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SILENT READING IN RUSSIAN PRIMARY SCHOOLCHILDREN: AN EYE TRACKING STUDY

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Abstract

The study investigates silent reading in the Russian language during the early stages of acquiring this skill by employing the method of eye tracking. For this purpose we developed the corpus consisting of 30 sentences with target words with controlled length and frequency. Second grade pupils ($n = 37$; average age is 8.6 ± 0.33 years old) participated in the study. In addition to reading tasks, all the children passed neuropsychological assessment, adapted for 6-9 years olds. The analysis of eye movements was carried out in comparison with a similar study conducted in the German language (Tiffin-Richards & Schroeder, 2015). Results show that during reading Russian children made more single fixations and skips than German children. However effects of frequency and length were similar in the both languages. Based on neuropsychological scores we distinguished three groups of children: (1) with the weakness of visual and visual-spatial information processing, (2) with the weakness of kinesthetic and auditory information processing and (3) without these weaknesses. The comparison of eye tracking indices for the three groups showed that children with low scores on visual and visual-spatial processing generated more and longer fixations than the children of the two other groups. The obtained data do not contradict the dual route models of word recognition, but require for their specification new researches.

Keywords: silent reading, eye movements, children, length effect, frequency effect, neuropsychology.

Reading is a main means of acquiring knowledge and a prerequisite for developing other skills. That is why the development of reading skills is one of the most important tasks of primary school. Reading is a complicated and multicomponent process. Subsequently, the deficit in mastering the reading (dyslexia) is the most frequent variant of learning disabilities (Inshakova, 2008; Shaywitz & Shaywitz, 2005). Within this work we study reading in the Russian language during the first stages of acquiring this skill by employing the method of eye tracking that allows for investigation the mechanisms of mastering reading in junior schoolchildren.

Analysis of eye movement during reading is one of the most informative ways of investigation how visual information processing goes on and which cognitive processes occur during reading (Clifton et al., 2016). Analysis of

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eye movement parameters such as quantity and duration of eye fixations makes it possible to show that word perception depends upon its frequency and length (Kliegl, Grabner, Rolfs, & Engbert, 2004). In particular, depending on word length, the probability of gaze fixation on the word changes; with increasing word length the probability of skips increase (Rayner, Slattery, Drieghe, & Liversedge, 2011) and the quantity of repeated fixations decreases (Vergilino & Beauvillain, 2000). Orthographic regularity (Radach, Inhoff, & Heller, 2004), word polysemy (Rayner, Cook, Juhasz, & Frazier, 2006) and other word parameters may also influence the number and duration of fixations.

The study of reading of words of different complexity in early stages of skill acquisition is especially interesting, because it allow us to evaluate reading mechanisms before they are automated. It facilitates the understanding of the skill structure. As reading is a core learning objective in the classroom, understanding its development is important in typically and atypically developing children. Very few studies have examined oculomotor activity in children with and without reading deficits, although eye movement and reading deficits is well studied in adults. For instance, eye movements during reading by dyslexic adults show that the distribution of fixations inside the word may be depended upon the form of dyslexia (Ablinger, Huber, & Radach, 2014). The analysis of errors (Coltheart, 1978; Marshall & Newcombe, 1973) makes it possible to distinguish three types of dyslexia (phonological, surface and deep) and postulate the presence of two different strategies (two routes) of reading. These are the "lexical" (i.e., when the word is perceived as the whole) and "sublexical" (i.e., when the word is recognized successively, in parts) strategies. Other studies allowed to detect these types of dyslexia and two reading strategies in children, and disclose the features of the both strategies (Temple, 1997). Within the sublexical strategy of word reading words are decoded successively (letter by letter or syllable by syllable) and combined into the word's phonological representation which activate the word's meaning (Coltheart, Curtis, Atkins, & Haller, 1993). In case of the lexical strategy of reading the word's whole form is identified as a known unit that is directly related to the word's meaning. The higher the frequency with which a reader meets a word, the stronger is the connection between the visual word's form and its corresponding meaning. If a visual form of a rare word is not identified, then the reader comes to the sublexical strategy. Thus, in the lexical strategy there is an effect of word frequency and in the sublexical one – an effect of its length. At that, the effects of word frequency and length interact; the less frequent the word is, the more probable the usage of the sublexical strategy is (for review see Blythe, 2014).

