Web User Interface Adaptation for Low Vision People: An Exploratory Study Based on a Grounded Theory Review Method

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Abstract. People with visual impairments (PVI) are characterized as a diverse population of users due to multiple vision impairments like visual acuity, light and glare sensitivity, contrast sensitivity, limited field of vision, color blindness. In that context, adaptation is a key element for coping with diversity in the field of Human-Computer Interaction (HCI). This study explores the adaptation to provide accessible web user interfaces for low vision people. To do so, we relied on Grounded Theory (GT) as a review method to cover academics and mainstream web perspectives. In the spirit of all is data, we collected a set of scientific publications, initiatives led by leading actors in Information and Communication Technology, and PVI organizations over the past ten years. Our findings show that academics followed particularist, user-centered, and proactive principles, but rarely included PVI in the early project stage. While most solutions are based on adaptivity, adaptation is still under investigation. Regarding the mainstream web perspective, recent initiatives followed universality, multi-stakeholder involvement, and proactivity principles. In opposition to the academic perspective, accessibility has been exclusively based on adaptability and tailored user interfaces. As the adaptability features become more and more advanced, the frontier between specialized assistive technology will be blurred. Hence, we recommend investigating environments of adaptation stacking with a better alignment between academics and industry.

Keywords: Accessibility · Universal access · Adaptation · People with visual impairments · Low vision · Web technology · Grounded theory

1 Introduction

According to the World Health Organization, 86% of people with visual impairments (PVI) have a low vision [1]. Low vision refers to visual impairments other than blindness including visual acuity, light and glare sensitivity, contrast sensitivity, limited field of vision, and color blindness [1, 2]. Moreover, most of PVI reported multiple types of visual impairment [2]. In that context, accommodating the diversity of users is challenging in

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Human-Computer Interaction (HCI) [3]. Moreover, awareness of universal access must be increased [4].

To better address accessibility issues, the past few decades have been marked by multiple paradigm shifts: a shift from a *particularist* account to a *universalist* account of access, a shift from a *maker-centered* to a *user-centered* perspective, and a shift from a *reactive* to a *proactive* approach to accessibility [5]. Moving from an '*accessibility for users with disabilities*' approach to an '*inclusive-design*' approach benefits a wide range of users, those with disabilities but also those without [6].

In the context of web accessibility, the Web Content Accessibility Guidelines (WCAG) aims to make content accessible to a wider range of people with disabilities by providing a single shared standard that meets the needs of individuals, organizations, and governments internationally [7]. However, being compliant with web accessibility norms does not guarantee that a specific population can reach their goals with reasonable time and effort [8–11].

With the knowledge that *one size does not fit all* [12], adaptation is a key element for coping with diversity [13]. Recent efforts aim to cope with diversity towards adaptation. For example, the WCAG 2.1 makes a short mention of the term *visually customized* [14]. Moreover, the W3C Low Vision Task Force provides accessibility requirements dedicated to people with low vision [1]. Many requirement statements are oriented with a focus on adaptability (i.e., a user-invoked adaptation [13]). Hence, makers have to create an adaptable system to benefit low-vision people.

In this study, we review adaptation approaches applied to provide accessible but also usable web content to PVI. We were particularly focused on people with low vision because their diversity fit well with universal access. We endeavor to answer the following research question: *How web user interfaces are adapted for low vision people?* To answer this question, we conducted a literature review based on Grounded Theory (GT), including both academic and mainstream web perspectives.

This paper is organized as follows. The first section presents our methodological choices. The second section presents the results obtained. The third section highlights our research contributions, outlines the limitations, and suggests future avenues of research. Finally, the fourth section concludes the study.

2 Methodology

This research used GT as a review method [15]. The GT research process may be described as "*investigating an area of interest to the researcher in order to highlight the main concern that emerges from the field through collected data; the purpose of this process is to identify a core category that also emerges from the researcher's data as explaining this main concern"* [16]. The Grounded Theory Literature Review (GTLR) invokes GT as a method during the analysis stage, and uses the content from the papers as empirical material that is coded and constantly compared, thus grounding the insights of the review [15]. GTLR is composed of five stages, namely: 1) defining the scope of the review (inclusion and exclusion criteria, sources of information, search terms); 2) searching for the potential papers; 3) selection of the papers for the review (filtering, refine sample based on title and abstract); 4) in-depth analysis of the papers (through

different coding levels); and 5) present the emerging categories from the papers. To include both academics and mainstream web perspectives, Fig. 1 illustrates the GT *zigzag* approach [17] (i.e., movement in the form of process) related to GLTR.

