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IMPACT OF ACCESSIBILITY BARRIERS ON THE MOOD OF USERS WITH MOTOR AND DEXTERITY IMPAIRMENTS

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Abstract: With the aim of knowing the impact of accessibility problems on persons with motor impairments, we did a user test with this user group. The focus of the test was the analysis of this collective user's mood relative to different accessibility barriers comparing two parallel web pages: one accessible and another non-accessible. The study identified web forms and Flash elements as the most important aspects for this kind of users. On one hand these elements are useful to users, meanwhile, on the other, they raise many accessibility issues. The analysis of results indicates that persons who use assistive technologies are more efficient and effective interacting with web pages, than users who do not use them independently of the severity of their disability.

Overall, users had a positive mood while navigating the accessible website, and were more negative when interacting with the non-accessible website. Our investigation contributes to a better understanding of users with motor impairments confronting accessibility barriers.

Keywords: web accessibility barriers, motor impairments, user mood, user test, users with disabilities, real-world data collection.

Introduction

Nowadays, a large number of websites present accessibility barriers and people with disabilities have difficulties accessing the contents. Different studies show that one fifth of the working age population has a disability and almost 60% of the population would be likely to benefit from web accessibility [62][13]. Some studies have discussed that there is a high variability regarding the accessibility level of Web pages and that few pages reach a high accessibility level [34][33]. Taking this into account, web content usability and web content accessibility deserve special attention in order to improve the quality of websites. An interactive system is more usable as it is easy to learn, understand and use under context-specific conditions [24]. We will use classical user tests [38] evaluation method, which take into account efficiency, efficacy and satisfaction as attributes conforming usability [25], in our research with people with disabilities (PWD). Web accessibility means that PWD and older people can perceive, understand, navigate, interact and contribute to the Web [22].

This article evaluates the mood of a group of users with motor disabilities while they interact with two websites (A-site, an accessible website, and NA-site, a non-accessible website). The final objective is to measure the severity of different accessibility barriers through this group of users' moods when confronted with them. In the framework of our research collected data will be used to communicate accessibility errors to non-technical web content authors in an empathetic way [42]. Web authors will confront persona characters depicting a negative mood when they fail to create accessible content and get the characters mood changed when they repair problems [43]. The failure of legal requirements to date suggests that other means should be considered in transmitting accessibility criteria, and the authors believe it will be easier to get an attitude change by means of empathy with final users. Other articles have suggested similar reasoning [11][49][52].

Related work

Web Content Accessibility Guidelines (from now on, WCAG) [10][12][28], published by the World Wide Web Consortium are commonly used to evaluate the accessibility of websites. To avoid fragmentation they have been repurposed as an ISO standard [26]. Their adoption as a unique method to evaluate accessibility has raised much criticism [46][21][45].

The term "accessibility barrier" refers to any obstacles that make it difficult or impossible for people with disabilities to achieve a goal while they are using an interactive system (in our case, when they are navigating a website) using specific assistive technology [8]. A site without barriers will offer better usability, and will increase people's self-determination and autonomy, two key aspects of their welfare and quality of life [50]. Cited by WebAIM experts as the main accessibility barriers to people with motor impairments are small clickable elements, mouse-dependent actions, and time constraints in user answers [56]. Common assistive technologies (from now on, AT) used by this collective are alternative keyboards, pointing devices, eye-tracking equipment, voice-recognition software and screen scanning options. Some authors have observed that users with motor impairments are forced to do complex movements with standard mouse devices, while they do better with trackball devices. These authors observed also that the use of speech-recognition software presents its own problems, sometimes worse than the problems presented by the content itself [60][24].

Some authors in the accessibility field, such as Lazar [30][31][32], have thoroughly studied the effects of accessibility barriers on websites and desktop applications. Other researchers derive the needs of users with disabilities from user test results [45][23][53]. However, no studies have analyzed the mood of users with motor disabilities while confronting barriers while browsing the web.

Emotions can be classified into three continuous dimensions [44] valence, which takes values from nice to nasty; activation, going from calm to excited; and power, characterized by strong and weak ends. Primary emotions have positive (joy, happiness ...) or negative (anger, fear, sadness ...) valence and, depending to the emotion's intensity, its activation degree will go from "calm" (boring) to "excited" (tense).

