Accessible Web Design for Older Adults: Challenges and Solutions

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Abstract

The growing number of older adults online has spurred interest in improving web accessibility for this demographic. To evaluate the current state of this field, we conducted a systematic review of studies published between 2014 and 2023. Our research aimed to identify the challenges older adults face online and effective solutions for accessible web design. From 4,052 articles, we identified 25 types of accessibility issues, 104 improvements to enhance website accessibility, 24 technological resources to design these accessibility enhancements, and 20 evaluation methods. Despite notable progress enhancing web accessibility for older people, our findings underscore the need for ongoing improvements for a truly inclusive web, considering the differences within this heterogeneous group and understanding old age not as a problem but as an opportunity.

Keywords: web design, older adults, Human-centered computing, accessibility

1. INTRODUCTION

The 2022 United Nations (UN) report highlights a steady rise in the global population of older adults (individuals aged 65 years and older [86]), projecting that this demographic will constitute 12% of the global population by 2030 and 16% by 2050 [131]. Europe and North America have the highest proportion of older people in 2022, with almost 19% of the population. By 2050, one in four individuals in these regions is expected to belong to this demographic. This demographic shift is reshaping global societal structures and creating both opportunities and challenges, particularly in digital inclusion [20, 121]. Industries such as tourism [59, 119] banking and finance [47, 105], education [115], insurance and health services [50, 52, 70, 107] increasingly recognize the potential of older adults as active participants in the digital economy.

Traditionally, older adults have been perceived as resistant to adopting new technologies, but recent data contradicts this assumption [51, 87, 89]. Reports from the Organization for Economic Cooperation and Development (OEDC) [93] and studies by Chevalier et al. [26] highlight the increasing acceptance and enthusiasm of older adults for using websites, driven by the benefits they offer for daily activities, social engagement and enhancing overall quality of life [5, 24, 87]. Despite their growing presence in digital spaces, older adults face numerous barriers when interacting with web platforms. Research highlights challenges such as difficulties navigating hyperlinks, understanding complex web interfaces, and performing online transactions [26, 27, 85, 137].

These challenges are compounded by age-related changes in cognitive, sensory, and motor functions, which can significantly hinder effective interaction with digital environments [4, 6]. For instance, Sakaguchi-Tang et al. [112] reported that older adults encounter persistent issues using patient portals, while Waterworth & Honey highlighted their limited web skills in conducting online searches. Rodrigues et al. [108] noted that older adults encounter challenges when using online educational platforms due to interfaces that fail to consider their specific needs, such as clear navigation and simplified design. These findings underline the need for inclusive web design practices tailored specifically to the unique needs of older adults.

Among the most prominent guidelines devised for creating accessible websites are those included in the Web Accessibility Initiative (WAI) [11] outlined by the World Wide Web Consortium (W3C). Although the W3C guidelines represent a significant step forward, they also introduce complexities for web developers who do not always implement them correctly [78]. It is common for websites to be designed by individuals lacking technical expertise, who might not even be aware of these guidelines [78, 130]. Moreover, the effective implementation of the W3C guidelines is debilitated by various problems, including a limited understanding of the principles and a lack of formal methods for incorporating accessibility practices into web development [56]. For example, Idrobo et al. [56] emphasize that Web Content

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Accessibility Guidelines (WCAG) lacks clear provisions for simplifying content structure and reducing cognitive load, which are critical for older users. The WebAIM Million 2025 study reveals that 94.8% of homepage designs do not fully conform to WCAG 2 standards, underscoring the persistent disconnect between established accessibility guidelines and their practical implementation [142]. Therefore, the existence of these guidelines is not enough and other accessibility proposals for older adults are emerging. To address this gap, researchers such as Dombrovskaia and Vilches [33] have extended WCAG with age-specific design checklists aimed at older users.

Despite the availability of interesting accessibility solutions, a critical gap remains in their application to address the unique challenges faced by older adults. Existing solutions often treat older adults in a negative (deficit-focused) way, presenting this population as a subgroup of individuals with disabilities, which overlooking the unique characteristics of aging as a process [66, 134]. This implies that aging be presented as a “problem” focusing on the deterioration of cognitive and physical abilities, health problems and reduced social networks, which result in loneliness and social isolation. However, as stated in [134] it is necessary to rethink the “older user”, eliminate this negative approach to old age and open up new design spaces. Therefore, ageing should be considered as a multifaceted phenomenon, requiring a response across both academic disciplines and society as a whole [134]. On this same line, studies by Colley et al. [28] and Mack et al. [74] emphasize that older adults require holistic approaches that consider their cognitive, physical, and psychological profiles as a whole.

Categorical separation of older adults, for example by designing a different version of the website for them is not a solution either, because it would make this group of users perceived as divergent and problematic, and would encourage ageism [66]. In addition, it is not practical to contemplate the creation of multiple versions of user interfaces, including one that adheres to accessibility guidelines for older adults. In order to address this issue, the software development community employs a variety of approaches, including *design for all*, *universal access*, and *inclusive design*, which can enhance accessibility. These approaches emphasizes the goal of designing interfaces that meet the needs of the broader set of users, ideally accommodating everyone [102]. However, the prevalent practice is designing web interfaces for the *typical* user, who is frequently assumed to be of a younger demographic [75]. The representation of older adults during the web design phase is very limited, which should be changed and denotes the need for further research in this field [74]. In addition, authors such as [134] insist that older adults are too heterogeneous a group to be treated as a single type of user. By way of solution, Garrido *et al*. [45], Ferretti *et al*. [39], Kurniawan *et al*. [67] and other authors consider customizing the web page to each user appears to be the best solution.

Currently, there is a lack of truly inclusive web design solutions, which poses a significant risk of digital exclusion (particularly as digital services become an integral part of the lives of older adults) [66]. Addressing these gaps requires a deep understanding of the barriers faced by this demographic and the development of practical solutions tailored to their specific needs, from an opportunity approach, not a deficit approach. A Systematic Literature Review (SLR) [61–63, 65] provides a rigorous methodology for synthesizing existing research, identifying knowledge gaps, and proposing actionable solutions to enhance web accessibility for older adults. In this work an SLR approach has been used to address the identified gaps by categorizing and evaluating the challenges and solutions associated with web accessibility for this population.

Consequently, the primary objective of this study is to provide a detailed overview of the current state of web accessibility for older adults by addressing two main research questions:

a) What are the main problems that older adults face when using the web?
b) What solutions exist for designing websites so that they are accessible for older adults?

In addition, considering that older adults are not a homogeneous group as stated in [134], it will be necessary to analyze the solutions that allow adapting the web interfaces to the characteristics of each elderly person, since old age is not a state but a process and each person goes through it with a unique experience.

Through a rigorous analysis of 4,052 publications, this study identifies 25 key accessibility challenges, 104 design improvements, 24 technological resources, 21 evaluation methods, and 12 adaptation proposals. These findings contribute to a more understanding of inclusive web design for older users and offer actionable insights for researchers, designers, and policymakers. By focusing on the specific needs of older adults, this article aims to bridge the gap between accessibility theory and practice, fostering a more inclusive digital environment for this growing demographic. The main contributions of this paper are summarized as follows:

- Identification of web accessibility challenges faced by older adults and the main existing solutions.
- Definition of a level-based framework to guide the creation of solutions tailored to the needs of older adults.
- An analysis of existing practices to assess the effectiveness of the accessibility solutions for this population.

The remainder of this article is organized as follows: Section 2 reviews related work to contextualize this study within existing research. Section 3 outlines the methodology, detailing the systematic review process. Section 4 presents the findings, categorizing challenges, solutions, and technological resources. Section 5 offers an in-depth analysis and discussion of the results. Finally, Section 6 discusses limitations, and Section 7 outlines our conclusions and details our future lines of work.

2. RELATED WORK

This section reviews previous works of web-accessibility for older adults in the scientific literature. The examined studies report usability issues, barriers to adoption, and design recommendations, thereby clarifying the distinct requirements of this demographic. The consolidation of these findings reveals unresolved gaps and establishes a basis for developing more inclusive accessibility solutions.

The increasing adoption of technologies has transformed the way people access information and services, and their social interactions. However, older adults face barriers linked to age-related changes that limit their full participation in the digital environment. Many older adults had limited exposure to digital technologies during their formative years, which contributes to both psychological and usability barriers when navigating the web [60]. Other older adults, although familiar with technology, begin to experience cognitive decline and other physical or mental challenges that make its use more difficult [20]. A growing body of research highlights the critical role of web accessibility in addressing these challenges. Accessible design facilitates digital inclusion by improving access to essential services such as online banking, government information, electronic transactions, telemedicine, social networking, and participation in virtual community events, thereby supporting greater autonomy and overall well-being among older adults [55, 56, 127]. Adopting accessibility standards and simplifying content are effective strategies for enhancing older users' web-browsing experience. This approach reduces the stress associated with technology use and encourages gradual learning, supporting the ongoing adoption of digital resources among older adults [108].

Recent research increasingly recognizes that ageing presents a unique set of design challenges that are not adequately addressed by frameworks focused solely on disability-specific impairments. This distinction underscores the importance of dedicated attention to ageing within the broader development of inclusive technologies. Colley, Kränzle, and Rukzio [28] examined 3617 Human–Computer Interaction (HCI) publications and discovered that only 16.6 % considered older adults explicitly, despite the fact that many experience age-related changes in vision, hearing, mobility, or cognition that do not map neatly onto single disabilities. A longitudinal review by Mack, McDonnell and Jain [74] covering the period 1994 – 2019 confirmed this imbalance: more than 43 % of studies centered on blindness or low vision, whereas solutions targeting older users appeared in merely 8.9 % of the corpus. This highlights a critical research gap, and underscore the need for holistic, user-involved investigations that treat ageing as a multifaceted process rather than a subset of disability [28].

Several literature reviews explore the barriers older adults face when interacting with the web, although they typically address this issue from specific perspectives. For instance, Sakaguchi-Tang et al. [112] conducted a review of 17 studies on patient portals and electronic personal health records (ePHRs), reporting that concerns about privacy, limited connectivity, and low technical proficiency hinder the adoption of web technologies, particularly among older adult populations. In a related context, the review conducted by Bhattacharjee, Baker, and Waycott [20] covers 22 studies across human-computer interaction, gerontechnology, healthcare, and education (published between 2015 and 2019).

This study identified five barriers in the use of web applications: age-related factors (cognitive and physical abilities), technological characteristics (complex interfaces, frequent updates, and unfamiliar technologies), perceptions of low self-efficacy, discriminatory social attitudes, and complexity of training materials. The authors propose action lines grounded in HCI and instructional design, although they do not provide a formal specification of these accessibility solutions.

For touch-based systems, Nurgalieva et al. [92] analyzed 52 empirical studies and organized 434 design guidelines according to the capabilities of older adult users, which can be affected by four types of limitations: perceptual, cognitive, psychomotor, and motor. This research focuses only on touch interfaces, but many of the proposed design recommendations (divided in: interaction behaviors, context, visualization, feedback, and forms) are applicable to older adults interaction with web applications. The study also identified several research gaps, especially in under-explored areas such as auditory interactions, muscle effort and speech deterioration. Focusing on accessibility requirements for older adults interaction with web applications, Moreno and Martínez [82] performed other interesting review. Although this study does not present a systematic analysis, it is useful to categorize accessibility barriers (divided into sensory, cognitive, and physical) and proposes 20 design recommendations (based on WCAG 2.0 accessibility guidelines).

In another contribution, Ghenai et al. [49] synthesized 25 empirical studies published between 2010 and 2023 on the accessibility of social media platforms for older adults. Their analysis yielded 10 recommendations covering: typographic formatting, non-text content description, navigation support, contextual aids, social connection features, and privacy protection, among other aspects. While this work offers valuable insights, it, like many existing reviews, centers on a very specific context and therefore do not build a global vision of the problem of older adults in their web interactions and the possible solutions.

Wang, Zhang, and Xiong [136] conducted a bibliometric study focused exclusively on the digital divide in older adulthood, analyzing 560 papers published between 1991 and 2021. Their analysis shows a marked increase in research after 2007, but also reveals that empirical work rarely translates into concrete interface adaptations for older users. On the other hand, the review conducted by Mack, McDonnell, and Jain [74] revealed that the predominant methodological approaches in accessibility studies rely heavily on controlled experiments, interviews, usability testing, and field studies. However, there is limited use of participatory or co-design approaches that would allow older adults to shape the resulting technologies. These gaps underscores the relevance of continuing research in this area.

Summarizing the foregoing, we can conclude that most existing work tends to group older adults within disability research, often addressing their needs through isolated fixes aimed at individual impairments. However, as Colley [28] argues, the concurrent sensory, cognitive, and motor changes of ageing are best viewed as age-related conditions, not disabilities. Mack et al. [74] similarly advocate for integrated solutions that simultaneously address these interrelated needs. Bhattacharjee et al. [20] add that age introduces distinct issues (low digital self-efficacy and stronger social influences) that the standard disability guidelines overlook. These findings underline the need for new holistic approaches tailored to older adults rather than a patchwork of impairment-specific remedies. On the other hand, existing literature reviews often focus on specific application contexts. For example, reviews centered on social platforms [49] or e-health services [112] highlight domain-specific challenges but fail to provide a comprehensive view. Through a broad-scope systematic review, our study aims to address these limitations. An integrative approach will enable us to identify recurring barriers and formulate design recommendations applicable across multiple contexts, thereby contributing to the development of more inclusive and holistic web solutions for older adults.

3. METHODOLOGY

The Systematic Literature Review (SLR) performed in this study follows the methodological approach proposed by Kitchenham et al. [61–63, 65], which has been widely validated in the field of software engineering for its ability to provide a structured and reproducible framework. SLRs are essential in complex technological fields, as they help identify common patterns, provide a comprehensive overview of the state of the art, and enhance the accuracy and validity of findings [98]. The rigor of the SLR ensures the relevance of the results, aids in identifying knowledge gaps, and fosters the development of new research directions [22]. The SLR methodology involves three main phases [43]: planning, execution, and result documentation. In the planning phase, we defined the research questions and the inclusion and exclusion criteria to ensure the selected studies were relevant to web accessibility and older adults. During execution, a comprehensive search was conducted across relevant databases employing precisely formulated search queries. Finally, the results have been documented in this article in a structured manner to ensure replicability and usefulness for future research.

During the protocol selection phase, we considered both the PCC (Population, Concept, Context) and PICO (Population, Intervention, Comparator, Outcome) frameworks. PCC provides a flexible structure commonly employed in exploratory and scoping reviews [64], whereas PICO offers a more structured approach to defining research questions and organizing search criteria [63, 103]. To conduct a rigorously structured review, and in line with approaches adopted by other authors conducting systematic literature reviews in similar contexts [46, 91], we decided to use the PICO framework. In addition, we followed the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines [95]. Several authors highlight the benefits of combining both approaches (PICO and PRISMA) to improve the quality of results [43, 97, 103]. PRISMA provides a standardized method for reporting systematic reviews. Additionally, we complemented the SLR with a Systematic Mapping Study (SMS). SMS [133] is a methodology that categorizes existing literature to identify research patterns and trends. Its goal is to organize studies into clear categories, facilitating large-scale analysis and supporting future research [133].

Our research was conducted in March 2021 and later updated in December 2023. As a result of this comprehensive analysis, we aim to gain a broad understanding of web accessibility issues, existing design solutions, and their impact on the browsing experience of older adults. The detailed review process is described in the following subsections.

3.1. Research questions

In accordance with the objective of this research, the following research questions were formulated:

- RQ1: What are the main problems that older adults face when using the web? This enables us to establish user requirements, to classify them, and to determine their possible solutions.
- RQ2: What solutions exist for designing websites so that they are accessible for older adults? This provides insight into both the limitations and opportunities when designing accessible websites for older adults.

In order to complement the previous research questions, other questions relating to the systematic mapping process were defined. These mapping questions (MQ) enable us not only to obtain a more detailed perspective on the subject but also to characterize the publications on the subject and their predominant trends. On this basis, six MQs were formulated and are shown in Table 1 associated with each research question (RQ1 and RQ2).

