International Journal of Human–Computer Interaction

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/hihc20

Accessibility Design Issues beyond the Standards of Government e-Services for People with Low Vision

Aritz Sala, Myriam Arrue, J. Eduardo Pérez, Sandra M. Espín-Tello & Lourdes Moreno

To cite this article: Aritz Sala, Myriam Arrue, J. Eduardo Pérez, Sandra M. Espín-Tello & Lourdes Moreno (2023): Accessibility Design Issues beyond the Standards of Government e-Services for People with Low Vision, International Journal of Human–Computer Interaction, DOI: 10.1080/10447318.2023.2241609

To link to this article: https://doi.org/10.1080/10447318.2023.2241609

Published online: 06 Aug 2023.

INTERNATIONAL JOURNAL OF HUMAN–COMPUTER INTERACTION
https://doi.org/10.1080/10447318.2023.2241609

Accessibility Design Issues beyond the Standards of Government e-Services for People with Low Vision

Aritz Sala[a], Myriam Arrue[a], J. Eduardo Pérez[a], Sandra M. Espín-Tello[b], and Lourdes Moreno[c]

[a]EGOKITUZ, University of the Basque Country, San Sebastián-Donostia, Spain; [b]IIS Aragón, Universidad de Zaragoza, Zaragoza, Spain; [c]HULAT, University of Carlos III, Madrid, Spain

ABSTRACT

Governments have been investing considerable resources into making their services to citizens available through the Internet. However, people face barriers when accessing these e-services. Barriers affect people with disabilities to a greater extent. Taking into account the accessibility-in-use in addition to the required standards while designing these services would mitigate some of these issues. In this work, five e-services from the Spanish government were selected from among the most used ones and tested with fifteen participants, of whom ten participants belong to the group of people with low vision. Different qualitative and quantitative measures were analyzed to determine whether participants with low vision had more difficulties performing the tasks and to identify the design issues required to achieve improvement. The results highlighted some issues to be incorporated into the complexity and cognitive accessibility evaluations of e-services to anticipate difficulties (e.g., error prompting/prevention mechanisms). In addition, contributions to existing accessibility standards are proposed to be considered in the design of the e-services.

KEYWORDS

Web accessibility; people with low vision; e-government; e-services; online forms; user evaluation; assistive technology; user experience; usability testing

1. Introduction

All around the globe, the use of information and communication technology (ICT) on public administration websites, more commonly known as e-government, has been steadily increasing in recent years. E-participation indicates using ICTs to facilitate citizen participation in government-related processes, encompassing administration, service delivery, and policy formulation. E-participation shares close ties with e-government and e-government participation and enables citizens to connect with each other through ICTs (Jafarkarimi et al., 2014; Macintosh, 2004). Compared with their previous analysis, the United Nations identified significantly increased electronic participation (e-participation) in 2022 (United Nations, 2022). E-government encourages citizens to participate in administrative processes to a greater degree and provides them with a way to complete administrative tasks via e-services more easily, thus increasing citizens' independence. Unfortunately, carrying out many routine administrative tasks in person has not been possible during the last couple of years because of the COVID-19 pandemic, forcing people to change how they interact with the public administration.

According to the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD), access to ICT, including the Internet, is considered a basic human right (UNCRPD, 2006). Thus, many countries have proposed a range of guidelines and laws to address Web accessibility. Over the last few years, directives and laws have been implemented in numerous countries to address web accessibility issues, which are normally mandatory for government websites. Moreover, the European Parliament approved the European Directive on Web Accessibility for Public Sector Websites in October 2016 (European Parliament, 2016). Nevertheless, people with disabilities continue to face accessibility barriers on some e-government websites even though progress has been made recently (ELMER, 2011; OECD, 2015). Several studies prove that most e-government websites do not fully comply with the current laws in force (Olsen, 2010; Paternò & Schiavone, 2015). Said studies evaluated public websites' compliance with, for example, the WCAG standard accessibility guidelines (W3C, 2018) through both manual and automated evaluation methods.

E-services can be used to carry out a wide range of tasks, such as employment searches, seeking out social care services, making appointments with various public administrations, etc. Completing web forms is one of the basic ways in which citizens interact with government e-services (Money et al., 2011; Winckler et al., 2010). A report issued by the Organisation for Economic Co-operation and Development (OECD) found that administrative forms have been filled out electronically by a significant number of individuals and businesses, 33 and 78%, respectively (OECD, 2015). However, unless these e-services are completely accessible, certain users may experience difficulties when accessing them (Jaeger, 2006). These difficulties are more pronounced with regard to government e-service websites since they

CONTACT Myriam Arrue myriam.arrue@ehu.eus EGOKITUZ, University of the Basque Country, San Sebastián-Donostia, Spain

often require more interaction from citizens, and they have to face complex interaction elements not included in informational web pages, such as calendars, controls, captcha, etc. Most public websites continue to present accessibility barriers that may exclude many individuals with disabilities (Gambino et al., 2016; Shi, 2006a). This is why accessibility-in-use evaluations are crucial for e-services, as they enable the detection of accessibility barriers that may not be detected with any other evaluation method (Vigo & Harper, 2013a, 2013b).

One of the collectives that would potentially benefit most from the use of e-services is people with low vision. However, due to the fact that web experiences are primarily based on interacting with visual elements, people with low vision are also the collective who may be most likely to suffer from the accessibility barriers found on these websites.

The number of individuals living with some manner of disability has been steadily increasing all around the world. According to the World Health Organization (WHO), it is estimated that the percentage of the world's over 60 year-old population will nearly double between 2015 and 2050 from 12 to 22% (WHO, 2022). A significant increase in disabilities due to the rise of chronic diseases caused by age-related issues in all areas of the globe has been predicted in the Global Burden of Disease study (IHME, 2017) carried out by the WHO and the World Bank. According to WHO estimates, around 246 million people worldwide are considered to have "low vision" (WHO, 2014). This impairment is found in individuals with a visual acuity of 20/70 in the eye with the healthiest vision and is one that cannot be corrected with glasses, contact lenses, medication, or surgery (Whittaker et al., 2016). Furthermore, the vision of a portion of this population is not stable and may degenerate even further over time.

In light of this situation, this article has evaluated five e-service websites with regard to their accessibility. Additionally, these government e-services have been tested by fifteen participants. Ten of these fifteen participants are people with low vision. With this evaluation, we hope to make headway with two research questions: (1) Whether participants with low vision have more difficulties than non-disabled participants in completing tasks in the e-services, (2) which steps in the process of filling in online forms of the e-services is particularly difficult for participants with low vision to shed light on some ways to develop more accessible e-services.

After this introduction, background and related work are included in Section 2. In the following Sections, the experimental study with users is presented: Section 3 describes the method used, followed by the results of the experimentation in Section 4. Section 5 provides a discussion of the results. Finally, conclusions and future and ongoing work are presented.

2. Related work

Web accessibility continues to be a global issue, as evidenced by the legislation that has been passed in numerous countries around the world (Moreno & Martínez, 2019a). Accessibility barriers can be found on many public organization websites despite legislative efforts having been made (Paternò & Schiavone, 2015). Providing individuals with disabilities equal e-participation in digital services allows them to access the enormous potential job market, information, and other services in general, while, at the same time, promoting their social inclusion in the digital society. For this reason, equal access to all government e-services must be made a priority (Bonacin et al., 2010; Carter & Markel, 2001; Moreno et al., 2018). This section presents related work, such as evaluation studies of accessibility in government websites and web forms, an existing interactive element in e-services processes. In addition, work on how people with low vision interact with the contents of government websites is presented.

2.1. Web accessibility assessment studies

According to the current regulatory framework in force, government e-services are required to comply with Section 508 (Access-Board, 1998), the European EN 301 549 (ETSI, 2021), and the WCAG 2.1 (W3C, 2018) standards, among others (Moreno & Martinez, 2019b). To assess the accessibility of government e-services, numerous studies, based on the previously mentioned standards, have been carried out over the last ten years. The results of these studies have shown that many government websites do not comply with the current laws. Some of the most relevant studies with regard to this issue are the Government Website Accessibility in Slovenia (Kous et al., 2021), Australia and China (Shi, 2006b), Alabama (King & Youngblood, 2016; Potter, 2002), Italy (Gambino et al., 2016), and Africa (Verkijika & De Wet, 2017). The results of a study on the accessibility issues found on government websites in the UK showed that said websites do not fully comply with the guidelines established by accessibility laws (Kuzma, 2010). Even though the Section 508 law has been in effect for nearly a decade, some articles have reported that compliance with this law by federal government websites in the United States continues to be low (Jaeger, 2006; Lazar & Olalere, 2011). While evaluation technology was used in all these works, most of these studies limited themselves to evaluating only with automatic testing methods, and only the homepage compliance with the WCAG guidelines is evaluated (Potter, 2002; Shi, 2006a; Youngblood, 2014). Some of them follow better testing methodologies based on a combination of automated and manual testing (Kuzma, 2010).

Examples of the inclusion of people with disabilities in assessing government services websites in the literature are scarce. In Jaeger (2006), data was collected and accessibility was evaluated in this study by a range of methods: policy analysis, expert testing, user testing, automated testing, and webmaster questionnaires. Combining these methods provided a unique perspective regarding the accessibility issues detected. Based on Section 508 guidelines, this study assessed the main sites used by citizens to interact with government e-services and those in which persons with

disabilities are most interested. A total of ten individuals with either visual or mobility impairments participated in the user testing. Through user testing, issues that were not detected through other methods were revealed in the results. Additional studies that assessed websites not associated with government e-services showed similar results. For example, in the study described by Power et al. (2012), blind users evaluated 16 websites, and the results showed that 49.6% of the accessibility problems encountered were not related to any of the checkpoints established in the WCAG 2.0. For this reason, assessing websites with the participation of users capable of detecting accessibility barriers while interacting with webpages is fundamental.

2.2. Web forms accessibility assessment studies

As stated by Moreno et al. (2018), special care must be taken when evaluating forms. Very few studies evaluate the flow processes found in web forms. The manner in which web form design influences accessibility and usability on the part of users with cognitive impairments has been examined by certain studies. Certain research, such as Lines et al. (2007) focused on improving the online forms found on public websites for the elderly. This work offered general recommendations for the design of online forms, such as providing spacing between questions and answers, simplifying the structure of questions, customizing forms, etc. Nevertheless, techniques for implementing these requirements were not suggested. As regards measuring the complexity of online forms, Money et al. (2011) developed a set of metrics (Bespoke Online Form Selection–BOFS) to assess the complexity of these forms for older adults, which were subsequently evaluated in a study with 80 participants (Elliman et al., 2008). However, qualitative data obtained by applying think-aloud methods were used to carry out the evaluation, and real user interaction data were not analyzed. Currently, no international standards for accessible design patterns exist, and official national patterns must be relied upon, such as those found in the United Kingdom (UK Government, 2022). Norway is another country where this complementary pattern is used (ELMER, 2011). Furthermore, an initiative in the United States encourages the creation of common guidelines for the user interfaces of public forms found in all government agencies, which will facilitate access to all the federal government's e-services for all citizens (Standards.usa.gov US, 2022). These initiatives aim to simplify e-services and improve communication between users and the public sector.

