, in both cases, small corrections +-1 were applied after a better understanding of the logic.

Limitations

In this kind of research, sizing the sample is very complicated as bigger sizes imply a time cost difficult to assume. Moreover, the time cost is multiplied by the number of evaluators. On the other hand, information saturation is a good indicator of having covered the many different cases that could appear. Information saturation signifies that new cases do not add new information to the research, as the results are homogeneous, and at some point, even repetitive. This is the case for this research. The sample of 10 journals, and a total of 47 charts, may be limited for generalization to the broad spectrum of LIS journals; nonetheless, it is representative enough to expose common practices and the most frequent accessibility problems in these contexts, and the results were coherent and repetitive among the sample.

Findings/Results

Artwork submission policies

None of the journals analyzed had a specific accessibility policy statement on their websites, but Elsevier’s journals link to the accessibility policy of the publisher's website.

Elsevier stands out among the other publishers by including in its *Artwork and media instructions* different recommendations that help ensure the accessibility of the statistical charts included in its publications. For example, the use of a color-blind safe colors' palette.

All the journal websites include information about how to submit artwork in papers, although with very different degrees of exhaustiveness. None of the journals include all the requirements listed in the heuristics proposed in this work to ensure the accessibility of the statistical charts.

None of the journals offer information about how to supply the axes of the charts (H3) in case they are required; on whether or not to include the data source and in what way (H6); they do not give advice for the inclusion of a short text alternative or long descriptions (H8 and H9); they do not mention the requirement to support a magnification up to 200% without loss of content or functionality (H14); and, finally, they do not tell authors the possibility of including vector charts with separated elements capable of receiving focus (H16), of being navigable through different interfaces (H17), or of allowing greater customization (H18).

The *Journal of the American Medical Informatics Association* is the only one that requires authors to include always a title (H1), and legends (H2) for their charts when necessary (see table 5, column 10, rows 4 and 5). Seven out of the 10 journals analyzed (except *Journal of computer-mediated communication*, the *Journal of knowledge management* and the *Journal of the American Medical Informatics Association)* require authors to include captions to their figures (H4). The *International journal of information management* also requires authors to provide it outside the image and not as an image of text. This is an important point, because as text it can be read by a screen reader, and customized to the user's preferences for font family, size or color. All Elsevier journals emphasize that the caption should comprise a brief title and a description of the illustration.

Elsevier's journal guidelines advise authors to minimize the text within the illustrations and to explain all symbols and abbreviations used (H5) (see columns 2-7, row 9 of the table 5). The rest of the editors do not make any specific mention to the abbreviations of the figures, although most of them do refer generically to the abbreviations used throughout the text.

Although optimizing the PDF version is the publisher's duty (H7), Elsevier is the only one that allows authors to decide if the figures in their papers should appear as a single, 1.5 or 2-column fitting image, thus allowing better use of the entire width of the page (see table 5, columns 2-7, row 11).

All journals except *MIS quarterly* ask authors to use safe colors for people with CVD (H10). In the case of the *Journal of computer-mediated communication*, they also mention the use of patterns in combination with color so that the differentiation of elements does not rely on color alone. It is precisely this journal the only one that underlines the importance of using images with adequate color contrast (H11) (see table 5, column 11, row 15).

Regarding the aspects related to legibility (H12), all the journals except the *Journal of knowledge management* and the *Journal of the American Medical Informatics Association*, present different recommendations related to the choice of the font family, its minimum size or line spacing. However, not all of these guidelines coincide with the recommendations of authors such as (Bernard *et al*., 2001), the recommended 12 pt. or 16 px equivalents for minimum font size (Nielsen, 2002; Kitchel, 2019), or the use of line spacing of at least 1.5 pt. (Rusell-Minda *et al*., 2007; Calabrese *et al*., 2010; Blackmore-Wright *et al*., 2013), or with the preferences of low vision users (WebAIM, 2018) regarding the use of sans-serif fonts.

Finally, all journals except the *Journal of computer-mediated communication*, the *Journal of knowledge management* and the *MIS quarterly*, require authors to send images of sufficient quality and in formats suitable for their intended use.

The complete results of the analyzed editorial policies are shown in table 5.

Table 5. Analysis of the journal’s editorial policies.