Table 1. Systematic research mapping questions

Mapping question	RQ1	RQ2
MQ1: What type of web access problems have been identified for older adults?	●	
MQ2: What enhancements have been suggested to make websites more accessible for older adults?	●	●
MQ3: What technological resources have been used to design web accessibility solutions aimed at the older adult user?		●
MQ4: What accessibility norms or standards have been used to perform the implementations?		●
MQ5: What adaptation models have been used to make the interface accessible?		●
MQ6: What methods have been used to validate the accessibility proposals?	●	●

In order to structure our SLR, the PICO framework was applied. The instantiation of the four components of the PICO matrix is the following:

- P (Population): Older adults as target users of websites.
- I (Intervention): Accessibility solutions proposed in the scientific literature to enhance the web experience for older adults.

- C (Comparison): None.
- O (Outcome): Information on web accessibility challenges faced by older adults and the proposed solutions to address them.

Following the guidelines of Kitchenham et al. [64], the comparison component is only relevant when it aligns with the review's objective [88, 96, 98]. In our case, a comparison intervention was not performed since the purpose of this review is not to contrast different approaches but to integrate the information on existing barriers and solutions to be able to analyze it as a whole. in line with other studies employing PICO in software engineering, we excluded the comparison component from the PICO matrix [44, 88, 96, 98]. Frandsen et al. [41] indicates that including the comparison in systematic searches has minimal impact on retrieving relevant articles, which ensures that the comprehensiveness of our review is not compromised. Table 2 shows the PICO matrix, which includes the keywords selected for each research question in the components: population, intervention, comparison and outcome.

Table 2. PICO matrix elements for each research question

Scope	FOR RQ1:	FOR RQ2:
Population:	Older adult	Older adult
Intervention:	Web	Web Accessibility
Comparison:	(There is no comparative intervention)	(There is no comparative intervention)
Outcome:	Accessibility Problem	Design solutions for accessibility

3.2 Search strategies

Based on the research questions RQ1 and RQ2 and the elements defined in the PICO matrix, the key terms relating to the research topic are determined. These terms are then used to construct search expressions. Table 3 shows the key terms and the alternative terms used for each research question.

Table 3. Keywords and alternative terms for each research question

Research question	Key terms	Alternative terms	PICO element
RQ1: What are the main problems that older adults face when using the web?	Older adult	Elderly, senior, older age, older people, older person, third age, silver surfer, older user	Population
	Web		Intervention
	Accessibility		Outcome
	Problem	Difficult, barrier, digital divide, digital gap	Outcome
RQ2: What solutions exist for designing websites so that they are accessible for older adults?	Older adult	Elderly, senior, older age, older people, older person, third age, silver surfer, older user	Population
	Web		Intervention
	Accessibility		Intervention
	Design Solution	Solution, design, guide, guideline, pattern, standard, recommendation, proposal, approach, scheme, layout, model, sketch, development, redesign	Outcome

The following is a justification for the inclusion of each term and its possible alternative terms in the scientific literature:

- **"Older adult":** Multiple terms such as "older user/s", "elderly", "senior/s", "third age", and "silver surfer" were included to capture distinct variations used in the literature to describe this population. This strategy ensures the retrieval of relevant studies regardless of the specific terminology used by the authors.
- **"Web":** The term "web" was used as the only alternative to focus the search on studies related to environments accessible through browsers, excluding other digital media such as Internet of Things (IoT), streaming services, or native mobile applications. Unlike "internet," which refers to the global network infrastructure, "web" specifically denotes the hypertext-based system accessible via browsers using HTTP or HTTPS protocols [13, 19]. It should be noted that the other possible alternative terms, such as web page, website or web application would be found by searching for the term "web". For this reason, it has not been necessary to include them explicitly.

- **"Problem":** To identify studies documenting key accessibility challenges, terms such as "problem/s," "difficult/ies," "barriers," "digital divide/s," and "digital gap/s" were considered.
- **"Accessibility":** This term was used as a general descriptor for studies focused on digital accessibility, aligning with international W3C guidelines for accessible web content. Accessibility is the core concept underlying this review, addressing the ability of older adults to interact with web content without facing design-related barriers. The term accessibility includes web accessibility, digital accessibility, online accessibility, information accessibility and website accessibility, addressing all possible alternative terms. However, to include adjectives and adverbs related to accessibility, such as "Accessible" and "Accessibly", the "Accessib*" pattern will be also included in the search expression. The term usability and other quality properties of user experience have not been introduced, as they are not the focus of the research [10, 118, 125].
- **"Design solution"**: To capture all potential design solutions documented in the literature, terms such as "design," "solution," "guide," "guideline," "standard," "recommendation," "model," "layout," and "development" were included. A flexible approach has been followed when choosing the alternative terms in this case, since very different types of solutions are interesting when designing the accessibility of websites and we do not want to eliminate any of them, even if this requires more effort during the filtering stage of the resulting articles. By using patterns such as "Model*" in the search, derived words (i.e., modelling) will also be retrieved, which allows to enrich the results.

Each keyword and its alternative terms in Table 3 were used to generate the query string to be applied for each research question RQ1 and RQ2. Each alternative term is linked to its main term through the logical OR operator. Each search expression formed by the keyword and its alternatives is linked to the others through the logical AND operator.

The query string for RQ1 is SQ1: *("older adult*" OR "elderly" OR "senior*" OR "older age" OR "older people" OR "older person*" OR "third age" OR "silver surfer*" OR "older user*") AND ("web") AND ("accessibility" OR "accessib*") AND ("problem*" OR "difficult" OR "barrier*" OR "digital divide*" OR "digital gap*")*

The query string for RQ2 is SQ2: *("older adult*" OR "elderly" OR "senior*" OR "older age" OR "older people" OR "older person*" OR "third age" OR "silver surfer*" OR "older user*") AND ("web") AND ("accessibility" OR "accessib*") AND ("design*" OR "solution*" OR "guide*" OR "pattern*" OR "guideline*" OR "standard*" OR "recommendation*" OR "proposal*" OR "approach*" OR "scheme*" OR "layout*" OR "model*" OR "sketch*" OR "development*" OR "redesign*")*

Note: The asterisk * denotes truncation or a wildcard search.

In order to review the relevant literature, it is necessary to be able to access reliable digital bibliographic databases, and for this, we have selected the Web of Science (WoS), the IEEE Xplore Digital Library (IEEE Xplore), and the ACM Digital Library (ACMDL) as our main information sources. The choice of these platforms is based on the breadth and diversity of their content, as well as their advanced search functionalities, making them essential tools for comprehensive literature reviews in the ICT field [132].

3.2. Review protocol

A review protocol establishes the parameters to be used in conducting an SLR and minimizes the likelihood of bias. In this case, the systematic review planning and the review protocol were jointly established by the three authors. The protocol established guidelines to obtain the research questions from the objectives, the rules to define the inclusion and exclusion criteria (conditions on which an article is accepted or rejected), the search strategy in the scientific databases, and the mode for processing the data.

In order to accept a publication as part of the research, four inclusion criteria (IC) were considered (the exclusion criteria were the exact opposite):

- Thematic relevance (IC1): Only articles addressing web accessibility for older adults were included. This criterion ensures that the selected studies provide evidence directly aligned with the objective of our research.

- Full access to publications (IC2): Only studies with full access available to the authors, either through institutional licenses or open access, were considered, enabling a thorough analysis of each article's content.
- Language (IC3): Publications in English were included, as it is the dominant language in the major scientific databases used in this review, such as IEEE Xplore, ACM Digital Library, and Web of Science.
- Publication Year Range (IC4): The selected publications span from 2014 to 2023, ensuring the inclusion of recent and relevant studies in the field of web accessibility for older adults.

With regard to IC1, given the limited detailed discussions on web accessibility challenges specifically faced by older adults, articles were not initially rejected even if their focus was not this group. That is, all those articles that dealt with some aspect of web accessibility related to older adults were considered, even if the article was not focused only on this group, or even if this group was not the main concern of the article. Our review, therefore, considers any study that references older adults to offer a more comprehensive perspective on their web accessibility needs. With regard to IC2, we had no difficulty obtaining the full-text of the articles, no article was rejected by this criterion. No article was rejected by the criterion IC3 either.

Additionally, the protocol defined the way in which the data are processed, and three tools used for this purpose:

- WoS, IEEE Xplore, and ACMDL digital bibliographic databases.
- Parsif.al. This tool enables researchers to define goals and objectives, import articles via BibTeX files, remove duplicates, define selection criteria and generate reports [22, 99].
- Microsoft Access. The content stored in Parsif.al was migrated to the database in Access and the data was processed with greater agility.

Data processing for the selection of publications was performed following these steps:

i. Apply the search expression in the data search engine. The query result is migrated to Parsifal via BibTeX files.
ii. Remove duplicate publications. Parsifal has an automatic process for this.
iii. Scrutinize the titles and abstracts of the publications, applying both inclusion and exclusion criteria. This initial selection of studies was conducted by the first author, reducing the initial set of publications to those meeting the basic requirements for full review.
iv. Analyze the document. All content is subjected to a thorough review. We apply inclusion and exclusion criteria and confirm conformity with the research questions and systematic mapping. We discard publications that do not fit the research context. We used Parsifal's data export function to migrate articles to the database into Microsoft Access. The selected articles were then jointly reviewed by all three authors. In cases of uncertainty or disagreement about an article's inclusion, the three authors engaged in a discussion, reaching a consensus to ensure consistency in the selection process and minimize potential individual bias. Key findings were assigned a simple index label as an identifying code. For example, findings related to general cognitive impairments were coded as "P01", while issues related to text comprehension were coded as "P02". The initial codes were grouped into broader categories based on their shared characteristics. For instance, codes related to various types of physical difficulties, such as motor skill impairments ("P06") and visual impairments ("P07"), were consolidated under the category "Physical Difficulties" (CP2). This step helped to structure the data and identify key recurring patterns.
v. Obtain data relating to the research questions and systematic mapping. Information is recorded in a Microsoft Access format to effectively address the research questions and specify the problems and solutions outlined in the paper.

3.3. Selection of primary studies and data processing application

Following the procedures stated by PRISMA [95], a bibliometric review followed by a systematic content analysis of the articles was conducted. The number of documents retrieved from the digital bibliographic databases are shown in Table 4. A total of 4,052 research articles were analyzed.

Table 4. Documents retrieved from the digital bibliographic databases

Research Question	**Digital bibliographic databases**	**Documents obtained**	**Selected documents**
RQ1	WoS	171	15
	IEEE Xplore	23	2
	ACMDL	1597	20
Total		**1791**	**37**
RQ2	WoS	385	6
	IEEE Xplore	49	5
	ACMDL	1827	15
Total		**2261**	**26**

Figure 1 presents a diagram of the publication selection process and the results obtained for RQ1. The application of the SQ1 query resulted in 1,791 publications. After migrating the data to Parsifal, a verification process was conducted, and 23 duplicate publications were removed. During the review of the titles and abstracts, it was found that 1,707 publications were not relevant to the context of our research. Many of these articles focused on unrelated topics, such as the use of health platforms, elderly monitoring systems, the design of Internet of Things (IoT)-based systems, healthcare support technologies, the development of assistive hardware devices, or general studies not applicable to older adults on the web. Additionally, articles centered on multimedia applications, augmented or virtual reality solutions, and systems designed for broader accessibility contexts without a focus on web accessibility for older adults were excluded. Only those studies directly addressing web accessibility issues and solutions for older users were retained for further analysis. The full text of the remaining 61 publications was then reviewed and 24 of these were rejected on the grounds that their content would not answer the research and systematic mapping questions (they addressed collateral aspects, but not the problem being addressed by the current research). The final result of the screening process was 37 articles with a relevant contribution to RQ1.

Figure 2 illustrates the publication selection process and RQ2 results. The implementation of the SQ2 query produced 2,261 publications, of which 46 were duplicates. Titles and abstracts were screened according to the inclusion and exclusion criteria, resulting in the elimination of 2163 papers. Many of these excluded articles were not directly related to the research context, focusing instead on topics such as generic usability studies, accessibility in non-web contexts, assistive technologies for healthcare or physical environments, and hardware-based accessibility solutions without relevance to web design for older adults. The full text of the remaining 52 publications was then analyzed in detail to determine whether each article satisfied the research criteria. This phase resulted in the exclusion of 26 publications that failed to provide the necessary data. Therefore, 26 papers met the required standards to sufficiently address the research questions.

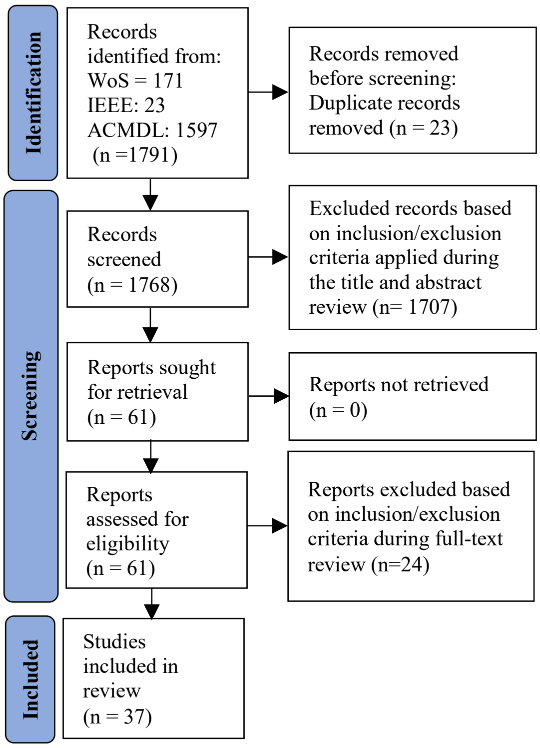

Figure 1. PRISMA flowchart and selection of articles for RQ1.

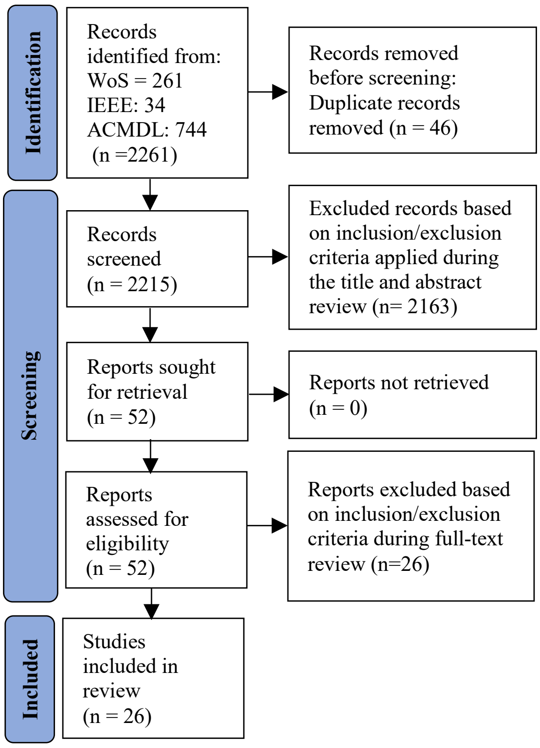

Figure 2. PRISMA flowchart and selection of articles for RQ2.

4. RESULTS

Figures 3 and 4 illustrate the publication trends from 2014 to 2023 from the SLR answering the first and second research questions (RQ1 and RQ2). For RQ1, 24.3% of these publications were journal articles and 75.7% were proceedings papers. Similarly, the review for RQ2 indicated that 23.1% of the publications were journal articles and 76.9% were proceedings papers. These findings are consistent with observations by Salih *et al* [113]. and Palomino *et al.* [97], who, through SLR, noted the common practice of presenting results from computer implementations with empirical evidence at conferences.

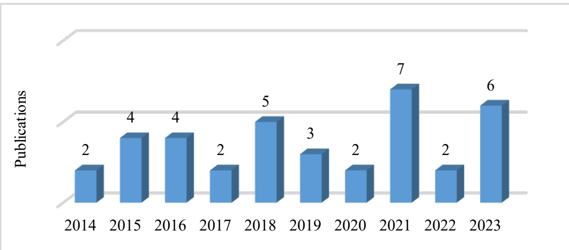

Figure 3. Number of publications relating to RQ1

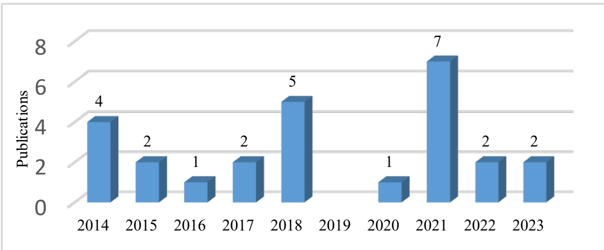

Figure 4. Number of publications relating to RQ2

The following sections present the results of the application of the systematic review protocol performed for each of the research mapping questions included in Table 1.

