

Layout Guidelines for Web Text and a Web Service to Improve Accessibility for Dyslexics*

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ABSTRACT

In this paper, we offer set of guidelines and a web service that presents Web texts in a more more accessible way to people with dyslexia. The layout guidelines for developing this service are based on a user study with a group of twenty two dyslexic users. The data collected from our study combines qualitative data from interviews and questionnaires and quantitative data from tests carried out using eye tracking. We analyze and compare both kinds of data and present a set of layout guidelines for making the text Web more readable for dyslexic users. To the best of our knowledge, our methodology for defining dyslexic-friendly guidelines and our web service are novel.

Keywords

Dyslexia, Web accessibility, usability tests, browsing web service, accessibility guidelines, readability.

1. INTRODUCTION

In this paper, we present the first prototype of a web service that makes Web texts more accessible to people with dyslexia. The guidelines for developing this service are based in quantitative and qualitative data collected from a set of experiments carried out with a group of dyslexic users.

Related to its social relevance, there are three reasons motivating the decision to approach Web accessibility for dyslexic users: (a) dyslexic people are a relatively large group of users, since dyslexia is universal and frequent; (b) this kind of accessibility practices are not only good for dyslexics but also useful for all users; and (c) it contributes to the democratization of the Web. Next, we elaborate on these reasons:

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(a) **Frequent and universal:** There is a universal neuro-cognitive basis for dyslexia [30] but its manifestations are variable due to different orthographies [17]. Depending on the language, the estimations on dyslexia varies. For instance, Brunswick [6] estimates 10% for English and 3.5% for Italian while the Interagency Commission on Learning Disabilities [20] states that 10-17.5% of the population in the U.S.A. has some level of dyslexia. We found no estimations of the prevalence of dyslexia in Spanish speakers. We made an estimation of the presence of dyslexic texts 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 [2].

(b) **Good for dyslexics, useful for all:** The employment of Web accessibility practices for dyslexic users is beneficial for all, since dyslexic-accessible practices alleviate difficulties faced by all Internet users, as well as other users with disabilities [25; 13; 26, etc.] (see Section 2).

(c) **Web democratization:** The essential property of the Web is its universality since it is fundamentally designed to work for all people. Moreover, the Web is an increasingly important resource in many aspects of life such as education, employment or health care. Therefore, the access by everyone regardless of any disability is an essential aspect [42]. Indeed, access to information and communication technologies is recognized as a basic human right by United Nations [40]. Hence, our proposal would improve the ability of dyslexic people to read and access a wider range of information content, empowering them by slightly leveling the playing field.

To the best of our knowledge, our web service and our approach are novel. There are no similar applications which offer an alternative to dyslexic users when reading text in the Web (see Section 2). Moreover, this is the first time that eye tracking is applied with dyslexic users to measure textual accessibility complementing the information gathered using interviews and questionnaires to define layout guidelines for dyslexic users.

Therefore, this paper presents the following two main contributions:

- A set of guidelines for displaying dyslexic-friendly text in the Web based on the analysis of an extensive user study which combines qualitative and quantitative data.
- A user customizable browsing web service 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 existent tools for dyslexics. In Section 3 we define dyslexia and explain the common problems dyslexic people encounter. Section 4 explains the experimental methodology, while Section 5 presents the results that lead to our set of guidelines proposed in Section 6. Finally, in Section 7 we present our prototype, AccessibleNews DysWebxia, finishing with some conclusions and ideas for future work in Section 8.

2. RELATED WORK

Related to our contributions, we distinguish two areas of related work: (a) usability tests, guidelines and methods used to determine dyslexic-friendly recommendations; and (b) applications or resources for dyslexic users.

