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Research Article

The effect of a dyslexia-specific Cyrillic font, LexiaD, on reading speed: further exploration in adolescents with and without dyslexia

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ABSTRACT

The current study aims to test the assumption that a specially designed Cyrillic font, LexiaD, can assist adolescents with reading problems and facilitate their reading experience. LexiaD was compared with the widely used Arial font. Two groups of adolescents with dyslexia (N = 34) and without dyslexia (N = 28) silently read 144 sentences from the Russian Sentence Corpus (Laurinavichyute et al., 2019), some of which were presented in LexiaD, and others in Arial, while their eye movements were recorded. LexiaD did not show the desired effect for adolescents at the beginning of the experiment: Arial outperformed it in reading speed in both participant groups. However, by the end of the experiment, LexiaD showed a better performance. Although the speed of the higher-level cognitive processing (e.g., lexical access) in both fonts did not differ significantly, the feature extraction was found to be better in LexiaD than in Arial. Thus, we found some positive effect of LexiaD when participants with and without dyslexia got accustomed to it. A follow-up study with an explicit exposure session is needed to confirm this conclusion.

Keywords: dyslexia, font, eye tracker, printed text, Russian

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Introduction

Dyslexia is one of the most common disabilities affecting language learning. People suffering from it experience difficulties mastering reading and writing skills (I. D. Association, 2021). Most researchers claim that the main cause of dyslexia is linked to issues with phonological processing (I. D. Association, 2021; Ramus et al., 2003; Shaywitz et al., 2004; Snowling, 2012). People diagnosed with dyslexia struggle with grapheme-phoneme associations, namely representing and activating phonemes (Ramus et al., 2003).

Nevertheless, visual origins of reading problems stemming from visual recognition and eye movement control dysfunction are also put forward by certain authors (Stein, 2018; Stein & Walsh, 1997). From the end of 19th century and till the mid-1950s, dyslexia was even called "word blindness" (Hinshelwood, 1917; Morton, 1980; Orton, 1925). The British Dyslexia Association (BDA) emphasizes that some people with dyslexia may experience visual processing difficulties (B. D. Association, 2021a). A lot of teachers who experience dyslexia firsthand in their students support the view that the main issue consists in letters changing the order inside the word during the reading process (Washburn et al., 2014). Besides, people with dyslexia themselves report letters in words being swapped or blurred and lines of text shifted, although those common difficulties are true for some people with dyslexia and not for others (Brunswick, 2012).

Altogether, it seems reasonable to believe that there is a subset of people with dyslexia that struggle with reading difficulties due to deficient visual processing only or in combination with phonological issues. Therefore, interventions addressing this issue could target the visual representation of a text, namely, eliminate or replace visually difficult features.

Several studies elaborated on the typographical features that cause difficulties for people with dyslexia. These features include small character size (O'Brien et al., 2005), standard distance between letters that results in their appearance being influenced by surrounding letters (a so-called crowding effect) (Perea et al., 2012; Zorzi et al., 2012) and cursive letter shapes (Rello & Baeza-Yates, 2013). All these features constitute the essence of a typeface — a lettering design including variations in letter appearance. Therefore, specialized typefaces bring hope that reading will become easier at least for some people with dyslexia.

Following this logic, several Latin-based dyslexia-friendly fonts were created (i.e., Dyslexie, OpenDyslexic, Sylexiad, Read Regular, EasyReading™). Its developers claim that they enhance text readability. The first scientific (empirical) findings failed to prove a reading advantage for Dyslexie and OpenDyslexic (Duranovic et al., 2018; Kuster et al., 2018; Leeuw, 2010; Marinus et al., 2016; Rello & Baeza-Yates, 2013; Wery & Diliberto, 2017; Zikl et al., 2015). However, it is worth noticing that no evidence was found in these studies that specialized fonts worked worse than the control ones (Arial, Times New Roman, Times, CMU, Courier, Helvetica, Verdana, Myriad, Garamond) at least in terms of reading speed. Moreover, it was shown that EasyReading™ had positive impact on reading performance (Bachmann & Mengheri, 2018).

Moreover, OpenDyslexic is currently an optional choice on many websites, including Amazon Kindle[3], Instapaper[4], and Kobo eReader[5]. We believe that those inclusion efforts should be further supported. Further effort on the dyslexia-friendly typefaces might be rewarded in the future and such typefaces should be given a try for languages with non-Latin-based writing systems.

Cyrillic font LexiaD and other dyslexia-specific Cyrillic fonts

Specialized fonts for people with dyslexia have been developed for Cyrillic as well. For example, members of the Faculty of Philosophy in Skopje (North Macedonia) created a font Dyslexic FZF (Karovska Ristovska & Filipovska, 2018). It is a Sans Serif font that is based on Open Dyslexic font. Its main features are heavier bottoms of the letters (that are thought to prevent letters from turning upside down or rotating when the reader sees them), an increased letter size, a wider distance between lines, and a stronger contrast. In addition, Dyslexic FZF, as well as Dyslexie, features tilting of the vertical and horizontal lines of the letter and

[3] https://www.amazon.com/b/?node=11516960011

[4] https://blog.instapaper.com/post/31834532875

[5] https://help.kobo.com/hc/en-us/articles/360020048733-Use-the-OpenDyslexic-font-on-your-Kobo-eReader

increased openings (for instance, in “e”, “s”, and “a”). Dyslexic FZD font does not feature a thickening of the capital letters (Karovska Ristovska & Filipovska, 2018).

Another example is the font АнтиДислексия, a core feature of the app ПростоСлово (http://app.prostoslovo.com). The app lets people with dyslexia change the visual representation of the texts (in particular, letter size, spacing between letters, words, and lines, background color, text color). The font АнтиДислексия is inspired by the Dyslexie font (A. Minz, personal communication from November 01, 2021). It is a fixed-width font that features increased distances between characters and words, and characters with wider and heavier bottoms (that are believed to work like an anchor). Elements that are the same in regular fonts are designed as unique which is thought to prevent letters from being confused.

To the best of our knowledge, these fonts have not been empirically tested. Several books designed by A. Minz (personal communication from November 01, 2021), however, were used as an intervention in the Speech remediation center in Moscow (Russia). Based on speech therapists’ opinion from the center, these books help 50% of people with dyslexia to read more efficiently.

