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High-literate and Low-Literate User Interaction: A Comparative Study Using Eyetracking in an Emergent Economy

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Abstract. The information technology including, increasingly, the services offered to citizens, this necessitates the development of web pages accessible to everyone, regardless of education level. Whereas a significant portion of the Brazilian population is within the low literacy profile, the objective of this research was to analyze the different forms of navigation among users of high and low literacy. Data were collected through user testing through eye tracking. The experiences of interaction were performed from two tasks initiated in the Google search engine and completed in two popular sites. At the end, some suggestions were proposed interface improvements.

Keywords: Accessibility, Low-Literate Users, Eyetracking, Interface.

1 Introduction

The frequent use of technology is growing worldwide. Currently, there is a gradual migration of daily routines, to the electronic mean and the Web tools became part of everyday life [17] and perform a social role especially for users with disabilities [10].

Access to information should be facilitated and guaranteed, so this migration brings new challenges to researchers and systems developers, since their interfaces need to be accessible to all users' profiles.

To help users to retrieve web content, search engines are often used: 80% of the access to Web pages comes from these tools [20]. Search involves analyzing different types of media, so it is a mentally exhausting activity that requires focus and attention [7],[13]. But there are users who have limitations related to literacy that can jeopardize the interaction mainly because the available content on the Web is mostly textual [10],

[12]. The most usability problems on the Web are related to finding, reading and understanding information [17]. People with low reading skills have these problems magnified due to lack of language skills, so it is characterized also as an accessibility issue. The lack of these skills affects the way people interact with computer interfaces as search engine [9],[6], used to retrieve Web content, that is predominantly textual [7].

Users with low reading skills have peculiarities that should be considered on the design and development of sites, such as content perception limitations and search strategies [6],[9]. So, they use the web in a different way from those users whom have high reading skills [3],[10],[14]. The aim of this research was observed and analyze users, with two different profiles (high-literate users and users with low reading skills), toward to identify their experience and interaction details, during queries formulations on search engine, Google, and the desired information from two different popular commercial sites.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) [14] considers as functionally illiterate, persons lacking in reading, writing, calculation and science skills, whose level of schooling is equivalent to less than four years of school attendance. This classification, adopted by the National Institute of Education Studies and Research Anísio Teixeira (INEP) and the Brazilian Institute of Geography and Statistics (IBGE) [21], [8] was utilized. According to the Brazilian agency, the rate of functional illiteracy at the year 2013 in Brazil was estimated at 20% of the total.

To observe the users interactions, it was adopted the eyetracking method to collect data. It was used the Tobii T120 eye tracker equipment from Tobii Technology [19]. To investigate the relevance between text and image in the information available on the sites analyzed, the pattern of saccadic movements and fixations was used.

For the tasks execution, ten users were observed, five for each profile. This number was defined taking in account the recommendations proposed by Nielsen [18]. As the number of users increases, the information that is collected tends to repeat itself, providing a smaller amount of news information. According to research, five users are able to detect 85% of usability problems [18]. To select and define the users' profile, the volunteers answered to a questionnaire [1].

During the tests, the participants perfomed two queries on a search engine (Google) and completed the determined tasks on two different commercial sites, selected based on the familiarity with their physical stores. The time complete the tasks was established among researchers, but unknown by users to promote naturalness during the interaction.

Besides the eyetracking, direct observation method (in which researchers observes the path followed during navigation) and thinking aloud verbal protocol were adopted.

The tests were conducted in a controlled laboratory environment. After responding the questionnaire and signing a consent term, the eyetracking equipment was introduced to each participant. After calibration, tasks, printed on sheets, were presented to the users. A short questionnaire was filled by users at the end of each task, to verify the difficulties around the task, and find out interface improvement suggestions.