(a) Dyslexia and accessibility studies: Compared to other groups of users with special needs, studies about dyslexia and Web accessibility are scarce [26]. In the current recommendations for the accessible Web [7, 24], dyslexia is only one more disability within a diverse group of cognitive disabilities. However, there are considerable barriers for dyslexics when using the Web [1]. Previous usability tests with dyslexic users were carried on using: semi structured interviews (10 dyslexic users) [1], assignments after reading texts (27 dyslexic users) [25], interviews, questionnaires, log sheets and focus groups (9 dyslexic users) [11] and performing tasks in a website (6 dyslexic users) [38]. There is a common agreement in specific studies about dyslexia and Web accessibility that the application of dyslexic accessible practices benefits also the readability for non-dyslexic users [25; 13; 26, *etc.*]. Consequently, the guidelines for developing Web sites friendly to dyslexic users [4, 34, 43] usually overlap with guidelines for low-literacy users [28] or other disabilities such as low vision [16]. However, there is no universal profile of a dyslexic user and therefore some authors recommend using a customizable environment for dyslexic users [28, 19].

(b) Tools for dyslexics: Although there is already software (e.g., spell-checkers) designed specifically for dyslexics, most frequently visited Web pages currently offer no accessibility options for their dyslexic users.

The applications most closely related to our web service are: *SeeWord* [18], a word processing software designed to allow users to optimize writing and reading conditions in Microsoft Word by controlling how information is displayed; *Penfriend XL*¹ which predicts the next word dyslexics want to type; *Claro ScreenRuler Suite*² which allows part of the screen to be highlighted or underlined, the contrast changed and the background colored or grayed out; *Colour Explorer*³ that allows users to adapt the background, foreground and font color combinations in all documents; and a spell-checker specially developed for dyslexic users [31]. Reading applications such as *Claro Read Standard*⁴, *ReadingPenTS Oxford*⁵ and *DiTres*⁶ use text-to-speech technologies.

¹<http://www.penfriend.biz/>

²<http://www.clarosoftware.com/index.php?cPath=348>

³<http://www.microlinkpc.com/colour-explorer>

⁴<http://www.clarosoftware.com/index.php?cPath=355>

⁵<http://www.wizcomtech.com/eng/catalog/a/readingpents/default.asp>

⁶<http://www.rehasoft.com/dislexia/ditres/>

Our study differs from related approaches because it combines eye tracking, interviews and questionnaires to determine the guidelines for designing our web service. At the same time, our service offers a new dyslexic-friendly customizable alternative for reading texts in the Web using a regular browser.

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 [21].

Brain structure, brain function and genetics studies confirm the biological foundations of dyslexia [41]. However, despite its universal neuro-cognitive basis, dyslexia manifestations are variable and culture-specific [17]. This variability is due to the different language orthographies concerning their grade of consistency and regularity [6]. English has an opaque –or deep– orthography in which the relationships between letters and sounds are inconsistent and many exceptions are permitted. English presents a significantly greater challenge to the beginning reader than other languages, such as Italian, with a more regular alphabetic system that contains consistent mappings between letters and sounds, that is, a transparent –or shallow– orthography. For instance, in [30], Italian dyslexics performed better on reading tasks than English. Along an orthographic transparency scale for European languages, English appears as the language with the deepest orthography and Spanish as the second most shallow after Finnish [36]. Since the challenge of mapping phoneme to grapheme for dyslexic people depends on the orthographic transparency of the language, Spanish shall be not be as challenging to dyslexics as other languages according to this scale [36].

Dyslexia has been called a *hidden* disability, due to the difficulty of its diagnosis in languages with shallow orthographies [41].

3.1 Types of Dyslexia

Research broadly agrees in distinguishing three different types of dyslexia: phonological, surface and deep dyslexia. Phonological and surface dyslexia can both be acquired or developmental; deep dyslexia is most frequently acquired. However, the delimitation of these three types is not clear and symptoms of different types of dyslexia overlap. Our study takes into account phonological and surface dyslexia because they are the most common types –specially the phonological type.

