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LINGUISTIC DEFICIT AND DEVELOPMENTAL DYSLEXIA: AN EXPERIMENTAL STUDY OF RUSSIAN-SPEAKING CHILDREN

Dissertation Summary
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Doctor of Philosophy in Philology and Linguistics

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Olga Dragoy, Candidate of Sciences

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Publications

Four publications were selected for the defense:

1. Dorofeeva, S. V. Lingvisticheskie aspekty korrekcii disleksii i disgrafii: Opyt uspeshnogo primeneniya kompleksnogo podhoda. [Linguistic aspects of the treatment of developmental dyslexia and dysgraphia: Case study of the successful application of the complex approach] // Voprosy psiholingvistiki [Questions of psycholinguistics], №3, 2017. P. 185–201.
2. Dorofeeva, S. V., Reshetnikova, V., Serebryakova, M., Goranskaya, D., Akhutina, T. V., & Dragoy, O. Assessing the Validity of the Standardized Assessment of Reading Skills in Russian and Verifying the Relevance of Available Normative Data // The Russian Journal of Cognitive Science, 6(1), 2019. P. 4–24.
3. Tomas, E., Dorofeeva, S. Mean Length of Utterance and Other Quantitative Measures of Spontaneous Speech in Russian-Speaking Children // Journal of Speech, Language, and Hearing Research, Vol. 62, 2019. P. 4483–4496. DOI 10.1044/2019_JSLHR-L-18-0339.
4. Dorofeeva, S. V., Laurinavichyute, A., Reshetnikova, V., Akhutina, T. V., Tops, W., & Dragoy, O. Complex Phonological Tasks Predict Reading in 7 to 11 Years of Age Typically Developing Russian Children // Journal of Research in Reading (published online as Early View). DOI 10.1111/1467-9817.12327.

The results of the present study have also been presented in the following papers:

5. Dorofeeva, S. V. Disleksiya i problema Platona-Homskogo [Dyslexia and the problem of Platon-Chomsky] // Vestnik Moskovskogo universiteta. Seriya 9: Filologiya [Bulletin of the Moscow University. Series 9: Philology], № 5, 2017. P. 189–196.
6. Dorofeeva, S. V. Korrekciya disleksii i disgrafii. Opyt uspeshnogo primeneniya kompleksnogo podhoda [Treatment of dyslexia and dysgraphia. Case study with the successful application of the comprehensive approach] // V kn.: Vysshaya shkola: opyt, problemy, perspektivy. Materialy X Mezhdunarodnoj nauchno-prakticheskoj konferencii. Izdatel'stvo RUDN [In the book: Higher school: experience, problems, prospects. Materials of the X International Scientific and Practical Conference.: Publishing House of RUDN], 2017. P. 135–139.
7. Dorofeeva, S. V., Reshetnikova, V. A., Zyryanov, A. S., Goranskaya, D. N., Gordeeva, E. A, Serebryakova, M. N., Akhutina, T. V., Dragoy, O. V. Batareya testov dlya vyyavleniya osobennostej fonologicheskoj obrabotki u russkoyazychnyh detej: dannye normy i

gruppy detej s disleksiej [Battery of the tests for revealing features of phonological processing in Russian-speaking children: the results of typically developing and dyslexic children]// V kn.: Vos'maya mezhdunarodnaya konferenciya po kognitivnoj nauke: tezisy dokladov. M.: Institut psihologii RAN [In the book: Eighth International Conference on Cognitive Science: Abstracts. M.: Institute of Psychology RAS], 2018. P. 331–333.

8. Dorofeeva, S. V., Reshetnikova, V. A., Laurinavichyute, A. K., Akhutina, T. V., Dragoy, O. V. Issledovanie vzaimosvyazi navykov fonematicheskoj obrabotki i navykov chteniya [A study of the relationship between phonological processing and reading skills]// V knige.: Kognitivnaya nauka v Moskve: novye issledovaniya. Materialy konferencii 19 iyunya 2019. / Pod obshch. red.: Pechenkova, E.V., Falikman, M.V. M.: Buki Vedi [In: Cognitive Science in Moscow: New Research. Conference proceedings, June 19, 2019 / Ed.: Pechenkova, E. V., Falikman, M. V. M.: Buki Vedi], 2019. P. 151–156.

