Web accessibility for people with dyslexia: A systematic literature review

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Abstract

As the digital age advances, the internet has become a vital source of information and social participation; And with it, opportunities and benefits are manifested that can only be obtained through this single means. That is why it is essential to ensure that everyone can have equal access and opportunities when browsing the web. This review focuses on investigating the current state of knowledge of web accessibility for people with dyslexia. To achieve this, various computer solutions, design recommendations and study of web accessibility guidelines were reviewed, whose main objective is to improve the experience of users with dyslexia when browsing the web. A total of 120 original articles were extracted from the Scopus database, of which 22 studies met the inclusion criteria. The results showed that many of the web design customization options provided by these solutions were able to improve the web browsing and reading experience for people with dyslexia. In conclusion, this RSL allowed to identify a large number of software-based solutions and design recommendations to provide accessibility to people with dyslexia. Among the most important factors considered in these studies is the organization of content, typography and color contrast. Additionally, it is important to highlight the need to continue adjusting these proposals according to the different opinions and suggestions provided by the participants during the evaluations. And finally, it is recommended to obtain larger samples of participants so that, in this way, more representative results can be obtained during future research.

1. Introduction

Since its conception, web accessibility has become a field of study of great importance for web design, this has evolved over time becoming this whole set of practices, guidelines, and recommendations that we know now and that every website must follow if you want to avoid some type of penalty depending on the country in which you are.

In the 90s the World Wide Web Consortium (W3C) made the decision to develop a series of standards so that every website can be correctly interpreted by web browsers, regardless of the type of device or the software used to access them. Since that time, the W3C has continued to develop various guidelines and recommendations aimed at web accessibility, including the Web Content Accessibility Guidelines (WCAG). The WCAG establishes guidelines for accessible web content and defines the required accessibility levels (A, AA, AAA). These guidelines are widely instructed to web designers through university courses, training sessions, and various books (1).

Lack of accessibility means that a large number of people are excluded from accessing information and services online. That is why, one of the main objectives of the WCAG and web accessibility in general, is that any website developed can be used by all kinds of people, regardless of their abilities or disabilities.

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According to (1), the WCAG guidelines focus primarily on visual impairments. Since it has been found that the most active users in matters of computational accessibility with a long history of social commitment to promote these interests are those with visual disabilities (1).

This research focuses on accessibility for people with dyslexia which, in this context, is relatively related to visual disabilities because it is a disability that involves sight and problems understanding what is shown in front of the computer screen.

According to, although the W3C has developed guidelines and recommendations to ensure web accessibility, these have not reached the maximum levels of accessibility, especially on websites of great relevance to people with dyslexia, such as the platforms of public government entities, employment sites, commerce, health and education sites. In addition, all information on web accessibility best practices aimed at people with dyslexia is outdated (1) (2) (3).

It is for this reason, that the problem that this research work takes is the need to develop a new systematic literature review (RSL) that focuses on determining the most effective software solutions to ensure web accessibility for people diagnosed with dyslexia. Looking for knowledge gaps, discrepancies and new perspectives in current web accessibility practices. Since, although three articles relevant to the research topic were found, two of them are more than ten years old so they are outdated. While the other article, although it has been developed in current times, this one focuses on web accessibility and cognitive disabilities using a general approach, which does not indicate specific practices and recommendations for people with dyslexia (1) (2).

The justification for developing this work is to be able to contribute to the improvement of web accessibility for people diagnosed with dyslexia. In turn, that this information collected can be used in future work to develop new software solutions that can be implemented in the most important and relevant websites for people with dyslexia.

In this review, we aim to investigate the state of web accessibility for people with dyslexia. Therefore, it aims to review the different computer solutions presented in studies over the years and observe the level of effectiveness and usability that they have reached; as well as reviewing the different guidelines and recommendations in the field of web accessibility provided by some studies to improve the experience of these users when browsing the Internet.

In this way, the rest of the document is organized into four sections. Section 2 presents the methodology used for this systematic literature review, from the formulation of the research questions to the procedures carried out for the selection of studies relevant to this research. Section 3 shows the results obtained from the selected studies by organizing them as answers to each research question on the state of web accessibility for people with dyslexia. Section 4 discusses and interprets the main findings and limitations found in the results. Finally, section 5 defines the conclusions of the study and proposes recommendations for future work.

