Methodology for Designing User Test Environments to Evaluate Web Accessibility Barriers with Disabled Users

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Abstract — **This work presents a new methodology for designing user tests that evaluate the impact of different Web accessibility barriers affecting people with disabilities. The methodology is based on several steps that help in the creation of Web content to be tested by users with specific disabilities. Several user tests have been carried out to check the validity of the steps defined in the methodology. The paper includes the methodology used, a case study and the key findings of the analysis. The results of the case study have been positive as the objective of providing a methodology has facilitated the creation of an evaluation environment: selection of the elements to be evaluated and the tasks to be performed by users who carried out the test. As a conclusion, we can state that the introduced methodology helps to include elements in user tests and optimizes the time and available resources needed for the preparation of an accessibility test.**

Keywords - Design, User test, Barriers, Web accessibility, Users with disabilities

I. INTRODUCTION

A large number of people have difficulty accessing the Web. The World Report on Disability [1] estimates that between 15% and 19% of the population have some type of disability, a substantial group of consumers that should not be ignored. However, current accessibility involves a compromise between ideal accessibility and available resources. As in classical usability, it is common sense to place more emphasis on problems with greater impact and/or that recur more frequently [2]. Therefore, it is important to understand the difficulties caused by different elements when experienced by specific user groups, in order to prioritize actions taken to improve accessibility for them. Technical accessibility, the most widespread, attempts to place all users and all contexts on the same level, but usability –and accessibility– are contextual and depend upon the type of user [3]. User testing is recommended to ensure the accessibility of a Web site. These tests provide quantitative and qualitative data about real users that perform real tasks with a product [4].

In this paper, we focus on web context and propose a new methodology that facilitates the creation of a user test environment (elements to be evaluated, tasks to be performed) adapted to the characteristics of users with disabilities. In this sense, preparing a user test environment aimed at assessing specific barriers for disabled users can be quite an effort for the evaluator preparing the test: selecting barriers affecting each disability to evaluate, choosing specific HTML elements that incorporate the barriers and adequate coding of the elements, deciding how to approach the tasks to be performed, etc.

Without a systematically automated process, there is no way to ensure that the tools used for proper testing incorporate all the elements to guarantee adequate results. Additionally, it hardly ensures an adequate and exhaustive list of tasks to run during the test.

Moreover, accessibility barriers cannot be generalized: accessibility barriers related to mobility-impaired users are different from those associated with visually impaired users, and in each specific case the evaluation environment (Web site/s) should incorporate different elements to ensure the validity of the test.

Hence, accessibility evaluators should raise several questions when designing experimental Web user tests for people with disabilities:

- To which group do my main users belong?
- What elements are especially problematic for this group?
- What tasks should be performed by users on my Web site to assess the impact of problematic elements?
- What Web content should be added to the Web site to allow the user group to carry out tasks?

To address these questions and explain the methodology, the paper is organized as follows. Section 2 describes the related work. The methodology is introduced in Section 3. Section 4 presents a case study and the last section presents the conclusions of the work.

II. RELATED WORK

By barrier, we mean any condition that prevents the execution of an objective by users with disabilities. Initiatives such as the "Accessible Project" [5] and the "Barrier Walkthrough" [6]have studied the most problematic Web barriers affecting different profiles of users with disabilities (visual, low vision, hearing, cognitive and

motor). It is important to point out that disabled users interact with the Web in different ways [7] and it is necessary to analyze their characteristics in order to understand which barriers cause a greater impact in each case.

There are methodologies, proposed in [8], [9] and [10] based on the importance of user testing for developing software, but they do not take into account the process of preparing the necessary environment for carrying out the user test. In this sense, the methodology we propose provides a proper framework.