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2 Literacy in Brazil

Literacy can be analyzed by different perspectives and conceptualized in different ways. A common understanding about literacy involves oral, reading and writing skills, besides abilities with logic, mathematics, symbolic analysis (images and sounds) and text interpretation [21]. In fact, the concept of functional illiteracy varies from region to region. Nowadays it is a common approach to consider that these skills must be contextualized and they are not developed equally among different individuals. Besides, literacy concept also considers functional aspect that means the ability to apply oral, reading and writing on different areas of daily life, as in computing, ecology, health and other areas [21].

The United Nations Educational, Scientific and Cultural Organization [14],[21] considers as functionally illiterate people between 15 and 64 years old, which lack mastery of skills in reading, writing, calculations and science, corresponding to an education of less than four years of study [4],[14]. This classification, adopted by the National Institute of Education Studies and Research Anísio Teixeira (INEP) and the Brazilian Institute of Geography and Statistics (IBGE) [21] was utilized in the present work. A research performed by IBGE showed that 29 million people in Brazil are functional illiterate that means more than 20% of the total population [14]. In this work, we adopt this concept but we call the participants as "low literate users", once one of the protocols used to guide the study recommended not to call them functional illiterates [3].

There are other criteria that could be used instead of considering only age and years of study on formal education. There are institutions that developed specific literacy and numeracy tests, with levels of difficulty and punctuation, to evaluate people's skills in reading, writing, calculations and science. However, these tests are private, so there are no public tools that allow us to classify users this way [3].

2.1 Eyetracking and tests with users

Eyetracking is the technology that allows tracking ocular movements of the observer by means of infra-red rays, recording both the course taken by the eye and its focus point [2]. Once it has tracked the course taken by the user's eyes, it can support the development and improvement of the interface, which, if well designed, can become a source of motivation or, conversely, become a decisive factor in rejecting the system [5].

Within the web context, it is important to consider the functionally illiterate as potential users and propose accessible technological solutions for this group, taking into consideration the accessibility guidelines [16]. One of the drawbacks for low-literacy users is text comprehension. Intelligibility is the word used to describe the characteristic

of a text that is easy to read and understand. Easy texts can compensate for low levels of prior knowledge, poor reading skills, or lack of interest or motivation [2]. Thus, the proposed solutions should be made adequate to the more learned public, while guaranteeing that it can be easily read and understood by functional illiterates as well [3].

2.2 Related Works

In his research studies, Barboza [2] put together an interesting bibliographical survey on usability and on the plain and simple language used on government websites for those with high or low literacy, where he also mentions the use of eye tracking. However, he did not apply tests to the above mentioned users.

In his work, Lukasova [11] used eyetracking in conjunction with Functional Magnetic Resonance tests to investigate changes in behavior and neural functioning in children and adults with the aim of contributing to future studies for specific clinical groups, such as developmental dyslexia, autism and schizophrenia. Despite the relevance of this work, the author did not use adults with any type of deficiency or learning difficulty.

3 Research Method

The current research study, of an exploratory nature, is based on the qualitative method of data collection consisting of four stages, as described below:

a. Selecting the profile of users to take part in the study: ten adults were chosen, forming two distinct groups. The first group was composed of 5 adults with at most three years of schooling, i.e., less than 4 years of completed formal studies in accordance with the UNESCO [21] classification. The second group, composed of 5 fully literate adults, had 5 years or more of schooling. All participants have at least three months of practical knowledge of web browsing and are between the ages of 18 and 64.

b. Selecting sites and defining tasks: two commercial sites for popular Brazilian stores were chosen according to the profile of the users. In the first store - "Casa Show," which sells construction materials, - the user was supposed to look up the price of a certain item. In the second store - "Óticas do Povo", which sells eyeglasses, - the user was supposed to find the address of a specific shop location.

c. Case Study: a case study was set up for the two groups showing their performance of the required tasks (details in section 4).

d. Data analysis: Eyetracking technology generates complementary results to those of traditional usability tests, with reports on user web browsing [19]. The data provided by this type of test come in various formats (quantitative, statistical, with images and videos), showing the path covered sequentially during browsing, indicating the duration at each focus point of the participant's eyes, and capable of detecting where there was

more cognitive effort or likely problems of non-explored usability. The results of the use of eyetracking tests are presented in section 5 of the Data Analysis.

