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Phonological and orthographic parafoveal processing during silent reading in Russian children and adults

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ABSTRACT

Studies on German and English have shown that children and adults can rely on phonological and orthographic information from the parafovea during reading, but this reliance differs between ages and languages. In the current study, we investigated the development of phonological and orthographic parafoveal processing during silent reading in Russian-speaking 8-year-old children, 10-year-old children, and adults using the gaze-contingent boundary paradigm. The participants read sentences with embedded nouns that were presented in original, pseudohomophone, control for pseudohomophone, transposed-letter, and control for transposed-letter conditions in the parafoveal area to assess phonological and orthographic preview benefit effects. The results revealed that all groups of participants relied only on orthographic but not phonological parafoveal information. These findings indicate that 8-year-old children already preprocess parafoveal information similarly to adults.

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Introduction

Efficient reading requires processing of orthographic codes, phonological processing, and retrieval of lexical and semantic information from the mental lexicon. Previous studies have shown that skilled readers can extract information not only from a currently fixated word but also from the upcoming word in the sentence, which is called parafoveal processing (Rayner, 1998). During parafoveal processing, readers can preprocess the orthographic and phonological properties of the word (Schotter et al., 2012). Parafoveal processing is one of the markers of fluent reading, and it undergoes a developmental change. Scattered evidence suggests that primary school children can preprocess phonological information (Milledge et al., 2022b; Tiffin-Richards & Schroeder, 2015) and orthographic information (Johnson et al., 2018; Milledge et al., 2021; Pagán et al., 2016) parafoveally. However, less is known about the developmental patterns as well as the timeline of the phonological and orthographic parafoveal preprocessing on its way to the adult level.

In German, Tiffin-Richards and Schroeder (2015) showed a developmental change from a greater reliance on phonological information in the parafovea in children to a greater reliance on orthographic information in adults. The authors tested 8-year-old school children and adults in a reading experiment using the gaze-contingent boundary paradigm (Rayner, 1975). The participants silently read sentences with embedded target nouns that were presented in original (*Blech, Rand*), pseudohomophone (*Blech–Bläch*), transposed-letter (*Rand–Rnad*), lowercase, or control (*Bläch–Blüch; Rnad–Rcod*) conditions in the parafovea. As soon as the reader's eyes crossed the invisible boundary that preceded the target word, the preview was replaced by the target noun. Phonological preview benefit manifested in shorter fixation durations on the target when the preview was phonologically similar to the target (*Bläch*) as compared with when it was unrelated to the target (*Blüch*). This difference indicated that the preview with the same phonological but different orthographic representation activated the word's recognition, unlike the preview with the different phonological representation. Similarly, orthographic preview benefit manifested in shorter fixation durations on the target after the preview *Rnad* compared with *Rcod.* The preview *Rnad* with two letters of the target word *Rand* being transposed contained the whole letter identity information about the target word, unlike the control condition *Rcod.* Tiffin-Richards and Schroeder (2015) found evidence of pseudohomophone preview benefit effects for children and transposed-letter preview benefit effects for adults. The results supported the developmental view that reading initially depends on phonological processing, whereas orthographic processing becomes increasingly important with age (Ziegler et al., 2014); reliance on orthographic information does not reach the adult level by 8 years of age.

At the same time, Milledge and Blythe (2019) summarized evidence for English that pseudohomophone phonological preprocessing effects can be detected in adults. The authors associated them with phonological recoding skills, which is a fast activation of phonological codes converting the character string into sounds. Milledge and Blythe argued that during reading development there is not a transition from the reliance on phonology to the reliance on orthography; instead, phonological recoding replaces phonological decoding—a strategy that children use when learning to read sounding out and blending the phonemes one by one to associate them with a word's meaning (Castles et al., 2018). Similarly, according to the multiple-route model of reading, phonological effects diminish with age but do not disappear completely (Grainger et al., 2012). Thus, parafoveal phonological effects should exist in adult readers as they do for English (Ashby et al., 2006; Pollatsek et al., 1992) and French (Miellet & Sparrow, 2004), which conflicts with the results for German. Studies on parafoveal phonological processing in children have not been conducted in alphabetical languages other than German and English, so we still do not know whether and to what extent children rely on phonological information in the parafovea.

