An Eye Tracking Study on Text Customization for User Performance and Preference

Luz Rello
Web Research Group & Natural Language Processing Group
Centre for Autonomous Systems and Neuro-Robotics
Universitat Pompeu Fabra, Barcelona, Spain
luzrello@acm.org

Mari-Carmen Marcos
DigiDoc & Web Research Group
Universitat Pompeu Fabra
Barcelona, Spain
mcarmen.marcos@upf.edu

***Abstract*—This paper presents a user study which compares reading performance versus user preference in customization of the text. We study the following parameters: grey scales for the font and the background, colors combinations, font size, column width and spacing of characters, lines and paragraphs. We used eye tracking to measure the reading performance of 92 participants, and questionnaires to collect their preferences. The study shows correlations on larger contrast and sizes, but there is no concluding evidence for the other parameters. Based on our results, we propose a set of text customization guidelines for reading text on screen combining the results of both kind of data.**

***Keywords*-user interfaces; usability; text customization; readability performance; user preference; eye tracking; grey scales; colors; font size; character, line and paragraph spacing; column width.**

I. Introduction

Readability refers to the legibility of a text, that is, the ease with which text can be read, while understandability refers to comprehensibility, the ease with which text can be understood. Since readability strongly affects text comprehension, sometimes both terms have been used interchangeably [14]. This study focus on readability performance focusing only on the legibility of the text.

Text customization has an impact on readability. At the same time, some textual layouts are preferred to others regarding reading comfort. Although there are studies about reading performance and user preference, to the best of our knowledge, the combination of these factors using eye tracking in Spanish is novel.

The goal of this study is to present a set of recommendations which benefits the reading performance on a computer screen and its comparison with the user preferences. The quantitative data related to the performance are extracted from eye tracking and the qualitative data pertaining to the preferences was collected from a survey. The main contributions of this paper are:

- An extensive user-based study using eye tracking for measuring reading performance and preference in Spanish.
- An analysis between the reading performance and the perceived reading comfort, taking into consideration the following parameters of text customization: grey scales in the font and in the background, color pairs, font size, character, line and paragraph spacing and column width.
- A set of guidelines for displaying text in the screen based on the analysis of both kind of data: quantitative (performance) and qualitative (preference).

The rest of the paper is organized as follows. Section II explains related work done about readability performance and preference. Section III explains the experimental methodology, while Section IV presents the results that lead to our set of guidelines proposed in Section V. Finally, some conclusions and ideas for future work are presented in Section VI.

II. Related Work

Empiric studies about readability on screen and printed format are mainly focused on layout and typography.

The first studies (from 1929 to 1955) on printed format took in consideration the following variables: font size [21], [25], column width [29], font color [22], space between lines [23] and font style [24], [30]. According to these studies, font type does not affect readability and the recommended size is 8 and 10 points for a line length of 80mm [29], [21]. These results were later confirmed using eye tracking [25], [30].

Later studies (starting from 1980) on screen showed that reading speed increases on paper due to the poor image quality displayed on the screen by the cathode ray tube (CRT)[1] [12], [9].

Recent studies on screen have considered specific factors related to reading performance such as speed, comprehension or memory. Most of then use surveys to collect the participants' preferences. Following, we present the results of previous research regarding to the variables tackled in our study.

Font size, font type and paragraph length are most frequently studied variables concerning readability, but there is not a full agreement between the findings. The biggest

[1]The cathode ray tube (CRT) is a vacuum tube containing an electron gun (a source of electrons) and a fluorescent screen used to view images. CRTs have largely been superseded by more modern display technologies such as LCD, Plasma display, LED and OLED.

978-0-7695-4839-5/12 $26.00 © 2012 IEEE
DOI 10.1109/LA-WEB.2012.13

font sizes (12 or 14 points depending on the experiment) showed better performances in relation to smaller font sizes (8 and 10 points) [3], [5]. Moreover, the largest sizes were also preferred in the surveys [1]. Serif types performed better than sans serif types [3], [5], [7], however the users revealed to prefer sans serif types [3], [5], [7], [1].

The performance on reading seems to be better for short lines -around 55, but it depends on the user goal, if they only need to scan a document, long lines show more efficiency [11], [4], [20]. We found less amount of related work taking into consideration specifically font and background colors and space between lines. Users prefer strong contrasts [13] as well as moderate italics, regular fonts and just one color instead of four or six on a website [6].