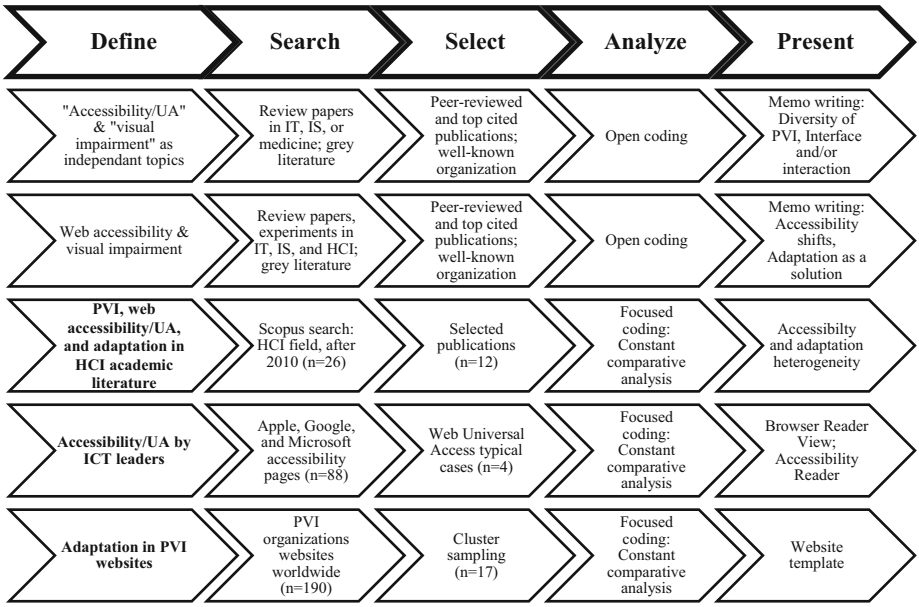

Fig. 1. GTLR process.

2.1 Review Scope

We first performed both iterations related to: a) accessibility and visual impairment as distinct topics, and b) web accessibility in the context of visual impairment. This led us to the topic of adaptation as a solution to support universal access. This orientation has been influenced by field observations of the research team (e.g. textbook adaptation for PVI), meta-review in HCI [12], W3C's low vision recommendations [1], and observations made on websites of organizations of and for PVI (e.g. World Blind Union, American Foundation for the Blind). Also, we clarified the PVI population singularity and their accessibility needs with experts (e.g. local PVI organizations) through informal interviews.

We delimited our research scope on web technology because most of the digital documents provided to PVI are in HTML [18], the importance of web accessibility to address a wide range of people with disabilities is recognized [19], and the web is the most popular technology in accessibility research related to Information and Communication Technology (ICT) [20]. At the end of both iterations, we obtained the core categories of our analytical framework (see Appendix 1).

PVI, Web Accessibility, and Adaptation in HCI Academic Literature. On the 7th of June 2021, we collected 26 scientific publications on Scopus based on the following

query: *TITLE-ABS-KEY ((accessibility OR "universal access" OR "inclusive design" OR "accessible design" OR "design* all") AND (web OR www) AND (adaptation OR adaptab* OR adaptiv*) AND ("vis* disabilit*" OR "vis* impair*" OR "low vision" OR "partial vision" OR "residual vision" OR "vision loss" OR "color blind*" OR "color* defic*" OR sensitivity)) AND DOCTYPE (ar OR cp OR re) AND SUBJAREA (soci OR comp) AND (PUBYEAR > 2010) AND LANGUAGE (english).* This query includes different variations of accessibility and connected concepts [21], different formulations and types of vision impairment [22], and different kinds of adaptation [23]. We retained only publications published the last ten years because it characterized a period when accessibility paradigm shifts occured [5]. Regarding the choice of the metadatabase, Scopus is recognized as having a broader coverage of scientific publications [24]. Also, Scopus provides subject area filters that helped us to frame the research. The subject area Social Sciences (SOCI) contains Human Factors and Ergonomics while Computer Sciences (COMP) contains Human-Computer Interaction.

We analyzed the title, abstract, and keywords of each of the 26 scientific publications. Exclusion criteria covered extended abstract, publications on which the web technology, the adaptation, or PVI diversity were not the primary concern. For instance, we excluded studies concerned with hardware (e.g. TV device), or solely focused on blind users without aiming to widen the scope. When a research group published similar studies, we retained the most detailed one after a full document analysis. Finally, we obtained a set of 12 publications.

Web Accessibility to PVI through Adaptation by ICT Leaders. By embedding accessibility into mainstream solutions, we move towards Universal Design [25]. For that reason, we focused on mainstream user agents providing features to assist individuals with disabilities. The difference with assistive technologies is that mainstream user agents target broad and diverse audiences that usually include people with and without disabilities [14].