The studies of oculomotor activity during reading in children show that in the course of mastering the reading skill the character of eye movement changes: fixations duration decreases, the quantity of repeated/return movements shrinks and information volume processed during the fixation increases (Blythe, 2014; Starr & Rayner, 2001; for review see Frey, 2016). The power of the effects of word length and frequency turns out to be greater in children than in adults (Joseph, Nation, & Liversedge, 2013).

Eye-movement studies of reading in children, examining length and frequency of words are rare. In particular, a detailed research taking into consideration these parameters was conducted in German-speaking 2nd grade children (Tiffin-Richards & Schroeder, 2015). A similar approach is adopted in our study. We also selected to test children in the second grade (8–9 years old) because one may speak of difficulties in the acquisition of reading skill and dyslexia only by the end of the first grade (Kuzovkova, 2008). Exactly during the second school year one can observe a striking differences in mastering of reading skills.

In our study we assume that there can be different reading strategies in the initial stages of developing this skill, and that these strategies can be expressed in the character of oculomotor activity during reading. To show the dependence of strategy selection upon higher mental functions (HMF) state, a neuropsychological assessment of children and a comparative study of the oculomotor activity during reading in children in a different state of separate HMF components were conducted. Selection of suitable stimuli was a critical aspect of our method as it was important to evaluate the influence of various properties of the text upon the process of its reading. The analysis of literature shows that the different types of stimuli are used in an eye-tracking during reading: from single words to several sentences. One of the approaches is developing and using of sets of sentences (corpora) in which various properties of a text are controlled. For instance, corpora of sentences were developed for use with eye tracking in adults in German (Kliegl, Nuthmann, & Engbert, 2006), Spanish (Fernández, Shalom, Kliegl, & Sigman, 2014), English and Thai (Winskel, Radach, & Luksaneeyanawin, 2009), Finnish (Hujanen, 1997). Corpora of text and sets of sentences were also developed and employed for the study of reading in children (Schroeder, Würzner, Heister, Geyken, & Kliegl, 2015). No study to date has examined reading in Russian language in children for example the validation of corpora of sentences for adults is under way (Laurinavichyute, Sekerina, Bagdasaryan, Alekseeva, & Zmanovsky, 2016). We have developed a corpus of sentences in Russian to be used to evaluation reading skills in primary schoolchildren.

Method

Subjects

Children (n = 37; 17 female; average age 8.6 ± 0.33) attending the 2nd grade in school participated in the study. The children were tested in the school, with informed consent of their parents and school authorities.

Experimental setting

We used an EyeLink 1000 eye-tracker (SR Research, Ontario, Canada) to record eye-movements during reading at a rate of 1000 Hz. A subject sat before the screen (22 inches diagonal, the monitor update frequency was 200 Hz) at the distance of 90 cm. The subject's head was fixed using a chin rest.

Stimuli

A corpus of sentences was created to study eye movements during reading in the Russian language in primary schoolchildren. The Russian version of the Potsdam corpus consisting of 144 sentences was employed as a basis (Kliegl et al., 2006; Laurinavichute et al., 2016). The preliminary analysis revealed that the sentences of the “adult” corpus are too complicated for reading in children 8–10 years old. Therefore new age appropriated sentences were composed. There were 28 key nouns selected from the Russian version and two new nouns were added. Criteria for word selection were the following:

1. Word length: short words of 3–4 letters, mid-length words of 5–6 letters, and long words of 7–8 letters.

2. Frequency: high-frequency (more than 60 ipm) and low-frequency (less than 30 ipm).

The frequency was determined by means of the sub-corpus of texts for children of 1920–2015 years of the National Corpus of the Russian Language (http://ruscorpora.ru).