4.1. MQ1: What types of web access problems have been identified for older adults?

The analysis of the MQ1 query required an exhaustive examination of each article to identify web access challenges encountered by older adults, and 25 different issues were identified. The details of each issue are documented in the supplementary references cataloged in Table 5 (D01, D02,..., D34). Appendix 1 lists these 34 documents. The terminology used to describe each accessibility issue (Pi) derives from the nomenclature adopted by the authors of the reviewed publications. Since terminology varied according to the author, it was decided that the most prevalent terms would be used and any derogatory terms would be avoided (e.g., *older adults* are preferred to *the elderly*).

In order to systematically organize the problems identified, they were categorized into the six distinct groups that are displayed in the first column of Table 5: cognitive difficulties, physical difficulties, psychological difficulties, technological skill difficulties, privacy and security concerns, and structural barriers relating to connectivity access. This categorization (CPi) involved considerable effort in terms of unification, abstraction, and decision-making from terms used in bibliographic sources. The second column in Table 5 indicates the number of publications in each accessibility issue and category.

Table 5. Categorized web access problems of older adults

Problem Category / Problem	**Number of publications**	**Publications ID**
CP1. Cognitive Difficulties	**32 (28.3%)**	
P01 General cognitive impairments	21	D01; D02; D04; D06; D08; D09; D10; D11; D14; D17; D20; D21; D22; D24; D26; D27; D31; D33; D34; D35; D36
P02 Text comprehension	8	D03; D06; D07; D08; D14: D20; D28; D30
P03 Perceptual speed	2	D33; D34
P04 Memory	1	D34
CP2. Physical Difficulties	**48 (42.5%)**	
P05 Physical in general	11	D04; D08; D09; D10; D14; D22; D24; D26; D27; D33; D36
P06 Motor skill	13	D01; D03; D11; D12; D16; D19; D20; D22; D26; D32; D33; D34; D35
P07 Visual	14	D02; D03; D13; D15; D17; D18; D19; D20; D26; D29; D33; D34; D36
P08 Hearing	9	D02; D03; D11; D17; D19; D20; D29; D33; D35
P09 Mobility	1	D34
CP3. Psychological Difficulties	**9 (8.0%)**	
P10 Anxiety	3	D01; D21; D23
P11 Attitudinal issues	3	D24; D26; D33
P12 Intrapersonal attributes	1	D31
P13 Technophobia	2	D21; D24
CP4. Technological Skill Difficulties	**20 (17.7%)**	
P14 Training, skill, ability to use technology/Internet	9	D04; D05; D08; D14; D24; D26; D33; D34; D37
P15 Interpersonal support	2	D24; D31
P16 Lack of familiarity with hypertext (hyperlink)	2	D03; D24
P17 Low performing	2	D01; D03
P18 Characteristics of existing technology	1	D24
P19 Difficulty in searching and locating information	1	D03
P20 Difficulty navigating	1	D03
P21 ICT jargon terms	1	D20
P22 Processing speed	1	D21
CP5. Privacy and Security Problems	**1 (0.9%)**	
P23 Privacy and security	1	D25
CP6. Structural Barriers — Connectivity Access	**3 (2.7%)**	
P24 Cost problems	1	D24
P25 Demographic and socioeconomic	2	D31; D33
TOTAL	**113 (100.0%)**	

CPi: Category of Problem i; Pi: Problem i

Regarding the different categories, cognitive difficulties (28.3%), physical difficulties (42.5%), and technological skill difficulties (17.7%) are the most relevant. When it comes to **cognitive limitations** (CP1), the ones with the highest weighting are those relating to text comprehension (P02). Since the authors do not always specifically detail cognitive problems, we classify these cases as *general cognitive impairments* (P01). Within **physical limitations** (CP2), motor skills (P06) and visual difficulty (P07) are most mentioned. **Psychological difficulties** (CP3) are discussed in nine publications (8.0%) and include anxiety (P10), attitudinal issues (P11), and technophobia (P13). **Technological skill difficulties** (CP4) are documented in 20 publications, encompassing a lack of necessary training and skills (P14), difficulties with hypertext navigation (P16 and P20), and issues with the performance of existing technologies (P17). Additional details of each problem identified are not given since this falls into a medical or psychological context, but more information can be obtained from the associated references.

Privacy and security problems (CP5), on the other hand, although critical, are only mentioned in one publication, indicating a potential gap in literature. In D25, Ellefsen and Chen [36] indicate that to use more complex passwords or two-factor authentication increases security, but it also results in increased complexity and limits the accessibility of older adults when using web applications. Lastly, **structural barriers relating to connectivity and access** (CP6), such as cost issues (P24) and demographic and socioeconomic factors (P25), are mentioned in 3 publications. For example, D24 explains that older adults may be discouraged from using the Internet because of its prohibitive cost. This is particularly true for people with disabilities who rely on assistive technologies such as screen readers [20]. Idrobo *et al.* (D33) indicates that although regulations and policies exist to guarantee access to information and web accessibility, governments have been slow to implement these effectively, even on their own governmental websites [56].

4.2. MQ2: What enhancements have been suggested to make websites more accessible for older adults?

Through the literature reviews conducted with RQ1 and RQ2, we identified 104 different proposals for enhancing web accessibility for older adults (S001 to S104). These solution proposals have been organized into seven distinct categories (CS1 to CS7) as shown in the first column of Table 6. The terminology used in each proposal is sourced from the documents reviewed. The categories were established by clustering solutions based on their shared characteristics and then apply an abstraction process. Table 6 displays each proposed category, the improvements included in that category and the documents detailing those improvements (D01, D02, ..., D37), differentiating between those obtained from either RQ1 (third column) or RQ2 (fourth column). The two last columns in the table indicate the relation of these improvements with the accessibility principles established by the W3C. Appendix 1 lists every document.

Table 6. Improvements suggested to enhance website accessibility and its relation to WCAG

Improvement Category / Improvement	Number of publications	Publications ID from RQ1 and RQ2	Closer relationship with WCAG	
			Principle (*) and Guideline	Success Criterion
CS1. Web Design Improvements – Presentation of the Information	105 (51.5%)			
S001 Adapted menus	2	D09; D20	P: 1.3 Adaptable O: 2.4 Navigable	2.4.5 - Multiple Ways 1.3.1 Info and Relationships
S002 Adequate spacing between text and buttons	2	D13; D26	P: 1.4 Distinguishable O: 2.5 Input Modalities	1.4.12 Spacing 2.5.5 Target Size
S003 Alternative text on image	1	D38	P: 1.1 Text Alternatives	1.1.1 Non-text Content
S004 Background color	1	D47	P: 1.4 Distinguishable	1.4.3 Contrast (Minimum)
S005 Break long forms into shorter parts	1	D02	O: 2.4 Navigable U: 3.3 Input Assistance	2.4.6 Headings and Labels 3.3.2 Labels or Instructions
S006 Choose the color of visited links and menus	2	D02; D14	P: 1.4 Distinguishable O: 2.4 Navigable	1.4.1 Use of Color 2.4.7 Focus Visible
S007 Clustered information with fewer options	2	D05; D20	P: 1.3 Adaptable O: 2.4 Navigable	1.3.1 Info and Relationships 2.4.6 Headings and Labels
S008 Help and Cognitive Support: Clear instructions, understandable error messages, and personalized assistance features)	1	D22	U: 3.3 Input Assistance	3.3.2 Labels or Instructions 3.3.3 Error Suggestion
S009 Correct use of contrast	9	D03; D08; D11;	P: 1.4 Distinguishable	1.4.3 Contrast (Minimum)

Improvement Category / Improvement	Number of publications	Publications ID from RQ1 and RQ2	Closer relationship with WCAG	
			Principle (*) and Guideline	Success Criterion
		D13; D20; D35; D36; D47; D48		1.4.6 Enhanced Contrast
S010 Develop buttons with labels instead of images	1	D26	P: 1.1 Text Alternatives U: 3.3 Input Assistance	1.1.1 Non-text Content 3.3.2 Labels or Instructions
S011 Enough space around the links	1	D03	P: 1.4 Distinguishable O: 2.5 Input Modalities	1.4.12 Spacing 2.5.5 Target Size
S012 Extended guidance on what to do and how to do it (feedback)	1	D02	U: 3.3 Input Assistance	3.3.2 Labels or Instructions 3.3.3 Error Suggestion
S013 Font color	11	D03; D04; D13; D14; D20; D26; D35; D36; D43; D47; D48	P: 1.4 Distinguishable	1.4.3 Contrast (Minimum)
S014 Font Size	17	D02; D03; D04; D05; D09; D11; D13; D14; D20; D26; D30; D35; D36; D40; D41; D43; D47	P: 1.4 Distinguishable	1.4.4 - Resize Text
S015 Font style	2	D13; D43	P: 1.4 Distinguishable	1.4.8 Visual Presentation
S016 Font type	7	D11; D13; D14; D20; D26; D30; D41	P: 1.4 Distinguishable	1.4.8 Visual Presentation
S017 Highly contrasting colors in selections	1	D03	P: 1.4 Distinguishable	1.4.3 Contrast (Minimum)
S018 Icons and Image with label or tag	4	D02; D08; D26; D33	P: 1.1 Text Alternatives U: 3.3 Input Assistance	1.1.1 Non-text Content 3.3.2 Labels or Instructions
S019 Indication of scroll bars	2	D02; D14	O: 2.4 Navigable	2.4.7 Focus Visible (Indirect relationship)
S020 Large clickable area	5	D03; D05; D09; D12; D14	P: 1.4 Distinguishable O: 2.5 Input Modalities	1.4.4 Resize Text 1.4.8 Visual Presentation 2.5.5 Target Size
S021 Line spacing	5	D04; D13; D14; D20; D26	P: 1.4 Distinguishable	1.4.12 Spacing
S022 Linear navigation	6	D03; D04; D05; D14; D26; D30	O: 2.4 Navigable U: 3.2 Predictable	2.4.3 Focus Order 2.1.1 Keyboard 3.2.3 Consistent Navigation
S023 Links emphasized by underlining	3	D20; D26; D43	P: 1.4 Distinguishable	1.4.1 Use of Color (Indirect relationship)
S024 Personalized Guidelines	1	D22	U: 3.2 Predictable U: 3.3 Input Assistance	3.2.3 Consistent Navigation 3.3.3 Error Suggestion 3.3.5 Help
S025 Simple and direct structure	4	D03; D21; D22; D36	P: 1.3 Adaptable U: 3.2 Predictable	1.3.1 Info and Relationships 1.3.2 Meaningful Sequence 3.2.3 Consistent Navigation
S026 Simplified roadmap	2	D23; D36	O: 2.4 Navigable U: 3.2 Predictable U: 3.3 Input Assistance	2.4.5 Multiple Ways 3.2.3 Consistent Navigation 3.3.5 Help
S027 Navigation improvements (step progress navigation, navigation as tabbed browsing)	7	D11; D11; D20; D22; D37; D30; D45	O: 2.4 Navigable U: 3.2 Predictable	2.4.5 - Multiple Ways 3.2.3 Consistent Navigation
S028 Size of images and buttons	1	D20	P: 1.1 Text Alternatives P: 1.4 Distinguishable O: 2.4 Navigable	1.1.1 Non-text Content 1.4.11 Non-Text Contrast 1.4.12 Text Spacing 2.5.5 Target Size
S029 Space between adjacent links	1	D14	P: 1.4 Distinguishable O: 2.4 Navigable	1.4.12 Text Spacing 2.4.4 Link Purpose
S030 Text alignment	2	D13; D20	P: 1.4 Distinguishable U: 3.1 Readable	1.4.8 Visual Presentation 1.4.12 Text Spacing 3.1.5 Reading Level
CS2. Web Design Improvements – Interaction with the Information	37 (18.1%)			
S031 Adaptive Bubble Cursor	1	D16	O: 2.5 Input Modalities	2.5.5 Target Size 2.5.1 Pointer Gestures
S032 Animation control	2	D43; D45	P: 1.4 Distinguishable O: 2.2 Enough Time U: 3.2 Predictable	1.4.2 Audio Control 2.2.4 Interruptions 3.2.2 On Input
S033 ARASAAC Pictograms	1	D46	U: 3.1 Readable	3.1.5 Reading Level

Improvement Category / Improvement	Number of publications	Publications ID from RQ1 and RQ2	Closer relationship with WCAG	
			Principle (*) and Guideline	Success Criterion
				3.1.2 Language of Parts
S034 Avoid double clicks	1	D14	O: 2.5 Input Modalities	2.5.2 Pointer Cancellation 2.5.4 Motion Actuation
S035 Blinking /Flashing Text Control	2	D11; D37	O: 2.2 Enough Time O: 2.3 Seizures and Physical Reactions	2.2.2 Pause, Stop, Hide 2.3.1 Three Flashes or Below Threshold
S036 Block banners and advertisements	1	D02	O: 2.2 Enough Time O: 2.3 Seizures and Physical Reactions	2.2.2 Pause, Stop, Hide 2.3.1 Three Flashes or Below Threshold
S037 Correction of missing labels on forms	1		O: 2.4 Navigable U: 3.3 Input Assistance	2.4.6 Headings and Labels 3.3.1 Error Identification 3.3.2 Labels or Instructions
S038 Deletion of swear words	1	D28	U: 3.1 Readable	3.1.5 Reading Level
S039 Difficult words highlighting	1	D28	U: 3.1 Readable	3.1.5 Reading Level
S040 Dynamic contents of the website are not displayed	1	D20	O: 2.2 Enough Time O: 2.3 Seizures and Physical Reactions	2.2.2 Pause, Stop, Hide 2.3.1 Three Flashes or Below Threshold
S041 Empty button removal	1	D38	O: 2.4 Navigable	2.4.4 Link Purpose (In Context)
S042 Empty links removal	1	D38	O: 2.4 Navigable	2.4.4 Link Purpose (In Context)
S043 Hide Image	1	D43	O: 2.2 Enough Time	2.2.2 Pause, Stop, Hide
S044 Find in Page	1	D43	O: 2.4 Navigable	2.4.8 Location (Indirect relationship)
S045 Generation of "dynamic breadcrumbs"	1	D23	O: 2.4 Navigable	2.4.5 Multiple Ways 2.4.8 Location
S046 Highlight buttons	1	D42	P: 1.4 Distinguishable	1.4.1 Use of Color 1.4.3 Contrast (Minimum)
S047 Highlight input fields	1	D42	P: 1.4 Distinguishable	1.4.1 Use of Color 1.4.3 Contrast (Minimum)
S048 Highlighting (box/underline) clickable	1	D40	P: 1.4 Distinguishable O: 2.4 Navigable	1.4.1 Use of Color 1.4.3 Contrast (Minimum) 2.4.7 Focus Visible
S049 Notifications and assistance to users when they experience pointing difficulties	1	D16	O: 2.5 Input Modalities U: 3.3 Input Assistance	2.5.1 Pointer Gestures 2.5.4 Motion Actuation 3.3.3 Error Suggestion
S050 Pop-up Blocker	1	D43	O: 2.2 Enough Time O: 2.3 Seizures and Physical Reactions	2.2.2 Pause, Stop, Hide 2.3.1 Three Flashes or Below Threshold
S051 Recorded verbal instructions to guide users	1	D42	U: 3.3 Input Assistance	3.3.2 Labels or Instructions
S052 Remove non-task related UI elements	1	D21	P: 1.3 Adaptable O: 2.2 Enough Time O: 2.3 Seizures and Physical Reactions U: 3.2 Predictable	1.3.1 Info and Relationships 2.2.2 Pause, Stop, Hide 2.3.1 Three Flashes or Below Threshold 3.2.3 Consistent Navigation
S053 Remove unnecessary menu and icons	1	D43	P: 1.3 Adaptable U: 3.2 Predictable	1.3.1 Info and Relationships 3.2.3 Consistent Navigation
S054 See the effects of the action without committing	1	D23	U: 3.3 Input Assistance	3.3.2 Labels or Instructions 3.3.4 Error Prevention (Legal, Financial, Data) 3.3.5 Help (Indirect relationship)
S055 Show security information of a link destination	1	D02	P: 1.3 Adaptable U: 3.3 Input Assistance	1.3.5 Identify Input Purpose 3.3.2 Labels or Instructions 3.3.4 Error Prevention (Legal, Financial, Data) 3.3.5 Help (Indirect relationship) 3.3.9 Accessible Authentication (Enhanced)
S056 Sign language	1	D47	P: 1.2 Time-based Media	1.2.6 Sign Language (Prerecorded)
S057 Slow down the speed of video presentations	1	D02	O: 2.2 Enough Time	2.2.2 Pause, Stop, Hide
S058 Spoken help for data format in input fields	1	D02	U: 3.3 Input Assistance	3.3.5 Help
S059 Static and non-flashing graphic elements	2	D20; D33	O: 2.2 Enough Time O: 2.3 Seizures and Physical Reactions	2.2.2 Pause, Stop, Hide 2.3.1 Three Flashes or Below Threshold