2.3. Web interaction studies of people with low vision

With regards to how individuals with low vision interact with the Internet, certain works specifically focus on how users with low vision interact with screen magnification technology (Gowases et al., 2011; Legge et al., 2001; Moreno et al., 2021; Xiao et al., 2010). According to all these sources, difficulties are experienced by users when interacting with screen magnification tools. One of the most common issues these users have is that they can only see a portion of the web page they are interacting with. Additionally, users may lose context due to the fact that, when using this software, users must move their field of vision frequently. Furthermore, many magnification methods require the user to perform horizontal scrolling tasks. The use of specific screen magnifiers with a responsive web design that requires fewer horizontal scrolling tasks is compared in the study (Hallett et al., 2015). Rather than using the original web design and screen magnifiers, responsive designs were more user-friendly. Some efforts toward evaluation have been made to order and group the WCAG's success criteria by user profiles. The Barrier Walkthrough Method proposed by Brajnik (2011) is one example of an attempt to group the success criteria by user categories. This method adapts the heuristic walkthrough method used for usability investigations where barriers replace the principles. The basic primary idea is that it is better to start from known types of problems rather than using general design guidelines for testing and assessment purposes. This has made it possible to perform accessibility evaluations based on certain user groups' specific needs or categories (blind people, people with low vision, motor-impaired people, etc.), enabling the identification of specific barriers for said groups. As with the WCAG guidelines, the success criteria that can be applied to forms are also included in each user category and other criteria types. The Accessibility Requirements for People with Low Vision (W3C, 2023), in which the needs people with low vision have when accessing electronic content are described, has been launched by the World Wide Web Consortium (W3C). This working draft contains general guidelines on how to present information (font, text size, style, etc.). However, it does not make reference to the common interaction elements found on online forms (i.e., input fields, field labels, action buttons, feedback, etc.).

2.4. Conclusions

Fundamentally, the studies found reflect accessibility barriers to access to government e-services. This situation entails a loss of opportunities for people with disabilities in domains, such as employment, education, and social. This loss of rights must be avoided by governments. Given the significant increase in digitally offered services, governments must work to guarantee the accessibility of government e-services to people with disabilities.

The clear conclusion is that research regarding the accessibility of the forms found on government e-services is lacking. This is especially true for users with low vision, where the study has been limited to using mostly automatic testing evaluation technology. Therefore, as shown in this work, the interaction between users with low vision and web forms of e-services must be more diligently and thoroughly researched.

Table 1. Information about the participants in the study.

User ID	Sex	Age	Web experience	Vision issues	Assistive technology
P1	M	59	High	–	–
P2	M	28	High	–	–
P3	W	35	High	–	–
P4	M	33	High	–	–
P5	W	24	High	–	–
P6	M	57	High	Legally blind	Browser zoom and Windows Magnifier (400%)
P7	M	23	High	Legally blind	Browser zoom
P8	W	28	High	Low Vision	Browser zoom
P9	M	19	High	Legally blind	Browser zoom
P10	W	31	High	Low Vision	Browser zoom
P11	W	37	High	Low Vision	Browser zoom
P12	W	71	Low	Low Vision	Browser zoom
P13	W	62	Low	Low Vision	Browser zoom
P14	W	33	High	Low Vision	Browser zoom
P15	W	21	High	Low Vision	Browser zoom

3. Experimental study

To study the interaction between users with low vision and government e-services, we carried out a web-based experiment including people with low vision and people without disabilities. The main task was to follow the procedure for making an appointment with e-services. Interaction data was recorded during the experimental sessions for later analysis. In addition, participants were interviewed to gather subjective measures regarding their experience. This study was approved by the Ethics Committee for Research Involving Human Beings from the University of the Basque Country (CEISH-UPV/EHU, M10_2019_037).

3.1. Participants

The participants were recruited according to the following inclusion criteria:

- Adult users without visual impairment with experience browsing the web.
- Adult users with visual disabilities (low vision or legally blind[1]) who are users of screen magnifiers and with experience browsing the web.

A total of fifteen participants took part in this study (P1–P15). Ten participants (P6–P15) belonged to the group of people with low vision (mean = 38.2 years, $SD = 17.5$), three of them men (P6, P7, and P9) and seven women. Three participants (P6, P7, and P9) were legally blind, whereas the others had low vision. The experiment consisted of a sole session of ~1 hr. Participants with low vision performed the experiment using their usual assistive technology, which was the browser zoom for all of them except P6, who also used the Windows Magnifier. The other five participants (P1–P5) had no visual disability. The mean age of the participants was 35.8 years ($SD = 12.2$), and four of them were women (P3, P5, P8, and P10). All participants reported having high experience with computers and Web browsing except P12 and P13, the two eldest in the sample. All participants reported having high experience browsing the web (they browse more than twice a week) except P12 and P13, whose browsing frequency is once a month.

The experimental sessions were carried out in two locations: a laboratory at the Informatics Faculty of the University of the Basque Country (P1–P10) and a laboratory at the University Carlos III of Madrid (P11–P15). Table 1 shows information about the participants in the study.

3.2. Apparatus

The same computer was utilized in all sessions: a Dell Precision M6700 laptop with these characteristics: intel core i7-3740M 2.70Gh processor with 8 RAM and 512GB of disk storage. The operating system was 64 bits version of Windows 7 Enterprise. A virtual machine of Windows 7 Enterprise was specifically created for the experimental sessions to ensure consistency between experimental sessions and the correct running of the assistive technology required by each participant. It included Mozilla Firefox 44.0.1, ZoomText 2019, Jaws 2019, and Windows Magnifier. The virtual machine was played by VMPlayer version 15.0.2. An additional widescreen LCD monitor (aspect ratio 16:10) with a diagonal size of 24 inches and a display resolution set to 1920×1200 pixels was used to present stimuli to participants.

All sessions were video-recorded and the interaction data (page load, start and end of tasks, links visited, scroll, clicks, etc.) was collected by the RemoTest platform previously implemented by some of the authors (Valencia et al., 2015; Arrue et al., 2019).

3.3. Stimuli

Five Spanish government e-services were selected as stimuli for the experiment. The selection was made taking into consideration the results of the study described in (EDAD2020, 2022). In this study, 93% of people with disabilities in Spain reported using health services and 14% social services in the last 12 months. The selected services were: DNI,[2] the public website of the Ministry of Home Affairs; SPE,[3] the public website of the Public Service of State Employment; SGS,[4] the public website of Social Security; DON,[5] the public website of social services in the Donostia-San Sebastián Town Hall; and OSA,[6] the public website of the public health service in the Basque Country.

All the selected e-services included information about accessibility on a dedicated web page (through a link labeled "Accessibility"). WCAG guidelines were mentioned in every case and the conformance level to these guidelines was specified: DNI and SPE Double-A of WCAG 1.0, SGS and OSA level AA of WCAG 2.0, DON level AAA of WCAG 2.0. However, we performed an accessibility evaluation based on the Barrier Walkthrough Method (Brajnik, 2011) for the category of people with low vision to detect the presence and severity of any accessibility barriers in the web pages of the e-services. The results summary of this evaluation can be found in Table 2. The barriers can be critical, significant, or minor depending on their importance and consequences (Brajnik, 2011). It can be seen that all the e-services contain barriers.

The online-forms with more barriers detected were in the DNI and OSA services, with a total of five barriers in both of them (four significant and one critical in DNI, and four significant and one minor in OSA), followed by SGS with four (one critical, one significant and two minor), SPE with three (one significant and two minor), and DON with two minor barriers. Insufficient visual contrast was a common barrier in all the e-services. In two of them (DNI and SGS) the severity of the barrier was critical, in one (OSA) it was significant, and in the other two (SPE and DON) it was minor. Inflexible page layout was a significant barrier in three e-services (OSA, DNI, and SPE), and minor in one (SGS). Missing layout clues were identified as a significant barrier in two (DNI and OSA) and as a minor in another two (SPE and DON). Significant barriers were detected concerning rich images badly positioned, as well as image maps in DNI, widely formatted forms in OSA, and images used as titles in SGS. We also detected minor barriers concerning too long lines of text in two online-forms (OSA and SGS).

3.4. Web forms filling in process

The filling in of the online-forms in e-services usually follows a process including several steps. All the selected e-services followed this kind of process for "making an appointment." We identified common steps in all of them, including the following: providing personal information (UserId, "User Identification"), selecting the service (ServSel, "Service Selection"), selecting the location (LocSel, "Location Selection"), selecting the date and time (DateSel, "Date Selection"), answering security questions (SecQue "Security Question") and the date and time confirming step where the selected date and time are presented and the user has to confirm (Confirm, "Confirmation step"). However, the information required from users in each step varies in the e-services. In addition, the number of web pages is also different for the same step in the e-services, spreading out the content of the same step across several web pages in some cases and joining contents of different steps in the same web page in other cases. For example, regarding the UserId step, the zip code and the identification (ID) card number are required on the first page of the SPE service whereas the name and surname of the user are requested on the second page. On the other hand, the DNI service joins the UserID step with the SecQue step as it presents different elements for user information introduction as well as the CAPTCHA element on the same web page (on page 2). Table 3 shows the total number of pages for each e-service as well as the pages where different steps of the process are presented. It should be mentioned that the first page of DNI is only an introductory page with textual information containing only one button at the bottom of the page, so this was not considered as a step in the process. The ServSel step is the one that is divided into more web pages in the OSA e-service (a total number of 3 web pages, specifically web pages 2, 3, and 4). The first page of SPE and SGS e-services are the one combining components of further different steps of the filling in process (UserID, ServSel, and SecQue steps in SPE and UserID, LocSel, and SecQue in SGS).

An evaluation of the cognitive accessibility of the e-services was performed based on the design patterns proposed in the "Making Content Usable for People with Cognitive and Learning Disabilities (COGA)" documentation of W3C to measure the cognitive load of the filling in process in the different e-services (W3C, 2021). For this, the concrete design patterns concerning sets of pages and step processes were selected:

- "Plain Process," which corresponds to the 4.2.4 design pattern (Make Each Step Clear). It evaluates if a clear step-by-step process is followed, that is, if users are

Table 2. Summary of the results obtained in the evaluation of the e-services based on WCAG conformance and barrier walkthrough method (BWM).

	WCAG	BWM			
	Conformance	Total barriers detected	Minor	Significant	Critical
SPE	AA (1.0)	3	2	1	–
DON	AAA (2.0)	2	2	–	–
OSA	AA (2.0)	5	1	4	–
DNI	AA (1.0)	5	–	4	1
SGS	AA (2.0)	4	2	1	1

Table 3. Information about the selected e-services (TNP: total number of pages in the e-service; Page N.: page number in the e-service). The shading represents the relation of steps of the process presented in each e-service web page.

		DON				OSA						DNI							SGS					SPE		
	TNP	4				6						7							5					3		
	Page N.	1	2	3	4	1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	1	2	3
Process steps	UserID																									
	ServSel																									
	LocSel																									
	DateSel																									
	SecQue																									
	Confirm																									

informed at which step they are in the process, the number of steps remaining before finishing the task, and if controls are provided for moving to previous and following steps.
- "Plain and Descriptive title," which corresponds to 4.2.1 Pattern (Make the Purpose of Your Page Clear). It evaluates if each page has a clear title that summarizes the purpose of the page.
- "Consistent and Recognized Design," which corresponds to patterns 4.2.2 (Use a Design that the User is Likely to Recognize and Understand) and 4.2.3 (Use a Consistent Visual Design). It evaluates if all pages in the service are based on a consistent design pattern.
- "Logical Structure," which corresponds to the design patterns 4.2.6 (Make the Relationship Clear Between Controls and What They Affect), 4.3.3 (Use a Clear and Understandable Page Structure) and 4.4.10 (Use White Spacing). It evaluates the use of presentation features to group the different content blocks: using controls for clearly recognizing regions, headings, graphic elements, or white spacing used to group and highlight information.
- "Help," which corresponds to design patterns 4.8.1 (Provide Human Help) and 4.8.2 (Provide Help and Alternative Content for Complex Information and Tasks). It evaluates if there are mechanisms for providing help to the users during the process.

