Can we create accessible charts with Microsoft Excel?

a review of possibilities and limits, with a special focus to users with low vision

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Abstract

Introduction: statistical charts are key to data literacy and essential in the process of communicating abstract science concepts and relationships that are difficult to understand through other representations. These types of visualization can present numerous challenges for users with low vision, an often-overlooked group despite its enormous prevalence. To evaluate MS Excel's as an accessible authoring tool analyzing ATAG 2.0 compliance, and its capability to create accessible charts according to a set of heuristic indicators proposed by the authors. **Methodology:** evaluate a) the compliance of Microsoft Excel software as an authoring tool with ATAG 2.0 guidelines; and b) the compliance of MS Excel-generated charts with a domain heuristic set. For the heuristic evaluation, apart from the original MS Excel chart (XSLX), three exported versions (DOCX, HTML and SVG) of the same chart were created using all the accessibility features available in the software. **Results:** regarding ATAG compliance, 48 desired accessibility features applying to MS Excel have been identified and the software meet just 26 of them (54.17%). Regarding heuristic evaluation, the four versions of the chart present a percentage of compliance with the heuristics equal to or greater than 66.66%. The versions that have obtained the best scores are MS Excel original and MS Word exported charts with 72.2% of indicators achieved, followed by SVG and HTML exported charts, both with 66.66%. Even though MS Excel does not meet a good part of the ATAG 2.0 success criteria, it has been possible to create charts with a good level of accessibility following the suggested heuristic principles.

Keywords

Statistical charts, Low vision, Digital accessibility, Microsoft Excel, ATAG 2.0, WCAG 2.2, Digital documents

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1. Introduction

Carlson and Johnston in their seminal work on data information literacy [1] advocate data literacy as a key skill for future researchers. They rely on Hunt's [2] definition of data literacy as "involves understanding what data mean, including how to read graphs and charts appropriately, draw correct conclusions from data, and recognize when data is being used in misleading or inappropriate ways". Charts play a crucial role in the communication of abstract scientific concepts [3] and can make visible abstract relationships that are challenging to understand through other representations [4]. If data literacy is deemed crucial, and statistical charts are pivotal in conveying data, the accessibility of charts is essential to ensure inclusivity.

Among users with disabilities, there is an often-forgotten group that hasn't received sufficient attention, despite its significant prevalence. This group comprises people with low vision, a visual disability affecting around 217 million individuals globally, representing 85.77% of people with visual disabilities [5]. Low vision encompasses a diverse range of user profiles, with variations in visual acuity or field of vision (central or peripheral) [6], and additional effects related to diseases like diabetic retinopathy, cataracts, or hemianopsia, resulting in dark spots in the visual field, a blurred or misty effect, or blindness in half of the visual field, respectively. Other individuals with low vision may experience sensitivity to contrast, light or glare, or have color vision deficiency (CVD). All these conditions impact their ability to perceive information, particularly when it involves mathematical formulas, engineering drawings, diagrams, charts, and other types of visualizations. Additionally, individuals with low vision utilize a diverse range of assistive technologies, with screen magnifiers being prominent, followed by others like screen readers, built-in zoom options in web browsers, high contrast settings, etc.

As a first approach to do a reality-check of the accessibility of charts, this paper aims to evaluate a very widely adopted tool, Microsoft (MS) Excel, as a feasible authoring tool for creating accessible charts. Among all the tools available for creating statistical charts, the authors have chosen to evaluate MS Excel because Microsoft Office is the office suite par excellence of the most used operating system in home and professional environments for desktop computers. In addition, a significant number of organizations have integrated Microsoft services as the suite of tools they offer to their staff. Alternatives to MS Excel include highly specialized statistical packages, like IBM SPSS or SAS/STAT, or very specific packages for visualization such as Tableau or software libraries like Bokeh, Plotly, or similar. These tools are often targeted at very specific domains, and require specialized knowledge; on the contrary, MS Excel is a highly adopted software in all areas of business, education [7], and government. In this article the authors analyzed the latest version available at the time of writing, MS Excel MSO 16.0.10356.20006 for 64-bit Windows desktop operating systems.