2. Methodology

2.1. Review Questions

To find studies relevant to the topic of this research, a strict methodology was followed, which initially consists of the formulation of a PICO question: What computer solutions and accessibility recommendations in web design have been implemented to improve accessibility levels for people with dyslexia? From this question, we proceeded to divide into secondary review questions for the extraction of data from the documents and the establishment of conceptual lines (4) (5) (6) (7) (8).

Table 1. Review questions.

Q.	Review question	Required Information
RQ1	What bibliometric indicators do the selected studies present?	- Year of publication - Type of document (articles, conference paper, book chapter, etc.) - Publisher where it was published (IEEE, Elsevier, etc.) - Country where the empirical research was developed
RQ2	What is the objective of the research?	- Main objective of the solution, tool or experiment
RQ3	What assistive tools or technologies were used to improve web accessibility for people with dyslexia?	- The tools, solutions or technologies used - Type of solution - Functionality
RQ4	How were the evaluations conducted?	- Number of participants - Characteristics of the participants (Age, sex, have dyslexia or not, number of participants) - Type of study (Qualitative or quantitative)

		- Details of the environments (classroom, offices, platforms, remote, face-to-face, controlled environments, etc.). - Methods for assessing accessibility should be presented
RQ5	What results were obtained when applying the solutions proposed by the authors?	- Results of the evaluation
RQ6	What practices are recommended to improve web accessibility for people with dyslexia?	- Strategies or techniques recommended in the articles
RQ7	What were the barriers and challenges in implementing web accessibility practices for people with dyslexia?	- Limitations found must be extracted

2.2. Search strategy

After this, the keywords related to each component of the PICO question were identified.

Table 2. PICO questions and related keywords.

P	Web design	"Web design" OR "Inclusive web design" OR Web OR "Web browser" OR "Assistive technology" OR "Customized websites" OR "Individual website adjustments"
I	Web accessibility for people with dyslexia	"Web content accessibility Guidelines" OR "Web content accessibility" OR "WCAG 2.1" OR "Web accessibility" OR Accessibility OR Accessible OR "User agent accessibility guidelines" OR Uaag OR "Authoring tool accessibility guidelines" OR Atag OR "Design guidelines" OR "WCAG 2.1" OR "IEC 40500" OR "ISO standard*" OR guideline*
O	Usability levels for people with dyslexia	"User testing" OR "User experience" OR "User-centered design" OR "User interface" OR Ui OR "User experience" OR Ux OR "Usability testing" OR "User-Computer Interface" OR "Software Testing" OR "User experience testing" OR "Users' experience*" OR "User experience research" OR "User experience research" OR "Usability engineering" OR "Usability testing" OR "Digital literac*" OR "Source code analysis" OR "Human computer interaction*" OR "user-centered approach" OR "user centered approach" OR "user reading" OR "E-learning" OR "Design and implementations" OR Customization OR Readability OR "User interface*"
C	In the context of people with dyslexia	Dyslexia OR Legasthenia OR Dyscalculia OR "Dyslexic people" OR "Dyslexic person*" OR "Dyslexia accommodation*" OR "Dyslexia-friendly" OR "People with dyslexia" OR Dyslexic

With the keywords organized in each component, the following search equation was formulated, obtaining a total of 120 results relevant to the research topic.

Table 3. Search equation.

TITLE-ABS-KEY ("Web design" OR "Inclusive web design" OR web OR "Web browser" OR OR "Assistive technology" OR "Customized websites" OR "Individual website adjustments") AND TITLE-ABS-KEY ("Web content accessibility Guidelines" OR "Web content accessibility" OR "WCAG 2.1" OR "Web accessibility" OR accessibility OR accessible OR "User agent accessibility guidelines" OR uaag OR "Authoring tool accessibility guidelines" OR atag OR "Design guidelines" OR wcag OR "WCAG 2.1" OR "IEC 40500" OR "ISO standard*" OR guideline*) AND TITLE-ABS-KEY (dyslexia OR legasthenia OR dyscalculia OR "Dyslexic people" OR "Dyslexic person*" OR "Dyslexia accommodation*" OR "Dyslexia-friendly" OR "People with dyslexia" OR dyslexic

To avoid finding articles that are not relevant to the topic of this research, we proceeded to follow the systematic methodology of PRISMA studies (2020). Starting by defining the inclusion and exclusion criteria to filter the search results in Scopus.

Table 4. Inclusion criteria.