Table 4 shows the results of the evaluation of these five criteria. OSA is the one e-service conforming to all the evaluated design patterns. DON and SGS e-services only fail the "Help" design pattern. SPE and DNI are the ones obtaining worse evaluations. They do not even conform to "Plain and Descriptive title" (SPE does not provide titles whereas DNI provides an inadequate title "Login to the system"). The "Help" pattern is the one with the worst results in this evaluation. The OSA service provides documentation with frequently asked questions and an explanatory image. All the selected e-services accomplish the "Consistent and Recognized Design" pattern as templates are applied in all cases to achieve consistency of web page design.

3.5. E-services components and complexity

There is a lack of uniformity between the design of the selected e-services which are composed of different form elements as well as having a different form structure. However, the information required of the user is similar in many steps.

Table 4. Cognitive accessibility evaluation based on W3C-COGA documentation.

	SPE	DON	OSA	DNI	SGS
Plain process	No	Yes	Yes	No	Yes
Plain and descriptive title	No	Yes	Yes	No	Yes
Consistent and recognized design	Yes	Yes	Yes	Yes	Yes
Logical structure	No	Yes	Yes	No	Yes
Help	No	No	Yes	No	No

Table 5 shows a summary of the interaction elements in each e-service step. In addition, it specifies the number of compulsory elements and the number of web pages for each step. The number of options displayed to the users for some of the interaction elements, such as radio button, select, image maps, and set of hyperlinks is shown in brackets. There are alternative paths for completing some steps which are identified in the table showing the number of options for each path separated by the character "/." In some cases, the number of options displayed to the users depends on the previously inserted data. These cases are identified in the table as "var."

The heterogeneity of the forms is tangible based on the information presented in Table 5. This heterogeneity can make some steps more complex for users. For example, there are a few steps where all the fields of the form have to be filled in (e.g., UserId in OSA, UserId in DON, ServSel in SPE, and SecQue in SGS). In these cases, users are not meant to decide which fields to fill in. The behavior of the users will vary in those cases where not all the fields are required as some users may notice that introducing some information is optional while others may not. These could affect their behavior, as some users will have to decide for each optional field whether to fill it in or leave it blank. Accordingly, the form elements showing different options to choose from may also add some difficulty when the number of options is high. Table 5 shows that the number of options varies between 2 and 52 (LocSel in SGS). This could also affect the user experience, as it is more difficult to select the correct one from 52 options than between two different options. DateSel step is a special case as the options presented by services depend on the appointment possibilities for the selected date (these cases are noted as "var"). Another special case is LocSel in DNI. There are alternative ways for choosing the province: the user could directly click on the image map displayed in the form to select a province or could first select the autonomous community from a list of links (the name of each autonomous community is a link) and then the province from a list of provinces for the selected autonomous community (list of links where each link is the name of a province). Users can choose between these two options that are displayed together in the form. This increases the complexity of the form since more items are shown together but at the same time, it does make alternative options available to the users.

The complexity of the selected e-services was measured based on BOFS metrics proposed by Elliman et al. (2008). These metrics consider the number of interaction elements and the number of options displayed to the user in a form. More interaction elements and more options increase the complexity of the form.

According to the obtained values, the ranking of evaluated e-services is, from less to more complex, as follows: SPE (58), DON (75), OSA (187), DNI (390), and SGS (459). In addition, BOFS metrics were calculated for each web page in e-services (Sala et al., 2020). Table 6 shows this information.

Table 5. Summary of the number of interaction elements in each process step (BUT: button; TXT: input text; CHK: checkbox; RAD: radio button; MAP: image map; SEL: select; HYP: hyperlink; CAL: calendar), the total number of interaction elements, the number of compulsory elements (required) and the number of pages of each step in the selected e-services.

	BUT	TXT	CHK	RAD	MAP	SEL	HYP	CAL	Total	Required	Num. pages
User identification											
SPE	2	5	–	–	–	–	–	–	7	6	2
DON	1	2	–	–	–	–	–	1	4	4	1
OSA	1	2	–	–	–	–	–	1	4	4	1
DNI	2	5	–	–	–	–	2	–	9	6	1
SGS	1	4	–	–	–	1 (3)	–	–	5 + 1 (3)	3 + 1 (3)	1
Service selection											
SPE	1	–	–	1 (9)	–	–	–	–	1 + 1 (9)	1 + 1 (9)	1
DON	–	–	–	–	–	–	–	–	–	–	–
OSA	7	–	–	2 (2)	–	–	–	–	7 + 2 (2)	3 + 2 (2)	1
DNI	–	–	–	–	–	–	3	–	3	1	1
SGS	2	–	–	1 (10)	–	–	–	–	2 + 1 (10)	1 + 1 (10)	1
Location selection											
SPE	–	–	–	–	–	–	–	–	–	–	–
DON	–	–	–	–	–	–	–	–	–	–	–
OSA	–	–	–	–	–	–	–	–	–	–	–
DNI	–	–	–	–	1 (50)	–	28	–	1 (50)/28	2/3	2
SGS	2	–	–	1 (8)+1 (3)	–	2 (52)	–	–	2 + 1 (8)	2	2
Date selection											
SPE	–	–	–	–	–	–	–	–	–	–	–
DON	6	1	–	var	–	–	–	1	8 + var	3	2
OSA	8	1	–	1 (2)+var	–	–	–	1	9 + 1 (2)+var	3 + 1 (2)	2
DNI	–	–	–	–	–	–	var	–	Var	1	1
SGS	4	–	–	var	–	–	–	–	4 + var	4	2
Security question											
SPE	1	1	–	–	.	–	2	–	4	2	1
DON	–	–	–	–	–	–	–	–	–	–	–
OSA	–	–	–	–	–	–	–	–	–	–	–
DNI	1	1	–	–	–	–	1	–	3	2	1
SGS	1	1	–	–	–	–	–	–	2	2	1
Confirmation											
SPE	2	–	–	–	.	–	–	–	2	1	1
DON	2	2	–	–	–	–	–	–	4	2	1
OSA	–	–	–	–	–	–	–	–	–	–	–
DNI	2	3	1	–	–	–	–	–	6	2	1
SGS	–	–		–	–	–	–	–	–	–	–

Table 6. BOFS metrics for the selected services: NP-page identification, PM-BOFS metric value for the web page, GM-BOFS metric value for the service.

	DON				OSA						DNI							SGS					SPE		
NP	1	2	3	4	1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	1	2	3
PM	10	6	45	10	10	6	9	12	13	129	22	10	145	8	10	70	86	202	45	21	185	13	33	14	4
GM			75					187						390						459				58	

The web pages obtaining the highest values are page 6 in OSA (129), page 3 in DNI (145), and pages 1 and 4 in SGS (202 and 185, respectively). Page 6 in OSA corresponds to DateSel step where eight buttons are displayed as well as an option for appointments variable showing each one as a radiobutton. Page 3 in DNI is the one for LocSel step containing the image map and the alternative list of options. Page 1 in SGS groups together fields for UserId, LocSel, and SecQue.

Based on the analysis performed on the forms of the selected services, grouping different steps in one page as in the case of SGS may increase the complexity of the form as users are required to introduce information regarding different aspects. However, in the case of OSA, where some of the fields on page 6 are optional and may vary depending on the date of appointment it is not clear whether there is an increase in complexity. In the DNI service, the complexity computed by BOFS is high due to the alternative selection method adding more elements to the form although this could be beneficial for some users, making this step easier in many cases. Therefore, we found some limitations of the BOFS metrics which could be summarized as follows: they do not distinguish between required and optional fields, they do not deal with variable numbers of options in a selection type element, or alternative ways displayed by the form for selecting from different options.

3.6. Tasks and materials

During this study, participants had to follow the procedure for making an appointment with each website. This task was divided into two parts: searching for the e-service and using the e-service (filling in the online forms in the e-service for making an appointment). The first part consisted of a browsing task starting on the homepage of each public website and searching for the first step of the online-form. The results presented in this article focus on the second part of the task, the analysis of the interaction of participants with

the online forms. More information about the results of the first part of the task can be found in (Sala et al., 2019).

To avoid any concerns about providing their own data, participants were provided with detailed personal data to be inserted. This data was printed in large format and before starting the task it was explained to the participant. It was not necessary to provide braille material for these participants.

The following is an example of the explanation given for the task in DNI: "Please access the Ministry of Home Affairs website and ask for an appointment to renew your ID card. The appointment should be in the office at Donostia-San Sebastian and on the first possible date before 10 am." An ID card printed in large format was provided to participants as they were asked to type in data from the card into the forms.

3.7. Procedure

First, participants were briefed on the purpose of the experiment and they then signed a consent form. Information on demographics and expertise was collected through a brief pre-session interview and the system was adjusted according to the participants' preferences. These preferences had been previously agreed with the participants. Experimenters contacted each participant to make an appointment for the study and asked about the assistive technology they use (browser zoom, windows magnifier, augmented mouse cursor, etc.). Therefore, experimenters configured the assistive technology for each participant before the appointment and it was verified with participants at the beginning of the session.

Then, participants were asked to perform a set of tasks, one on each public website; these tasks were presented in a counterbalanced order. The time for completing the task was limited to 10 min. This limit is based on previous studies involving participants with low vision (Sala et al., 2020). The initial web page for the task was the homepage of the service so the participants had to browse and find the online form. The experimenters followed the actions of the participants on a secondary screen. If the participant was having too much trouble finding the online form (e.g., they were browsing in a circular way, they did not see the link to the form even if they were on the correct path, etc.) the experimenters helped them to locate it (approximately after 4 min of browsing) so that they were able to continue with the second part of the task. The objective was also to determine the difficulties participants had in finding the online forms in the different public services. The results obtained in the first part of the task were published in (Sala et al., 2020). If participants required assistance in finding the online form the first part of the task would be annotated as a failure but not the second part devoted to filling in the online form. Both parts of the task were independently analyzed.

Regarding the second part of the task, participants had to deal with some official documents in two services (DNI and OSA). These documents were provided by experimenters and some information was required in the online forms to correctly make an appointment (the document issuing authority identification in DNI and the social security number in OSA). Some participants had difficulties locating this information and so the experimenters gave verbal assistance but this would not count as a failure in the second part of the task. We considered that these problems were not directly related to the interaction with the online form. Experimenters did not provide any other assistance during the online form completion process but observed the interaction on the secondary screen. Errors made when introducing information into the online forms, such as failure to provide the required information or using erroneous values/formats of inserted information, were annotated. If the participants did not complete the online form the task would automatically finish after 10 min and the task was registered as uncompleted.