We searched for projects, products, or features within ICT leaders (GAFAM) websites and blogs related to accessibility or universal access. We narrowed the scope to Apple, Google, and Microsoft because they have a clear positioning in universal access, develop tools to consume information on the web (i.e. web browsers), and produce accessible information (i.e. authoring tools and guidelines). On the 23rd of August 2021, we extracted 88 titles and descriptions of projects, products, or features within accessibility and blog web pages published from 2010. We manually performed the filtering because websites do not provide advanced search options.

Adaptation is a primary concern of the three actors analyzed, but rarely linked with web technology. Apple and Microsoft are generally focused on assistive technology (AT) and accessibility features of their operating system. Related to web technology and adaptation, we noticed that: a) Apple briefly mentioned a dark mode that can be applied in several applications (i.e. Safari Browser), b) Microsoft provided adaptability features in the Immersive Reader, and c) Google explicitly mentioned adaptability in the Chrome browser, as well as developed an interactive experience of storytelling for PVI. We performed a typical case sampling (purposive sampling) based on these findings. We selected four cases covering adaptation and mainstream web user agents: Safari Reader Mode, Chrome Reader Mode, Auditorial (Google), and Microsoft Immersive Reader.

A Reader Mode or a Reader View reduces the colorfulness and visual complexity of web pages [26]. Reader Views are perceived as accessibility features by the PVI community [27]. Moreover, more advanced Reader Views (e.g. Immersive Reader) promote universal access because they benefit people with varying reading skills [26]. For example, simplifying the web page layout helps people with visual and those with cognitive impairments.

Adaptation in Website for PVI. To complete the mainstream web perspective, we retained a cluster 17 websites of PVI organizations (see Appendix 2). Each website is maintained by a PVI organization, member of the World Blind Union, and located in a top-ranked country by region according to the Digital Accessibility Rights Evaluation Index (DARE) Index 2020 [28].

2.2 Analysis

Analytical Framework. In line with a GT concept-centric review [16], our analytical framework is based on two core categories. The first one concerns the paradigm shifts on accessibility as reported by recent and valuable works related to universal access in HCI [5, 12, 25]. The second one places the adaptation as a solution to address accessibility issues in respect to these paradigm shifts [12, 13].

Paradigm Shifts on Accessibility. Greco [5] reported three paradigm shifts regarding accessibility in various fields including HCI: a shift from *particularist* accounts to a *universalist* account of access, a shift from a *maker-centered* to a *user-centered* perspective, and a shift from a *reactive* to a *proactive* approach.

The first shift considers the move from a *particularist* to a *universalist* approach to accessibility. Specialized adaptations and add-on assistive technologies are replaced by universal solutions catering to a diverse set of user needs [25]. It is also highlighted by a contemporary definition of accessibility: '*the extent to which products, systems, services, environments and facilities are able to be used by a population with the widest range of characteristics and capabilities (e.g. physical, cognitive, financial, social and cultural, etc.), to achieve a specified goal in a specified context.*' [21]. Moreover, moving from an '*accessibility for users with disabilities*' approach to an '*inclusive-design*' approach benefits a wide range of users, those with disabilities but also those without [6].

The second shift refers to the considered perspective when developing accessible solutions (hardware or software). The dominant attitude was based on the assumption that the maker's knowledge of users with disabilities is the only one that matters [5]. This approach caused a complex series of gaps between the different stakeholders involved, of which the *maker-user* and the *maker-expert-user* gaps were the most prominent. To bridge these gaps, inclusive design practices based on *user-centered* approaches emerged. Such practices take into account the knowledge of users, but also experts and other stakeholders, which are all as important as the maker's knowledge [5]. A suitable design process should be a co-construction where multiple agents must work together [5, 12, 25].

The third shift concerns the accessibility consideration within the design process. This process can be broken down into *ex-ante*, *in itinere*, and *ex-post* stages [5]. First

efforts pursued accessibility via *a posteriori* adaptation, for instance, by employing assistive technology and add-ons to provide access to applications that were originally designed and developed for non-disabled [5, 12]. In that case, accessibility is reactive or an afterthought [29]. In rare cases, accessibility was addressed *in itinere* [5], which may produce a loss in functionality or provide limited and low-quality access [12]. Respecting the proactivity principle calls for a proactive attitude to comply with the access requirement, and building access features into a product as early as possible (e.g. design phase) [25, 29]. Best fixing complex accessibility issues require sometimes revisiting the overall approach [30].