Readability studies using eye tracking come from psycholinguistics research and they focus on eyes movements to measure different aspects of readability [25], [30], [4], [5] and word predictability [19], [17]. More recently, electroencephalogram measures (brain response) were used to complement eyes movements measures [10], [18].

The variables of our study have been previously taken into consideration in accessibility studies for people with dyslexia [27] to create tools such as eBook readers [16] or games [26]. However, in non-accessibility related human-computer interaction literature, there is a lack of knowledge about reading performance and preference taking into consideration text customization factors further than font size, font type or line length. Our study aims to fill this gap by (1) adding new variables such as character spacing and line spacing, and (2) combining both methodologies: eye tracking and surveys. Moreover, to the best of our knowledge, this is the first time that such approach is carried out for Spanish language, while previous studies focused on English and German.

III. Experimental Methodology

In our methodology we combine the use of eye tracking testing and questionnaires. Ninety two participants undertook the experiments. They read 36 small text fragments with the eye tracker, and then, completed a questionnaire about each of the texts.

A. Participants

Ninety two native Spanish speakers took part in the study, 55 of whom were female and 37 male. Their ages ranged from 13 to 43, with a mean age of 26. All participants are frequent users of internet and frequent readers; 22 read less than four hours per day, 46 read between four and eight hours per day, and 24 participants read more that eight hours daily.

B. Design

We used one reading test to be recorded by the eye tracker and one questionnaire. Along 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 story[2] is written in verse and contains 724 words, while the second story is a fragment in prose[3] with 204 words.

We divided the overall text in 36 fragments 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 and some of them were presented in groups in the same slide. There were a total of 20 slides. The parameter values were presented in random order. The text was presented in a recommended font type for readability, sans serif arial [3], [5], [7], [1] and unjustified text. The parameters were chosen taking into account previous user studies on readability and user preferences regarding text customization (see Section II) Next, we present the independent variables and the values studied.

(a) **Grey scale in the font.** We tested four brightness values (0% –pure black in the font–, 25%, 50% and 75%) for the fonts with white background.
(b) **Grey scale in the background.** We tested four brightness values (100% –pure black in the background–, 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.[4] We chose these pair of colors because they are frequent and their color and brightness are recommended by the W3C [8].
(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%.[5]
(f) **Line spacing.** The four 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.

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

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

[4] The CMYK code for the colors used and their contrast are shown in the Appendix.

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

C. Equipment

The eye tracker used was the Tobii T1750 [31] that has a 17-inch TFT monitor with a resolution of 1024x768 pixels. 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.

D. Procedure

The sessions were conducted at Pompeu Fabra University and they took around twenty minutes each. In each session the participant was alone with the interviewer in the quiet room prepared for the study, and had to do the following three steps.

First, we began with a questionnaire designed to collect demographic information. Second, the participant was asked to read on screen in silence two stories contained in the test, while the eye tracker recorded their eye movements. 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. Out of the 92 participant we got 90 successful recordings. The data of a few text fragments of some of these recordings were not reported by the eye tracker because of different reasons, for instance, the participant could have moved his or her head for some a few seconds.

E. 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 fragments 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 fragments (texts containing less that 22 words). Also, these shorter fragments were extracted from the story written in verse so other variables such as the rhythm or the meter of the sentence are controlled.

The dependent variables used for the comparison of the text fragments were (1) the average fixation duration for the readability performance and (2) the relative percentage of the preferred options for the user preferences.

To measure the readability impact, we analyzed a surrogate variable derived from eye-tracking data, and therefore, from visual behavior: the average fixation duration of each fragment. In general, shorter fixations are preferred to longer ones since readers make longer fixations at points where processing loads are greater [15], [28].

Differences between the eight groups and parameter values were tested by means of a one-way analysis of variance and correlations were computed using the Pearson correlation coefficient.

IV. Results

In this section we present the analysis of the reading performance and the user preferences.

First, we studied the distribution of the fixation duration means of the participants for all the fragments and then we made a analysis of the different values among the users presented in the following subsections.