More recently, a special Cyrillic font, LexiaD, for people with reading disorders was developed for the Russian language (Alexeeva et al., 2020). LexiaD (see Figure 1) is a proportional sans serif font designed for larger letter sizes (starting from 14 pins); the spacing between letters, words, and lines is increased; the volume of white inside the letters is larger; the superscript and subscript elements are elongated, and the bases of the letters are thickened. Unlike its Latin-based counterparts, the font is based on letter-similarity ratings assessed objectively in a pretest eye-tracking study (Alexeeva & Konina, 2016). This study determined which Russian letters are similar in isolation and when surrounded by neighboring letters. Different letter shapes (e.g., cursive ones) were used for perceptually similar letters in LexiaD (cf. in the example in Figure 1, the letters "т" and "г" were designed as "m" and "г"). The font was created in consultation with a person diagnosed with dyslexia who uses it for prolonged reading in Cyrillic (other Cyrillic fonts do not work for her when she needs to read long texts).

абвгдеёжзийклмнопрстуфхцчшщъыьэюя
АБВГДЕЁЖЗИЙКЛМНОПРСТУФХЦЧШЩЪЫЬЭЮЯ

Figure 1. The Russian alphabet in LexiaD font

The LexiaD font was tested in a silent reading task on primary school children (9-12 years old) with and without reading disorders (Alexeeva et al., 2020). LexiaD was compared with freely available modern fonts PT Sans (sans serif) and PT Serif (serif). These fonts are highly rated by font experts. All three fonts were unfamiliar to the children in the experiment, but the control fonts consisted of typical letter shapes. Participant eye movements were recorded during the reading task.

The LexiaD font showed an advantage over the control fonts in feature extraction (determining the letters that make up a word) and when information integration failed (demonstrated by fewer re-readings). However, the lexical access (determining the meaning of a word) in LexiaD was slower than in the control fonts. Results did not differ for children with or without reading disorders. LexiaD thus showed a positive impact on reading fluency in several aspects for primary school children.

The present study

Still, evidence from one study is not enough to draw strong conclusions. Therefore, in this study, we aimed to put the LexiaD font to a tougher test. First, we recruited adolescents with and without dyslexia who had more reading experience than primary school children meaning that they were exposed to several fonts (e.g., ones from the textbooks or online) more than others. Second, we compared reading performance of an entirely new font, LexiaD, that our participants had never seen before to a fairly familiar font (Arial) used as a control. Arial is widely used; for instance, it is the default font of the Google Docs and one of the core Microsoft fonts.

Third, we also would argue that it is probable that students with dyslexia from an older age group would have more solidified reading issues than primary school students from our previous study who could compensate for them in the future. 5-

10% of students with impaired reading resolve their problems when passing to the next grade (Law et al., 2017).

Finally, we compared silent reading speed in two fonts, whereas in most previous studies (Bachmann & Mengheri, 2018; Duranovic et al., 2018; Kuster et al., 2018; Leeuw, 2010; Marinus et al., 2016; Wery & Diliberto, 2017) participants were asked to read aloud. We believe that silent reading is a more dominant reading mode due to the sheer volume of silent reading adolescents do daily compared to oral reading (Van den Boer et al., 2014). Besides, our research group owns a highly accurate eye-tracker (see below in the Equipment section) that allows for precise reading speed measurements during silent reading.

When reading skills are assessed orally, measures like total reading time (of certain sentences or texts) or the number of words per minute (reading rate; wpm) are usually used. The eye-tracking allows us to investigate the reading process in detail. This methodology captures basic eye movements, that is, fixations (when the eyes are relatively still) and saccades (short movements to reposition the eyes). Since the visual intake occurs only during fixations (Rayner, 2009), fixational measures are usually of greater interest when investigating reading.

The eye-tracking provides many different fixation measures that may be divided into local (calculated for a particular target word) and global (calculated for a particular trial that corresponds to the whole sentence or text). Global measures include mean fixation duration (MFD), total sentence/text number of fixations (TSNF), number of fixations per word, average reading time per word, etc., as well as total sentence/text reading time (TSRT) and the number of words per minute (WPM) mentioned above.

Local measures include first fixation duration (FFD, the time a reader spends fixating on the target word for the first time), gaze duration (GZD, the sum of fixation durations on the target word before the reader moves forward), total viewing time (TVT, the sum of all fixation durations, including any re-readings of the target word), etc. Early measures like the first fixation duration and gaze duration are particularly informative for analyzing factors that may have an impact on the initial access to lexical representations. Later measures like total time as well as global measures may be useful when investigating higher-order cognitive processing in reading (Rayner, 1998).

Previously, eye-tracking was successfully used to compare different fonts and other typographical features in readers with and without dyslexia (Beymer et al., 2008; Perea & Gomez, 2012; Rayner et al., 2006, 2010; Rello & Baeza-Yates, 2013; Slattery, 2016). For example, analyses of both global and local eye movement measures (Rayner et al., 2006) showed that Old English (it mimics a gothic script) is more difficult to read than Times New Roman for older and young adults without any reading disorders. Based on mean fixation duration (global analysis), it was concluded that italic fonts decreased reading performance in people with dyslexia (Rello & Baeza-Yates, 2013).

Thus, the goal of the research is to check whether the new unfamiliar but specially designed font, LexiaD, works better than a familiar font for the students with persistent reading problems and considerable reading experience while reading silently.

The font performance will be assessed via fluency measures (local and global eye movement variables), comprehension accuracy, and preference ratings. We hypothesized that sentences typed in LexiaD would be faster to read than in Arial, at least for people with dyslexia. In particular, we expected that the advantage of LexiaD would be found in First fixation duration because the input of perceptual information (letter features) seems to precede cognitive processing and First fixation duration reflects the earliest eye movements on a word.

Since previous research on the dyslexia-friendly fonts did not determine a relationship between reading comprehension and the fonts (Bachmann & Mengheri, 2018; Duranovic et al., 2018; Kuster et al., 2018; Leeuw, 2010; Marinus et al., 2016; Rello & Baeza-Yates, 2013; Wery & Diliberto, 2017; Zikl et al., 2015), we conducted an explorative analysis without a particular hypothesis regarding this measure.

As for preference ratings, previous studies (Kuster et al., 2018; Leeuw, 2010; Rello & Baeza-Yates, 2013) provided mixed results: a positive impact of the specialized font (but without statistical analysis) in a paper by Leeuw (2010), no difference between dyslexia-friendly and some of the control fonts (Rello & Baeza-

Yates, 2013), and preference for some of the control fonts over the dyslexia-friendly one (Kuster et al., 2018, Experiment 2; Rello & Baeza-Yates, 2013). Therefore, we did not assume that LexiaD would have advantage over Arial in preference ratings.

Method

Participants

We recruited high school students with and without dyslexia (15-17 years old), the experimental and the control group, respectively. Adolescents with dyslexia (N = 34; 14 girls) were studying at the speech remediation school No3 in Saint Petersburg, Russia. Adolescents without dyslexia (N = 28; 20 girls) were studying at the public school No491 in Saint Petersburg, Russia. Both participant groups had (a) a normal level of intellectual development; (b) normal vision; (c) no comorbid diagnoses (e.g., autism), and (d) were naive to the purpose of the experiment. Adolescents without dyslexia did not report any speech or reading problems in their childhood[6].