In short, these paradigm shifts concern the target population, the population implied during the development process of accessible software, and the moment when accessibility efforts are performed.

Adaptation as a Promising Solution. On the one hand, users' needs vary widely across people with low vision, and one user's needs may conflict with another user's needs [1]. On the other hand, the industry is facing the necessity to target all people with disabilities, while developing multiple and completely different software is difficult [12]. Considering these constraints and the aforementioned paradigm shifts, taking the path of adaptation seems a promising solution [13].

Systems that can adapt according to various requirements and criteria, or even upon request is not new [23]. Coarsely, approaches to adaptation of interactive systems can be classified into two broad categories, namely user-invoked adaptation (*adaptability*) and automatic adaptation (*adaptivity*) [23]. Interactive systems may also mix both approaches [31]. An adaptable system (via adaptability mechanisms) offers its users the capability to alter the system's characteristics. Users select or set between different alternative presentation and interaction characteristics, among the ones built into the system. Adaptation is defined at the design time. A typical example includes customization of system presentation or behavior (i.e. navigation facilities) through preference dialogs. The second approach to adaptation, adaptivity, refers to the ability of the interface to dynamically derive knowledge about the user, the usage context, etc., and to use that knowledge to further modify itself to better suit the revised interaction requirements [13]. An adaptive system automatically alters its characteristics at runtime, based on assumptions about the user's current usage [31]. In addition to adaptability and adaptivity, a tailored adaptation refers to user interfaces (UI) adapted at design-time, by a maker or a system, and are instantiated at runtime [32].

To comprehend *what is adapted?*, we used the User Interface Markup Language (UIML) [33]. In UIML, a UI is a set of interface elements with which the end-user interacts. A UI is conceptualized as a stack of structure, style, content, and behaviors. The behavior needs to be considered as follows: *what behavior do parts have?*. We focused on graphical user interfaces because low vision people prefer to take advantage of their residual sight [4].

Coding Procedure. Following a constructivist GT approach [34], we combined various sampling techniques, constant comparison, and two coding cycles. In the first coding cycle, we coded paragraphs within each publication related to the two first iterations following a descriptive coding technique [35]. The goal was to obtain a categorized

inventory of the data's contents. Once our analytical framework was developed, we performed deductive coding based on the list of codes [36]. This led us to a broader view of adaptation (adaptability, adaptivity, tailored UI) than that mentioned commonly in the literature (e.g. the adaptability-adaptivity distinction [23] or the tailored UI-adaptivity continuum [32]). In a second coding cycle, we developed the final list of codes. The categories did not change, but we performed continuous changes in codes as new papers were analyzed. Compared to an inductive approach, a top-down constructivist approach implied better questioning, theory integration, insight and a richer picture [37]. Also, a constructivist approach has been motivated by the fact that adaption in well defined in theory [13, 38–40]. One researcher performed the coding, while the analysis has been discussed through socialization between two researchers.

3 Results

3.1 Academics Perspective

Studies of our sample have been published between 2012 and 2021. Seven publications are conference proceedings, and five are journal articles. Publications have primarily been published in Universal Access in the Information Society (3), in Lecture Notes in Computer Science that includes UAHCI proceedings (3), and in Web for All (W4A) Conference (2). Almost all publications focused on web technology in a desktop context, and two focused on mobile web [41, 42]. Publications are varied in terms of goals. They addressed accessibility issues like non-accessible colors [43–46], unstructured table issues [47], unadapted multimedia on mobile devices [41], non-compliant websites [48]. Other authors address specific limitations of web content and assistive technologies [49], the limitations of voice-based systems [50], while others aim to improve user's navigation [51], skimming strategies [42], or the automated generation of UI [52].

Five studies provide a methodological outcome such as adaptation techniques for tailored UI or adaptive systems [47–49], as well as a theoretical outcome (e.g. ontology) [45, 51]. Regarding artifact outcome, studies mainly relied on the methodological or theoretical outcome they created [42, 47–49], rather than using a preexistent method or model [52] (Table 1).

Accessibility. Regarding the target population, most of the publications focused on a particular, sometimes diverse, type of PVI [48–50, 52], while two explicitly refer to a universal approach to accessibility. Such studies included sighted and blind users or target people with different disabilities [42, 43].

Regarding the design perspective, ten publications are user-centered. One concerns a trade-off between the user and the maker [44], and another adopts a holistic perspective by integrating multiple stakeholders [48].

