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LEXIAD, THE FIRST DYSLEXIA-SPECIFIC CYRILLIC FONT COMPARED TO THE POPULAR TIMES NEW ROMAN AND ROBOTO FONTS WHEN READ BY ADULTS

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Abstract

The LexiaD font was developed for Russian-speaking people with reading disorders (dyslexia) (Alexeeva et al., 2020). LexiaD demonstrated an advantage in letter feature extraction and information integration over other modern Cyrillic fonts (PT Sans and PT Serif) while reading by primary school dyslexic and non-dyslexic children. However, for dyslexic and non-dyslexic adolescents, the familiar Arial font was more effective (Alexeeva, Zubov, 2020).
In this study, we tested two possible reasons for the advantages of Arial: familiarity or its structure. LexiaD was compared to Times New Roman (TNR; another familiar font) and Roboto (a font similar to Arial, but less familiar than TNR) when reading texts printed on a paper page. The study involved 42 adults without reading disorders. The previous studies did not show that the font effect interacts with the participant group (with/without dyslexia).
The participants read silently three parts of the text about Easter Island and answered comprehension questions. The texts and tasks were borrowed from The Program for International Student Assessment (PISA). During the reading, eye movements were recorded using a mobile tracker (PupilCore) with a sampling frequency of 200 Hz. The mean word reading rate (reading speed) and the mean number of fixations per word were analyzed.
Mixed-design ANOVA showed a significant difference between the fonts in reading speed ($p=0.05$) and the number of fixations ($p=0.03$). LexiaD was inferior to Roboto in both measures. There was no evidence that the control fonts differed from each other or LexiaD differed from TNR.
Thus, it could be assumed that the design made Arial a facilitating font in the previous study. A longitudinal study of LexiaD is required to test how it will perform when it becomes more familiar to readers.

Keywords: *Dyslexia, font, mobile eye-tracker, printed text, Russian.*

1. Introduction

According to International Dyslexia Association: “Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected concerning other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede the growth of vocabulary and background knowledge” (International Dyslexia Association, 2021)

Five main theories explain the origin of the reading difficulties (Grigorenko, 2010). The first and the most popular theory of the deficiency is related to phonematic processing. Namely, people with dyslexia have difficulties creating grapheme-phoneme associations, saving, representing, and activating phonemes (Ramus et al., 2003). Fast auditory processing deficit theory implies that dyslexia may be caused by difficulties in processing auditory information (Tallal, 1980). The theory of deficits in cerebellar functioning is based on the fact that people with dyslexia often have problems with motor skills (Haslum & Miles, 2007). The double deficit theory means that people with dyslexia have two main difficulties – phonological processing and naming speed (Wolf & Bowers, 1999).

In this study, we adhere to the theory of visual deficiency. People with dyslexia face difficulties related to the graphic component of text – letters often change places and become blurred (Stein & Walsh, 1997). Thus, for the subset of people with dyslexia whose reading problems are related to visual processing, the intervention would be to use special fonts that prevent letters from moving down the line and getting mixed up with other letters. In line with this, dyslexia-friendly Latin fonts have been created, such as Dyslexie, OpenDyslexic, Read Regular, EasyReading™, etc. Still, only one of them (EasyReading™) proved effective (Bachmann & Mengheri, 2018). The Latin fonts were developed based on the personal intuition of the font designers about what letters are visually similar. In the present project, the Cyrillic dyslexia-friendly font LexiaD was created based on empirically derived data on the similarity of Cyrillic letters (Alexeeva, Dobrego, & Zubov, 2020).

LexiaD was empirically tested (silent reading using eye-tracker) in several age groups and compared with different control fonts. In primary school children (Alexeeva et al., 2020) with and without reading difficulties, it was shown that in several aspects, LexiaD was faster to read than modern and highly rated by font experts Cyrillic fonts PT Sans and PT Serif. Namely. LexiaD demonstrated an advantage in letter feature extraction (measured by a word's first fixation duration) and information integration (measured by a word's total viewing time). For dyslexic and non-dyslexic adolescents, on the other hand, the effectiveness of LexiaD wasn't proved (Alexeeva, Zubov, & Konina, under revision). In that case, LexiaD was compared with Arial. Overall, Arial surpassed LexiaD in reading speed, but the difference between the fonts disappeared by the end of the experiment. Perhaps, it was because the participants were getting used to LexiaD. Alexeeva, Zubov, and Konina (under revision) suggested two possible reasons why LexiaD did not show the advantage in reading by adolescents: specific letters' design of Arial or its familiarity. For example, Arial is a well-known font that is used as the default font in Google Docs. The subsequent study was conducted to verify these assumptions.

