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Parafoveal processing of inflectional morphology on Russian nouns

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ABSTRACT
The present study investigated whether inflectional morphology on Russian nouns is processed parafoveally during silent reading. The boundary-change paradigm [Rayner, K. (1975). The perceptual span and peripheral cues in reading. *Cognitive Psychology*, *7*, 65–81] was used to examine parafoveal processing of nominal case markings of Russian nouns. The results yielded preview *cost* for morphologically related preview in gaze duration (vs. an identical baseline) and in total time (TT) (vs. a non-word baseline) and preview *benefit* in regressions out of the target word. The contribution of the study is two-fold. First this is the first demonstration that bound nominal inflectional morphemes are processed parafoveally in a language with linear concatenated morphology (Russian). Second the observed preview effects suggest that parafoveal preview of a morphologically related word was processed fully in the parafovea and interfered with the integration of the target word into the syntactic structure of the sentence.

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Parafoveal processing; Russian; eye-movements; morphological processing

Introduction

Reading is one of the most complex cognitive activities people engage in (Huey, 1908/1968). Reading a word requires that it be identified and processed on multiple levels: orthographically, phonologically, morphologically, syntactically, and semantically. Words also need to be integrated into larger units —sentences. Evidence suggests that many of the cognitive processes involved in reading are interactive. It takes around 50 ms to relay the visual features from the printed page through the retina to the brain (Clark, Fan, & Hillyard, 1994; Foxe & Simpson, 2002; Reichle & Reingold, 2013; VanRullen & Thorpe, 2001). Consequently, it takes time to program an eye movement (saccade) to the next location on the page. Attention thus shifts to the saccade target before the eyes fixate it (see Figure 1). Information is obtained during any given fixation not only from the word being fixated, but also from a word or two to the right of fixation, i.e. from the parafovea (see Rayner, 1998, 2009; Schotter, Angele, & Rayner, 2012).

Researchers disagree about the type of information available for processing in the parafovea, an area that extends from 1 to 5 degrees from the centre of fixation. A productive paradigm for examining information processing in the parafovea, the gaze contingent boundary-change paradigm (Rayner, 1975), was used in the experiment reported here. In eye-tracking experiments using the boundary-change paradigm, an invisible boundary is placed in the text preceding a target word (n). Prior to the eyes fixating word n, it may appear in some altered form (see Figure 2); this form is visible in the parafovea as the eyes are fixated on the immediately preceding word ($n-1$). As the eyes saccade across the boundary, the preview word is replaced with a target word automatically by the computer controlling the eye tracker.

Participants normally do not notice the change due to saccadic suppression (Matin, 1974). The critical dependent variables are fixation durations on the target word. Generally, the fixation time on the target is faster when the preview was identical to the target or similar in certain ways (see discussion below) compared to a non-word or unrelated word (baseline) preview. In this case, the difference

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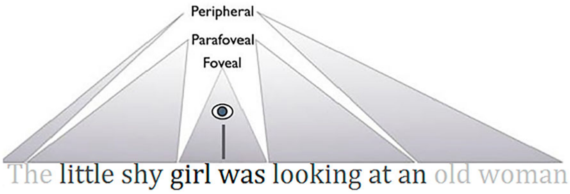

Figure 1. The foveal, parafoveal, and peripheral regions when three characters make up 1° of visual angle. The eye icon and the line point to the location of the fixation (adapted from Schotter et al., 2012).

Yesterday a girl saw the woman| outside of the supermarket.

Yesterday a girl saw the woman| cnfaebi of the supermarket.
+
Yesterday a girl saw the woman| outside of the supermarket.
+

Figure 2. The + sign shows the location of the eye during a fixation on the line above the +. The vertical line shows the location of the invisible boundary.

between helpful preview and unhelpful preview in processing time on word *n* is called a preview *benefit* effect.