Written informed consent forms were signed by children's parents or legal representatives; the study was approved by the Ethics Committee at Saint Petersburg State University, Russia (protocol No. 02-173 from 20.02.2019).

Material and design

Participants read the Russian Sentence Corpus (Laurinavichyute et al., 2019) silently while their eye movements were recorded. This corpus was specifically created for eye-tracking studies in Russian. It consists of 144 sentences with different grammatical structure. For each word in the corpus, wordform frequency, length, and predictability measures are provided. Predictability is calculated based

[6] In author's study on primary school children (Alexeeva et al., 2020), the control group was recruited from the same school. As for the participants with dyslexia, there were two experimental groups: one reading in LexiaD and PT Serif and another one reading in LexiaD and PT Sans. The former consisted of the students from the same speech remediation school as in this study. Children from the latter group lived in Moscow and were diagnosed with dyslexia following the Neuropsychological Test Battery (Akhutina et al., 2016) by a specialist from the Center for Language and Brain, HSE Moscow.

on a separate predictability norming study using a cloze task (Laurinavichyute et al., 2019). Wordform frequencies were borrowed from the "Frequency grammar of Russian" project (Lyashevskaya, 2013) via the StimulStat database (Alexeeva et al., 2018). They were calculated after the morphological disambiguation of each word was completed (Laurinavichyute et al., 2019).

The sentences were created based on the seed words. The seed words were selected to cover all combinations of the three manipulated factors: lemma word frequency (high, >50 ipm / low, <10 ipm), word length (short, 3-4 letters / medium 5-7 letters / long, 8-10 letters), and grammatical category (noun, verb, and adjective). Lemma frequencies for seed words were taken from "Chastotnyj slovar' sovremennogo russkogo jazyka" (Frequency dictionary of the modern Russian language; Lyashevskaya & Sharov, 2009).

For each participant, the corpus was randomly divided into four sections (36 sentences in each section), with two presented in LexiaD and the other two in Arial (see Figure 2). Sentences in LexiaD were typed in 21 pt and sentences in Arial – in 16pt but font height was equal. As both fonts are proportional, the sheer physical width of the stimuli sentences was different. All sentences fit into one line. The order of font presentation, the order of sentences within a section, and the split of sentences into sections were random for each student. All the materials were presented as black on the white background.

Дорога ведет в глухой лес, петляя по склонам. *LexiaD*

Дорога ведет в глухой лес, петляя по склонам. *Arial*

Figure 2. An example sentence (*The road leads to the dense forest, winding along the slopes.*) in LexiaD and Arial fonts.

Equipment

To record participant eye movements, we used an eye-tracker EyeLink 1000 Plus (SR-Research) in monocular mode, with a chin rest to minimize head movements. With the sampling of 1000 Hz, the eye movements were recorded every millisecond. The experiment was designed via the Experiment Builder software, proprietary to SR-Research. We used 19’ LCD monitor (Samsung SyncMaster E1920) with a refresh rate of 60 Hz (screen resolution 1280x1024). The viewing distance was 72 cm. The sentences were placed at the center of the screen in relation to the vertical axis. Horizontally, there was a margin of 100 px from the left edge of the screen.

Procedure

The researcher instructed participants to read each sentence silently as carefully as possible. Each participant underwent 9-point gaze calibration lasting approx. 5 minutes. The researcher checked calibration accuracy before every trial (sentence). If it failed, recalibration took place. After the participants finished reading every sentence, they pressed a key on the keyboard to proceed to a question or to the next sentence. 35% of sentences were followed by a forced-choice comprehension question with three options to control for participants’ comprehension. To reply to a question, participants had to press a button on the keyboard.

After having read 36 sentences (after each part, see 3.1.2), participants took a break. At the end of the experiment, participants were asked to answer two preference questions: which font was easier to read (further, *readability*) and which font they liked more (further, appeal).

For the participants to get accustomed to the procedure, we introduced three practice sentences at the beginning of the experiment.

Not all participants read the whole corpus due to technical or organizational problems. One student with dyslexia and three students without dyslexia read half of the corpus and three participants with dyslexia read three quarters of the corpus. For these participants, we included all available data in the analysis (but see Preprocessing stage below).

Dependent variables and preprocessing

In our experiment, we analyzed both the global measures (TSRT, TSNF, MFD, and WPM) and local measures (FFD, GZD, and TVT). Global measures were calculated for each sentence separately, whereas local measures were determined for each word. Following standard practice in corpus eye movement research, the first and last words in every sentence were excluded from the local measure analysis (Bai et al., 2008; Yan et al., 2014). Local measures are based only on fixation durations, whereas global measures contain both fixation and saccade durations.

Fixations were identified by SR-Research proprietary algorithms and were preprocessed in the following way. Fixations under 80 ms within one character of the next or previous fixation were combined with the respective fixation. Remaining fixations that were shorter than 80 ms and longer than 2000 ms, as well as fixations before and after a blink, were discarded. Sentences with whole or partial recording loss were removed from the analysis (33 sentences in the experimental group and 15 sentences in the control group).

In local measure analysis, we discarded words that were skipped entirely (15.6% of all observations; 14.2% for participants with dyslexia and 17.4% for students without dyslexia). First fixation duration and gaze duration were calculated only if a word was not skipped first.

In addition to eye movement measures, comprehension accuracy and preference ratings were analyzed. As for comprehension accuracy, the analysis input was the sentence ID and the answer (1 – correct; 0 – incorrect).

As for the subjective preference of the font, there could be three possible answers for each question (the first referring to readability, the second referring to appeal). Namely, Arial, LexiaD, or 'it does not matter'. Answers 'it does not matter' were discarded from the analysis (readability: participants with dyslexia – 4, the control group – 6; appeal: participants with dyslexia – 3, the control group – 3). As a result, we had 52 observations for the readability question (30 for participants with dyslexia and 22 for students without dyslexia) and 56 observations for the appeal question (31 for students with dyslexia and 25 for students without dyslexia). The number of observations for local eye movement measures, global eye movement measures, and comprehension score for students with and without dyslexia are provided in Tables 1, 2, and 3 respectively.

Data analysis

Local eye movement measures

We performed linear mixed-effects analyses (LMM) using the lme4 package (version 1-1.17; Bates et al. 2015) in R (R Core Team, 2021) on each of the measures. The fixed effects were font (LexiaD / Arial) and participant group (with / without dyslexia), as well as the interaction between them. Controlled effects were added to the analyses: word length, word frequency, word predictability, word index, trial index, sentence length, section[7], and their two-way interactions with each of the fixed effects. Random effects of the full model (see below) included intercepts for participant ID, sentence ID, and word ID, as well as by-participant slope for the font.