This time LexiaD was compared to Roboto (a font that is similar to Arial) and Times New Roman (another popular and commonly used font) in adolescents (Alexeeva, Zubov, & Konina, submitted) who read silently printed texts. Non-dyslexic adolescents were recruited since the previous studies (Alexeeva et al., 2020, under revision) did not show that the font effect interacted with the participant group (with/without dyslexia). That study didn't show the difference between Roboto and Times New Roman, but both fonts proved to be more effective than LexiaD. Thus, it seems that LexiaD is probably inferior to both familiar fonts and fonts similar to Arial. The drawback of the study was that the authors measured the familiarity of the control font empirically. Roboto is the default font of Google applications, including YouTube, and thereby it is familiar to adolescents too.

In the present study, we aimed to overcome the drawback by collecting familiarity ratings for LexiaD and the control fonts. Overall, we replicated the study procedure by (Alexeeva et al., submitted), meaning the LexiaD was compared with Times New Roman and Roboto, but adults instead of adolescents were involved this time. We believe that adults have more reading experience than adolescents. Therefore, if familiarity was a key factor of better performance in the previous studies, it would be more pronounced in reading by adults: Times New Roman would have an advantage over LexiaD, and Roboto would not have it, or the advantage would be smaller since this font is not as familiar. If Roboto surpassed LexiaD and TNR did not, then it would point that the design of Roboto (and of Arial)[1] facilitates reading. The latter would be particularly the case if the higher familiarity rating for Roboto than TNR was determined.

In addition, we collected the participants' subjective preference for each font for explorative analysis. In particular, we asked participants to assess subjective easiness of reading and subjective similarity.

2. Method

2.1. Participants

A total of 42 non-dyslexic adults participated in the study (8 males and 36 females). All of them were native speakers of Russian and had a normal or corrected vision. The average age of participants was 21.4 years. This study was approved by the Ethics Committee at St. Petersburg State University, Russia (protocol No. 02-173 on 20.02.2019).

2.2. Materials and design

Two texts about Mars (Grigorenko, 2012) were training, and three texts (related to each other) about Rapanui were sampled from the Programme for International Student Assessment manual (PISA,

[1]Both fonts are similar to Helvetica (https://medium.com/@zkooyer/the-case-for-roboto-acfc00a3008; https://creativepro.com/helvetica-vs-arial-difference)

2020). There were 280 words in the first text, 218 words in the second, and the third text contained 191 words. Training texts were presented to familiarize participants with the procedure. There were 8 statements after the second training text: half of them corresponded to the text, the other did not. Participants were asked to choose correct statements. After each of three texts about Rapanui, there were 8 comprehension questions in total. Each text was printed on a separate piece of paper and presented in three different fonts: Roboto (14 pt, 1.5 line spacing), Times New Roman (13 pt, 1.45 line spacing) and LexiaD (16 pt, single line spacing). Physical letter and line spacing sizes (in pixels) were the same. There were 6 experimental protocols in total (depending on font order). Participants randomly were assigned to protocols.

2.3. Equipment

Eye movements were recorded using the Pupil Core Eye Tracker (by Pupil Labs) with a frequency of 200 Hz. The distance between the eye tracker and piece of paper, where texts were printed, was between 600 and 700 mm.