Improvement Category / Improvement	Number of publications	Publications ID from RQ1 and RQ2	Closer relationship with WCAG	
			Principle (*) and Guideline	Success Criterion
S060 Suggested for similar words or phrases in text	1	D28	U: 3.1 Readable P: 1.3 Adaptable	3.1.5 Reading Level 1.3.1 Info and Relationships
S061 User Security, Privacy Protection and Assurance	2	D22; D37	U: 3.3 Input Assistance	3.3.2 Labels or Instructions 3.3.4 Error Prevention (Legal, Financial, Data) 3.3.5 Help (Indirect relationship)
S062 Written instructions in the form of dialogue balloons	1	D42	U: 3.1 Readable P: 1.3 Adaptable	3.1.5 Reading Level 1.3.1 Info and Relationships
S063 Zooming mechanism	1	D16	P: 1.4 Distinguishable	1.4.4 Resize Text 1.4.10 Reflow 1.4.12 Text Spacing
CS3. Complementary Software	**30** (14.7%)			
S064 Acronyms expansion	1	D13	U: 3.1 Readable P: 1.3 Adaptable	3.1.4 Abbreviations 1.3.1 Info and Relationships
S065 Adaptive User Interfaces (AUI) designs for pointing	1	D32	P: 1.3 Adaptable O: 2.5 Input Modalities U: 3.2 Predictable U: 3.3 Input Assistance	1.3.1 Info and Relationships 2.5.1 Pointer Gestures 2.5.4 Motion Actuation 3.2.1 On Focus 3.2.2 On Input 3.2.3 Consistent Navigation 3.3.3 Error Suggestion
S066 Captions (subtitle)	1	D04	P: 1.2 Time-based Media U: 3.1 Readable	1.2.2 Captions (Prerecorded) 1.2.4 Captions (Live) 3.1.5 Reading Level
S067 Contextual help	1	D31	U: 3.2 Predictable U: 3.3 Input Assistance	3.2.3 Consistent Navigation 3.3.3 Error Suggestion 3.3.5 Help
S068 Language translation	1	D13	U: 3.1 Readable	3.1.1 Language of Page 3.1.2 Language of Parts
S069 Mouse control	2	D01; D16	O: 2.5 Input Modalities	2.5.1 Pointer Gestures 2.5.4 Motion Actuation
S070 Natural language descriptions of UI screenshots	1	D15	P: 1.1 Text Alternatives	1.1.1 Non-Text Content
S071 On-screen keyboard	1	D04	O: 2.1 Keyboard Accessible O: 2.5 Input Modalities	2.1.1 Keyboard 2.5.6 Concurrent Input Mechanisms
S072 Personalization toolbar	1	D43	Distinguishable U: 3.2 Predictable	1.4.10 Reflow 3.2.3 Consistent Navigation
S073 Screen Reader	2	D11; D18	P: 1.1 Text Alternatives P: 1.3 Adaptable O: 2.4 Navigable	1.1.1 Non-Text Content 1.3.1 Info and Relationships 2 .4.6 Headings and Labels
S074 Speech rate	1	D04	U: 3.1 Readable O: 2.2 Enough Time	3.1.5 Reading Level 2.2.1 Timing Adjustable
S075 Speech synthesizer	2	D04; D44	P: 1.4 Distinguishable O: 2.1 Keyboard Accessible U: 3.1 Readable	1.4.5 Images of Text 2.1.1 Keyboard 3.1.1 Language of Page
S076 Speech-to-Text	1	D11	O: 2.1 Keyboard Accessible O: 2.5 Input Modalities	2.1.1 Keyboard 2.5.6 Concurrent Input Mechanisms
S077 Sticky keys (one-finger typing)	1	D04	O: 2.1 Keyboard Accessible	2.1.1 Keyboard 2.1.4 Character Key Shortcuts
S078 Text-to-speech	3	D06; D11; D36	P: 1.4 Distinguishable O: 2.1 Keyboard Accessible U: 3.1 Readable	1.4.5 Images of Text 2.1.1 Keyboard 3.1.1 Language of Page
S079 Textual conversion to pictograms	1	D06	U: 3.1 Readable	3.1.5 Reading Level 3.1.2 Language of Parts
S080 Textual simplification	7	D06; D17; D20; D22; D26; D28; D46	U: 3.1 Readable	3.1.5 Reading Level
S081 Voice assistant technologies	2	D18; D22	P: 1.4 Distinguishable O: 2.1 Keyboard Accessible O: 2.5 Input Modalities U: 3.1 Readable	1.4.5 Images of Text 2.1.1 Keyboard 2.5.6 Concurrent Input Mechanisms 3.1.1 Language of Page
CS4. Interaction and	**9** (4.4 %)			

Improvement Category / Improvement	Number of publications	Publications ID from RQ1 and RQ2	Closer relationship with WCAG	
			Principle (*) and Guideline	Success Criterion
Input/output Methods				
S082 Control the multimedia screen	1	D47	O: 2.5 Input Modalities	2.5.1 Pointer Gestures 2.5.2 Pointer Cancellation 2.5.4 Motion Actuation
S083 Controlling a pointing device	1	D32	O: 2.5 Input Modalities	2.5.1 Pointer Gestures 2.5.2 Pointer Cancellation 2.5.4 Motion Actuation
S084 Haptic feedback	1	D26	P: 1.3 Adaptable	1.3.3 Sensory Characteristics
S085 Keep gestures simple to perform basic commands of the system	1	D26	O: 2.5 Input Modalities	2.5.1 Pointer Gestures 2.5.2 Pointer Cancellation 2.5.4 Motion Actuation
S086 Keyboard navigation	1	D11; D36	O: 2.1 Keyboard Accessible	2.1.1 Keyboard 2.1.2 No Keyboard Trap
S087 Size and visual appearance of the mouse pointer	2	D39; D40	P: 1.3 Adaptable O: 2.5 Input Modalities U: 3.2 Predictable	1.3.1 Info and Relationships 2.5.1 Pointer Gestures 2.5.4 Motion Actuation 3.2.1 On Focus 3.2.2 On Input 3.2.3 Consistent Navigation
S088 Tactile interfaces adapted	1	D26	O: 2.5 Input Modalities	2.5.1 Pointer Gestures 2.5.2 Pointer Cancellation 2.5.4 Motion Actuation
S089 User (Voice) Commands	1	D18	P: 1.4 Distinguishable O: 2.1 Keyboard Accessible O: 2.5 Input Modalities U: 3.1 Readable	1.4.5 Images of Text 2.1.1 Keyboard 2.5.6 Concurrent Input Mechanisms 3.1.1 Language of Page
CS5. Web Standards	**12** (5.9 %)			
S090 WAI-AGE guidelines	1	D37		
S091 ATAG 2.0	1	D29		
S092 UAAG 2.0	1	D29		
S093 WCAG 2.0 (2008)	3	D08; D19; D34		
S094 WCAG 2.1 (2018)	3	D07; D19; D29		
S095 WCAG 2.2 (2023)	1	D33		
S096 ISO 9241-171:2008	1	D34		
S097 Nordic Recommendations for the Accessible Computer	1	D34		
CS6. Auto Adapting	**6** (2.9%)			
S098 Adapt the UI at Run-Time	2	D10; D27		
S099 Adapting content with transcoding	1	D13		
S100 Generating or injecting XML-HTML-CSS to adapt the Website UI to users	2	D13; D20		
S101 Simplifies presentation and interaction	1	D27		
CS7. Assistance	**5** (2.5%)			
S102 Education or training	3	D01; D05; D24		
S103 Government or e-government policy development	1	D25		
S104 Support or Advice of family	1	D24		
TOTAL	199 (100.0%)			

* The WCAG principles are abbreviated as follows: P for Perceivable, O for Operable, and U for Understandable. No associations were identified with the Robust principle.

We divide web design improvements into two groups: those that focus on enhancing the presentation of website information (CS1), and those that improve user interaction with the website (CS2). The category **Web Design Improvements – Presentation of the Information** (CS1) emphasizes the visual and structural presentation of information on a website. Effective presentation includes the use of appropriate font sizes (S014), font colors (S013), and contrast levels (S009), which not only aid readability but also enhance overall user interaction by aligning with user mental models of navigation and information retrieval [140]. The category **Web Design Improvements – Interaction with the Information** (CS2) focuses on how users engage with the website content. This involves designing interactions that ensure every user can effectively engage with website functionalities, from accessing varying levels of content detail to navigating through sections or entering data in forms [120].

The category CS1 is one of the most frequently mentioned in the articles reviewed, with 30 proposals (referenced in 51.5% of the publications). This category emphasizes the need to optimize web designs to fulfill the unique needs of older adults. Most recommendations focus on improving the form of the web page, such as font type (S016), alignment (S030), element size (S020, S028), spacing (S002, S021), color (S004, S009, S013, S017), etc. However, they also highlight those relating to the way the web page is structured, suggesting improvements in the presentation of menus (S001), linear navigation (S022), splitting long forms into shorter parts (S005), clustered information with fewer options (S007), and a simple and direct structure and simplified roadmap (S025, S026). The sizing of clickable elements such as images and buttons are recommended to ease interaction (S020, S028). Another suggestion is that redesigns are based on cognitive help and support (S008), extended guidance (S012) on what to do and how (feedback), and personalized guidelines (S024).

The CS2 category, which is mentioned in 18.1% of the papers, encompasses 33 strategies (S031 – S063) aimed at enhancing the user interface and interaction of web applications for older adults. This includes ensuring that web elements are easily navigable and actionable and involves simplifying user actions such as avoiding double clicks (S024) and blocking intrusive banners (S036) and advertisements that can disrupt the user experience (S040). Other improvements include slowing the speed of video presentations (S057) to accommodate varying cognitive processing rates. In order to enhance the performance and effectiveness of web interface use, interaction elements can be modified, such as implementing zooming mechanisms (S063), adaptable bubble cursors (S031), generating *dynamic breadcrumb* trails (S045), and providing notifications and assistance to users who struggle with targeting (S049). More inclusive features include the integration of sign language (S056), spoken help for data format in input fields (S058), recorded verbal instructions to guide users (S051), and written instructions in the form of speech balloons (S062). Additionally, this category considers improvements relating to webpage text such as the deletion of swear words (S038), highlighting difficult words (S039), suggestions for similar words or phrases in the text (S060), and the use of pictograms (S033).

The **complementary software category** (CS3), encompassing 14.7% of proposals, details a range of auxiliary tools designed to enhance web accessibility for older adults. These tools address various accessibility challenges (e.g., visual or hearing impairments) by providing functionalities such as text-to-speech (S078) for users who find it difficult to read text, and speech recognition (S073, S075, S076, S081) for those with motor difficulties. Furthermore, software solutions such as mouse control (S069) and sticky keys (S077), which facilitate one-finger typing, are indispensable. In terms of language, aspects such as natural language descriptions of UI screenshots (S070), translators (S068), textual conversion to pictograms (S079) and textual simplification (S080) were considered. These provide essential alternatives for individuals with motor impairments, enabling them to navigate and interact with digital content more seamlessly.

The **interaction and input/output methods category** (CS4) are mentioned in 4.4% of the reviewed documents, with the focus on simplifying user interaction with digital platforms. This approach incorporates technological aspects such as touch interfaces (S088), simple gestures (S085), and haptic feedback (S084) to improve web accessibility. Innovations include enhanced keyboard navigation (S086) and voice commands (S089), which significantly reduces cognitive load and simplify the execution of common tasks.

The **web standards category** (CS5) is mentioned in 5.9% of the articles as an accessibility solution for the elderly, the application of the accessibility guidelines issued by the W3C, ISO 9241-171:2008 standard, and country-specific standards such as the Nordic Recommendations for the Accessible Computer. Among the W3C guidelines mentioned are WAI, UAAG, ATAG and WCAG (S090-S097).

The **auto-adapting category** (CS6) is mentioned in 2.9% of the articles and focuses on dynamic solutions that tailor the user interface in real-time to meet the specific needs of older adults. For example, in S099 Ferretti *et al.* [39] suggest adapting the contents using transcoding to modify the DOM of an HTML page by injecting new attributes and modifying the CSS file. In D20 of the proposed solution S100, Pirsa *et al.* [104] also applied techniques to generate or inject XML, HTML, or CSS code to adapt the website interface for older adults. In another case, new approaches such as the gracefully adaptive user interfaces (GAUI), which were proposed in D27, suggest the creation of systems that can be gradually adjusted to adapt to the changing needs of users, especially those with declining cognitive and physical abilities due to age [40]. Similarly, Wickramathilaka and Mueller (D10, in S098) focus on using model-driven engineering (MDE) and domain-specific design languages (DSL) to model context-of-use scenarios and user interface adaptation rules in order to generate adaptive interfaces that meet the accessibility needs of older adult users [139].

The **assistance category** (CS7) emphasizes support mechanisms to improve web accessibility for older adults. It includes educational programs (S102), policy development for e-government services (S103), and human technical assistance (S104). These solutions aim to empower older adults with the necessary skills and knowledge to navigate the digital world effectively [35]. A number of studies [12, 20, 35] also highlight how family support and guidance can encourage and help older adults use technology and ICTs.

Most of the design recommendations identified in our SLR fit directly within the WCAG success criteria. Table 6 highlights the connection between web accessibility improvements for older adults (from SLR) and the Principles, Guidelines, and Success Criteria of the WCAG. For instance, improvements in information presentation, such as optimizing font size (S014) and Linear navigation (S022), address the principles of Distinguishable (1.4) and understandability (3.2) , respectively. Similarly, proposals related to input/output methods, such as Keyboard navigation (S086) and voice commands (S089), emphasize operability (2.1 Keyboard Accessible, 2.5 Input Modalities). Table 6 could serve as a practical guide for web developers aiming to align their work with WCAG compliance. In most cases, there is an alignment between the improvements and the guidelines. However, in certain instances, the improvements identified in our SLR are more explicit than the WCAG guidelines. For example, "S005: Break long forms into shorter parts", "S020: Large clickable area", and "S038: Deletion of swear words" are more straightforward and specific compared to the interpretation required for some WCAG guidelines.

4.3. MQ3: What technological resources have been used to design web accessibility solutions for the older adult user?

Table 7 illustrates various technological resource proposals used to design web accessibility solutions (TR01, TR02, …, TR24) that can enhance website design for older adults. We analyzed the reviewed proposals from RQ2 and classified these into six categories (CT01, CT02, …, CT06): software framework, web framework, web design technique, client-side implementation, server-side implementation, and advanced technologies. This classification is another contribution of this work since it was not mentioned in any of the reviewed articles.