Heuristic	Gov. Inf. Q.	Int. J. Inf. Manage.	J. Informetr.	Inf. Manage.	Inf. Process. Manage.	J. Strateg. Inf. Syst.	J. Knowl. Manag.	MIS Q.	J. Am. Med. Inf. Assoc.	J. Comput.-Mediat. Commun.
Publisher	Elsevier						Emerald	Management Information Systems Research Center, Carlson School of Management, University of Minnesota	Oxford University Press	Wiley
General accessibility policy	Yes						No	No	No	No
General accessibility guidelines	No mention									

Heuristic	Gov. Inf. Q.	Int. J. Inf. Manage.	J. Informetr.	Inf. Manage.	Inf. Process. Manage.	J. Strateg. Inf. Syst.	J. Knowl. Manag.	MIS Q.	J. Am. Med. Inf. Assoc.	J. Comput.-Mediat. Commun.
H1	No mention								This requirement is included in authors' guidelines You must include figure titles and legends within the manuscript file—they should not be included in the image file.	No mention
H2	No mention								You must include figure titles and legends within the manuscript file—they should not be included in the image file.	No mention
H3	No mention									

<table>
<tr><th>Heuristic</th><th>Gov. Inf. Q.</th><th>Int. J. Inf. Manage.</th><th>J. Informetr.</th><th>Inf. Manage.</th><th>Inf. Process. Manage.</th><th>J. Strateg. Inf. Syst.</th><th>J. Knowl. Manag.</th><th>MIS Q.</th><th>J. Am. Med. Inf. Assoc.</th><th>J. Comput.-Mediat. Commun.</th></tr>
<tr><td>H4</td><td>This requirement is included in authors' guidelines

Ensure that each illustration has a caption. Supply captions separately, not attached to the figure.</td><td colspan="5">This requirement is included in authors' guidelines

Ensure that each illustration has a caption. Supply captions separately, not attached to the figure. A caption should comprise a brief title (not on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

This requirement is included in authors' guidelines

All figures (include relevant captions)

The corresponding caption should be placed directly below the figure.</td><td>No mention</td><td>This requirement is included in authors' guidelines

Supply succinct and clear captions for all tables, figures and plates.</td><td colspan="2">No mention</td></tr>
<tr><td>H5</td><td colspan="6">This requirement is included in authors' guidelines

Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

This requirement is included in authors' guidelines.</td><td colspan="4">No mention</td></tr>
<tr><td>H6</td><td colspan="10">No mention</td></tr>
<tr><td>H7</td><td colspan="6">This requirement is included in authors' guidelines

Indicate per figure if it is a single, 1.5 or 2-column fitting image.

This requirement is included in authors' guidelines</td><td colspan="4">No mention</td></tr>
<tr><td>H8</td><td colspan="10">No mention</td></tr>
</table>

Heuristic	Gov. Inf. Q.	Int. J. Inf. Manage.	J. Informetr.	Inf. Manage.	Inf. Process. Manage.	J. Strateg. Inf. Syst.	J. Knowl. Manag.	MIS Q.	J. Am. Med. Inf. Assoc.	J. Comput.-Mediat. Commun.
H9	No mention									

Heuristic	Gov. Inf. Q.	Int. J. Inf. Manage.	J. Informetr.	Inf. Manage.	Inf. Process. Manage.	J. Strateg. Inf. Syst.	J. Knowl. Manag.	MIS Q.	J. Am. Med. Inf. Assoc.	J. Comput.-Mediat. Commun.
H10	This requirement is included in authors' guidelines Ensure that color images are accessible to all, including those with impaired color vision. This requirement is included in authors' guidelines						This requirement is included in authors' guidelines Graphics may be supplied in color to facilitate their appearance in color if hosted online but will be printed in black and white.	No mention	This requirement is included in authors' guidelines Note that the use of red and green in figures may cause difficulty for color-blind people For advice on how to avoid this problem, please see http://jfly.iam.u-tokyo.ac.jp/html/manuals/pdf/color_blind.pdf.	This requirement is included in authors' guidelines Use a pattern in combination with color so that the differentiation of elements does not rely on color alone. Label colored areas directly in the image or use lines to connect the object to its label rather than placing the label in a legend, if possible. When you use this strategy, readers do not have to match colors in the figure to colors in the legend and the figure can be made more accessible.

Heuristic	**Gov. Inf. Q.**	**Int. J. Inf. Manage.**	**J. Informetr.**	**Inf. Manage.**	**Inf. Process. Manage.**	**J. Strateg. Inf. Syst.**	**J. Knowl. Manag.**	**MIS Q.**	**J. Am. Med. Inf. Assoc.**	**J. Comput.-Mediat. Commun.**
H11	No mention	No mention	No mention	No mention	No mention	No mention	No mention	No mention	No mention	This requirement is included in authors' guidelines It is important that color figures have adequate color contrast to allow users living with color-vision deficiencies