Concerning the moment when accessibility features are taken into account during the development process, we coded all publications as proactive. We explain this choice because in accessibility studies, and authors think about accessibility from the start. Regarding the proactive principle's application, two studies asked for users' problems or requirements at the project design phase [48, 51]. Studies usually used a proxy such

Table 1. Accessibility Shifts and Adaptation as a Solution in the Academic Literature (n = 12)

Core category	Category	Codes	References
Accessibility/universal access	Target population	Particularist	[41, 44–52]
		Universalist	[42, 43]
	Design perspective	User-centered	[41–43, 45–47, 49–52]
		Maker/user-centered	[44]
		Multiple stakeholders	[48]
	Accessibility efforts	Proactive	All
		Design phase (direct)	[48, 51]
		Evaluation phase (direct)	[42, 45, 48, 49, 51]
Adaptation	Adaptation type	Adaptability	[50]
		Adaptivity	[41–43, 47, 51]
		Tailored	[46, 48, 49, 52]
		Adaptability-Adaptivity	[44]
		Adaptivity-tailored	[45]
	Adaptation on UI	Content, or structure, or style, or behavior	[41, 43–47, 50]
		Content-structure	[51]
		Content-behavior	[42, 48]
		Structure-style	[49]
		Content-structure-style	[52]
	Adaptation sources	User	[43, 46–48, 50–52]
		User-technology	[41, 42, 45, 49]

as a common accessibility issue, a PVI needs, or accessibility guidelines (e.g. WCAG). Regarding the evaluation phase, five studies directly involved PVI, one performed a technical evaluation related to accessibility [52], and six did not perform a user-centered evaluation.

Adaptation. Publications investigated adaptation in different ways. Five publications focused on adaptivity, four on tailored UI, one on adaptability, and two combined two types of adaptation.

Seven publications adopted a unidimensional approach to UI adaptation. It is important to highlight that advanced computations such as page recoloration [43], table restructuration [47], or multimedia adaptation [41] often implied one UI dimension. One study implemented a system that adapts the four dimensions of a UI [48].

Content adaptation is preferred over modality adaptation. Three UI dimensions are often considered, respectively the style (6), the content (5), and the structure (4), while the behavioral dimension is less studied (2). Regarding the style, the color [43–46], the font [49, 52], and the visual effects (i.e. contrast, blur) [49, 52] are investigated. Publications

solely focused on the style exclusively focused on people with color deficiencies [43–46]. Regarding the content, transformation and filtering [41, 48], hiding [50, 52], and enrichment [42, 50] are investigated. Concerning the structure, layout adaptation [49, 52], table reorganization [47], and semantic-based restructuration [51] are developed. When the behavioral dimension is investigated, is it through links (that impacts user's navigation [42]), or the auditory modality (human to computer [50], or computer to human [48]).

Authors sometimes completed or compared adaptivity with makers (i.e. tailored UI) or users (i.e. adaptivity). Regarding colorblind people, manually colored interfaces obtained in the majority the best results [46]. Also, combining design-time generation with runtime adaptation through responsive design technology is a way to address the limitations of manual or automatic generated UI [52].

Regarding the source of the adaptation, researchers generally relied on user features, through their preferences [42, 44–46, 48], and/or disability [45, 46, 52], but rarely on user's knowledge (i.e. browsing activity) [42]. Pathology types, needs, and individual user preferences are simultaneously taken into account in the context of automatic color selection [45]. Four studies combined user features with the technology used (e.g. device, assistive technology). Regarding low vision people, some adaptation techniques depended on the type of assistive technology used to access the web [49]. In the context of color deficiencies, there are significant differences among the adaptation techniques according to different contexts [46].

3.2 Mainstream Web Perspective

The four accessible retained cases of ICT leaders, as well as 17 PVI organizations' websites analyzed were grouped into three implementations of adaptation (see Table 2). The *Website Template* approach is based on a responsive HTML/CSS template[1] that is often compliant with accessibility standards. Such an approach allows fitting a web interface to a user profile or user preferences and guarantees that the page layout will not be broken after a user-invoked adaptation. Our analysis shows that 53% (9 out of 17) of websites analyzed support adaptability (see Appendix 2). Also, ICT leaders support web accessibility by developing basic and advanced readers. A *Reader Views* and *Accessibility Readers* are both web user agents [53]. They aim to enhance the visual presentation of web content through a format for easy reading, without ads, navigation, or other distracting items. The origin of *Website Templates* for PVI dates back to before 2010,[2] *Reader Views* emerged around 2010 [54], while *Accessibility Readers* appeared at the end of the last decade.[3]

Accessibility Approach. The three types adopt a universalist approach because they target diverse users. Regarding the *Website Template*, websites target PVI and sighted people, and some go beyond these profiles. For example, the QSCCB website includes

[1] https://www.a11yproject.com/.