2.4. Procedure

Before starting the experiment, each participant listened to instructions and was familiarized with the procedure of calibration. Then calibration took place (which was repeated before each text). After the calibration participants read two training texts and answered corresponding questions. Then participants read three experimental texts, and after each part, they answered comprehension questions. During all reading tasks, eye movements were recorded. When participants were answering questions, the recording was stopped. Each text stood in front of a laptop screen at eye level; the laptop served as a stand. At the end of the experiment, participants were asked to choose the font they considered easy to read (subjective easiness) and the font they liked the most (subjective appeal). In addition, the familiarity rate for each font was collected using a seven-point Likert scale. The duration of the experiment was between 15-25 minutes.

3. Analysis and results

3.1. Dependent and independent variables

In reading speed analysis our independent variable (IV) was font (3 levels: LexiaD, Times New Roman, Roboto; a within-participant variable). As for a controlled effect (a covariate: a between-participant variable), we used comprehension accuracy. It was measured as % of the sum of correct answers to questions after training and experimental texts. All questions were rated as 1 point.

When we look at something our eyes are constantly jumped (eye jumps ware called saccades). Between saccades the eyes are relatively still. These time intervals are called fixations. During fixations visual input is processed. The mean word reading time (MWRT) and the mean number of fixations on a word (MNFW) were chosen as dependent variables (DV). To calculate the mean word reading time, we divided the sum of the duration of all fixations on the text by the total number of words. The mean number of fixations on a word was calculated similarly, the total number of fixations on the text was divided by the number of words. Since the texts were of different lengths, this averaging allowed us to compare texts with each other. All measures were calculated for each participant and for each font separately to estimate the overall reading speed.

As for familiarity rating analysis, the IV was font with same three levels. The DV was familiarity rate (from 1 to 7 point).

In subjective preference analyses the effect of a font (the IV with three levels) was assessed for frequency distribution of each of three possible answers (LexiaD, Times New Roman, Roboto).

3.2. Preprocessing

Reading speed analysis. The fixations were defined using the Pupil Player application (developed by Pupil Labs) with following parameters: min duration: 80 ms; max duration: 1000 ms; dispersion: 1.5°. The data of four participants were excluded from the analysis due to poor quality of eye tracking.

Familiarity rating. 29 out of 42 participants provided familiarity rate for each font.

Subjective preference. 37 and 39 out of 42 participants provided subjective easiness to read and subjective appeal of each font, correspondently.

3.3. Analysis

The analysis was performed in the R environment. The graphs were generated using the ggplot package. For each reading speed dependent variable, we performed mixed-designed ANOVA using *aov* function. Each of DVs was log-transformed to meet normal distribution requirement. Tukey-adjusted post hoc analysis was conducted using *emmeans* and *pairs* functions from package *emmeans*). Familiarity rating was analyzed using repeated measure ANOVA with subsequent Tukey-adjusted post hoc test (same functions as for reading speed analysis were run). The familiarity rate was z-transformed based on mean and standard deviation for each participant across all three assessments for the three fonts. Chi-square was used for each preference variable (function *chisq.test*). Post-hoc tests were conducted using the same analysis (Chi-square test) but with Bonferroni adjustment.

3.4. Results

Figure 1 shows the mean word reading time for LexiaD, Roboto and Times New Roman. Figure 3 and 4, show similar data for the mean number of fixations on the word and familiarity rate respectively.