Phonological dyslexia is a disorder of reading characterized by impairment in pseudo-word⁷ (e.g. *happisfaction*) reading ability [10]. Surface dyslexia is characterized by poor reading of low frequency irregular words (e.g. *vase* pronounced as /vāz/), coupled with accurate reading of pseudo-words. Errors made in reading irregular words tend to be

⁷A pseudo-word is a unit of speech or text that appears to be a pronounceable word in a certain language, while in fact it has no meaning in the lexicon, e.g. *atitica*.

regularizations [29]. While phonological dyslexics use a visual reading route (read one word at once), surface dyslexics use a phonological reading route (grapheme-to-phoneme conversion rules). While phonological dyslexics remember an orthographic and phonological vocabulary, surface dyslexics encounter problems using the grapheme to phoneme conversion rules.

3.2 Difficulties of Dyslexia

Now we present the dyslexic reading problems which could be partially related to the layout of the text. These problems mainly pertain to the recognition and recollection of diverse elements as well as fixation problems. There are other dyslexic difficulties which are related to term frequency, new words, long words, etc. However, we have not include them in this list because they cannot be tackled with design recommendations. According to our results and the participants opinions, we believe that changes in the layout of the text could help these difficulties. Moreover, previous research [19] have shown that visual changes in the presentation of the text may alleviate some of the problems shown below. These difficulties were extracted from the cognitive neuroscience and accessibility literature and were grouped according to the language level where they occur. The ones belonging to the discourse level are not difficulties *per se* but recommendations taken from Web accessibility literature regarding to dyslexic users.

- **Surface dyslexia:**
 - (a) Phonology:
 - Homophonic words or pseudo-homophonic words, *e.g. weather* and *whether* [29].
- **Phonological dyslexia:**
 - (b) Orthography:
 - Orthographic similar words, *e.g. addition* and *audition* [15].
 - Number and letter recognition/recollection [27].
 - (c) Lexicon & Syntax:
 - Word additions and omissions [27].
 - Word recognition and recollection [27].
 - Functional words substitution, *e.g. of by for* [29].
 - Confusions of small words, *e.g. in by is* [12].
- **Both dyslexias:**
 - (d) Discourse:
 - Fixation problems [27].
 - Punctuation recognition [27].

4. EXPERIMENTAL METHODOLOGY

In our methodology we combine the use of semi-structured interviews, eye tracking testing and questionnaires. Twenty two dyslexics were interviewed face-to-face about their various dyslexia-related difficulties and how these challenges have affected their reading in the screen. After the first interview they read 36 small texts with the Eye Tracker, and then, completed a questionnaire about each of the texts. Finally, we carried out an open interview about the layout of the text and their reading needs.

4.1 Participants

Twenty two native Spanish speakers with a confirmed diagnosis of dyslexia took part in the study, twelve of whom were female and ten male. Their ages ranged from 13 to 37, with a mean age of 21.1. There were two participants with attention deficit disorder. All participants are frequent users of internet and frequent readers; ten read less than four hours per day, nine read between four and eight hours per day, and three participants read more than eight hours daily. Ten people were studying or already finished university degrees, ten were attending school or high school and two had no higher education. All the participants were asked to bring their diagnoses to the experiment. In the Catalanian protocol of dyslexia diagnosis [9] the different kinds of dyslexia, extensively found in literature, are not considered. Therefore, we can only guarantee that the participant was diagnosed in a authorized center or hospital but not the exactly his or her type of dyslexia.

A control group of 22 participants without dyslexia and similar age average (21.27) also participated in the experiment.

4.2 Design

We used two semi structured interviews, one questionnaire and one reading test to be recorded by the eye tracker.⁸ Along the interviews and the questionnaire we collected the qualitative data while the recordings of the eye tracker provided the quantitative data of this research.

The reading test was composed by two stories. The first story⁹ was written in verse and contains 724 words, while the second story is a fragment in prose¹⁰ with 204 words.