2. Background

Web Content Accessibility Guidelines (WCAG) [8], is the main reference document in the field of accessibility. The current version (2.2) focuses on improving accessibility for mobile devices and addresses some previously unmet requirements related to users with low vision and cognitive disabilities. In the area of accessible charts, WCAG is a bit too generalist and two proposals for more specific guidelines have been issued [9]. This research relies on the first one [9], a specific set of heuristic indicators (HI) developed by the authors (see Table 1). Results from several heuristic evaluations (HEU) and a user test conducted with this indicator set [11,12, 13, 14] demonstrate that these indicators enable the detection of a greater number of unique problems, offer a better distribution of problems across heuristics, and allow the identification of more severe and specific issues compared to WCAG. The evaluation could also rely on Elavsky et al. [10], heuristic principles set, but it encompasses a broader scope, rather than specifically focusing on individuals with low vision. Conversely, Authoring Tools Accessibility Guidelines (ATAG), with its latest version (2.0) dated on 2015 [15] aim to establish requirements for authoring tools to enable, support, and promote the production of more accessible web content. These guidelines are divided into two parts: Part A includes

guidelines on the user interface of the authoring tool, and Part B includes guidelines to support the production of accessible content. Additionally, W3C has researched the requirements of individuals with low vision with a non-normative document [16]. Several authors have published evaluations of authoring tools based on ATAG 2.0 guidelines [17, 18, 19, 20], but to the authors' knowledge, no studies have reviewed MS Excel's compliance with the ATAG.

Table 1. Heuristic set and barriers related

ID	Heuristic name	Related barriers
H1	Title	Not providing textual elements such as title, legends, axes titles, captions or labels can hinder chart comprehension for any user profile [21, 22, 23, 24].
H2	Legend	
H3	Axes	
H4	Caption	
H5	Abbreviations	Abbreviations may confuse some readers in different ways, and they also harm people with visual disabilities who lose context when they zoom in with a screen magnifier [25].
H6	Data source	This recommendation, beyond being a good practice (ensuring data reliability and trustworthiness), solves the need of some users to access raw data and to open it with their favorite applications.
H7	Print version	Reading on screen may introduce additional difficulties for some low vision users. It is common for these users to read from a very short distance from the screen, which means a very harsh posture causing fatigue [16].
H8	Short text alternative	People who have difficulty perceiving visual content or have difficulty understanding the meaning of charts may need a text alternative. If information is conveyed exclusively through an image, some users could miss details of important features of the chart. On the other hand, text in images of text is also not available to screen readers [26, 27, 28, 29].
H9	Long description	Some users may require a long description to access a textual representation of the chart suitable for them, which also includes a table with the data from which the chart was generated [29, 30,31].
H10	Safe colors	People with CVD may have problems or an inability to distinguish certain color combinations used to distinguish categories on a chart. When colors do not offer enough contrast, they act as a barrier for users with CVD [16, 27, 28, 32, 33].
H11	Contrast	People with poor contrast sensitivity may have problems differentiating certain color combinations used for text and its background. [16, 27, 34]. When foreground and background contrast in both text and graphical elements is not enough many users are not able to distinguish figure elements or read the content [16, 35]. When color is used to encode variables and the different values do not offer enough contrast, users with CVD may not be able to distinguish them [16, 26, 27].
H12	Legibility	Very small font size, insufficient line height, space following paragraphs, letter spacing (tracking), MS Word spacing or an inadequate font face, prevents some users from reading content [16, 36, 37, 38, 39, 40, 41].
H13	Image quality	Bitmap images of text lose quality when magnified [28, 41].
H14	Resize	A significant percentage of users with low vision rely on the magnification of the content to adapt the size of the interface elements to their visual acuity. If font size is too small and cannot be amplified, legibility is not ensured. If chart elements are coded with absolute units or the layout is not responsive, magnifiers reducing the visual area could result in overlapping content, horizontal scrolls or elements disappearing from the users' view [16, 33].
H15	Without disturbing elements	Watermarks or advertising banners on the image may prevent total or partial vision of the chart [11].
H16	Focus visible	Users might be lost without an indication of their current point of focus. Usually zoom interaction implies constant zooming in and out with important changes of context [16, 42].
H17	Device independent navigation	Screen reader users rely on keyboard to navigate the content, so when elements only react to mouse interactions, they become useless [43, 44].
H18	Customization	Images of text do not allow users who require a particular visual presentation of text to be able to adjust the text presentation as needed (font size, color, line spacing). Some users with CVD use a personal CSS on the browser to customize colors. This will have no effect on image text [16, 26].