Table 7. Technological resources to design web accessibility solutions for older adult users

Technological resources Category / Technological resources	Number of publications	Publications ID
CT01 Software Framework	**1 (3.0%)**	
TR01 Model-Driven Engineering (MDE) + Domain-specific language (DSL)	1	D10
CT02 Web Framework	**1 (3.0%)**	
TR02 Web Framework Bootstrap: HTML + CSS+ JavaScript	1	D41
CT03 Web Design Techniques	**2 (6.1%)**	
TR03 Responsive web design technique	1	D41;
TR04 Concept of Gracefully adaptive user interfaces (GAUI)	1	D27
CT04 Client Side Implementation	**18 (54.5%)**	
TR05 Adaptive Bubble Cursor	1	D16
TR06 ARASAAC Pictograms	1	D46
TR07 Client-side app to modify menus	1	D09
TR08 Client-side app to modify background and font color	1	D48
TR09 Enhanced Area Cursors: Adaptive Click-and-Cross	1	D39
TR10 Preferences wizard + JavaScript + JSON	1	D11
TR11 Creation of a web browser	1	D43

Technological resources Category / Technological resources	Number of publications	Publications ID
TR12 Control pointing performance	1	D16
TR13 HTML and CSS technology to define webpage enhancements	3	D13; D20; D40
TR14 Web browser extension (Plug-in, Extension, API, Component)	7	D13; D16; D18; D27; D41; D42; D46
CT05 Server Side Implementation	**5 (15.2%)**	
TR15 System Architecture Adapte-me! Tool — Adapt menu applying WCAG	1	D09
TR16 PHP and SQL database to implement AdaptNow AI, create user profiles, store user settings, and history	1	D40
TR17 Word-Sense Disambiguation (WSD) System	1	D46
TR18 Profiling Schema.org metadata	1	D35
TR19 Web Service for Lemmatization + Definition + Synonyms and antonyms + Difficult words	1	D28
CT06 Advanced Technologies	**6 (18.2%)**	
TR20 Artificial Intelligence: GoldNet expert system	1	D42
TR21 Natural Language Processing (NLP)	2	D46
TR22 Lexical simplification of texts in Spanish	1	D46
TR23 Visual tracking and personalization	1	D21
TR24 Adaptive User Interfaces (AUIs)	1	D32
TOTAL	**32 (100.0%)**	

In the **software framework category** (CT01), document D10 proposes the use of web content accessibility guidelines (WCAG) as a framework for designing domain-specific languages that can model use context scenarios and user interface adaptation rules in accordance with accessibility standards. In this proposal, by employing MDE, models are automatically transformed into code artifacts, facilitating the generation of adaptable and accessible user interfaces more efficiently. Additionally, domain-specific languages (DSLs) are used to formally and comprehensively express the accessibility needs relating to the older adult user [139].

The **web framework category** (CT02) encompasses platforms that facilitate the development and upkeep of web applications, including services, resources, and APIs (application programming interface). One example of the web framework is the proposal described in document D41, which highlights Bootstrap as a crucial tool for implementing responsive design in automated web page generation. Bootstrap is an open-source framework developed by Twitter and is used to facilitate the design and development of responsive and mobile-friendly web interfaces. It provides a wide range of preset components, such as grids, buttons, forms, and navigation systems, enabling developers to create modern web interfaces that adapt to various devices and screen sizes. Additionally, Bootstrap includes predefined CSS styles and utility classes that simplify the customization of the interface elements' appearance [106].

In the **web design technique category** (CT03), appear two proposals (6.1% of the articles) in which adaptation techniques are presented, particularly directed at adapting interfaces according to the devices used by users. The proposal in document D41 employs responsive design (T03) aimed at enhancing accessibility for individuals with visual impairments, specifically those with low vision. Responsive design ensures that the web interface dynamically adjusts to various screen sizes and display settings, making content legible and accessible to all users [106]. Another web design technique included in CT03, as outlined in D27, focuses on the concept of gracefully adaptive user interfaces (TR04) to meet the needs of older adults in digital environments. This approach involves designing interfaces that gradually and personally adapt as users age, simplifying interaction while maintaining essential functionality [40].

The **client-side implementation category** (CT04) represents the highest percentage of articles (54.5%) and focuses on adaptations that are implemented directly on the user's device. Documents D11, D13, and D41 present technological solutions that modify various aspects of web content, including fonts, colors, contrast, text spacing and alignment, highlighting of key elements, adaptation to different screen sizes, reorganization of elements, and grouping of related information [39, 101, 106]. Various proposals enhance interface operation (as demonstrated in D16) by providing personalized assistance to help users overcome pointing difficulties, through an adaptive bubble cursor that dynamically adjusts to the user's pointing performance, as well as controlling the signaling performance [77]. This group also includes the proposal in article D46, which integrates an ARASAAC pictogram resource to provide graphical representations of complex words for people with communication disabilities [7].

The client-side implementation category also includes various proposals for web browser extensions that use plugins, APIs, or components to modify web pages (TR13). For example, ExTraS (D13) employs a plugin for the Firefox web browser that activates a contextual menu to establish personalized adaptations [39]. Document D41 discusses the use of a specific plugin called NoCoffee that simulates how a web interface would appear to a user with visual impairments (more specifically, glaucoma) [106]. The PINATA plugin (D16) provides users with variable pointing abilities thanks to an adaptive, personalized tool to enhance their web interaction, offering notifications, assistance, and real-time feedback to optimize their browsing experience [77]. The Firefox Voice proposal (D18) features a browser extension that allows users to navigate the web and control browser utilities through voice commands [21]. The GoldNet plugin (D42) serves as a support tool to enhance internet accessibility for older adults, providing step-by-step, real-time guidance for performing online activities efficiently [128]. Klara Facebook (D27) is a web browser extension that enables users to modify Facebook content to better suit the individual needs of older adult users [40]. EASIER extensions for Chrome and Mozilla browsers (D46) offer features to identify complex words and provide synonyms for selected text on any web page [7].

Additionally, solutions from client-server architecture are included in CT04, detailing actions performed on the client side. For example, within TR12, proposals use HTML and CSS technology to define webpage enhancements, such as AdaptNow (D40) which uses a web browser to adjust text size, buttons, and zoom enhancements [31]. Similarly, through the ExTraS extension in Firefox (D13), changes are made to the HTML and CSS of the webpage on the client side to apply accessibility and readability adaptations according to user preferences [39]. Likewise, D20 adapts the front-end of websites using technologies such as CSS, JQuery, and JavaScript to make content more accessible and user-friendly for older adults and those with disabilities [104]. Documents D13, D20, and D40 present technological solutions that modify various web content aspects, including fonts, colors, contrast, text spacing and alignment, highlighting of key elements, adaptation to different screen sizes, reorganization of elements, and grouping of related information.

Other client-side solutions are more specific. For instance, the FSilver browser (D43) was designed by removing less frequently used features from a standard browser, simplifying its assistance functions, and redesigning the user interface layout [117]. The Adapte-me tool (D09) is tailored to adapt web menus for mobile devices, with a particular focus on enhancing accessibility and usability for older adults. Similarly, in D48, a client-side app to modify background and font color. This tool intercepts server responses and adapts the menu according to user preferences [72]. Another client-side proposal is the adaptive click-and-cross (D39), which when the user clicks on or near a user interface element, a circular overlay is activated to display various nearby elements. Users can then move the mouse pointer over the circle to select the desired item. This technique offers an alternative method of element selection which is particularly useful for those with motor difficulties [71]. Document D11 focuses on the development and evaluation of an accessibility preferences assistant (wizard) that identifies and stores user requirements to create user profiles. This wizard allows users to customize various aspects of web content, such as fonts, colors, and interface layout, based on accessibility recommendations. It also enables mechanisms such as text-to-speech conversion [101].

In the **server-side implementation category** (CT05), we focus on proposals involving server-side actions. Approximately 15.2% of the technology proposals are categorized under this segment. Documents D09, D40 and D46 detail client-server architecture implementations named Adapte-me!, AdaptNow, and EASIER, respectively. Adapte-me! (D09) enhances the user experience with web navigation menus on mobile devices. This tool intercepts the server response and adapts the menu according to user preferences, seamlessly transforming the webpage with a new menu that complies with WCAG guidelines [72]. Similarly, AdaptNow (D40) operates on a client-server model, where the user interacts with the platform through a web browser to access services and functionalities offered by the AdaptNow server, which is responsible for applying automated and personalized accessibility enhancements to web pages [31].

Document D46 describes the functionality of EASIER, where the server processes text entered by the user to identify complex words and applies word-sense disambiguation (WSD) techniques to provide contextualized definitions, thereby enhancing the cognitive accessibility of Spanish texts [7].

In the same CT05 category, there are also solutions that implement web services, such as the EasyNavigation system detailed in D28. EasyNavigation deploys web services to provide functionalities such as lemmatization, word definition, synonym and antonym searches, and to identify challenging words. These web services enable communication between the client (web browser) and the server to access additional information and simplification tools [18]. In D35, the server uses Schema.org to process and manage metadata relating to the accessibility needs of e-learning platform users with disabilities. With Schema.org, detailed user profiles are created, and the user interface is automatically adapted, enhancing the accessibility of the platform [114].

In the **advanced technologies category** (CT06), we have grouped six innovations (18.2% of the total) that propose accessibility improvements. Among these, the GoldNet expert system (D42) stands out, offering real-time interactive guides to assist older adults step-by-step as they perform online operations [128]. Among the technologies that we consider within CT06, those that use natural language processing (NLP) techniques are grouped together in TR20. In TR20, we discuss the word sense disambiguation (WSD) system which has been designed to enhance the accessibility of Spanish texts for older adults (D46). This system uses NLP to tokenize sentences, identify verbs, nouns, and adverbs, and normalize words to enrich the contextually relevant vocabulary [7]. Another notable proposal, documented in D47, suggests employing technologies such as automatic speech recognition (ASR), natural language user interfaces, and interaction management to enhance web navigation accessibility and usability for visually impaired users [14].

Other technologies included in CT06 involve personalization solutions that adapt web content based on user behavior, in addition to adaptive user interfaces (D32) that dynamically adjust to cater for the needs of older adult users [76]. In D21, visual tracking is used to identify interface elements that negatively impact the user experience of participants with computer anxiety. These findings can be used to simplify the interface, thereby eliminating unnecessary or distracting elements and improving accessibility for this user group [34].

4.4. MQ4: What accessibility norms or standards have been used to perform the implementations?

In order to identify the most frequently used accessibility criteria or standards referenced to perform the implementations, we analyzed the content of each RQ2 article. The results of this analysis are presented in Table 8.

Table 8. Accessibility norms or standards used to support the implementations

Norm or Standard	Number of publications	% mentions	Publications ID
N/A	13	43,3%	D13; D16; D18; D21; D27; D28; D32; D37;D39; D40; D44; D44; D48
SilverWeb Guidelines 2.0	1	3,3%	D43
UNE 153101: 2018 standard for Easy Reading in Spain	1	3,3%	D46
W3C-COGA	1	3,3%	D46;
WAI-ARIA 1.0	1	3,3%	D45
WCAG (not specific)	1	3,3%	D10
WCAG 2.0	7	23,3%	D09; D20; D38; D41; D42; D43; D46
WCAG 2.1	4	13,3%	D11; D42; D43; D46
WCAG 2.2 (draft)	1	3,3%	D35
TOTAL	30	100,0%	

N/A: Not available

As Table 8 shows, a high percentage of articles (43.3%) do not mention any specific norm or standard as a reference for the implementation of technological solutions focused on improving web accessibility for older adults. The most cited accessibility guidelines in the reviewed publications are the W3C recommendations (WCAG and WAI-ARIA, W3C-COGA), in their different versions, reaching 50.0% of the mentions of these guidelines. WCAG 2.0 is the most used standard in the articles with 23.3% of the references, followed by WCAG 2.1 with 13.3%. It is worth noting that D35 mentions WCAG 2.2 recommendations, although it is still in its draft version. Several publications (D42, D43 and D46) refer to several norms or standards simultaneously.

4.5. MQ5: What adaptation models have been used to make the web interface accessible?

Table 9 summarizes the proposals that include some way to fit the older user. Some of these proposals involve automatic adaptation, where predefined adaptation rules are triggered, while other proposals allow for customization, where older adults explicitly select options from their user profile to modify the web interface. According to Oliveira et al. [94], an adaptation model defines the adaptation semantics by relating user model data to the website domain model in order to provide the desired adaptation; being important to differentiate between the customization performed by the user and the adaptation process managed by the system itself [138]. In this case, most of the solutions found in the scientific literature focus on interface customization so that the web page changes are directly selected by the older adult according to their user profile.

Table 9. Adaptation model used to make the interface accessible in RQ2

Adaptation model category / Adaptation model	Number of publications	Publications ID
N/A	**8 (36.4%)**	D18; D20; D28; D32; D38; D41; D44; D45
CAM01 Based on Web Accessibility Guidelines	**6 (27.3%)**	
AM01 Changes interfaces based on W3C guidelines	3	D09; D42; D46
AM02 Apply domain-specific languages (DSL) to model the requirements	1	D10
AM03 Recommendations interpreted by the researcher based on the analysis of concerns identified in focus groups and in the literature	1	D37
AM04 User profiles in XML format. These profiles contain the necessary information about the accessibility needs of the users	1	D35
CAM02 Based on User Interaction	**5 (22.7%)**	
AM05 Adaptive approach based on tracking the user's signaling performance and the dynamic response of the interface to this varying performance	1	D16
AM06 Visual tracking to customize user interfaces	1	D21
AM07 A reinforcement learning algorithm based on a mathematical reward/punishment model is used as the machine learning system that manages the user's profile.	1	D13
AM08 Adaptive Click-and-Cross	1	D39
AM09 Multi-linear modeling approach using step-wise regression, to create a model of user preferences	1	D40
CAM03 Based on User Preferences	**3 (13.6%)**	
AM10 Gradual customization and simplification process of the interface, guided by the GAUI concept and the reverse multi-layered design	1	D27
AM11 Identifying and storing of user requirements, generating user profiles that consider the main difficulties they may have in accessing web content	1	D11
AM12 Browser interface simplification + ad blocker, animation blocker, image zooming, image hiding and increased line spacing to adapt web content	1	D43
TOTAL	**22 (100.0%)**	

N/A: Not Available

The **category based on web accessibility guidelines** (CAM01) includes six publications (27.3% of the 21 papers) that base their adaptation models on established accessibility standards or guidelines. This means that changes in the website design are not made based on a general user, but according to specific guidelines for older adults. In AM01, we group technological proposals that modify web interfaces according to the guidelines established by W3C. For example, in D09 the Adapte-me! tool improves the user experience of web navigation menus on mobile devices. It intercepts the server's response and adapts the menu based on the user's preferences, resulting in a transformed web page with a new menu that complies with WCAG guidelines [72]. The GoldNet system (D42) is a Google Chrome extension that has interactive guides to specific websites. Any button or field that the user clicks or completes is highlighted with a blinking frame to attract the user's attention. This blinking follows a rule that there should be no more than three blinks a second according to WCAG 2.1 [128]. D46 presents a solution to help people with language and learning difficulties understand texts with uncommon words. The solution meets success criterion 3.1.3 of the WCAG 2.1 standards, which requires a mechanism to identify specific definitions of uncommon words or phrases, such as idioms and slang [7].

D10 uses WCAG-compliant domain-specific languages (DSLs) to propose tailored accessibility solutions that address the specific needs of older adults. The proposal suggests an iterative approach that includes elicitation of requirements, modeling of accessibility needs, development of MDE processes, prototyping of adaptive interfaces, evaluation with older adult users, and refinement based on feedback [139]. For its part, D37 uses empirical data from focus groups and literature reviews to interpret and implement accessibility design recommendations. These recommendations were used to propose accessibility improvements to online social networking sites for older adults [90]. On the other hand, D35 suggests a user model for e-Learning platforms that considers the needs of disabled users. Metadata for accessibility needs is based on Schema.org. Accessibility parameters are established during the design phase and used to create user profiles. The profiles contain information to adapt interfaces. The user can configure their profile through the interface. The system uses this information to adapt interfaces dynamically [114].

The **category based on user interaction** (CAM02) includes those methods that enable adjustment to the particularities of each older adult while using the system. This category includes five publications (22.7%), which are described below. D16 uses the PINATA adaptive approach that tracks the user's signaling performance to adjust the interface in response to these changes. PINATA offers users the option to receive interactive notifications when signaling errors are detected. The user can specify that the notifications appear as a Bar+ or Dialog Box [77]. Similarly, D21 employs visual tracking to customize user interfaces, tailoring the web experience to the individual's visual capabilities [34]. D39 explores the Adaptive Click-and-Cross interaction technique which enhances navigation for users with limited dexterity by adapting interface elements according to user input [71]. D13 uses the ExTraS adaptation model which tracks user behavior as they browse the web to learn their preferences and automatically apply appropriate adaptations in future interactions. In this proposal, reinforcement learning is employed to compute automatic adaptations based on user interactions, thereby optimizing the user experience through adaptive technology [39]. AdaptNow (D40) learns from user interactions and web page characteristics to perform real-time automatic, personalized adaptations. As the user browses a web page, AdaptNow automatically adjusts page presentation and functionality according to user preferences and needs. AdaptNow uses a multi-linear modeling approach, using step-wise regression to create a model of users preferences based on web page characteristics [31].