We divided the overall text in 36 parts and each of them was presented to the participants with a different layout. To maintain the independence of the variables, there were no combinations among features. Depending on the length of the text, some of them were presented in a single slide, some of them were presented in groups in the same slide. There were a total of 20 slides. The order was balanced because the parameter values were presented in random order. The text was presented in a recommended font type for dyslexics, sans serif arial [1] and unjustified text [32]. The parameters were chosen taking into account: (1) the difficulties that dyslexic people find, (2) the literature about designing web pages for dyslexic readers [32, 5, 4] and (3) previous user studies [1, 19, 18]. More details of our parameters in comparison with the literature are given in Section 5. Next, we present the parameters and the values studied.

- (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, yellow/white, black/white, black/off-white, white/off-black, white/yellow.

⁸The materials used in these experiments can be found at: <http://luzre11o.com/Dyswebxia.html>

⁹*Los Encuentros del Caracol Aventurero (The Encounters of the Adventurous Snail)* by Federico García Lorca.

¹⁰From the book *Soy dix-leso? (I am dix-leso?)* of the *Papelucho* series by Marcela Paz.

low/black, white/blue, creme/black, light mucky green/dark brown, dark mucky green/ brown and yellow/blue.¹¹

- (d) **Font size:** We tested four sizes for arial: 14, 18, 22 and 26 points.
- (e) **Character spacing:** We tested four different distances between characters: -7%, 0%, +7% and 14%.¹²
- (f) **Line spacing:** The fours values tested for line spacing were 0.8, 1, 1.2 and 1.4 lines.
- (g) **Paragraph spacing:** The texts in the slides presented four different values for the spacing between paragraphs: 0.5, 1, 2 and 3 lines.
- (h) **Column width:** The average number of characters for the four columns widths tested were: 22, 44, 66 and 88 characters per line.

4.3 Equipment

The eye tracker used was the Tobii T50 (17-inch TFT monitor). The eye tracker was calibrated for each participant and the light focus was always in the same position. The distance between the participant and the eye tracker was constant (approximately 60 cm. or 24 in.) and controlled by using a fixed chair.

4.4 Procedure

The sessions were conducted at Pompeu Fabra University and they took from one hour to over an hour and a half each, depending on the amount of information given by the participant. In each session the participant was alone with the interviewer (first author) in the quiet room prepared for the study, and had to do the following four steps.

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 encounter when reading in different devices, which strategies do they normally use to overcome the problems and which assistive technology the participant makes use of.

Second, we proceeded to the recordings of the passages using eye tracking. The participant was asked to read in silence two stories contained in the test. Third, after the participant read the texts we replayed the slides (without eye-tracking recording) 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. Whenever the participant selected two or three values as favorite, we gave the weights 0.5 and 0.33 respectively, to those values.

Finally, 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. A beta version of our prototype was shown to 14 of the participants and they all found it useful and proposed improvements to the interface. This beta version was done using the

¹¹The CMYK code for the colors used and their contrast are shown in the Appendix.

¹²Although there are others units that can be used, the simplest is to use a percentage of the current font size.

preliminary qualitative results from the first 8 participants who participated in the experiment. All the data obtained from the interviews was written down for subsequent analysis.

4.5 Data 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 36 sections were organized in 8 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 than 22 words). Also, these shorter texts were extracted from the story written in verse so other variables such as the rhythm or the meter of the sentence are controlled. The measure used for the comparison of the text passages was the average duration of fixations. 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.

5. RESULTS

In this section we present the analysis of the user preferences (qualitative data) and the average fixation duration of the recorded readings (quantitative data). Shorter fixations are preferred to longer ones because according to previous studies [22] readers make longer fixations at points where processing loads are greater. First, we studied the differences between the dyslexics and the control group and then, we made a detailed analysis of the different values among the dyslexic users presented in the following subsections. In Table 1 we present the results comparatively.