Inclusion criteria	
CI1	Documents can be articles or conference papers
CI2	Documents should address the issue of web accessibility for people with dyslexia
IC3	Documents should provide solutions, best practices, or recommendations in developing and designing websites for people with dyslexia
CI4	Documents should include people with dyslexia as a target group

Table 5. Exclusion criteria

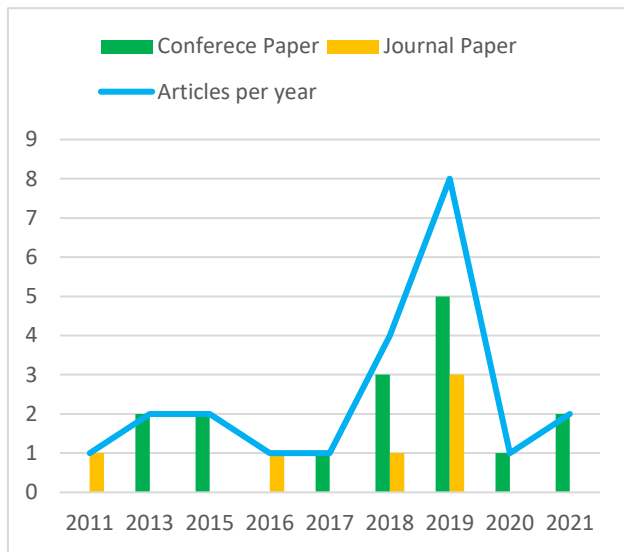| Exclusion criteria	
CE1	Documents prior to 2011
CE2	Documents published in languages other than English and Spanish
CE3	Documents that focus exclusively on other disabilities

Finally, the PRISMA selection process was carried out on the 120 results obtained with the search equation previously shown.

The process had 5 phases:

1. The automatic filters of the Scopus database were used to eliminate a total of 44 documents. Which corresponded to review and conference review type documents indicated in the inclusion criterion CE1; as well as documents with a publication date prior to 2011, since the previous systematic review of literature on web accessibility and dyslexia was carried out in 2010.
2. We then reviewed the titles and abstracts of the remaining 76 records, eliminating a total of 29 studies.
3. The remaining 47 full-text documents were then searched. Where only one document could not be recovered.
4. With 46 documents recovered, an in-depth reading of each of them was carried out to verify if they met the aforementioned inclusion and exclusion criteria. Here were eliminated 10 documents that did not meet the inclusion criterion CI2 because they did not address issues related to web accessibility for people with dyslexia and 14 documents that did not meet the inclusion criterion CI3 because they did not provide solutions, recommendations or best practices for the development and design of websites for people with dyslexia. A total of 24 studies were excluded.
5. Finally, a total of 22 documents met the inclusion and exclusion criteria, becoming included in the systematic literature review.
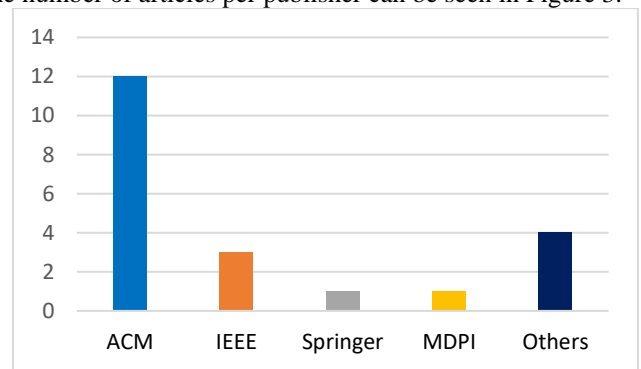
The document selection process can be seen more clearly in the following PRISMA flowchart:

Figure 1. Literature search and selection process

3. Results

This section presents the information collected from the articles analyzed to show the results and main characteristics of the studies, through research questions mentioned in Table 1.