More evidence that conflicts with the results from Tiffin-Richards and Schroeder (2015) for German is that English children rely on orthography in the parafovea. Pagán et al. (2016) explored a transposed-letter preview benefit in 8- to 10-year-old children and found that children extracted letter identity and letter position information from the parafovea. Milledge et al. (2021) revealed that the substitution of external letters of the word in preview conditions complicated reading in 8- and 9-year-old children, which indicates that they perceive the whole-word representation from the parafovea and are sensitive to orthography. Johnson et al. (2018) found that, already at 6 years of age, children gained letter identity information from the parafovea. Furthermore, Milledge et al. (2022a, 2022b) compared effects of phonological and orthographic manipulations in parafovea and concluded that orthography was more important than phonology in both children and adults. The inconsistency between the studies for English and German children may be due to the difference between the types of orthographies of these languages.

Languages vary in the degree to which graphemes in a word represent its phonological structure. Orthographies with simple grapheme–phoneme correspondence rules and high predictability (i.e., with a low percentage of irregular words), such as Finnish, are called *consistent* or *shallow* (Schmalz et al., 2015). Orthographies with complex grapheme–phoneme correspondence rules and low predictability (i.e., with a high percentage of irregular words), such as French and English, are called *inconsistent* or *deep*. Orthographies with complex grapheme–phoneme correspondence rules and high predictability, such as German, are in the middle of the continuum (Landerl et al., 2013; Schmalz et al., 2015). The inconsistency of orthography influences reading development (Schroeder et al., 2021; Ziegler & Goswami, 2005); readers in consistent orthographies switch faster from the effortful phonological decoding to the rapid parallel lexical processing because the simple grapheme–phoneme correspondence rules and, more important, high predictability automatically activate the phonological and orthographic codes.

The orthography of Russian is in the middle of the consistency continuum because of complex grapheme–phoneme correspondence rules and a high degree of predictability (Zhukova & Grigorenko, 2019). Among inconsistencies, there are cases when words with the same spelling have different pronunciations (e.g., *muká* 'flour' vs *múka* 'torture') as well as cases when words are pronounced the same but have different spelling (e.g., [prút] can refer to *prut* 'rod' and *prud* 'pond'). Phonotactic rules in Russian are influenced by the phonological context and position of phonemes (Ulicheva et al., 2016). Thus, vowels can undergo qualitative and quantitative reduction in unstressed syllables (*molokó* 'milk' is pronounced as [məlakó]), and consonants can be hard or soft (e.g., /m/ in *mat'* [mat'] 'mother' and the soft pair *mjat'* [m'at'] 'to crumple'), voiced or voiceless (e.g., /z/ is voiced in *zont* [zont] 'umbrella' and voiceless in *taz* [tas] 'washbowl') (Grigorenko, 2013; Mołczanow, 2007). Because Russian and German orthographies are similar in their degree of consistency, one could expect that 8-year-old children reading in Russian should already rely on phonology in parafovea, whereas adults should rely more on orthography, like in Tiffin-Richards and Schroeder (2015).

In the current study, we investigated the development of phonological and orthographic parafoveal processing in Russian. Using the gaze-contingent boundary paradigm, we tested three groups of participants: 8-year-old children in Grade 2, 10-year-old children in Grade 4, and adults. Based on previous studies, we had two sets of expectations. On the one hand, there might be the same trajectory in the development of parafoveal processing in Russian as in German because of the similarity in orthography consistency. Thus, we hypothesized that there would be a shift from a greater reliance on phonology in second graders to a greater reliance on orthography in fourth graders and adults. Specifically, we expected that second graders would benefit only from pseudohomophones (i.e., would have shorter fixation durations on the target words after pseudohomophone previews vs their control previews with another pronunciation) but not from transposed-letter previews compared with their control previews. On the contrary, adults would have only transposed-letter preview benefit effects (i.e., would have shorter fixation durations on the target words after transposed-letter previews with the same letter identity information vs their control previews with another orthography). Because we do not know when children reach the adult level of parafoveal processing, we expected that eye movements in fourth graders might be similar to those in either second graders or adults. On the other hand, beginning readers in Russian might have the same preview benefit effects as English children, whereas adult reading might follow the multiple-route model. In this case, we hypothesized that adults and children would rely on both phonological and orthographic information.