Various methodologies are followed for evaluating the accessibility of a Web site [11], [12]. Traditionally, accessibility evaluation is carried out by applying the Web Content Accessibility Guidelines (WCAG) [13] [14], or its ISO equivalent, ISO/IEC 40500:2012 [15]. However, WCAG guidelines are primarily a legal instrument and, as several authors point out [16] [17] [18], compliance with them does not guarantee 100% accessibility of the Web site. Moreover, according to some authors [19] [20], WCAG 2.0 guidelines do not address all the needs of users for accessing content. Consequently, although WCAG guidelines provide an important starting point, conducting user tests is very important for detecting errors to as great an extent as possible [20] [4].

Given the importance that WCAG guidelines have gained, several tools have been developed to automate the evaluation of Web accessibility [22]. However, not all elements can be evaluated automatically, given that it is necessary to complement the evaluation with a manual review.

In general, automatic accessibility evaluation tools provide result reports that are too technical, making it difficult for people who are untrained in accessibility to understand them. There are some examples that make accessibility evaluation available to the non-expert evaluator, helping that person to understand WCAG guidelines and to create Web content. Accessibility Evaluation Assistance (AEA) [23] [24] is a tool that shows the aspects that must be taken into account for applying WCAG guidelines, thus facilitating the evaluation process. Accessibility Example Generator (AEG) [25] is another tool that assists in the process of creating examples of both accessible and inaccessible Web pages.

Related to all this, the Web Accessibility Initiative (WAI) of the W3C has two projects that work with aspects related to Web content source code: (i) the project WCAG 2.0 Test Samples Repository [26] features accessible and inaccessible code samples within the context of WCAG 2.0 guidelines; and (ii) the project "Before and After Demonstration" [27] is a set of web pages showing examples of accessibility barriers.

In this sense, the methodology we propose is focused on minimizing the effort of creating the user test environment aimed at people lacking a background in accessibility in order to adapt content to the needs of an organization. The tool automates the methodology, optimizes the time and resources needed to create the HTML elements to be tested and streamlines a process which is costly if done manually.

III. METHODOLOGY

The proposed methodology has the following key strengths:

- To optimize the effort for preparing the user test environment: evaluators can reduce the time needed to create code or to analyze the guidelines relevant to their case.
- To reduce the time to prepare and generate the user test environment: evaluators can minimize the creation time of the test environment by using a tool that automates the methodology.
- To ensure the inclusion of all the HTML elements to be tested from a selection of profiles and HTML elements, specific accessibility barriers are listed for assessment, as well as tasks likely to cause access problems for previously selected user profiles.
- Ease of use: accessibility related information is presented in a simple and understandable manner for users without prior knowledge of accessibility.

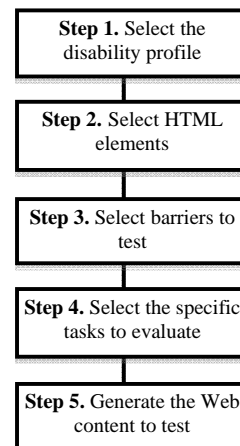Below (Figure 1) is an outline of the methodology presented.

```
┌─────────────────────────┐
│ Step 1. Select the      │
│ disability profile      │
└─────────────────────────┘
            │
┌─────────────────────────┐
│ Step 2. Select HTML     │
│ elements                │
└─────────────────────────┘
            │
┌─────────────────────────┐
│ Step 3. Select barriers to │
│ test                    │
└─────────────────────────┘
            │
┌─────────────────────────┐
│ Step 4. Select the specific │
│ tasks to evaluate       │
└─────────────────────────┘
            │
┌─────────────────────────┐
│ Step 5. Generate the Web │
│ content to test         │
└─────────────────────────┘
```

Figure 1: Outline of the methodology presented.

A. Description of the methodology

The methodology uses and lists several data sources: disabilities, Web page elements, accessibility barriers and WCAG guidelines, which are put together to obtain a list of tasks to run on a web page with accessible and inaccessible source code. The methodology consists of five steps in which the evaluator selects the user profile of the test (step 1), HTML elements that present problems to the selected user (step 2), barriers to testing (step 3) and specific tasks to perform in the test (step 4) to finally obtain a source code with a web implementation that collects all aspects of the previous selections (step 5). The evaluator has the code that best fits the needs of the user test or that best performs the test using all the information resources generated.