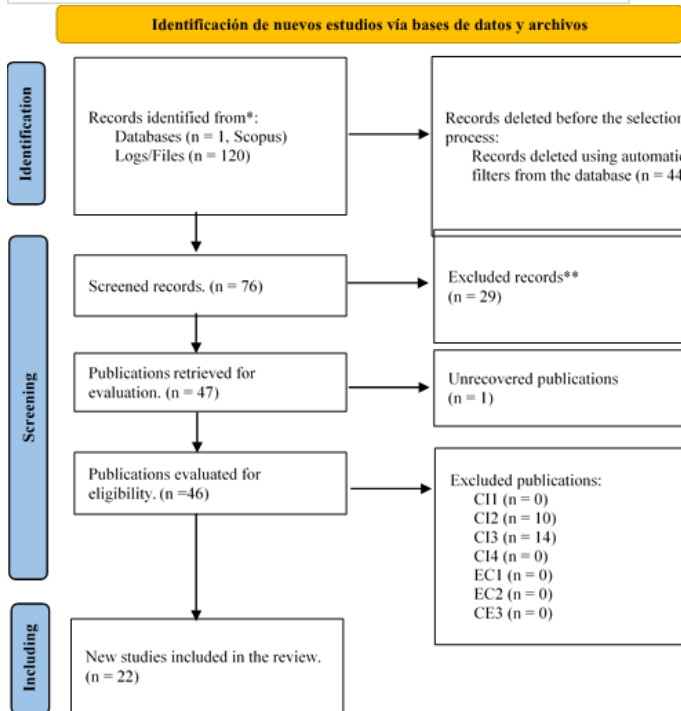### 3.1. RQ1: What bibliometric indicators do the selected studies present?

According to the observed results, the selected studies were published from 2011 to 2021 with a notable increase in 2019 of 36% (8 documents). More than half (62%) were conference papers, while (38%) were documents published as articles. Information on the number of studies published per year and the percentage by type of document are detailed in Figure 2.

Figure 2. Combined graph of percentage of publication types and documents by year

Most of these studies were published in the scientific publications publisher Association for Computery Machinery (ACM) with 53% (12 documents), while the rest of the studies were published in different publishers such as IEEE, Springer, MDP, among others; More detailed information on the number of articles per publisher can be seen in Figure 3.

**Figure 3.** Number of documents per publisher

Among the countries where the empirical research was carried out, it was observed that 27% (6 documents) were from Italy, 14% (3 documents) came from Brazil, another 14% (3 documents) from the United States, 9% (2 documents) from the United Kingdom, another 9% (2 documents) from Slovenia, and the rest of the documents came from Norway, Germany, Spain, Belgium, India and Jordan as can be seen in Figure 4.
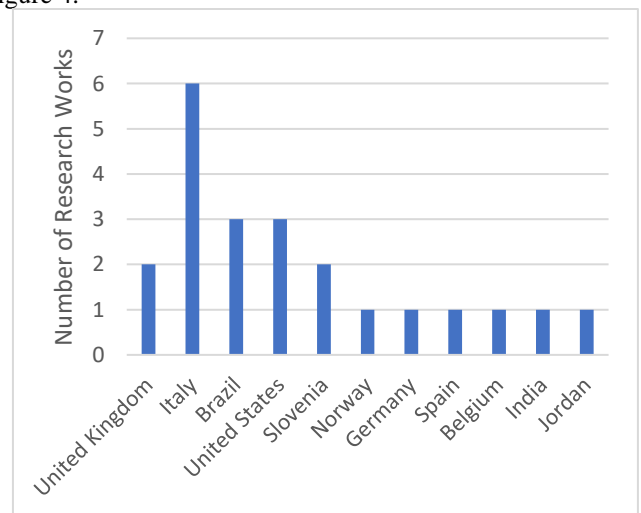
Figure 4. Number of Research Works

3.2. RQ2: What is the objective of the research?

The reviewed publications present different approaches to dealing with web accessibility research for people with dyslexia, with a predominance of studies focused on presenting software solutions, followed by analysis and proposals for measuring the level of accessibility presented by existing websites. Main information collected from the studies analyzed regarding the objectives of the research can be seen in Table 6. Ten studies focused on presenting and evaluating different types of solutions and software implementation models to improve web accessibility for
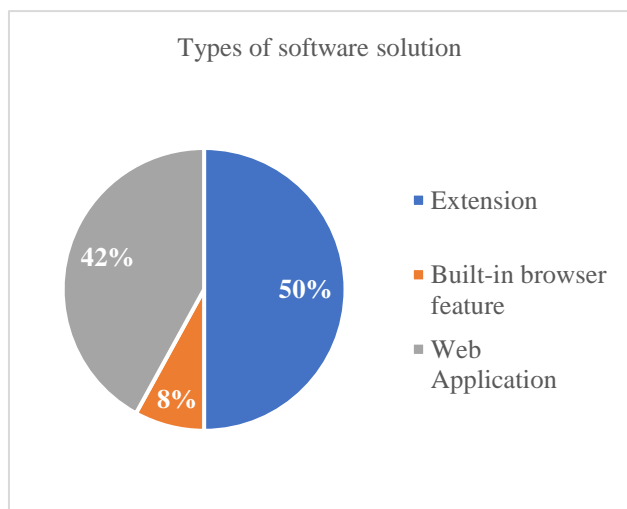
people with dyslexia, in addition to gathering participants to evaluate the effectiveness of this solution, except for studies that did not have participants so its usability could not be evaluated. There are six studies in which the objective of the research is to examine the level of accessibility presented by websites, evaluating readability, font type and size, line spacing, etc. The studies focused specifically on reviewing authentication methods and the level of accessibility with which they are designed, with the aim of demonstrating the challenges faced by people with dyslexia when authenticating on a website. Another particular study had as its main objective to present Text to Speech technologies to integrate into websites, and therefore, to serve as an assisted guide for people who present difficulties during reading as is the case of dyslexics (9) (10) (11) (12).