Figure 1. The mean word reading time depending on a font

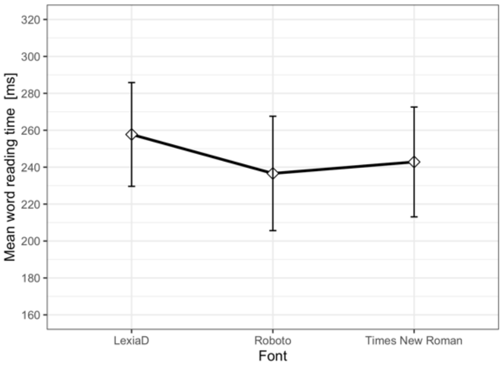


Figure 2. The mean number of fixations on a word depending on a font

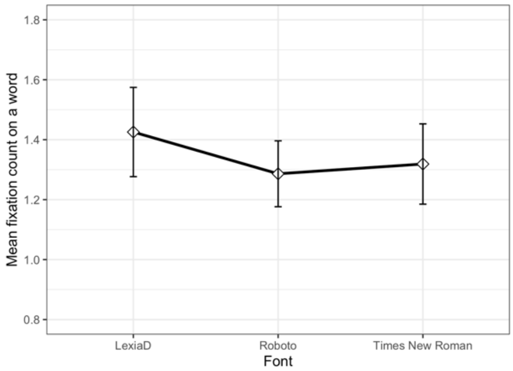
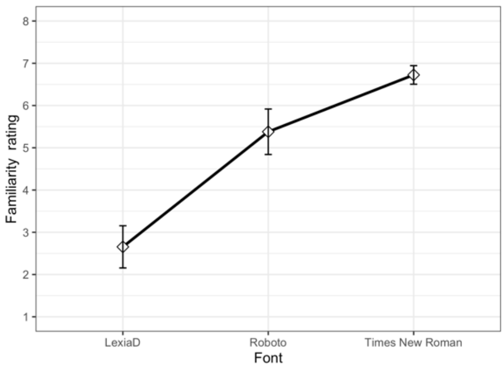


Figure 3. Familiarity rating for each font



There was a significant font effect for the mean word reading time ($F(2, 74) = 3.06$, $p = 0.05$) and the mean number of fixations on a word ($F(2, 74) = 3.65$, $p = 0.03$). Pairwise comparisons revealed that reading in LexiaD was significantly slower than reading in Roboto ($p=0.04$) and texts typed in LexiaD had significantly more word fixations than ones typed in Roboto ($p=0.03$). There was no evidence that the control fonts differed from each other or LexiaD differed from TNR in both measures (ps>0.05). We also found that fonts differed depending on subjective familiarity ($F(2, 56) = 12.00$, $p < 0.001$). Multiple comparisons showed that LexiaD was less familiar than both Times New Roman and Roboto ($p<0.001$ and $p=0.03$, respectively) but the difference between the control fonts did not reach significance ($p=0.06$).

As for subjective preferences, the frequency distribution of answers about easiness of reading was following: 8% of participants preferred LexiaD, 51% — Roboto and 42% — Times New Roman. The chi-square test showed the main effect of font ($X^2(2, N=37) = 11.24$, $p = 0.003$). Post-hoc analysis revealed that both control fonts differed significantly from LexiaD (Times New Roman: $p=0.004$; Roboto: $p<0.001$). The same analysis was conducted for subjective appeal. 56% of participants liked Times New Roman the most, 21% — Roboto and 23% — LexiaD. Again, the font effect was significant ($X^2(2, N=39) = 9.38$, $p = 0.009$). Post-hoc analysis showed that Times New Roman was preferred more often than Roboto ($p=0.01$), but preferences for the other pair of fonts were not significantly different ($p>0.05$).

4. Discussion

The results showed that Roboto had an advantage over LexiaD while reading by adults both in an empirically measured and a subjectively assessed reading speed. Participants considered a text presented in Roboto to be easier to read than one in LexiaD; they made fewer fixations on a word and spend less time on a word to recognize it when a text was typed in Roboto compared to LexiaD. Times New Roman outperformed LexiaD in subjective easiness of reading and subjective appeal. More readers preferred Times New Roman compared to LexiaD in both preference measures.

Since we did not find evidence that the control fonts differed between each other in relation to subjective familiarity (however, both fonts were considered to be more familiar than LexiaD), but Roboto had an advantage over LexiaD in eye-tracking measured reading speed and Times New Roman did not, we can speculate that it was the letter design (and not the familiarity) that helped Roboto outperform LexiaD in the present study and in the study where the control font was Arial (Alexeeva et al., under revision). Bear in mind that Roboto and Arial are similar to each other (see Introduction). It is worth noting that there is a limitation to the conclusion since it was partly based on unsignificant results. A longitudinal study of LexiaD is required to test how it will conduct when it becomes more familiar to readers.

In the study with the same procedure in adolescents both controlled fonts outperformed LexiaD in the mean number of fixations on a word (Alexeeva et al., submitted) thus showing some advantage in reading speed. This suggests that the choice of the facilitating font probably depends on an age group. However, this suggestion is preliminary too, since unsignificant results were involved to come up with it.

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