Thus, five sentences were included in each cell for design 3 × 2. The length of sentences consisted of 6 through 9 words. The targeted word never turned out to be the first or last. The questions were composed for each sentence to control the understanding by the subject. The examples of the sentences were the following: “Дорога вела в глухой лес, петляя по склонам” (eng. The road led to a dense forest curving along the slopes) – the targeted word was “лес” (eng. forest) which was short and frequent; the control question was: “Was the road straight?”. “На диване лежало покрывало ярко зеленого цвета” (eng. There laid a cover of bright green on the divan), the targeted word was “покрывало” (eng. cover) that was non-frequent and long; the control question was “Was the cover blue?”. The sentences were presented in monospaced font (Ubuntu Mono Normal, size 26 pt). The text was displayed in the black color on a light grey background.

Procedure

Children were asked to read 33 sentences (3 were used for training) silently. After reading of 3 training and 5 test sentences the subjects were asked questions regarding the meaning of the sentences.

At the beginning the participants were instructed to read silently the sentences presented on a computer screen and to be ready to answer related questions.

A nine dot calibration of the eye-tracker was conducted and validated with each participant until a calibration accuracy of at least 1° was achieved. The calibration was also repeated in the middle of the session.

The presentation of sentences started with three training trials. After each training sentence the children answered a control question. The first test sentence was the same for all subjects. It was accompanied by a control question. All the remaining sentences were presented to the child in quasi-random order, which was unique to every subject. Questions appeared in random order four more times. The child read them silently and answered them by mouse clicks.

The sentence presentation was arranged in the following way: first participants fixated for 500 ms on a black circle on the left edge of the screen. Then the black point disappeared, and the sentence appeared. After they finished reading the sentence children were asked to look on the red circle at the right low bottom corner of the screen. After fixating on the red circle for 500 ms the text disappeared. Following a pause of 2 seconds the next sentence presentation began. Trial timing and example of stimulus sentence are shown on Figure 1.

Data analysis

A primary processing of eye movements data was carried out by standard software (Data Viewer, SR research). Only data related to the target words in the test sentences were included in further analyses. The following parameters of eye movements were extracted for each subject:

1) total fixation count;
2) single fixation duration;
3) first fixation duration;
4) average fixation duration;
5) gaze duration (duration of all fixations on a target before the first saccade leaves a target);
6) total time of fixation (all fixations on a target).

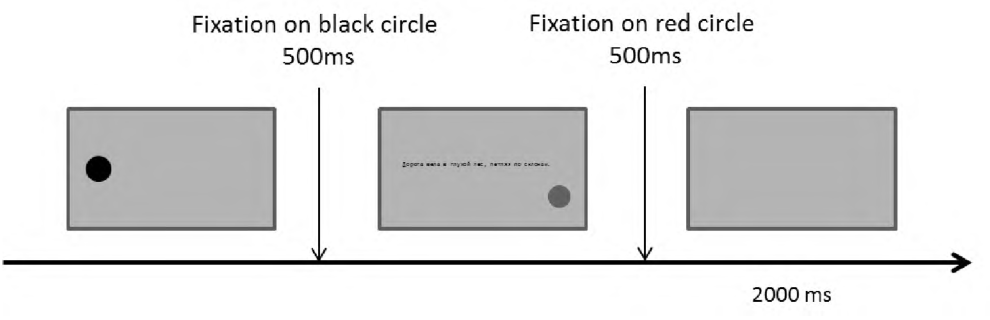
The proportions of the trials with single fixation, with re-fixations, and with no fixations (i.e. skips) were also counted. Fixations shorter than 80 ms or two standard deviations longer than the average fixation duration for the whole trial were excluded from analysis. Subsequently, we excluded extremely short and long fixation duration and provided comparability of our results with those of the German colleagues (Tiffin-Richards & Schroeder, 2015).

Data for separate words were averaged for six conditions: short, mean and long frequent and non-frequent words. We used R software (ver. 3.2.5) for the further data processing and statistical analysis

All subjects passed a neuropsychological assessment adapted for children 5–9 years (Akhutina et al., 2016). It included 20 tests aimed at the evaluation of different components of HMF.

Figure 1

Timing for a typical trial



Note. Timing for a typical trial. The sentence on the second screen: “Дорога вела в глухой лес, петляя по склонам” [“The road led to a dense forest curving along the slopes”].