9. Dorofeeva, S. Izuchenie i diagnostika lingvisticheskogo deficita pri disleksii. [The investigation and the diagnosis of the linguistic deficit in developmental dyslexia] // Sbornik tezisov uchastnikov tret'ej Mezhdunarodnoj nauchnoj konferencii «Nauka budushchego» i chetvyortogo Vserossijskogo molodyozhnogo nauchnogo foruma «Nauka budushchego – nauka molodyh», Sochi [Abstracts of the Third International Scientific Conference "Science of the Future" and the fourth Russian Youth Scientific Forum "Science of the Future - Science of the Young", Sochi], 2019. P. 158–159.

Conference presentations and public demonstrations of the results

The main results and conclusions of the present study have been presented in 2017–2020 in oral and poster presentations at international conferences, including:

- International Symposium of Psycholinguistics (2019);
- International Workshop on Reading and Developmental Dyslexia (IWORDD) (2019);
- 3rd Summer School “Infant Studies on Language Development in Europe” (ISOLDE) (2018);
- Workshop on Reading, Language and Deafness (WoRLD) (2018);
- Workshop on Infant Language Development (WILD) (2017);
- Conference “Cognitive Science in Moscow” (2019);
- The Third International Scientific Conference “Science of the Future” and the fourth Russian Forum “Science of the Future - Science of the Young” (organized by the Ministry of Science and Higher Education of the Russian Federation) (2019);
- HSE April International Conference (2018);
- International Conference on Cognitive Science (2018).

1. Introduction

The papers included in this dissertation are united by the topic of applying linguistic methods to investigate linguistic deficit leading to developmental dyslexia (specific reading impairment) in children. We considered the problems of treatment of developmental dyslexia using a linguistically based approach, as well as the validity of the existing standardised test for diagnosing this disorder, and the investigation of linguistic deficit as one of the factors that can lead to developmental dyslexia. The published articles show how the theory of language makes it possible to structure and supplement the traditional Russian approaches to the investigation of reading impairment mechanisms.

The investigation of dyslexia mechanisms is an actual challenge, caused, among others, by the growing demand of society for the results of such studies – improving the instruments for diagnosing dyslexia, as well as increasing the effectiveness of treatment methods. In the Russian language, for a long period, the main amount of dyslexia studies was conducted in the framework of neuropsychology (Akhutina et al., 2016; Semenovich, 2008), clinical pathopsychology (Kornev, 2003, 2006), speech therapy and correctional pedagogics (Bezrukikh, 2009; Rusetskaya 2007). However, although the linguistic deficit (for which different authors use the terms speech / language/ speech-language / auditory / phonological deficit, etc.) is acknowledged by researchers as one of the key factors in developmental dyslexia (Rusetskaya, 2007; Volkova & Shakhovskaya, 1998; Ramus et al., 2013; Torgesen et al., 1994), insufficient attention to this problem from linguists delayed the development of Russian investigations in this direction to a certain extent.

With the shortage of a sufficient linguistic basis in the studies of speech and language disorders leading to developmental dyslexia in Russian, important aspects were ignored, such as taking into account psycholinguistic parameters when selecting stimuli for research, diagnostic tests, or methodological materials for intervention programs. *The relevance* of this dissertation is due to the current shortage of the use of linguistic methods to the studies of developmental dyslexia, which precludes the use of contemporary achievements of psycho- and neurolinguistics in the studies of the mechanisms of reading impairments in Russian-speaking children. *The scientific novelty* of the study consists in the fact that the mechanisms of linguistic deficits in developmental dyslexia in Russian were thoroughly studied using linguistic analysis. In particular, the process of reading and writing intervention was constructed and described using a knowledge of the level structure of the language. To the best of our knowledge, this is the first attempt at such research.

The central goal of this study was to show that linguistic knowledge can advance the research on the developmental dyslexia mechanisms, and that studies focused on the linguistic deficit in dyslexia can supplement the current understanding of language system development in children, in particular the understanding of the stages of phonological skills acquisition. This corresponds to the general trend in linguistics and neurolinguistics of recent years for interdisciplinary research on speech disorders of various etiologies.

In addition, we developed and standardized a Russian phonological test battery (Dorofeeva et al., 2018), which includes seven tests of different levels of linguistic complexity. The items of these tests were selected, taking into account a number of psycholinguistic parameters (such as the length and frequency of words, age of acquisition of words, etc.). This phonological battery made it possible to conduct a study of the relationship between phonological processing and reading in Russian-speaking primary school children, and to obtain experimental data showing how the level of complexity (measured as the number of linguistic processes involved in a particular phonological test) affects the relationship between phonological processing and reading that researchers can reveal.

