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EXPERIMENTAL STUDY OF READING IN DIFFERENT POPULATIONS

Dissertation summary
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Publications

Three publications were selected for the defense. They report three eye-tracking studies of reading in different groups of participants, where several factors affecting reading process are considered. The publications are:

1. Parshina O., Lopukhina A., Sofya Goldina, Ekaterina Iskra, Serebryakova M., Staroverova V., **Zdorova N.,** Dragoy O. Global reading processes in children with high risk of dyslexia: a scanpath analysis. // Annals of Dyslexia. 2022. Vol. 72. No. 3. P. 403-425. https://doi.org/10.1007/s11881-021-00251-z
2. **Zdorova N.,** Malyutina S., Laurinavichyute A., Kaprielova A., Anastasia Zuibanova, Lopukhina A. Do we rely on good-enough processing in reading under auditory and visual noise? // Plos One. 2023. Vol. 18. No. 1. Article e0277429. https://doi.org/10.1371/journal.pone.0277429
3. **Zdorova N.,** Parshina O., Ogly B., Bagirokova I., Krasikova E., Ziubanova A., Unarokova Sh., Makerova S. and Dragoy O. (2023) Eye movement corpora in Adyghe and Russian: an eye-tracking study of sentence reading in bilinguals. // Front. Psychol. 14:1212701. https://doi.org/10.3389/fpsyg.2023.1212701

Nina Zdorova is the first and corresponding author of the two articles mentioned, both of them were published in Q2 journals, which are included in HSE University List A of the high-rank journals. In the article Parshina et al. (2022), published in Q1 journal, Nina Zdorova contributed with the conceptualization, data collection, and took part in the discussion of results.

Conferences

The findings of the study were presented at international scientific conferences listed below.

1. AMLaP 2023: Architectures and Mechanisms of Language Processing (San-Sebastian, Spain, 2023). Poster presentation: Lexical and morphological effects on eye movements while reading a sentence corpus in a polysynthetic language.

2. Cognitive Science in Moscow 2023: New Research (Moscow, Russian, 2023). Poster presentation: Reading scanpaths in Russian-speaking children and adults. [in Russian]
3. Cognitive Science in Moscow 2023: New Research (Moscow, Russian, 2023). Poster presentation: Eye-movement benchmarks while reading in a polysynthetic language in Russian-Adyghe bilinguals. [in Russian]
4. The 36th Annual Conference on Human Sentence Processing (Pittsburgh, USA, online, 2023). Poster presentation: Global reading patterns in Russian-speaking children and adults: a scanpath analysis.
5. Problems of ontolinguistics – 2022: the speech world of a child (universal processes and individual manifestations. (Russia, online, 2022) Oral presentation: Reading development in Russian-speaking primary school students: evidence from an eye-tracking study. [in Russian]
6. 9th Summer Neurolinguistics School 2022 on Experimental Studies of Russia's Ethnic Languages (Moscow, Russia, online, 2022). Oral presentation: Reading in morphologically distinct languages: an eye-tracking study in Russian-Adyghe bilingual children and adults.
7. SRCD 2021 Biennial Meeting (USA, online, 2021). Poster presentation: The Impact of Phonological and Orthographic Processing on Reading Development in Russian Children.

Introduction

Reading is a complex and cognitively loaded process that involves decoding of graphical information, a coordination with its phonological form, lexical access and retrieval, syntactic integration, and finally conceptualization of the written information that brings us to comprehension. Fundamental studies of reading aim to address the mechanisms of reading development, to model a reading process once it becomes a developed and trained skill, and to establish psycholinguistic factors that affect reading.

Reading development undergoes several stages from letter naming and syllabic reading towards holistic word and sentence reading, which is ultimately supposed to embrace both reading fluency and reading comprehension. Years of psycholinguistic behavioral and eye-tracking research reported less fluent, longer and less accurate reading in children with reading difficulties compared to typically developing children (see Barrington, 2019 for review). However, it remains debatable whether atypical reading necessarily implies qualitatively different stages of reading development, or it is rather associated with quantitative delay.

A developed reading skill in adults raises other psycholinguistic questions regarding language processing and reading model. According to the theory of communication, a communication channel is inevitably noisy (Shannon, 1948), where noise is understood very broadly. Under noise, our language processing tends to rely more on semantics rather than on actual syntactic relations (Gibson et al., 2013; Levy 2008, 2011). Simultaneously, a good-enough sentence processing model claims this to be true disregarding noise and proves it on the semantically implausible reading materials (Ferreira 2003; Ferreira et al., 2002). This hypothesis was barely studied in languages other than English and was not tested in light of a noisy-channel (i.e. more naturalistic) approach yet.