To ensure a normal distribution of model residuals, durations (FFD, GD, and TVT) were log-transformed (here and further natural logarithm was used). Font and Participant group factors were coded as sliding contrasts (with LexiaD and participants with dyslexia as a reference level respectively). Word length was centered and scaled; word frequency was log-transformed, predictability was logit-transformed. Trial index, sentence length, and section were centered and scaled.

The lmerTest package (version 3.0-1; Kuznetsova, Brockhoff, & Christensen, 2017) in R was used to estimate the p-values. Step procedure was conducted for the optimal model selection (*step* function in R). *Step* function uses the full model with all fixed, controlled, and random effects and goes downwards excluding one term (the most insignificant effect) per step comparing the goodness of fit of the models with and without the term. If the model with the term describes the data better, this model is considered optimal. Otherwise, the term is removed.

The final models for local eye movement measures are reported in Appendix A.

Global eye movement measures

LMM was used for each of the global eye movement measures with the same fixed effects as for the local eye movement measures. The analysis contained the following controlled effects: trial index, sentence length, section, and their two-way

[7] We thank the anonymous reviewer for the suggestion to include the section and trial index as controlled effects in the analyses (here and further).

interactions with each of the fixed effects. Full random model structure contained intercepts for participant ID and sentence ID, as well as a by-participant slope for the font, as random effects. We used the same coding scheme, transformation technique, and optimal model selection as in local eye movement analysis. See Appendix B for summaries of the final models for each of the global eye movement measures.

Accuracy

We performed generalized linear mixed-effects analyses (GLMM) for accuracy using the lme4 package (version 1-1.17; Bates et al. 2015) in R (R Core Team, 2021). The fixed effects were font (LexiaD / Arial), participant group (with / without dyslexia), and interaction between font and participant group. The controlled effects were section, trial index, and the interaction between font and section. Random effects in the full model (see below) include intercepts for participant ID and sentence ID, as well as a by-participant slope for the font. Accuracy being a binary dependent variable was fit with GLMMs with a logistic link function. The coding scheme for fixed effects was the same as for the fluency measures. The step procedure was conducted manually using *anova* function in R since *step* function works only for interval dependent variables. The final model is provided in Appendix C.

Preference ratings

Chi-square analysis for each preference variable was conducted. The analysis was performed for students with and without dyslexia separately.

Data and statistical analysis can be found at the following link: https://osf.io/x87e2/?view_only=ed270510898e4b5fa908176f4523ff6f.

Results

We will first report the results for local eye movement measures, then for global eye movement measures. Finally, accuracy and subjective preference results will be provided. For each dependent variable group, we first describe the results for the font effect; then we explore the dyslexia effect and the interaction between font and dyslexia.

Local eye movement measures

The means and standard deviations for all local eye movement variables depending on font and participant group are presented in Table 1.

Table 1.
Word-level (local) aspects of reading performance for students with and without dyslexia depending on Font[8].

		FFD (ms)			GZD (ms)			TVT (ms)		
Group	Font	*M*	*SD*	*Nobs*	*M*	*SD*	*Nobs*	*M*	*SD*	*Nobs*
Students with dyslexia	LexiaD	268	102	13812	412	208	13812	551	288	14768
	Arial	272	109	13912	402	214	13912	539	297	15247
Students without dyslexia	LexiaD	233	80	10709	293	128	10709	393	201	11825
	Arial	235	82	10173	283	122	10173	385	200	11608

Note. *M* – mean, *SD* – standard deviation, *Nobs* – number of observations, *FFD* – word first fixation duration, *GZD* – word gaze duration, *TVT* – word total viewing time.

Effect of LexiaD

We did not discover the main effect of font on FFD (see the results of the statistical analysis in Appendix A). However, we found evidence of a statistically significant interaction[9] between font and word frequency that points towards the advantage of LexiaD for high-frequency words and towards the absence of the effect for low-frequency words. In addition, LexiaD revealed an advantage over Arial at the end of the sentences; we did not find any evidence that the beginning of the sentences differed between fonts (see the significant interaction between

[8] The means and standard deviations here and further were calculated based on partial effects, with variance attributable to random and (controlled) fixed effects removed using the *keepef* function (Hohenstein & Kliegl, 2014).

[9] The plots showing this and further interactions were placed into the folder titled "interaction plots" in the OSF-repository for the project: https://osf.io/x87e2/?view_only=ed270510898e4b5fa908176f4523ff6f.

font and word index in Appendix A). More interestingly, we found an interaction between font and section to be significant (see Appendix A): by the end of the experiment, reading time in LexiaD was less than in Arial, whereas at the beginning of the experiment, we did not find evidence for the font effect.

The effect of font was significant for GZD. However, it was Arial that had advantage in reading speed: words typed in LexiaD were fixated significantly longer than words typed in Arial (see Table 1, Appendix A). We also found a significant interaction between font and word frequency (see Appendix A), meaning no significant effect for high-frequency words and a disadvantage of LexiaD for low-frequency ones. In addition, LexiaD was inferior to Arial in reading longer words. However, there was no significant difference between reading short words in both fonts (see the significant interaction between font and word length in Appendix A). As for the significant interaction between font and section (see Appendix A), we revealed that at the beginning of the experiment, Arial had advantage over LexiaD, but by the end of the experiment, the difference vanished.

For TVT, again, LexiaD worked significantly worse than Arial (see Table 1, Appendix A). However, in addition to the main effect of font, we revealed a significant interaction between font and word frequency (see Appendix A). It showed an advantage of LexiaD for high-frequency words and the absence of the effect for low-frequency ones. Moreover, the interaction between font and section was significant (see Appendix A). It replicated the results for GZD: the more familiar LexiaD became, the less pronounced the difference between Arial and LexiaD was.

Effect of Dyslexia

In all local measure analyses, students with dyslexia showed a disadvantage compared to reading-level students (see Table 1, Appendix A).

In addition, several interactions were found to be significant (see Appendix A). First, participants with dyslexia slowed down more pronouncedly than students without dyslexia while reading low-frequency words compared to high-frequency words in all local eye movement measures. Second, in FFD, participants with dyslexia showed the length effect (short words were read faster than the long ones) whereas we found no evidence of the length effect for students without reading disorders. In GZD and TVT, the length effect was more salient for students with dyslexia than for students without dyslexia: longer words were particularly difficult for the former.

Third, when it comes to FFD, the control group slowed down more than participants with dyslexia while reading from the beginning till the end of the sentence (see significant interaction between group and word index in Appendix A). In GZD, the control group did the same, whereas participants with dyslexia sped up by the end of the sentence. In TVT, the results were similar to the ones in GZD, the only difference being that the controls barely slowed down.