The theoretical significance of the research:

- The study showed the essential positive effect of applying a linguistically based approach to the reading and writing intervention program (especially regarding speech and language deficit in developmental dyslexia);
- We experimentally confirmed that it is necessary to use relevant (actual) normative data when applying a standardized test for assessing reading skills to diagnose developmental dyslexia;
- We experimentally investigated the relationship between the phonological processing and reading skills in Russian;
- We explored, how the level of complexity of phonological tests affects the ability of these tests to predict reading skills;
- We contributed to the development of instruments for the early diagnosis of linguistic deficit through the investigation of methodological and theoretical aspects of using mean length of utterance as a method for the early assessment of spontaneous speech in preschool Russian-speaking children.

The practical significance of the study:

- The diagnostic validity of the only Russian Standardized Assessment of Reading Skills (SARS) (Kornev, Ishimova, 2010) was explored, and new, relevant, control levels for reading

skills were obtained. We showed that these new control levels help to increase the sensitivity of SARS;

- A diagnostic instrument for assessing phonological processing skills in Russian children was developed and programmed as an application for the Android tablet;

- The educational program “Dyslexia and Dysgraphia: The neurolinguistic approach”, was developed for bachelor students of the HSE School of Linguistics (the program was tested for two years).

2. The application of a complex linguistically based approach to the treatment of developmental dyslexia (case study)

Article selected for the defense: [Dorofeeva S. V., 2017].

The most important goal of developmental dyslexia investigations is to develop treatment methods for this disorder and to verify their effectiveness. The first article selected for the defense describes a case study of treating a reading and writing disorder in a Russian-speaking child, who at the time of the intervention program was 10 years old. In this paper, we described how linguistic knowledge can help to structure the intervention program in case of a linguistic deficit leading to reading and writing impairment.

From the point of view of Russian traditional psychological and pedagogical classifications (Lalaeva, 2002), the signs of phonological, visual, agrammatic dyslexia, and dysgraphia could be detected in a child undergoing the intervention program. A strong association was noted between the quality of reading and writing, and the psychophysiological condition (Akhutina, 2001). A detailed examination of psychological aspects is essential, but goes beyond the linguistics and this thesis (for more details see Dorofeeva, 2017). A sample of the child's written work prior to treatment is shown in Figure 1.

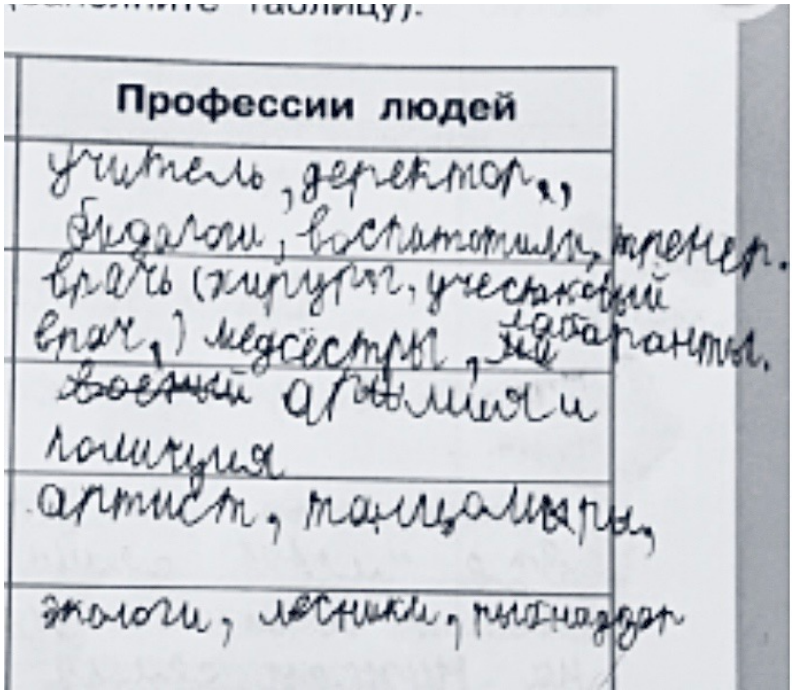


Figure 1. A sample of the child's written work prior to treatment at the beginning of the 4th grade