The mean and standard deviation of the average fixation duration data for our population ($N = 90$) is found to be 0.190 ± 0.046 sec. We checked the normality and the homogeneity of the datasets. They resemble a normal distribution according to the Shapiro-Wilk normality test ($p = 0.068$, for the participants fixation duration means) and we found homogeneity in all the datasets using the Bartlett's test, thus, we conducted further t-tests to assess the effects of the different parameters values of the independent variables.

In Table I we present the results comparatively.

A. Font and Background

Users prefer strong contrasts [13]. However, we found no specific guidelines about gray scales and readability. The majority of the participants preferred a pure black font using pure white in the background (78 users, 84.78%) and pure white font with pure black background (41 userFs, 43.62%); For the font the user preferences are consistent with their performance since the shortest fixations are observed in the fragments with black font and white background; however, for the background, the best values for readability are reached when using 50% grey scale in the font and not pure black background (see Figure 1). Consistently, the quantitative and the qualitative values are more correlated for the use of different grey scales in the font (-0.726) that in the background were no correlation was found (-0.140). We found statistical significance ($F(1, 172) = 7.09,\ p = 0.008$) taking into account the fixation duration mean for the grey scale values in the background (25% and 50%) also, values close to significance ($F(1, 164) = 3.38,\ p = 0.067$) were found when using different values for grey scale in the font (0% and 25%)

B. Colors

With the exception of the off-white/off-black color pair, the participants tend to prefer color pairs with a high color and brightness contrast (see Figure 2). The following color pairs were the most selected (in parentheses the number of participants that preferred that option): white/black (33), yellow/black (23), creme/black (16), off-white/off-black (12) and white/blue (11). Although the pair off-white/off-black is popular it has the highest mean for the fixation durations.

Parameter	Value	Fixations Duration (ave. in sec.)	(%)	User Choice (%)
Font size	26 points	**0.172**	–	29.79
	22 points	0.178	3.3	**48.94**
	18 points	0.197	12.8	19.15
	14 points	0.219	21.6	2.128
Grey scale in the font (white background)	0% (pure black)	**0.178**	–	**84.78**
	25%	0.197	10.9	11.96
	50%	0.193	8.0	3.26
	75%	0.185	2.0	–
Line spacing	1.4 lines	**0.185**	–	**42.86**
	1.2 lines	0.189	1.7	23.08
	1 line	0.200	7.5	29.67
	0.8 lines	0.201	7.7	23.08
Paragraph spacing	3 lines	0.189	4.5	22.55
	2 lines	**0.181**	–	20.43
	1 line	0.189	4.5	**38.65**
	0.5 lines	0.188	3.8	18.37
Column width	88 characters/line	**0.174**	–	8.33
	66 characters/line	0.181	4.1	18.75
	44 characters/line	0.175	1.0	**68.75**
	22 characters/line	0.181	3.9	8.33
Foreground/ background color pairs	white/black	0.178	4.1	**32.67**
	off-white/off-black	0.193	11.6	11.88
	creme/black	0.178	3.9	15.84
	white/blue	0.182	6.0	10.89
	yellow/blue	0.187	8.7	–
	yellow/black	0.182	6.1	22.77
	light mucky green/dark brown	**0.171**	–	4.95
	dark mucky green/ brown	0.190	10.2	0.99
Character spacing	+14%	**0.166**	–	16.30
	+7%	0.182	8.7	**47.83**
	0%	0.178	6.9	32.61
	-7%	0.181	8.5	3.261
Grey scale in the background (white font)	100% (pure black)	0.195	4.6	**43.62**
	75%	0.203	8.3	40.43
	50%	**0.186**	–	15.96
	25%	0.207	10.0	–

Table I
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.

On the other hand, light mucky green/dark brown which has the lowest mean was only chosen by 5 participants. We found statistical significance taking into account the fixation duration mean between off-white/off-black and light mucky green/dark brown ($F(1, 169) = 9.00,\ p = 0.003$) and between light mucky green/dark brown and dark mucky green/brown ($F(1, 164) = 5.49,\ p = 0.020$). However, we found no correlations among the performance and the preference for the color pairs.