Method

Participants

All 169 participants were native speakers of Russian: 65 adults (39 women; M_{age} = 23.6 years, SD = 11.5), 56 children from Grade 2 (31 girls; M_{age} = 8.3 years, SD = 0.5), and 48 children from Grade 4 (21 girls; M_{age} = 10.2 years, SD = 0.5), which is the last year of primary school in Russia. Children were tested in the second half of their school year. All children had age-appropriate reading fluency and comprehension (assessed with the Standardised Assessment of Reading Skills; Kornev & Ishimova, 2010) and nonverbal intelligence (assessed with the Colored Progressive Matrices; Raven, 2003). Second graders' mean reading fluency was 81.1 words per minute (SD = 18.5, range = 55–121), and their mean question response accuracy was 7.7 out of 10 (SD = 1.3, range = 5–10). Their mean accuracy in the nonverbal IQ task was 29.6 out of 35 (SD = 3.3, range = 23–35). Fourth graders' mean reading fluency was 121.6 words per minute (SD = 21.8, range = 89–167), and their mean question response accuracy was 8.7 (SD = 1.1, range = 7–10). Their mean accuracy in the nonverbal IQ task was 32 (SD = 3.5, range = 21–35). The participants reported no history of reading, neurological, or psychiatric disorders.

This study was performed in line with the principles of the Declaration of Helsinki. The experiment was approved by the HSE Committee on Interuniversity Surveys and Ethical Assessment of Empirical Research (from 30 January 2020). Adult participants and children's caretakers signed an informed consent before the start of the experiment.

Materials

There were 60 experimental sentences, each containing a target noun. All target nouns were 5 letters long (30 in the feminine gender and 30 in the masculine gender), had an average lemma frequency of 31.8 items per million (range = 10–100), and were selected from the StimulStat database (Alexeeva et al., 2018). For each noun, we generated five preview conditions: identical (ID), pseudohomophone (PsH), control for pseudohomophone (CPsH), transposed-letter word (TL), and control for transposed-letter word (CTL) (see Table 1). A two-sample t test analysis showed that bigram frequencies (Lyashevskaya & Sharov, 2009) in the PsH and CPsH previews did not differ (p =.22), as was the case in the TL and CTL previews (p =.26).

Target nouns were embedded in sentences that were age appropriate and appealing to primary school children. Sentences were 7 to 10 words long (M = 8.6 words, SD = 0.6) and had target nouns in the fifth or sixth position, for example, *На кухонном столе стоял сладкий| пирог с малиной* ('There was a sweet raspberry pie on the kitchen table'). Targets were in singular form in the nominative

Table 1
Preview conditions for the words *pirog* 'pie' and *nitka* 'thread'.

Condition	Stimulus	Description
Identical (ID)	pirog nitka	Preview is identical to the target word.
Pseudohomophone (PsH)	piro**k** ni**d**ka	Preview differs in spelling but preserves the phonology of the target. One letter in the middle or at the end of a word is changed. We changed the third letter in 28 words, the fourth letter in 3 words, and the fifth letter in 29 words. In our stimuli, these phonemes are voiceless but can be represented by both voiced and voiceless graphemes.
Control for pseudohomophone (CPsH)	piro**b** ni**p**ka	Preview differs both in spelling and in phonology. The same letter as in the pseudohomophone is changed.
Transposed-letter (TL)	p**ri**og ni**kt**a	Two letters of the target are swapped (either second and third letters for 32 words or third and fourth letters for 28 words).
Control for transposed-letter (CTL)	p**le**og ni**sn**a	The same letters as in the transposed-letter condition are substituted, vowels with vowels and consonants with consonants.

or accusative case for 10 nouns when the accusative form matched the nominative form. All targets were preceded by adjectives with an average length of 6.96 letters (*SD* = 0.71) and an average frequency of 61.7 items per million (range = 10–100). The invisible boundary was placed behind the last letter of the adjective.