Heuristic	Gov. Inf. Q.	Int. J. Inf. Manage.	J. Informetr.	Inf. Manage.	Inf. Process. Manage.	J. Strateg. Inf. Syst.	J. Knowl. Manag.	MIS Q.	J. Am. Med. Inf. Assoc.	J. Comput.-Mediat. Commun.
H12	No Aim to use the following fonts in your illustrations: Arial, Courier, Times New Roman, Symbol, or use fonts that look similar. Line weights range from 0.10 pt to 1.5 pt	Always include/embed fonts and use the recommended fonts where possible: Arial, Helvetica, Courier, Times, Times New Roman, Symbol **font size** As a general rule, the lettering on the artwork should have a finished, printed size of 7 pt for normal text and no smaller than 6 pt for subscript and superscript characters. Smaller lettering will yield text that is hardly legible. This is a rule-of-thumb rather than a strict rule. There are instances where other factors in the artwork (e.g., tints and shadings) dictate a finished size of perhaps 10 pt. Line weights range from 0.10 pt to 1.5 pt Always include/embed fonts and use the recommended fonts where possible: Arial, Helvetica, Courier, Times, Times New Roman, Symbol **font size** As a general rule, the lettering on the artwork should have a finished, printed size of 7 pt for normal text and no smaller than 6 pt for subscript and superscript characters. Smaller lettering will yield text that is hardly legible. This is a rule-of-thumb rather than a strict rule. There are instances where other factors in the artwork (e.g., tints and shadings) dictate a finished size of perhaps 10 pt. Line weights range from 0.10 pt to 1.5 pt Always include/embed fonts and use the recommended fonts where possible: Arial, Helvetica, Courier, Times, Times New Roman, Symbol					No mention	Half compliance figures [...] should be in Arial font.	No mention	Half compliance Within figure images, use a sans serif font with a type size between 8 and 14 points Words within the image part of a figure may be single-spaced, one-and-a-half-spaced, or double-spaced, depending on which is the most effective layout for the information. Align the text of an APA Style paper to the left margin Table and figure numbers (in bold), titles (in italics)

H13	This requirement is included in authors' guidelines Size the illustrations close to the desired dimensions of the published version EPS (or PDF): Vector drawings, embed all used fonts. TIFF (or JPEG): Color or grayscale photographs (halftones), keep to a minimum of 300 dpi. TIFF (or JPEG): Bitmapped (pure black & white pixels) line drawings, keep to a minimum of 1000 dpi. TIFF (or JPEG): Combinations bitmapped line/half-tone (color or grayscale), keep to a minimum of	This requirement is included in authors' guidelines **File formats** EPS (Encapsulated PostScript) is the preferred format for vector graphics (charts, graphs, technical drawings, annotated images). TIFF (Tagged Image File Format) is the recommended file format for bitmap (line art), grayscale and color halftone images that are solely using pixels. XLS, XLSX JPEG files are accepted for grayscale and color halftone images	This requirement is included in authors' guidelines Formats Regardless of the application used, when your electronic artwork is finalized, please 'save as' or convert the images to one of the following formats (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below): EPS (or PDF): Vector drawings. Embed the font or save the text as 'graphics'. TIFF (or JPG): Color or grayscale photographs (halftones): always use a minimum of 300 dpi. TIFF (or JPG): Bitmapped line drawings: use a minimum of 1000 dpi. TIFF (or JPG): Combinations bitmapped line/half-tone (color or grayscale): a minimum of 500 dpi is required. Please do not: • Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); the resolution is too low. • Supply files that are too low in resolution. • Submit graphics that are disproportionately large for the content. Color artwork Please make sure that artwork files are in an acceptable format (TIFF (or JPEG), EPS (or PDF), or MS Office files) and with the correct resolution.	No mention	No mention	This requirement is included in authors' guidelines Images of maps, charts, graphs, and diagrams are best rendered digitally as geometric forms called vector graphics. Common file types are .eps, .ai, and .pdf. .eps files will be converted for online publication. Vector images use mathematical relationships between points and the lines connecting them to describe an image. These file types do not use pixels;	No mention

	500 dpi Please make sure that artwork files are in an acceptable format (TIFF (or JPEG), EPS (or PDF), or MS Office files) and with the correct resolution.	(photographs, micrographs, etc.). **Minimum Resolution and pixel dimensions** One column: 300 ppp width 1063 1,5 columns: 300 ppp width 1654 Double column: 300 ppp width 2244 For linear art used for graphs and charts minimum resolution of 1000 dpi (or 1200 dpi if the image contains very fine line weights) width 3543 (single column), 5512 (1,5 column), 7480 (double column)				therefore, resolution does not apply to vector images. Figures prepared as .doc/.docx or .jpeg/.jpg files may not be accepted.		