Fourth, in TVT, we found a significant interaction between section and group that pointed towards a salient slow down by the end of the experiment for controls and a slight slowdown for students with dyslexia (see Appendix A). To our surprise, the significant interaction with another variable related to the experimental procedure — trial index — showed that in all local eye movement measures, both groups speed up, but participants with dyslexia did it more slowly than students without dyslexia (see significant interaction between group and trial index in Appendix A).

Font X Dyslexia interaction

The step procedure (see Data analysis section for the details) did not include Font X Dyslexia interaction into the optimal model for any of the local eye movement measures at hand. This means that we found no evidence that the fonts had a different impact on reading performance in experimental and control groups in any of the studied measures (see Appendix A).

Global eye movement measures

Table 2 presents the means and standard deviations for all global eye movement measures depending on font and participant group.

Table 2.
Sentence-level (global) aspects of reading performance for students with and without dyslexia depending on Font

			TSRT (ms)		TSNF		MFD (ms)		WPM	
Group	Font	*Nobs*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Students with dyslexia	LexiaD	2287	4499	1236	18.4	4.8	245	25	137	36
	Arial	2396	4349	1247	17.2	4.7	253	27	142	37
Students without dyslexia	LexiaD	1902	3188	862	14.5	3.7	221	24	192	46
	Arial	1899	3094	872	13.7	3.6	227	26	199	50

Note. *M* – mean, *SD* – standard deviation, *Nobs* – number of observations, *TSRT* – total sentence reading time, *TSNF* – total sentence number of fixations, *MFD* – mean fixation duration, *WPM* – reading rate (in words per minute).

Effect of LexiaD

We found evidence for significantly better reading performance in Arial compared to LexiaD in three (TSRT, TSNF, and WPM) out of four global measures at hand: reading rate was higher, total reading time was less, and the number of fixations was fewer in Arial. As for the mean fixation duration (MFD), the effect was the opposite (see Tables 1, Appendix B).

We also found a significant interaction between font and section in TSRT, TSNF, and WPM (see Appendix 1). In TSRT and WPM, similarly to GZD and TVT, the font effect vanished by the end of the experiment. In TSNF, the difference between the fonts became much smaller by the end of the experiment.

Effect of Dyslexia

In all global measures, students without dyslexia outperformed students with dyslexia (see Tables 1, Appendix B).

In TSRT and WPM, we saw two significant interactions, one between group and section and one between group and trial index (see Appendix A). Similarly to TVT the former showed a less pronounced slow down for participants with dyslexia than for the controls by the end of the experiment and the latter pointed towards more salient speed-up for the controls than for participants with dyslexia by the last sentence of the experiment. In TSNF, only the interaction between group and section was significant and it replicated the results for TSRT and WPM. In MFD, on the other hand, trial index significantly interacted with the group and again, the exploration of the interaction showed the same results as for TSRT and WPM.

Font X Dyslexia interaction

No significant interactions were found in any of the studied global measures based on the step procedure (see the similar section for local eye movement analysis and Appendix B).

Accuracy

The means and standard deviations for comprehension accuracy depending on font and participant group are presented in Table 3.

Table 3.
Sentence comprehension accuracy for students with and without dyslexia depending on Font.

		Accuracy (%)		
Group	*Font*	*M*	*SD*	*Nobs*
Students with dyslexia	LexiaD	83.0	38	792
	Arial	86.6	34	867
Students without dyslexia	LexiaD	88.4	32	674
	Arial	89.9	30	675

Note. *M* – mean, *SD* – standard deviation, *Nobs* – number of observations.

Effect of LexiaD

No effect of font on comprehension accuracy was revealed (see Table 1, Appendix C).

Effect of Dyslexia

Participants with dyslexia answered comprehension questions worse than students without dyslexia (see Table 1, Appendix C).

Font X Dyslexia interaction

The results did not show that comprehension accuracy in experimental and control groups differed depending on font since the step procedure (see Data analysis section for details) excluded the term during optimal model selection (see Appendix C).

Subjective preference

We performed separate analyses in experimental and control groups for each preference question (see Data Analysis section).

Effect of LexiaD in students with and without dyslexia

As for the readability question, more students with dyslexia preferred Arial over LexiaD font (20 vs. 10), but the effect of font did not reach significance ($X^2(1, N = 30) = 3.33$, $p = .07$). There was no evidence that the preference choice of the students without dyslexia (14 voted for Arial, 8 – for LexiaD) was dependent on the font ($X^2(1, N = 22) = 1.64$, $p = .20$). For the appeal question, the font effect was insignificant for both groups: participants with dyslexia, $X^2(1, N = 31) = 0.03$, $p = .86$ (Arial – 15, LexiaD – 16); the control group, $X^2(1, N = 25) = 0.36$, $p = .55$ (Arial – 11, LexiaD – 14).

Discussion

The majority of studies attribute reading and writing issues that people diagnosed with dyslexia encounter to the underdeveloped phonological processing. It has been attested by some studies (Stein, 2018; Stein & Walsh, 1997) and the firsthand experience of professionals working with students with dyslexia that at least some portion of this population struggles with the visual component as well, for instance, letters interchanging inside a word. To address this issue, several designers came up with dyslexia-friendly fonts (Dyslexie, Opendyslexic, etc.). The majority of them are Latin-based, but we could also find examples tailored specifically to Cyrillic alphabets. These fonts usually stem from personal experience with dyslexia and are not based on empirical studies nor tested before release. The efficacy of these fonts has been investigated on the basis of reading speed and was deemed to be insufficient.

In the current study, we further investigated LexiaD, a Cyrillic dyslexia-friendly font that has the advantage of being developed based on letter recognition studies. We recruited adolescents with and without reading disorders and compared LexiaD with the popular Arial font in a silent reading task.

Comparing LexiaD with Arial

The results for five fluency measures out of seven (word gaze duration, GZD; word total viewing time, TVT; total sentence reading time, TSRT; total sentence number of fixations, TSNF; reading rate, WPM) showed that Arial is more readable than LexiaD. In the sixth fluency measure — mean fixation duration (MFD), — LexiaD outperformed Arial[10]. Finally, our data did not provide evidence that fonts differed in the first fixation duration on a word (FFD). In reading comprehension score, subjective readibility preference, and subjective appeal ranking, the fonts did not differ significantly. These results are valid both for participants with dyslexia and the control group: there was no evidence that the font effect was dependant on the participant group.