[2] The AFB website provided text size adaptation on the 1st of January 2010. See: https://web.archive.org/web/20100101192728/https://afb.org/.

[3] https://github.com/microsoft/immersive-reader-sdk/releases.

Table 2. Accessibility shifts and adaptation as a solution in mainstream web

Core category	Category	Website template	Reader view	Accessibility reader
Accessibility/universal access	Target population	Universalist	Universalist	Universalist
	Design perspective	Not mentioned	Not mentioned	Multiple
	Accessibility efforts	At itinere	At itinere	Proactive
Adaptation	Adaptation type	Tailored UI; adaptability	Tailored UI; adaptability	Tailored UI; adaptability
	Adaptation on UI	Content; structure; style; behavior	Content; structure; style; behavior	Content; structure; style; behavior
	Adaptation source	User	User	User
	Examples	PVI organization websites sample	Safari Reader [54]; Chrome Reader Mode [55]	Microsoft Immersive Reader [56]; Google Auditorial [57]

sighted, visually impaired, and blind people profiles. The RSB website provides a font suitable to dyslexic users, while the ONCB website provides sign language videos. *Browser Reader Views*, which initially did not mention accessibility [54], are now part of accessibility settings [55]. Such solutions benefit people with varying reading skills [26]. The Microsoft Immersive Reader primarily targets people with learning disabilities (e.g. dyslexia), but also PVI [56, 58]. Dedicated explicitly to blind and low vision people, RNIB, Guardian, and Google jointly developed Auditorial [57], an experiment in storytelling that can be adapted to suit the user's needs and preferences.

Regarding the stakeholders involved during the development process, *Accessibility Reader* implementations involved users and educators (Immersive Reader), as well as users, accessibility specialists, and journalists (Auditorial) [57].

Because PVI organization websites and *Browser Reader Views* included accessibility features during the evolutive maintenance,[4] adaptation has been integrated *in itinere*. Both *Accessibility Reader* cases emphasize the importance of including the user at an early project stage. The Immersive Reader is based on Universal Design, and is built on top of empirical research related to text appearance, readability, and reading comprehension [59]. In addition, Auditorial redesigned the overall storytelling experience with accessibility in mind.

[4] Safari integrated the Reader Mode in version 5 [54]. The original version of the AFB website did not integrate adaptability. See: https://web.archive.org/web/20000302105032/https://afb.org/.

Adaptation Approach. All kinds of mainstream web adaptations can mix tailored UI and adaptability approaches. Web designers are responsible for preparing the content that the user could further adapt.

In the majority of cases that use adaptation by a template, the user obtains the original/sighted version of the website first. If the user has a vision impairment, the interface can be adapted through customization. In the QSCCB website, the user needs to select a profile (sighted, visually impaired, blind) that will affect the web interface and then adapt the font size. Such interfaces are tailored because they consider the specific disabilities of the users at design time [32]. They are also adaptable due to the presence of user-invoked adaptation. Also, not all web pages are compatible with the *Reader Mode*.[5] Regarding the Immersive Reader, the designer has to markup the page elements that can be viewed within the reader.

Although the three implementations provide quite similar capabilities in terms of UI adaptation, they differ in terms of advances. This is particularly illustrated in the *Website Template* category. The AFB website provides one option to change the font size. Four websites provide additional color schemes options (ONCB, UNCU, ACB, AICB). The five remaining websites provide more advanced accessibility features that affect at least two dimensions of a UI, but rarely more. For instance, the VOS website presents page content on a narrow page with a menu moved to the left side, support a simplified style, and filter informational noise (e.g. logo). The CNIB website provides options to place the table of content at the top of the page and emphasize interactable inputs (i.e. links, buttons). *Reader Views* provide structure linearization, narrow page presentation, information filtering[6], and basic adaptability features (e.g. font, font size, and background color selection). When the read-aloud functionality is present, the user can rely on the auditive modality. *Accessibility Readers* such as Microsoft Immersive Reader and Auditorial are more advanced [27]. Microsoft Immersive Reader contains artificial intelligence-powered features like reading aloud, translating languages, focusing attention through highlighting, and extracting text from images.[7] Auditorial is highly customizable (zoom, color, image, motion) and provides two modalities (visual, auditive) to experiment with the story. Each content is thoroughly tailored to support an interactive and immersive experience.

4 Discussion

Regarding the accessibility approach, academics followed mostly particularist, user-centered, and proactive principles. They often used a proxy to access PVI needs (i.e. PVI report, common accessibility issues). In the mainstream web, recent initiatives led

[5] From a randomly selected sample of 100 website URLs, only 2% of homepages and 41% of child pages were available in Firefox Reader View [26].