C. Font Size

Previous studies agree that most convenient font size is 14 points [3], [5], [1]. However, that comparison was made taking into consideration smaller fonts (8, 10 and 12 points) being 14 the biggest one. In our experiments we wanted to find out the threshold regarding font size and tested: 14, 18, 22 and 26 points. Surprisingly, the fragments which were faster to read and preferred by the user was the ones containing again the biggest sizes, 22 and 26 points (see Figure 3). Moreover, the greatest correlation among performance and preference was found in font size (-0.865). Also, font size is the parameter which has the highest impact in performance. We found statistical significance taking into account fixation duration means between 14 points and 26 points ($F(1, 173) = 34.59,\ p = 0.0000$), 14 points and 22 points ($F(1, 174) = 26.21,\ p = 0.0000$), 14 points and 18 points ($F(1, 174) = 7.584,\ p = 0.0065$), and 18 point and 22 points ($F(1, 174) = 7.183,\ p = 0.0080$). However, further investigations shall be done to find out which is the turning point when a very large font size make reading more difficult.

D. Column Width

Although no correlation was found (-0.3165) the most selected value (66 participants, 68.75%) for column width (44 characters per line) presents the second lowest fixation

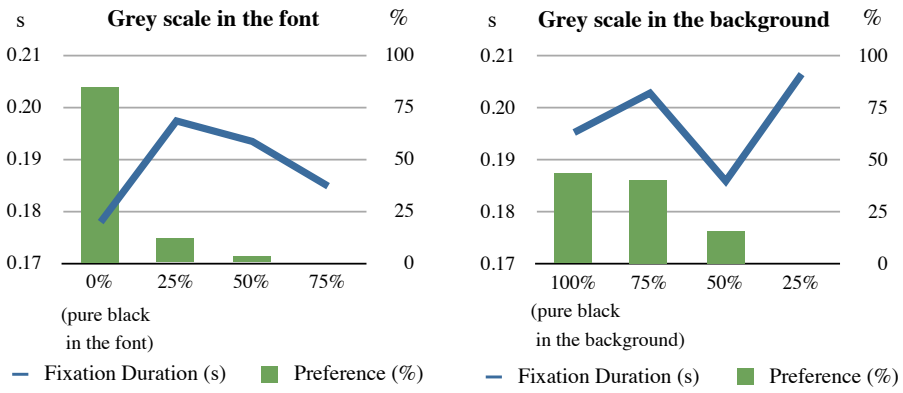

Figure 1. Grey scale for the font and the background.

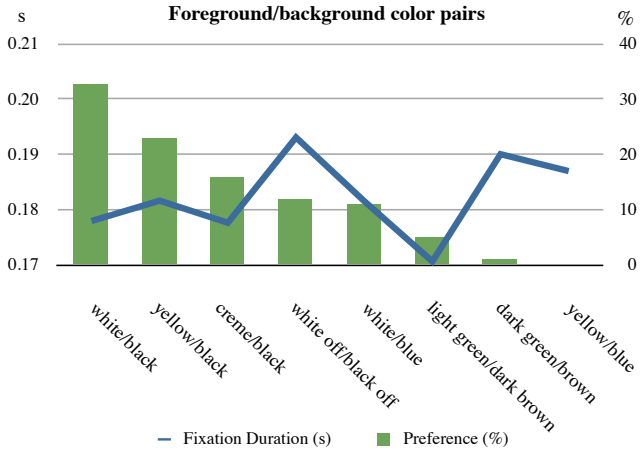

Figure 2. Foreground/background color pairs.

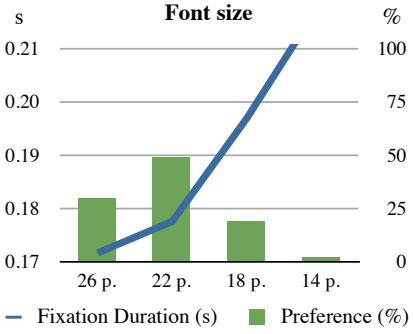

Figure 3. Font size.

duration mean (0.175), very close to the lowest value (0.174) for 88 characters per line (see Figure 4). The preference of the participants in consistent with [11] were 55 characters per line is recommended. No statistical significant was found among the fixation durations means for any of the values.

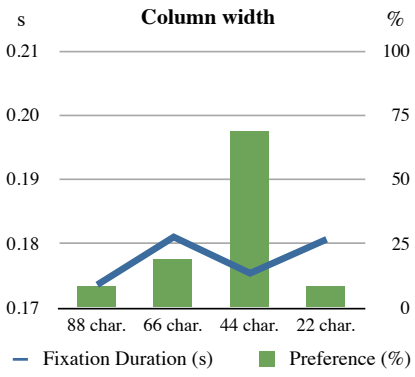

Figure 4. Column width.