The following integrated indicators were calculated on the results of the examination: 1) index executive functions; 2) index serial organization of movements and actions; as well as indices of the functions of processing information: 3) kinesthetic; 4) auditory; 5) visual; 6) visual-spatial.

Results

Analyses of the whole sample

Percentage of single fixations, several fixations and no fixations registered on the target words are computed. Current results in comparison with data by Tiffin-Richards and Schroeder (2015) are in Table 1.

The probability of skipping words during reading by Russian children turns out to be slightly higher than German children. One may also point out that according to our data children do a single fixation more often, whilst during reading in German multiple fixations are more probable.

Descriptive statistics of the main parameters of fixations is presented in Table 2 in comparison with the data obtained by Tiffin-Richards & Schroeder (2015).

Table 1

Percentage and standard error (in brackets) of fixations during reading target words

Probability of first pass	Russian Children	German children
Single fixation (%)	42.47 (0.12)	30.66 (0.28)
Within-word refixation (%)	37.48 (0.15)	56.35 (0.30)
Skips (%)	19.82 (0.19)	12.98 (0.21)

Table 2

Mean fixation and standard error (in brackets) of fixation duration on the words of a different length and frequency

	Russian children						German children			
	High frequency			Low frequency			High frequency		Low frequency	
	S	M	L	S	M	L	S	L	S	L
Single fixation duration	244 (18)	323 (16)	304 (24)	354 (32)	313 (20)	283 (18)	348 (10)	344 (15)	425 (14)	416 (34)
First fixation duration	288 (17)	299 (12)	286 (12)	325 (19)	332 (16)	330 (14)	313 (6)	294 (5)	357 (8)	315 (6)
Average Fixation Duration	289 (17)	359 (17)	314 (12)	350 (14)	300 (10)	338 (11)	--	--	--	--
Gaze duration	391 (36)	643 (113)	656 (81)	529 (42)	783 (79)	926 (109)	629 (20)	1016 (31)	742 (22)	1730 (45)
Total time	452 (36)	644 (60)	888 (85)	710 (61)	1106 (107)	1150 (106)	803 (23)	1273 (37)	1000 (29)	1979 (47)

Note. S — short, M — medium, L — long.

The results of rmANOVA with length and frequency as within-subject factors and fixation durations as dependent variables (DV) are presented in Tables 3 and 4.

The rmANOVA shows a significant interaction of word length by frequency on single fixation duration. In short words, fixation duration differ noticeably depending on frequency, whilst the differences are much less in the case of mid-length and long words.

The single fixation duration depends upon word frequency. Its duration is less during reading frequent words in comparison with infrequent ones; at that, word length does not influence this parameter.

Fixations duration is affected by both word length (the duration increases for word elongation) and its frequency (fixations duration is more for reading infrequent words).

Finally, total time is influenced by both factors separately (the duration rises in the course of word length growth and its frequency decrease) and their interaction. For frequent words the duration grows almost linearly with increasing word length, whereas in infrequent words one can observe a sharp rise of reading time from short to mid length words and almost the same time of reading for mid-length and long words.

Mean values of fixations count on target words and the portions of the trials with single fixation on a target word are presented in Table 5.

The results on length and frequency as within-subject factors and these two parameters as DV are presented in Table 6.

Table 3

Results of rmANOVA with length and frequency as within-subject factors and fixation durations as DV

	Single fixation duration			**First fixation duration**			**Mean fixation duration**		
	F	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Length	.509	.606	.029	.245	.783	.007	.647	.527	.018
Frequency	2.213	.155	.115	**13.37**	**.001**	**.271**	**46.35**	**.000**	**.563**
Length × Frequency	**10.49**	**>.001**	**.382**	.098	.907	.003	2.945	.059	.076

Table 4

Results of rmANOVA with length and frequency as within-subject factors and gaze duration and total time as DV

	Gaze duration			**Total time**		
	F	*p*	η^2_p	*F*	*p*	η^2_p
Length	**16.253**	**>.001**	**.311**	**47.206**	**>.001**	**.567**
Frequency	**12.259**	**.001**	**.254**	**38.159**	**>.001**	**.515**
Length × Frequency	1.171	.316	.032	**3.213**	**.046**	**.082**