Heuristic	Gov. Inf. Q.	Int. J. Inf. Manage.	J. Informetr.	Inf. Manage.	Inf. Process. Manage.	J. Strateg. Inf. Syst.	J. Knowl. Manag.	MIS Q.	J. Am. Med. Inf. Assoc.	J. Comput.-Mediat. Commun.
H14	No mention									
H15	No mention									
H16	No mention									
H17	No mention									
H18	No mention									

Evaluation results

All the charts have a legend (H2) if they require it and the majority of them (70.22%) have received scores between 2 and 4 (acceptable and excellent compliance). Only in 4.79% of the cases (9 out of 188 evaluations) the heuristic H2 has been scored with a 1 (low compliance), while the score of zero has only been given in 2.13% of the cases (4 out of 188 evaluations).

The H3 heuristic (axes) has also been evaluated positively in most cases, with scores of 2, 3 or 4, in 46.28% (87 out of 188 evaluations), 37.23% (70 out of 188 evaluations) and 4.26% (8 out of 188 evaluations) of cases, respectively. Even though, as mentioned above, most authors were not offered specific guidance in this aspect.

In those charts in which abbreviations (H5) were used, 17.02% of the cases (32 out of 188 evaluations) corresponded to standardized abbreviations, and the evaluators considered the lack of text expansion not a problem. In 35.11% of the cases (66 out of 188 evaluations), the charts showed abbreviations that were not expanded in the same chart, but instead they were expanded within the body of the article, and thus received a low score.

All publishers offered an optimized version for printing in PDF format. However, in many cases (34,57%) the two columns layout of the article make the charts too small to be readable.

Only 10.64% of the charts (20 out of 188 evaluations) do not present any type of short textual alternative. However, only in 14.89% of cases (28 out of 188 evaluations) the highest score was given to this heuristic. On the contrary, long descriptions have not been found in almost any chart, scoring a zero in 97,34% of cases (183 out of 188 evaluations).

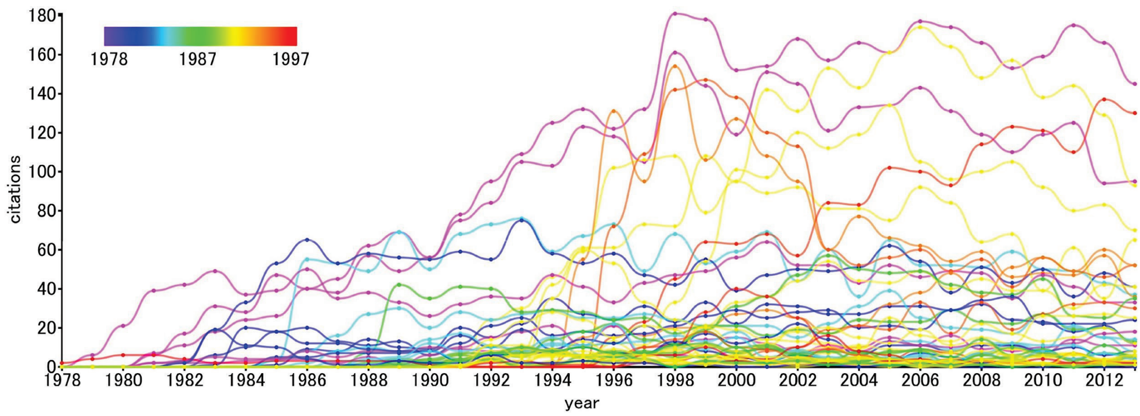

Figure 1. This chart of the *Journal of Informetrics* does not meet some of the heuristics: the legend does not help to identify the represented values, the line colors are not safe for color-blind people, and the non-text contrast is insufficient.

In 72,34% of the charts (136 out of 188 evaluations), color is used as a visual means of conveying information or distinguishing a visual element, and in 67,65%% of these cases a safe color palette or a pattern is used to facilitate differentiation. In all other cases, the colors used are not safe for one or more CVD profiles.

32.45% of the charts (61 out of 188 evaluations) has a text or non-text contrast ratio sufficient or higher than required. In the rest of the charts (65.55%, 127 charts) one or more color combinations do not reach the minimum required ratios.

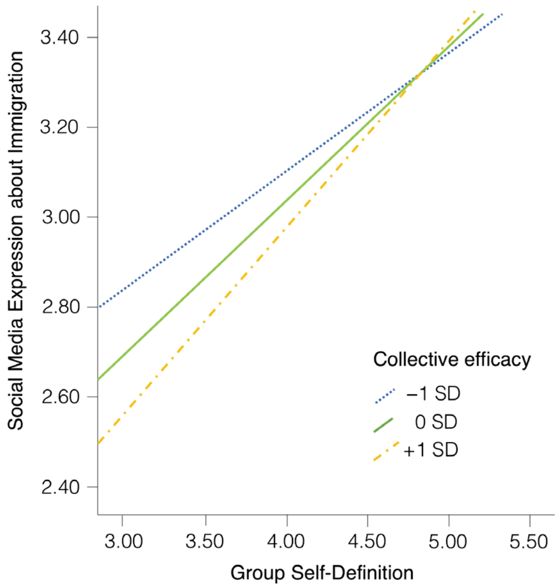

Figure 2. When the contrast between the color of the lines and the background is not sufficient, people with low contrast sensitivity will have serious difficulties or even be unable to perceive them. In this example of the *Journal of computer mediated communication*, the contrast ratio between the yellow and the green line with the background is 1.7:1 and 1.8:1 respectively, far from the 3:1 ratio recommended by the W3C.