Some website adaptations are made **based on user preferences** (CAM03). In this category, the user profile is defined on the basis of specifications established according to their criteria. Five articles (22.7%) obtained from our SLR apply this type of adaptation model. For example, D27 implements a web browser extension called Klara Facebook which adapts Facebook to suit the user's needs. When a user installs Klara Facebook, they will see a wizard. The wizard will ask the user a series of questions about their preferences. These questions will help Klara Facebook make changes that improve accessibility for the older adult user [40]. In D11, a *preferences wizard* was developed to allow users to configure their accessibility preferences, for example, by changing font size/type and contrast, or by activating a screen reader. Users configure their settings by answering the wizard's prompts, which then generates a personalized accessibility profile to match their specific needs. This customization tool was developed using JavaScript and follows WCAG 2.1 guidelines [101]. Finally, in D43, the FSilver special-purpose browser was created by removing lesser-used features, thereby simplifying the support features. FSilver models the browser interface by managing the removal of unnecessary elements, the reorganization of the user interface, and the inclusion of personalization tools to allow older adults to adjust the display of web pages according to their individual needs [117].

4.6. MQ6: What methods have been used to validate the accessibility proposals?

The MQ6 was applied to reveal whether any method was used to evaluate the proposed solution. We identified various methods to validate these solutions (E01, E02 …, E21) and these were organized into three categories: automated evaluation tools, user-centered evaluations, and expert-based evaluations. The different methods, grouped into their corresponding categories, are described below, as displayed in Table 10.

Table 10. Methodologies applied to validate accessibility solutions

Method Category / Method to validate accessibility solutions	Number of publications	Publications ID from RQ1	Publications ID from RQ2
CE01 Automated Evaluation Tools	**5 (9.0%)**		
E01 Automated accessibility evaluation tools	6	D07; D08; D19; D20; D35	D20; D35; D38
CE02 User-Centered Evaluations	**52 (77.6%)**		
E02 Survey	6	D02; D12; D16; D18; D32	D16; D18; D32; D44
E03 Questionnaire	16	D01; D06; D08; D09; D11; D13; D14; D17; D21; D27; D28; D30; D36	D09; D11; D13; D21; D27; D28; D43; D45; D47;
E04 System Usability Scale (SUS) questionnaires	2	D35; D37	D37
E05 Technology Acceptance Model (TAM)	1		D44
E06 Think Aloud Tests	4	D04; D09; D21; D27	D09; D21; D27
E07 Crowdsourcing study	1	D15	
E08 Group discussions	1		D32
E09 Interview	3	D35	D35; D40; D45
E10 Semi-structured interviews	2	D16; D25	D16
E11 Usability test	4	D05; D14; D26; D31	
E12 Debriefing Form	1	D09	D09
E13 Performance Analysis	7	D09	D09; D39; D42; D43; D45; D47; D48
E14 Eye Tracking System	2	D21	D21; D42
E15 User interaction logs	1	D01	
E16 Qualitative Evaluations	1	D14	
CE03 Expert-Based Evaluations	**9 (13.4%)**		
E17 Human Review	1	D07	
E18 Validation of checklist with experts	1	D03	
E19 Literature review	6	D22; D23; D24; D29; D33; D34	
E20 Simulations mimicking user behavior	1	D13	D13
TOTAL	**67 (100%)**		

The **automated evaluation tools category** (CE01) includes tools that automatically compare web pages against recognized web accessibility guidelines. Accessibility assessment tools are mentioned in six articles (9.0%), although they are sometimes applied together with other forms of assessment such as human review (D07), questionnaires (D08), and interviews (D35). In D07, AChecker was used to assess Spanish public hospitals for compliance with WCAG 2.1 [81]. Similarly, in D08, both AChecker and Nibbler were employed to automatically test health-related websites across European countries [122]. Additionally, D20 mentions the use of AChecker to evaluate the most visited Croatian websites [104]. Meanwhile, the WAVE tool was used in D38 to evaluate eGovernment services in Latin America [1]. D19 uses WAVE and Tenon tools to evaluate e-health websites [3]. Both WAVE and ARC Toolkit were used in D35 to conduct a study to identify potential accessibility barriers in an e-Learning platform prototype [114].

The **user-centered evaluations category (CE02**) includes 52 methods (77.6%) to collect direct feedback from users, reflecting the emphasis on user experience in accessibility. Surveys (E02) and questionnaires (E03) prove to be the most popular methods for validating web accessibility solutions. For instance, Affonso de Lara *et al.* (D02) conducted a survey to study older adults acceptance of interaction aids on websites [4]. Alotaibi *et al.* (D12) compared original and modified user interfaces, asking users to rate their preferences on a 5-point Likert scale and interface attractiveness on a numerical scale from 1 to 10 [9]. In order to evaluate the proposed PINATA solution (D16), participants interacted with the accessibility proposal's notification designs and completed a survey to assess various aspects such as familiarity and language [77]. Firefox Voice (D18) also used surveys at two different points: a first survey was completed by beta testers after their first week using the Firefox Voice extension, and the second once it had been uninstalled [21]. Martin-Hammon *et al.* (D32) primarily employed participatory design methods to assess adaptive user interfaces (AUIs) designed to assist with performance changes in signaling. [76]. In D44, a survey with a nine-point Likert scale was used for participants to express their satisfaction with each accessible feature of the portal [37].

Questionnaires (E02) are employed in 16 articles to collect user feedback on the usability and accessibility of web interfaces and are also used to assess specific accessibility features or tools. For example, in D01, the computer anxiety rating scale (CARS) was used to evaluate the impact of accessibility features on computer anxiety among older adults [35]. Similarly, in D06, D08 and D09, questionnaires have been instrumental in assessing the ease of use and user satisfaction with adapted web interfaces and assistive technologies ([72, 111, 122]). Ashok *et al.* (D47) used a structured questionnaire to evaluate the accessibility approach, specifically the web screen reading automation assistant (SRAA) and the web entity model (WEM) [14]. Questionnaires are also employed to gather user feedback about their preferences and satisfaction with web accessibility modifications, and in various studies (D13, D17, D21, D28, D43), older adults rated their preferences about adapted web interfaces using this method [18, 34, 39, 80, 117]. Questionnaires were also used in D11 to evaluate e-health platforms and obtain usability criteria [3, 101]. In D30, questionnaires were used to ask participants to identify their preferred combination of font and font size [25]. Several authors (D27, D14, D45) combine questionnaires with other types of assessment. In such cases, the questionnaires provided a broader assessment of the older adult web experience and included aspects such as readability, ease of navigation, and overall satisfaction [40, 58, 100].

Specific questionnaire models were also deployed to assess accessibility proposals (D35, D37). For example, Hanson (D37) used SUS (E04) as a quantitative tool to measure the perceived usability of two user interface versions (the control UI and the modified UI) in a study aimed at enhancing accessibility for older adults on online social networking sites [90]. Similarly, Farhan and Razmak (D47) used Technology Acceptance Model (TAM) (E05) as a theoretical framework to evaluate an accessibility proposal for a patient portal. TAM enabled us to understand the acceptance and behavioral intentions of participants towards the future use of the accessible web patient portal [37].

During the think-aloud protocol tests, participants are prompted to express their thoughts, feelings, and actions as they navigate the website. This testing method is employed in D04, D09, D21, and D27 to gain insights into user interaction and experience [15, 34, 40, 72]. The crowdsourcing method (E07), on the other hand, collects data from various participants to analyze the effectiveness of the UI descriptions generated by the XUI method proposed in D15 ([69]). Martin-Hammond *et al.* (D32), meanwhile, used focus groups (E08), a method that allows participants to give direct feedback on adaptations in adaptive user interfaces (AUIs) [76].

Interviews (E09) are pivotal in evaluating web accessibility, especially for older adults, as they provide direct insights into the user experience. For instance, in the AdaptNow project (D40), interviews revealed how older adult users would adjust web features such as cursor size and page scrolling to enhance browsing [31]. Similarly, in the assessment of an e-Learning platform (D35), interviews alongside SUS offered a mixed-method approach, quantifying usability and exploring user interactions and barriers [114]. In another case, a website redesign study for older adults (D45) used interviews to gather feedback post-interaction, employing retrospective probing to deepen understanding of user preferences and challenges [100]. In the study by Martin-Hammond *et al.* (D16), semi-structured interviews (E10) were key for evaluating the PINATA accessibility proposal [77]. These interviews, tailored to extract deep insights into users' expectations and needs for adaptive signaling solutions, allowed researchers to refine the web navigation interfaces based on user feedback. Similarly, the study by Ellefsen and Chen (D25) used semi-structured interviews to explore older adults challenges with online privacy and data security [36].

Usability tests (E11) have also been used to improve web accessibility for older adults. In the study conducted by Arfaa and Yuanqiong (D05), testing identified various difficulties that older adults faced with text size, layout, and navigation on social network sites [12]. Similarly, Dai *et al.* (D31) used these tests to evaluate how older adults managed tasks such as inserting photos into an email, gathering feedback on design preferences that could further refine the interface [30]. Additionally, Junqueira *et al.* (D14) applied usability testing to explore how older adults interact with legislative e-participation platforms, identifying barriers that could hinder their online engagement [58]. D26 also performs usability tests to evaluate the accessibility and usability of web interfaces on tablets/iPads, especially focused on older users [8]. From another perspective, Antonelli *et al.* (D09) used debriefing forms (E12) after participants used adapted web menus on mobile devices [72]. These forms enable specific questions to be asked about the tasks to be performed and challenges faced, and to gather general impressions about accessibility improvements and any suggestions they may have.

With other approaches, the application of performance analysis (E13) in evaluating web accessibility emphasizes the use of performance metrics to evaluate the effectiveness of accessibility solutions, particularly in web environments tailored for older adults. For instance, in the study by Antonelli *et al.* (D09) performance analysis was used to compare the efficiency of interacting with adapted versus original web menus on mobile devices, highlighting improvements in task completion times for adapted interfaces [72]. Similarly, Li and Gajos (D39) used performance metrics such as task completion times and error rates in their study on adaptive click-and-cross interfaces, which were designed to enhance the web interaction experience for users with impaired dexterity [71]. In another study, Sa-nga-ngam and Kiattisin (D43) focused on the effectiveness and efficiency of a personalized web browser for older adults, comparing it against the standard Firefox browser. Their performance analysis included metrics such as task success rates and older user satisfaction levels [117]. Azam et al (D48) conducted performance testing focusing on specific aspects, such as contrast adjustments between background and text, and font resizing options [16].

In another user-centered approach, Taieb-Maimon and Vaisman-Fairstein (D42) use eye tracking (E14) to monitor how participants engage with web interfaces using GoldNet [128]. This method evaluates whether users can effectively follow visual cues, such as highlighted elements, during their online activities. Similarly, in the research conducted by Donizetti and Figueredo (D21), eye-tracking systems are used to identify distracting or confusing elements on the interface, specifically for users experiencing computer anxiety [34]. In another article by the same researchers, Donizetti and Figueredo (D01) analyze interaction logs (E15) to study web usage among older adults. These logs provide insights into navigation and interaction patterns, helping to locate areas for improvement. The analysis also accurately assesses the participant's levels of computer anxiety [35].

Qualitative evaluations (E16) focus on the subjective aspects of user experience and provide insights into how real users interact with and perceive web interfaces. These evaluations are crucial for identifying accessibility issues that are not always apparent from automated tools or quantitative measures. For example, the data collected in D14 during the qualitative evaluations were encoded into categories, such as ease of use, clarity of information, navigation, and interactivity. This coding enabled identification not only of the patterns and trends in older adult experiences but also of any accessibility challenge faced [58].

Finally, the **expert-based evaluations category** (CE03) includes human review, expert validation checklist, literature review and simulations. Applied in 13.4% of the articles, these methods offer valuable evaluations by exploiting expert knowledge to identify accessibility improvements. For example, in the study by Moreno *et al.* (D04), human reviewers (E17) meticulously evaluated Spanish public hospital websites, focusing on elements that automated tools often miss, such as contextual interpretation and user experience, emphasizing content legibility and ease of navigation [81].

Additionally, Rodrigues *et al.* (D03) conducted expert reviews to validate a checklist (E18) designed to identify accessibility and usability issues, thereby ensuring that the evaluation criteria are clear, comprehensive, and sensitive to the aspects that influence user interactions [108]. Ferretti *et al.* (D13), on the other hand, used simulations (E20) to imitate user behavior, evaluating the adaptability of personalized web content and how it reacts to inconsistent feedback from users [39]. We clearly state that we use the term *literature review* (E19) when evaluators empirically compare interface design improvements with accessibility recommendations from scientific publications that differ from or extend the W3C guidelines. We observed this type of evaluation in the articles identified with D22, D23, D24, D29, D33, and D34 [2, 20, 49, 56, 124, 126].

5. DISCUSSION

While considerable progress has been achieved in improving web interfaces to the needs of older adults (as shown in the results), our subsequent analysis (structured in sections 5.1 to 5.3) underscores significant gaps. It should be noted that this section analyzes web accessibility barriers focused primarily on changes directly related to aging. We deliberately avoid emphasizing specific problems arising from generational effects (cohort effects such as the digital divide), as these are transient and vary depending on individual prior technological experience.

5.1. From Findings to Insights: Age-Related Factors

Prior studies organize the web barriers encountered by older adults around diverse perspectives. Common frameworks typically group these challenges into categories such as physical, cognitive, and behavioral limitations due to aging [6, 135]. Other analyses emphasize digital-divide aspects including technological characteristics, attitudinal factors, training availability, and economic constraints [17]. Additionally, barriers related to privacy, security, internet access, cognitive processing speed, spatial orientation, and working memory have been specifically highlighted [68, 79, 112]. Further research points out additional challenges such as attention difficulties [109], socioeconomic disparities [42, 54, 84, 129], unfamiliar ICT jargon [104], and cognitive demands from hypertext navigation and information-processing speed [23, 123]. Our systematic review integrates these multiple perspectives into a set of 25 recurring challenges. Each challenge is based on enduring age-related factors, rather than traits unique to a specific cohort, in order to provide an explanatory perspective that remains applicable as generations grow older.

5.1.1. Impact of age-related changes on web accessibility

Physical changes can significantly hinder older adults' ability to interact with web content. Common limitations include reduced visual acuity and contrast sensitivity [2, 21, 39, 80, 108, 124], hearing [2–4, 56, 80, 101, 104] and motor skills [9, 76, 77, 104, 108]. These challenges can make it difficult to click small interface elements, navigate complex menus, or perform tasks requiring actions such as double-clicking or dragging [8, 72]. Motor and visual impairments account for 42.5% of the barriers reported in our corpus. Despite being among the most significant challenges, findings from WebAIM Million 2025 indicate that 79% of analyzed pages contain low-contrast text, and 56% lack alternative text for images [142].

Cognitive difficulties in older adults, such as decreased working memory [124], information processing speed [56], and text comprehension [58, 81] are factors that can make it difficult to navigate and understand information online. In our review, 28.3 % of the papers addressed this issue. Reduced cognitive abilities often lead to slower information processing and increased errors during navigation. For example, a decline in working memory makes it harder for older adults to retain information and follow steps in multi-page processes [4]. Additionally, they experience greater difficulty understanding web page layouts, particularly when faced with complex structures or non-linear navigation systems [7, 128].

Older adults may encounter privacy and security challenges when browsing the web, including protecting personal data and avoiding online fraud [36]. Additionally, they often struggle to understand privacy policies and terms of service, which are typically written in technical, inaccessible language [104]. Moreover, our findings indicate that older adults may experience higher levels of anxiety when faced with online security threats [34]. In our corpus, **psychological**

concerns, privacy/security, and structural factors together make up only 11.6 % of the total identified issues, a very low representation considering the growing consensus around their relevance to the technology acceptance. For example, Jokisch et al. [57] found that privacy concerns were stronger predictors of older adults' reluctance to use digital health services than general ICT competency. Therefore, web application designers should prioritize simplicity and clarity in the presentation of privacy policies and security settings, aiming to reduce the cognitive load associated with managing these tools and generating greater confidence.

The chart in Figure 5 shows the evolution of how these types of problems faced by older adults in their web interaction have been addressed in the scientific literature. As can be seen, studies addressing physical challenges (CP2) remain dominant throughout the analyzed period, with notable peaks in 2016, 2018, 2021, and 2023, while psychological challenges (CP3) and structural barriers (CP6) remain marginal, with the exception of a brief increase in research on CP3 in the year 2021.