3.1 Limitations

It was necessary to categorize users and so the UNESCO classification was chosen, which has been adopted by the Brazilian Institute of Geography and Statistics (IBGE). If other tests had been chosen to assess reading and writing abilities of users, other results might have been obtained. Despite the wide range of ages adopted as a criterion, users having the same level of schooling and similar computer skills were chosen, so as to minimize a possible bias caused by the age criterion.

4 Case study

Preparation of test environment: Initially, researchers defined user profiles and classified them in two distinct groups, with 5 participants in each, being that the first group contained members with little schooling and the second, members with higher schooling. Then invitations to join the research study were sent out to associations, universities and community centers outlining the educational profile of the users in question. Eleven users were willing to join the study, being that one of them was selected for the pilot test.

Implementation of tests: One of the users was given a pilot test which was comprised of two tasks to be performed on two commercial sites of popular Brazilian shops, and only then was the test given to the remaining 10 users. All users signed an informed consent form in order to partake of the study which was read out loud by the researchers. Further clarification about the research work at hand was also provided at this time. Afterwards participants replied to a printed questionnaire, which had been used for the profile classification according to each one's declared schooling time.

Next, the Eyetracking equipment was introduced and each participant had his eyes calibrated by the machine, besides receiving the necessary information about posture and concentration in order to avoid possible loss of registration by the tracking device. The number of tasks required on the test was outlined, as well as the freedom and the expected autonomy each user would have to perform said tasks, before seeking help from the researchers. To assure anonymity of participants, their names were entered in code as follows: LL_01, LL_02, LL_03, LL_04 e LL_05 for the low-literacy group and HL_01, HL_02, HL_03, HL_04 e HL_05, for high-literacy users. Table 1 shows the profile of each participant and the total time needed to perform each task.

In order to understand better the logical and strategic content that led each user to make a decision while undertaking a task, be it due to error, misapplication or distraction, participants were requested to verbalize their thoughts after the assessment session, i.e., a protocol of consecutive verbalization was adopted. Simultaneous verbalization was

not chosen because according to the "Web Accessibility Assessment Protocols for Functional Illiterates" proposed by Capra [3],[4], simultaneous verbalization is a barrier for low-literacy users.

Table 1. Users profile.

Basic users data				
User	**Age**	**Formal Education**	**Execution time task 1**	**Execution time task 2**
LL_01	59	3 years of schooling	06 min e 50s	05min e 22s
LL_02	64	3 years of schooling	04min e 05s	10min e 03s
LL_03	58	3 years of schooling	02min e 42s	06min e 55s
LL_04	62	3 years of schooling	02min e 22s	06min e 49s
LL_05	59	3 years of schooling	05 min e 31s	05 min e 26s
HL_01	36	PhD	01min e 49s	34s
HL_02	35	Graduate	01min e 02s	36s
HL_03	38	PhD	51s	36s
HL_04	40	PhD	57s	44s
HL_05	33	PhD	46s	39s

Application of tests: After initial adjustments, the 10 users began taking the tests, which contained the same tasks as the pilot test. A video of the tests was recorded by the tracker whilst researchers took notes using the direct observation technique in sync with the recordings. Each task was oriented with positive comments in order to encourage users to continue the test. Each task was to take 10 minutes, though researchers could only offer their help after the 5 initial minutes had passed. At the end of each task, a questionnaire about the performance of the task was filled out and a quick interview with the user ensued, focused on the interaction process with the sites and the functionality of the tasks. Once the reports had been written, a survey of the data using certain collected metrics during web browsing of participants was made for later comparison with reports generated by eye tracking, model TOBII T120. Ocular tracking equipment can generate the most varied types of reports according to the metrics needed by researchers. Because of this, once the tests had been completed, the Areas of Interest (AOI) that would be relevant for the research were determined. Then quantitative data was extracted, with image and video of each participant showing not only the path taken during browsing, but also the behavior of the user.