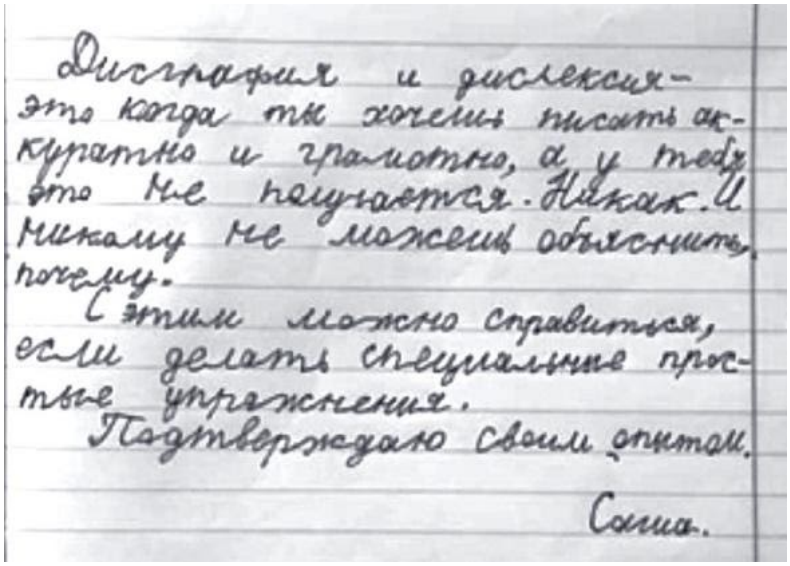
We analysed the errors of the child from the point of view of the theory of language: from units of the micro level (phonemes and graphemes), to units of the macro level (text, discourse). Some errors were found, indicating difficulties with phonological processing, as well as errors indicating a lack understanding of the morphological level and the insufficiency of paradigmatic and syntagmatic representations. No semantic impairment was detected, and no impairment of verbal memory was revealed. At the discourse level, the child had a good comprehension of oral speech, however, the speech production was limited – the child used the minimum number of sentences and simple constructions.

An intensive remediation program lasted three weeks. Classes were held every day from 8 am to 8 pm, every hour for 3, 5 or 7 minutes. The principle of separate training of individual skills was used (exercises of one type were done every hour) and exercises were selected in the zone of proximal development. The focus of the linguistic deficit correction program was to provide an adequate amount of experience for the development of language representations of each language level, through special exercises.

The phonological level presumes the understanding and acquiring of meaning-distinguishing functions of phonemes. For training at this level, we used a task to select a word with replacing one phoneme with another, differentiated by one acoustic feature (ball game with the code name "bochka-pochka", for more details see Dorofeeva, 2017). This exercise, despite its apparent simplicity and play form, involves a large number of linguistic processes and leads to the development of advanced phonological skills, which, as shown by Kilpatrik (2015), is one of the key components of effective reading intervention programs. We also trained the ability to distinguish graphemes using two exercises: the "spy" and the "three words". Exercise "spy" is focused on finding and highlighting certain graphemes with specific colors. The "three words" exercise is focused on developing attention to units of different levels. First, the child was asked to connect with an arrow, pairs of identical words (three pairs), and then inside these words to color certain letters with specific colors.

In the first week, we trained only basic skills and in the second week we switched to the morphological and paradigmatic representations. In the "three words" game, the child had to color not individual letters, but the given fragments corresponding to morphemes. Ball games included tasks for declension of nouns by cases, and later, the conjugation of verbs. At the end of the second week, we included the most difficult exercise in this stage: rewriting one short sentence. Each sentence was analyzed before rewriting, using, according to the terminology of Lalaeva, "the principle of maximum support of multimodal afferentations" (Lalaeva, 2002).

In the third week, we increased the length and complexity of the texts for writing, and trained syntagmatic representations. We trained the use of words in phrases, analysed the sentences, starting with simple variants. On the same days, but at different times, we continued to carry out exercises for phonemes and graphemes discrimination to consolidate the corresponding skills. By the end of the third week, significant progress was observed (see Figure 2). In the fourth week, the child came back to school.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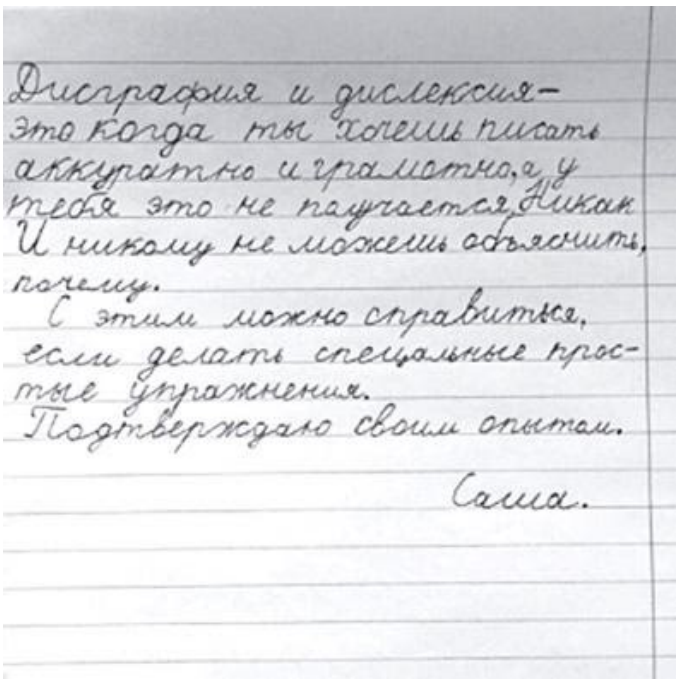
никому не можешь объяснить,
почему.
С этим можно справиться,
если делать специальные прос-
тые упражнения.
Подтверждаю своим опытом.
Саша.