3. Methodology

This research is divided into two parts: a) evaluation of MS Excel's ability to create accessible statistical charts, focusing on Part B of the ATAG to provide a framework for measure; and b) evaluation of a chart created by MS Excel and three versions of this chart exported to other formats, using all accessibility features available in MS Excel and making every effort to meet all accessibility requirements established by [9].[1] In particular, the chart was exported from MS Excel to MS Word (by copying and pasting the chart to embed it in the document), to HTML (by selecting the default option save as > HTML), and finally to MS PowerPoint, and then saved as a vector image in SVG format (by copying and pasting the chart to embed it in the document and then saving the slide in SVG format from inside MS PowerPoint). These four versions of the chart were then tested against the heuristic set mentioned above. The evaluation was conducted by four expert evaluators with previous experience in HE, two of whom also had with previous experience in ATAG.

ATAG is a set of guidelines that are very general in nature. However, the guidelines have been tailored to the elements of charts and the research team limited the evaluation to 48 requirements considered essential for the creation of an accessible statistical chart. In this sense, some aspects of the heuristic set need to be assimilated into ATAG requirements. In particular, the following heuristic indicators had been incorporated into ATAG requirements: H2 (Legend), H3 (Axes), H4 (Caption), H6 (Data source), H7 (Print version), H12 (Legibility), H13 (Image quality), H14 (Resize, that only applies to text in WCAG), H15 (Without disturbing elements) and H18 (Customization). For example, the requirements set in ATAG success criteria B.1.1.2 have been repeated for each relevant element in charts.

4. Results

4.1. MS Excel ATAG evaluation

The first three authors, in order of signature, carried out the MS Excel ATAG evaluation individually, and then the results were consolidated. Table 2 summarizes the result of the evaluation. It also indicates the heuristic principles related to each feature. The column "Rationale" provides an explanation of the evaluation. To offer solutions in case of failure, a column was added with the suggestion of a workaround to achieve maximum accessibility.

Table 2. Evaluation results of the ATAG success criteria by MS Excel

ID	ATAG required accessibility features, particularized to charts	Heuristics related	ATAG 2.0 success criteria	ATAG 2.0 compliant	Rationale	Workarounds
1	If the title is automatically generated it is already accessible or the author is warned by some mechanism.	H1	B.1.1.2	No	MS Excel generates a text box for the title with an example title (chart title). Title is generated during the session, so B.1.1.1 does not apply.	Edit the example title. The author must be attentive to the title, without any warning or checking mechanisms.
2	Does not generate legend automatically.	H2	B.1.1.2	No	MS Excel generates a legend by default at the bottom of the chart from the values of the data series and with the colors of the default palette.	Edit the default legend (position, size...).
3	Does not generate axes titles automatically.	H3	B.1.1.2	Yes	MS Excel does not generate automatic axes titles during the session.	-

[1] Charts and the results of the heuristic evaluations are available online at https://doi.org/10.6084/m9.figshare.25555698