Arial is a well-known font that is most commonly seen on screen compared to other fonts (Rello & Baeza-Yates, 2016). The British Dyslexia Association (B. D. Association, 2021b) and other researchers (Evett & Brown, 2005; Lockley, 2002) recommend people with dyslexia to use it when reading. In spite of this, we also

[10] It is worth noticing that this advantage is illusory. Both TSRT and TSNF were higher in LexiaD than in Arial and mean fixation duration is calculated as TSRT divided by TSNF. The true positive effect of LexiaD in MFD could be confirmed if both TSRT and TSNF were less in LexiaD or if TSRT was less and TSNF did not differ or TSNF was less and TSRT did not differ.

found that font effect in six out of the seven fluency measures (FFD, GZD, TVT, TSRT, TSNF, and WPM) changed by the end of the experiment. The more familiar LexiaD became, the less salient the difference between Arial and LexiaD was. By the end of the experiment, LexiaD outperformed Arial in FFD; in GZD, TVT, TSRT, and WPM, the difference vanished; in TSNF, it became much smaller.

Following our own previous study (Alexeeva et al., 2020), we assume that first fixation duration mainly reflects feature extraction (determining the letters that make up a word), gaze duration is primarily related to lexical access (determining the meaning of a word), and total viewing time captures text integration (recovering from any semantic or structural failure that causes re-readings). Also, we believe that global eye movement measures reflect general processing across the text/sentence. In line with these assumptions, we can conclude that once participants get accustomed to LexiaD, it helps the readers to extract letter features faster and stops worsening the speed of the higher-level cognitive processing (e.g., lexical access or text integration).

It is worth noticing that better performance of LexiaD in relation to the feature extraction was revealed for high-frequency words even at the beginning of the experiment. Since letters in LexiaD were designed differently (where possible), several letters have untypical shapes. Uncommon letter shapes are perhaps more salient in rarer letter combinations that occur more often in low-frequency words compared to high-frequency ones (Rice & Robinson, 1975). Therefore, we suggest that participants need to get used to unusual letter repsesentation in low-frequency words. This is probably the reason why our data did not provide evidence for the font effect for words of this frequency range at the beginning of the experiment.

Comparing LexiaD with PT font family

In the previous study involving *primary* school students with and without dyslexia (Alexeeva et al., 2020), LexiaD was compared with another Sans Serif font — PT Sans. It is a modern freely distributed font that is highly rated by the font experts. It was also unfamiliar to participants but consists of typical letter shapes. Confirming our familiarity hypothesis regarding FFD results, LexiaD outperformed PT Sans (both for high- and low-frequency words) in this measure both for the controls and participants with dyslexia. However, when we compared LexiaD with PT Serif (a Serif analogue of PT Sans) in an experiment with primary school children (Alexeeva et al., 2020), the results for FFD were the same as in the present study.

Several explanations come to mind as for why the FFD results of the present study on adolescents resemble the ones for primary school children reading PT Serif and LexiaD and are slightly worse than the ones for primary school children reading PT Sans and LexiaD. First, for primary school children, serif fonts could be more readable than sans serif fonts (resulting in an advantage for low-frequency words compared to LexiaD). However, as far as we know, no significant difference was previously registered for reading performance speed between serif and sans serif fonts in primary school children (Bernard et al., 2002) and adults without reading disorders (Beymer et al., 2008; Perea, 2013). In adults with dyslexia, overall text reading duration (Rello & Baeza-Yates, 2013) did not differ significantly between serif and sans serif fonts, but mean fixation duration showed an advantage for sans serif fonts over the serif ones (but see note 10).

Second, children with dyslexia from PT Sans and PT Serif groups study in different schools. Children from the former group study in ordinary Moscow schools (see note 4) whereas the ones from the latter group go to the same remediation center as adolescents with dyslexia from the present study. Therefore, LexiaD could work better for children with less severe reading problems. However, all primary school children and adolescents that were invited as controls were from the same ordinary school in Saint Petersburg, and the results for the controls and the participants with dyslexia did not differ significantly between age groups. Thus, it is not clear why the results for FFD for adolescents (LexiaD / a Sans Serif Arial) are the same as for the primary school children in LexiaD / PT Serif subgroup and slightly worse than the ones for the primary school children in LexiaD / PT Sans subgroup.

Font familiarity

Contributing to the discussion on font familiarity (the key finding of the present study), typographers suggest that familiar typefaces are processed faster (Wang, 2013). The issue of the typeface familiarity is raised in typography when designers discuss appropriateness of letterform change in new and old fonts. For some designers, familiarly can be quantified as the amount of time readers have spent using a particular typeface. They tend to support the exposure hypothesis that states that the more exposed the reader is to the typeface, the more familiar they are with it. New uncommon typefaces thus can be designed, and readers will get used to them in time. Other designers support the prototype hypothesis suggesting that typeface familiarity is rooted in common letter shapes. Typeface design then must not deviate from strict parameters, and new typefaces are frowned upon.

Beier (2009) and Beier and Larson (2013) tested these hypotheses by measuring reading speed in a test[11] and subjective preferences prior to and after reading a 20-minute story. The experiment had three conditions: a known font with common letter shapes (Times/Helvetica), a new font with common letter shapes (Spencer/PykeText), and a new font with uncommon letter shapes (SpencerNeue/PykeTextNeue). Future designers without reading problems were recruited as participants. It was shown that the reading speed increased after the exposure session, but the effect of the letter shape commonality did not reach significance (both before and after the exposure session). The authors concluded that the exposure hypothesis is thus more plausible. In addition, they found that participants assessed new fonts with uncommon letter shapes as less appealing for reading in the future, taking more attentional recourses, and less comfortable to read.

The results of these studies have the following implications for our data. First, unfamiliar fonts become more readable after some exposure. This means that a longitudinal study of the LexiaD font is needed to check how it will perform when participants are familiarized with it even more. To reiterate, in almost all fluency measures, LexiaD caught up with Arial in speed efficiency by the end of our experiment (during an exposure of just 144 sentences).

Second, in Beier (2009) and Beier & Larson (2013) studies, there was no evidence found that reading speed differs between known-common fonts and new-uncommon fonts even before the exposure session. In our study, LexiaD (a new font with uncommon letter shapes) clearly performed worse than Arial (a

[11] The reading test consisted in finding an absurd word in several short paragraphs within two minutes. The number of successfully completed paragraphs was measured.

known font with common letter shapes) at the beginning of the experiment. But it is worth noticing that fonts used in Beier (2009) and Beier & Larson (2013) contain only regular letters whereas in LexiaD, the designer used italic to create several letter shapes in the regular typeface (for example, "m") to disambiguate often confused letters. Italic typefaces are more difficult to read both for people with dyslexia (Lockley, 2002; Rello & Baeza-Yates, 2013) and people without reading difficulties (Slattery & Rayner, 2010) compared with regular typefaces.