Participants were interviewed at the end of each task for a particular website. The After-Scenario Questionnaire (ASQ) (Lewis, 1991) was applied to rate their satisfaction with the system. It consisted of three closed-ended questions with Likert-scale (1–7) type responses relating to the participants' satisfaction with the ease of completing the task, the amount of time it took to complete the task, and with the support information provided by the system. Any comments arising from participants about the experience and the barriers detected in the public websites and e-services were also annotated by the experimenter during the sessions. The comments were annotated in two different groups: comments relating to the first part of the task and comments relating to the second part of the task. Focusing on the comments relating to the second part of the task, experimenters would annotate in different subgroups to facilitate the later analysis: comments on the difficulties in filling in the fields, comments about the form buttons, comments about error prompting, general comments about the process of filling in the form and comments about the information to provide for the form.

3.8. Research questions and measures

In this study, the accessibility barriers issues faced by people with low vision when accessing e-services, as well as a measure of their complexity, are covered. Two research questions have been defined for the study, as summarized below:

- RQ1: Do participants with low vision have more difficulties than non-disabled participants in completing tasks in e-services?
- RQ2: Do participants find any step in the process of filling in online-forms particularly difficult?

To respond to Research Question 1 (RQ1), aspects, such as disorientation, and exploring whether the participants repeatedly access the same pages were analyzed. In addition, success in the completion of the tasks, the amount of time needed, and the number of errors made by participants with or without disabilities were also analyzed. To this end, the following measurements were calculated and analyzed from

the data gathered in experimental sessions: task completion ratio, time for completing the task, error events, and lost index. Data collected in the ASQ questionnaire is also analyzed so user satisfaction with the ease of use and the time employed for the tasks as well as their perception of the information provided by the system are measured.

The objective of Research Question 2 (RQ2) was to explore how the participants carried out the different steps in the process of the e-services, and thus detect which steps of the process entail greater difficulty. For this, the following measurements were calculated and analyzed from the data gathered in experimental sessions: time for completing each step in the process and errors-trials for completing each step in the process. In addition, annotations made by experimenters and participants' comments are also provided to detect the specific challenges faced during the tasks.

4. Results

In this section, we analyse the data collected from participants during experimental sessions.

4.1. Task completion ratio

Figure 1 shows the task completion ratios. The uncompleted tasks belonged to participants with low vision. All the participants without disabilities finished the tasks. Four of the ten participants with low vision completed the tasks in all the e-services. Participants with low vision obtained significantly worse values for the task completion ratio (Wilcoxon–Mann–Whitney $W = 762.5$, $Z = 2.52$, $r = 0.29$ with $p < 0.02$). OSA is the only e-service where all the participants with low vision were able to complete the task. SGS and DNI e-services had the lowest ratio of task completion for participants with low vision (five participants, 50% of participants with low vision, completed the task in SGS, and six participants, 60% of participants with low vision, in DNI). Regarding the assistance when completing the online-forms, participants without visual disabilities required it once (P4 in SGS) whereas people with low vision needed assistance six times (P7 in SGS and DNI, P9 in DON, P12 in OSA, P14 in DNI and P15 in DNI). Therefore, DNI and SGS were the e-services requiring more assistance.

4.2. Time for completing tasks

The time needed for completing tasks was calculated for the finished tasks. The task completion time was computed from when the first web page of the online form was loaded on the browser until the appointment was made. Figure 2 shows the mean time for completing tasks for both participant groups in each e-service. Participants with low vision obtained significantly higher values (Wilcoxon–Mann–Whitney $W = 285$, $Z = -2.55$, $r = 0.32$ with $p < 0.02$). DNI and SGS e-services are the ones obtaining the worst values for both groups. DNI is the one with the highest average value for participants with low vision (the average time for completing the task is 6′41″) whereas SGS is the one for participants without disabilities (the average time for completing the task is 4′11″). The e-services with the lowest average value are DON for participants with low vision (the average time for completing the task is 3′38″) and SPE for participants without disabilities (the average time for completing the task is 1′46″). The e-service with the most difference between the two groups is DNI (more than 50% increment for participants with low vision, 3′03″ for participants without disabilities, and 6′41″ for participants with low vision).

4.3. Error events

The errors that occurred during the process of filling in the forms were computed. Two types of errors were identified: not providing the required information and the erroneous value/format of inserted information. Figure 3 presents the

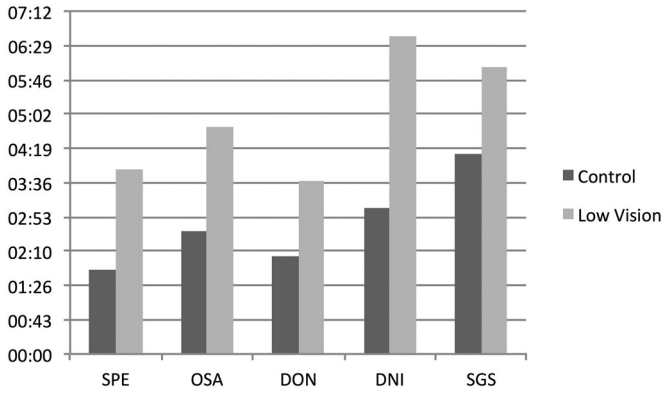


Figure 2. Mean task completion time for both participant groups (control-participants without disabilities and low vision-participants with low vision).

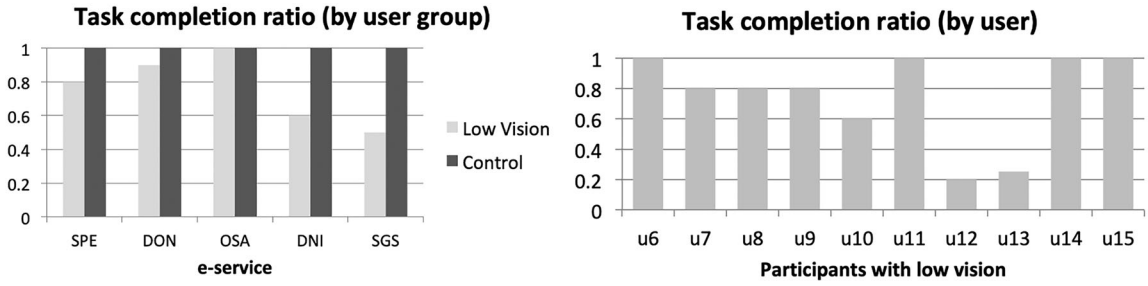


Figure 1. Task completion ratio (left) by user group, and (right) by participant with low vision.

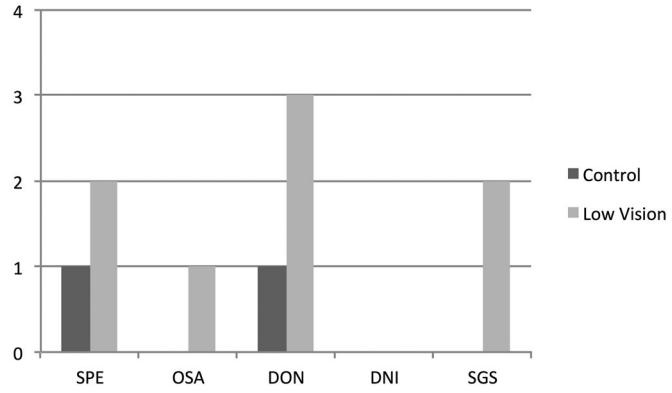


Figure 3. Error events caused by required fields.

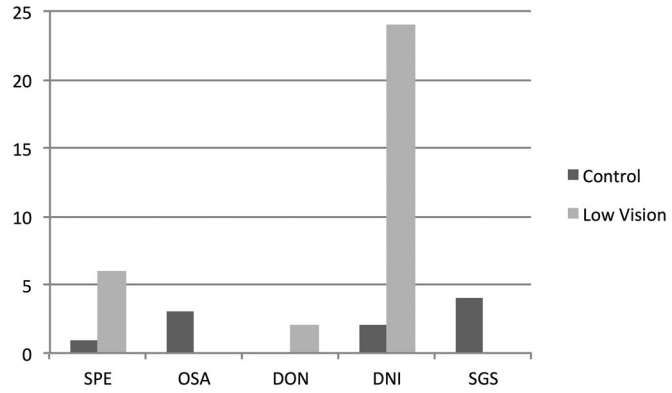
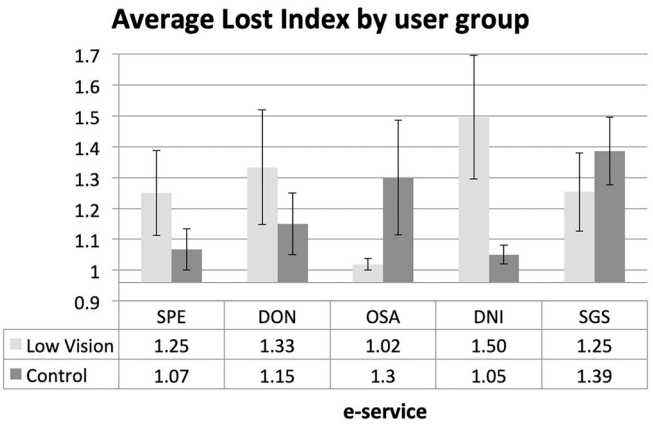


Figure 4. Error events caused by invalid value or format in the fields.

error events due to required fields not being filled in. Participants with low vision had more errors of this type (a total number of eight error events whereas there were only two events for participants without disabilities). Significantly more error events occurred during the interaction of participants with low vision (Wilcoxon-Mann-Whitney $W = 467.5$, $Z = -2.24$, $r = 0.26$ with $p < 0.03$). DON e-service is the one with more error events of this type (three errors for participants with low vision and one error for participants without disabilities). OSA and SGS e-services produced this type of error only for participants with low vision (one error event and two error events, respectively). Errors in both user groups were recorded in SPE (two errors for participants with low vision and one error for participants without disabilities). It has to be highlighted that the two error events for participants with low vision in SPE were triggered after correcting errors in another field as users were not aware that the required field needed to be refilled in the following trials (the system did not record and present the data previously introduced by users).

In addition, errors occurred when introducing an invalid value or format in the fields. These error events were more numerous. Figure 4 presents the results obtained for these error events. Participants with low vision obtained worse values for these events, a total number of 32 events whereas participants without disabilities registered only 10 events. The DNI e-service registered the highest number of events for participants with low vision (24 events), whereas SGS registered the highest number of events for participants



	SPE	DON	OSA	DNI	SGS
Low Vision	1.25	1.33	1.02	1.50	1.25
Control	1.07	1.15	1.3	1.05	1.39

Figure 5. Lost index, ratio of visited pages over the total for each service and user group. Error bars represent ±1 standard error.

without disabilities (four events). Some of these events occurred when the system detected an error, but the participants were not able to correctly detect the introduced erroneous data so the error was triggered again. This occurred in the DNI e-service for participants with low vision (15 of the 24 events were of this type).

4.4. Lost index

Figure 5 shows the ratio of visited pages and the total number of web pages for each e-service for participants completing the task (a value of 1 means the participant could complete the task without repeating any step of the process whereas a greater value means more difficulties finishing the task). In general, participants obtained mean values close to 1. Participants with low vision appeared to repeat more steps in SPE, DON, and mainly in DNI (1.25, 1.33, and 1.5, respectively). However, we did not find statistical significance for this measure. Participants without disabilities obtained a high value in OSA (1.3), whereas participants with low vision obtained a value close to 1 for this e-service (1.02). The closest values between both groups were obtained in SGS (1.25 for participants with low vision and 1.39 for participants without disabilities).