Studies that have measured the preview benefit for a valid preview condition have established that low-level information is processed parafoveally. More specifically identification of orthographic codes (Balota, Pollatzek, & Rayner, 1985), abstract letter codes (Johnson, 2007; Johnson, Perea, & Rayner, 2007; McConkie & Zola, 1979; Rayner, McConkie, & Zola, 1980), phonological codes (e.g. Ashby, Treiman, Kessler, & Rayner, 2006; Chace, Rayner, & Well, 2005), and syllable codes (Ashby & Rayner, 2004; Fitzsimmons & Drieghe, 2011) have yielded a preview *benefit* effect compared to the unrelated baseline. In these and similar studies, a preview benefit effect is observed during first-pass measures (single fixation (SF), first fixation (FF), and gaze duration (GD)) that are considered measures of early word identification stages. Consequently, the consensus in the field, based on these studies, is that the above mentioned low-level factors facilitate lexical access (Schotter et al., 2012).

However, there are two caveats with this approach that are being re-examined in the literature on parafoveal processing in reading. First, a few researchers have demonstrated a preview *cost* measured by an increase in reading time for some invalid conditions. For example, Kliegl, Hohenstein, Yan, and McDonald (2013) and Marx, Hawelka, Schuster, and Hutzler (2015) report disruptions in processing time as measured by inflated fixation durations on word *n* compared to a baseline. This preview cost is observed in first-pass measures traditionally associated with early stages of word identifications: SF, FF, and GD. These results suggest that parafoveal preview may not only facilitate but also interfere with lexical access of the target word *n*. This finding questions the traditional view that the sole utility of the parafoveal information is for it *to be integrated* (e.g. Pollatsek et al., 1992; Rayner, 1975) with the foveal information during reading. Instead, the emerging evidence of preview cost points toward a view that information that is available in the parafovea can *independently* influence the processing of the target word either by facilitating (preview *benefit*) or interfering (preview *cost*) with its lexical access (Schotter & Leinenger, 2016).

Second, letters, phonemes, and syllables cross-linguistically have different information density. For example, single English letters (if they are not an *I*, *a*, or *-s*) or syllables (if they are not inflectional morphemes such as *-ed* or *-ing*) are not usually syntactically informative. In a language like Russian, however, which has a shallow orthography and rich inflectional paradigm, letters and syllables, especially at the end of the words, bear semantic and syntactic information. As a result, when it comes to higher-level processing, cross-linguistic differences may emerge in the relative utility of apportioning attentional resources to various features of the input.

Morphology has been found to be processed parafoveally in Hebrew and Korean (Deutsch, Frost, Pelleg, Pollatsek, & Rayner, 2003; Deutsch, Frost, Pollatsek, & Rayner, 2005; Kim, Radach, & Vorstius, 2012). Perceptual bias seems to be able to account for the observed effects in both of these languages. Hebrew, like other Semitic languages (e.g. Arabic), has non-concatinative morphology with root and suffix patterns that are very closely intertwined. Consequently, root morphemes have rigid conditional probabilities for the sequences of consonant letters, rendering root morphemes very salient for readers (e.g. Velan & Frost, 2011). Furthermore, verb morpheme patterns are also salient, with only seven morpheme patterns compared to hundreds of nominal patterns. Deutsch et al. demonstrated parafoveal processing for root (2003) and verb but not noun morphemes (2005). Although Korean has concatinative morphology, the writing system is a hybrid syllabary-alphabet that is compact horizontally. Kim et al. (2012) observed morphological processing in the parafovea, signalled by disruptions in foveal processing when the preview was either phonologically incorrect (i.e. correct case in an inappropriate phonological realisation) or syntactically incorrect (i.e. inappropriate case marker). The authors speculated that the left-branching structure of Korean and the associated extensive left-embedding that is possible in left-branching languages (Mazuka & Lust, 1990) place a premium on parafoveal processing, as upcoming case markers allow readers to determine clause boundaries. Thus, the evidence from languages in which morphology is processed parafoveally implicates a combination of low-level (e.g. writing system features) and higher-level (e.g. saliency of syntactic linguistic structures) factors that can account for the results.