In addition, it is easier to process strings typed in one font (gothic font or serif font) than strings made up of letters from two different typefaces (gothic letters mixed with serif letters; Sanocki, 1988). In our case, some words in LexiaD could be considered mixed letter strings combining regular and italic letters. Perhaps, these are the two reasons why LexiaD showed worse performance compared to Arial at the beginning of the experiment.

However, it is worth noticing that in previous studies (Beier, 2009; Beier & Larson, 2013), the difference between known-common fonts and new-uncommon fonts before the exposure session could be hidden due to the difficulty of their reading test (see note 11). In fact, their test measured reading performance speed (as it was assessed by our fluency variables) plus the time to complete the comprehension task. If we compared the results of these studies (Beier, 2009; Beier & Larson, 2013) for this test with our comprehension score results, then they would be alike.

The difference in the reading task could also explain why there was no evidence that Latin-based dyslexia-friendly fonts differed from the control ones in terms of reading speed (see Introduction) and why we obtained an opposite result for most of the measures at the beginning of the experiment. All the studies of Latin dyslexia-friendly fonts (Duranovic et al., 2018; Kuster et al., 2018; Leeuw, 2010; Marinus et al., 2016; Wery & Diliberto, 2017) except one (Rello & Baeza-Yates, 2013) use reading aloud as the task whereas we used silent reading. Mean fixation duration in oral reading is usually 20-25% longer than in silent reading due to word articulation and related eye repositioning (Rayner, 2009). Extra time that was needed for articulation could thus cover the processing difference between fonts in an oral reading task.

Preference rankings

In the preference rankings (both regarding subjective readability and subjective appeal), we did not find significant preference for any of the fonts used in the experiment in any participant group. LexiaD was new to participants but many of participants with dyslexia (half in the appeal question and one third in the easiness-to-read question) preferred this font. In (Rello & Baeza-Yates, 2013), participants with dyslexia assessed OpenDyslexic to be less likable than Verdana and Helvetica but did not articulate a preference between OpenDyslexic and Arial, Times, CMU, Courier, Myriad, and Garamond. In Experiment 1 of (Kuster et al., 2018), where the participants were diagnosed with dyslexia, no statistical information was provided on how Dyslexie compares to Arial. In the Experiment 2, given the choice between Arial, Times New Roman, and Dyslexie, participants with dyslexia and the control group together were fewer than expected to show a preference for Dyslexie or no preference at all. At the same time, more participants showed a preference for Arial and Times New Roman than expected. Also, it was mentioned that the distribution of the preferences choices for the students with and without dyslexia differed, but no statistical analysis was provided showing where the difference lies.

In a study by Leeuw (2010), a more positive attitude towards the Dyslexie font than Arial in participants with dyslexia compared to readers without dyslexia was mentioned, but no statistical analysis was provided to support the claim. More importantly for us, Kuster and colleagues (2018) did not provide any evidence that subjective preference has in impact on reading performance. Even though a participant could subjectively prefer the control font over the dyslexia-friendly one, it does not necessary mean that s(he) will read faster in it. Following that, our conclusion is based on reading speed results.

Conclusion

All in all, a previous study (Alexeeva et al., 2020) in primary school chidren with and without dyslexia who obviously had less reading experience than adolescents showed some advantages of LexiaD over unfamiliar but highly rated control fonts, PT Sans and PT Serif. In the present study, we found some positive effect of LexiaD compared to very common onscreen font, Arial, when adolescents with and without dyslexia got accustomed to LexiaD. Thus, it seems that LexiaD has the potential to be a supporting font for these age groups. However, follow-up studies with an exposure session are needed to confirm our conclusion. Moreover, it is interesting to explore how LexiaD will perform when adults who had even more reading experience than adolescents are recruited. Do they need more time than adolescents to get used to LexiaD? In addition, other familiar Serif fonts (e.g., Times New Roman) need to be tested in comparison with Sans Serif LexiaD. The last but not the least, although Arial is very widespread, font experts (e.g., Danilova, 2021) point out that Cyrillic letters in Arial are of low quality. Therefore, more modern analogues of Arial (e.g., Roboto) should be examined.

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Conflict of interest

The author of the study commissioned the font in question. I have disclosed those interests fully to Primenjena psihologija, as well as the plan for managing any potential conflicts arising from that.

Data availability statement

The dataset is deposited in the online repository:
https://osf.io/x87e2/?view_only=ed270510898e4b5fa908176f4523ff6f.

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Appendix A

Mixed-effect modelling results for local eye movement measures.

	First Fixation Duration				Gaze Duration				Total Viewing Time			
Optimal model	FFD ~ font + group + f + l + p + sect + tr_id + sent_l + w_id + font:f + font:sect + font:w_id + group:f + group:l + group:tr_id + group: w_id + (1 + font | subj) + (1 | sentence_id) + (1 | word)				GZD ~ font + group + f + l + p + sect+ tr_id + w_id + font:f + font:l + font:sect + group:f + group:l + group:tr_id + group:w_id + (1 + font | subj) + (1 | sentence_id) + (1 | word)				TVT ~ font + group + f + l + p + sect + tr_id + w_id + font:f + font:sect + group:f + group:l + group:sect + group:tr_id + group:w_id + (1 + font | subj) + (1 | sentence_id) + (1 | word)			
Predictors	Model estimates				Model estimates				Model estimates			
	b	*SE*	*t*	*p*	*b*	*SE*	*t*	*p*	*b*	*SE*	*t*	*p*
Intercept (Int)	5.470	.015	366.31	**<.001**	5.742	.026	223.76	**<.001**	6.015	.033	182.72	**<.001**
Font	.009	.007	1.35	0.179	-.032	.011	-2.97	**.003**	-.029	.012	-2.38	**.020**
Group	-.129	.027	-4.73	**<.001**	-.314	.046	-6.81	**<.001**	-.325	.059	-5.55	**<.001**
Frequency (f)	-.013	.001	-10.91	**<.001**	-.029	.002	-14.55	**<.001**	-.039	.003	-15.19	**<.001**
Length (l)	-.007	.003	-1.93	.053	.163	.006	27.27	**<.001**	.183	.008	23.78	**<.001**
Predictability (p)	-.016	.003	-6.07	**<.001**	-.036	.004	-8.75	**<.001**	-.054	.005	-11.06	**<.001**
Section (sect)	.016	.006	2.63	**.008**	.011	.008	1.35	.176	.032	.009	3.75	**<.001**
Trial index (tr_id)	-.013	.006	-2.21	**.027**	-.022	.008	-2.79	**.005**	-.067	.009	-7.85	**<.001**
Sentence length (sent_l)	-.007	.003	-2.60	**.010**								
word index (w_id)	.033	.003	10.90	**<.001**	.010	.005	2.15	**.032**	-.014	.005	-2.62	**.009**
font:f	.003	.001	3.35	**.001**	.005	.002	2.52	**.012**	.006	.001	4.64	**<.001**
font:l					-.019	.006	-3.29	**.001**				
font:sect	.010	.004	2.60	**.009**	.020	.005	3.84	**<.001**	.017	.005	3.20	**.001**
font:w_id	.010	.004	2.53	**.011**								
group:f	.006	.001	4.04	**<.001**	.017	.002	9.19	**<.001**	.017	.002	8.95	**<.001**