There exist several techniques for measuring emotions classified into objective and subjective techniques. The objective techniques are mainly designed to analyze the bodily changes of a person, by means of studying facial expressions or measuring reactions of the human body, such as heartbeat or dilated pupil. According to James-Lange theory [56], different emotions produce changes in the body that cannot be controlled.

The subjective techniques measure the moods of a user through questionnaires, interviews and self-report. They provide information about user experience when performing a specific task. Nevertheless, they are based on a subjective perception and the result may be biased by the user own interests and desires. Related with this technique, we find two different types of self-reports: verbal and non-verbal. In verbal reports the participant use words to indicate the perceived mood, as for example in [57] and [48]. In non-verbal reports, a set of images representing the variety of moods are shown to the users, whom only have to point out which image represents the particular perceived mood, as for example in [28][15][16][14]. Because this last option is easier, in our study we have chosen a subjective technique based on non-verbal language.

In fact, this document presents the results of phase 3 of a more complete research divided into four phases, each involving the same websites being evaluated by users with different disabilities: cognitive (phase 1) [41], impaired sight (phase 2) [40], motor (this article, phase 3) and impaired hearing [39] (phase 4). Phase 2 showed very mild emotional responses to common visual accessibility pitfalls, while phase 1 the importance of readability of texts. Phase 4 is still ongoing at the moment of writing.

Study Context

The purpose of the study was to analyze how an accessibility barrier could influence motor impaired user groups, and try to learn the emotional effects of such difficulties on users, in order to communicate them to content authors.

Experiment configuration

Two sites were created for the experiment: An accessible-site (A-site) [4] and a non-accessible website (NA-site) [37]. Wordpress Content Management System (CMS) [61] was used to develop them. Each site contained touristic information of a city, divided into four html pages: the city, monuments, accommodation, contact.

To grant maximum accessibility in the A-site, we follow the methodology proposed by López [35]: use an accessible template [54] and [1]; review generated code in HTML view; use of plugins such as CCPlayer plugin [9] to enable video accessibility and AAP plugin [2] to enable audio accessibility.

In the NA-Site we use the standard Wordpress configuration: use of a standard template (Twenty Twelve), code generated by the web editor, and without installing any additional plugin. Moreover, several accessibility barriers were created intentionally.

We verified both sites' accessibility following the suggested W3C methodology [55]. This included an automatic evaluation with two online tools: TAW [51] and eXaminator [18], and a human revision with the support of the Firefox Web Developer toolbar [19] and WAT [59] on IExplorer.

A-site does not present any accessibility problem, while NA-site presents problems related to content, template and HTML and CSS code. Table 1 details the content characteristics of each site and the WCAG 2.0 accessibility problems affecting the NA-site.

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Table 1. List of web elements and WCAG 2.0 success criteria with errors. (Pages: All–All pages, 1–The city; 2–Monuments; 3–Accommodation; 4–Contact)

Pages	NA-Site	A-Site
All	No web map (2.4.5) Page without titles (2.4.2) Skip links not implemented (2.4.1) No page headings (1.3.1, 2.4.10) No visible focus (2.4.7, 2.1.2) Source HTML not validated (4.1.1, 4.1.2) Keyboard non-operable (2.1.1, 2.1.2)	Web map Pages with appropriate titles Skip links implemented Page headings Visible focus Correct spacing Source HTML and CSS validate Access to functionality with Keyboard
1	Audio player non-accessible (2.1.2) Video player non-accessible (2.1.2) Video without subtitles and audio description (1.2.1, 1.2.2, 1.2.3, 1.2.5) Google Maps standard (1.1.1, 2.1.2)	Accessible Audio Player (AAP) Accessible Video player (CCPlayer) Video with subtitles and audio description Google maps with accessible features
2	Generics links (2.4.4, 2.4.9) Table layout (1.3.2, 1.3.1) Skip links not implemented (2.4.1) Link opens a new window (3.2.1, 3.2.5) Links/buttons that are too small	Informative text on links Layout without tables Skip links implemented Link opens the same windows Links/buttons cover a sufficiently large clickable area
3	Links/buttons that are too small	Links/buttons cover a sufficiently large clickable area
4	Form controls (1.3.1, 4.1.2, 2.4.6) Form with information (3.3.1, 3.3.2) Image of button without contrast (1.1.1, 1.2.1, 1.2.9, 1.3.1, 1.3.2, 1.4.1, 1.4.4, 1.4.5, 2.4.7, 1.4.8 and 1.4.9) Order focus (2.4.3)	Form controls identified Image of button with contrast Focus without order