ID	ATAG required accessibility features, particularized to charts	Heuristics related	ATAG 2.0 success criteria	ATAG 2.0 compliant	Rationale	Workarounds
4	Does not generate axes titles automatically or author can specify to create a WCAG compliant chart with axes titles.	H3	B.1.1.1	Yes	MS Excel does not generate automatic axes titles.	Axes titles are important according to the heuristics; so, the author should include them although they are not required by ATAG. MS Excel has an option to do it.
5	Does not generate a caption automatically.	H4	B.1.1.1	Yes	MS Excel does not generate automatic captions nor make suggestions to the author.	-
6	Does not generate alternative text automatically.	H8	B.1.1.1	Yes	MS Excel does not generate automatic alternative texts nor make suggestions to the author.	-
7	Does not generate a long description automatically.	H9	B.1.1.1	Yes	MS Excel does not generate automatic long descriptions nor make suggestions to the author.	-
8	Warns the author when textual elements of the chart are converted to graphics.	H1-H6	B.1.2.1	No	When the chart is exported as HTML format it is converted into a bitmap image without notifying the author.	-
9	Preserves all the accessibility information when the chart is exported as HTML.	-	B.1.2.1, B.1.2.4	No	When the chart is exported as HTML, the alt text is preserved, but other text elements like the title, title axes or the legend are converted into an image.	In this case it is better to add some of these textual elements later using HTML tags.
10	Preserves all the accessibility information when the authoring tool is both the source and the destination of the copy-pasted chart.	-	B.1.2.2, B.1.2.4	Yes	When the chart is copy-pasted into another sheet or MS Excel document all the chart's characteristics (title, legend, colors...) including the alternative text, are preserved.	-
11	Preserves all the accessibility information when the chart is copy-pasted from the authoring tool to a MS Word or PowerPoint document.	-	B.1.2.2, B.1.2.4	Yes	When the chart is copied and pasted into a MS Word or PowerPoint document, all the chart's characteristics (title, legend, colors...) including the alternative text, are preserved.	If the palette differs between the source and target documents, colors may change. Authors must be attentive to this.
12	Allows inserting a title for the chart from the user interface.	H1	B.2.1.1	Yes	MS Excel allows adding a title to any type of chart.	-
13	Allows inserting a legend for the chart from the user interface.	H2	B.2.1.1	Yes	MS Excel allows adding a legend to any type of chart.	-
14	Allows inserting axes with titles for the chart from the user interface.	H3	B.2.1.1	Yes	MS Excel allows adding axes titles to any type of chart, except for charts that do not have axes (pie or ring charts).	-

ID	ATAG required accessibility features, particularized to charts	Heuristics related	ATAG 2.0 success criteria	ATAG 2.0 compliant	Rationale	Workarounds
15	Allows inserting a caption for the chart from the user interface.	H4	B.2.1.1	No	MS Excel does not have a specific option to add a caption.	Add the caption using a nearby cell, HTML tag or the specific option to add captions of the Microsoft MS Word, as appropriate.
16	Allows for providing the expansion or explanation of an abbreviation in its first occurrence.	H5	B.2.1.1	No	MS Excel does not have a specific option to add an abbreviation.	The first occurrence of the abbreviation should appear and be explained before the chart.
17	Allows inserting the data source for the chart from the user interface.	H6	B.2.1.1	No	MS Excel does not have a specific option to add a data source.	In this case, the data source should be linked before or after the chart
18	Allows to generate an accessible print version.	H7	B.2.1.1	Yes	MS Excel allows generating a custom accessible print version of the chart.	-
19	Allows inserting alternative text from the user interface	H8	B.2.1.1	Yes	MS Excel has a specific text box to insert alt text up to 65532 characters.	-
20	Allows inserting a URL for the long description from the user interface.	H9	B.2.1.1	Yes	MS Excel allows adding a link to the long description into any type of chart.	-
21	Allows editing of title from the user interface.	H1	B.2.2.2	Yes	The author has the option to edit the title but does not have any check on accessibility properties.	The user must be aware of accessibility issues related to titles.
22	Allows editing of the legend from the user interface.	H2	B.2.2.1, B.2.2.2	Yes	The author has the option to edit the legend but does not have any check on accessibility properties.	The user must be aware of accessibility issues related to legends.
23	Allows editing of axes titles from the user interface.	H3	B.2.2.1, B.2.2.2	Yes	The author has the option to edit the axes title but does not have any check on accessibility properties.	The user must be aware of accessibility issues related to axes title.
24	Allows editing the expansion or explanation of an abbreviation from the user interface.	H5	B.2.2.2	No	MS Excel does not have a specific option to add an abbreviation.	In this case, the first occurrence of the abbreviation should appear and be explained before the chart.
25	Allows editing the data source for the chart from the user interface.	H6	B.2.2.2	No	MS Excel does not have a specific option to editing a data source.	In this case, the data source should be linked before or after the chart.
26	Allows editing the characteristics of the print version from the user interface.	H7	B.2.2.2	Yes	Author has the option to edit the characteristics of the print version at any moment.	-
27	Allows editing the alt text from the user interface.	H8	B.2.2.2	Yes	Author has the option to edit the alternative text at any moment.	-