In contrast, derivational morphology in English (Kambe, 2004; Lima, 1987), and Malay (Winskel & Salehuddin, 2014), as well as compound nouns in Finnish (Bertram & Hyona, 2007; Hyöna, Bertram, & Pollatsek, 2004) modulate word identification only after the eyes fixate directly on the target words in these languages (foveal processing). Lima (1987) examined effects of partial preview where only a prefix was available (rexxxx) on the processing of a prefixed verb (*remind*) and pseudoprefixed verb (*relish*) in comparison with the full (identical) preview and did not find any significant difference between the partial availability of the prefix on prefixed or pseudoprefixed verbs. The author concluded that the processing of prefixes is a foveal rather than parafoveal process. Kambe (2004) found that a non-word preview that shared a prefix (*rehsxc*) or stem (*zvduce*) with the target (*reduce*) obtained significant parafoveal preview benefit only for the whole word (identical) condition. The author argued against morphological processing in the parafovea and attributed the source of facilitation obtained in the manipulated identical condition to the abstract letter code. Analogously, Winskel and Salehuddin (2014) found identical preview benefit for prefixed Malay nouns (*pelari*) and orthographic controls (*pelita*), while an affix (pexxxx) condition did not differ significantly from the control (xxxxxx). Finally, Bertram and Hyona (2007) showed that identical previews for Finnish compounds *toimintakyky*/toiminta—action; kyky—ability to/did not yield a preview benefit compared to a non-word preview in which the first three letters remained the same as the target word (*toi*zxddidqyh). However, it is also possible that the use of *x*es and letters in the non-word preview conditions in these studies were overly strong manipulations that inhibited any effects induced by prefix or stem previews (Hutzler et al., 2013; Taft, 2004). Additionally, in terms of saliency, derivational prefix *re-* might not be the best option for English. Inflectional phoneme *-ed* is more salient (Brown, 1973; Slobin, 1985), but whether it is processed parafoveally in English is still an open question. For Malay, there are 25 derivational affixes and only 2 inflectional affixes (Prentice, 1987). From the saliency perspective, the inflectional affixes have a higher chance of being integrated parafoveally, but they have not been tested. For an agglutinative language like Finnish, morphemes bear more than just purely grammatical information. The compounds that were tested in Finnish (Bertram & Hyona, 2007; Hyöna et al., 2004) bear more semantic information, and as such are arguably less syntactically salient than the morphemes tested in Hebrew. Thus, evidence from languages with shallow alphabetic scripts and linear concatenated morphology seems to suggest that such higher-level linguistic information as derivational and compound morphology is not processed parafoveally.

An open question remains whether inflectional morphological information is accessible for parafoveal processing in languages with concatinative morphology, shallow alphabetic scripts, and flexible word order, where morphology provides a more reliable cue than linear order to syntactic roles. To answer this question, we examine Russian, an Indo-European language with linear concatenated morphology (similar to English), relatively free word order (similar to Finnish), and an alphabetic orthography (Cyrillic) that has not yet been examined in this regard.

Relevant characteristics of Russian

Inflectional morphology

Russian is morphologically rich, with obligatory inflectional paradigms for nouns, adjectives, verbs, numerals, and pronouns. The declensional paradigm for nouns is based on grammatical gender: masculine, feminine, and neuter. While masculine gender is considered the default (larger) class taking approximately 46% of the lexicon, feminine class is the second largest (41%) followed by neutral (13%) (e.g. Akhutina et al., 2001; Comrie, Stone, & Polinsky, 1996, among others). There are also six cases. Table 1 illustrates the declension for nouns of first class singular, as only nouns from this class were used in the present experiments because the word forms for the agent (subject; word form in the nominative case) and the recipient (object; word form in the accusative case) are equal in length. Only singular feminine nouns were used in the experiments reported below.