group:l	.013	.004	2.85	**.004**	-.065	.006	-11.20	**<.001**	-.052	.006	-8.40	**<.001**
group:sect									.052	.017	3.01	**.003**
group: tr_id	-.015	.004	-4.17	**<.001**	-.015	.005	-3.18	**.002**	-.043	.017	-2.53	**.012**
group: w_id	.009	.004	2.29	**.022**	.041	.005	7.58	**<.001**	.046	.006	8.25	**<.001**
Random effects												
	Var	*SD*	*Cor*		*Var*	*SD*	*Cor*		*Var*	*SD*	*Cor*	
Word (int)	.003	.05			.010	.10			.019	.14		
Sentence (int)	<.001	.02			.002	.04			.007	.08		
Subject (int)	.011	.10			.032	.18			.052	.23		
Subject (slope:font)	.002	.04	-.04		.003	.05	.09		.006	.08	-.06	
Residuals	.112	.33			.193	.44			.237	.49		

Note. Significant effects are in bold.

Appendix B

Mixed-effect modelling results for global eye movement measures.

	Total Sentence Reading Time				Total Sentence Number of Fixation				Mean Fixation Duration				Reading rate (wpm)			
Optimal model	TSRT ~ font + group + sect + tr_id + sent_l + font:sect + group:sect + group:tr_id + (1 + font | subj) + (1 | sentence_id)				TSNF ~ font + group + sect + tr_id + sent_l + font:sect + group:sec + (1 + font | subj) + (1 | sentence_id)				MFD ~ font + group + sect + tr_id + group:tr_id + (1 + font | subj) + (1 | sentence_id)				WPM ~ font + group + sect + tr_id + sent_l + font:sect + group:tr_id + group:sec + (1 + font | subj) + (1 | sentence_id)			
Fixed effects																
Predictors	Model estimates				Model estimates				Model estimates				Model estimates			
	b	*SE*	*t*	*p*	*b*	*SE*	*t*	*p*	*b*	*SE*	*t*	*p*	*b*	*SE*	*t*	p
Intercept (int)	8.189	.040	206.27	**<.001**	2.730	.036	76.41	**<.001**	5.459	.013	417.91	**<.001**	5.075	.040	127.87	**<.001**
Font	-.034	.013	-2.71	**.009**	-.065	.011	-6.13	**<.001**	.031	.005	6.40	**<.001**	.034	.013	2.72	**.009**
Group	-.340	.075	-4.52	**<.001**	-.229	.068	-3.37	**.001**	-.107	.026	-4.18	**<.001**	.340	.075	4.52	**<.001**
Section (sect)	.049	.012	4.19	**<.001**	.020	.011	1.82	.069	.027	.005	5.69	**<.001**	-.049	.012	-4.19	**<.001**
Trial index (tr_id)	-.092	.011	-8.01	**<.001**	-.061	.011	-5.55	**<.001**	-.029	.005	-6.24	**<.001**	.092	.011	8.01	**<.001**
Sentence length (sent_l)	.086	.012	7.43	**<.001**	.087	.011	8.16	**<.001**					.063	.012	5.49	**<.001**
font:sect	.018	.007	2.52	**.012**	.017	.007	2.48	**.013**					-.018	.007	-2.51	**.012**
group:sect	.060	.023	2.58	**.010**	.025	.007	3.83	**<.001**					-.060	.023	-2.58	**.010**
group: tr_id	-.051	.023	-2.22	**.026**					-.015	.003	-5.41	**<.001**	.051	.023	2.22	**.026**
Random effects																
	Var	*SD*	*Cor*		*Var*	*SD*	*Cor*		*Var*	*SD*	*Cor*		*Var*	*SD*	*Cor*	
Sentence (int)	.020	.014			.017	.013			<.001	.03			.020	.01		
Subject (int)	.088	.030			.071	.027			.010	.01			.088	.03		

Subject (slope:font)	.008	.09	.013	.005	.07	.06	.001	.03	.09	.008	.09	.013
Residuals	.069	.26		.064	.25		.011	.01		.069	.03	

Note. Significant effects are in bold.

Appendix C

Mixed-effect modelling results for accuracy.

	Accuracy			
	Fixed effects			
Model	Accuracy ~ font + group + (1 | subj) + (1 | sentence_id)			
Predictor	Model estimates			
	b	SE	z	p
Intercept (int)	2.510	.205	12.28	<.001
Font	.180	.118	1.53	.126
Group	.436	.216	2.02	**.043**
Random effects				
	Var	SD		
Sentence (int)	.477	.69		
Subject (int)	1.380	1.76		

Note. Significant effects are in bold. The font effect was preserved during optimal model selection since it is of the main interest to the research.

Efekat ćiriličnog fonta specifičnog za disleksiju, LexiaD, na brzinu čitanja: dalje istraživanje kod adolescenata sa i bez disleksije

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SAŽETAK

Ova studija ima za cilj da testira pretpostavku da specijalno dizajnirani ćirilični font, LexiaD, može pomoći adolescentima sa problemima u čitanju i olakšati njihovo iskustvo čitanja. LexiaD je upoređena sa široko korišćenim fontom Arial. Dve grupe adolescenata sa disleksijom (N = 34) i bez disleksije (N = 28) u tišini su čitale 144 rečenice iz ruskog korpusa rečenica (Laurinavichiute et al., 2019), od kojih su neke predstavljene u LexiaD, a druge u Arialu, dok su im zabeleženi pokreti očiju. LexiaD nije pokazao željeni efekat za adolescente na početku eksperimenta: Arial ga je nadmašio u brzini čitanja u obe grupe učesnika. Font LexiaD pokazao se uspešnijim of fonta Arial, iako se brzina kognitivne obrade višeg nivoa (npr. leksički pristup) u oba fonta nije značajno razlikovala, pokazalo se da je izdvajanje karakteristika bolje u LexiaD nego u Arial. Pronađen je pozitivan efekat LexiaD kada su se učesnici sa i bez disleksije navikli na njega. Da bi se potvrdio ovaj zaključak, potrebna je dodatna studija sa eksplicitnom sesijom izlaganja

Ključne reči: disleksija, font, pokreti očiju, štampani tekst, ruski