Finally, reading mechanisms in adults are believed to share some features like dependence on word frequency and word length across different languages (Inhoff & Rayner, 1986; Rayner, 1998; Staub & Rayner, 2007), but they might also have language-specific differences, like the ones in eye-movement benchmarks (cf. Kliegl

et al., 2004 and Laurinavichyute et al., 2019). A bulk of research addressing reading universalities and language specific features is conducted on the reading materials in well studied languages, and this psycholinguistic knowledge remains anglo-centric. Importantly, no eye-tracking evidence was earlier collected in polysynthetic languages that open a field to test universality and language specificity of reading depending on lexical and morphological features.

The dissertation presents three eye-tracking studies of reading in Sections 1 to 3 correspondingly. Section 1 describes the study into reading development in children (Parshina et al., 2022). Section 2 covers the study into reading model in monolingual adults (Zdorova et al., 2021). Section 3 reports the study into benchmarks of reading in bilingual adults who are literate in typologically different languages (Zdorova et al., 2023). One study applies a classical 2x2 experimental design, and two other studies use a corpus approach that is currently gaining momentum in cross-linguistic eye-tracking research.

The aim of the thesis to establish how age and psycholinguistic features modulate reading mechanisms. The lack of cross-linguistic research in these directions applying both experimental and corpus designs determines the **relevance of the study** that expands fundamental research of reading towards understudied and typologically different languages.

The object of the study is reading as a complex cognitive process. Age and psycholinguistic factors affecting reading compose **the subject of the study.** The study applies eye tracking as a main research method and relies on statistical analysis performed in R (R Core Team, 2020).

The primary **theoretical significance** of the study lies in the expansion of the fundamental eye-tracking research towards less studied and typologically diverse languages. Experimental evidence from these languages enables us to test language specificity of reading models and psycholinguistic factors that are believed to affect reading universally. Moreover, the study on reading development applies a cutting-edge method in eye-tracking data analysis (analysis of scanpaths) that gives us an insight into language processing on a global scale apart from a word level.

The practical significance of the study is threefold. First, reading patterns (scanpaths) described in typically developing children and children with a high risk of dyslexia provide specialists in education and speech-and-language pathology with a deeper understanding of reading mechanisms in dyslexia. This is an essential milestone in dyslexia diagnosis that opens a field for future development of automatized dyslexia diagnostic tools based on eye-movements-while-reading data. Second, the findings from the experimental study of language processing under noise are to be applied in education, marketing, and design, where an impact of external noise (auditory and visual) is to be taken into consideration in order to make a client/customer perceive target information in a more efficient way. Finally, the Adyghe Sentence Corpus (ASC) created within the third study is freely available at the osf platform and can be used by other researchers, educators and students for research and teaching purposes.

The key findings of the study and **the provisions for the defense** are as follows:

1. Reading development undergoes similar qualitative stages in both typically developing children and children with a high risk of dyslexia with the latter having a 3-year quantitative reading delay.
2. Adult native speakers of Russian do rely on good-enough language processing while reading, but this reliance is not modulated by external linguistic noise (either auditory or visual).
3. Reading in a polysynthetic language (Adyghe) does depend on psycholinguistic features being universally claimed as essential ones, however Adyghe-Russian bilinguals can differently rely on those features while reading in a polysynthetic language (Adyghe) and a synthetic language (Russian).

1. Development patterns of typical and atypical reading: evidence from eye movements

The article selected for defense: Parshina et al. (2022)

This study aimed to understand reading patterns of typically developing children and children with dyslexia. Namely, the study investigated whether these groups of children in grades 1-5 differ quantitatively in the basic word-level eye-movement characteristics and global patterns of sentence reading. The study was also addressing the questions of a critical age in the reading development if those differences occur.

A bulk of research over decades reported that children with reading difficulties (including developmental dyslexia, DD) have longer fixations, more regressions, and shorter rightward saccades for the readers with dyslexia (Barrington, 2019 for review, De Luca et al., 2002; Hatzidaki et al., 2010; Hawelka & Wimmer, 2005; Lefton et al., 1979). Moreover, they tend to skip words less and reread them more compared to typically developing peers (De Luca et al., 1999, 2002; Hawelka et al., 2010; Hutzler & Wimmer, 2004).