Procedure

Participants were tested individually in a silent room. We tested all adults and 46 children in the laboratories in Moscow and Sochi and tested 58 children at school in Nizhny Novgorod. Prior to the experiment, we conducted behavioral testing for children that lasted about 15 min. Our experiment started with a 9-point calibration. Then, participants read silently at a comfortable pace starting with 5 practice trials. Each trial started with a drift correction at the position of the first letter in the sentence, and if the correction was successful a sentence appeared on the screen. After reading the sentence, participants clicked the mouse button that triggered either the next trial or a comprehension question. Practice sentences and 20 experimental sentences were followed by a comprehension question with two response options to which participants responded with a mouse click. The sentences were presented in random order. Stimuli were presented on an ASUS VG248QE monitor and on an ASUS ROG Zephyrus S GX701GV-EV006 laptop with a refresh rate of 144 Hz and a resolution of 1920×1080 pixels. Participants' eye movements were recorded with an EyeLink 1000 Plus or an EyeLink Portable Duo eye-tracker with a sample rate of 1000 Hz (SR Research, Ottawa, Ontario, Canada). The experiment lasted approximately 30 min and included two breaks.

Analysis

All fixations less than 60 ms were deleted from the analysis. This led to exclusion of 5.2 % of the data. Then, for each participant in each eye movement measure, we deleted fixations if the duration was 2.5 standard deviations above the mean separately for each condition. Less than 2 % of the data was deleted in each measure.

Analysis was conducted using the R program for statistical computing (R Core Team, 2021). The models were estimated with the package 'lme4' (Bates et al., 2021). Three fixation duration measures were analyzed using hierarchical linear regressions: *first fixation duration* (FFD; the only fixation or the first of multiple fixations on a target), *gaze duration* (GD; all fixations on a target before the first saccade leaves the target), and *total time reading* (TT; all fixations on a target including rereading). We aimed to estimate the effects of ID, PsH, and CPsH previews in the three participant groups (in the phonological processing models), as well as the effects of ID, TL, and CTL previews in the three participant groups (in the orthographic processing models), on fixation duration on the target nouns. For that, we built a set of models that estimated the main effects of preview condition and participant group as well as the group-by-condition interaction. Sum contrasts were used to code group (with -1 corresponding to Grade 2), and condition (with -1 corresponding to PsH for the phonological processing models or to TL for the orthographic processing models).

The random structure included random intercepts for participants and sentences. We also included by-item and by-participant random slopes for the main effects of group and condition and excluded them one by one until the models converged. All the models had no random slopes. The models' structure was as follows: log*(fixation_duration)* ~ *group*condition + (1 | participant) + (1 | sentence).* Significant effects were adjusted for multiple comparisons using Bonferroni correction at an alpha level of.017. The significance of the overall effects was tested using the *Anova* function in the R package 'car' (Fox & Weisberg, 2019). To contrast the slopes of the predictors in the model, we used the R package 'emmeans' (Lenth et al., 2021), which calculates pairwise comparisons (Bonferroni correction applied).

Results

Estimates for the dependent eye-tracking measures across conditions and groups are summarized in Tables S1 and S2 of the online supplementary material. In the phonological processing models, the results were similar for all dependent variables (FFD, GD, and TT). Specifically, we found that fourth graders and second graders had comparable fixation durations, whereas adults had shorter FFD, GD, and TT compared with second graders. Nouns in the ID condition were read faster and nouns in the CPsH condition were read slower compared with the PsH condition. None of the interactions was significant after Bonferroni correction. The analysis of variance showed that the main effects of group and condition were significant (*p*s <.001) in all eye movement measures, whereas the group-by-condition interactions were significant in FFD (χ^2 = 12.59, *p* =.01) and GD (χ^2 = 9.86, *p* =.04) but not in TT (χ^2 = 5.10, *p* =.28). The post hoc pairwise comparison of conditions within participant groups revealed no significant difference between the ID and PsH conditions or between the CPsH and PsH conditions in any of the measures in second graders. Fourth graders and adults had shorter fixation durations for all dependent variables in the ID condition compared with the PsH condition and had no difference between the CPsH and PsH conditions (see Table 2). Slope contrasts (ID − PsH) for FFD in fourth graders were *Est.* = −0.09, *SE* = 0.02, *z* ratio = −3.70, *p* =.008, and in adults they were *Est.* = −0.08, *SE* = 0.02, *z* ratio = −3.76, *p* =.006. Slope contrasts for GD in fourth graders were *Est.* = −0.13, *SE* = 0.03, *z* ratio = −5.11, *p* <.001, and in adults they were *Est.* = −0.09, *SE* = 0.02, *z* ratio = −4.17, *p* =.001. Slope contrasts for TT in fourth graders were *Est.* = −0.12, *SE* = 0.03, *z* ratio = −4.24, *p* <.001, and in adults they were *Est.* = −0.09, *SE* = 0.02, *z* ratio = −4.14, *p* =.001. The full outputs with the results of the post hoc analyses are available at https://osf.io/6gnxe/.