Russian has 11 verb classes, ranging in morphological complexity and size. Russian verbs consist of a stem and an inflection. The stem reveals semantic information and inflection communicates such features as gender, person, and number. We used the verbs in the past-tense singular forms in the experiment (see Table 2 for an example of a complete conjugational paradigm) to increase the expectation of the single feminine nouns since only verbs in the past form provide clues for both gender and person (non-past verbs only mark for person: singular vs. plural, but not gender). Reference to the past using perfective aspect (used in the experimental stimuli) is prototypical according to language acquisition (Avrutin, 2000, 2006; Gagarina, 2004; Stoll, 1998) and experimental data (Dragoy & Bastiaanse, 2013). Importantly, only transitive verbs were used in this study. This means that the verb requires two singular arguments, and at least one of them (the subject) has to be feminine.

Word order

Russian allows all six basic word orders (SVO, OVS, VOS, VSO, SOV, OSV) but is canonically SVO (Babyonyshev, 1996; but cf. King, 1995 for arguments in favour of VSO). As such, syntactic subject in Russian is not determined by, or confounded with, word order. Suffixed nominal case markers convey thematic roles. For example, although the constituent order in both (1a) and (1b) is VP-NP-NP, (1a) asserts that *A woman saw a girl*, whereas (1b) asserts that *A girl saw a woman*; the thematic roles are signalled by the nominative and accusative case markers on each noun.

(1a) Увидела женщин**а** девочк**у**.
Saw $_{3rdPsSG}$ woman$_{NOM}$ girl$_{ACC}$.
(1b) Увидела женщин**у** девочк**а**.
Saw $_{3rdPsSG}$ woman$_{ACC}$ girl$_{NOM}$.

In the experiments reported in this study we examined VP-NP-NP word orders ((1a) and (1b)), because corpora data (Bivon, 1971; Kempe & McWhinney, 1999; Lobanova, 2011) suggest that the VP is equally likely to be followed by the subject or the object: VSO (50%), VOS (50%). Thus, in a VP-initial string, the case/role of the first noun has a 50/50 chance of being the syntactic subject or the syntactic object.

Table 1. Example of the declension paradigm for the nouns of first class.

Cases	"doll"
Nominative	Кукл**а** */kukla/*
Genetive	Кукл**ы** */kukly/*
Dative	Кукл**е** */kukle/*
Accusative	Кукл**у** */kuklu/*
Creative	Кукл**ой** */kukloj/*
Instrumental	Кукл**е** */kukly/*

Table 2. Example of the conjugation paradigm for a verb ждать /zhdat'/ "to wait" in the past tense.

	Singular		
Person	Masculine	Feminine	Plural
First	ждал */zhdal/*	ждал**а** */zhdala/*	ждал**и** */zhdalee/*
Second	ждал */ zhdal /*	ждал**а** */zhdala/*	ждал**и** */zhdalee/*
Third	ждал */ zhdal /*	ждал**а** */zhdala/*	ждал**и** */zhdalee/*

Morphosyntactic processing in Russian

Evidence suggests that Russian morphology is processed early and used to anticipate upcoming structure (Fedorenko, Babyonyshev, & Gibson, 2004). Native Russian speakers are also sensitive to the syntactic canonicity of the argument positions. In a self-paced reading study, Slioussar (2011) demonstrated that native speakers in a self-paced reading paradigm processed syntactic arguments in non-canonical positions (pre-verbal objects and post-verbal subjects) more slowly than in canonical positions (pre-verbal subjects and post-verbal objects). However, animacy information can outweigh less informative (ambiguous) inflectional morphology of the Russian nouns in the processing of non-canonical (NP-NP-VP and VP) sentences (Stoops, Luke, & Christianson, 2014). The emerging picture suggests that inflectional morphology, when informative, is a salient cue to the interpretation of the message. However, self-paced reading differs in several ways from normal silent reading. In self-paced reading, the whole sentence is not available at once, and the position of the eye at any given moment is not known. It is therefore impossible to measure in self-paced reading whether any parafoveal processing occurs. This study is the first to examine parafoveal processing in Russian using eye-tracking.