1) Step 1: Select the disability profile: In the first step, the characteristics of the user who will participate in the test

are selected. The user profiles offered by the International Classification of Functioning, Disability and Health (ICF) [28] were considered, but we thought that it was more appropriate to group the characteristics into a total of four groups further split by the severity of disability.

1. People with mobility impairments: 1a) mild and moderate limitation and 1b) severe limitation.
2. People with cognitive impairments: 2a) mild and moderate limitation and 2b) severe limitation.
3. People with hearing impairments: 3a) mild and moderate limitation and 3b) severe limitation or total deafness.
4. People with visual impairments: 4a) low vision, 4b) severe limitation or blindness and 4c) color-blind.

2) Step 2: Select HTML elements: All HTML elements that are of interest to test and that cause some problem for the users of the profiles chosen in step 1, are selected.

3) Step 3: Select barriers to test: The accessibility barriers to be tested are selected in the next step. Only the barriers that cause problems are listed according to the HTML elements and the user profiles previously chosen. We have used the following information sources to obtain the list of barriers: the accessible project [5], which lists the disability accessibility barriers that most directly have an impact and the work of Cunningham [29], which lists the most problematic HTML elements for each type of disability.

Keep in mind that the same barrier can affect one or more of the various disabilities.

4) Step 4: Select the tasks to evaluate: The possible tasks to perform in the user tests according to previous selections are chosen in this step of the methodology. As a barrier can affect one or more disabilities, the principle of the task is different for each affected group. For example, the barrier "moving content" is perceived differently depending on whether the user has visual or cognitive disabilities. Therefore, an adequate approach for participants with disabilities is essential.

5) Step 5: Generate the Web content to test: The last step of the methodology is to obtain the Web content (accessible and inaccessible), which will be incorporated into the pages to test, in keeping with the previously selected parameters.

This may not be the final code since its aim is to inspire and facilitate the task of creating a test page by the team responsible for carrying out the user test.

The methodology also offers information on how to evaluate the accessibility barriers in order to supplement the information given to a new evaluator.

IV. CASE STUDY

In the following section, we show a case study that implements the previously proposed methodology through a mock-up of the tool. This case study was based on an evaluation by the authors of the paper [31], rather than with actual evaluators with no technical knowledge. The examples of web pages were inspired by W3C WAI and provided by [32].

It begins with the premise of running a user test for people with severe visual impairments or blindness and to find out the difficulties that a contact form can cause.

A. Steps of methodology

Below are the steps to be followed:

1) Step 1: Select the disability profile: A user test is prepared, adapting it to a specific user profile. As an example, the following profile is selected: People with severe visual impairments or blindness. To empathize with these users and to better understand the difficulties they encounter, a profile of a user with the selected disability is displayed.

TABLE I. HTML ELEMENTS THAT AFFECT USERS WITH VISUAL DISABILITIES AND THE WCAG1 AND WCAG2 REGULATIONS RELATED TO THEM.

HTML element	WCAG 1.0	WCAG 2.0
Browsing		
Shortcuts	13,6	2.4.1
Keyboard shortcuts	9.5	--
Design		
Color	2.1	1.4.1
Header/page title	13.2	2.4.2
Tables as layouts	3.3, 5.3, 5.4	1.3.1, 1.3.2
Structure		
Headings (H1, H2)	3.5	2.4.10, 1.3.1,
Frames	12.1 12.2	2.4.1, 4.1.2
Popups	10.1, 9.4, 9.5	3.2.1, 3.2.5
Language definition	4.1, 4.3	3.1.1, 3.1.2
Content		
Images	1.1, 3.1	1.1.1, 1.4.5, 1.4.9, 1.3.1
Opaque objects	1.1	1.1.1
Moving or blinking content	1.1, 7.2, 7.3	1.1.1, 2.2.2
Links	10.5, 12.3, 13.1	2.4.4, 2.4.9, 2.4.10
Data tables	5.1, 5.2, 5.5, 5.6, 10.3	1.3.1
Multimedia: Video	1.1, 1.4	1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.5, 1.2.7, 1.2.8, 1.2.9
Forms	5.3, 7.5, 9.4, 10.2, 10.3 12.4, 12.3	1.3.1, 1.3.2, 2.4.3, 2.4.7, 4.1.2, 2.4.10
Text	3.1	1.4.5, 1.4.9
Time limit	7.4, 7.5	2.2.1, 2.2.4, 3.2.5
Javascript/Flash	6.3, 6.4, 6.5, 8.1	2.1.1, 2.1.3, 4.1.2
Events		
Dynamic Changes	6.3 8.1	4.1.2 3.3.1, 3.3.2, 3.3.3
Event controllers Mouse events and keyboard	6.3, 6.4, 9.3	2.1.1, 2.1.2, 2.1.3