Table 6. Distribution of studies by research objective

Objective of the Research	Number of studies (Percentage of occurrence (%))	References
Present software solution to improve the experience of users with dyslexia on websites	8 (36.36%)	(11)
Research and evaluate the usability of different modifications and customizations to websites, through feedback given by people with and without dyslexia	12 (54.55%)	(9)
Evaluate implemented solutions that have already been implemented previously	2 (9.09%)	(13)

3.3. RQ3: What assistive tools or technologies were used to improve web accessibility for people with dyslexia?

Of the studies that were dedicated to presenting original software solutions to improve web accessibility for dyslexics, 60% (6 documents) belonged to browser extensions. It should be noted that all studies were developed to work specifically in a single web browser. As shown in Figure 5 there were 30% (3 papers) of studies that developed web applications that function as assistive technology for people with reading disabilities. Finally, it presents a function incorporated in the Mozilla Firefox browser to evaluate its usability for dyslexic people. Not all the publications analyzed were dedicated to presenting software solutions for dyslexics (11) (14). More detailed information on the solutions and their functionalities can be seen in table 7.

Figure 5. Distribution of solution types found in studies.

Table 7. Distribution of software solutions according to their general functionalities

Functionality	Number of studies	References
Adapt websites at runtime, offering various easy-to-use tools for people with dyslexia to customize the website to their comfort	6	(9)
Customize user authentication interfaces to improve the experience for people with dyslexia	2	(15)

Offer assistance to users with dyslexia at the time of writing through suggestions	2	(16)
Offer exercise templates to teach languages and cultures to students with dyslexia	1	(14)

3.4. RQ4: How were the evaluations conducted?

Of the studies reviewed, many of them required volunteers to perform usability tests of their solutions as well as to determine the most appropriate settings to facilitate the web experience of users with dyslexia. More detailed participant information and evaluations can be seen in detail in Table 8. For the selection of participants, these were usually found through advertisements on the Internet, such as social media posts and in some cases communicating with organizations dedicated to providing help and support to people with disabilities.

As can be seen in Figure 6, less than 9 people agreed to participate in some of the studies 29% (n = 5), 24% (n = 4) of the studies had between 10 to 29 participants, while 18% (n = 3) corresponded to studies in which 30 to 80 participants were obtained and there were another 29% (n = 5) of studies that obtained large numbers of participants greater than 80. Additionally, there was one case in which the demographic information of the participants was not reported, so the number of people who participated in that study could not be determined. The age of participants in the 17 studies with demographic information ranged from 8 to 72 years, so both children and adults were recruited to participate in the different evaluations (17).
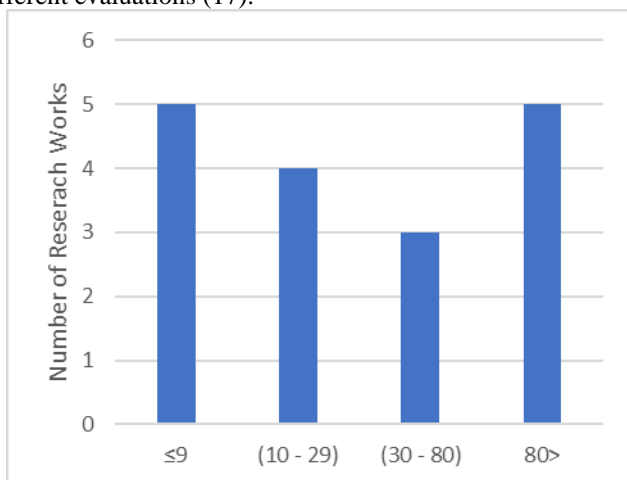

