Guideline for Designing Accessible Systems to Users with Visual Impairment: Experience with Users and Accessibility Evaluation Tools

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Abstract: Nowadays, society uses computer systems in diverse day to day activities, such as shopping, social interaction, study, research, etc.; however, a considerable number of the population, who has some kind of special necessity, faces difficulties in using those systems for various reasons, for example, there are codes not written in a way that allows screen readers to identify the menus, contents, etc., to make the correct reading for users. In that context, this paper contains the description of a research done to identify guidelines and/or techniques that address a code document to facilitate interaction between the visually impaired and computer. By applying those guidelines to a prototype and then submitting it to testing with visually disabled users, it was observed that the source code was more legible for screen readers and user interaction was facilitated; however, during user testings, improvements that could be applied to the existing guidelines were observed. Beside user testings, this paper reports a research on automated validators and their criteria on source code's accessibility. It is noted that this automated verification does not exclude tests involving users, because both tests are important in the process of accessibility assurance.

1 INTRODUCTION

The World Health Organization (WHO) (2015), defines disability as a "restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being".

According to a report published by the World Bank (2011), made by the World Health Organization considering 59 countries, describes that at least 15.4% of the world's population has some type of disability, resulting in about 1.1 billion people around the world. There are estimates that by 2050, the total number of people with disabilities will be nearly 50%.

In the workplace, people with disabilities suffer with higher rates of unemployment (World Bank, 2011), with only 53% of disabled man and 20% of disabled women employed.

The World Health Organization (2012), in the search for workplace insertion and quality of life improvement, defined some main objectives, and one of them includes the promotion of use and availability of assistive technologies (WHO, 2015).

There are different types of disability, such as: vision, hearing, motor, advanced age, dyslexia, cognitive or neurological, among others. (W3C, 2012).

In the context of visual disability, accordingly to WHO (2011), 161 million people worldwide are blind or visually impaired, while another 153 million have an uncorrected visual impairment. Also, it is estimated that by 2020, the total of people with visual disability in the world could double.

Visual disability creates an obstacle to people as they are excluded or have trouble in accessing the advantages brought by computing and technology in general. WHO (2012) states that more than 285 million people in the world, as a result of some visual impairment, cannot read all the content available on a web site. This lack of accessibility reflects in disabled people's lives granting them less opportunities in work, education and entertainment.

Given that background, this paper contains the description of a website prototype developed taking accessible design guidelines into consideration. The use of it by users with visual impairment was

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observed in order to identify difficulties during interactions, as well as, automated validators were investigated to identify possible errors that could become an obstacle in the interaction between people with visual disability and computer.

2 TYPES OF DISABILITY

Disability may appear on birth or occur during the life of the individual, and can affect people in different ways. As mentioned previously, there are some types of disability. Table 1 shows some characteristics about them.

Table 1: Types of disability (W3C, 2012).

Disability	Characteristics
Vision	Moderate vision impairment to complete loss of vision, color blindness
Hearing	Partial to total loss of hearing
Motor	Mobility impairments in limbs or reduced dexterity
Advanced Age	Reduced vision, hearing, mobility or any impairment due to ageing
Dyslexia	Difficulties in reading, writing, spelling or word comprehension
Cognitive or neurological	Disorders in any part of the nervous system, including the brain

In that context, Figure 1 presents the total of individuals that have some kind of disability.

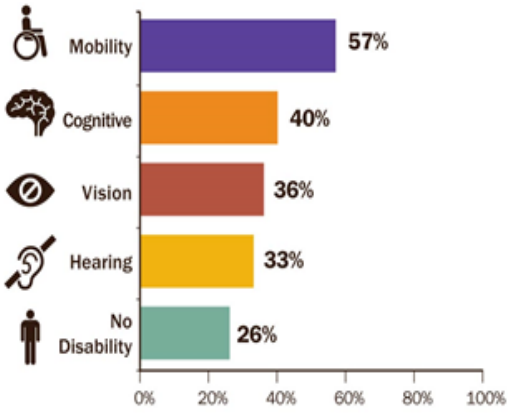

Figure 1: Estimates of adults per type of disability (Center For Disease Control and Prevention, 2014).

According to Center For Disease Control and Prevention (2014) 36% of people are visually impaired. Within this context, Figure 2 shows the amount of blindness, low vision and visual impairment people, considering some countries. In the world, India contains the most of the cases of blindness a year, because there are 30.000 new cases every year (World Health Organization, 2012).