However, the differences in eye movements while reading seem to disappear if the readers are matched based on their reading fluency (Hyönä & Olson, 1995; Rayner, 1985a, b, 1998). Rayner (1998) suggests that the observed eye-movement differences are in fact the consequences of the delays in reading skill development stemming from the deficit in linguistic processing of the material (cf. Hutzler et al., 2006).

The study was conducted in two groups of children from grades 1 to 5: children with a high risk of dyslexia (N = 72, Mage = 9.47, SD = 1.24) and in the control group of typically developing children (N = 72, Mage = 9.35, SD = 1.14). The children were identified as at high risk of DD or typically developing according to the Standardized Assessment of Reading Skills in Russian (SARS, Kornev, 1997).

Participants read a set of 30 sentences comprising the child version (Korneev et al., 2017) of the Russian Sentence Corpus (Laurinavichyute et al., 2019) and answered comprehension questions to some of them. While children were reading

sentences from a computer screen, their eye movements were recorded with an EyeLink 1000 + or an EyeLink Portable Duo (SR Research) eye tracker, both of a 1000 Hz sampling rate.

Data analysis in R (R Core Team, 2020) included first calculation and comparison of basic eye movement measures (FFD — First Fixation Duration, SFD — Single Fixation Duration, GD — Gaze Duration, TT — Total Time reading, skipping, and regression probabilities) between the two groups. To compare eye movements between groups, we ran a series of (generalized) mixed-effects linear models with each eye-movement measure as an outcome and group, grade, word frequency, word length, and four two-way interactions (group X length, group X frequency, grade X length, and grade X group), as well as the relative position of the word as fixed predictors, with random intercepts for participants, sentences, and words.

Results showed that GD, TT, but not FFD differed between groups: high-risk group fixated on words longer than the control group (all $ps < 0.004$). The grade affected most of the duration measures (FFD, GD, TT): with a higher grade of the participants, all duration measures decreased (all $ps < 0.001$). In SFD, however, the duration decreased with higher grades only in the control group.

We found a significant interaction between the group and the grade on the skipping probability. Namely, while the skipping probability increased from younger to older children in the control group, it plummeted in the group with high-risk of dyslexia ($p = 0.003$). In addition, children in the high-risk group did not skip short words as much as children in the control group ($p < 0.001$).

After the comparison of basic eye-movement measures, we analyzed the common global reading processes that were identified via a scanpath approach. The latter includes plotting and comparing reading patterns based on their dissimilarity scores which was then followed by the cluster analysis (von der Malsburg & Vasishth, 2011). As a result, we identified five global reading processes.

The first fluent reading process is characterized by short fixations (Gaze Duration = 426 ms), some skipping (23%), and very few regressions (14%). The

advanced and upper-intermediate processes resemble the fluent process with the main difference in fixation durations (GD = 585 ms and GD = 716 ms, respectively). The intermediate process is characterized by even longer fixation durations (GD = 808 ms) and more short regressions (22%). The beginner reading process signaled the "global" difficulties in information integration and general comprehension observed in multiple rereadings of the entire sentences (regression probability = 26%, each word was reread on average 3 times, GD = 1004 ms, sentence reading time = 20 s).

The examination of the five global reading processes revealed qualitative similarities in reading patterns between the groups. Children in the control group progressed quickly and by the 4th grade engaged in a fluent reading process. The high-risk group started with the beginner reading process, then similar to first graders in the control group, engaged mostly in the intermediate and upper-intermediate reading processes in 2nd to 4th grades. They reach the advanced process in the 5th grade, the same pattern preferred by the control group second graders.

To summarize, we found that the main difference in word-level measures between groups was the reading speed reflected in fixation durations. The scanpath analysis revealed that despite the quantitative differences in the word-level eye-tracking measures between groups, qualitatively children in the high-risk group read on par with typically developing peers but with a 3-year reading delay.

2. Good-enough language processing while reading under noise

The article selected for defense: Zdorova et al. (2021)

This study tested a good-enough sentence processing model while reading under noise, which is considered an inevitable part of communication flow in a theory of communication (Shannon, 1948). Noise is understood broadly as any disturbance in a communication channel or any additional signal that affects the target information. According to the noisy-channel language model (Levy, 2008; 2011; Gibson et al., 2013), in a presence of noise we tend to rely more on words' semantics instead of parsing a sentence based on its actual syntactic relations.