Figure 2. Sample of written work immediately after an intensive intervention course. 4th grade

For several months, additional to the school classes, we continued daily supporting classes aimed at reinforcing reading and writing skills. Later lessons became less frequent, but during one year we monitored the dynamics and, if necessary, repeated the exercises. A year later, the same child could rewrite a small text successfully (see Figure 3). In addition, in the 5th grade, he fully adapted to school life, which is difficult for children with dyslexia in the absence of adequate treatment [Daniel et al., 2006].



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Подтверждаю своим опытом.

Саша.

Figure 8. A sample of written work, a year after an intensive intervention course, 5th grade

This work emphasizes that to improve the treatment methods of linguistic deficit in developmental dyslexia, interdisciplinary studies are required, involving not only educators, physiologists and neuropsychologists, but also linguists, because knowledge of the levels and modalities of the language is useful for developing intervention programs.

3. Assessing the validity of the Standardized assessment of reading skills in Russian, and verifying the relevance of available normative data

Article selected for the defense: [Dorofeeva et al. 2019]

One of the actual problems for dyslexia studies in Russian is the shortage of standardised instruments for diagnosing dyslexia and its type corresponding to the underlying cognitive deficit. Standardised tests are necessary for reliable (with reproducible and stable results), and valid (allowing to make reliable conclusions) quantitative assessment of reading abilities. Standardised reading tests have been developed for languages such as Dutch (Brus & Voeten, 1973; van den Bos et al., 1994), German (Moll & Landerl, 2010; Wimmer & Mayringer, 2014), and English (Torgesen et al., 1999; Wechsler, 1990; Woodcock, 1999).

At the time this study was conducted, the only Standardized Assessment of Reading Skills (SARS) available was for the Russian language (Kornev & Ishimova, 2010). Despite a number of obvious advantages, SARS has some limitations (for more details see Dorofeeva et al., 2019). The second article selected for the defense describes the results of our study aimed at overcoming the current limitations of the SARS and improving the possibilities of its clinical use.

According to the original guidelines of SARS, reading fluency was measured as the number of words read correctly in one minute, and reading comprehension was measured as the number of correct answers to the questions to the texts. We used the first halves of Text I and Text II ("How I caught a crayfish" and "Ungrateful spruce") which were recommended by the authors for primary diagnosis, and questions relating to these texts. The first text was more simple, the second text was more difficult according to the authors of the methodology (Kornev & Ishimova, 2010: 13). To quantify the level of difficulty of Text I and Text II, we analysed the words included in terms of frequency (in instances per million, using the StimulStat Project database (Alexeeva et al., 2018)) and length (in syllables and in letters). The results of the analysis showed that Text I includes higher-frequency words, and Text II includes longer words.

To verify the relevance of the available normative data, we collected new data on SARS by testing typically developing Russian-speaking children who did not have diagnosed neurological impairment. The analysis included 90 children (48 girls; 7 left-handed; mean age = 8.7 years, SD = 1.13) with measured, typically developing nonverbal intelligence and normal hearing, as well as with normal or corrected to normal vision. As a result, we have published (Dorofeeva et al., 2019) new data on reading fluency and reading comprehension for each of the primary school grades.

In addition, we examined the validity of SARS for the diagnosis of developmental dyslexia. To do this, we tested 50 children who were clinically diagnosed with dyslexia, and analysed the correspondence between the clinical diagnosis and the reading performance of these children according to SARS, using the original normative data given in the latest published test guide (Kornev & Ishimova, 2010) and our new data for this test. All participants with dyslexia (N = 50, 17 girls; 1 lefthander; mean age = 8.9 years, SD = 1.2) were native Russian speakers, primary school students with normal hearing, vision, and non-verbal intelligence (Raven, 2004).