Figure 6. Distribution of the number of participants in the studies

Regarding the type of evaluation that was carried out, it was observed that 54% (13 studies) were quantitative in nature, 23% (3 studies) were qualitative and quantitative studies (Mixed), and the remaining 23% (3 studies) were qualitative in nature as shown in Figure 7.
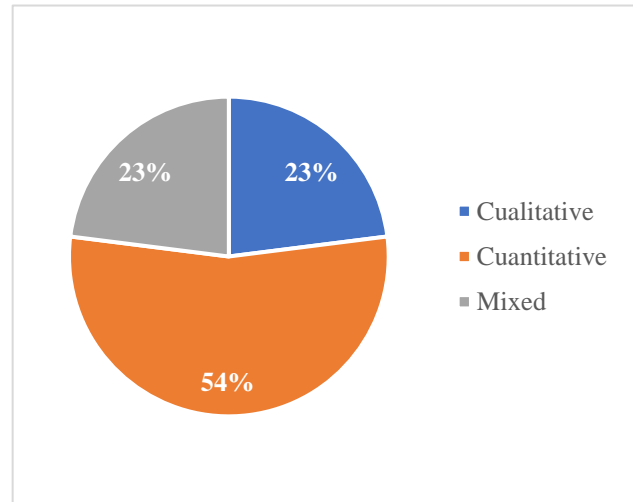

Figure 7. Distribution of study types

For the assessment environments 52% (11 studies) of the studies were conducted online, while 38% (8 studies) were conducted face-to-face in a controlled environment, and finally (13) it was conducted in a classroom and in a computer room of a school, details of the assessment environments are shown in Figure 8.
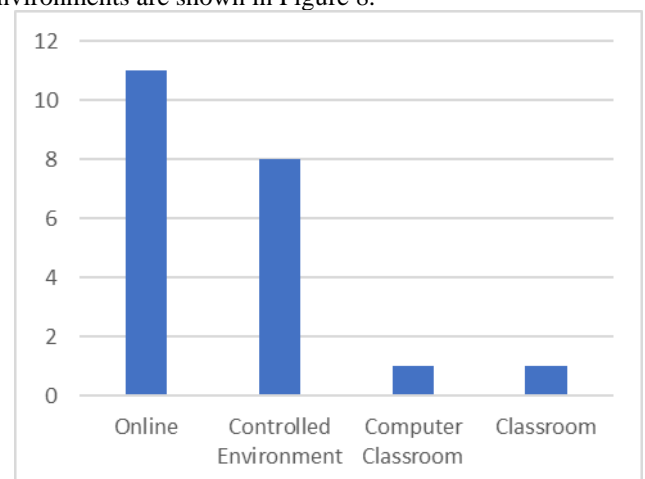
Figure 8. Environments where participant assessments were conducted.

Finally, regarding the evaluation methods, the type for which the researchers mostly opted was the realization of questionnaires focused on the perception of the user 43% (n = 13) to the participants, followed by usability tests 23% (n = 7), interviews 17% (n = 5), measurement of eye movements 7% (n = 2) of the participants when performing certain activities on websites, measured the participants' reading speed 7% (n = 2) when reading texts on the web, and finally made use of a checklist to evaluate the usability of online

learning websites, all of which are shown in detail in Figure 9 . (17)