We found statistical significance among the dyslexic and non-dyslexic groups ($p < 0.038$) taking into account that the mean of fixation time was 0.23 seconds for dyslexic users and 0.20 seconds for non-dyslexic participants. Our results are consistent with the most recent eye-tracking study to diagnose dyslexics that found differences [14] while the previous one did not [37].

5.1 Font and Background

Using a pure black text on a pure white background is not recommend for dyslexics due to its high contrast, as many dyslexic users are sensitive to the brightness and this can cause the words to swirl or blur together [4]. However, we found no guidelines about gray scales and readability for dyslexics apart from the suggestion of using a light gray as background [39]. Most of our participants said that grey actually did not help them. For the font (using pure white in the background) 16 users (72.73%) 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 track grounds were preferred by 14.5 participants (65.91%). 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 at odds which each other, that is, inversely correlated (-0.510). This is consistent with the fact that the darker the background, the more difficult is to read. Further experiments shall be done about the role of the background because light on dark has different

Parameter	Value	Fixations Duration		User Choice
		(ave. in sec.)	(%)	(%)
Font size	26 points	0.209	–	63.64
	22 points	0.217	3.8	36.36
	18 points	0.239	14.4	–
	14 points	0.288	37.8	–
Paragraph spacing	3 lines	0.230	4.5	–
	2 lines	0.220	–	63.64
	1 line	0.242	10.0	–
	0.5 lines	0.240	9.1	36.36
Line spacing	1.4 lines	0.228	–	38.64
	1.2 lines	0.245	7.5	22.73
	1 line	0.240	5.3	34.09
	0.8 lines	0.238	4.4	4.55
Grey scale in the font	0%	0.249	6.0	72.73
	25%	0.237	0.9	22.73
	50%	0.235	–	4.55
	75%	0.243	3.4	–
Grey scale in the background	100%	0.255	4.5	65.91
	75%	0.244	–	15.91
	50%	0.244	–	18.18
	25%	0.3	23.0	–
Character spacing	+14%	0.205	–	9.09
	+7%	0.219	6.8	36.36
	0%	0.233	13.7	38.64
	-7%	0.233	13.7	15.91
Column width	88 characters/line	0.215	–	27.27
	66 characters/line	0.225	4.7	31.82
	44 characters/line	0.221	2.8	31.82
	22 characters/line	0.230	7.0	9.09
Foreground/background color pairs	creme/black	0.214	–	18.18
	yellow/blue	0.220	2.8	6.05
	light mucky green/dark brown	0.222	3.7	1.50
	dark mucky green/ brown	0.226	5.6	4.55
	white/black	0.229	7.0	13.64
	off-white/off-black	0.234	9.3	–
	white/blue	0.238	11.2	18.18
yellow/black	0.239	11.7	37.86	

Table 1: Comparison of eye tracking and user survey. The parameters are sorted in order of agreement between both studies. The average fixation time results are presented in seconds and the percentage shows their fixation extra time in comparison with the lowest value.

readability requirements than for dark on light [8].

5.2 Colors

Poor color selections are one of the key problems encountered by dyslexics when reading the Web [26]. Out of the eight pairs of color tested, six pairs were chosen as favorites by our dyslexic participants. Using the questionnaire the following color pairs were selected (in parentheses the number of participants that preferred that option): yellow/black (8.3), white/blue (4), creme/black (4), white/black (3), yellow/blue (1.33) and light mucky green/dark brown (1).

Although the pair off-white/off-black is the one recommended for Web accessibility for dyslexics [4], none of the users selected it. Consistently, dark mucky green/brown and yellow/blue pairs were chosen by dyslexics as in the experiments carried out by Gregor and Newell in [18, 19].

Surprisingly, the most selected pair (yellow/black) has the highest mean for the fixation durations (0.239 seconds), be-

ing the average of all the color pairs 0.228. On the other hand, the color pair which was the fastest to read was creme/black (mean of 0.214 for the fixation duration). This pair of colors is used by the British Dyslexia Association for their Website.¹³ Moreover, the largest statistical difference was found for the pairs yellow/black and creme/black ($p < 0.109$). However, no correlation was found among the eye tracking data and the personal choice of the users.