5 Data analysis

In order to analyze the data, the following ocular tracking metrics were adopted: First Fixation Duration (FFD), the duration in seconds of the first fixation on an AOI; Fixation Count(FC), the number of times a participant fixates on an AOI; Mouse Click Count (MCC), the number of times a participant clicks the mouse on an AOI; Time To

First Fixation (TTFF), the time elapsed from the stimulus onset to the first fixation on an AOI; and Time To First Mouse Click (TTFMC), the time elapsed until the participant first clicks the mouse on an AOI.

The areas of interest were chosen based on the heat map resource that registered the areas that most caught the attention of participants, as well as interface elements that would receive user interaction in order to finish tasks. The following areas of interest were selected: “Google search button”; “lower Google search button”; “Google search engine on inner page”; “Google search engine”; “upper Google search engine”; “link to the initial site page”; “first Google-sponsored link”; “search suggestion in text area”; “Casa Show search area”; “Casa Show hydraulics menu”; “small water tank image”; “large water tank image”; “Óticas do Povo menu”; “Óticas do Povo central banner”; “Óticas do Povo lower banner”; “Óticas do Povo image map”; “Óticas do Povo text map”; “Óticas do Povo shop address” and “Óticas do Povo Ctrl + F”.

5.1 Observation made during the first task

During the first task, users were to start at the Google site, then locate the site for the Casa Show shop and consult the price for a 1000 liter Fortlev water tank. On average, the time needed to complete the first task was 258 seconds for low-literacy users, and approximately 65 seconds for high-literacy participants.

1st Step (Searching the Google site): Associating FC metrics (Fixation Count) to the area of interest (AOI) “Google search engine”, it was observed that before entering, nine users clicked on the search engine and only one (LL_01) clicked on the “Google search” button. This user commented during consecutive verbalization that he had needed to “turn on” Google by clicking on the button, before initiating the search.

Based on TTFMC metrics (Time To First Mouse Click) in connection with the area of interest (AOI) “Google search engine,” one can affirm that on average low-literacy users took 38.8 seconds to click on this field while those of high-literacy took 3.6 seconds.

Regarding the association of MCC metrics (Mouse Click Count) with the AOI “Google search button,” it was observed that all participants disregarded the Google search Button and opted to use the ENTER key, with the exception of the first low-literacy user.

The scroll bar resource was used by all low-literacy users, unlike the other group that preferred to use the (Ctrl + F) shortcut, or search fields to the sites.

As regards the association of FC metrics (Fixation Count) and MCC (Mouse Click Count) with the AOI “suggestion of Google search auto-completion,” it was possible to note that of the three high-literacy users who read the Google suggestions, only one took advantage of this resource. In contrast, all low-literacy users ignored the suggestions. This behavior had already been ascertained during the study. Capra [4] states that low-literacy users behave differently from high-literacy users. The user’s context,

such as his country, culture, language, level of schooling, age and experience with computers, also reflects his mental models [5]. Users with less knowledge are less flexible in their search strategies and tend not to resort to new approaches [15].

In relation to the association of the FFD metrics (First Fixation Duration) and TTFMC (Time To First Mouse Click) with the AOIs "link to the initial site page of the task" and "Google sponsored link", it was seen that all low-literacy users became confused with the sponsored links to competitors' sites, in detriment to the attention they should have been paying to links to initial pages of the site proposed in the task. Thus all of them had to reinitiate the task. The tendency to abandon the search was also perceived when they became satisfied with their search results, even though they had not obtained the best or the most correct result, which coincides with the research studies of Modesto [15].

Now the majority of high-literacy users disregarded the sponsored links, paying much more attention to the objectives proposed in the tasks.

The Google search engine site displays search results in two lines: the first as a link (underlined), taking users to another page, and the second (positioned under the link), as a URL of the visited site. Knowing that the link is composed of key words of the search conducted by the user and that not always does the URL associated to the link correspond to the address awaited by the user, it was perceived that the low-literacy participant would get confused with this analysis of results.