Participants

Eight participants took part in the experiment and it was carried out from June to October 2013. Five out of eight users had a spinal cord Injury, one of them had multiple sclerosis which caused him fatigue after tasks of long duration, one interacted with only three fingers (thumb, index and ring) of the left hand, and the last one had cerebral palsy, with a mild cognitive disability that was not relevant to the fulfillment of tasks. This one was the only person with a disability from birth, while the others had become disabled as adults. The users belong to several organizations: ASPID [3], ATADES [5] and Virgen del Pilar [6]

In the users with a spinal cord Injury, there were different degrees of severity in how their upper limbs were affected: two users with very low mobility in hands with stiff fingers were able to use a standard mouse and keyboards with difficulties; two users had almost no mobility in hands (they only could move one or two fingers) and used a special mouse with TrackBall and an onscreen keyboard; finally one user had mobility only with her head and used speech-recognition software as the means of interaction. The user with cerebral palsy used the onscreen keyboard and a joystick. The user with multiple sclerosis and the user who could only move his left hand used a standard mouse and keyboards. All users had more than five years' experience with their AT. Table 2 summarizes these details.

Table 2. User characteristics in the case studies.

Id	Sex	Health Condition	Schooling	Functional	Device
U1	M	Multiple sclerosis	High school	NO AT	Standard Mouse and Keyboard
U2	W	Only three fingers of left hand	High school	NO AT	Standard Mouse and Keyboard
U3	W	Spinal Cord Injury (hands low mobility)	University degree	NO AT	Standard Mouse and Keyboard
U4	W	Spinal Cord Injury (hands low mobility)	Elementary school	NO AT	Standard Mouse and Keyboard
U5	M	Cerebral Palsy	Elementary school	AT	Joystick and on screen keyboard
U6	M	Spinal Cord Injury (hands low mobility)	High school	AT	TrackBall and on screen keyboard
U7	M	Spinal Cord Injury (hands low mobility)	University degree	AT	TrackBall and on screen keyboard
U8	W	Spinal Cord Injury (Only head movement)	University degree	AT	Speech recognition software

Equipment and software

A personal computer with Windows 7 Operating System (Service Pack 3), standard keyboard and 2-button mouse with scroll wheel was used. Each task was recorded with Morae software, version 3.1 [36], and we used a webcam to record gestures and comments of users.

Following BS8878:2010 [7] we grouped the users according to their AT profile, so we differentiate participants which did not adapt any feature of the computer and participants who used their own ATs (Joystick or Oversized TrackBall mouse) and set the operating system on-screen keyboard. Due to the low number of users we included also in this later group the user needing speech recognition software. The exact speech recognition software used was Dragon NaturallySpeaking [17] with the MouseGrid option, which creates a numbered grid on the screen whose cells can be reached just saying its number.

Methodology

We followed the step-by-step approach to usability testing from Rubin [47] and Nielsen [38]. All user tests were carried out in the laboratory UsabiliLAB [20] (GRIHO research group's usability laboratory). The tasks were adapted focusing on barriers affecting users with motor impairments (see Table 3).

We measured efficiency, effectiveness and perceived difficulty, in addition to the user's mood, which was selected with the aid of emoticards [14].

Before the tasks, a pre-test questionnaire (see annex 1) was administered related to past experiences with web accessibility barriers. During the task time and task fulfillment were recorded. At the end of the whole test, a post-test questionnaire (see annex 2) was administered with questions that paralleled the pre-test questionnaire complemented with perceived difficulty of tasks, but related to the current experience. The average time spent on each test was 30 minutes in the case of users with no specific AT usage and 45 minutes in the case of users using personalized AT. In the test every user did task 1 to task 7 on A-site and also on NA-site. Tests were balanced across users, and tasks were randomly ordered to avoid learning or fatigue effects.