In general, the charts enjoy a good score for the legibility heuristic (H12), which was rated like “acceptable compliance” in 37.23% of cases (70 out of 188 evaluations), “high compliance” in 33,51% (63 out of 188 evaluations) and “excellent compliance” in 18,62% (35 out of 188 evaluations). It has only been scored with 1 in 9.04% of the cases (17 out of 188 evaluations), and with 0 in 1.6% (3 out of 188 evaluations).

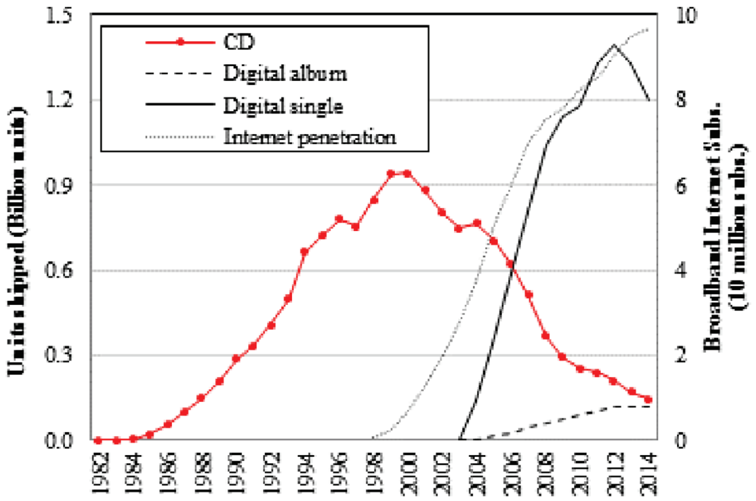

Figure 3. When the image quality is extremely low, the legibility of the chart can be compromised not only by readers with low vision, but by anyone. This chart from *MIS Quarterly* journal is a good example, as we can see on the pixelated text.

In all the papers analyzed, images in bitmap format (JPEG or PNG) are used for their charts. The vast majority (84.57%) get a score of 4 on the Likert scale (159 out of 188 evaluations), while only 2.13% of cases (4 out of 188 evaluations) have scored “no compliance” or “low compliance” in heuristic H13 (image quality).

In 95.21% of cases (179 out of 188 evaluations), the resize heuristic (H14) was scored with a 4, corresponding to “excellent compliance”. This is explained, in part, by the methodological choice of the best version available of the image (HTML, PDF, PPTX or the high-resolution JPEG or PNG version linked from the HTML version).

The heuristics related to the visibility of focus (H16) and device independent navigation (H17) have been rated as not applicable in all cases, because charts are raster images in which their marks (lines, points or bars) cannot be accessed. It is worth pointing out that we have not found any chart made with Highcharts (see introduction) in Elsevier’s journals.

If the images used are raster images, they prevent or greatly hinder the personalization of charts through assistive technologies, which automatically scores 0 (no compliance) in heuristic H18 (customization).

Figure 4 shows the average score by journal and the total average score and table 6 shows the average score of all the evaluators by chart.