4.5. Step completion time

The average time needed to complete each step of the process in the e-services was computed. The time was obtained by calculating the interaction time for each participant with the components included in each step (the time introducing information in the fields for each step, see Table 5). Figure 6 shows the results obtained for each step in e-services. Participants with low vision obtained significantly higher values for step completion times (Wilcoxon–Mann–Whitney $W = 4308$, $Z = -4.1$, $r = 0.27$ with $p < 0.01$). They obtained the highest values for all steps except in DateSel step in DON and SGS (an average of 29.70 s for participants without disabilities and 18.70 s for participants with low vision in DON e-service; 14.30 s for participants without disabilities and 13.50 s for participants with low vision in SGS service), Confirm step in SPE e-service (an average of 8.60 s for

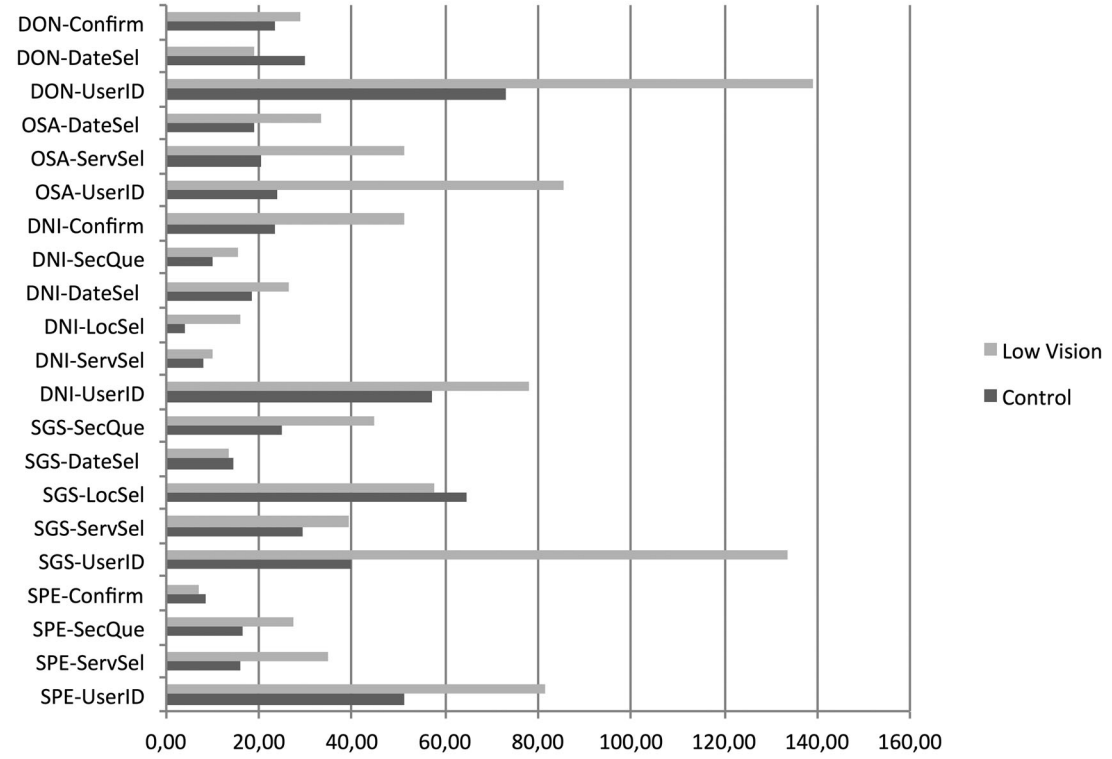


Figure 6. Completion time (in seconds) for each step in the process of tested e-services by user group.

participants without disabilities and 7.20 s for participants with low vision) and LocSel step in SGS e-service (an average of 64.74 s for participants without disabilities and 57.61 s for participants with low vision). The UserId step registered the highest values of completion time for all e-services and for both participant groups. In this sense, the DON e-service obtained the highest results and SGS was the one with the highest difference in values for UserID between the two groups (39.9 s for participants without disabilities and 133.4 s for participants with low vision).

4.6. Errors-trials for completing steps

Failed attempts for each step were also computed, referring to the average number of erroneous trials by user group (due to any type of error). This data is shown in Figure 7 (only steps with failed attempts are included in the figure). Participants with low vision obtained significantly higher values for error-trials in general (Wilcoxon–Mann–Whitney $W = 4171.5$, $Z = -2.23$, $r = 0.15$ with $p < 0.03$). Focusing on each step, participants with low vision took significantly longer for all steps except for DateSel, the results of the Wilcoxon-Mann-Whitney test were the following: $W = 315$, $Z = -2.93$, $r = 0.35$ with $p < 0.01$ for UserId, $W = 186.5$, $Z = -2.41$, $r = 0.33$ with $p < 0.02$ for ServSel, $W = 106.5$, $Z = -2.12$, $r = 0.34$ with $p < 0.04$ for SecQue, $W = 12.5$, $Z = -3.07$, $r = 0.65$ with $p < 0.01$ for LocSel. The results show that 78% of failed attempts corresponded to participants with low vision (a total number of 13 failed attempts were computed for participants without disabilities, whereas 47 were failed attempts for participants with low vision). The SecQue step registered the worst values for this parameter. Participants with low vision had difficulties with this step in DNI and SPE e-services. DNI returned greater differences in values obtained by both groups (an average of 0.2 failed attempts for participants without disabilities and 1.6 for participants with low vision). This step in the SGS e-service presented difficulties only to participants without disabilities (an average of 0.8 failed attempts).

4.7. Results of the ASQ questionnaire

The After-Scenario Questionnaire (ASQ) consisted of the following three questions asked to participants at the end of each task: "I am satisfied with the ease of completing the task" (ASQ1), "I am satisfied with the amount of time it took to complete the task" (ASQ2) and "I am satisfied with the support information provided by the system" (ASQ3). Each question was rated on a Likert-scale between 1 and 7 points, 1 corresponded to completely dissatisfied and 7 to completely satisfied. Table 7 shows the mean results obtained by each service and user group.

For ASQ1 the service obtaining the best result is SPE for participants without disabilities (5.4) whereas OSA is the one with the best result for participants with low vision (5.8). It is remarkable that OSA obtains good results for participants without disabilities as well (5.2). Both groups gave similar values to DNI (3.8 for participants without disabilities and 3.3 for participants with low vision). DNI is the service rated worst for participants without disabilities whereas SGS is rated worst for participants with low vision (2.9). SGS is the second service with the lowest rates for participants without disabilities.

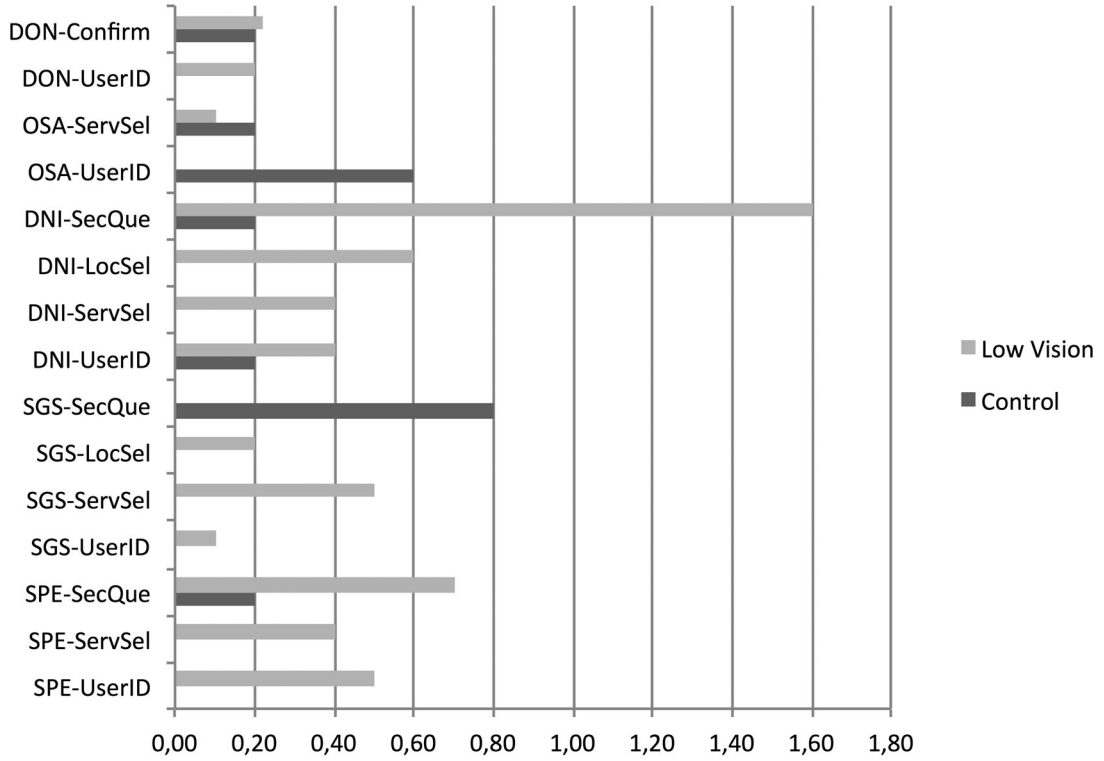


Figure 7. Average failed attempts for each step in the process of tested e-services by user group.

Table 7. Summary of the results obtained in the ASQ post-session questionnaire for each service and user group (Ctrl: participants without low vision; LV: participants with low vision; mean: mean values considering all participants in both groups).

	ASQ1			ASQ2			ASQ3		
	Ctrl	LV	Mean	Ctrl	LV	Mean	Ctrl	LV	Mean
SPE	5.4	4.1	4.5	5.4	4.4	4.7	4.6	3.6	3.9
DON	4.8	5.2	5.1	5	5.3	5.2	4.4	4.8	4.6
OSA	5.2	5.8	5.6	5	5.8	5.5	4.4	5.7	5.2
DNI	3.8	3.3	3.5	3.4	2.8	3	4.2	2.8	3.3
SGS	4	2.9	3.3	3.6	3	3.2	3.4	3.2	3.3

For ASQ2 SPE is the service with best results for participants without disabilities (5.4) and OSA for participants with low vision (5.8). OSA is also well-rated by participants without disabilities (5). Regarding the service obtaining the worst results, DNI is the one for both groups (3.4 for participants without disabilities and 2.8 for participants with low vision). It is noticeable that there are slight differences between SGS and DNI services for both groups.

For ASQ3 SPE obtains the best results for participants without disabilities (4.6) whereas OSA returns better results for participants with low vision (5.7). SGS is the service with the lowest mean value for participants without disabilities (3.4) whereas DNI is for participants with low vision (2.8).

In short, SPE is the most highly rated service by participants without disabilities for all aspects of the questionnaire whereas OSA has the best results for participants with low vision. DNI and SGS register the lowest ratings for both groups.

4.8. Annotations and participants' comments

This section summarizes the annotations made by experimenters during the sessions as well as the comments made by participants during the interview.

Participants of both groups complained about the fields to fill in for SecQue step. Comments about the difficulty to complete this step were annotated for the three services containing this step: SGS, DNI, and SPE. In the group of participants without disabilities P2 and P3 complained about this step in SGS, P3, and P5 complained about this step in DNI, and P3 about SPE. The SecQue step which raised more complaints in the group of participants with low vision was the one in SPE (P6, P9, P10, P13, P15). In addition, four complaints were annotated for DNI (P9, P10, P11, P13) and two for SGS (P6 and P10). Some participants with low vision pointed out the lack of contrast and small size of the textbox type fields (P8 in SGS, P13 in OSA, and P14 in DON).