In the orthographic processing models, we also found that fourth graders and second graders had comparable FFD, GD, and TT, whereas adults had shorter FFD, GD, and TT compared with second graders. Similarly, we found a main effect of condition; nouns in the ID condition were read faster, and those in the CTL condition were read slower, compared with the TL condition. None of the interactions was significant after Bonferroni correction. The analysis of variance showed that the main effects of group and condition were significant (*p*s <.001) and that the interactions were not significant in any of the eye movement measures. The pairwise comparisons among groups and conditions showed no significant difference between the ID and TL conditions in any measure for all participant groups. However, all groups had longer GD and TT in the CTL condition compared with the TL condition (see Table 2). Slope contrasts for GD in second graders were *Est.* = 0.08, *SE* = 0.02, *z* ratio = 3.48, *p* =.02, in fourth graders they were *Est.* = 0.13, *SE* = 0.03, *z* ratio = 5.19, *p* <.001, and in adults they were *Est.* = 0.09, *SE* = 0.02, *z* ratio = 4.35, *p* <.001. Slope contrasts for TT in second graders were *Est.* = 0.15, *SE* = 0.03, *z* ratio = 5.89, *p* <.001, in fourth graders they were *Est.* = 0.12, *SE* = 0.03, *z* ratio = 4.33, *p* <.001, and in adults they were *Est.* = 0.11, *SE* = 0.02, *z* ratio = 4.55, *p* <.001.

Discussion

We aimed to investigate reliance on phonological and orthographic parafoveal information during silent reading in Russian-speaking 8-year-old children in Grade 2, 10-year-old children in Grade 4, and adults using the gaze-contingent boundary paradigm. Overall, the results revealed that all participants relied on orthographic information and did not use phonological information from the parafovea.

Specifically, we found that both children and adults had comparable fixation durations in the pseudohomophone preview condition and in the control for the pseudohomophone preview condition. These findings indicate that Russian readers do not preprocess phonological information from upcoming words, unlike English and French adults as well as English and German children who relied on phonological information in the parafovea (Ashby et al., 2006; Miellet & Sparrow, 2004; Milledge et al., 2022b; Tiffin-Richards & Schroeder, 2015). Our results for the phonological preprocessing in adults partly contradict the predictions of the multiple-route model, which presumes that phonological recoding skills are inherent to skilled readers (Grainger et al., 2012). In addition, we found that fourth graders and adults slowed down in the PsH condition compared with the ID condition, whereas second graders seemed not to notice the difference between these conditions. It means that letter

Table 2
Back-transformed average fixation durations (in milliseconds), 95% confidence intervals, and preview effects for three eye movement measures for children in Grade 2, children in Grade 4, and adults.

	Phonological preview effects		
	First fixation	Gaze duration	Total time
Children in Grade 2			
Identical	291 (282–301)	453 (436–471)	608 (584–633)
Pseudohomophone	295 (285–305)	482 (462–503)	642 (619–665)
Control	298 (287–310)	485 (470–502)	664 (642–687)
ID − PsH (*pirog* − *pirok*)	−4	−29	−34
CPsH − PsH (*pirob* − *pirok*)	3	3	22
Children in Grade 4			
Identical	232 (225–239)	279 (270–287)	350 (338–362)
Pseudohomophone	253 (244–262)	318 (309–328)	392 (379–406)
Control	258 (249–267)	326 (316–336)	405 (393–418)
ID − PsH (*pirog* − *pirok*)	−21**	−39***	−42***
CPsH − PsH (*pirob* − *pirok*)	5	8	13
Adults			
Identical	200 (196–204)	213 (208–218)	248 (241–255)
Pseudohomophone	216 (211–221)	233 (228–238)	273 (266–281)
Control	225 (220–229)	244 (239–249)	289 (282–296)

(*continued on next page*)