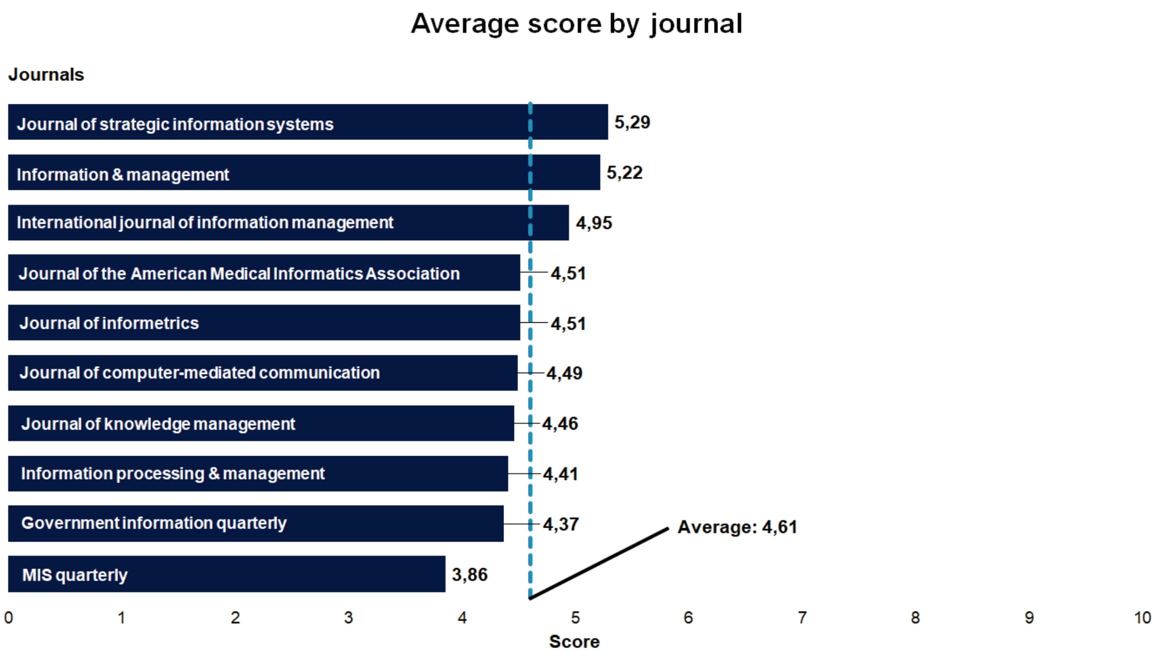

Figure 4. Average score by journal on a scale of 0 to 10.

Table 6. Average score by chart.

Journal	Chart	Score
International journal of information management	Chart 1	4.58
	Chart 2	5,13
	Chart 3	5,24
	Chart 4	4,17
	Chart 5	5,63
Journal of computer-mediated communication	Chart 6	4,67
	Chart 7	4,31
Journal of knowledge management	Chart 11	3,88
	Chart 12	5,30
	Chart 13	5,40

Journal	Chart	Score
	Chart 14	5,00
	Chart 15	4,69
MIS quarterly	Chart 16	2,91
	Chart 17	4,14
	Chart 18	3,91
	Chart 19	4,06
	Chart 20	4,25
Government information quarterly	Chart 21	4,25
	Chart 22	4,15
	Chart 23	4,54
	Chart 24	4,67
	Chart 25	4,24
Journal of the American Medical Informatics Association	Chart 26	4,52
	Chart 27	4,73
	Chart 28	5,02
	Chart 29	4,89
	Chart 30	3,41
Information & management	Chart 31	5,46
	Chart 32	5,08
	Chart 33	4,50

Journal	Chart	Score
	Chart 34	5,88
	Chart 35	5,18
Journal of strategic information systems	Chart 36	4,48
	Chart 37	5,79
	Chart 38	5,50
	Chart 39	5,45
	Chart 40	5,24
Information processing & management	Chart 41	4,08
	Chart 42	5,31
	Chart 43	4,00
	Chart 44	3,74
	Chart 45	4,91
Journal of informetrics	Chart 46	3,50
	Chart 47	4,93
	Chart 48	5,34
	Chart 49	4,07
	Chart 50	4,72

Microsoft Excel conformance with heuristics

As described in the methodology section, 4 charts were reproduced in Excel with default options and then evaluated with the heuristics, in order to verify the role of the authoring tool on the result.

Six heuristics do not relate to the authoring tool and thus were not considered: abbreviations (H5), version for printing (H7), resizing (H14), receiving focus (H16), independent navigation (H17) and customization (H18).

The requirements set by three of the heuristics, caption (H4), data source (H6) and long description (H9), were not fulfilled by the charts as the tool does not have any procedure or interaction to include them. On the contrary, four heuristics could be correctly implemented by the tool: title (H1), legend (H2), alternative text (H8) and image quality (H13).

Finally, four elements: data axes (H3), safe colors (H10), contrast (H11) and legibility (H12), do not meet the requirements unless the default options are changed. In fact, none of the four color sets (called "Palettes") nor the 7 monochrome color schemes provided by Microsoft Excel by default, meet the criteria for safe color and contrast set by the WCAG 2.1 (3:1 in chart sections next to each other). Thus, in order to meet the requirements, the author must manually select accessible colors and contrasts, as well as establish adequate legibility parameters. Table 7 summarizes the results of the heuristic evaluation.

Table 7. Heuristics applied to Microsoft Excel.