Participants without disabilities were critical of the form buttons. Experimenters annotated seven complaints about the buttons in every service except SPE (P1, P2, P4 in OSA; P4, P3 in DON; P1 in SGS and P2 in DNI). Comments were related to the location of the button (e.g., "Navigation button at the bottom of the screen, difficult to see," P1 in SGS; "The button was at the corner," P4 in DON; "The button was located too far to the left," P4 in OSA), the size of the buttons (e.g., "Small buttons," P2 in OSA; "Small controls," P2 in DNI). Only two comments were raised by P8 and P12 in OSA ("Low contrast in the button" and "The button to submit was on the right side and I could not see

it," respectively) and one comment in DON ("The starting button is not well located," P15).

Difficulties with the error prompting mechanism were annotated for the group of participants with low vision. Most of the comments are related to DNI. P8 and P9 did not notice the error messages prompted by the system so they were confused and had to make several attempts.

Regarding the process of filling in the form, there are difficulties annotated for participants with low vision: P9 arrived back at the initial page of the form in DON due to confusion during the process as did P11 in DNI. P14 commented that there were too many options to select from in SPE, and P11 commented that the information was in too many columns in SGS.

Finally, some comments were annotated relating to the information required by services for performing the task. Participants from both groups agreed that the technical language used by some services made the task difficult and complained about the amount of information needed in the form (P1, P5, P9, P10, P14). Following are some of the comments: "I did not understand the term NIF" P9 in SGS, "I did not understand the issuing authority term," P10 and P14 in DNI, "Technical language difficult to understand" P5 in SPE, "They have to think more about the user and use less technical language" P1, "They require more information than they really needed for making an appointment" P10 in SGS, "I did not know about some of the information they were asking" P14 in DNI.

5. Discussion

5.1. Difficulties in completing the tasks

The Research Question RQ1, which posits "Do participants with low vision have more difficulties than non-disabled participants in completing tasks relating to e-services?" was supported by the results obtained in Sections 4.1 (Task completion ratio), 4.2 (Time for completing tasks), 4.3 (Error events), and 4.4 (Lost index).

Participants with low vision obtained the worst values for the Task Completion Ratio, indicating that it was more difficult for them to complete some tasks. All the participants without disabilities, on the other hand, were able to finish all the tasks. A similar situation was found with regard to the assistance needed by participants when filling in the online forms. Those without visual disabilities only needed assistance once, while those with low vision required assistance six times. The worst task completion ratio was seen for the DNI and the SGS e-services, for which participants needed the most assistance. With regards to Time for Completing Tasks, the DNI and the SGS e-services registered the worst values for both groups of participants. As the results show, participants with low vision obtained significantly higher values. The mean task completion time was higher in participants with low vision for all e-services.

Two different types of Error Events were assessed: error events in which required fields were not completed and errors that occurred when invalid information or formats were entered. Participants with low vision obtained worse results for both types of error events. All the e-services showed similar results based on the type of error event. One notable result was that the DNI e-service website obtained the best results with regard to avoiding error events when entering information in the required fields.

Participants with low vision experienced higher levels of disorientation, as evidenced by the higher number of pages visited. The Lost Ratio percentage values calculated for participants with low vision were, in general, worse than for those without disabilities. The only exception was the OSA e-service as participants with low vision obtained better values.

These findings indicate the existence of accessibility barriers for all participants when performing tasks, being greater and more critical for participants with low vision compared to participants without disabilities. Regarding which e-services present the greatest difficulties, all of them, as indicated, present barriers, with the public DNI e-service obtaining the worst results. This e-service obtained low rates in the ASQ questionnaire (mean values lower than 3.5 out of 7 for all questions), especially for ASQ2 relating to participant satisfaction with the time required to perform the task, and ASQ3 relating to the information provided by the system (mean value 2.8 out of 7 in both cases). In Martin (2013), a study was performed for estimating the time required to fill in the fields in a form. 80 participants took part in the study in which a form consisting of different interaction elements (text input, radiobutton, checkbox, etc.) was displayed and the time required to fill in each of the elements was automatically computed.

Based on the findings in our study estimating the time required to fill in a form is complex since the time for completing one field could depend on the other fields displayed in the same web page. For example, participants complained about the error prompting mechanism and alerts applied in DNI as sometimes they did not notice which field was prompting the error alert or did not understand what the required fields were or the format of the data to be introduced. These events increase the time needed for filling in the form. With this in mind, the combination of COGA and BOFS evaluation methods would appear to be valuable to anticipate difficulties and to increase time required for the filling in process. However, the error prompting mechanisms should be taken into consideration to avoid difficulties. As stated by Pauwels et al. (2009), "Knowing what input a process needs to proceed and how exactly to enter data in the correct format are the two main problems form design needs to address from the information worker's perspective." In our study, there were many error events due to these two main problems. The conclusion of the study by Pauwels et al. is that colored required field marking is better than asterisk based marking. In another study (Sayago et al., 2012) a simple binary classification of fields (required or optional) turned out to be the best method between using large asterisks or adding text labels in a study involving 88 elderly people. In the case of the e-services selected for this study, all of them except the DNI mark the required fields with asterisks. In the case of DNI, at the top of the page a

message says that all the fields are required but they are not marked. This information should be considered in the complexity evaluation of e-services so no marked required fields would increase the complexity. Moreover, investigating into different methods for distinguishing required and optional fields in forms is necessary to improve the user experience of people with low vision.

5.2. Difficulties with steps of the filling in process

The Research Question RQ2, which posits "Do participants find any step in the process of filling in online-forms particularly difficult?" was supported by the results obtained for Step Completion Time and Error-Trials presented in Sections 4.5 and 4.6, respectively.

The Step Completion Time gathered in the experimental sessions clearly shows higher values for participants with low vision. The step requiring the most time for both groups in all e-services was UserID, where participants had to introduce their personal information. Comparing all the e-services times, the DNI and SPE are the ones with the best values, whereas DON and SGS have higher values. Both the latter services (DON and SGS) present the UserID step as the first step in the filling in process.

With regard to the amount of data required of the users in the UserID step, DNI and SPE are the ones requiring more data as the step is composed of more interaction components (DNI presents nine components, six of which are required and SPE presents seven components, of which six are required). DON and SGS present four interaction components to the users, all of which are required. Therefore, it should be noticed that the time computed in DON and SGS is not affected by the number of interaction components. Existing systems for automatically filling in forms with personal data would benefit users of e-services as most of the information required is repeated in these forms. Some different approaches have been developed (Winckler et al., 2011; Wang et al., 2013) some of them are client-side systems that store information to share with web forms others are server-side systems storing the information in remote computers. In both cases, there are privacy issues to consider when using those systems (Lin et al., 2020). Designers should also consider including citizen digital identification mechanisms instead of those systems to facilitate the UserID step. All these mechanisms require different e-services of the government making an effort toward uniformity in relation to the information required as well as the terminology used and it would alleviate some of the concerns raised by participants about the technical language used in some of them.

Another parameter to be considered is the Error-Trial measure as the Step Completion Time might be made worse by the errors occurring in the filling in process. However, the Error-Trial values obtained in the experiments showed that DON and SGS do not have the most failed attempts (0.2 failed attempts on average for participants with low vision in DON and 0.1 trials for participants with low vision SGS, 0 failed attempts for participants without disabilities).

In the case of the SGS e-service, this presents UserID, LocSel, and SecQue steps together on the same web page. The combination of these steps adds some interaction components to the web page: three radio buttons-RAD, one input text-TXT and two select SEL for LocSel, and one input text-TXT component for SecQue. The three steps share the same submit button-BUT component. It turned out to be the most complex web page according to BOFS (with a value of 202). The completion time for each step was independently computed considering only the interaction time with components directly involved in the step. Based on the results obtained, it seemed that the combination of different steps on the same web page affected not only the complexity score but the completion time of the step. Dividing the steps into more pages should be considered in the design of online-forms so the complexity value for each step is kept low and users are not confused with interaction components related to other steps in the process.

In the case of the DON service, the UserID step is a standalone step not combined with any other. This service obtained the second-best value for complexity as well as good COGA evaluation results, conforming to four out of five COGA principles. However, during the experimental sessions, some difficulties were noticed when introducing the date of birth of the users with the CAL (Calendar) component. These types of interaction components are not included in complexity metrics (as they were not used when the metrics were defined). Therefore, there is a need to update the metrics to accommodate new features and interaction components currently displayed in e-services. The Calendar components are very common in online-forms (the OSA service also integrates one Calendar in UserID step and it obtained high time completion values for participants with low vision). In Martin (2013) the participants of the study using the calendar element instead of typing the date in an input text were more efficient. However, only five out 78 participants used this alternative. In our study, five participants directly typed the date instead of using the calendar (P1, P3, P4, P11, P14). Thus, most of the participants tried to use the calendar. However, some participants could not correctly insert the date and carried out manual corrections (P5, P7, P10, P13). In addition, there were some comments complaining about the use of this element: "Too many options to click in the element" P4, "It is not easy to use" P6, "I don't like calendars" P11, "I would prefer not to have the option of calendar" P13, "I thought I had to use it because I did not see any other option. I don't like calendars" P15. Based on these results, designers should provide alternative options to facilitate the introduction of dates in online forms and avoid barriers for people with disabilities and users in general.

The second step requiring more completion time on average for both groups of participants was SecQue in SGS (44.80 s average time for participants with low vision and 25.10 s for participants without disabilities) than in the other e-services (27.50 and 16.30 s in SPE, 15.50 and 9.90 s in DNI). This step in SGS had no errors for participants with low vision, but it had the highest values of errors for participants without disabilities (0.8 failed attempts on average for

participants without disabilities). It shows that this step itself was not difficult for participants with low vision but combining different steps in one web page could affect the completion time of the steps for both groups (it is combined with the UserID step). This combination also makes it more difficult to solve errors when they are prompted. This is reflected in the amount of Error-Trials in this step. Based on the ELMER 2.2.1 guideline (included in the guidelines for designing governmental e-services in Norway): "Questions which concern one and the same logical topic should be presented on one and the same form page" (ELMER, 2011). This guideline should be considered by designers so unrelated information is not required on the same page of an online-form.

As discussed, all the steps in filling in online-forms in all e-services present difficulties in their interaction, leading to longer completion times and lower success rates when users perform the task, these barriers being more pronounced for people with low vision. These results should encourage more research into design patterns, accessibility evaluation methods, and complexity measuring metrics to improve accessibility and interaction in e-service based on a step-by-step online-form filling process.

5.3. Limitations of the study

Although the results of this study provided relevant information, there are some limitations. The first limitation is the small number of e-services analyzed. In addition, the study is focused on "make an appointment" e-services which are a specific type of electronic service provided by public administrations. However, the selected e-services provided a wide range of user interaction components and different web page compositions. We believe that the accessibility barriers specifically detected in these e-services could be representative of the barriers people with low vision have when interacting with most of the current e-services.