Rationale and predictions

The present experiment measured eye movements as reflections of cognitive processes during reading (Rayner, 1998, 2009). It is widely accepted that the movement of the eyes through text is directed by cognitive control (Rayner, 1998, 2009); however, the exact relationships between eye movements and underlying cognitive processes are not yet completely understood. Under the E-Z Reader model of eye movement control in reading (Reichle, Liversedge, Pollatsek, & Rayner, 2009; Reichle, Warren, & McConnell, 2009), it is proposed that eye movements are triggered by lexical identification of the currently fixated word; once the previously fixated word ($n - 1$) has been sufficiently identified, attention shifts covertly to the target word (n), at which point low-level information is processed parafoveally before the eyes fixate word n. This parafoveal pre-processing is hypothesised within E-Z Reader to inform decisions about the length of the saccade that is to be programmed and also to initiate early lexical recognition processes. E-Z Reader is able to account for preview benefit effects that indicate that low-level information such as phonemes and syllables in English are processed parafoveally as part of this early word recognition process (e.g. Ashby et al., 2006; Fitzsimmons & Drieghe, 2011). Recently, Schotter, Reichle, and Rayner (2014) performed a simulation of semantic preview benefit for synonymous previews observed in English (Schotter, 2013) and reported that E-Z Reader reached the L2 stage of processing (the presumed semantic processing stage) 8% of the time. The simulation revealed that E-Z Reader predicts situations where higher-level (semantic in this case) information on the word n can be processed parafoveally, while the eyes are still fixating word $n - 1$. However, E-Z Reader (a model where the word is the unit of operation) was developed to account for word processing in English, a language with one highly dominant word order (SVO); thus, syntactic processing is not the main focus of this model. In its current inception there is a higher-level stage *I* (higher-level postlexical integration stage) that has been introduced (Reichle et al., 2009) but has not been fully specified or explicitly tested.

Alternatively, attention-gradient models of eye movements during reading (e.g. SWIFT, Engbert, Nuthmann, Richter, & Kliegl, 2005) postulate that several words can be processed at the same time, but the processing speed of the words that fall in the parafovea is a function of the eccentricity of the word n from the current fixation point. SWIFT additionally proposes two stages of word activation: rising and falling. As a result two words that are processed in parallel can be at two different stages of the identification process. An important caveat is that SWIFT was not intended as a model of syntactic processing; as such, it does not make clear-cut predictions about the processing of syntactic information that inflectional morphology signals.

A final challenge is to dissociate the processing of inflectional morphology from orthographic and word-level effects. In the experiment reported here, the non-word, identical, and related previews all share the same root and differ only by one final letter (e.g. лодк**д**/лодк**а**/лодк**у** [boat]). Thus the non-word preview should prime the lexical word identification (pre-activation of "boat") but not the role "a boat" plays in the sentence. The inflectional case markers "a" vs. "y" differentiate whether the entity in the sentence ("a boat") acted in some way or an action was done to it, whereas the non-word inflection "д" does not communicate any information regarding the role the target word plays in the sentence.

If observed, a traditional preview *benefit* effect for morphologically related previews compared with non-word previews, recorded usually in early first-pass measures (SF, FF, GD), would not conclusively show that it was morphological information and not simply lexical (word vs. non-word or root-priming) effects that facilitated recognition. By the same token, a preview *benefit* for the identical preview over the morphologically related preview compared with the non-word baseline could also be attributed to orthographic-level processing and not morphological processing per se (same word vs. different word). The inflectional morphology of the related preview that is tested here signals the opposite thematic role from the target. If processed fully in the parafovea, the morphologically related inflection should interfere with the current thematic role assignment that is being communicated by the inflection on the target word. As a result, it should manifest itself as a preview *cost* compared with the non-word and/or identical preview, possibly as early as GD if the thematic role information communicated by the morphemes tested here is used during lexical word identification stages, but mostly in later measures that include second-pass reading times and are associated with syntactic structure-building processes (e.g. total time (TT) and/or regressions).