One of the latest language processing models, a good-enough processing, also states a greater importance of semantics over syntax in a language comprehension process. Namely, according to the good-enough theory (Ferreira 2003; Ferreira et al., 2002; Ferreira & Patson, 2007), the determining factor in language comprehension is a correspondence of a described situation to the life realia and habitual life scenarios (disregarding of noise). The theory states that two parsing mechanisms are being launched simultaneously while processing a sentence input: an algorithmic processing path that is purely based on syntax, and a semantic path that relies on words' meaning. Semantic parsing can be completed earlier if the meaning grasped from the sentence matches our world knowledge.

However, this understanding might not necessarily match the real meaning of a sentence. For instance, the good-enough processing model was tested in semantically implausible passive sentences like *The dog was bitten by the man* (e.g., Ferreira 2003, Ferreira & Stacey, 2000). One third of participants (32%) incorrectly identified the agent of the sentence (Ferreira & Stacey, 2000), endorsing a semantically plausible interpretation instead of the actual syntactically licensed one.

The present study aimed to answer two research questions:

1) Is there a greater reliance on semantics than on syntax while reading Russian sentences, as a good-enough processing model states?

2) Is this reliance on semantics modulated by external noise, in line with the noisy-channel theory?

To answer the research questions, two eye-tracking experiments were conducted. Experiments shared reading materials an procedure with two counterbalanced sessions (noise session and no-noise session), but differed in the type of noise accompanying reading stimuli: Experiment 1 was accompanied with auditory noise, Experiment 2 – with visual noise. We expect that a greater reliance on semantics will be seen in more comprehension errors in semantically implausible sentences disregarding noise.

The noise effect could be two-fold. On the one hand, participants could prioritize speed over comprehension. The fast and superficial reading would result in accuracy decrease across both plausible and implausible conditions. That would be an accelerating main effect of noise on reading time and a detrimental effect of noise on comprehension accuracy. On the other hand, participants might prioritize comprehension over speed and read sentences more slowly to compensate for the increased cognitive load. The slow-down in reading might enable them to succeed in sentence comprehension (which was observed earlier in Cauchard et al., 2012; Hyönä, & Ekholm, 2016; Kemper et al., 2008; Vasilev et al., 2019; Yan et al., 2018).

Reading materials in both experiments consisted of 56 unambiguous Russian sentences, where we manipulated attachment site and semantic plausibility. All experimental sentences were followed by a binary-choice comprehension question targeting the attachment site of the participle. Example of an experimental item is provided below, where sentences (1) and (2) are semantically plausible, and sentences (3) and (4) are semantically implausible. Attachment site is high in (1) and (3) is and low in (2) and (4). It should be mentioned though that the attachment site was not in focus of the analysis, as experimental study by Chernova et al. (2016) has already demonstrated a high attachment preference in Russian, and Lopukhina et al. (2022a) showed that semantic plausibility modulates sentence processing in both, low- and high-attachment sentences while the high-attachment preference is preserved.

(1) *Дима работал с **доктором** президента, **лечащим** маленьких детей.*
Dima worked with **the doctor (Instr, masc)** of the President (Gen, masc), ***who treat-PART* (Instr, masc)** small children.

*Кто лечил маленьких детей? — **Доктор** / Президент*
Who treated small children? — **Doctor** / President

(2) *Дима работал с доктором **президента**, **управляющего** целой страной.*
Dima worked with the doctor (Instr, masc) of **the President (Gen, masc)**, ***who run-PART* (Gen, masc)** an entire country.

*Кто управлял целой страной? — Доктор / **Президент***
Who ran an entire country? — Doctor / **President**

(3) *Дима работал с **доктором** президента, **управляющим** целой страной.*
Dima worked with the **doctor (Instr, masc)** of the President (Gen, masc), ***who run-PART* (Instr, masc)** an entire country.

*Кто управлял целой страной? — **Доктор** / Президент*
Who ran an entire country? — **Doctor** / President

(4) *Дима работал с доктором **президента**, **лечащего** маленьких детей.*
Dima worked with the doctor (Instr, masc) of the **President (Gen, masc)**, ***who treat-PART* (Gen, masc)** small children.