Table 5

Fixation count and proportion of trials with single fixation depending on a target word length and frequency

Word frequency	High Frequency			Low Frequency		
Word length	Short	Medium	Long	Short	Medium	Long
Fixation count	2.0 (0.2)	2.8 (0.2)	3.9 (0.3)	2.7 (0.2)	4.0 (0.3)	4.5 (0.4)
Probes with single fixation (%)	58 (3)	42 (4)	38 (4)	46 (4)	39 (3)	31 (4)

Table 6

Results on length and frequency as within-subject factors and fixation count and proportion of trials with single fixation as DV

	Fixation count			Probes with single fixation (%)		
	F	p	η^2_p	F	p	η^2_p
Length	**48.086**	**.000**	**.572**	**10.981**	**.000**	**.392**
Frequency	**46.728**	**.000**	**.565**	**6.626**	**.014**	**.159**
Length × Frequency	2.434	.095	.063	0.869	.428	.049

The results of the analysis indicate a significant influence of length and frequency on the both indices. The total fixations count rises as a function of the increase of word length as well as during reading infrequent words in comparison with frequent ones. On the contrary, the proportion of single fixations diminishes in cases of word length increase and it is higher in cases of frequent words in comparison with infrequent ones.

Analyses as a function of HMF performance

Next we address the question of strategy choice depending on the state of HMF in children. According to a widespread traditional viewpoint (e.g. Shaywitz & Shaywitz, 2005; but see also another viewpoint in Facoetti et al., 2010; Vidyasagar & Pammer, 2010) we would assume that underdevelopment of visual and visual-spatial functions will lead to lexical strategy weakness and sublexical strategy preference; expressed in a considerable number of fixations independent of words frequency. For a deficit of auditory and kinesthetic functions that related to sound analysis, the sublexical strategy was expected to suffer and lexical one – to prevail. Word frequency is expected to play a greater role than word length during reading in children with deficits in auditory and kinesthetic function.

The following way was used to test these hypotheses. Two integrated indices were calculated on the basis of neuropsychological tests: A) processing of visual and visual-spatial information and B) processing of kinesthetic and auditory information.

The following three groups of children are distinguished on the base of these indices ratio:

The group with a relatively good state of cognitive functions (both indices were better than the mean value in the sample). Ten children passed this criterion and we named this group N+.

The group of children with a relative weakness in visual and visual-spatial functions (index A was worse than index B and performance was worse than the mean of the sample). Twelve children fulfilled these criteria and we named this group Visual.

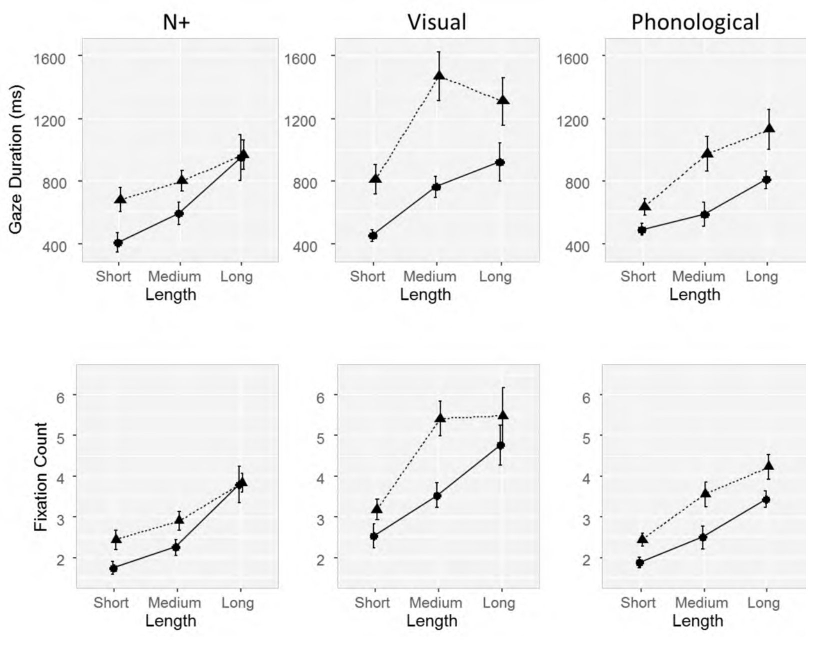
The group of children with a relative weakness in kinesthetic and auditory functions (index B was worse than index A and it was worse than the mean of the sample). Fourteen children fulfilled these criteria and we named this group Phonological.