Method

Participants

Fifty-four Russian native speakers (25 female; mean age = 32; range = 18–69) in the Champaign-Urbana area participated. Six participants were excluded from the analyses; five participants reported seeing the change manipulation, and one participant's eye movements could not be consistently tracked. Participants received $15 for their time.

Materials and design

The stimuli were 50 sets of sentences averaging 7 words in length (range 7–12) presented all in 1 line (see Appendix 1). There were three preview manipulations on the target word: identical (no change), morphologically related (different inflectional ending), and non-word (inflection replaced with a consonant). Short Russian nouns (five characters) served as stimuli for this experiment. They were controlled for word frequency ($M = 123$ per million words; $SD = 78$) and lexeme frequency ($M = 103$, $SD = 83$), according to the online frequency dictionary for Russian (http://www.artint.ru/projects/frqlist/frqlist-en.php). An example of the preview manipulations for one target noun in both syntactic positions is provided in (2a)–(2c). The target word was inserted into a VP-NP-NP sentence frame at the argument position immediately after the verb. The vertical lines indicate the position of the invisible boundary. When the eyes made a saccade across the boundary, the preview word was replaced with the target word.

(2a) *Identical*: В доке загородила| **лодка** доску у мостка.
In the dock blocked boat$_{NOM}$ log$_{ACC}$ by the bridge.

(2b) *Related*: В доке загородила| **лодку** доску у мостка.
In the dock blocked boat$_{ACC}$ log$_{ACC}$ by the bridge.

(2c) *Non-word*: В доке загородила| **лодкд** доску у мостка.
In the dock blocked non-word log$_{ACC}$ by the bridge.

"In the dock a boat blocked a log by the bridge."

Word order was held constant across conditions. The target noun appeared in post-verbal V**S**O position. In the control condition the non-word served as the preview. To form the non-word a non-descender inflection (*а*) was replaced with a descender (д). In the test conditions, inflections were replaced with the inflection indicating the object accusative case (a descender (у)) or with an identical inflection (*а*). Items were distributed across three lists in a Latin square design. Due to the relatively limited subject pool of native Russian speakers in the Champaign-Urbana area, this experiment was run concurrently with several other experiments that tested word orders different from the one reported in this manuscript. All sentences served as fillers for each other.

Norming studies

The plausibility of the sentential arguments as both subjects and objects was assessed in a separate norming procedure. Two sentences (VP-NP-NP) were constructed in such a way that the target word was the subject in one and object in another, while the second argument was always the opposite argument. Fifty experimental sentences were divided into two lists to ensure that the two versions of the same experimental sentence were in separate lists. Twenty-two Russian native speakers who did not take part in the eye-tracking experiment provided plausibility judgments on a 1–7 scale for each sentence. Experimental items had both a plausibility rating higher than 3 and an equal plausibility rating for both nouns with a mean plausibility score of 4.6 ($SD = 0.6$) on the 7-point scale. The norming study confirmed that both nouns were equally plausible as subjects and objects in the experimental sentence frames.

An additional norming study was carried out with the canonical word order (SVO) to assess that thematic relationship between the items did not change as a result of the non-canonical (VP-NP-NP) word order, ensuring that semantic information was held constant regardless of the syntactic frame. An additional 20 Russian native speakers who did not take part in the experiment provided plausibility judgments on a 1–7 scale for each sentence. Experimental items had both a plausibility rating higher than 3 and an equal plausibility rating for both nouns with a mean plausibility score of 5.2 ($SD = 1.7$) on the 7-point scale.

Plausibility ratings obtained from the two norming studies did not differ significantly (both *ps* > .1).