ID − PsH (*pirog* − *pirok*)	−16**	−20**	−25**
CPsH − PsH (*pirob* − *pirok*)	9	11	16
	Orthographic preview effects		
	First fixation	Gaze duration	Total time
Children in Grade 2			
Identical	291 (281–301)	453 (436–471)	608 (585–631)
Transposed-letter	288 (276–301)	476 (457–495)	610 (588–632)
Control	307 (297–317)	520 (501–540)	714 (686–743)
ID − TL (*pirog* − *priog*)	3	−23	−2
CTL − TL (*pleog* − *priog*)	19	44*	104***
Children in Grade 4			
Identical	231 (225–238)	279 (272–286)	350 (339–362)
Transposed-letter	245 (238–251)	294 (287–301)	361 (350–372)
Control	260 (253–267)	336 (324–347)	408 (393–424)
ID − TL (*pirog* − *priog*)	−14	−15	−11
CTL − TL (*pleog* − *priog*)	15	42***	47***
Adults			
Identical	200 (196–204)	213 (208–218)	249 (242–256)
Transposed-letter	205 (200–209)	220 (216–225)	261 (253–269)
Control	218 (213–223)	243 (237–248)	290 (282–300)
ID − TL (*pirog* − *priog*)	−5	−7	−12
CTL − TL (*pleog* − *priog*)	13	23***	29***

Note. Confidence intervals are in parentheses. Gray cells represent the pseudohomophone (PsH) and transposed-letter word (TL)

preview benefit effects. Significance was estimated using the package 'emmeans'. ID, identical; CPsH, control for pseudohomophone; CTL, control for transposed-letter word.
*p <.05.
**p <.01.
***p <.001.

substitution in the PsH condition was notable for fourth graders and adults, who consequently might rely on orthography more than second graders.

The strongest evidence for the use of orthographic preprocessing in parafovea in all age groups is that the CTL condition provoked longer reading time than the TL condition in all fixation durations for all three groups of participants. These findings match the results of English and German studies where adults relied on orthography in the parafovea (Johnson et al., 2007; Tiffin-Richards & Schroeder, 2015) as well as the results of English studies where children had an orthographic preview benefit (Johnson et al., 2018; Milledge et al., 2021; Pagán et al., 2016). At the same time, the post hoc comparisons of gaze duration and total time reading in the ID and TL conditions did not differ for both adults and children. Together, these results revealed that Russian readers are sensitive to the letter identity information but are not sensitive to the letter position information. This pattern meets the predictions of the multiple-route model (Grainger et al., 2012). According to this model, reliance on letter position decreases due to the development of parallel letter processing in which fast word retrieval is more important than accurate letter position processing. Furthermore, our results match the findings of Milledge et al. (2021) and Pagán et al. (2021), who concluded that both adults and children encode internal letter information flexibly.

Despite similar orthography consistency in Russian and German (Landerl et al., 2013), the absence of reliance on phonology and the overall reliance on orthography in the parafovea in Russian second graders, fourth graders, and adults conflicts with the findings from German that postulate a change from a greater reliance on phonology in second graders to a greater reliance on orthography in adults (Tiffin-Richards & Schroeder, 2015). Still, fourth graders and adults may rely on orthography more than second graders, who notice only the substitution of two letters of the word (the only difference found was in the TL and CTL conditions). The difference in the results between Russian and German may be caused by the difference in preview changes. Tiffin-Richards and Schroeder (2015) substituted vowels in the PsH and CPsH conditions, whereas we substituted consonants, which might cause greater disruption for our participants than for German adults and children (Lee et al., 2002). It is worth mentioning that the results of the orthographic preview benefit in German indicated that children had a TL preview benefit in single fixation duration, similarly to adults. Because the preview benefit was found only in this measure, the authors concluded that children did not rely on orthography. However, it is also possible that German 8-year-old children partly rely on orthographic information in the parafovea at the very early preprocessing stage, which is in line with our results. Moreover, it is possible that Russian children rely on phonology, similarly to German children, but earlier than in Grade 2.

Conclusions

We found that 8-year-old and 10-year-old Russian children already use orthographic parafoveal preprocessing, similarly to adults, whereas none of the participant groups use phonological parafoveal information. We revealed that the adult-like pattern of reliance on parafoveal information during reading appears already in Grade 2. Unlike previous studies, our study showed that children and adults might use the same types of information during parafoveal processing, so the pattern could vary across languages and orthographies.

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Data availability

The data that support the findings of this study and the materials are openly available in the Open Science Framework at https://osf.io/6gnxe/.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2022.105571.

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