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A Mobile Application for Displaying More Accessible eBooks for People with Dyslexia

Luz Rello[a], Gaurang Kanvinde[b], Ricardo Baeza-Yates[c]

[a]*NLP & Web Research Groups, Universitat Pompeu Fabra, Barcelona, Spain*
[b]*Accessible Systems, C/2, MadhavBaug Society, Sir M V Road, Andheri(E), Mumbai 400 058*
[c]*Yahoo! Research Barcelona & Web Research Group, Universitat Pompeu Fabra, Barcelona, Spain*

Abstract

In this paper we present an ebook reader for Android, which displays ebooks in a more accessible way according to user needs. Since people with dyslexia represent a substantial group with a reading disability, we designed a set of specific guidelines which are included in the tool. These layout guidelines for people with dyslexia are based on a user study with a group of twenty two users with dyslexia. The data collected from our study combines quantitative data from tests carried out using eye tracking and qualitative data from interviews, questionnaires and the think aloud technique. The ebook display includes the most readable options observed with the eye tracking and user preferences; however the settings are customizable.

Keywords: Dyslexia, Accessibility Guidelines, Readability, Usability Tests, eBook Reader, Android.

1. Introduction

There are two reasons motivating the decision to develop the guidelines and include them as a dyslexia friendly option in the IDEAL eBook Reader.

First, in the last years we have experienced an increasing growth of ebook usage. For instance, in January 2011 the Association of American Publishers reported that eBook sales increased by 115.8 percent [1] and in the UK, the adult fiction market saw spectacular e-book growth in 2011, up from 2.8% of purchases in the four weeks ending 26th December 2010 to 12.5% in the four weeks to 27th November 2011 [2].

On the other hand, people with dyslexia represent a relatively large group of potential ebook users [3]. There is a universal neuro-cognitive basis for dyslexia [4], but its manifestations are variable due to different orthographies [5]. Depending on the language, the estimations on the prevalence of dyslexia varies. For instance, Brunswick [6] estimates 10% for English and 3.5% for Italian while [7] states that 10-17.5% of the U.S.A. population has some level of dyslexia. We made an estimation of the presence of texts with dyslexic errors in the Web to know their real impact and our results show that at least 0.28% of web pages in English have dyslexic text [8]. Moreover, the use of accessibility practices for users with dyslexia is beneficial for all, since dyslexic-accessible practices alleviate difficulties faced by all Internet users, as well as other users with disabilities [9, 10, 3, etc.].

Reading eBooks provides the possibility of adapting the layout of the book to the users needs. Also, previous work with users with dyslexia[11, 12] proved that changes in the presentation of the text helped some of the problems

Email addresses: luzrello@acm.org (Luz Rello), gaurang@accessiblenews.co.in (Gaurang Kanvinde), rbaeza@acm.org (Ricardo Baeza-Yates)

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that people with dyslexia encounter when reading a text. In this paper we present the first eBook Reader application for Android which has an option for displaying the eBooks for people with dyslexia. The guidelines for developing this options are based in data collected from a set of experiments carried out with a group of users with dyslexia. To the best of our knowledge, there are no similar applications which offer an alternative outline to users with dyslexia when reading eBooks in mobile devises.

Therefore, this paper presents the following two main contributions:

– A set of guidelines for displaying dyslexic-friendly text in a mobile device based on the analysis of an extensive user study which combines qualitative and quantitative data.
– A user customizable eBook reader for Android that, by default, presents the text according to the dyslexic-friendly guidelines defined.

The rest of the paper is organized as follows. Section 2 explains related work done in defining guidelines and existenting tools for people with dyslexia. In Section 3 we define dyslexia and explain the common problems people with dyslexia encounter. Section 4 explains the experimental methodology, while Section 5 presents the guidelines proposed. Finally, in Section 6 we present the features of the IDEAL eBook Reader, finishing with some conclusions and ideas for future work in Section 7.

2. Related Work

Considering our contributions, there are two areas of related work: (a) mobile applications for users with dyslexia and (b) usability tests, guidelines and methods used to determine dyslexic-friendly recommendations.