*Кто лечил маленьких детей? — Доктор / **Президент***
Who treated small children? — Doctor / **President**

Reading materials in both experiments consisted of 56 unambiguous Russian sentences, where we manipulated attachment site and semantic plausibility: cf. *Dima worked with the doctor (Instr, masc) of the president (Gen, masc), *who treat-PART* (Instr, masc) small children* (attachment site corresponds to realia) and *Dima worked with the doctor (Instr, masc) of the president (Gen, masc), *who treat-PART* (Gen, masc) small children* (attachment site does not correspond to realia). All experimental sentences were followed by a binary-choice comprehension question targeting the attachment site of the participle.

Apart from experimental sentences, there were 128 filler sentences that differed in their structure, and their questions never targeted the site of participle attachment. The total number of experimental and filler items was equally divided

into two sets to be used alternately in the noise and no-noise session. Each stimuli set contained 28 stimuli and 64 filler sentences, which resulted in four experimental lists according to the Latin square design.

Experiment 1

The total of 71 participants (38 women; Mage = 22 years; SD = 4.9; range 20–40; mean years of education = 14, range 11–20) took part in the Experiment 1. They read sentences from screen, while the movements of their right eye were recorded with an eye tracker EyeLink 1000 Plus. In a noise-session, the reading materials were accompanied with auditory noise – a three-talker babble – that participants were receiving through a headset.

Experiment 2

The total of 70 participants (30 women; aged 20–40; Mage = 23 years; SD = 5.5; mean years of education = 14.5, range 11–22) took part in the Experiment 2 with visual noise. None of them participated in Experiment 1 with auditory noise. The procedure resembled the one in Experiment 1, but the reading materials in a noise-session were accompanied with visual noise. The latter was short Russian phrases and idioms from 2 to 5 words in length that appeared on the screen around experimental sentences for 300–400 ms. From 3 to 4 randomly chosen phrases could appear at random position on the screen around the experimental sentence.

Data analysis in R (R Core Team, 2020) included calculation of response accuracy and three eye-movement measures: First Fixation Duration (FFD), Gaze Duration (GD), and Total reading Time (TT). Eye movement measures were analyzed in two critical regions: the participle and the noun preceding it. The full structure of the model for comprehension accuracy as dependent variable was as follows: accuracy ~ plausibility * noise + (1 + plausibility || unique.item) + (1 + plausibility + noise || subject.id). The full structure of the model for eye-tracking measures as dependent variable was as follows: log(eyetrackingmeasure_AOI) ~ plausibility * noise + plausibility:accuracy + length.centered + frequency.centered + (1 + plausibility + noise || unique.item) + (1 + plausibility + noise || subject.id).

Results of the Experiment 1 (with statistical analysis performed in R, R Core Team, 2020) showed that plausibility decreased comprehension accuracy in implausible sentences ($p < 0.001$), whereas it did not affect fixation durations. Auditory noise did not affect comprehension accuracy, but it increased first fixation durations ($p < 0.001$ in both regions, the participle, and the preceding noun) and decreased gaze durations ($p < 0.001$ in both regions). Probably, participants lengthened their initial fixations to process words more carefully, and as a result, needed less subsequent fixations on a word, which reduced gaze duration. No interaction between plausibility and noise was found, though there was an interaction between plausibility and accuracy in TT in both regions, on the participle ($p = 0.008$) and on the preceding noun ($p < 0.001$). Longer reading times on participles in implausible sentences led to correct responses.

Results of the Experiment 2 demonstrated that plausibility decreased comprehension accuracy in implausible sentences ($p < 0.001$), but it did not affect fixations durations. Visual noise decreased gaze duration and total reading time on the participle (both $ps = 0.015$). Presumably, participants accelerated in task completion to avoid a disturbing visual noise, while they managed to preserve a high comprehension accuracy, as in no-noise condition. No interaction between plausibility and noise was found, though there was an interaction between plausibility and accuracy in TT on the participle ($p = 0.004$) in the same direction, as in Experiment 1.

To summarize, the present study showed evidence for the reliance on good-enough sentence processing (Ferreira et al., 2002; Ferreira & Patson, 2007) during reading in Russian. However, we did not confirm the predictions of noise increasing reliance on semantics. Importantly, auditory and visual noise affected reading differently: in the presence of auditory noise, readers were first distracted and slowed down at the earliest, but they sped up later, whereas under visual noise readers accelerated their processing. We have to acknowledge though that auditory and visual noise were not matched in saliency, and dynamic/ static nature, which does

not enable us to directly distinguish whether the effects of visual and auditory noise differ due to their modality, saliency or static/dynamic nature.