To assess the specificity of the test, we analysed what percentage of participants without dyslexia would fall into the typically developing group based on SARS. According to the results of this analysis, the specificity of SARS can be estimated as 100%. We also checked how the specificity of the test would change when using diagnostic criteria based on our new data. Of the 90 children, results of 5 children would fall into the dyslexia group, which would reduce the specificity of the test from 100% to 94.4%.

To assess the sensitivity of the test, we analysed what percentage of children with clinically diagnosed dyslexia would fall into the dyslexia group based on SARS. Using the normative data published by the authors in 2010 and Text I, the test sensitivity was 36.6%, while using Text II – 39.0%. When using our new cutoff levels and Text I, the test sensitivity was 72.0%, while using Text II – 60.0%. In addition, we checked how the sensitivity of SARS would change if, in addition to reading fluency, reading comprehension would be assessed. When using Text I, the sensitivity of the reading comprehension test was 20%, while using Text II – 38%.

The low sensitivity of SARS was associated with the fact that 14 children (i.e., 28% of our tested cohort of children with clinically diagnosed dyslexia) were within the normative range by both criteria of SARS. We performed an additional analysis in search of an explanation of this fact. For that, we listened again to the audio recordings of children's reading, and weighted the types of errors using a system of penalty points developed by us (for more details see Dorofeeva et al., 2019).

We found that for each of those 14 children, a weighted error score for at least one of the texts was more than 1.5 standard deviations higher than the average values for the corresponding class in a group of typically developing children. In other words, these children read fluently, but with a large number of errors of greater weight, and this impairment of the quality of reading, rather than fluency, went unnoticed when using the original criteria of SARS. Applying this new criterion, when using Text I, the sensitivity of SARS was 64%, and when using Text II it was 77.5%.

Thus, the relatively low sensitivity of SARS is the result of using only one (albeit the most important) diagnostic criterion – the speed of decoding. However, the three aforementioned deficits (slow reading, numerous major errors while reading and poor comprehension of what is read) may occur in children with dyslexia, both in isolation and in combination. Therefore, we propose the use of two, or preferably three, criteria for diagnostic purposes, since none of the criteria separately provides a test sensitivity close to 100%. In addition, screening of non-verbal intellectual abilities, vision and hearing, should accompany reading abilities testing, otherwise non-specific reading disorders may be erroneously attributed to dyslexia, while the problem may be caused by another concomitant impairment (Snowling et al., 2019).

Our study confirms that standardized tests for diagnostic purposes should be used with actual normative data, because normative performance may change over time (Raven, 2000).

4. Exploring the relationship between the phonological processing and reading skills in Russian

Article selected for the defense: [Dorofeeva et al., 2020 (published online as Early View)].

In addition to standardised tests for assessing reading skills for the correct diagnosis of developmental dyslexia, standardised tests are also needed for assessing the main types of cognitive deficits leading to reading impairment. One type of the linguistic deficit associated with developmental dyslexia is a deficit in phonological processing (Berninger et al., 1987; Del Campo et al., 2015; Hogan et al., 2005; Wagner & Torgesen, 1987). The aim of the third study included in this dissertation was to investigate, in Russian, the role of phonological processing in reading. In particular, we studied whether the general level of complexity of phonological tests can be a significant predictor of reading fluency and reading comprehension.

The well-known theoretical model of phonological processing (Wagner et al., 1994) distinguishes three main components: phonological awareness, phonological memory, and rapid automatized naming. Despite the growing consensus among researchers that each of these components contributes to reading (Sunseth & Bowers, 2002; Torgesen et al., 1994), it remains unclear which phonological tests are better suited for research in this area (Georgiou et al., 2008; Parrila et al., 2004; Kilpatrick, 2012).

The hypothesis that the linguistic complexity of the task used for the phonological test affects the ability of this test to predict reading skills has never been experimentally tested. To fill this gap, we developed a Russian battery of tests, which consists of seven phonological tests, varying in linguistic complexity, and used it in our study of reading in Russian-speaking children. The Russian version of the title for this test is ZARYA, which means 'Zvukovoj Analiz Russkogo YAzyka' [Sound Analysis of the Russian Language] (Dorofeeva et al., 2018), the English version of the title is RuToPP, which means 'Russian Test of Phonological Processing'.