Not applicable	Not meeting the requirements	Not meeting the requirements unless the default options are changed	Meeting requirements
H5. Abbreviations	H4. Caption	H3. Data axes	H1. Title
H7. Version for printing	H6. Data source	H10. Safe colors	H2. Legend
H14. Resizing	H9. Long description	H11. Contrast	H8. Alternative Text
H16. Receiving focus		H12. Legibility	H13. Image quality
H17. Independent navigation			
H18. Customization			

Discussion

Some incoherencies between the technical suggestions of image submission and their application in analyzed charts also emerged. For example, in the *Journal of informetrics* and the *Information processing & management* of Elsevier we found some papers where safe colors were not used to meet the needs of all profiles with CVD. A situation that repeats in two of the five charts analyzed of the *Journal of the American Medical Informatics Association*. In the case of the *Journal of computer-mediated communication*, even though its guidelines indicate the need for the figures to have adequate color contrast, the two papers analyzed from this journal do not meet this requirement. In contrast, in the *MIS quarterly* journal, although this requirement was not found in its authors guidelines, all charts that use color to convey information comply with a very high or excellent level due to the use of patterns.

All analyzed charts have a caption. However, in most cases, these are limited to function as replacements for the title. In most cases, the text alternative is limited to repeating the caption, therefore, far from being useful for users.

Regarding abbreviations, although Elsevier clearly indicates in its guidelines for authors that all the symbols and abbreviations used should be explained, the truth is that in the five journals from this publisher: *International journal of information management* (3 out of 3 cases), *Government information quarterly* (1 out of 2 cases), *Information & management* (4 out of 4 cases), *Journal of strategic information systems* (2 out of 2 cases) and *Information processing & management* (2 out of 2 cases), a common practice is that the abbreviations are explained in the main body of the article and not in the same chart. Thus, despite the publisher's requirement is met, the reader is forced to search for the meaning of the abbreviation in the text even if he or she only wants to consult the results of the research available in the charts.

In two out of the three journals that do not include technical requirements related to image quality (resolution, dimensions, etc.), the *Journal of knowledge management* and *Journal of computer-mediated communication*, this is not an obstacle to high quality images, which is a similar outcome to that of the publishers who include it in their guidelines. The exception is *MIS quarterly* journal, in which we find a chart that does not meet the indicator and two other charts in which it can be significantly improved.

Despite having evaluated statistical charts of the journals with the greatest impact in the area of library and information science, the results show a considerable number of accessibility problems and several inconsistencies with the editorial policies of the publishers. This observation showcases that even the largest publishers, which are motivated by increasing the quality of their publications and possess a larger budget and a larger editorial team, do not always guarantee quality aspects of their publications, such as accessibility.

The results of the evaluation confirm our initial hypothesis that there is a significant number of accessibility barriers for people with low vision in the charts included in papers of scientific journals beyond those detected in other works published by other authors, making it difficult or impossible for this group to access research results. In comparison with the results collected by Simon *et al*. (2019), the evaluation carried out has allowed finding a greater number of accessibility problems on the set of statistical charts evaluated. Unlike this other work, in our case, the captions in general have overcome the related heuristic. However, we have also encountered various legibility problems related not only to the font size but also to the font family used, the line height, or the contrast.

Unlike our previous work of evaluation of a set of statistical charts published in digital newspapers (Alcaraz *et al*., 2020b), the problem of the lack of text alternatives has not occurred in most of the charts analyzed. However, other problems coincide. In particular, the common problems in both types of publications are a poor non-text contrast ratio, a too small font size, the non-systematization of the use of color palettes appropriate for people with CVD, poor use of indicators to highlight the elements that receive focus –a functionality present only in certain vector charts–, or the inaccessibility through a keyboard interface.

It is difficult to compare these results with the related work, because there are no other similar evaluations apart from the one by Simon *et al*. (2019) and those made by our group.

Finally, Microsoft Excel, a very widespread tool in creating charts, offers default options that do not help authors in creating accessible charts. Significant changes need to be implemented to reach a high degree of accessibility, but simple improvements in color palettes and legibility would clearly improve the results.

Conclusions

From the point of view of publishers, accessibility is important for three reasons. First and foremost, to reach more readers making library and information science journals accessible to researchers with disabilities; second and equally important, to fulfill the accessibility regulations of many countries affecting public administration purchase policies (European Union, 2019). Finally, regarding brand image, accessibility helps comply with corporate social responsibility.

To help improve the accessibility of the statistical charts included in academic journals, publishers could do the following, amongst other actions:

- Include a clear and complete policy on accessibility based on WCAG 2.1 for authors to adhere to when preparing their papers for publication and to guide their staff in producing accessible documents. This policy must include specific requirements so that the statistical charts included in the papers are accessible. The heuristics proposed in this research are a good starting point to generate these guidelines.

- Encourage authors to use authoring tools that conform to accessibility standards and help in producing accessible charts, fostering the use of vector charts.
- Comply with accessibility requirements for HTML version of the papers and adopt the accessible PDF/UA-compliant file format for the downloadable content.