Table 3. List of tasks evaluated according to the profile of each participant.(Pages: 1–The city; 2–Monuments; 3–Accommodation; 4–Contact)

Task	Description	Page	Barriers
T1	Looking up a map	1	Opaque objects Keyboard Trap
T2	Playing a video file	1	Opaque objects Keyboard Trap
T3	Playing an audio file	1	Opaque objects Keyboard Trap
T4	Looking up a monument address	2	Internal links are missing Skip links not implemented
T5	Accessing links for more information	2	New Windows Links/Buttons that are too small
T6	Booking a room	3	Links/buttons that are too small
T7	Fill-in and Sending a form	4	Forms with no LABEL tags Links/Buttons that are too close to each other Links/Buttons that are too small

Results

Test results are detailed in the next sections: first we introduce the mood of the users from the pre-test followed by the efficiency, effectiveness and perceived difficulty during task execution, together with mood measurement. Finally, we describe the mood of users in the post-test questionnaire.

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Pre-test

On the pre-test, participants were asked about their user profiles and their moods on previous experiences interacting with either accessible or non-accessible websites. Figure 1 and Figure 2 show that all participants affirmed having a negative mood when they visited websites with accessibility problems (Figure 1), and a more positive mood when they interacted with websites without accessibility problems (Figure 2).

Figure 1. Emotional evaluation in pre-test questionnaire. (a) Non-Accessible website. Question: "How do you feel when you face a non-accessible website?" Source: Prepared by the authors.