Among the mobile applications for users with dyslexia there are: games [13] spell checkers such as American Wordspeller and Phonetic Dictionary. Phone Apps for Spelling which converts phonetic spelling to proper spelling[1], applications that exploit speech recognition such as Dragon Search and Dragon Dictate,[2] which make use of voice recognitive technologies to search in search engines and dictate email or messages and reading assistances that use text to speech for reading texts to people with dyslexia such as Web Reader,[3] and CapturaTalk[4]. Although people with dyslexia are encouraged to modify the setting of eBook readers to facilitate their reading, to the best of our knowledge there is not an application which adapts automatically the text layout with dyslexic friendly parameters.

We found no user studies which take into account dyslexia and mobile accessibility. The work most related to our topic are the user studies about dyslexia and Web accessibility. However, compared to other groups of users with special needs, studies about dyslexia and Web accessibility are scarce [3]. Previous usability tests with users with dyslexia were carried on using: semi structured interviews (10 users with dyslexia) [14], assignments after reading texts (27 users with dyslexia) [9], interviews, questionnaires, log sheets and focus groups (9 users with dyslexia) [15], performing tasks in a website (6 users with dyslexia) [16], and our previous work in Web accessibility which combined eye tracking, interviews and questionnaires (22 users with dyslexia) [12]. Since dyslexic accessible practices benefits also the readability for users without dyslexia [9, 10, 3, *etc.*], the guidelines for developing Web sites friendly to users with dyslexia [17, 18, 19] usually overlap with guidelines for low-literacy users [20] or other disabilities such as low vision [21]. However, there is no universal profile of a user with dyslexia and therefore some authors recommend using a customizable environment for users with dyslexia [20, 11].

IDEAL eBook Reader offers a new dyslexic-friendly customizable alternative for reading eBooks in Android while it also includes text-to-speech technology. Our approach combines eye tracking, interviews and questionnaires and adds to our previous research in Web accessibility [12] the use of the think aloud technique when interacting with the application.

[1] http://www.wordspeller.us/
[2] http://shop.nuance.es/store/
[3] http://itunes.apple.com/us/app/web-reader-text-to-speech/id320808874?mt=8
[4] http://www.capturatalk.com/

3. Dyslexia

Dyslexia is a specific learning disability which is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge [22].

From all the difficulties that people with dyslexia find when reading a text there are some that might be alleviated if some changes in the visual environment are made [11, 12]. The following language difficulties are a subclass of the problems that people with dyslexia find which are related to the presentation of the text. They are extracted from the cognitive neuroscience literature and accessibility literature:

- The recognition and recollection of number, letter, words and punctuation [23], showing special difficulties with homophonic words or pseudo homophonic words *e.g. weather* and *e.g. whether* [24] and orthographic similar words, *e.g. addition* and *audition* [25].
- Word additions and omissions [23], substitutions of functional words *e.g. of* and *for* [24] and confusions of small words *e.g. in* and *is* [26].
- Fixation problems [23].

4. User Study

Below we summarize the experimental methodology of this user study. This methodology except front the application of the think aloud technique to evaluate the interactions of the user with the beta version of the application was used to define the guidelines of web service for people with dyslexia, AccessibleNews Dyswebxia [12]. That previous study also helped us the define the guidelines for this work.

4.1. Participants and Design

Twenty two native Spanish speakers with a confirmed diagnosis of dyslexia took part in the study. Their ages ranged from 13 to 37, with a mean age of 21.1. Ten people were studying or already finished university degrees, ten were attending school or high school and two had no higher education. A control group of 22 participants without dyslexia and similar age average (21.27) also participated in the experiment.

We used two semi structured interviews, one questionnaire, one reading test to be recorded by the eye tracker and the think aloud technique. The recordings of the eye tracker provided the quantitative data of this research while the others represented the qualitative data.

The reading test was composed by one story[5] written in verse and containing 724 words. We divided the overall text in 32 parts and each of them was presented to the participants with a different layout. The text was presented in a recommended font type for people with dyslexia, sans serif Arial [14] and unjustified text [17]. Following we present the seven parameters and the values take into consideration.