Because executive functions and organization of serial movements also can influence the reading processes in the three groups, we verified if these factors were similar in all groups. Analysis of variance showed no significant differences between the three groups ($p > 0.655$ in the both cases).

Full data of mean indices of eye movements depending on word length and frequency in the three groups are in appendix 1. Intergroup differences are obtained in the parameters of total time and gaze duration. Mean values and standard errors of these parameters in the three groups under different conditions are in Figure 2.

Figure 2

Total time (upper row) and Fixation Count (lower row) in the three groups (columns)



Note. Circles with solid lines – frequent words, triangles with dotted lines – non-frequent words. Error bars – standard errors of the mean.

Results of rmANOVA with word length and frequency as within-subject factors, and state of HMF as between-subject factor for the indices reveal a significant effect of group (Table 7).

A significant difference between group was observed for fixations count: in group Visual children generate many more fixations in comparison with the two other groups. The interaction between group and word length also influences significantly the total fixation time. In group Visual the total time rises drastically in the course of the transition from short words to mid ones, and fixation duration is similar for the course of transition for mid and long infrequent words in this group. In the two other groups (N+ and Phonological) the total time of fixations in the course of the elongation of words grows slower and quite evenly both from short to mid and from mid to long words.

One may also point out a marginally significant result for the interaction between word frequency and group for total time of fixations. In group N+ there are minimal differences in fixation duration for frequent and infrequent words, differences are minimally larger for the Phonological group, whereas the largest differences are observed for the Visual group. Thus, a dominant influence of visual and visual-spatial functions on reading development is supported. The employment of different strategies by children of Visual and Phonological groups will be considered in the discussion.

Discussion

One of the goals of our study was to validate the created corpus of sentences for use with eye tracking in children during reading so to establish its ability to detect differences in oculomotor activity. An analysis of linguistic properties of the words showed that word frequency significantly affects the characteristics of eye movements. On the whole, children were capable of reading frequent words much easier than the words of mid and low frequency. Such parameters as average fixation duration

Table 7

Results of rmANOVA with word length and frequency as within-subject factors, and state of HMF as between-subject factor

	Total time			Fixation count		
	F	p	η^2_p	F	p	η^2_p
Length	47.632	.000	.591	47.902	.000	.592
Frequency	37.120	.000	.529	46.522	.000	.585
Group	1.010	.375	.058	3.345	.048	.169
Length × Frequency	2.537	.087	.071	2.070	.134	.059
Length × Group	2.728	.036	.142	1.511	.209	.084
Frequency × Group	3.119	.057	.159	2.278	.118	.121
Length × Frequency× Group	1.330	.268	.075	.726	.577	.042

and the first duration fixation were considerably shorter during reading frequent words. The subjects performed fewer fixations on frequent words. The total gaze duration was also less. This expected effect is consistent with data of other investigations (for instance, Joseph et al., 2013).

Word length significantly influenced a fewer parameters. There were expectedly more total fixations duration; and, the probability of skips on a long word was less than on a short one. These data are consistent with data obtained during reading in the German language (Tiffin-Richards & Schroeder, 2015). At that, the increase of the total reading time of words in the course of their elongation took place mostly at the expense of the fixations growth. The average fixations duration in children did not show the influence as a function of word length.