E. Character, line and paragraph spacing

In general, participants prefer large spacing, +7% spacing among characters (44 participants, 47.83%), 1.4 lines among lines (39 participants, 42.86%) and 1 line among paragraphs (36 participants, 38.65%). Consistently, the texts with 1.4 line spacing presented the shortest eye fixations (see Figure 5). Although character spacing of +7% was preferred, +14% presented the best performance. There was found statistical significance between the fixation means of the +7% and +14% values ($F(1, 164) = 4.084,\ p = 0.0449$). Also statistical significance was found among -7% and +14% values ($F(1, 167) = 4.074,\ p = 0.0452$). In line spacing values close to significance were found between 1.4 and 0.8 line spacing ($F(1, 174) = 3.7,\ p = 0.056$). We found a no correlation between preference and performance in spacing among characters (0.2712), lines (-0.5491) and paragraphs (0.4234).

V. Guidelines

In Table II we present a set of guidelines for formatting the text taking into account both the fixation length and the user preferences

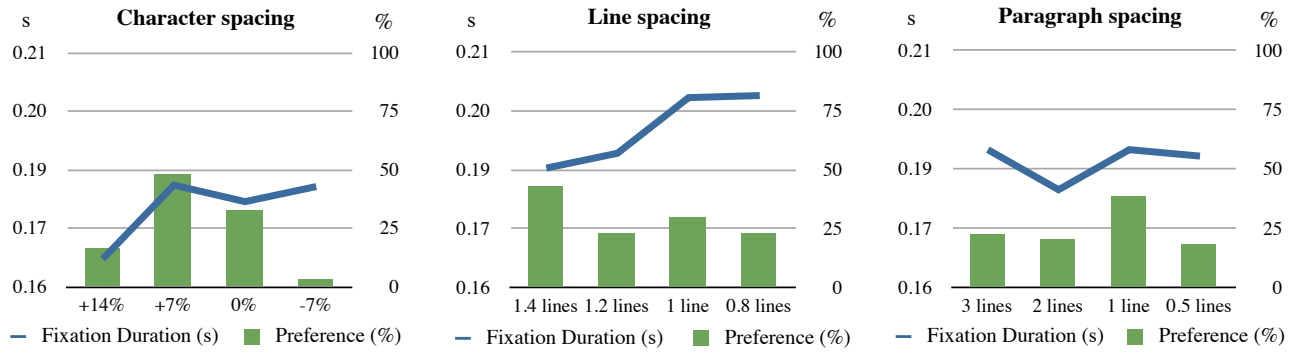

Figure 5. Character, Line and Paragraph Spacing.

Parameter	Value
Grey scale in the font	0% (black font)
Grey scale in the background	100 (black background) or 50%
Color pairs	white–cream/black
Font size	22–26
Column width	44 or 88 characters/line
Character spacing	7–14%
Line spacing	1.4
Paragraph spacing	1.5

Table II
GUIDELINES FOR READING TEXT ON SCREEN.

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 [2]. When there was not a clear preferred or optimal value we present the two best values. We chose the biggest font sizes since 26 points was the most readable and 22 points the most popular size. Clearly more experiments are needed to refine these guidelines, but they should be useful in the context of reading text on screen.

VI. Discussion and Future Work

In this paper we have presented a set of recommendations for text layout based on a user study taking into account the reading performance and the preference of the participants. However, this study has some weaknesses which would be tackled in future work.

First, we cannot be certain if some of the results could be affected by the position of the textual fragment in the slide. Therefore, we will be carry out further randomizations of the parameters giving as a result different tests with more participants. Also, in new experiments we will include longer texts and comprehension questions to tackle the understanding. Finally, we will compare this text layout values in other reading contexts such as Web navigation.

Acknowledgment

This work has been partially funded by the HIPERGRAPH project (TIN2009-14560-C03-01) from the Spanish Economy and Competitiveness Ministry. We also thank Jofre Capdevila, Ferran Gavin and Lara Pasarín for giving us the possibility of enlarging our group or participants by helping to carry out more experiments. Special thanks to all the anonymous volunteer participants.

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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;
- off-white (FFFFE5) / off-black (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.