As low-literacy participants have difficulty in quickly transferring their attention from one subject to another without getting lost, they could only keep their focus, when typing, either on the text entry field or on the keyboard. The resource had no influence on searches when they were about supplying feedback more quickly to the user [15]. This observation can be confirmed based on the path taken by the eyes (gaze plot) which shows there were more fixations on the links than on the URLs (positioned under each link of the search results.)

2nd Step (Searching the Casa Show site): The initial "Casa Show" site page was visited by 8 participants, 4 of each profile, as shown by TTFF metrics (Time To First Fixation) with the AOI "Casa Show hydraulic menu", being that the behavior of each profile of participants was distinctive. Those at low-literacy levels would browse starting from the vertical site menu, aided by the scroll bar, but only one of them realized that the sub item on the menu containing the option "Hydraulics" would lead to the "water tank" product proposed in the task, which can be proven by FC metrics (Fixation Count) with the above mentioned AOI.

Based on the TTFC metrics (Time To First Fixation) with the AOI "small Casa Show water tank image" it was seen that within those in the low-literacy profile, 3 complied with the task by image fixation, differently from the other 2, who did so by text analysis, as the value of this metric (TTFF) with regard to the area of interest resulted in zero.

Of the 4 high-literacy users who browsed the initial page, only one located the inner page with the product by clicking on the "Hydraulics" option, according to the association between MCC metrics (Mouse Click Count) with the area of interest (AOI) "Casa Show hydraulics menu." The analysis of the MCC metrics (Mouse Click Count) and the AOI "Casa Show search field" allowed researchers to observe that 2 participants of this profile found the inner page with the help of the Casa Show site search field. The other high-literacy user used the site images, according to data obtained by the association between MCC metrics (Mouse Click Count) and the area of interest (AOI) "small water tank image."

Continuation of subsection 5.1

By means of the association between FC metrics (Fixation Count) and the AOIs "small water tank image" and "large water tank image" it is possible to state that low-literacy users, before interacting with images related to the researched product, had 3 times greater fixation on the texts than did high-literacy users. To accomplish the task, low-literacy users undertook lengthy reading of the greater part of the information in the texts and only then did they compare this to the images in order to interact with the interface. However, high-literacy participants browsed in a more objective way and perhaps due to greater experience with the Internet, used resources to optimize the search, often disregarding both the menus and the images.

5.2 Observations made during the second task

During the second task, participants were to start at the Google site, then locate the Óticas do Povo site to find the store address in the neighborhood of Campo Grande. The time needed to complete the second task was 415 seconds for low-literacy users, and 38 seconds for high-literacy participants, i.e., the latter were on average eleven times faster.

1st Step (Searching the Google site): With reference to TTFF metrics (Time To First Fixation) and TTFMC (Time To First Mouse Click), one can observe that in order to perform the first step (arrive at the initial "Óticas do Povo") site page, low-literacy users took, on average, 356 seconds, while the high-literacy users took 26 seconds, i.e., the latter were on average 13.6 times faster.

The date in which the 2nd task was performed, the AOI "Google-sponsored link" corresponded to a competitor's site to the one that should have been searched. Thus, related to the FFD metrics (First Fixation Duration) and MCC (Mouse Click Count) it was possible to note that in this AOI, low-literacy users paid less attention and spent less time, fixating their eyes on this link for 0.11 seconds, on average. However, high-literacy users displayed fixation duration on average of 0.32 seconds and did not click on the competitor's site, opting for the link of the expected site for the task. This might

justify the fact that the majority of low-literacy users became confused with competitors' sites, feeling the need to restart the task. By virtue of the greater time of fixation for the AOI "Google-sponsored link", it was seen that high-literacy users were not dispersive with the link of a competitor's site and were able to focus better on the task.