The developed tests include between 24 and 42 items. All audio stimuli were pre-recorded by a professional speaker, and the test battery was programmed as an application for a tablet on the Android platform. Together, this provides the possibility of a standardized presentation of all items to different children undergoing testing (for details on the phonological tests, see Dorofeeva et al., 2020).

We conducted a study of the relationship between the phonological processing and reading skills in typically developing Russian-speaking children. Study participants were native Russian speakers from 7 to 11 years of age, and had no problems with reading acquisition. All had normal or corrected to normal vision, normal hearing, and measured intact nonverbal intelligence. Reading

fluency and reading comprehension were assessed using SARS (Kornev & Ishimova, 2010). Phonological skills were assessed using our seven phonological tests.

We expected that children would make more mistakes in more complex phonological tests, and we found that this was indeed the case. In addition, we expected that the performance in the most complex phonological tests would be most strongly associated with the results of the reading skills assessment. To check this, for each child we extracted an individual estimate of the decrease in accuracy associated with the introduction of one additional linguistic process in the phonological test, and analysed whether these individual estimates were associated with reading fluency and reading.

We found that the higher cost of processing one additional linguistic process in the phonological test was significantly associated with a decrease in reading fluency. This result is in agreement with the conclusions made by Kilpatrick (2012), who had shown that a (more complex) test for phonological manipulation predicts reading skills better than a (less complex) test for phonological segmentation. This also explains the varying degree of correlation between reading fluency and different tasks focused on the same traditionally distinguished component of phonological processing (Del Campo et al., 2015; Law et al., 2014; Ramus et al., 2003).

The study and the developed diagnostic instrument may have value both for future studies on the reading impairment mechanisms and for the diagnosis of phonological deficit in Russian dyslexic children, as well as for the development of intervention programs for reading disorders caused by phonological deficit. For research and diagnostic purposes, the developed phonological test battery is useful because phonological tests, constructed taking into account the underlying linguistic processes, can help to reveal the specific locus of deficit in developmental dyslexia caused by phonological impairment. To improve intervention programs, the study is important because it experimentally confirmed the association between advanced phonological skills and reading speed (see also a study on the effectiveness of various reading intervention programs (Kilpatrick 2015)).

5. Mean length of utterance as a method of early assessment of speech development

Article selected for the defense: [Tomas & Dorofeeva, 2019].

In addition to phonological, other linguistic deficits can lead to the developmental dyslexia and other learning difficulties in children: morphological processing deficit, difficulties in acquiring the lexical-semantic processing skills, as well as in acquiring the ability of processing syntactic structures (Deacon et al., 2018; Torkildsen et al., 2007). Moreover, of great practical importance

is the possibility to detect such deficit in children at the earliest possible age. Therefore, the urgent challenge is to develop instruments for reliable and valid assessment of the linguistic abilities of Russian-speaking children of preschool age, and this challenge is being gradually solved. Thus, the KORABLIK test (Clinical Assessment of the Basic Linguistic Competencies (Lopuhina et al., 2019)) was developed at the Center for Language and Brain of the Higher School of Economics. We also contributed to the elaboration of early diagnostic methods for detecting linguistic deficit in preschool age, and studied, in Russian, one of the widely used methods for the early assessment of spontaneous speech in children – the mean length of utterance (MLU).

The mean length of utterance (MLU) is traditionally calculated as the average number of words (MLUw) or morphemes (MLUm) per utterance based on a sample of 75–150 contiguous and fully intelligible utterances (Brown, 1973; Casby, 2011; Guo & Eisenberg, 2015; Miller, 1981; Paul, 2007). The idea of using MLU in morphemes to measure the child's morphosyntactic skills has been introduces by Brown (1973), who demonstrated that grammatical morphemes tend to be acquired by a certain biological age and in a specific order, and that the average number of morphemes in an utterance increases with age.

It was shown that MLUm does not correspond directly to the biological age of children (it gives only a rough estimation) due to its high individual variability (de Villiers & de Villiers, 1973), but remains a valuable tool when working with clinical and other atypical population of children (Rodina, 2017; Yip & Matthews, 2006; Rice et al., 2006). The spontaneous speech used in the MLU calculation has greater ecological validity compared to standardized tests, and this is its important advantage as a screening tool. Our fourth article describes the results of a study of quantitative methods for assessing spontaneous speech in Russian-speaking children.