		Blindness	Low vision	Visual Impairment
WHO Region	Total population (millions)	No. in millions (percentage)	No. in millions (percentage)	No. in millions (percentage)
Afr	804.9 (11.9)	5.888 (15)	20.407 (8.3)	26.295 (9.2)
Amr	915.4 (13.6)	3.211(8)	23.401 (9.5)	26.612 (9.3)
Emr	580.2 (8.6)	4.918 (12.5)	18.581 (7.6)	23.499 (8.2)
Eur	889.2 (13.2)	2.713 (7)	25.502 (10.4)	28.215 (9.9)
Sear	579.1 (8.6)	3.974 (10.1)	23.938 (9.7)	27.913 (9.8)
Wpr	442.3 (6.6)	2.338 (6)	12.386 (5)	14.724 (5.2)
India	1181.4 (17.5)	8.075 (20.5)	54.544 (22.2)	62.619 (21.9)
China	1344.9 (20)	8.248 (20.9)	67.264 (27.3)	75.512 (26.5)
World	6737.5 (100)	39.365 (100)	246.024 (100)	285.389 (100)

Figure 2: Visually impaired people by severity and region (World Health Organization, 2012).

There are countries, like Brazil, where the amount of people with visual disabilities overcome every other disability, as shown in Figure 3.

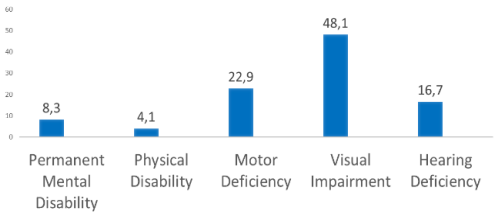

Figure 3: People with disabilities in Brazil (IBGE, 2000).

Analyzing that scenario could be inferred how fundamental to provide technology inclusion of all people in the society is, because computer takes part of many people's activities every day. Therefore, it is not supposed to find any barriers while interacting with systems or devices, considering ideal world.

3 DEVELOPMENT STRATEGIES

There are techniques, guidelines, standards, and others that can be used to back design decisions in order to support the design of accessible systems. This topic presents some of them, which can be employed in scenarios for various types of disability; however, the emphasis here considers techniques and information when related to visual impairment.

- **WCAG (Web Content Accessibility Guidelines) (2012**): recommendations and accessibility rules for displaying web content. The WCAG are accessibility guidelines which define a standard for how to maintain web accessible content for every person (WCAG, 2012; W3C, 2011). For instance, it contains a guideline on how to display alternative text for images and symbols in the interface, in a way that a screen reader could identify and reproduce in an appropriate way what it is shown on the content.

- **UAAG (User Agent Accessibility Guidelines) (2015)**: composed by 12 guidelines, each one formed by orientations called checkpoints. Those guidelines specify accessibility recommendations to certificate that the user interface is operable.

One of these checkpoints consists of a sequential website navigation, making sure that the user can interact with the website via keyboard. The use of the key "Tab" is one of the mechanisms that allow people with visual impairment to use websites, because they can navigate through menu, content, figures of the site pressing this key. The navigation sequence via the key "Tab" must be designed to provide a valid navigation for the user (UAAG, 2015).

- **Accessible Guidelines for People with Visual Disability**: guidelines formalized from experiencing and observation of users with visual disability while they had been interacting with various websites. Those guidelines contain understanding such as the compared eagerness of people with visual disabilities and with non-disable people, because both show impatient behavior, e.g., non-disable people do not read every word on the content, and disabled people do not listen to every word (Theofanos, Redish, 2006).

In some countries, such as Brazil, as a state initiative, a document was elaborated, containing recommendations to standardize and help accessibility decisions in the accessible web sites or systems development. In the case of Brazil there is the document called eMag.

- **eMag (Accessibility Model in Electronic Government):** recommendations and guidelines for the construction and adaptation of Brazilian Government content for the internet (eMag, 2014). One of these guidelines is related to provide links to navigate to content instead of making the user navigate through every option in the menu, pressing the key "Tab" multiple times, before reaching the desired content.