3. Eye-movement benchmarks while reading in a polysynthetic language

The article selected for defense: Zdorova et al. (2023)

The present study expands the eye-tracking-while-reading research towards less studied languages (Adyghe) and languages of different typological classes (polysynthetic Adyghe vs. synthetic Russian) that use a Cyrillic script. Decades of eye-tracking research have already established what psycholinguistic features affect readers' eye movements and, consequently, their language processing. The most robust lexical effects on eye-movements are imposed by word frequency, word length and word predictability (Inhoff & Rayner, 1986; Rayner, 1998; Staub & Rayner, 2007). They were shown to affect both fixation durations and probabilities of skipping. Apart from lexical features, morphological and morphosyntactic ones also affect eye movements across languages.

Having said that, the listed features were primarily studied in Roman and Germanic languages, or in the biggest representatives of some other language brunches like Chinese, Finnish, and Turkish. In this regard, a limited amount of cross-linguistic experimental evidence poses a question regarding universality of those features or their language specificity. To answer that question, reading corpora are currently being used (see The Multilingual Eye-tracking Corpus of eye movements while reading texts (MECO, Siegelman et al., 2022); Potsdam Sentence Corpus (Kliegl et al., 2004); Ghent corpus of bilingual text reading (Sui et al., 2022); Russian Sentence Corpus (RSC, Laurinavichyute et al., 2019); The child version of the Russian Sentence Corpus (ChiRSC, Korneev et al., 2017; Lopukhina et al., 2022b); The Bilingual Russian Sentence Corpus (BiRSC, Parshina et al., 2021) etc.).

Following this line of cross-linguistic research, the present study collected and analyzed reading data of two sentence corpora in a group of 50 bilingual adult speakers of Russian and Adyghe (44 women; Mean age = 32.7, SD = 14.1, range 18–60). The mean education level among participants was 15.1 years, SD = 2.1, range 11–20. Self-reported language use in participants according to their filled LEAP-Q form (Marian et al., 2007) was shared as 58.6% of Adyghe language during

the day and 41.4% of Russian. On a 1-5 scale, participants evaluated their reading skills in Adyghe with 4.0 points and their reading skills in Russian –with 4.0 points.

The materials of the study consisted of two sentence corpora: The Russian Sentence Corpus with 144 sentences (RSC, Laurinavichyute et al., 2019) and The Adyghe Sentence Corpus with 100 sentences (ASC), which was compiled in an analogous way to the RSC. All words in ASC were annotated for parts of speech, word frequency (according to the Adyghe corpus by Arkhangelskiy et al., 2018), word length and included morpheme annotation. To enable an experimental design, the ASC included target words in 8 conditions based on the POS (nouns and verbs), word length (short and long), and word form frequency (low and high). Each condition was represented with 8 target words in the middle of a sentence resulting in 64 sentences with a target word.

While participants were reading two sentence corpora from a laptop screen, their eye movements were recorded with an eye-tracking system EyeLink Portable Duo (SR Research, Canada), with sampling rate of 1,000 Hz. The sequence of corpora presentations was counterbalanced, a short break was made between reading them. Some sentences in both corpora were followed with a comprehension question that participants answered with a mouse click on a binary choice option.

The first part of the data analysis in R (R Core Team, 2020) included regression models (linear models for continuous eye-tracking measures and logistic models for probabilistic measures) to examine the influence of (psycho)linguistic factors and reading skills on eye movements when reading in the Adyghe language. A total of 9 dependent variables were analyzed (First fixation duration FFD, Single fixation duration SFD, First reading time GD, Total reading time TT, probability of skipping the word P0, probability of single fixation on the word P1, probability of more than two fixations P2+, probability of regression from the word RO, and probability of regression to the word RG) along with a number of independent variables (word length and frequency, part-of speech class, length and frequency of the preceding and following words, relative position of the word in the sentence, number of lexical affixes, landing position, and the level of reading skill in Adyghe).

Such models were constructed for two datasets: for all words in the Adyghe sentence corpus of and for target words.