The second limitation is that the study did not consider the heterogeneity of the group of people with low vision. Ten participants with low vision took part in the study and plenty of accessibility barriers were detected in the interaction with the e-services. Moreover, some of the problems were detected by almost all participants. However, all of them had similar interaction behavior and used their residual vision to interact aided by the browser zoom (only one participant, P6, also used a Windows Magnifier). Some people with low vision usually need text-to-speech functionalities to browse parts of web pages. We did not include any participant with this characteristic in this study but they will be considered in future studies. In this sense, tools, such as the one described in (Ferdous et al., 2022) which facilitates the use of screen readers for accessing the fields in online forms will be considered.

5.4. Standard accessibility guides and evaluation methods for online-forms

Developers have to deal with different documents when designing accessible online-forms for e-services. The most well-known and most used accessibility guidelines are the WCAG. They provide accessibility guidelines for creating accessible form controls. However, there is no specific section for online-forms in which developers have to analyze the guidelines included in the four principles (perceivable, operable, understandable, and robust) and decide on their applicability to the form controls included. For example, if there is a need to include a CAPTCHA component, it would be necessary to apply success criteria from different principles, such as Success Criterion (SC) 1.1.1 (Non-text Content), SC 1.4.3 (Contrast), SC 1.4.5 (Images of Text), SC 1.4.7 (Low or No Background Audio), SC 2.4.3 (Focus Order), SC 2.4.4 (Link Purpose), SC 2.4.7 (Focus Visible), SC 2.5.4 (Motion Actuation), SC 3.2.1 (On Focus), SC 3.3.1 (Error Identification), SC 3.3.2 (Labels or Instructions), SC 3.3.5 (Help), SC 3.3.6 (Error Prevention), SC 4.1.2 (Name, Role, Value). Therefore, developers have to analyze the success criteria one by one and apply them if they are applicable to the component.

Recently, the WAI launched a complementary tutorial on how to create accessible online-forms (W3C, 2019), which lays out seven main concepts, structuring within them the success criteria according to WCAG guidelines: Labelling Controls, Grouping Controls, Form Instructions, Validating Input, User Notifications, Multi-page Forms and Custom Controls. This resource is very helpful for developers and facilitates the task of developing accessible online-forms and complements the WCAG guidelines. Unfortunately, this resource is not particularly well-known among web developers.

The results of this study show that User Notifications and Validating Input were two critical aspects for participants with low vision. These are not specifically addressed in WCAG but are analyzed in the tutorial. Participants had difficulties when introducing data in specific formats and getting prompted with error notifications. Both aspects are not covered by automated accessibility evaluation tools, which only analyze the interaction components in the online-form but not the possible errors or user notifications prompted. Neither do other methods, such as The Barrier Walkthrough Method (Brajnik, 2011) consider the accessibility of recovery methods when users with disabilities introduce erroneous input.

In this respect, some recommendations to be considered for people with low vision can be highlighted from the results of this study:

- "Labelling Controls." It was clearly demonstrated that using label elements to associate text labels with interaction components, such as radio buttons or checkboxes is required for people with low vision and not only for users with impaired motor control (Success Criterion 3.3.2, technique H4) as it makes the clickable area for the control larger.
- "Grouping Controls." Grouping the controls from a visual or from a semantic point of view as well as from a code point of view, as indicated is essential to improve the success of the task. Adhering to this guideline is

essential for people with low vision because, if the controls are not grouped and contextualized, due to loss of context derived from the use of magnifiers, some of the controls are not detected and the task is not performed successfully.

- "Form Instructions." In individual web pages as well as in-step processes it is essential to provide instructions to help users understand how to use the controls and complete the task. It is important to highlight that these instructions must be simple to understand.
- "Validating Input." Validating user-provided input and providing options to undo changes and confirm data entry is another critical guideline that has been brought to light in this study.
- "Marking Required Fields." Making required-fields clearly visible at first sight is essential to facilitate, speed up and prevent errors in the form filling in process. Different options have been proposed based on the literature but further research is needed to determine the best method for people with low vision. "User Notifications." Providing user notifications to users about the successful completion of the task, as well as any errors, and also providing instructions to help them fix the errors is important for them to complete the task successfully.
- "Multi-page Forms." It has been confirmed that dividing long forms into logical steps or stages and informing users about their progress is beneficial for users, especially for users with low vision, since dividing pages into more compact steps with less content helps users avoid context changes provoked by the use of magnifiers.
- "Custom Controls." Using styles for custom form elements for different user groups, such as people with low vision, is important. This can be done using progressive enhancement techniques to provide custom controls.

The results of this study highlight the significance of improving some of these concepts so that online-forms are developed to be more accessible and easier to fill in for people with low vision.

6. Conclusions

E-government services are of benefit to both governments and citizens as they are efficient channels of communication. However, they often present barriers, especially for people with disabilities. Consequently, there is a subsequent loss of rights for people with disabilities due to the inaccessibility of these e-services.

The study presented in this article identified accessibility barriers and critical design issues in five widely used Spanish government e-services. The structure and design of these e-services have been analyzed and the online-forms were evaluated to measure their accessibility, complexity, and cognitive load. Further, user testing was carried out with five participants without disabilities and ten participants with low vision. Participants with low vision had more difficulties to finish the tasks. Several design issues requiring improvement were detected during the experimental sessions as well as following the analysis of the collected interaction data. The results obtained in this study confirmed that people with low vision face more barriers when using e-services. In addition, the most difficult steps were detected and the design of some web form elements which caused barriers was also discussed. As a conclusion of the study, essential guidelines are given to be followed by developers to create more accessible e-services. For example, unifying the information required by e-services, adequately designing error prompting and preventing mechanisms, simplifying form steps, marking required fields, paying special attention to complex elements, such as calendars, etc. Recommendations to be included in accessibility standards and guidelines are proposed based on the findings.

Future work will focus on continuing to analyze the collected interaction data to explore problematic navigation behavior with components of the e-services. For example, different designs for selecting dates will be thoroughly analyzed; mechanisms for including security questions in the e-services will be studied; mechanisms for error alerts will be investigated. In addition, we plan to extend the study to include other groups of people with disabilities.

Notes

1. http://ophthalmology.pitt.edu/vision-impairment/what-vision-impairment
2. http://www.interior.gob.es/
3. https://www.sepe.es/
4. http://www.seg-social.es/wps/portal/wss/internet/Inicio
5. https://www.donostia.eus/taxo.nsf/fwHome?ReadForm&idioma=cas
6. https://www.osakidetza.euskadi.eus/r85-ghhome00/es

Acknowledgments

The authors thank all the individuals who participated in this study as well as the support given by Begiris, Begisare, and Amires associations.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was funded by the Department of Economic Development and Competitiveness of the Basque Government (ADIAN, IT1437-22) and also received funding from R&D&i ACCESS2MEET (PID2020-116527RB-I0) project financed by MCIN (AEI/10.13039/501100011033/).

ORCID

Myriam Arrue http://orcid.org/0000-0001-8859-8964

References

Access-Board (1998). About the ICT Accessibility 508 Standards and 255 Guidelines. Retrieved from https://www.access-board.gov/ict/about/

Arrue, M., Valencia, X., Pérez, J. E., Moreno, L., & Abascal, J. (2019). Inclusive web empirical studies in remote and *in-situ* settings: A user evaluation of the RemoTest platform. *International Journal of*

Human–Computer Interaction, *35*(7), 568–583. https://doi.org/10.1080/10447318.2018.1473941

Bonacin, R., Melo, A. M., Simoni, C. A. C., & Baranauskas, M. C. C. (2010). Accessibility and interoperability in e-government systems: Outlining an inclusive development process. *Universal Access in the Information Society*, *9*(1), 17–33. https://doi.org/10.1007/s10209-009-0157-0

Brajnik, G. (2011). Barrier walkthrough method. Retrieved from https://people.uniud.it/node/3465

Carter, J., & Markel, M. (2001). Web accessibility for people with disabilities: An introduction for web developers. *IEEE Transactions on Professional Communication*, *44*(4), 225–233. https://doi.org/10.1109/47.968105

EDAD2020 (2022). La nueva encuesta discapacidad-dependencia en España. Revista actas de coordinación sociosanitaria. Numero° 31/Noviembre de 2022 – Una explicación breve de la EDAD2020 (fundacioncaser.org). Fundación Caser. Retrieved from https://www.fundacioncaser.org/sites/default/files/adjuntos/fundacion_caser_revista_actas_n31_encuesta.pdf

Elliman, T., Money, A., Lines, L., & Fernando, S. (2008). Online form complexity assessment for developing assistive technologies. In *Proceedings of Americas Conference on Information Systems 2008 (AMCIS 2008)*, Paper 167.

ELMER (2011). User interface guidelines for governmental forms on the internet. N. M. of Trade and Industry. Retrieved from https://brukskvalitet.brreg.no/elmer21/elmer_2_1_english.pdf

European Parliament (2016). Directive (EU) 2016/2102 of the European Parliament and of the Council of 26 October 2016 on the accessibility of the websites and mobile applications of public sector bodies. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016L2102

European Telecommunications Standards Institute (2019). EN 301 549: Accessibility requirements suitable for public procurement of ICT products and services in Europe. Retrieved from https://www.etsi.org/deliver/etsi_en/301500_301599/301549/03.02.01_60/en_301549v030201p.pdf

Ferdous, J., Lee, H.-N., Jayarathna, S., & Ashok, V. (2022). InSupport: Proxy interface for enabling efficient non-visual interaction with web data records. In *Proceedings of the International Conference on Intelligent User Interfaces, IUI* (pp. 49–62). https://doi.org/10.1145/3490099.3511126

Gambino, O., Pirrone, R., & Di Giorgio, F. (2016). Accessibility of the Italian institutional web pages: A survey on the compliance of the Italian public administration web pages to the Stanca Act and its 22 technical requirements for web accessibility. *Universal Access in the Information Society*, *15*(2), 305–312. https://doi.org/10.1007/s10209-014-0381-0

Gowases, T., Bednarik, R., & Tukiainen, M. (2011). Text highlighting improves user experience for reading with magnified displays. In *Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems – CHI EA '11* (p. 1891). ACM Press. https://doi.org/10.1145/1979742.1979917

Hallett, E. C., Arnsdorff, B., Sweet, J., Roberts, Z., Dick, W., Jewett, T., & Vu, K.-P. L. (2015). The usability of magnification methods: A comparative study between screen magnifiers and responsive web design. In S. Yamamoto (Ed.), *Human Interface and the Management of Information. Information and Knowledge Design* (pp. 181–189). Springer International Publishing. https://doi.org/10.1007/978-3-319-20612-7_18

Institute for Health Metrics and Evaluation (2017). *Findings from the global burden of disease study*. IHME. Retrieved from https://www.healthdata.org/policy-report/findings-global-burden-disease-study-2017

Jaeger, P. T. (2006). Assessing Section 508 compliance on federal e-government web sites: A multi-method, user-centered evaluation of accessibility for persons with disabilities. *Government Information Quarterly*, *23*(2), 169–190. https://doi.org/10.1016/j.giq.2006.03.002

Jafarkarimi, H., Sim, A. T. H., Saadatdoost, R., & Hee, J. M. (2014). The impact of ICT on reinforcing citizens' role in government decision making. *International Journal of Emerging Technology and Advanced Engineering*, *4*(1), 642–646. Retrieved from http://eprints.utm.my/id/eprint/59983/

King, B. A., & Youngblood, N. E. (2016). E-government in Alabama: An analysis of county voting and election website content, usability, accessibility, and mobile readiness. *Government Information Quarterly*, *33*(4), 715–726. https://doi.org/10.1016/j.giq.2016.09.001