(a) Grey scale in the font: We tested four brightness values (0%, 25%, 50% and 75%) for the fonts with white background.
(b) Grey scale in the background: We tested four brightness values (100%, 75%, 50% and 25%) for the background with white fonts.
(c) Color pairs: We tried eight color pairs (background/font): white/black, off-white/off-black, yellow/black, white/blue, creme/black, light mucky green/dark brown, dark mucky green/ brown and yellow/blue[6]. All the pair colors selected by the participants match the [27] guideline brightness differences, with the exception of dark brown/green which was included because it was chosen by participants with dyslexia as in the experiments carried out by Gregor and Newell in [11].
(d) Font size: We tested four sizes (14, 18, 22 and 26 points).
(e) Character spacing: We tested four different distances between characters (-7%, 0%, +7%, 14%).
(f) Line spacing: The fours values tested for line spacing were 0.8, 1, 1.2 and 1.4.

[5] *Los Encuentros del Caracol Aventurero (The Encounters of the Adventurous Snail)*, by Federico García Lorca.
[6] The CMYK code for the colors used and their contrast are shown in the Appendix.

4.2. Procedure and Analyses

The sessions took from one hour to over an hour and a half each, depending on the amount of information given by the participant. First, we interviewed the participant. The first interview began with a questionnaire designed to collect demographic information. Then we continued with an open interview to collect data pertaining to the subjects experience about the difficulties they encountered when reading in different devices, which strategies do they normally use to overcome the problems and which assistive technology the participant makes use of. Then, we proceeded to the recordings of the passages using eye tracking. The participant was asked to read in silence the story contained in the test. The eye tracker used was the Tobii T50 (17-inch TFT monitor). Third, after the participant read the texts we replayed the slides and through a questionnaire, the participant chose what s/he thought was the best reading alternative between the options given for each of the parameters. Then, to achieve a better understanding of the participants' reading needs, we carried out an open interview about the difficulties they encountered when reading the tests and what would they like to find when reading in the Web. Finally, we presented a beta version of the IDEAL eBook Reader to 14 of the participants. They tried the application and proposed improvements to the interface. This evaluative data was gathered by using the think aloud technique. All the data obtained was written down for subsequent analysis.

The software used for analyzing the eye tracking data was Tobii Studio 3.0 and the R 2.14.1 statistical software. For the statistical analysis the 32 parts containing text segments were organized in 7 groups (one group per parameter) and the texts of each of the groups were compared. The texts contained in each of the groups are comparable to each other since all of them have the same number of words and the same number of syllables for the shorter passages (texts containing less that 22 words). Since the texts are written in verse, other variables such as the rhythm or the meter of the sentence are controlled. In Figure 1 we show an example of four text segments with different line spacing. The measures used for the comparison of the passages were: mean of the duration of fixations and number of fixations. Longer fixations points where processing loads are greater [28]. Differences between groups and parameter values were tested by means of a one-way analysis of variance (ANOVA) and correlations were computed using the Pearson correlation coefficient.