In this study, we collected audio recordings of spontaneous speech samples from 27 children aged 2;9 to 5;7 (years; months) in individual play sessions. The total duration of each session varied from 20 to 30 minutes. During sessions with children, researchers avoided closed questions and discussed topics related to the daily activities of children, aiming to ask all children the same type of questions. Data was transcribed from audio using Audacity program, version 2.1.2 (Audacity Team, 2017). In unclear cases, children's production recordings were revised in the Praat program (Boersma & Weenink, 2014). In cases where the spectrograms and waveforms were not sufficiently informative, the utterances were replaced by other utterances of the same child from the audio recording.

For each participant, we decoded the first 100 complete utterances. For each utterance, we calculated the number of words (MLUw), syllables (MLUs), the total number of morphemes (MLUm), as well as the number of derivational (MLUder) and inflectional (MLUinf) morphemes

separately. Morphemes were calculated manually, since there were no morpheme parsers for the Russian publicly available online at the time the study was conducted. The morphemic analysis of individual words was based on the Dictionary of Derivational Morphology of the Russian Language (Tikhonov, 1985). For each participant, we also calculated the average number of unique grammatical forms produced (AvUniqF).

The combination of Pearson correlation analysis and Blend-Altman difference plots allowed us to establish that, based on our data, the MLU might be appropriate for estimating language abilities in Russian-speaking children under the age of 3 years. This is precisely the age when speech abilities in children are already present and can be assessed, but it is still difficult to use standardized tests, since not all children at this age understand specific tasks and can perform them for a sufficiently long period of time, so assessment of spontaneous speech is preferred. In older children (up to 5;7 years), we observed increasing variability around the MLU scores, this suggests that, at this stage, the utterance length is less constrained by children's grammatical knowledge and depends more heavily on the conversational context. At the same time, the average number of unique grammatical forms remains a sensitive indicator for linguistic capabilities even in children over three and a half years of age. In addition, we showed that the classical approach to calculating morphemes can be replaced by counting syllables, since these metrics show consistent results.

6. Conclusions

The articles included in this dissertation present various studies of methods for assessment and treatment of linguistic deficit leading to developmental dyslexia in Russian-speaking children. The experience of applying a linguistically based approach to the reading and writing intervention program was considered, and the developed standardised phonological processing test for Russian was presented.

The study selected for Chapter 2 demonstrates how the theory of language can support the development of a linguistic deficit correction program. The work emphasizes that for further evolution and improvement of research methods for dyslexia studies, an interdisciplinary approach and the participation of specialists of different fields are important: speech therapists, physiologists, and neuropsychologists should cooperate with linguists, since knowledge of the levels and modalities of the language is the competence of linguists.

Chapter 3 describes the study which assessed the validity of the Russian Standardized Assessment of Reading Skills (SARS) (Kornev & Ishimova, 2010) for the diagnosis of developmental dyslexia in Russian-speaking children. This paper presents relevant (new) control levels for assessing the reading speed and reading comprehension in children using SARS and describes how the diagnostic validity of this methodology can be improved with the introduction of an additional criterion developed by us: a weighted error score.

The study selected for Chapter 4 presents the revealed, and for the first time experimentally confirmed pattern: with an increase in the number of linguistic processes involved in phonological tests, the predictive power of these tests for reading performance increases. This research was possible due to the Russian phonological test that we have developed (Dorofeeva et al., 2018). This test allows the analysis of the features of phonological processing in Russian-speaking children and, if there is an impairment, determine both the severity of the impairment (quantitatively) and the level of complexity of the phonological processing at which the impairment occurs (due to the special structure of the phonological test battery).

Chapter 5 presents a study which investigated methodological and theoretical aspects of using mean length of utterance (MLU) as a method for early assessment of spontaneous speech in Russian-speaking children. Early assessment of speech and language abilities is important for the early identification of children at risk of developmental dyslexia and other speech and language impairments. In this study, we analysed several types of utterance length measurements (MLUw, MLUs, MLUm, MLUder, MLUinf, AvUniqF) and explored the applicability of MLU to Russian. We demonstrated that MLU might be appropriate for estimating language abilities in Russian-

speaking children under the age of 3 years. Additionally, we specified the minimal requirements for data collection (sample size) and preprocessing for future research using MLU with clinical populations of Russian-speaking children.

To summarize the major contributions of the research: the results of the research allow for the identification of new patterns of the relationship between the level of linguistic competencies (e.g., phonological processing ability) in Russian-speaking children and reading, and for clarifying existing approaches to the diagnosis of developmental dyslexia. In addition, the presented papers show how important a scientific, linguistically based approach is, for future research in this field.

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