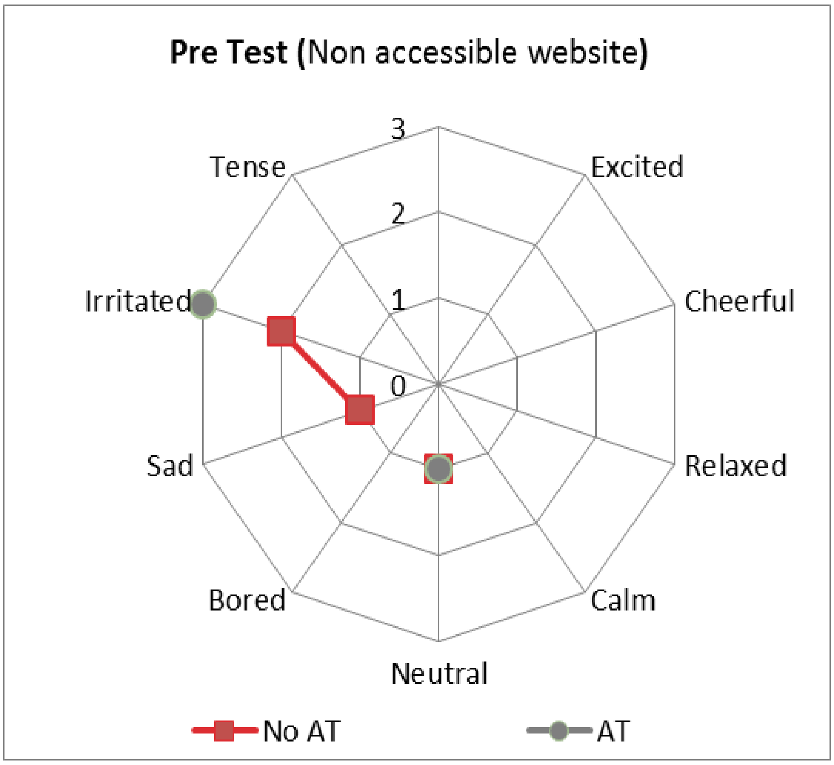

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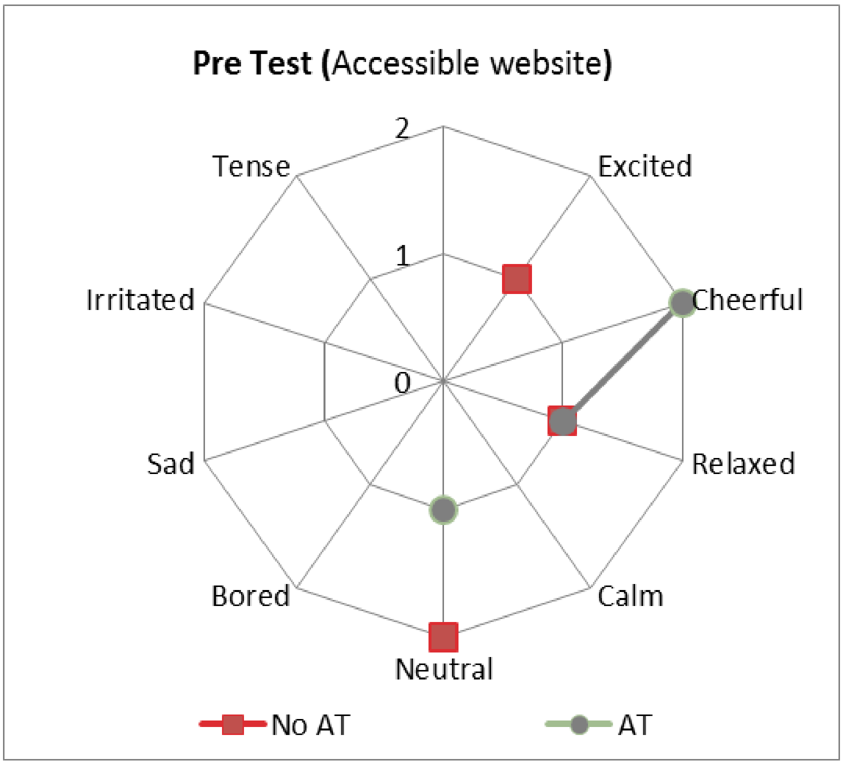
Figure 2. Emotional evaluation in pre-test questionnaire. (b) Accessible website. Question: "How do you feel when you face an accessible website?" Source: Prepared by the authors.



Efficiency

Efficiency was measured by the task completion time. Table 4 shows the average duration measured in minutes that each group of participants needed to perform each task. Although the 'thinking aloud' protocol was used during the test and the time should be considered with caution, the results provide enough information for comparison between the two websites. As can be seen in the "Total" column in Table 4, all users required less time (between 3-4 minutes) to perform the same set of tasks in the A-site than in the NA-site.

Users using specific ATs were quicker in task resolution in both webs than users with no specific settings, even when the severity of the disability was more severe in average in the first group.

Table 4. Average task duration (in minutes).

Task	AT USER A-site	AT USER NA-site	NO AT USER A-site	NO AT USER NA-site	ALL USERS A-site	ALL USERS NA-site
T1	0,73	3,31	1,3	2,97	0,97	3,14
T2	1,01	0,42	0,46	0,67	0,68	0,53
T3	0,64	0,51	0,36	0,6	0,48	0,55
T4	0,33	0,34	0,32	0,6	0,32	0,45
T5	0,08	1,37	0,24	0,96	0,14	1,15
T6	1,97	1,46	3,97	5,2	2,80	2,76
T7	1,72	2,1	2,07	1,89	1,89	1,99
Total /average	6,48	9,51	8,7	12,88	7,28	11,07

Effectiveness

Effectiveness was counted as 1 if the task was completed, and as 0 otherwise. If 3 out of 4 users were able to complete the task, the final result was 75%. As expected, better results are observed on the A-site than on the NA-site. (See Table 5).

All users were able to successfully complete the proposed tasks, although interaction with maps, links and forms caused them several difficulties. In task 1, related to accessing an interactive map (similar to a Google maps), users had difficulties moving around and interacting with the different elements of the map. On the other hand, in A-site, with a keyboard-friendly map, users did not experiment difficulties. Task 5, consisting of accessing an external link, caused similar difficulties to all users, and initially we thought it was due to the size of the links, which was very small or to their target, which was a new window. A later review of the recordings showed that the difficulty was related to a usability problem, as it was difficult to differentiate and to visualize which text elements were links. In task 7, related to filling in and sending a form, only the user working with voice recognition software had difficulties in correctly writing within the form fields. This task did not present particular problems for the rest of the users.

Table 5. Percentage of users who completed the tasks.

Task	AT USER A-site	AT USER NA-site	NO AT USER A-site	NO AT USER NA-site	ALL USERS A-site	ALL USERS NA-site
T1	100%	50%	75%	100%	87%	71%
T2	100%	100%	100%	100%	100%	100%
T3	100%	100%	100%	100%	100%	100%
T4	100%	100%	100%	100%	100%	100%
T5	100%	50%	100%	75%	100%	61%
T6	100%	100%	100%	100%	100%	100%
T7	100%	50%	100%	100%	100%	71%
Total /average	**100%**	**74%**	**96%**	**96%**	**98%**	**84%**

Perceived difficulty

As the measure of mood is parallel to perceived difficulty we restrict the evaluation of this indicator to the perceived difficulty of interaction on a Likert scale. At the end of each task the participant should value it according to his/her perception as Impossible (0), Very difficult (1), Difficult (2), Easy (3) or Very easy (4).