Figure 9. Evaluation methods used in the studies

Table 8. Distribution of studies by research objective

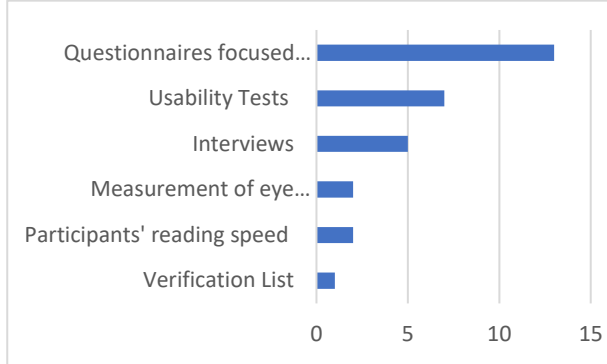| Author	Participants	Dyslexia	Evaluation approach	Evaluation Environment	Evaluation Method
Roy, A., Joglekar P, Abhijit, A. (18)	-	-	Quantitative	Online	Usability testing
Ophoff, J., Johnson, G., Renaud, K. (11)	13	13	Qualitative	Online	Interviews
Berton, R., Kolasinska, A., Gaggi, O., Palazzi, C.E., Quadrio, G. (9)	7 (4M; 3F) Under 26 years	7	Qualitative	Online	Questionnaire focused on user perception
Scaltritti, M., Miniukovich, A., Venuti, P., Job R., De Angeli, A., Sulpizio, S. (13)	79 Children + Adults	-	Quantitative	Controlled environment	Eye movement measurement - Questionnaire focused on user perception
Teotonio, W., Gonzalez, P.,	Unspecified	-	Mixed	Controlled environment	Usability testing
Maia, P., Muniz, P. (15) Damiano R., Gena, C., Venturino G. (19)	229 (63M; 166F) 18 - 65 years	30	Quantitative	Online	Questionnaire focused on user perception
Wu, S., Reynolds L., Li, X., Guzman, F. (16)	24 (5M; 19F)	24	Quantitative	Online	Questionnaire focused on user perception
Li, Q., Morris, M.R., Fourney, A., Larson, K., Rhyecke K. (14)	391 (176M; 215F) 11 - 72 years	42	Quantitative	Online	Questionnaire focused on user perception - Usability test - Reading speed measurement
Kous, K., Polančič, G. (20)	6 (3M; 3F) 18 years and older	6	Mixed	Controlled environment	Usability test- Questionnaire focused on user perception - Interview
Radovan, M., Perdih, M. (17)	49 websites		Quantitative	Online	Checklist
Venturino G., Gena, C. (19)	26 (16M; 10F) 8 - 15 years	-	Quantitative	Computer rooms- Classroom	Questionnaire focused on user perception - Interview
Berget, G., Mulvey, F., Sandnes, F.E. (21)	42 (18M; 24F) 18 - 30 years	21	Quantitative	Controlled environment	Usability testing - Eye movement

Avelar, L.O.D., Rezende, G.C., Freire, A.P.(22)	2 (2F) 19 - 38 years	-	Mixed	Online	measurement - Usability Testing - Interview
De Santana, V.F., De Oliveira, R., Almeida, L.D.A., Ito, M. (23)	4 (4M) 18 - 62 years	-	Qualitative	Controlled environment	- Questionnaire focused on user perception

3.5. RQ5: What results were obtained when applying the solutions proposed by the authors?

As for the studies where the tool was evaluated on different websites (19) the possibility of changing the font size, type, line spacing and reading modes (Reader View, reading ruler) were the ones that obtained the most approval from the participants. On the other hand, they were dedicated to making measurements of the eye movements of the participants; Among the results where these studies coincide the most, are with respect to dyslexics, with a greater number of fixations by dyslexics, as well as smaller eyepieces and greater slowness when reading texts on the web (13). One of the studies (19), showed that 51.26% of the participants preferred the font type EasyReading, a font specially designed to facilitate the reading of people with dyslexia, in this study it was shown that many of the participants did not know about this type of font so they were used to the Arial font 48.74%, but after reading different types of web pages with this font it was observed that many of the participants began to prefer EasyReading, especially in dyslexic participants with a 63.33% preference for this source.

3.6. RQ6: What practices are recommended to improve web accessibility for people with dyslexia?

Among the most recurrent recommendations made by the researchers, it is mentioned to make adjustments and modifications to websites such as font type and size, and provide the greatest number of customization options to users (10) . On the other hand, other studies recommended further assessments, as there was a certain proportion of participants where participants were missing or not adequate to give a more reliable result. Two studies recommended increasing the compatibility of the tools with websites (13) (15). And finally, he recommended adding more WCAG accessibility resources to his software solution (15).

3.7. RQ7: What were the barriers and challenges in implementing web accessibility practices for people with dyslexia?

Of the studies observed, the lack of participants is one of the barriers or limitations in which many researchers agree because with few participants it is not possible to determine the effectiveness of the solutions or find trends in the results. Another limitation was the lack of compatibility with more than one website, as is the case that they developed extensions that can only work in the Google Chrome browser and one of them only worked in the Mozilla Firefox browser. Finally, four publications did not carry out a formal evaluation, so many of the points such as evaluation, recommendations and barriers could not be documented in the analysis (9) (10) (11) (23).