2) Step 2: Select the HTML elements: The elements on which the test is focussed are selected.TABLE I. shows a list of all problematic elements that affect users with severe visual impairment. Each element is accompanied by related WCAG guidelines. This information is only needed in order to be able to list different information groups internally, and no information would be displayed in the user interface. In our case we selected the item "Form" to test the particular difficulties users may have in sending a contact form. To facilitate the communication of the Web element, each element is accompanied by an HTML example that may be incorporated into the test (See Figure 2).

```
<form id="form1" name="form1" method="post"
action="">
<legend>Registration</legend>
 <div>
  <span> <label for="txt">Name <label> </span>
  <span> <input type="text" name="txt" id="txt"/>
  </span>
 </div>
</form>
```

Figure 2.   A form example.

3) Step 3: Select barriers to test: With the previously selected information the accessibility barriers to be tested are shown. As a specific example, TABLE II. shows the barriers related to visually impaired users (step 1) and the form elements (step 2).

TABLE II.   LIST OF BARRIERS RELATED TO VISUALLY IMPAIRED USERS AND THE WEB "FORM" ELEMENTS

Barriers	Description
Forms that direct the user to a different page	The form is updated and loses the previously entered information when selecting the send button.
Forms with fields not semantically marked	Control labels (LABELs) must describe the data to be entered in each textbox.
Forms that are not correctly displayed on a screen reader	The elements of the label form and textbox are organized properly. When the user browses with the tabs, the user will find the following fields: Name (TAB) name textbox. (correct)

4) Step 4: Select the tasks to evaluate: A list of tasks permits the evaluation of previously selected barriers and elements, adjusted to the specified user profiles.TABLE II. shows only the information concerning the barrier "Forms with fields not semantically marked".

5) Step 5: Generate the Web content to test: A proper Web code is displayed for each selected Web element. TABLE IV. shows an example of the barrier "Forms with fields not semantically marked". Example web pages inspired in W3C WAI activity are provided by [32].

TABLE III.   LIST OF TASKS CONCERNING SEVERE VISUALLY IMPAIRED USERS AND THE WEB FORM ELEMENT AND THE BARRIER "FORMS WITH FIELDS NOT SEMANTICALLY MARKED".

Barrier	User task
Forms with fields not semantically marked	Fill in a form with personal information (name, email, city and gender)

TABLE IV.   WEB CONTENT ASSOCIATED WITH THE BARRIER "FORMS WITH FIELDS NOT SEMANTICALLY MARKED" AND THE TASK "FILL IN A FORM WITH PERSONAL INFORMATION."
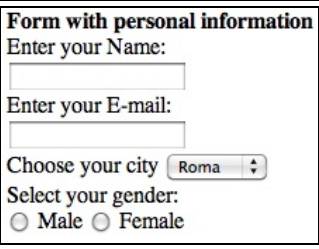
Content description
Each form field must be labeled with a label element. Additionally, it must be identified with a unique name that is also included in its corresponding label element.
Content example
Form with personal information Enter your Name: Enter your E-mail: Choose your city [Roma ▼] Select your gender: ○ Male ○ Female See correct and accesible code See code with accessibility errors
Verification of the barrier
Manual verification: To create the form we suggest the use of a form-builder tool. To validate the form code we suggest using the WAT tool: it displays the text fields that are identified with labels and IDs in the same form.