[6] The logic behind *Browser Reader View* is provided by Mozilla Firefox in open-source. See: https://github.com/mozilla/readability.

[7] Microsoft Immersive Reader is built into Microsoft applications (e.g. Word, OneNote, Outlook, Edge web browser) or can be used as a cloud service (Azure Cognitive Services). At this moment, Azure is the only major cloud provider offering this type of reading technology [63].

by leading ICT actors followed a universalist, holistic and proactive approach to accessibility. We explain the misalignment of the academic literature in regards to accessibility shifts by the difficulty to find and involve people with disabilities in a study [22], and the incremental nature of research (i.e. prior knowledge about PVI is known). However, HCI academics should involve PVI in all project phases [4]. While ICT leaders market their solutions to the PVI community, we only found studies that evaluated such solutions with people with cognitive impairments or without disabilities [59]. Similar to *Reader Views* [26], the utility of accessibility reading tools must be empirically validated with PVI.

Regarding adaptation, the academic literature is characterized by a wide diversity of adaptation types, even in our limited research scope. On the mainstream web side, adaptation is pervasive. Basic to advanced adaptability and/or tailored UI enhance the visual presentation of web interfaces. Mainstream web agents are in line with W3C's low vision recommendations [1]. However, academics are still investigating the advantages and drawbacks of adaptation types in different contexts of use [46, 48, 49].

Unlike the academic literature, the mainstream web has not embraced adaptivity, yet well defined in theory [38]. Advanced computation, often through the form of deep learning for computer vision, has been reserved to assist PVI in their daily lives. For now, one *Accessibility Reader* uses artificial intelligence to support adaptability for an educational purpose (e.g. text styled and enhanced with metadata for dyslexic users). This can be explained by the fact that designing for diversity is difficult [38]. Moreover, even if academics investigated adaptivity, it was performed in a limited technical scope, or completed by other kinds of adaptation. We believe that mainstream web user interfaces will soon explore adaptivity by taking the latest advances in machine learning.

One solution rarely works in all situations, and no unique solution would meet the needs of all low-vision users [29]. However, the more mainstream products will provide advanced accessibility features, the more the frontier between mainstream user agents and assistive technologies will be blurred. Mainstream web user agents provide overlapping adaptation features with assistive technology. For instance, ZoomText contains a special reading environment in which text is reformatted for easier reading, as well as fonts, contrasts, and magnification levels can be customized.[8] In an overlay of adaptation layers, the user could customize the display options at the operating system level, at the browser level, at the reader level, and at the level of the assistive technology used (i.e. screen magnifier). In that sense, we suggest investigating the superposition [49], the complementarity or the replacement of assistive technologies and mainstream user agents, as well as exploring adaptive strategies used by PVI to reach their goals in these environments stacking adaptations. To facilitate the customization needed by numerous adaptation layers, we suggest deeper investigating solutions in which all users can create flexible and portable personal profiles that customize interfaces to their needs [29]. For instance, a disability profile approach has been investigated in the context of Open Educational Resources [60]. However, the task will be difficult because few people are aware of current accessibility features [61].

This research provides a rich description of the adaptation applied to address a wide variety of users, and illustrates this phenomenon through multiple perspectives. Rich

[8] ZoomText User Guide, January 2021.

descriptions obtained by GT are valuable because they serve as sources of new domain knowledge, and new phenomena must be documented and understood before explaining their causes and effects [62]. We call for further investigations about the reason for the misalignments exposed and analyze in-depth adaptation methods and techniques of both perspectives.

4.1 Limitations

The main limitations of this study are the following. Firstly, we covered a limited scope that caused a small sample of scientific publications. However, we believe that the varied adaptation coverage reflects well the subfield of research. Secondly, to prevent the use of Scopus as a unique data source, we recommend including another one such as Web of Science. Thirdly, we retained three ICT leaders, of which adaptation occurs the most often at the operating system level. Somewhat, we believe that typical cases we selected faithfully represent the landscape of mainstream accessibility on the web. Fourth, taking multiple perspectives does not allow to compare data in all aspects (i.e. industry gives only a few details about the development process). We minimized this limitation by creating a complete picture by analyzing blog articles, projects, and features related to accessibility.

5 Conclusion

This research is born from the observation that PVI are a heterogeneous population with different needs in terms of access to ICT, applying generic web accessibility guidelines does not guarantee a usable experience to the full range of PVI, and accessibility moved to a universal, proactive, and holistic approach. Considering all these elements, taking the path of adaptation seems a promising solution.