According to the W3C algorithm [42], brightness differences less than 125 and color differences less than 500 are supposed to be not good. All the pair colors selected by the participants match this guideline except dark brown/green pair (brightness difference: 107, color difference: 240). However, the readability of colored background/text pairs is influenced by text size [8] and the font size used was big (20 points).

¹³<http://www.bdadyslexia.org.uk/>

The most favored color pair chosen by our participants (yellow/black) has the highest contrast color combination, which is not consistent with [4], that recommends to avoid high contrast. Moreover, according to [33] such high contrast creates so much vibration that it diminishes readability. Our explanation is that this pair was chosen because it is the one that has the highest contrast so it seems more readable at first sight although eye tracker data showed that it was actually the hardest contrast to read.

5.3 Font Size

Another of the key problems experienced by dyslexic people is finding the text too small [26]. Although the recommended font size for dyslexics is 12 or 14 points [1, 5, 4], some dyslexic readers may request a larger font [5]. Unexpectedly, 14 of the participants (63.64%) chose our biggest option (26 points) and the rest chose the second biggest option (8 users, 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 0.288 seconds ($\sigma = 0.09$) while the fixation mean for 26 points is 0.200 seconds ($\sigma = 0.05$). The column width could not influence in these decisions since all the columns had the same width (a mean of 50 characters for 12 points). Further investigations shall be done to find out which is the font size preferred by dyslexic users as clearly there must be a turning point as a very large font size will make reading more difficult.

5.4 Character, Line and Paragraph Spacing

In [32] it is recommended to create a slightly larger distance between individual words and reduce letter-spacing slightly so that the letters within a word lie closer together while [34] suggests to have clear spacing between letter combinations.

Our results show that 75% of the participants prefer either the standard spacing among characters (0%) (8.5 users, 38.64%) or more separated characters (+7%) (8 users, 36.36%). The favorite options for line spacing were not consecutive values: 34.09% (7.5 users) for single spacing and 38.64% (8.5 users) for 1.4 spacing among lines. We found a negative correlation for character spacing (-0.589) and line spacing (-0.592), that is, the narrower are the spaces among characters and lines, the longer it takes to read the passage.

According to [4], paragraphs –even when they have a single line– should always be spaced out with an empty line between each paragraph. Consistently, the most popular option (14 users, 65.91%) was this one.

5.5 Column Width

Accordingly to [5, 4] which recommend lines not be too long –60 to 70 characters– and avoid narrow columns [5], only two of our participants chose the narrowest column width while the most preferred ones were the intermediate values: paragraph with lines of 44 (7 users, 31.82%) or 66 characters (7 users, 31.82%). Some of the participants explained that they chose the widest column because it seemed to be less text there (they all have the same number of words). In this case the correlation among qualitative and quantitative data was the largest (-0.751), which implies that wider columns are better.

6. GUIDELINES

In Table 2, we present a set of guidelines for formatting the Web text in a way more accessible to people with dyslexia. To identify and formulate these guidelines, we have taken into account both the fixation length and the user preferences.

In case that the eye tracking data and the user preferences were at odds and the value was non numerical (e.g. color pairs), we gave priority to the eye tracking data because the user preferences might change with time [3]. When there was not a clear preferred or optimal value we used the average of the two best values selected, giving a bit more weight to the user survey (e.g. gray scales, character spacing and column width). We chose the biggest font size, 26 points, since it was the most readable and popular size, even though is quite large. Clearly more experiments are needed to refine these guidelines.

Parameter	DysWebxia
Grey scale in the font	10%
Grey scale in the background	90%
Color pairs	creme/black
Font size	26
Character spacing	+7%
Line spacing	1.4
Paragraph spacing	2
Column width	77 characters/line

Table 2: Dyslexic-friendly Guidelines for Web Text.