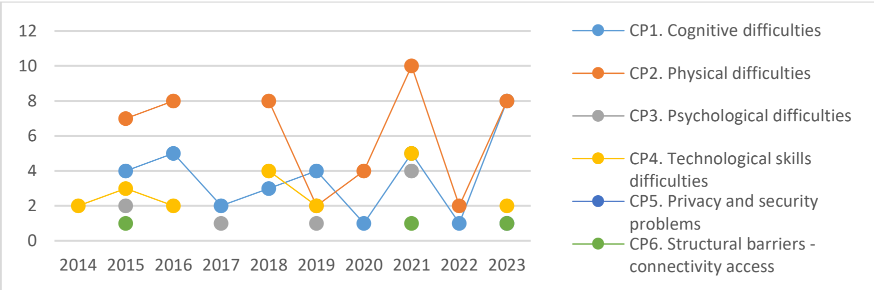

Figure 5. Evolution of the challenges faced by older adults (from the scientific literature).

Regarding the future evolution of these challenges, it is important to note that while sensory, motor, and cognitive decline after age 65 is expected to remain stable across cohorts [29, 48], some barriers resulting from this decline may diminish over time due to generational shifts in digital familiarity [55]. These trends suggest that future older adults may face fewer functional barriers due to increased lifelong exposure to digital technologies. However, age-related cognitive and sensory changes will continue to interact with the increasing complexity of interfaces and should remain a primary design focus.

5.1.2. Impact of technological skill as a barrier to web accessibility

Based on the findings of our review, various difficulties related to limited technological skills hinder older adults from interacting effectively with web interfaces. 17.7 % of these barriers are related to task execution. Older users tend to take longer to complete web-based tasks and are more prone to errors [35, 108]. Sometimes these problems are due to the condition of the person, but other times it is due to the website itself. Poorly designed navigation structures, unclear labels, and an overload of options can confuse older users, leading to frustration and abandonment [105]. In this line, Sanchiz et al. [116] found that older adults exhibit significantly more navigation regressions when menu depth exceeds their working memory span, rather than due to unfamiliarity with hyperlinks . Similarly, Hill et al. [53] demonstrated that eye movement patterns vary by computer experience: novice users aged 70–93 fixate more frequently and for longer durations, whereas experienced peers scan pages with a speed comparable to that of younger adults. Therefore, implementing a good design of the web interface and navigation tasks, which includes older adults from the start, will be essential to reduce the barriers arising from their technological skills.

Another important aspect to consider, which has not been considered in the reviewed literature, is the decline in self-efficacy that many individuals experience two years after retirement. Along these lines, several studies reveal a decline in the mastery of digital skills in the years after leaving the workforce [73, 83]. Consistently, 68 % of primary studies that mentioned hyperlink errors in our review also reported low self-efficacy scores, linking these types of barriers to the Perceived Ease of Use construct in TAM, which was reinforced by the Yang et al.'s meta-analysis [141].

Regarding the solutions proposed in the literature, we found that many focus on the digital divide among older adults. However, this divide will not exist in a few years [53]. Design guidelines should therefore focus on age-related factors that persist across generations, for example: reduced working-memory capacity, difficulties in memorizing, slower reasoning, etc. Simple information hierarchies, clear preview options, and step-by-step guides help reduce cognitive load and enhance self-confidence—two key factors for continued adoption. Focusing on these stable age-related factors will keep accessibility guidelines relevant for future older generations.

5.1.3. Impact of poorly designed websites

As mentioned above, our findings reveal that some web accessibility issues for older adults are caused by website design, not user traits or context. A lack of developer knowledge in implementing W3C accessibility guidelines has been identified as a major contributor [3, 122]. In addition, websites are frequently designed with younger users in mind, neglecting the specific needs and characteristics of older adults [58]. Key design issues include overly complex interfaces and poor readability, which pose significant challenges for users with diverse cognitive abilities [39]. Additionally, the organization of multimedia elements often fails to account for the potential confusion or overwhelm experienced by older users [1].

Based on the review performed, some recommendations have been drawn. First of all, to effectively support older adults in web environments, design considerations must address both sensory and cognitive changes associated with aging. Reducing visual distractions, such as animations, flashing graphics, drop-down menus, banners, and ads, not only limits visual overload but also prevents accidental clicks, which can be especially problematic for users with cognitive decline or reduced motor precision [4, 100, 104, 117]. Complementing this, generous whitespace around text and interface elements helps mitigate tremor-induced misclicks while enhancing overall readability for ageing eyes [8, 39]. High luminance contrast, achieved by pairing dark text with light backgrounds or the inverse, compensates for age-related declines in contrast sensitivity [39, 101, 108].

Equally important is enabling users to adjust font sizes and color palettes, allowing for personalized configurations that address common conditions like presbyopia or sensitivity to glare [37, 39, 72, 104]. Ensuring full and predictable keyboard navigation (through logical tab orders and well-placed shortcuts) offers essential alternatives for those experiencing discomfort, pain or hand tremors when using a mouse [101]. In terms of language, using concise sentences and familiar vocabulary significantly reduces working-memory demands and improves comprehension, particularly for individuals with mild cognitive impairments [18, 80, 104, 111].

Additionally, incorporating voice-based interaction, including speech input and auditory feedback, offers hands-free access for users with motor or visual limitations [21, 37, 49]. Providing an optional simplified view with summaries or easy-read formats supports varied literacy levels and mental fatigue [7, 104]. Finally, the ability to enlarge and recolor the cursor ensures that users with declining visual acuity or fine motor control can maintain accurate awareness of cursor position, contributing to a more user-friendly experience [31, 71].

5.2. Methods for Evaluating Accessibility in Web Interfaces for Older Adults

Our literature review revealed a diverse array of methods for evaluating web accessibility proposals for older adults, which were structured in the Section 4.6 in three categories: automated evaluation, user-centered evaluation and expert evaluation. **Automated evaluation tools** provide quantitative analysis to identify areas where web content fails to meet accessibility standards. Unlike automated evaluations, which are typically performed on operational websites, **user-centered evaluations** can be conducted at different stages. Some methods can be used in the early stages of design, such as requirements gathering, where observation and user surveys are important. In other cases, they are applied once the final product is available, such as user interaction logs or performance analysis, among others [33]. Based on the conducted systematic review, the following user-centered evaluation techniques for web accessibility with older adults can be suggested: interviews, surveys (performance-based tests, debriefing forms, and Technology Acceptance Model instruments) and observations. *Observations* involve users performing predefined tasks or being monitored during their usual activities. Some types of observations that can be used with older adults are: Interaction logs, time-on-task measures, think-aloud protocols, and group-based evaluations. Finally, **expert-based evaluations** assess web accessibility by having specialists identify the frequency and severity of barriers, emphasizing the role of informed judgment over the manual nature of the process. Common approaches in this category include: 1) Scenario analysis: experts simulate the experience of older users in a real scenario [15, 40], 2) Standardized methods: a formal method, such as WCAG-EM, guides experts through structured evaluation procedures [3, 32], 3) Checklist validation [2, 20, 49, 56, 124, 126], and 4) Simulations, allowing experts to mimic older adults' behavior [39].

In order to be able to detect which evaluation methods (Table 10) are used for each different type of solution (Table 6), we conducted a reanalysis of the revised state-of-the-art articles. This analysis is summarized in the Table 11, indicating the number of papers in the literature review that use each type of evaluation to evaluate the proposed solution. It is necessary to note that many proposals were evaluated with several methods (to evaluate different parts of the proposal or to evaluate the proposal from various perspectives). The evaluation methods more used are those with the highest value in the last column of the table. This reveals that the use of questionnaires (used in the evaluation of 25 proposals) stands out significantly from the rest. Surveys (10), performance analysis (8) and literature reviews by experts (8) are other very common methods to evaluate accessibility solutions.

Table 11. Methods to evaluate each type of solution

		Improvement Category						
Evaluation Category	**Evaluation Method**	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**	**CS6**	**Total paper**
CE01 Automated Evaluation Tools	Automated accessibility evaluation tools	4	2	1		3	1	11
CE02 User-Centered Evaluations	Crowdsourcing study			1				1
	Debriefing form	1						1
	Eye tracking		2					2
	Group discussions			1				1
	Interview	3	1		1			5
	Performance analysis	3	2	1	2			8
	Qualitative evaluations	1						1
	Questionnaire	9	5	8	1		2	25
	Semi-structured interviews			1				1
	Survey	3	2	3	2			10
	SUS questionnaires	2	1					3
	TAM	1		1	1			3
	Think aloud protocol	2	1	1			1	5
	Usability test	2	1	2	1			6
	User interaction logs			1				1
CE03 Expert-Based Evaluations	Human review					1		1
	Literature review	3	2			3		8
	Simulations mimicking user behaviour			1			1	2
	Validation of checklist with experts	2	2	1				5
	Total	36	21	23	8	7	5	

Globally, this analysis revealed that the user centered evaluation methods (CE02) are the most commonly used. These methods are much more widely applied with all types of solutions, except for the category CS5 where the expert-based evaluations (CE03) are used with comparable frequency. In a more detailed manner, interventions performed to improve the design of the information in a web site (CS1) are primarily evaluated through questionnaires (9), surveys (3), performed analysis (3), interviews (3), automated tools (4) and literature reviews by experts (3). Interventions in the design of a web site to improve its interaction (CS2) rely more heavily on questionnaire-based studies (5), surveys (2), eye-tracking (2), task-based performance measures (2), automated tools (4), validation of checklist with experts (2) and literature review (3). Supplementary software (CS3), such as browser extensions, are also mostly evaluated through questionnaires (8) and surveys (3). Solutions that interact with hardware (CS4) usually use surveys (2) and performance analysis (2). The solutions based on the application of web standards (CS5) are scarcely evaluated, as they rely on established reference models that have been previously validated. The most used methods in this type of solutions have been the literature review performed by experts (3), and the web accessibility evaluation tools (3). Finally, adaptive solutions (CS6) are the ones with the fewest evaluations and none of the evaluation methods used (automated accessibility evaluation tools, interviews, questionnaires, simulations mimicking user behavior and think aloud protocol) stands out above the rest. This seems to reflect the need to continue working on these types of adaptive solutions and their evaluation methods.

As discussed and reflected in the table, questionnaires are the most commonly used evaluation tools. However, it's unclear if this is sometimes due to limited awareness of other methods. This review can offer valuable insights by presenting a wider range of accessibility evaluation resources for future researchers to choose from.

5.3. A Multi-Level model for Age-Inclusive Web Accessibility Solutions

Based on the previous analysis, we were able to identify that there is no system in the scientific literature to organize accessibility solutions. In order to address this gap, the solution alternatives identified in the Section 4.3 have been structured into a multi-level model of abstraction (Figure) proposed as a contribution of the work. The higher levels of the proposed model lay out the conceptual and technical foundations, while the lower levels address specific aspects and practical applications of these foundations. These levels are: principles and guidelines, software design frameworks, software design methodologies, system architecture (further divided into client-server and client-side solutions), and advanced technologies. Solutions in each level can be used to create new websites that align with accessibility criteria for older adults, but can also be applied to adapt pre-existing systems that were not originally designed with this population in mind. In addition, this model enables researchers to position their contributions for web accessibility at a specific level and more easily identify other existing proposals for older adults at that level.

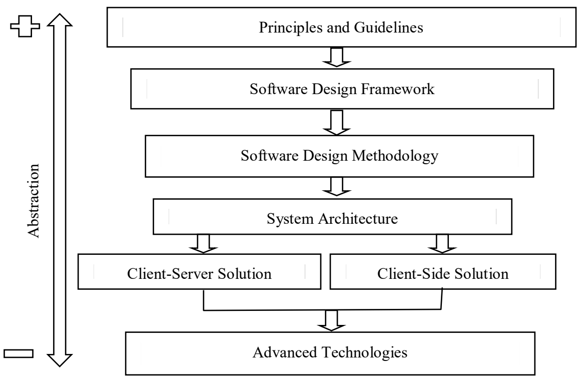

Figure 6. Abstraction levels for the design of accessibility solutions focused on older adults.

Principles and guidelines (highest level of abstraction of the model) encompass general standards that support the creation of accessible web content and facilitate interactions among users, authoring tools, and user agents. Solutions in categories CS1, CS2 and CS3 (Table 6) are usually located at this level. The most widely adopted accessibility guidelines are those developed by the W3C, including WCAG [2, 3, 7, 81, 122, 124], ATAG [2], and UAAG [2]. Additional guidelines for enhancing web accessibility include the SilverWeb Guidelines 2.0 [117] and ISO 9241-171:2008 [124]. It is important to note that many of the solutions found in the following levels of the model are based on these guidelines.

A **software design framework** (second level of the model) offers technical foundations and best practices for implementing the phases of design of the web application. Our review revealed no software-engineering framework that targets web accessibility for older adults, leaving designers to rely on generic disability guidance that overlooks age-specific constraints. In our opinion, two existing approaches provide a strong foundation for developing a framework tailored to older users. On one hand, Model-Driven Engineering (MDE) coupled with Domain-Specific Languages (DSL) could embed older adults-specific accessibility constraints directly in the code-generation pipeline [139]. On the other hand, mainstream responsive toolkits (e.g., Bootstrap's HTML/CSS/JavaScript stack) could be used to encode age-related interaction thresholds such as minimum hit size or maximum navigation depth [106].

Developing accessible websites for older adults requires to follow **software design methodologies** (third level) that prioritize user experience, accessibility, and adaptability to the unique needs of this demographic. The performed review allowed to identify key elements that can be integrated into existing methodologies for developing accessible web applications for older adults. In this line, Ferrer-Mavárez et al. [39] demonstrated the effectiveness of the user experience (UX) methodology in redesigning a communication and employment portal for older adults, where both graphical elements and platform functionalities were optimized through continuous evaluation [38]. Others reviewed works report success adapting Agile Methodologies to include older adults in backlog and review cycles [110], while user-centered approaches involve older adults in prototyping and usability testing from the beginning of the project. [30, 40]. This analysis of the results highlights the formalization of these practices into a full life-cycle methodology as a research opportunity that requires further exploration.

The **system architecture** (fourth level) determines where the accessibility logic is located. Solutions in CS3 and CS6 (Table 6) are usually located at this level. Most age-friendly websites integrate the adaptation engine on the server: this queries an older person's profile and returns a variant of the user-friendly interface [7, 18, 31, 72, 114]. Fewer studies move this logic to the client: JavaScript, CSS, and HTML run in the browser so that users can adjust the size, contrast, or layout of the text according to their needs [21, 39, 40, 77, 106]. In this way, we found no evidence of comparative studies between the two alternatives, which leads implementers to create them ad hoc. In our opinion, papers making such comparisons would be of great value.

Finally, **advanced technologies** (more specific level of the model) cover emerging technologies and adaptive approaches, such as artificial intelligence [128], expert systems [128], machine learning [39], and natural language processing [7, 14] all of which can enhance accessibility and improve the user experience for older adults. Given the rapid and ongoing advancement of Artificial Intelligence and other advanced technologies, such solutions are expected to proliferate even further in the coming years. As an example, the WSD system [7] can be mentioned. This disambiguation system uses NLP to simplify Spanish texts, making them more accessible for older adults with cognitive decline.

This abstraction model to structure the web accessibility solutions can offer valuable insights so that future researchers can identify at what level they wish to attack the problem of accessibility of older adults on the web and what other methodological or technological solutions exist at that level.

6. LIMITATIONS

Despite this review adhering to best practices for conducting systematic literature reviews, some limitations can be considered. Firstly, some interesting study may have been excluded due to database search constraints, the selection of keywords, or the applied inclusion criteria. To mitigate this limitation, the search strategy was refined through several pilot tests to achieve the most representative results.

Another potential limitation of our systematic review lies in the search strategy, which focused exclusively on terms related to web navigation, excluding broader concepts such as "Internet" or "multimedia." While this approach may have excluded some relevant studies in more general contexts, it was a deliberate decision to maintain a clear focus on the design and accessibility of websites. This decision allowed us to narrow the selection to studies specifically addressing information access and interaction through web browsers, ensuring their direct relevance to our research objective.