This work showed the first stage of statistical charts accessibility evaluation, through a set of heuristic indicators, currently the researchers are working on a second stage, including users on the evaluation, as they are key to the final validation (Power *et al*. 2012, Lechner 2013).

The results of our research show that there is still a long way to go to achieve full accessibility of graphical content in academic journals, especially for people with low vision. This work contributes to solving this problem in two ways. First, our evaluation serves to get an idea of the current situation and show the main existing accessibility problems. Second, the proposed heuristics are also useful as a guide for creating accessible charts that could be easily incorporated into the style guides of any journal.

Acknowledgement

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Appendix A

Chart 1: https://doi.org/10.1016/j.ijinfomgt.2018.09.015

Chart 2: https://doi.org/10.1016/j.ijinfomgt.2018.11.003

Chart 3: https://doi.org/10.1016/j.ijinfomgt.2018.11.015

Chart 4: https://doi.org/10.1016/j.ijinfomgt.2019.01.005

Chart 5: https://doi.org/10.1016/j.ijinfogt.2019.01.006

Chart 6: https://doi.org/10.1093/jcmc/zmz007

Chart 7: https://doi.org/10.1093/jcmc/zmz007

Chart 11: https://doi-org/10.1108/JKM-05-2018-0288

Chart 12: http://dx.doi.org/10.1108/JKM-11-2017-0554

Chart 13: http://dx.doi.org/10.1108/JKM-03-2018-0223

Chart 14: http://dx.doi.org/10.1108/JKM-02-2018-0088

Chart 15: http://dx.doi.org/10.1108/JKM-05-2018-0277

Chart 16: https://doi.org/10.25300/MISQ/2019/14812

Chart 17: https://doi.org/10.25300/MISQ/2019/14289

Chart 18: https://doi.org/10.25300/MISQ/2019/14530

Chart 19: https://doi.org/10.25300/MISQ/2019/14750

Chart 20: https://doi.org/10.1016/j.jsis.2018.12.003

Chart 21: https://doi.org/10.1016/j.giq.2018.11.002

Chart 22: https://doi.org/10.1016/j.giq.2018.08.001

Chart 23: https://doi.org/10.1016/j.giq.2019.05.006

Chart 24: https://doi.org/10.1016/j.giq.2019.03.003

Chart 25: https://doi.org/10.1016/j.giq.2019.07.002

Chart 26: https://doi.org/10.1093/jamia/ocy129

Chart 27: https://doi.org/10.1093/jamia/ocy145

Chart 28: https://doi.org/10.1093/jamia/ocy160

Chart 29: https://doi.org/10.1093/jamia/ocy183

Chart 30: https://doi.org/10.1093/jamia/ocz032

Chart 31: https://doi.org/10.1016/j.im.2018.07.002

Chart 32: https://doi.org/10.1016/j.im.2018.05.004

Chart 33: https://doi.org/10.1016/j.im.2018.08.003

Chart 34: https://doi.org/10.1016/j.im.2018.10.001

Chart 35: https://doi.org/10.1016/j.im.2018.11.002

Chart 36: https://doi.org/10.1016/j.jsis.2018.09.002

Chart 37: https://doi.org/10.1016/j.jsis.2018.12.003

Chart 38: https://doi.org/10.1016/j.jsis.2018.12.001

Chart 39: https://doi.org/10.1016/j.jsis.2018.07.002

Chart 40: https://doi.org/10.1016/j.jsis.2019.101577

Chart 41: https://doi.org/10.1016/j.ipm.2018.10.010

Chart 42: https://doi.org/10.1016/j.ipm.2018.07.006

Chart 43: https://doi.org/10.1016/j.ipm.2018.12.007

Chart 44: https://doi.org/10.1016/j.ipm.2019.03.002

Chart 45: https://doi.org/10.1016/j.ipm.2019.04.001

Chart 46: https://doi.org/10.1016/j.joi.2019.01.010

Chart 47: https://doi.org/10.1016/j.joi.2019.03.014

Chart 48: https://doi.org/10.1016/j.joi.2019.07.003

Chart 49: https://doi.org/10.1016/j.joi.2019.07.003

Chart 50: https://doi.org/10.1016/j.joi.2019.100976

Appendix B

1.1.1. Non-text content (A)

1.3.3. Sensory characteristics (A)

1.4.1. Use of color (A)

1.4.3. Contrast (minimum) (A)

1.4.4. Resize text (AA)

1.4.5. Images of text (AA)

1.4.11. Non-text contrast (AA)

1.4.12. Text spacing (AA)

2.1.1. Keyboard (A)

2.1.2. No keyboard trap (A)

2.4.3. Focus order (A)

2.4.6. Headings and labels (AA)

2.4.7. Focus visible (AA)

2.5.1. Pointer gestures (A)