Table 9. Distribution of studies according to their limitations

Limitations	Number of studies	References
Sample of participants is not representative	11	(6)
No formal (empirical) evaluation of the usability of the solution was carried out	4	(4)
Not enough depth in the evaluation generating unclear results	7	(8)
Software solution was only developed for one browser	3	[6,7,17]

4. Discussion

An increase in publications was observed during the years 2018 and 2019 (see Figure 2), this due to the different conferences that were held during this time, among them is CHI (Conference on Human Factors in Computing Systems), especially the one held in 2019 where three studies were presented that were analyzed in this RSL. It should be noted that this conference and others such as SIGIR or DIS are all sponsored by the ACM (Association for Computing Machinery). This may also explain why more than half of the selected studies were published by this publisher. This is also related to the large number of Conference Papers (62%) (15).

On the other hand, it was detected that most studies come from countries belonging to the European Union (see Figure 4), this may be due to the accessibility policy that requires all official pages of the EU institutions to follow the international guidelines for accessibility to web content (15).

In addition, many of the studies focused on presenting software solutions developed as web browser extensions to

function as assistive technologies to improve the experience of people with dyslexia when they surf the web. However, it was detected that many of these extensions were developed to work specifically in a single web browser. It is presumed that the reason for this is due to the different architectures and technologies used by each browser, as well as the restrictions and policies imposed by some browsers; causing compatibility issues (15).

Additionally, it was observed that some studies presented some difficulty when looking for participants to test the effectiveness of their proposals. The researchers mention the considerable difference in their country, which exists between the population suffering from dyslexia (3.2% of the Italian population) versus those without disabilities, so it was difficult for them to find participants who suffer from dyslexia and who have the necessary willingness to collaborate in their tests. This may also explain why the environments where the participants were tested were online (52%), since in this way a greater number of people who are outside the country from which the researchers come can be reached. Thus, the most likely cause that many authors reported the lack of participants as one of the main limitations during their research is due to the significant disparity between people with dyslexia and people without disabilities (15).

According to the study conducted and data triangulation from research similar to ours, future lines should include access to different platforms (24), the metaverse and its opportunities (25) (26) (27) (28) (29) (30), teaching the proper exploitation of these tools (31) (32) (33) (34) (35), attention to psychosocial factors and social networks (36) (37) (38) (39). Special attention should be paid to therapeutic uses (40) (41) (42), aimed at rehabilitation (43) (44) (45), the appropriate use of data for decision making (46) (47) (48) (49) (50) (51) (52), shared access to groups, communities and individual users for a shared learning experience (53) (54) (55) (56) (57).

Finally, in relation to software-based solutions, it was evident that many of the participants with dyslexia showed greater interest in website customization options such as changing the font and size and adding a reading mode. This can be explained by examining (15), in which eye measurements are made to people with dyslexia when reading texts on websites with and without accessibility customizations, resulting in more fixations and a greater slowness when reading websites without any modification compared to texts that provided web accessibility options to adapt the text to the preference of the dyslexic user. Still software-based is a grey area and more studies are needed to successfully adapt solutions from previous experiences (58).

5. Conclusions

In this study, a systematic literature review was conducted with the purpose of investigating the state of web accessibility for people with dyslexia, analyzing the effectiveness and usability of software solutions, tools and development models; as well as the different web accessibility guidelines and recommendations provided by other studies to improve the experience of these users when browsing the web. Since there are still many websites that do not adequately follow the established web accessibility guidelines, nor do the organizations in charge of developing these guidelines focus their attention on specific conditions such as dyslexia. During this research the development of different proposals to provide web accessibility to people with dyslexia was observed, the most notorious being the development of tools or software solutions, which works as assistance tools that are installed in the browser and allow to alter the design of any website through a set of tools designed to be easy to manipulate by user with dyslexia, and allow modifications to the website such as increasing the font size, changing the font type or adjusting the line spacing.

For future work, it is recommended to take advantage of the constant growth of social networks, as a way to get more participants and, in turn, opt for a global and widely used language such as English to reach a greater number of people; All this in order to find more people suffering from dyslexia and with it, the different variations that this disability presents.

Finally, it is important to apply all the adjustments and corrections provided by the participants during the evaluations, both in the next versions of tools and software solutions and when developing and designing a website.

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