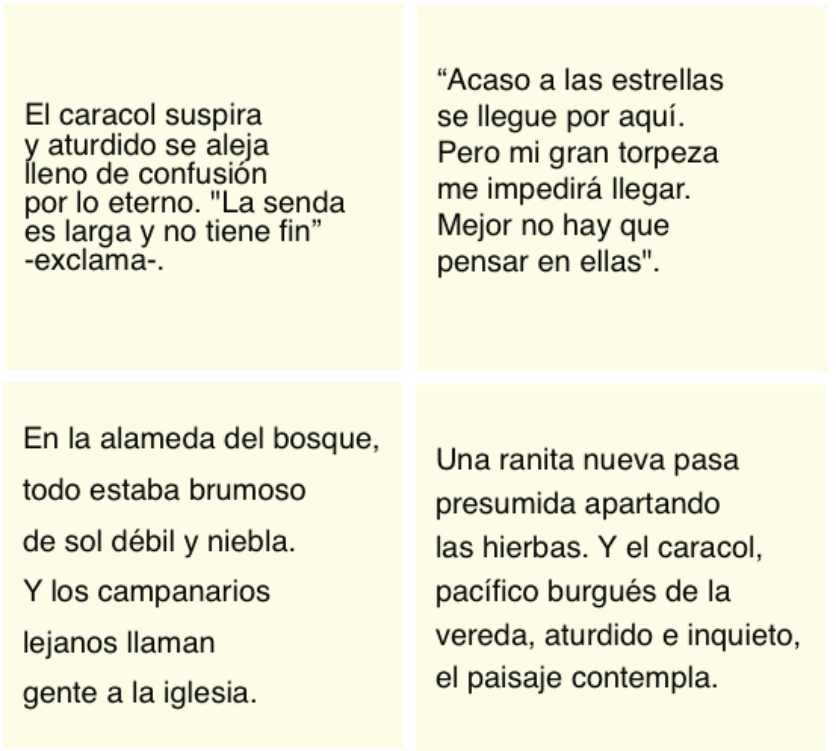

Figure 1. Test slide containing texts with different line spacing.

5. Guidelines

The addition of the data collected using the think aloud technique plus the size limitations of the mobile device make that the default values, called DysWebxia default, for the ebook reader are different from the ones chosen for the web service AccessibleNews Dyswebxia [12], except for the default color pair.

We found statistical significance among the groups with and without dyslexia ($p < 0.038$) taking into account that the mean of fixation time was 0.23 seconds for users with dyslexia and 0.20 seconds for participants without dyslexia.

Following we present the analysis of our qualitative and quantitative data for the users with dyslexia and the choice taken for a mobile device in contrast with [12] and we show the default values incorporated for the dyslexic friends option in the IDEAL eBook Reader [29].

We gave preference to the eye tracking data in the definition of the guidelines because user preferences might change with time [30].

5.1. Font and Background Grey scales and Colors

Although the use of pure black text on a pure white background is not recommend for people with dyslexia [19], most of our participants said that gray actually did not help them. For the font (using pure white in the background) 72.73% of the users preferred a pure black font instead of the three options of gray scale for the font. Similarly, pure black as background instead of different scales of gray for the backgrounds were preferred by 65.91% of the participants. The rest of the participants chose darker options of gray scales for both, font and background. Qualitative and quantitative data for the gray scales in background were inversely correlated (-0.51), which is consistent with the fact that the darker the background, the more difficult it is to read. Six pairs were chosen as favorites by our participants with dyslexia: black/yellow (37.86%), blue/white (18.18%), creme/black (18.18%), black/white (13.64%), blue/yellow (6.05%) and dark brown/light mucky green (4.55%). Although the pair off-white/off-black is the one recommended for Web accessibility for people with dyslexia [19], none of the users selected it. Surprisingly, the most selected pair (yellow/black) has the highest mean for the fixation durations (0.28 seconds), being the average of all the color pairs 0.24. On the other hand, the color pair which was the fastest to read was black/creme (mean of 0.22 for the fixation duration). Moreover, the largest statistical difference was found for the pairs yellow/black and black/creme ($p < 0.109$). However, no strong correlation was found among the eye tracking data and the personal choice of the users. The default colors chosen for the ebook reader are the most readable according to the eye tracker data: black (000000) on creme (FAFAC8) background.

5.2. Font Size

Arial font is used by default in the experiments following previous recommendations [14]. In the tool options the users can also chose among other fonts recommended for users with dyslexia: Comic Sans, Verdana, Tahoma, Century Gothic and Trebuchet [19, 18]. Unexpectedly, most of the participants (63.64%) chose our biggest option (26 points) and the rest chose the second biggest option (36.36%). A large statistical significance ($p < 0.001$) was found taking into consideration the means of the fixation durations among the texts with fonts of 14 points and 26 points. The overall mean of fixation duration for the texts with 14 points fonts is 0.28 seconds ($\sigma = 0.09$) while the fixation mean for 26 points is 0.20 seconds ($\sigma = 0.05$). However, when the participants tested the beta version of our tool the majority (6 participants) found it comfortable reading with 16 points font size, which is the font selected for the IDEAL eBook Reader.