ID	ATAG required accessibility features, particularized to charts	Heuristics related	ATAG 2.0 success criteria	ATAG 2.0 compliant	Rationale	Workarounds
28	Allows editing the URL for the long description from the user interface.	H9	B.2.2.2	Yes	Author has the option to edit the URL of the link to the long description at any time.	-
29	Provides accessible templates to create a new chart or includes a template selection mechanism that displays distinctions between the accessible and non-accessible ones.	-	B.2.4.1, B.2.4.2	No	There are no accessible templates for the new charts, nor is any related additional mechanism implemented.	MS Excel allows the user to create an accessible chart template collection. These templates are available under the chart template gallery from the user interface.
30	Provides safe color palettes for the charts by default.	H10	B.4.1.1, B.2.2.1	No	MS Excel does not provide safe color palettes by default for all the CVD profiles.	MS Excel allows the user to select a safer color palette in their custom templates.
31	Provides enough text contrast for the chart's textual elements (title, axes, legends...) by default.	H11	B.4.1.1, B.2.2.1	Yes	MS Excel provides enough text contrast for the chart's textual elements (by default: 7:1 contrast ratio).	MS Excel allows the user to select colors for the chart's textual elements with a sufficient contrast ratio in their custom templates.
32	Provides enough non-text contrast for the chart's marks by default.	H11	B.4.1.1, B.2.2.1	No	MS Excel does not provide enough non-text contrast for the adjacent chart's marks (by default 1.7:1 contrast ratio between blue and orange).	MS Excel allows the user to select colors for the chart's marks with a sufficient contrast ratio in their custom templates.
33	Warns the author if the title is not provided.	H1	B.3.1.1	No	MS Excel generates a text box to provide the title but does not warn the author when the title is not provided.	-
34	Warns the author if abbreviations are not expanded.	H5	B.3.1.1	No	MS Excel does not warn the author when an abbreviation is not expanded.	-
35	Warns the author if the print version is not accessible.	H7	B.1.2.1	No	MS Excel does warn the author when the print version is not accessible. MS Excel does not offer any information about accessible printed versions.	-
36	Warns the author if alternative text has not been provided	H8	B.3.1.1	Yes	MS Excel does not warn the author by default when the alternative text is not provided, but the author is warned if he or she uses the integrated automated accessibility validation tool.	-

ID	ATAG required accessibility features, particularized to charts	Heuristics related	ATAG 2.0 success criteria	ATAG 2.0 compliant	Rationale	Workarounds
37	Warns the author about the possibility that alternative text does not provide the same content or information conveyed by the chart	H8	B.3.1.1, B.2.3.2	No	MS Excel does not warn the author when alternative text does not provide the same information conveyed by the chart.	-
38	Warns the author if the color combination is not safe.	H10	B.3.1.1	No	MS Excel does not warn the author when the color combination is not safe.	MS Excel allows the user to select color combinations that ensure accessibility for people with CVD in their custom templates.
39	Warns the author if the text contrast is not enough.	H11	B.3.1.1	No	MS Excel does not warn the author when the text contrast is not enough. The MS Excel's included automatic validation only works for the cell's content.	MS Excel allows the user to select colors that ensure accessibility for people with CVD in their custom templates.
40	Warns the author if the non-text contrast is not enough.	H11	B.3.1.1	No	MS Excel does not warn the author when the non-text contrast is not enough.	-
41	Provides an accessibility status report based on the results of the accessibility checks.	-	B.3.1.4	Yes	MS Excel provides a report from its accessibility checker tool that provides information about accessibility issues (alternative text, contrast between text and background, column headers for data tables and any limitation throughout the document).	-
42	Gives an indication after the insertion that the alternative text should properly describe the image.	H8	B.3.2.1	No	MS Excel does not provide any indication or examples about how an alternative text should be.	-
43	Provides accessible content support features, which are active by default.	-	B.4.1.1	No	Features such as text size, color palette, among others, are not accessible by default.	Use accessible templates.
44	All accessible content support features are at least as prominent as features related to either invalid markup, syntax errors, spelling errors or grammar errors.	-	B.4.1.4	No	The Accessibility checker is not activated by default and accessibility problems are only shown when the author activates it. On the other hand, once activated, the message indicating that there are accessibility problems appears discreetly in the lower left part of the interface.	Activate the accessibility validator when starting to work and leave the window open with the inspection results.