Significant interactions between word length and frequency for total time and single fixations was driven by the fact that the average fixation duration on short and mid-length words did not differ so much as during reading long words. During reading infrequent mid-length and long words fixation duration did not significantly differ. This could be connected to the fact that reading of a mid-length frequent word did not appear to be a hard task for the children. Reading of infrequent words of the same size was rather difficult. According to our data, there was a single fixation even for long words in some children though this fixation duration was significantly longer than for reading short and mid-size words. The probability of that the subjects would generate a single fixation on the word was 42%, that is more than the proportion of single fixations in children reading in the German language (Tiffin-Richards & Schroeder, 2015). According to data obtained in the German sample, in children, unlike adults first fixation duration at a short word was longer than the first fixation on a long word, as for German children fixations typically reoccur. The probability of re-fixation on the word was 56% during reading in German and 37% only in our study. According to our data one should also point out that fixation duration during reading turned out to be less than that in the investigation of the German colleagues. That difference might be explained by differences in the language as well as the average age of our subjects (8.6 years old) was higher than that in the German sample (7.8 years old). As far as it was shown in different investigations, fixation duration diminished rapidly within this age range (Starr & Rayner, 2001).

A significant influence of word length and frequency during reading was also discovered in other studies of children (Rau et al., 2016). Like in our research, most reading difficulties are observed during reading of long infrequent words. When studying the formation of reading in German children 2, 3 and 4 grades, it was shown that children are all the more based on sequential reading (sublexical processing), the longer the word length. However, with age, there is a gradual reduction in the use of a sublexical strategy by increasing the number of words that are treated as whole units (Rau, Moeller, & Landerl, 2014). These data fully correspond to the dual route model of word recognition.

The last conclusion is important for discussing the dependence of the choice of reading strategies in dependence of the state of the children's HMF. From this it follows that in children with weak visual and visual-spatial functions one should expect more limited growth in the number of words that are processed as holistic images. These can be, first of all, short words, especially frequent ones. In children without weakness of visual and visual-spatial functions, one should expect that a group of holistically processed words will include not only short words, but also frequent words of medium length and even long ones, i.e. the influence of length of words will be less in these children. The difference in the total length of fixations when reading short and medium-length frequency words is the least in the Phonological group, which corresponds to the assumption that these children use lexical strategy. On the contrary, the significant influence of the length of words when reading by the children of the Visual group can be regarded as evidence of using of a sublexical strategy. These our results quite correspond to the dual route models of word recognition. However, the discovered fact that the maximum influence on the formation of reading has a state of visual and visual-spatial functions may have an additional explanation.

The question of the most important functions for reading development has come under discussion during recent years. On the one hand, it is traditionally considered that disturbances of acoustic information processing are the main reason of the most widespread form of reading difficulties – phonological dyslexia (Shaywitz & Shaywitz, 2005; see for review Vellutino, Fletcher, Snowling, & Scanlon, 2004). On the other hand, a group of the authors underline an important role of visual and visual-spatial functions in the process of reading (Facoetti et al., 2010; Vidyasagar & Pammer, 2010). Modern neuroimaging studies of reading detect an activation of the ventral visual pathway (visual system «what») when using lexical reading strategies and activation of the dorsal visual pathway (visual-spatial system «where?») during using the sublexical strategy (Coltheart et al., 1993). The researchers underline the interaction of auditory and visual-spatial processes (in particular, visual-spatial attention) in the process of the formation of word sound analysis and rules of sound-letter matching important for sublexical strategy (Vidyasagar & Pammer, 2010; Facoetti et al., 2010). In accordance with this viewpoint, one ought to expect the deficit of lexical and sublexical strategies in the children of our Visual group, and, the sublexical strategy weakness in the children of our Phonological group, which explains the worst results of the Visual group and the intermediate position of the Phonological group. However, this explanation requires additional research.

So, in our study it was revealed that in the second graders the state of visual and visual-spatial functions has a dominant influence on the formation of reading. The obtained data do not contradict the dual route models of word recognition, but require for their specification in further research.

One should point out that all the children under the present test did not suffer from learning difficulties and reading ones. Our future goal is to examine eye movements in a larger sample that distinguishes between children with and without visual and visual-spatial deficits, and includes a group of children with reading difficulties to obtain a clearer picture of how the two reading strategies are used.