The results for all-words analysis showed a significant effect of word length and frequency on several eye movement measures (GD, TT, P1, P2+, RG). However, the significant effect of word frequency in the analysis of target words was preserved only in total reading time (TT). We assume that these results might be due to a common linguistic dilemma of defining a word in polysynthetic languages (not graphically, but morpho-syntactically) raised earlier by Haspelmath (2018). Hence, a shift from word from frequency towards morpheme and/or bigram frequency might be suggested for further eye-tracking studies of reading in a polysynthetic language.

Longer previous words in Adyghe accelerated the total reading time of a current word (TT), whereas longer upcoming words did not show any effect. Adyghe verbs were read significantly slower than nouns (in TT), whereas other POS did not differ significantly from verb reading. Lexical affixes increased reading time.

The second part of the data analysis in R focused on investigating reading in two languages (Russian and Adyghe). The descriptive statistics of eye movement measures during reading in Adyghe-Russian bilinguals are characterized by longer fixations and lower skipping rate when reading in Adyghe compared to reading in Russian. When reading in Adyghe, participants tend to land closer to the beginning of the word (within the first 31% of word letters), whereas when reading in Russian, they land closer to the center of the word (within the first 48% of the word letters).

Main effects of various (psycho)linguistic parameters on reading in both languages and their interactions with the language involved regression models similar to those in the first part of the analysis. However, these models were fit on a combined dataset from reading both the Adyghe and Russian corpora, where the language of reading was included as a factor (which was significant in 8 out of 9 measures). Significant main effects of word length and frequency were observed in a number of eye movement measures (FFD, SFD, GD, TT, P0, P2+). However, significant interactions of these parameters with the language were found only in P2+ and RO for frequency and in GD, TT, P1, and P2+ for length. A significant

interaction between language and the characteristics of neighboring words (frequency and length) was observed only for the length of the preceding word (TT). This suggests that Adyghe-Russian bilinguals rely differently on information about neighboring words when reading in Russian and Adyghe.

To summarize, we confirmed word frequency and word length effects on eye movements while reading in a polysynthetic language, though it does question a necessity to rely on word frequency measure instead of bigram or morpheme frequency. We also confirmed morphological effects in Adyghe reading (part-of speech class and the number of lexical affixes) that were previously shown in some morphologically rich languages. Importantly, we demonstrated both similarities and differences between reading in synthetic Russian and polysynthetic Adyghe in Adyghe-Russian bilinguals.

Conclusions

The studies presented in this dissertation addressed fundamental questions related to the complex cognitive process of reading. Through eye-tracking studies in children, monolingual adults, and bilingual adults literate in typologically different languages, the study expands our understanding of reading mechanisms in less studied languages. The findings highlight the importance of age and psycholinguistic factors in modulating reading processes.

The study in Section 1 demonstrated that reading development undergoes qualitatively similar stages in typically developing children and those at a high risk of dyslexia. However, a quantitative difference in reading development of those groups is preserved. Typical development encompasses a quite fast change from a beginner reading pattern to the fluent once, whereas children at risk of dyslexia manage to make that shift with a 3-years delay.

The study in Section 2 contributed evidence in favor of good-enough language processing model and showed that native adult speakers of Russian do rely on semantics more than on syntax while reading. Nevertheless, we were unable to verify the predictions that an increase in external noise would result in a greater dependence on semantics. It is noteworthy that the impact of auditory and visual noise on reading varied: when faced with auditory noise, readers were initially distracted and slowed down, but then increased their speed; on the other hand, when faced with visual noise, readers sped up their processing.

The study in Section 3 established eye-movement benchmarks of reading in a polysynthetic language (Adyghe) and described reading mechanisms in bilinguals literate in two languages. We validated the well-documented lexical and morphological effects on eye movements in Adyghe-Russian bilinguals for both languages. Furthermore, we highlighted that the reading behavior of bilinguals in Adyghe differs in both quantity (language effects on reading times) and quality (distinct effects of landing and previous/upcoming words on eye movements within a current word) from their reading behavior in Russian.

Overall, the findings of the dissertation contribute to our understanding of reading universalities and language specificity, highlighting the importance of further research in this area in understudied languages. The theoretical significance of the study lies in its expansion of fundamental research towards typologically diverse languages with less studied scripts and orthographies. The practical significance of the study includes implications for dyslexia diagnosis, education, marketing, and design, as well as the creation of a freely available Adyghe Sentence Corpus for research and teaching purposes.

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