5.3. Character, Line and Paragraph Spacing

Our results show that 75% of the participants prefer either the standard spacing among characters (38.64%) or more separated characters (+7%) (36.36%). The participants favorite options for line spacing were not consecutive values: 34.09% for single spacing and 38.64% for 1.4 spacing among lines. As expected, we found a negative correlation for character spacing (-0.59) and line spacing (-0.60), that is, the narrower are the spaces among characters and lines, the longer it takes to read the passage. This data in combination with the user preferences when using the prototype in the mobile device led us to chose standard spacing among characters and 1.1 for line spacing.

6. IDEAL eBook Reader

The IDEAL eBook Reader is an eBook Reader for Android devices developed by Accessible Systems of India[7]. This application displays ebooks that have been formatted according to ePub, a free and open e-book standard by the International Digital Publishing Forum (IDPF)[8]. Epub is a globally adopted set of rules that define how an eBook should be constructed. When books follow this standard, they can be displayed with the same convenience and accessibility on a wide variety of platforms and devices.

6.1. Application Features

We explain below the general features of the IDEAL eBook Reader. As the features show, the application can be customized depending on the user needs and works for everyone. This way, all people are included, rather than a different reading application exclusively for each type of disability.

(a) It displays the text in a more accessible way making optimal use of the screen size. In figure 2 we can observe a PDF document and the same text displayed by the Reader.
(b) It displays a table of content of the ebook which allows the user to navigate to specific places within the eBook (see Figure 3).
(c) It also allows a user to customize how the eBook will be displayed. The users can choose the font styles, colours (background and font), brightness contrast, font size, and the character, line and paragraph spacing. Any individual can customize the parameters for greatest comfort while reading (see Figure 3). For users with dyslexia there is an option called DysWebxia default which sets all the parameters to our dyslexic friendly guideline (see Figure 3).
(d) Our reader supports text-to-speech technology that enables users to listen to the eBook content as an audio book. This feature helps people with vision impairments as well as dyslexia among other disabilities. The tool is compatible with a wide range of text-to-speech engines, and hence multiple languages are also supported, such as English, Spanish, Portuguese, German, French, Italian, Chinese, Japanese, among others.
(e) The text being read out loud is highlighted to make it easer to follow the reading.
(f) Control of the speech is gesture based, so it's convenient to use and very accessible. That is, the user can select the piece of text to be read. By this means, a person with dyslexia can learn how to read new words.

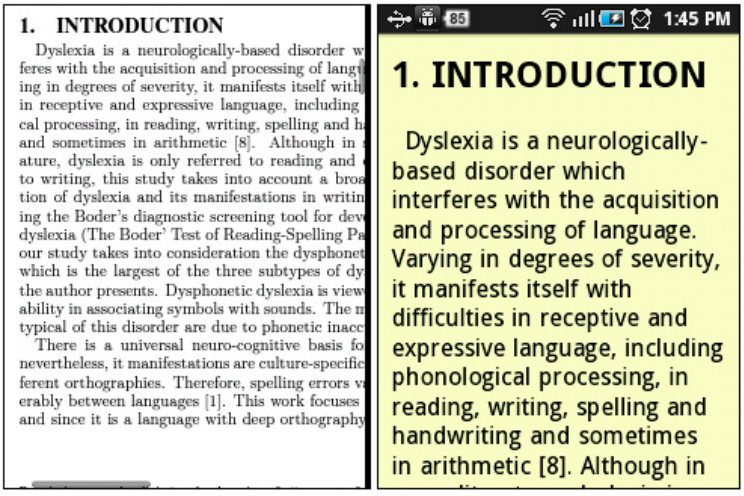

Figure 2. Example of a text without and with the IDEAL eBook Reader.