Results are displayed in Table 6. Moreover, as expected, there is a clear correlation between the results in Tables 5 and 6.

Table 6. Average perceived difficulty. 0–Impossible; 1–Very difficult; 2–Difficult; 3–Easy; 4–Very easy.

Task	AT USER A-site	AT USER NA-site	NO AT USER A-site	NO AT USER NA-site	ALL USERS A-site	ALL USERS NA-site
T1	3,7	2,5	3,2	4,25	3,44	3,26
T2	3,7	3,5	3	2,2	3,33	2,77
T3	3,2	3,2	3	2,7	3,10	2,94
T4	4	3,7	3,7	3,5	3,85	3,60
T5	4	2,5	3,7	2,5	3,85	2,50
T6	3,7	3,7	3,5	3,5	3,60	3,60
T7	4	3,2	3	3	3,46	3,10
Total /average	**3,75**	**3,15**	**3,29**	**3,03**	**3,51**	**3,09**

User’s mood

User’s mood was measured through an emoticard selection question [14]. Nine emoticards associated with different moods were shown: 1.Excited, 2.Cheerful, 3.Relaxed, 4.Calm, 5.Neutral 6.Bored, 7.Sad, 8.Irritated, 9.Tense.

Underneath we present the results of users’ mood selection organized by accessibility barrier. In this case, the test was planned to obtain the user's mood grouped into three groups of tasks (T1, T2, T3), (T4, T5) and (T6, T7). The grouping of tasks was based on accessibility barriers:

Tasks 1, 2 and 3: Opaque objects and keyboard trap,

Tasks 4 and 5: Internal links are missing, Skip links not implemented and New windows, and

Tasks 6 and 7: Forms with no LABEL tags, Links/buttons that are too close to each other and that are too small.

We proceeded like this because we found very difficult (if not impossible) to discriminate each barrier alone to obtain rich data to be analyzed.

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As the selection was administrated as a post-task questionnaire, sometimes it was not possible to uniquely differentiate each barrier. Next paragraphs analyze every group tasks.

Opaque objects and keyboard Trap

These barriers were evaluated in three different tasks: T1. Looking up a map, T2. Playing a video file and T3. Playing an audio file. In all cases, we used Flash components to show information on an interactive map, a video and an audio. In general, all users were able to complete the task and showed a neutral mood on the non-accessible page, with a more positive mood in the accessible page. (See tasks 1, 2 and 3 on Table 7).

Internal links are missing, Skip links not implemented and New windows

These barriers were evaluated in two different tasks: T4–Looking up a monument address, and T5–Accessing links for more information. None of them caused severe difficulties with links, and the users' moods were quite positive in both cases. (See tasks 4 and 5 on Table 7).

Forms with no LABEL tags, links/buttons that are too close to each other and that are too small

These barriers were evaluated in two different tasks: T6–Booking a room and T7–Filling in and sending a form. All users were able to complete the tasks without critical difficulties, although results show differences in execution time within the different tested groups. The user interacting with speech recognition software had the most significant difficulties while executing the tasks. In general user mood was positive (See tasks 6 and 7 on Table 7).

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Table 7. Autoevaluation of user's mood.

Task	AT USER A-site	AT USER NA-site	NO AT USER A-site	NO AT USER NA-site
T1 T2 T3	Excited (1) Calm (2) Neutral (1)	Neutral (4)	Cheerful (1) Relaxed (1) Neutral (2)	Calm (1) Neutral (2) Bored (1)
T4 T5	Excited (1) Relaxed (1) Calm (2)	Relaxed (1) Calm (2) Neutral (1)	Cheerful (1) Relaxed (1) Calm (1) Neutral (1)	Relaxed (2) Neutral (1) Bored (1)
T6 T7	Cheerful (1) Relaxed (1) Calm (1) Neutral (1)	Cheerful (1) Calm (2) Neutral (1)	Cheerful (1) Relaxed (1) Calm (1) Neutral (1)	Relaxed (1) Calm (1) Neutral (2)

Post-test results

After testing both websites, users were asked again about their mood while interacting with accessibility barriers, in order to compare them with reported moods from the pre-test. Figure 3 and Figure 4 show that all participants tended toward a neutral or calmed mood when they had visited websites with accessibility problems (Figure 3), while they stated having experienced more negative moods with inaccessibility and more positive moods interacting with websites without accessibility problems (Figure 4). This difference could be related to critical incident technique because users tend to remind worst case scenarios.