Considering these and other guidelines, WCAG represent the most guidelines used to design accessible sites or systems. There are user testing and results analysis concluding that websites which conformed to WCAG guidelines had obtained better scores on usability, aesthetics, reliability and loading time; on the other hand, more investigation in this field is still needed as a means of improving computer interaction (Schmutz, Sonderegger & Sauer, 2016; Gonçalves et al., 2013).

Research and guideline usage gives benefits in usability to both disabled and non-disabled users, because they describe how to display information with visbility, color constrast, as well as, how to organize it, among others. Next section reports the use of these described development strategies to design prototype.

4 PROTOTYPE

The investigated guidelines and techniques were applied for designing the first website's prototype, where visually disabled users had the opportunity to navigate. The results from usage tests observation were considered to improve the prototype, in a second version.

According to Bai, Mork & Stray (2016) it is possible to use automated tools for error identification as a means to save resources and maximize benefits. Thus, for the second version of the prototype, a study on automated validators was made, identifying their characteristics and, consequently, using those tools for prototype tests.

It should be noted that automated validators does not replace tests with users, but they could be used to complement the evaluation process. In this case, the

goal was to identify errors and improve the prototype's source code before submitting to users, avoiding errors that could be fixed before the tests had started.

4.1 The First Prototype Version

The prototype was made contemplating the information obtained in the development strategies, for example, the use of "Tab index", which permits the user to navigate the content in a sequential way; buttons with the functions to increase or decrease the typography size in the screen, as well as, alternate between more contrasting colors in the interface, allowing users with visual impairment improve the readability of the content as they need; division of the content in blocks containing areas of information, making the navigation between content easier; alternate describing text for images, by using the attribute "alt"; website responsiveness to make a readable and logical content website if it be resized; insert focus on content; link that allows the user to explore more about the information described - this option, added to the end of the paragraph, is clicked when the user accesses a small block of text and wants to know more about it.

In order to observe the use of the site, Comprehension Test and Key Test were performed with users of an association of the blind and visually impaired (Krug, 2014). The Comprehension test's objective is to allow users navigate in the website and observe/ask if they understand what is its meaning and organization. The Key-Task test is used to verify if users can accomplish previous elected tasks on the website

The content of website was related to soccer teams, soap opera, crafts, etc. In the Key-Task test was requested that the user navigate the website to find a specific topic about a determined subject, e.g., to find a resume about a soap opera. While the users were doing the required tasks to accomplish the result, observation of the process and behavior of the users took place.

The user group was composed of 4 males and 2 females. They interacted with the website through a screen reader called NVDA (NVDA, 2017).

User 1 was a male blind person, with knowledge in internet navigation for reading e-emails, working, playing game and talking using chats and Skype. He has experience with various screen readers, such as Dosvox, NVDA and Virtual Vision.

User 2 (male) was a blind person, with little knowledge in computer use. He was doing a typing course at the time the test were done. The test was his first access to a website, and he had difficulty with the keyboard, not having memorized the localization of important keys like "Tab" and "Enter".

User 3 (female) was also blind, and had knowledge in internet navigation for reading e-emails and news using screen readers such as Jaws and NVDA.

From the rest of the users in the group, two of them had low vision, being one of them the User 4 (male), who had 20% of vision capacity and little familiarity with computers, and at the time of the test, just starting web navigation classes. The other low vision user, User 5 (male), had 10% vision capacity in the right eye, and 5% in the left eye. User 5 already was familiar with computer use and could access news websites and social networks. The last user in the group, User 6 (female), was blind and no familiarity with computer use, and was just starting typing classes.

During the tests, only User 2 could not figure out the website's objective and neither accomplishes the requested task. The other users did finish the presented task.

After the ending of the tests, the users could point out any difficulties they had during the website navigation:

1 – By using "Tab", the screen reader NVDA could read the information displayed, but the same task was unsuccessful when using the keyboard arrows instead, like → or ←. For example, there were some options as A+ to increase size in the screen and A- to decrease it.

The describing information in the HTML tag was presented to the user when he navigated using "Tab", i.e., NVDA could read the meaning increase or decrease; on the other hand, with the arrows only the raw content of the tag was presented, as A and A for both options, providing no useful context to the user.

2 – Users did not know how to use the Access key, which are shortcut keys for accessing options, for example, by pressing Alt + A to access the "*Artesanato*" menu, in English Crafts menu.

With respect to the tests carried out, it allowed to analyze the results, as well as to develop a second version of the prototype, which sought to improve the user interaction with the system.