[7]http://www.accessiblenews.co.in
[8]http://en.wikipedia.org/wiki/EPUB

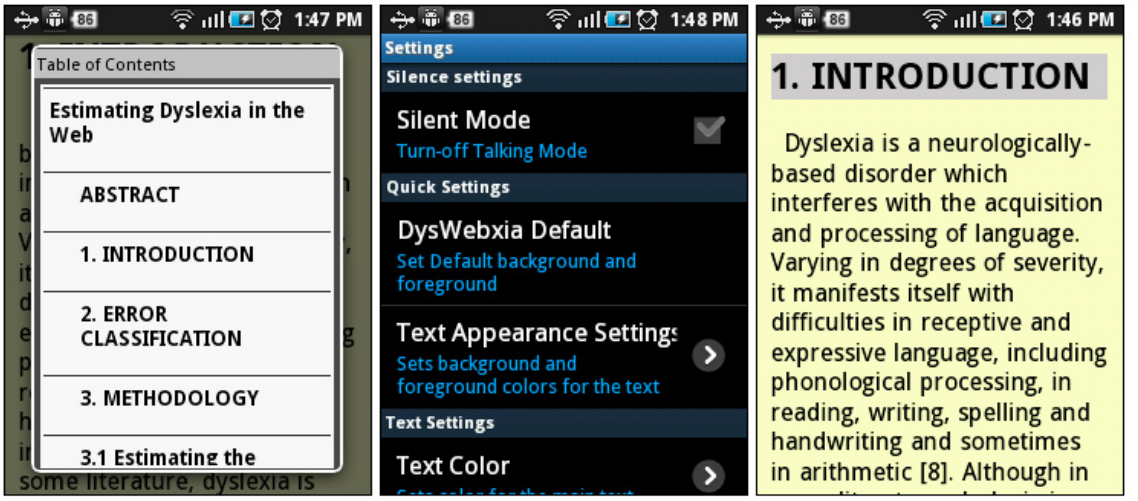

Figure 3. Example of Table of Content (left), Settings of the IDEAL eBook Reader (midle) and highlight or the title that it is being read out (right).

6.2. Using IDEAL eBook Reader

Using our application is simple. When the IDEAL eBook Reader starts, you can open an eBook from your phone memory, or you can download one from online sites such as Project Gutenberg, Feedbooks, etc. Once a book opens, the user can set the text font size, colour, spacing, according to his/her preferences. A dyslexic friendly option can be also selected. For speech, instructions are as follows: to start and stop speech, double tap the screen; to move to the next paragraph, swipe the finger across the screen from left-to-right; and to move to the previous paragraph, swipe the finger across the screen from right-to-left. It is possible to read even word-by-word or letter-by-letter if the user wishes. Volume keys on Android devices can be used for this purpose.

7. Conclusions and Future Work

From the analyses of our data we observe that dyslexia not only varies between languages but also between subjects. Even thought we believe that our tool helps people with dyslexia to read documents in their mobile devices, dyslexia is a learning disability that affects language, hence, we can assume that accessibility can be approached not only from the layout of the text but also from the text itself. The use of complicated language has been extensively pointed out as one of the key problems that people with dyslexia encounter [3]. However, all the existing applications at the moment, including ours, only modify its design but not its content. We are currently exploring which strategies that modify the text might be beneficial for people with dyslexia, such as the use of graphical schemes [31], and we plan to develop them in the future to enrich the eBook Reader.

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Appendix

The CYMK codes for the colors and contrast used are the following: white (FFFFFF) / black (000000): Color difference (diff.): 765, Brightness diff.: 255; white-off (FFFFE5) / black-off (0A0A0A): Color diff.: 735, Brightness diff.: 245; yellow (FFFF00) / black (000000): Color diff.: 510, Brightness diff.: 226; white (FFFFFF) / blue (00007D): Color diff.: 640, Brightness diff.: 241; light mucky green (B9B900) / dark brown (1E1E00): Color diff.: 310, Brightness diff.: 137 dark mucky green (A0A000) / brown (282800): Color diff.: 240, Brightness diff.: 107 creme (FAFAC8) / black (000000): Color diff.: 700, Brightness diff.: 244; yellow (FFFF00) / blue (00007D): Color diff.: 635, Brightness diff.: 212.