ID	ATAG required accessibility features, particularized to charts	Heuristics related	ATAG 2.0 success criteria	ATAG 2.0 compliant	Rationale	Workarounds
45	Provides examples that demonstrate accessible authoring practices for the creation of a chart.	-	B.4.2.1	Yes	Both the help integrated in the application and the web documentation, include examples demonstrating accessible authoring practices.	-
46	Provides instructions for using any accessible content support features in the documentation.	-	B.4.2.2	Yes	Both in the help integrated in the application and in the web documentation, MS Excel provides instructions for using all the accessible content support features available.	-
47	Provides a tutorial for an accessible authoring process that is specific to that authoring tool.	-	B.4.2.3	Yes	Both in the help integrated in the application and in the web documentation, MS Excel offers resources for an accessible authoring process that is specific to that authoring tool.	-
48	Provides index to support content creation with accessible headings.	-	B.4.2.4	Yes	The authoring tool documentation contains an index to the instructions for using all the features, including the accessible content support features.	-

Of the final 48 desired accessibility features analyzed, MS Excel meets 26 (54.17%) and fails in 22 (45.83%). MS Excel offers mechanisms to add and edit some of the most important elements of an accessible statistical chart such as title, legend, axes titles, or alternative text. However, it lacks specific options or fields for others, such as caption, data source or long description. Although these can be added in cells close to the chart or in other sheets, the programmatic relationship between them can only be established by means of an internal link.

In the area of chart generation, MS Excel does not provide default templates that consider accessibility requirements, nor does it provide information about the accessibility of the offered templates. Examples of features that could be included in templates are font size, safe color scales and contrast issues of several chart elements. Authors can use correct font sizes and safe color scales through manual selections, but the tool does not offer any guidance or warning when not done properly. It is also possible for authors to create new, more accessible, templates.

As a positive feature, MS Excel offers an automated accessibility validation tool that checks many important aspects of accessibility with the following set of rules triggering errors and warnings. Errors: a) all non-text content has alternative text (alt text); b) tables specify column header information; c) cells in an MS Excel worksheet do not use red-only formatting for negative numbers; d) document access is not restricted; Warnings: a) the table has a simple structure; b) sheet tabs have meaningful names; c) sufficient contrast between text and background. Authors have tested these features in real charts and found that an incorrect contrast between text and background did not trigger any warning when it was found within a chart.

All these features, both manually and automatically validated, are included in the documentation integrated into the tool and on the web. Specifically, the internal documentation includes information about how to add alternative text, how to use color and contrast, rename spreadsheet tabs, and use the accessibility checker. The web documentation covers how to include alternative text, add meaningful

hyperlink text, the use of sufficient contrast for text and background colors, give the sheet tabs unique names, and structure tables and specify column header information.

In the area of chart publishing, a common use of MS Excel charts is to repurpose them in a MS Word or MS PowerPoint document, both tools included in the suite of Microsoft Office and sharing many features with MS Excel. The repurposing is commonly achieved through a simple copy-and-paste operation from MS Excel to the new tool. Since these are closely related software, this operation preserves all the accessibility information included in the original chart. Conversely, when the chart is exported into HTML, much of this information is lost.