4.2 The Second Prototype Version

Through the analysis of the previous user group tests and observation of these users and others who were part of the same organization, while they used various websites, including Facebook and Gmail,

improvements were identified with the objective of facilitate the user interaction:

- Use of audio cues to inform that the web page loaded. The audio cue works as a signal that the page is ready to be interacted with, as this question is very common among the users.

- Descriptive text in the accessibility buttons. In the tests, the users could not identify the meaning of some of them as they were not displayed as intended for the users with disability. Thus, each button function was described literally, altering the "A+" button into "Increase Text Size".

- Menu items sorted in alphabetic order. It facilitates the identification of a logic order during the navigation. Visually disabled users related that they form a logic way when navigating, to make the interaction easier. For instance, if the current item starts with "A" and the user knows that the content is sorted alphabetically, he would know what is at the beginning of the content, thus, he could use the shortcut keys to jump back to the start without having to navigate between intermediate items. If there is no perceptible logic, they must go through all the items.

- Separate items in well-defined categories, improving accessibility as the content is better fitted for its audience, requiring less clicks for the users to reach its goal. For example, considering soap operas from different TV channels. It is better to choose one TV channel to access its soap operas, than to navigate through all soap operas from all TV channels to find one. In the second example, many "Tab" pressing is required.

- Inhibit access to the accessibility buttons initially by the keyboard, as blind users do not find use in the options of auto contrast, increase font size, etc. In this case, these buttons increase the number of items to be covered.

- After a menu item is selected, it should directly progress to an inner menu with its own items or progress to the specified content. Users in the Key-Test had difficulties in realizing that after the main menu selection, they should navigate to the selected category's own sub-navigation.

- The most important information should anticipate any other information. Disabled users are impatient as non-disabled users, because they hear the first words in a link or text block and, if it does not seem relevant, they advance their navigation (Theofanos, Redish, , 2006). For example, 'name of the soap opera' image, instead of image 'name of the soap opera'. Because, when user listens image firstly, he can think that it is an image related to advertisement, icon menu, etc. There is not a specific meaning.

After previous improvements were identified, a redesign of the site was done. One of the resultant screens can be seen in Figure 4.

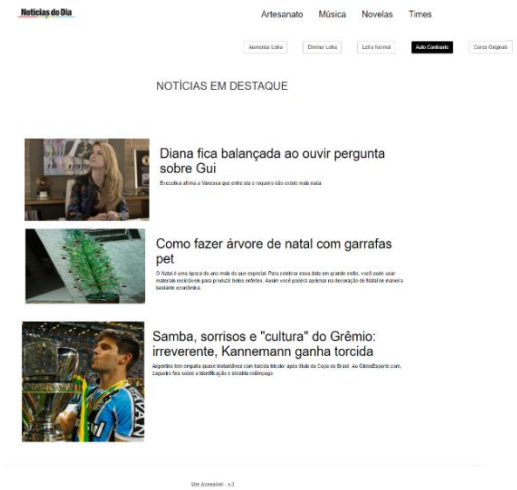

Figure 4: Website's prototype second version.

Figure 4 shows a screen with alphabethic order menu as *Artesanato, Músicas, Novelas* and *Times*, in English, Craft, Music, Soap opera and Soccer Teams.

Accessibility options as increase or decrease font size are not recognized through "Tabs" before content, because blind people do not use them; on the other hand, after reading the content of the page, these options are recognized, if users keep pressing "Tab".

In this example, screen readers will identity menu option as Craft, then the three Highlighted News and, after, accessibility options.

If user chooses a menu option as Craft, he does not need to navigate through menu options again or to find a link to go to content, because he will conducted automatically to content of the Craft page.

According to Preece et al. (2011), the usability validation, as well the accessibility, should be designed with the use of tools and human revision. Tatcher et. al (2002) asserts that the use of automatic code validation tools is important to verify that the syntax of web pages conforms to the accessibility recommendations, guidelines and standards.

In this context, for the second version of the website's prototype, research was made to identify automatic code validators and their characteristics, with the intent of using them on the web pages before the user tests take place.

5 CODE VALIDATORS

The automatic tools, from the code validation to verify that the syntax of the web pages conforms to

the recommendations, standards, etc., provide reports with the problems found and that must be corrected, making the site suitable. The use of these validators is simple, since they are all web-based, that is, no software installation is required. It is only necessary to insert the Uniform Resource Locator (URL) in the available text area (Thatcher et al., 2002). Thus follows, a list of tools as their characteristics.