In both questionnaires (pre- and post-test) the accessible page caused more positive results. Also in neither of them did any user report a very negative mood (sad, irritated or tense).

As the objective was to gather a first impression of the mood no further statistical analysis were done.

Figure 3. Mood's evaluation in post-test questionnaire. (a) Non-accessible website. Source: Prepared by the authors.

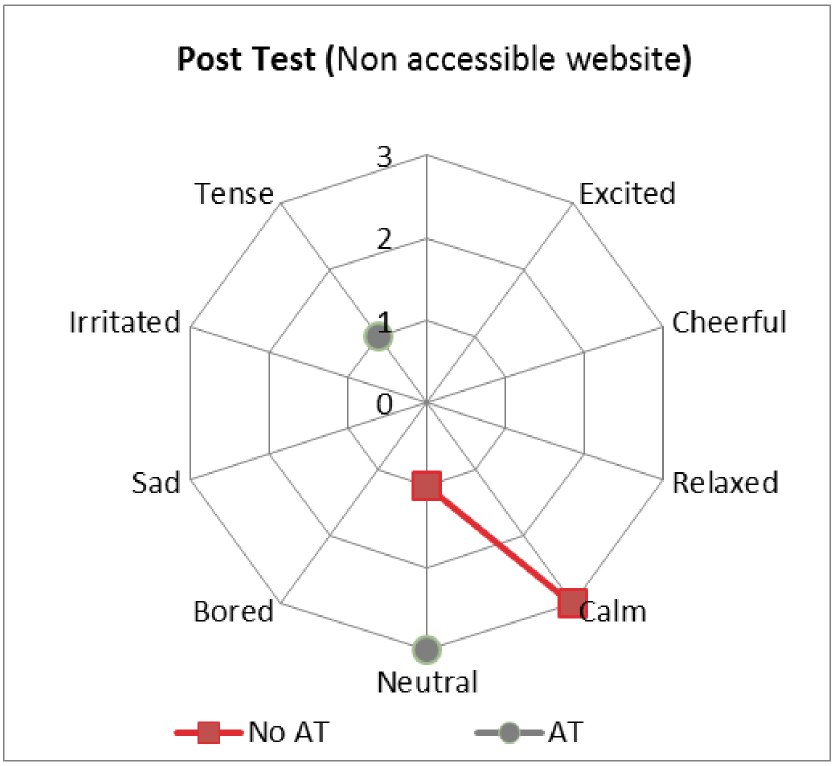
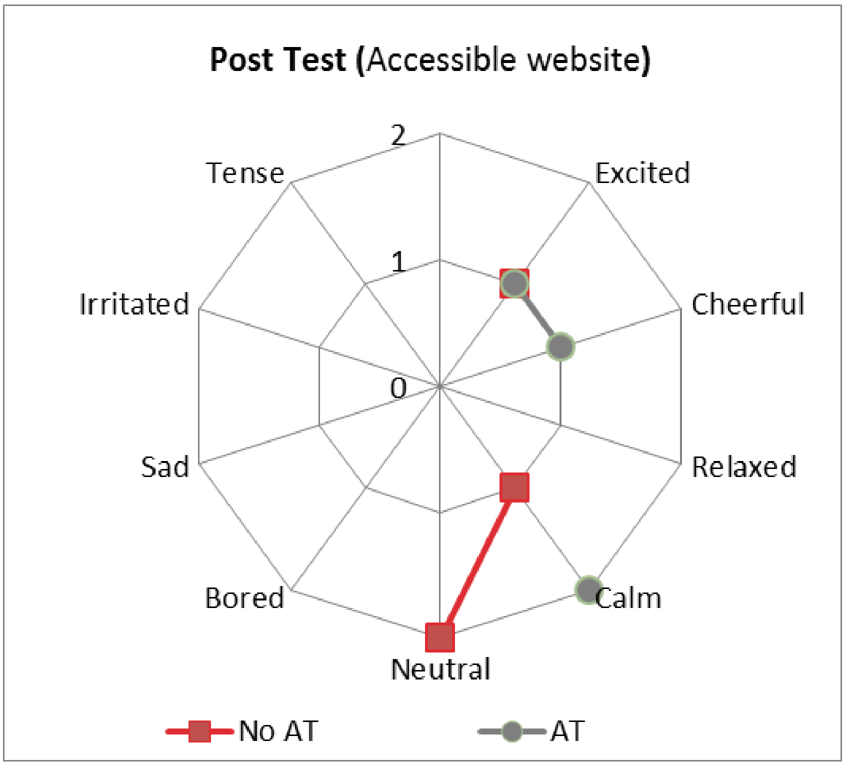