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Appendix 1

Mean indices of eye movements depending on word length and frequency in the three groups (in brackets standard errors of the mean)

	N +					
	High frequency			Low frequency		
	Short	Medium	Long	Short	Medium	Long
First fixation duration	297 (42)	297 (20)	266 (25)	305 (39)	338 (30)	262 (15)
Gaze duration	361 (70)	534 (98)	506 (83)	486 (76)	628 (70)	598 (78)
Total time	408 (88)	595 (103)	950 (214)	683 (114)	802 (100)	970 (136)
Fixation count	1.7 (0.2)	2.3 (0.3)	3.8 (0.6)	2.4 (0.3)	3 (0.3)	3.8 (0.3)
Probes with single fixation (%)	60 (7)	42 (10)	42 (8)	62 (9)	42 (6)	44 (4)
	Visual					
	High frequency			Low frequency		
	Short	Medium	Long	Short	Medium	Long
First fixation duration	290 (34)	304 (27)	285 (20)	347 (38)	341 (36)	362 (24)
Gaze duration	395 (71)	837 (306)	785 (225)	592 (72)	978 (163)	1191 (243)
Total time	452 (57)	764 (97)	924 (177)	811 (136)	1473 (225)	1311 (222)
Fixation count	2.5 (0.4)	3.5 (0.4)	4.8 (0.7)	3.2 (0.4)	5 (0.6)	5.5 (1)
Probes with single fixation (%)	62 (7)	40 (8)	38 (9)	38 (7)	40 (7)	30 (8)
	Phonological					
	High frequency			Low frequency		
	Short	Medium	Long	Short	Medium	Long
First fixation duration	278 (21)	293 (20)	294 (18)	315 (29)	320 (24)	347 (25)
Gaze duration	414 (57)	566 (130)	662 (75)	489 (76)	721 (141)	920 (175)
Total time	490 (54)	588 (112)	810 (80)	636 (76)	974 (160)	1129 (183)
Fixation count	1.9 (0.2)	2.5 (0.4)	3.4 (0.3)	2.4 (0.2)	4 (0.4)	4.2 (0.4)
Probes with single fixation (%)	53 (5)	44 (6)	34 (6)	41 (7)	37 (6)	23 (7)

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Чтение про себя у младших школьников: исследование движений глаз

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Резюме

Работа посвящена исследованию чтения на начальных этапах освоения этого навыка, с использованием методов регистрации движений глаз. В исследовании приняло участие 37 учащихся II класса (возраст — 8.6 ±0.33 года). Оценка глазодвигательной активности производилась с помощью специально созданного для этих целей корпуса предложений, содержащих ключевые слова с контролируемой длиной и частотностью. Также было проведено нейропсихологическое обследование, позволившее оценить состояние различных компонентов высших психических функций участников исследования. Анализировались следующие характеристики движения глаз: продолжительность и число фиксаций, общее время фиксаций на слове, частота единичных фиксаций на ключевых словах. Анализ полученных данных показал, что чтение частотных слов в целом дается детям гораздо легче, чем слов низкой частотности – на них зарегистрировано меньшее число фиксаций, продолжительность фиксаций меньше. Также обнаружено значимое влияние длины слова на характеристики глазодвигательной активности при чтении: при чтении длинных слов наблюдалось заметно большее общее время фиксаций, чем при чтении коротких. Данные сопоставляются с результатами аналогичного исследования, проведенного на немецком языке. Отдельно проводился анализ влияния развития когнитивных функций на характеристики чтения у детей. Были рассчитаны два интегральных показателя состояния двух групп когнитивных функций: (1) переработки зрительной и зрительно-пространственной информации, связанные в большей степени с функциями правого полушария; (2) переработки кинестетической и слуховой информации, связанные в большей степени с функциями левого полушария. Результаты исследования свидетельствуют, что максимальные трудности при чтении испытывали дети со слабостью переработки зрительной и зрительно-пространственной информации. Полученные данные обсуждаются в контексте выделения двух возможных стратегий чтения на начальных этапах его освоения — лексической и сублексической.

Ключевые слова: детская нейропсихология, чтение, движение глаз при чтении, младшие школьники.

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