B. Create the user test environment

Once the HTML elements are known, as well as the specific Web content to be added to the website, the next step is to proceed with its creation and implementation. At the end of the process, a summary is shown (See TABLE V.). The evaluator can embed an obtained code in a simple web page and start the test.

The authors of this article have checked the validity of the proposed methodology by creating several user tests aimed at people with cognitive disabilities [30] and visual disabilities [31]. By following the methodology, there is a reduction in the time needed for creating the user test environment and an improvement in the effectiveness of preparing the test environment to include the most problematic elements for users with disabilities. The studies carried out by the authors were focused on learning the mental state of users with disabilities as they interacted with each barrier to accessibility. It was necessary to be very precise when creating the HTML files to be evaluated.

TABLE V. SUMMARY OF STEPS TO CREATE USER TEST ENVIRONMENT

Summary of steps
If you want help in creating the web page, feel free to copy some of the example pages provided.
Your settings: • You selected blind and severe **visual disabilities group**   • You focused on **form elements**   • You selected the barrier "**Forms with fields not semantically marked**"   • A suggested task is to **ask users to fill in a form** with personal information (name, email, city, gender)   You could test the impact of this accessibility barrier with this user profile comparing a non-accessible implementation with an accessible implementation, both with an exact visual appearance, as follows.

Visual appearance
Form with personal information   Enter your Name: [ ]   Enter your E-mail: [ ]   Choose your city [Roma ▼]   Select your gender: ○ Male ○ Female

Source code (Accessible)

```
<legend>Registration</legend>
<form id="form1" name="form1" method="post"
action="">
 <label for="nom">Enter your Name:</label>
 <input type="text" name="txtnom" id="nom" />
 <label for="mail">Enter your E-mail:</label>
 <input type="text" name="mail" id="mail" />
 <label for="favcity">Choose your city</label>
  <select id="city" name="select">
   <option value="1">Roma</option>
   <option value="2">Paris</option>
   <option value="3">London</option>
  </select>
 <legend>Select your gender</legend>
 <input id="Male" type="radio" name="sen"
   value="Male">
  <label for="Male">Male</label>
  <input id="Female" type="radio" name="sen"
   value="Female">
  <label for="Female">Female</label>
</form>
```

Source code (Non Accessible)

```
Registration<br/>
<form id="form1" name="form1" method="post"
action="">
 <label>Name:</label>  <input type="text" />
  <label>E-mail:</label> <input type="text" />
 <span><label for="favcity">City</label>
 <label>
   <select name="select2" id="select">
    <option value="1">Roma</option>
    <option value="2">Paris</option>
    <option value="3">London</option>
   </select>
 </label>
 <label>Gender:</label>
 <input type="radio" name="radio1"
  id="radio1" /> Male
 <input type="radio" name="radio1"
  id="radio1" /> Female
</form>
```

V. CONCLUSIONS

This paper presents a new methodology that optimizes the design of a user test environment for people with disabilities. This methodology is shown through a case study. The proposed methodology is based on following a series of specific steps in order to provide suitable content and tasks for carrying out a user test for people with disabilities. The evaluators can conduct the user test without specific knowledge of accessibility, the methodology minimizes the effort needed for creating such an environment adapted to the specific needs of the organization. The methodology is accompanied by a tool that automatically performs some of the steps and speeds up implementation, thus reducing time and costs in creating the right environment for user tests. In the case study, with only five selections (and five mouse clicks) the evaluator has a suggestion of task, and the code of both accessible and non-accessible implementations.

The authors followed this methodology with users with cognitive disabilities [30]. As a conclusion we found that using the proposed methodology facilitates the inclusion of elements to be tested and optimizes the time and available resources used in the preparation of the test.

In a complementary manner, the methodology can also help webmasters to be aware of the most problematic elements (barriers) of a specific disability and with this knowledge, they are more aware of accessibility requirements in a Web page.

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