In this study, we investigated the adaptation of web content in a context of universal access by focusing on the wide range of people with low vision. We reviewed scientific publications and mainstream web user agents over the last decade. Our findings show that both perspectives covered adaptation differently. Academics mostly focused on adaptivity, indirectly involved users, and are still investigating the benefits and drawbacks of adaptability and tailored UI under different contexts of use. In the mainstream web, adaptability is widespread, solutions become universal with ever more advanced accessibility features, but must be proved empirically. Finally, there is no single approach to address accessibility issues through adaptation. Especially in environments that are stacking adaptation layers, both perspectives need to be better aligned to provide accessible and usable interactive systems to people with visual disabilities.

Appendix 1: Codebook

Category	Codes	References
Community of focus*	People with visual impairments (PVI); blind (B); people with low vision (PLV); people with color vision deficiency (PCVD); maker (M, e.g. web designers, developers); sighted or people without vision disabilities (S)	[1]
Study method[a]	Controlled experiment; interview; survey; usability testing; accessibility testing; case study; focus group; field study; workshop or design session(s); observation; other	[20]
Participant groups*	PVI; people with disabilities (PD); specialists (e.g., therapists, teachers); people without disabilities; researchers; no user study; other	[1, 20]
Use of proxies*	Yes; No	[20]
Contribution type[a]*	Empirical; artifact; methodological (accessibility guidelines/standards; adaptation technique; model); theoretical (e.g. model, ontology); survey	[20]
Target population (who is targeted)	Particularist (one disability, e.g. vision); Universalist (e.g. multiple disabilities, people with and without disabilities such as sighted and blind)	[5, 12, 25]
Design Perspective (who is involved)	Maker-centered; user-centered; maker/user-centered; multiple stakeholders	[5, 12, 25]
Accessibility Efforts (when and how accessibility is included)	Reactive (a posteriori adaptation) or proactive (accessibility thought by default). If proactive, can be direct (involve at early project stage; the design respect WCAG), undirect (start from a common accessibility issue), or N/A for design and evaluation phases	[5, 12, 25]
Adaptation Type*	Adaptability (user-invoked adaptation); adaptivity (system runtime adaptation); tailored (adaptation at design time, authored by the maker or generated by a system)	[13, 32]
Adaptation On* (what is adapted?)	Structure; style; content, behavior (of UI parts)	[33]

(*continued*)

(*continued*)

Category	Codes	References
Adaptation Source* (adapt from what)	User features (knowledge, preferences, task, disability, and position), technology used (device, connectivity, browser)	[32, 39, 40]

Note: An (*a*) indicates a category only for the academic perspective. A star (*) indicates if multiple codes are possible for the category.

Appendix 2: Sample of PVI Organization Websites

PVI Organization	Acronym	URL	Adaptation
African Union of the Blind	AFUB	http://www.afub-uafa.org/	Adaptability
Kenya Union of the Blind	KUB	http://kub.or.ke/	
The Royal Society for the Blind	RSB	https://www.rsb.org.au/	Adaptability
All Russia Association of the Blind	VOS	https://www.vos.org.ru/	Adaptability
Confédération Française pour la Promotion Sociale des Aveugles et Amblyopes	CFPSAA	http://www.cfpsaa.fr/	
Unione Italiana dei Ciechi e degli Ipovedenti	ONLUS-APS	http://www.uiciechi.it/	
Organização Nacional de Cegos do Brasil	ONCB	http://fundacaodorina.org.br/	Adaptability
Unión Nacional De Ciegos Del Uruguay	UNCU	https://www.uncu.org.uy/	
Qatar Social and Cultural Centre for the Blind	QSCCB	http://www.blind.gov.qa/en	Adaptability; Tailored UI
Canadian National Institute for the Blind	CNIB	https://www.cnib.ca/	Adaptability
American Foundation for the Blind	AFB	https://www.afb.org/	Adaptability
National Federation of the Blind	NFB	https://nfb.org/	
American Council of the Blind	ACB	https://www.acb.org/	Adaptability

(*continued*)

(*continued*)

PVI Organization	Acronym	URL	Adaptation
All India Confederation Of The Blind	AICB	https://www.aicb.org.in/	Adaptability
National Federation of the Blind	NFB	http://www.nfbindia.org/	
National Association for the Blind	NAB	http://www.nabindia.org/	
Pakistan Association of the Blind	PAB	https://pabnpk.org/	

Note: PVI Organizations (n = 17) are part of the World Blind Union, and in the top two countries in their respective region according to the DARE Index 2020.

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