4.2. Heuristic evaluation

The four authors conducted a HEU of the accessibility of the different versions of the chart created with MS Excel. For each feature, authors determined positive compliance (yes) or failure (no), opting not to use a more comprehensive Likert scale as in previous studies. The evaluation was complemented with a brief reasoning in case of a negative score. Each evaluator performed an independent evaluation, and a final meeting was conducted to review and consolidate the results. A consolidated summary of the results obtained is shown below. Details can be consulted online.[2]

The four versions of the chart generated by MS Excel present a compliance percentage with the heuristics equal to or greater than 66.66%. The versions that have obtained the best scores are the charts in MS Excel and in MS Word with 72.2% of indicators achieved, followed by charts in SVG and HTML, both with 66.66%. Among the most important limitations detected in the four versions, it must be highlighted the non-existence of specific fields to add a caption (H4); to indicate the full form of an abbreviation (H5); and to include the data source (H6); however, they could be added in other parts of the document. For example, in the version embedded in MS Word, it is possible to add a caption using the specific options offered by this other application, or in the case of HTML and SVG versions, with the <figcaption> element.

The default color schemes proposed by MS Excel does not offer safe color combinations for people with CVD (H10). Additionally, they do not guarantee the minimum contrast (H11) required by the WCAG is achieved.

The short text alternative (H8) originally added in the MS Excel chart, is included in MS Word and HTML versions, but it disappears upon converting the chart to SVG format. A similar situation occurs with the long description; while it remains linked to the chart in the HTML version, it cannot be automatically exported when converting the chart into MS Word (chart 2) and SVG (chart 4) formats. When exporting to HTML, two tabs are created, one with the chart and one with the long description; but by default, the long description one is shown at the beginning which difficult locating the chart.

Another heuristic not reached by any of the charts is H16 (focus visible), although it could be solved in the SVG version with CSS styles. Although MS Excel creates charts as vectorial drawings, when exporting the chart to HTML format, it is converted into a bitmap format, hindering many accessibility features. This conversion affects the image quality (H13) as the chart is exported into a given resolution and does not change when magnified, it makes it impossible to navigate through the marks (bars, axes ...) (H17) and severely limits its customization (H18). The two most flexible formats in terms of chart customization are the XLSX format and the DOCX format.

If the user tries to have a paper version of the chart, printing it, in the case of MS Excel and HTML versions, although the document can be configured to be printed properly, by default, the chart is cut. Consequently, authors have to take a conflicting decision when deciding the chart size: a larger size is good for the screen, a small size is good for printing.

5. Discussion and Conclusions

Accessibility has been mostly restricted to WCAG and primarily oriented towards blind people until now. Additionally, authoring requirements have been neglected by law enforcements. Now it is time to move forward. Guidelines are already evolving in this direction; WCAG 2.2 include new criteria for low vision, WCAG 3.0 promises to have a more global view of requirements. Moreover, the European

[2] https://doi.org/10.6084/m9.figshare.25555698

Directive 2016/2102 is also a significant advance, including ATAG and adopting a more holistic view of requirements, covering all technology products, not only web- based content. New guidelines are appearing for specific content beyond WCAG.

Within this new trend, this research evaluates a particular type of document: statistical charts, for low vision users –a commonly-forgotten user's profile– and includes ATAG and a more specific set of requirements than WCAG in the evaluation. In this shared path to a holistic and widespread accessibility, and as a temporary workaround, the authors try to help authors to understand in-depth the possibilities of MS Excel, follow good practices and offer the heuristic set and practical workarounds of this research as complementary guidelines to reach maximum accessibility.

Traditionally, the responsibility for accessibility in digital documents has mostly been directed towards code specifications and authors. Proof of this is the number of tutorials aimed at guiding authors on how to make documents accessible, without a strong criticism on authoring tools.

Our paper shows that MS Excel, a very popular and widely adopted tool, does not meet a significant part of the ATAG success criteria, and the generated charts (both original and exported to other formats) have important shortcomings. As a future work, accessibility researchers must keep track of some recent changes such as the introduction of Phyton in MS Excel, the inclusion of AI in chart generation or specific new features, incorporated into MS Office after the research was finalized, such as that the authors of a chart, after choosing a color, can select to view only high contrast color combinations, which hopefully will open the door to new chart types and introduce accessibility features that are easy to implement for authors.

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