Figure 4. Mood's evaluation in post-test questionnaire. (b) Accessible website. Source: Prepared by the authors.



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Taking into account that the users' reported moods were not very intense, perhaps in order to communicate the need for accessibility to web authors, the message should be reinforced through the missed opportunities of users, such as "I could be cheerful and excited after visiting your web, but due to the difficulties I experience with (this barrier), I'm just neutral".

Conclusions

The purpose of the study was to analyze how some accessibility barriers could influence users with motor and dexterity impairments, and try to learn the effects of such difficulties on users' mood. This fits a bigger research framework and these results will be used to communicate these moods to content authors through persona characters. The study was done on a small-size sample of users, eight persons in total.

In reference to the users' mood results, in both tests more positive moods were registered in the accessible page, but in general, moods were not as negative as previously stated by participants in the pre-test questionnaire. A possible explanation for this change is, as previously said, the worst case memory. The habit of confronting different degrees of accessibility could have reduced their reaction to adverse experiences in web navigation, while softening their bad reactions. Another possible motivation is that in a lab setting with observers, due to social desirability, users tend to increase their emotional control in disadvantageous conditions [27].

The study has identified opaque objects and keyboard traps elements as the most important web elements affecting people with motor disabilities. Form elements negatively affect completion time and caused particular problems tot the user interacting with voice-recognition software. Those are the aspects related to motor disabilities that shall be communicated to content authors.

In the test we observed that users using specific AT (joystick, trackball, and screen keyboard, i.e. assistive technologies customized to their particular needs), often with severe impairments, got better results in all the usability measures than users without any customization in the computer, even when some had mild motor disabilities. This is consistent with previous research findings [60] that stated that users with a common mouse require some combination of more complex movements than those using a trackball.

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Annex 1. Pre-test survey

Pre-test survey was organized in various question groups:

A. Questions related to user profile: 1. Genre; 2. Age; 3.Schooling; 4.Current job; 5. Diagnosis

B. Questions related to web access of disability person: 1. Which device do they use; 2.Computer configuration; 3. Mobile configuration

C. Questions related to kind of use: 1.Time of use of assistive technology; 2.Frequency of computer use; 3.Usual tasks; 4.Web services used.

D. Questions related to accessibility barriers: 1.Assessment of difficulty of content access; 2.Accessibility barriers related with different web elements; 3.Assessment of the user's mood when navigating a web page without accessibility problems: □ Excited □ Cheerful □ Relaxed □ Calm □ Neutral. 4. Assessment of the user's when navigating a web page with accessibility problems: □ Neutral □ Bored □ Sad □ Irritated □ Tens

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Annex 2. Post-test survey

Post-test survey was organized in a list of question:

1. Which web page seems to be more accessible?

□ Ávila □ Salamanca

2. What elements should you change of Avila web page to be more accessible? ____

3. What elements should you change of Salamanca web page to be more accessible? ____

4. Please, express your mood when you have been using Avila web page

□ Excited □ Cheerful □ Relaxed □ Calm □ Neutral □ Bored □ Sad □ Irritated □ Tense

5. Please, express your mood when you have been using Salamanca web page

□ Excited □ Cheerful □ Relaxed □ Calm □ Neutral □ Bored □ Sad □ Irritated □ Tense

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