Kous, K., Kuhar, S., Pavlinek, M., Heričko, M., & Pušnik, M. (2021). Web accessibility investigation of Slovenian municipalities' websites before and after the adoption of European Standard EN 301 549. *Universal Access in the Information Society*, *20*(3), 595–615. https://doi.org/10.1007/s10209-020-00732-9

Kuzma, J. M. (2010). Accessibility design issues with UK e-government sites. *Government Information Quarterly*, *27*(2), 141–146. https://doi.org/10.1016/j.giq.2009.10.004

Lazar, J., Olalere, A. (2011). Investigation of best practices for maintaining Section 508 compliance in U.S. federal web sites. In *Proceedings of the 2011 Human Computer Interaction International Conference* (pp. 498–506). Academic Press. https://doi.org/10.1007/978-3-642-21672-5_55

Legge, G. E., Mansfield, J. S., & Chung, S. T. L. (2001). Psychophysics of reading. *Vision Research*, *41*(6), 725–743. https://doi.org/10.1016/S0042-6989(00)00295-9

Lewis, J. R. (1991). A psychometric evaluation of an after-scenario questionnaire for computer usability studies: The ASQ. *ACM SIGCHI Bulletin*, *23*(1), 78–81. https://doi.org/10.1145/122672.122692

Lin, X., Ilia, P., & Polakis, J. (2020). Fill in the blanks: Empirical analysis of the privacy threats of browser form autofill. In *Proceedings of the ACM Conference on Computer and Communications Security* (pp. 507–519). https://doi.org/10.1145/3372297.3417271

Lines, L., Ikechi, O., & Hone, K. S. (2007). Accessing e-government services: Design requirements for the older user. In C. Stephanidis (Ed.), *Universal access in human–computer interaction. Applications and services* (pp. 932–940). Springer. https://doi.org/10.1007/978-3-540-73283-9_101

Macintosh, A. (2004). Characterizing E-participation in policy-making. In *Proceedings of the Thirty-Seventh Annual Hawaii International Conference on System Sciences* (pp. 5–8). IEEE. https://doi.org/10.1109/HICSS.2004.1265300

Martin, L. (2013). Estimating time requirements for web input elements. In *Proceedings of WEBI 2013 2nd International Workshop on Web Intelligence - In Conjunction with the 15th International Conference on Enterprise Information Systems, ICEIS 2013* (pp. 13–21). https://doi.org/10.5220/0004582400130021

Money, A. G., Lines, L., Fernando, S., & Elliman, A. D. (2011). e-Government online forms: Design guidelines for older adults in Europe. *Universal Access in the Information Society*, *10*(1), 1–16. https://doi.org/10.1007/s10209-010-0191-y

Moreno, L., & Martínez, P. (2019a). Accessibility compliance for e-government websites: Laws, standards, and evaluation technology. *International Journal of Electronic Government Research*, *15*(2), 1–18. https://doi.org/10.4018/IJEGR.2019040101

Moreno, L., & Martinez, P. (2019b). The harmonization of accessibility standards for public policies. *Computer*, *52*(7), 57–66. https://doi.org/10.1109/MC.2018.2888762

Moreno, L., Martínez, P., Muguerza, J., & Abascal, J. (2018). Support resource based on standards for accessible e-government transactional services. *Computer Standards & Interfaces*, *58*(Issue C), 146–157. https://doi.org/10.1016/j.csi.2018.01.003

Moreno, L., Valencia, X., Pérez, J. E., & Arrue, M. (2021). An exploratory study of web adaptation techniques for people with low vision. *Universal Access in the Information Society*, *20*(2), 223–237. https://doi.org/10.1007/s10209-020-00727-6

Olsen, M. G. (2010). How accessible is the Public European Web? Retrieved from http://mortengoodwin.net/publicationfiles/how_accessible_is_the_european_web.pdf.1

Organisation for Economic Co-operation and Development (2015). Use of e-government services by individuals and businesses. In *Government at a glance 2015*. OECD Publishing.

Paternò, F., & Schiavone, A. G. (2015). The role of tool support in public policies and accessibility. *Interactions*, *22*(3), 60–63. https://doi.org/10.1145/2745395

Pauwels, S. L., Hübscher, C., Leuthold, S., Bargas-Avila, J. A., & Opwis, K. (2009). Error prevention in online forms: Use color instead of asterisks to mark required-fields. *Interacting with Computers*, *21*(4), 257–262. https://doi.org/10.1016/j.intcom.2009.05.007

Potter, A. (2002). Accessibility of Alabama government web sites. *Journal of Government Information*, *29*(5), 303–317. https://doi.org/10.1016/S1352-0237(03)00053-4

Power, A., Freire, H., Petrie, D., Swallow. (2012). Guidelines are only half of the story: Accessibility problems encountered by blind users on the web. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)* (pp. 433–442).

Sala, A., Arrue, M., Pérez, J. E., & Espín-Tello, S. (2020). Measuring complexity of e-government services for people with low vision. In *Proceedings of the 17th International Web for All Conference*. ACM Press. https://doi.org/10.1145/3371300.3383350

Sala, A., Arrue, M., Pérez, J. E., Valencia, X. (2019). Accessibility-in-use of public e-services: An exploratory study including users with low vision. In *Proceedings of the XX International Conference on Human Computer Interaction, Interacción 2019*. ACM Press.

Sayago, S., Guijarro, J. M., & Blat, J. (2012). Selective attention in web forms: An exploratory case study with older people. *Behavior and Information Technology*, *31*(2), 171–184. https://doi.org/10.1080/01449291003767920

Shi, Y. (2006a). The accessibility of Chinese local government web sites: An exploratory study. *Government Information Quarterly*, *24*(2), 377–403. https://doi.org/10.1016/j.giq.2006.05.004

Shi, Y. (2006b). E-government web site accessibility in Australia and China: A longitudinal study. *Social Science Computer Review*, *24*(3), 378–385. https://doi.org/10.1177/0894439305283707

Standards.usa.gov US (2022). U.S. Web Design System (USWDS), A design system for the federal government. Retrieved from https://designsystem.digital.gov/

UK Government (2022). Design patterns. Retrieved from https://design-system.service.gov.uk/patterns/

United Nations (2022). UN E-government survey 2022. Retrieved from https://desapublications.un.org/publications/un-e-government-survey-2022

United Nations Convention on the Rights of Persons with Disabilities (2006). New York.

Valencia, X., Pérez, J. E., Muñoz, U., Arrue, M., & Abascal, J. (2015). Assisted interaction data analysis of web-based user studies. In *Proceedings Human–Computer Interaction – INTERACT 2015–15th IFIP TC 13 International Conference, Bamberg, Germany. Lecture Notes in Computer Science 9296* (pp. 1–19). Springer.

Verkijika, S. F., & De Wet, L. (2017). Determining the accessibility of e-government websites in sub-Saharan Africa against WCAG 2.0 standard. *International Journal of Electronic Government Research*, *13*(1), 52–68. https://doi.org/10.4018/IJEGR.2017010104

Vigo, M., & Harper, S. (2013a). Coping tactics employed by visually disabled users on the Web. *International Journal of Human–Computer Studies*, *71*(11), 1013–1025. https://doi.org/10.1016/j.ijhcs.2013.08.002

Vigo, M., & Harper, S. (2013b). Evaluating accessibility-in-use. In *Proceedings of the 10th International Cross-Disciplinary Conference on Web Accessibility (W4A '13)* (p. 7). https://doi.org/10.1145/2461121.2461136

Wang, S., Zou, Y., Upadhyaya, B., & Ng, J. (2013). An intelligent framework for auto-filling web forms from different web applications. In *Proceedings of IEEE 9th World Congress on Services, SERVICES 2013* (pp. 175–179). https://doi.org/10.1109/SERVICES.2013.19

Whittaker, S., Scheiman, M., & Sokol-McKay, D. A. (2016). *Low vision rehabilitation: A practical guide for occupational therapists*. SLACK Incorporated.

Winckler, M., Bernhaupt, R., & Pontico, F. (2010). Challenges for the development of user interface pattern languages: A case study on the e-government domain. *IADIS International Journal on WWW/Internet*, *8*(2), 59–84. Retrieved from https://www.academia.edu/27078979/Challenges_for_the_Development_of_User_Interface_Pattern_Languages_A_Case_Study_on_the_E_Government_Domain

Winckler, M., Gaits, V., Vo, D. B., Firmenich, S., & Rossi, G. (2011). An approach and tool support for assisting users to fill-in web forms with personal information. In *Proceedings of the 29th ACM International Conference on Design of Communication* (pp. 195–202). https://doi.org/10.1145/2038476.2038515

World Health Organization (2014). Visual impairment and blindness. Fact Sheet N°282. Retrieved from http://www.who.int/mediacentre/factsheets/fs282/en/

World Health Organization (2022). Ageing and health. Retrieved from https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

World Wide Web Consortium (2018). Web content accessibility guidelines 2.1, W3C recommendation 05 June 2018. Retrieved from https://www.w3.org/TR/WCAG21/

World Wide Web Consortium (2019). Design and develop overview, forms tutorial. Retrieved from https://www.w3.org/WAI/tutorials/forms/

World Wide Web Consortium (2021). Making content usable for people with cognitive and learning disabilities, W3C Working Group Note 29 April 2021. Retrieved from https://www.w3.org/TR/coga-usable/

World Wide Web Consortium (2023). Accessibility requirements for people with low vision. W3C Editor's Draft 28 March. Retrieved from https://w3c.github.io/low-vision-a11y-tf/requirements

Xiao, G., Xu, G., & Lu, J. (2010). iBrowse: Software for low vision to access Internet. In *3rd International Conference on Biomedical Engineering and Informatics, 2010* (pp. 2062–2066). https://doi.org/10.1109/BMEI.2010.5639642

Youngblood, N. E. (2014). Revisiting Alabama state website accessibility. *Government Information Quarterly*, *31*(3), 476–487. https://doi.org/10.1016/j.giq.2014.02.007

About the authors

Aritz Sala is a PhD student at the University of the Basque Country (Spain) since 2018. His current research interest includes the analysis of accessibility barriers to public e-services for people with disabilities. He has experience in evaluating the accessibility-in-use of web interfaces with users with low vision.

Myriam Arrue is currently an Assistant Professor at the University of the Basque Country and a researcher at the Egokituz Laboratory of HCI for Special Needs. Her research focuses on web accessibility evaluation, web navigation behavior analysis, and the application of transcoding techniques for improving UX in web interactions.

J. Eduardo Pérez was awarded his PhD in Computer Science by the University of the Basque Country (UPV/EHU) in 2020. His research interests focus on studying web navigation behaviors within diverse groups of users with special needs and testing different GUI enhancements to improve their web browsing ability.

Sandra M. Espín-Tello is an Occupational Therapist, Assistant Professor, and researcher at Grupo de Investigación en Bienestar, Ocupación, Participación y Salud (IBiOPS), at the Universidad de Zaragoza, Spain. Her research interests include promoting home and community participation of people with disabilities, especially through the use of technology.

Lourdes Moreno is an Associate Professor and researcher at the Human Language and Accessibility Technologies Group (HULAT) in the Computer Science Department at the Universidad Carlos III de Madrid (UC3M), Spain. Her research is focused on the design, development, and validation of accessible technology targeted to users with disabilities.