On the other hand, an inclusion criterion was applied to select articles written in English, given that this is the most common language for scientific publications. However, this choice may introduce a bias, since some interesting articles written in other languages may have been discarded. Future research could address this gap to ensure more inclusive findings.

Finally, in some instances, the designation 'N/A' (not available) was used to indicate that certain publications did not provide sufficient information on the required data (see Table 8 and Table 9). It may have introduced slight deviations in the results, although the effect of these omissions should be minimal.

7. CONCLUSIONS AND FUTURE WORK

Older adults are a growing demographic group, and their inclusion is essential to ensure their participation in society and promote their well-being. To achieve this goal, digital inclusion initiatives are essential since information and communication technologies play a fundamental role in today's society. Specifically, initiatives to improve access to the web are required if we want to break the digital divide and the fears stemming from age-related limitations and the sense of insecurity associated with these declining capabilities of older adults when interact with this type of system. At this point, it is necessary to study older adults as special individuals, with unique characteristics that cannot be described merely by the union of all their disabilities and impairments.

In order to achieve a real digital inclusion, it is necessary to consider not only the specific needs of older adults but also the possible web accessibility solutions. In order to map design improvements with accessibility issues in this field, two specific objectives were proposed in this work: firstly, to identify the main problems relating to the accessibility of older adults on the web, and secondly, to determine the existing solutions to improve the design of the website so that it is more accessible for older adults. With the aim of satisfying the first specific objective, we conducted an exhaustive review of literary publications from 2014 to 2023. We employed the PICO framework to define our research scope and keywords, and we combined SLR with systematic mapping to enhance result characterization and quality. We processed 4,052 articles and selected 35 that met our criteria for quality and relevance. A parallel process for our second objective reviewed 1,039 publications, ultimately accepting 23.

In the first SLR, we identified 25 types of accessibility issues faced by older adults online. These were organized into six distinct categories: cognitive difficulties, physical difficulties, psychological difficulties, technological skill difficulties, privacy and security problems, and structural barriers (i.e. connectivity access) as detailed in Table 5. The second SLR, focusing on web design options for accessibility, confirmed that the predominant standards or criteria for proposing adaptations are derived from W3C guidelines including WAI-ARIA, WCAG, ATAG, and UAAG. This review underscored the importance of addressing the specific needs and preferences of older adults in the design and adaptation of web interfaces. Based on the results of the systematic mapping and the subsequent analysis, various design alternatives were discussed. We classified the solutions into principles and guidelines, software design framework, software design methodology, system architecture, client-server solution, client-server solution and advanced technologies.

In order to ensure the validity of the proposed web accessibility adaptations for older people, it is important not only to propose solutions but also to establish means of verification. A systematic mapping of both SLRs was, therefore, included to identify the evaluation or testing methods used to validate the proposed design solutions (Table 10). The methodologies employed to validate these web accessibility solutions for older adults were diverse, with a clear preference for user-centered testing. This mix of methods emphasizes the multifaceted nature of research in web accessibility, combining user feedback, expert opinion and automated tools to enhance the digital experiences of older adults.

The findings related to proposed web accessibility improvements highlight not only their alignment with WCAG principles but also the gaps that persist in their effective implementation. While solutions in categories such as information presentation and input/output methods are well-documented, improvements involving automatic adaptation and technical assistance, although promising, face challenges in terms of personalization and scalability. This underscores the need for more dynamic approaches that not only comply with existing standards but also address the specific and evolving needs of older adults. At this point, it is important to recognize that existing accessibility guidelines (WCAG, UAAG, SilverWeb Guidelines 2.0, ISO 9241-171:2008, Section 508 , EN 301 549 , among others) are the basis for many of the accessibility solutions proposed in the scientific literature. However, while these guidelines have generally demonstrated their effectiveness, individual differences among older adults highlight the need for systems capable of providing user-specific adaptations. As the review has shown, there are hardly any works that propose specific adaptation models for the interaction of older adults on the Web.

Most of the design recommendations identified in our SLR fit directly within the WCAG success criteria. However, as the interactive complexity of web pages continues to grow, the need to periodically update accessibility guidelines becomes increasingly evident. For example, WCAG 2.2 does not cover auditing interfaces that change dynamically—such as those generated by Large Language Models (LLMs) to adapt layouts or menus in real time.

Accessible web design for older adults involves challenges that extend beyond compensating for age-related physical or cognitive decline. As noted by Knowles et al. [66], equating ageing with disability can reinforce ageist assumptions and constrain design innovation by framing older adults primarily in terms of deficit. This perspective risks overlooking contextual factors that could enhance the relevance and value of technology in later life [66, 134]. In response, we advocate for user adaptation approaches that personalize web interfaces to individual needs. Such strategies reposition accessibility as an opportunity for inclusive design, helping to ensure that older adults are not treated as a peripheral user group but as integral participants in the digital ecosystem.

Future work will focus on developing two taxonomies: one for classifying the accessibility barriers experienced by older adults, and another for categorizing existing design solutions identified in this review. These taxonomies will structure the concepts into hierarchical categories to support understanding, retrieval, and application of accessibility knowledge. Validation will be carried out through real-world case studies and expert assessments to refine clarity and usability. Building on these foundations, we also aim to define and implement an adaptive model for older users, with the goal of integrating it into a browser-based add-on. The insights gained from this review provide a solid basis for advancing adaptive approaches that promote digital inclusion in age-diverse web environments.

Conflict of interest

The authors declare no conflict of interest and no previous or simultaneous publications on related subjects.

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Appendix 1. List of RQ1 and RQ2 publications

Id.	Ref.	Title	Authors	Year	Document type	From RQ1	From RQ2
D01	[35]	A Computer Anxiety Model for Elderly Users Interacting with the Web	Donizetti dos Santos, Thiago and Figueredo de Santana, Vagner	2019	Proceedings Paper	●	
D02	[4]	A study on the acceptance of website interaction aids by older adults	Affonso de Lara, Silvana Maria and de Mattos Fortes, Renata Pontin and Russo, Cibele Maria and Freire, Andre Pimenta	2016	Article	●	
D03	[108]	A support to evaluate web accessibility and usability issues for older adults	Rodrigues, Sandra Souza and Scuracchio, Patrick Eduardo and de Mattos Fortes, Renata Pontin	2018	Proceedings Paper	●	
D04	[15]	A Tool for Capturing Essential Preferences	Ayotte, Dana and Brennan, Michelle and Frishberg, Nancy and Jimes, Cynthia and Petrides, Lisa and Quesenbery, Whitney and Rothberg, Madeleine and Schwerdtfeger, Rich and Tobias, Jim and Treviranus, Jutta and Trewin, Shari and Vanderheiden, Gregg C.	2016	Proceedings Paper	●	
D05	[12]	A Usability Study on Elder Adults Utilizing Social Networking Sites	Arfaa, Jessica and Wang, Yuanqiong (Kathy)	2014	Proceedings Paper	●	
D06	[111]	Able to Read My Mail: An Accessible e-Mail Client with Assistive Technology	Saggion, Horacio and Ferrés, Daniel and Sevens, Leen and Schuurman, Ineke and Ripollés, Marta and Rodríguez, Olga	2017	Proceedings Paper	●	●
D07	[81]	Accessibility and Readability Compliance in Spanish Public Hospital Websites	Moreno, Lourdes and Alarcon, Rodrigo and Martínez, Paloma	2023	Proceedings Paper	●	
D08	[122]	Accessibility Testing of European Health-Related Websites	Sik-Lanyi, Cecilia and Orban-Mihalyko, Eva	2019	Article	●	
D09	[72]	Adapting web menus to mobile devices for Elderly interactions	Antonelli, Humberto Lidio and Watanabe, Willian Massami and de Mattos Fortes, Renata Pontin	2018	Proceedings Paper	●	●
D10	[139]	Addressing Age-Related Accessibility Needs of Senior Users Through Model-Driven Engineering	Wickramathilaka, Shavindra and Mueller, Ingo	2023	Proceedings Paper	●	●
D11	[101]	Assessment of Wizards for Eliciting Users' Accessibility Preferences	Paulino, Dennis and Pinheiro, Paulo and Rocha, Jorge and Martins, Paulo and Rocha, Tania and Barroso, Joao and Paredes, Hugo	2021	Proceedings Paper	●	●
D12	[9]	Automated Repair of Size-Based Inaccessibility Issues in Mobile Applications	Alotaibi, Ali S. and Chiou, Paul T. and Halfond, William G. J.	2021	Proceedings Paper	●	
D13	[39]	Automatic web content personalization through reinforcement learning	Ferretti, Stefano and Mirri, Silvia and Prandi, Catia and Salomoni, Paola	2016	Article	●	●

D14	[58]	Challenges and barriers faced by older adults to access legislative e-participation platforms in Brazil	Junqueira, Luiza and Freire, Andre P. and Grutzmann, Andre and Zitkus, Emilene	2023	Article	●	
D15	[69]	Describing UI Screenshots in Natural Language	Leiva, Luis A. and Hota, Asutosh and Oulasvirta, Antti	2022	Article	●	
D16	[77]	Designing an Adaptive Web Navigation Interface for Users with Variable Pointing Performance	Martin-Hammond, Aqueasha and Hamidi, Foad and Bhalerao, Tejas and Ortega, Christian and Ali, Abdullah and Hornback, Catherine and Means, Casey and Hurst, Amy	2018	Proceedings Paper	●	●
D17	[80]	Designing and Evaluating a User Interface for People with Cognitive Disabilities	Moreno, Lourdes and Alarcon, Rodrigo and Martínez, Paloma	2021	Proceedings Paper	●	●
D18	[21]	Firefox Voice: An Open and Extensible Voice Assistant Built Upon the Web	Cambre, Julia and Williams, Alex C and Razi, Afsaneh and Bicking, Ian and Wallin, Abraham and Tsai, Janice and Kulkarni, Chinmay and Kaye, Jofish	2021	Proceedings Paper	●	●
D19	[3]	Framework for Accessibility Evaluation of Hospital Websites	Acosta-Vargas, Patricia and Acosta, Tania and Lujan-Mora, Sergio	2018	Proceedings Paper	●	
D20	[104]	Front-end Solution for Enhancing Web Sites Accessibility	Pirsa, Andrea and Stanic, Boris and Stracak, Lovro and Todorovic, Zoranand Vdovic, Hrvoje and Zilak, Matea and Vukovic, Marin and Car, Zeljka	2015	Proceedings Paper	●	●
D21	[34]	Gaze Interaction and People with Computer Anxiety: Paving the Way to User Interface Simplification	Donizetti dos Santos, Thiago and Figueredo de Santana, Vagner	2021	Proceedings Paper	●	●
D22	[49]	Guidelines for Designing Social Networking Sites for Older Adults: A Systematic Review with Thematic Synthesis	Ghenai, Amira and Ayeni, Philips and Yu, Jing and Cohen, Robin and Moffatt, Karyn	2023	Article	●	
D23	[126]	Identifying and Mitigating Technology-Related Anxiety	Steelman, Kelly and Wallace, Charles	2017	Proceedings Paper	●	
D24	[20]	Older Adults and Their Acquisition of Digital Skills: A Review of Current Research Evidence	Bhattacharjee, Priyankar and Baker, Steven and Waycott, Jenny	2021	Proceedings Paper	●	
D25	[36]	Privacy and Data Security in Everyday Online Services for Older Adults	Ellefsen, Jonas and Chen, Weiqin	2023	Proceedings Paper	●	
D26	[8]	Recommendations for the Development of Web Interfaces on Tablets/iPads with Emphasis on Elderly Users	de Almeida, Rafael Xavier E. and Leal Ferreira, Simone Bacellar and Soares, Horacio Pastor	2015	Proceedings Paper	●	
D27	[40]	Reversed Multi-Layer Design as an Approach to Designing for Digital Seniors	Finne, Rebecca and Larsson, Lisa and Mylonopoulou, Vasiliki and Andreasson, Sebastian and Hjelm, Tove and Rost, Mattias and Weilenmann, Alexandra and Torgersson, Olof	2022	Proceedings Paper	●	●

D28	[18]	Taking Text Simplification to the User: Integrating Automated Modules into a Web Browser	Bautista, Susana and Hervás, Raquel and Gervás, Pablo and Bagó, Axel and García-Ortiz, Javier	2018	Proceedings Paper	●	●
D29	[2]	Techniques for the Publication of Accessible Multimedia Content on the Web	Acosta, Tania and Zambrano-Miranda, José and Luján-Mora, Sergio	2020	Article	●	
D30	[25]	The Effect of Typeface and Font Size on Reading Text on a Tablet Computer for Older and Younger People	Chatrangsan, Maneerut and Petrie, Helen	2019	Proceedings Paper	●	
D31	[30]	Tipper: Contextual Tooltips That Provide Seniors with Clear, Reliable Help for Web Tasks	Dai, Yibo and Karalis, George and Kawas, Saba and Olsen, Chris	2015	Proceedings Paper	●	
D32	[76]	Understanding Design Considerations for Adaptive User Interfaces for Accessible Pointing with Older and Younger Adults	Martin-Hammond, Aqueasha and Ali, Abdullah and Hornback, Catherine and Hurst, Amy K.	2015	Proceedings Paper	●	●
D33	[56]	User-centered web accessibility: recommendations for ensuring access to government information for older adults	Idrobo Cruz, Claudia Sofia and Flor, Ember Ubeimar Martinez and Caicedo, Maria Isabel Vidal	2023	Article	●	
D34	[124]	Web Accessibility for Elderly	da Silva, Viviane Gomes and Silva de Souza, Ranniery Mazzilly and Oliveira, Mafalda and Medeiros, Rafael Lima	2016	Proceedings Paper	●	
D35	[114]	Model for Profiling Users With Disabilities on e-Learning Platforms	Sanchez-Gordon, Sandra and Aguilar-Mayanquer, Carmen and Calle-Jimenez, Tania	2021	Article	●	●
D36		Research on Web Interface barrier-free Design for Elderly People	Wang, Shao-Feng	2020	Proceedings Paper	●	
D37	[90]	What's on your mind? investigating recommendations for inclusive social networking and older adults	Norval, Chris and Arnott, John L. and Hanson, Vicki L.	2014	Proceedings Paper	●	●
D38	[1]	Accessibility of eGovernment Services in Latin America	Acosta, Tania and Acosta-Vargas, Patricia and Lujan-Mora, Sergio	2018	Proceedings Paper		●
D39	[71]	Adaptive click-and-cross: adapting to both abilities and task improves performance of users with impaired dexterity	Li, Louis and Gajos, Krzysztof Z.	2014	Proceedings Paper		●
D40	[31]	AdaptNow - A Revamped Look for the Web: An Online Web Enhancement Tool for the Elderly	Dias, Roberto and Bermudez i Badia, Sergi	2014	Proceedings Paper		●
D41	[106]	Combining Design-time Generation of Web-pages with Responsive Design for Improving Low-vision Accessibility	Rathfux, Thomas and Thöner, Jasmin and Kaindl, Hermann and Popp, Roman	2018	Proceedings Paper		●

D42	[128]	Improving older adults' accessibility to the web using real-time online interactive guides	Taieb-Maimon, Meirav and Vaisman-Fairstein, Elior	2022	Article		●
D43	[117]	Increasing Web Accessibility Through a Personalized Web Browser for Older Adults	Sa-nga-ngam, Prush and Kiattisin, Supaporn	2020	Article		●
D44	[37]	Prototyping and testing an accessible e-health patient portal designed to include patients with/without vision or hearing impairments	Farhan, Wejdan and Razmak, Jamil	2023	Article		●
D45	[100]	Redesigning websites for older adults: a case study	Patsoule, Evelina and Koutsabasis, Panayiotis	2014	Article		●
D46	[7]	Word-Sense disambiguation system for text readability	Alarcon Lourdes Alarcon, Rodrigo and Moreno, Lourdes and Martínez, Paloma	2021	Proceedings Paper		●
D47	[14]	Web Screen Reading Automation Assistance Using Semantic Abstraction	Ashok, Vikas and Puzis, Yury and Borodin, Yevgen and Ramakrishnan, I.V.	2017	Proceedings Paper		●
D48	[16]	Exploring User Preferences on eText Interface Design to Support Reading Among Low Vision Elders	Azam, Wan Anis Izzati Wan Affandi and Sulaiman, Suziah and Rambli, Dayang Rohaya Awang and Mean, Foong Oi	2021	Proceedings Paper		●