7. ACCESSIBLENEWS DYSWEBXIA

AccessibleNews DysWebxia is a web-based service, an extension of the AccessibleNews DAISY software built by Accessible Systems, India [23]. It detects useful text from an article web page, and renders it in a simplified manner. AccessibleNews DysWebxia resides on a server, and is accessed using a web browser. The server visits web-pages, processes them, and uses machine learning to identify the article of interest from each web page. This article is then displayed in a browser in a plain simple format, devoid of fancy styling. Since the display is browser-based, specific parameters of the text, such as the colors of the font size, can be individually changed using javascript. As a result, it is possible to create a combination best suited for persons with dyslexia. Further, any individual can customize the parameters for greatest comfort while reading (see Figure 2).

The findings of the previous section have been incorporated in this service as the default values for various parameters. The best settings for colors turned out to be black (text) on creme (background). The other most readable color options are offered in the settings menu. In the case that the user selects black and white either for the text or the background, by default the gray scales are 90% for the background and 10% for the font. The line spacing is 1.4 (mean of the most selected values) and character spacing is +7% since both values were the most readable according to the eye tracking data. Also, both parameters have a high correlation between stated user preferences and fixation duration. Paragraph spacing was set to two lines as, for that value, reading was quickest to read (sum of fixations durations), and it was the most chosen value. Column width has

The screenshot shows the original article on the National Geographic website. The page features the National Geographic logo, navigation links, and a featured article titled "Lady With a Secret" by Tom O'Neil. The article includes a photograph of the portrait and a detailed text block discussing the artwork's history and the mystery of its authorship.

This screenshot shows the same article as viewed through the AccessibleNews DysWebxia interface. The page is highlighted in yellow, and the text is presented in a larger, more readable font. The title "Lady With a Secret" is prominently displayed at the top, and the main text is clearly legible against the background.

Figure 1: Example of an article browsed with AccessibleNews DysWebxia (original on the left).

The screenshot displays the "Text Settings" menu. It includes a "Preview Window" showing the text "Yabba dabba doooooo!" in various color and background combinations. Below the preview, there are input fields for "Text Colour (RGB value in hex): #", "Background Colour (RGB value in hex): #", "Font Size", "Line spacing", "Letter spacing", and "Word spacing".

Figure 2: Settings of AccessibleNews DysWebxia.

a mean of 77 characters per line and the font size selected was not the most readable and popular one: 26 points.

Figure 1 shows an example, with an original article on the left and the same article using AccessibleNews DysWebxia on the right. The browser-based user interface of AccessibleNews DysWebxia can be accessed not only from a PC or laptop, but also from most smartphones and tablets. More examples of AccessibleNews DysWebxia can be found at <http://www.accessiblenews.co.in/dyswebxia/>.¹⁴

¹⁴This service is not yet fully open to the public but can be used in a trial basis.

8. CONCLUSIONS AND FUTURE WORK

In light of the results obtained when analyzing our quantitative data, we observe that dyslexia not only varies between languages but also between subjects.

Since there is no model to explain dyslexia, we identified the difficulties that dyslexia people encounter and test the related design parameters offering a set of guidelines which enclose the layout features that make more readable texts for dyslexics users. Currently, these experiments are being enriched to adapt our guidelines to other environments, such as mobile devices.

However, there are still problems found by dyslexic individuals which remain unsolved. Given that dyslexia is a learning disability that affects language, 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 dyslexic people encounter. However, all the existing applications at the moment, including ours, only modify its design but not its content. We are currently exploring to which extend spelling errors and non-normative words affects the readability and the understandability of dyslexic people [35] and which strategies that modify the text might be beneficial for dyslexic users.

However, more experiments concerning the layout should be carried out since there were some parameters for which we did not find a clear best alternative such as font size, for which people might like a font even larger than those offered as alternatives in the experiment. Similarly with the font type.

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APPENDIX

The CYMK codes for the colors and contrast used are the following:

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