The Figure 5 displays a relation of these tools and its characteristics, such as the standards and technologies each validator allows the website to be compared against, target website or code input method allowed and which types of accessibility guidelines validation each tool offers.

Tool	Evaluation Method			Validation Options			Guideline Version Options				
	URL	File	Source Code	HTML	CSS	View Code	Possibility Version Selection	WCAG 1.0	WCAG 2.0	e-MAG 1.0	e-MAG 2.0
AChecker	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗
daSilva	✓	✗	✓	✗	✗	✗	✓	✓	✓	✗	✓
Examinator	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗
Hera	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Ases	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗

Figure 5: Comparison of tools with input data.

The validator DaSilva (2014) was selected because it is the first tool to allow evaluation through the WCAG guidelines and eMag, and, therefore, evaluates the code considering a greater number of guidelines.

Thus, validation was performed with the tool DaSilva on the prototype, by inserting the website's URL on the validator interface. Figure 6 shows DaSilva's interface and its report on the prototype found errors, verification points, source code localization and total of occurrences.

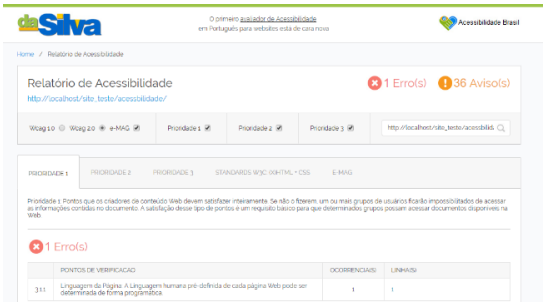

Figure 6: Error reporting.

The report provided by the validator shows an interface where the errors found were displayed in a table, defining the total of issues found and details about each error, such as the line position in the source code where it was found and which guideline the tested website was not in conformity.

In Figure 7, another interface of the validator is shown. This interface contains all warnings found in the website's code. One of the warnings in the report refers to the color use, asserting that " Color is not used as the only visual means of conveying information, indicating an action, prompting a response, or distinguishing a visual element.", that is, any information provided by using color, must also be evident also without color.

These warning refer to points where the validator cannot be sure about the existence of an accessibility non-conformance or syntax error, due to software limitation in this regard. The warnings require a human to make the decision if each issue identified is a real problem or a misinterpretation from the tool.

Figure 7: Warning report.

The validators are an important tool, but they cannot be the only method in asserting the conformity of accessibility guidelines or identifying errors in the website's code.

6 FINAL CONSIDERATIONS AND FUTURE WORK

There is a latent need to investigate and discuss about what more could be done to aid people with disabilities in their interaction with computer systems, because every concept, strategy and innovation can result in better interaction. Therefore, investigation and propagation of experiences and findings in the field should be encouraged, like some improvements, reported in this paper. They were not identified or expressly described in the researched guidelines, mentioned in Development Strategies section.

These improvements can be considered as complements to the guidelines presented in this paper, for instance, in the guideline that recommends

providing sequential navigation. In this case, through the findings in this paper, was identified that defining an alphabetical order for the sequence had better results.

In another example, the guideline that recommends the increase font/decrease font buttons could be improved by using a literal description on the names of buttons instead of the common approach of using its abbreviations (A+ or A-), as they could be ignored by the screen reader or misinterpreted by the user during navigation.

Besides the guidelines suggested improvements, another contribution by the paper was to present a comparison between some of existing validators, contemplating each own criteria on guidelines and its particularities.

User tests and automated tools provide major contributions in the making of an accessible website for visually disabled people, each providing useful insights on how accordance to the guidelines and knowledge of the target audience are essential to increase the reach and value of the web content.

There is a need to investigate and discuss what can be done to auxiliary people with disabilities in the interaction of computer systems. Strategy and innovation can result in a profound change in quality of life, increasing their participation in the labor market and consumption.

Should be noted that the computer accessibility concern is a growing trend, once the population of disabled people will continue to increase as the world population grows bigger and ages.

Future work include improving the prototype's interfaces to conduct new user testing, as well as continue research, with the aim of identifying and applying new improvements to enhance the interaction of visually impaired people and computer.

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