2nd Step (Searching the Óticas do Povo site): Based on the association of the TTFF metrics (Time To First Fixation) and TTFMC (Time To First Mouse Click) with the AOI "Óticas do Povo stores menu", one can state that the time frame between arriving at the initial site page and clicking on the "Stores" menu was greater for low-literacy users (94 seconds, on average) as compared to the time taken by high-literacy users (2 seconds, on average). One can thus affirm that low-literacy users are more susceptible to interface problems, such as the lack of legibility of the "Stores" menu, caused by the small font size and by little color contrast. This was confirmed during the post-test interview when participants were questioned about suggestions for improving the site, even though they had already written on the questionnaire that they had none. During the interview, however, they said that the size of the letters could be enlarged and that they were unable to see clearly due to the colors.

One characteristic that may have contributed to this longer period of time is low legibility of the "Stores" menu that displayed reduced font size and little color contrast.

As regards FC metrics (Fixation Count), one could observe that, although the tracker registered seventeen fixations on the "Stores" menu on the part of low-literacy user LL_04, he was unable to associate the menu label with the task objective. In addition, this same user, when associating the FC metric (Fixation Count) to the AOI "lower Óticas do Povo banner", which corresponds to a promotional link (with images of eyeglasses), made 28 fixations, believing this was the path to the store addresses. His intentions were made clear during the consecutive verbalization, when user LL_04 stated: - I was trying to "enter" the store by going through the shop window. The addresses should have been "inside." When the user clicked on this link, he was sent to a page of offers, becoming even more frustrated as he did not find the store addresses there. When 5 minutes of the test had passed (more than half the time given to perform the task), this user received help from the researchers and went back to browsing the upper horizontal menu so that he was finally able to interact with the "Stores" menu to finish the task. This same promotional link received on average 6 fixations from the other 4 low-literacy users, but was ignored by users of the other group.

6 Sugesttions for Improving the Interface for Low-Literacy Users

Owing to the study, some common behaviors and difficulties for low-literacy users were perceived:
Labels used for interface elements, such as buttons and menu items, among others, should be objective and clear so as not to induce the user to error. One such example occurred with the "Google Search" button, which caused two participants to select this

button before actually typing something into the search field, believing that only by this means could they initiate the Google search.
Interfaces should be designed using simple language in order to facilitate browsing for this type of user, since they do not have the ability to read and write to a full extent.

As this type of user does not normally make use of search tools on commercial sites, preferring to navigate the menu, these should not contain too many sub-items and should be labeled in a simple way. The use of unusual or technical words can lead to loss of time and user withdrawal. The word “Hydraulics”, present on the site of the first task, can be used as an example of this. A low-literacy participant could hardly be expected to know this word, which could be replaced by “pipes and water”. For the site of the second task, “Stores” on the menu could be replaced by “Addresses”.

One should seek to use only images that contribute to the understanding of the task. Gazeplot showed that one of the low-literacy participants was distracted by the photo of a famous Brazilian model, thus taking longer to accomplish the task.

Care should be taken with the use of images so that they do not cause ambiguities or confuse users.

Due to the time and difficulties low-literacy users had to conclude the second task, one might suggest the use of a search filter by alphabetical order.

7 Conclusion

The aim of this research work was to assess the interaction of low-literacy Brazilian users with web system interfaces, focusing on accessibility and usability characteristics, by means of eyetracking. Low-literacy and high-literacy user behavior was analyzed during browsing. In order to do this, Tobii T120 equipment was used during test application with video recording, in addition to questionnaires and interviews.

Researchers were able to determine metrics and areas of interest of participants and, after the conclusion of tests, the tracker produced navigation reports for each user with a large amount of data. This resource allowed the study to make use of fine details that only observation or even recording of users would not have shown.

Eyetracking results point to differences in navigation of users having distinctive literacy profiles. By means of eye-tracking metrics, mainly due to the quantity and duration of fixations, it was possible to measure the degree of difficulty that low-literacy users have when navigating, showing that this profile user reads the entire text on pages so as to be sure to make the right decisions and that images, when not contextualized, may be dispersion factors.

Recommendations for improving interface need validation though they were based on earlier work already mention in section 2.3. It is hoped that these suggestions can contribute to the development of accessible interfaces for this type of user.

It is recommended for future work that a larger number of users be used in order to perform a statistical treatment of the data.

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