Measures

Because the study focused on examining word identification stages and integration of the target word into the syntactic structure of the sentence, the analyses included five major measures of fixation duration and three probability measures.

First-pass (early) reading measures:

SF. The duration of the fixation on the target word when only one first-pass fixation on the target word was recorded.

FF. The duration of the FF on the target word regardless of the number of first-pass fixations.

GD. The sum of all first-pass fixations on the target word.

Second-pass (late) measures:

Go-past time (*GPT*). Time spent reading the target word and any words prior to that after initially entering the target region until the eyes move past the target region.

TT. The sum of all fixations on the target word, including re-fixations after the eyes have moved to other words in the sentence.

Regressions into the target word (*R*). Count of times the eyes re-fixated the target word after moving off the word to the later parts of the sentence.

Probability measures:

First-pass fixation probability on the target.

Regressions out of the target to words earlier in the sentence.

Regressions in to the target from words later in the sentence.

Apparatus

Eye movements were recorded with an SR Research Eyelink 1000 eye tracker set to a 1000 Hz sampling rate, with a spatial resolution of 0.01°. Given the sampling rate of the eye tracker the display change occurred on average within 8 ms. Text was displayed in 14-point Courier New mono-space font. Participants were seated 72.5 cm away from a 20 inch LCD monitor with the refresh rate of 120 Hz. At this distance, approximately 3.03 characters subtend 1° of visual angle. Head movements were minimised with chin and head rests. Although viewing was binocular, eye movements were recorded only from the right eye.

Procedure

Participants' eye movements were calibrated using a 9-point calibration procedure; maximum variance allowed was 0.3°. After a 12-item practice session, each trial began with a gaze trigger, which consisted of a black circle presented in the position of the first character of the text. Once a stable fixation was detected on the gaze trigger, the sentence was presented in full. Participants pressed a button on a standard game controller to indicate that they had finished reading the sentence. At this point, the sentence disappeared. On 25% of the trials a question about the content of the sentence appeared, which participants answered by pressing the corresponding button on the controller. Sentences were presented in a random order for each participant. After the first 60 sentences, participants had an option to take a break. The entire session lasted on average less than 60 min.

Results and discussion

Data exclusion criteria

Fixation durations shorter than 80 ms or longer than three standard deviations from the target word grand mean for each subject were eliminated. These criteria resulted in the removal of less than 5% of the data. The number of characters differs as a function of letters per visual angle. Therefore, different viewing conditions will generally lead to a different number of letters falling within the perceptual span. Given the parameters of our experiment, the fovea consists of three characters ahead of fixation and three characters behind. Even if the reader was fixating the final character of the pretarget word, the fovea would only encompass the first two characters of the target word (and the intervening space). Given that the parafovea extends from 1 to 5 degrees from fixation (i.e. from 3 to 15 characters given the characters per degree), the case marking on the target word when viewed from the pretarget word would fall within the parafovea. As a result, we conclude that the effects reported here can be attributed to parafoveal processing and not foveal processing. Additionally, to ensure that the target case marking was available in the parafovea prior to the eyes crossing the boundary change, we excluded any trial that contained fixations that originated from a region outside of the pre-boundary region, which consisted of the area from the ninth character space to the left of the invisible boundary (a total of three trials).

Fixations for the target word (*n*), the word prior the target word ($n-1$), and the word after the target word ($n+1$) were analysed. No significant differences were obtained for words $n-1$ or $n+1$. Results reported below reflect eye movement measures for word *n*. Condition means and standard errors for the reading measures are provided in Table 3. Indications of statistical significance refer to the observed difference between the indicated mean and the mean in the non-word condition.

Reading time data were analysed using linear mixed-effects (LME) models and fixation probability measures were analysed with generalised LMM (GLMM) using the lme4 package (Version1.1–7; Bates, Maechler, Bolker, & Walker, 2014) in R (Version3.2.0; R Core Team, 2015). Model selection was hypothesis-driven, with two custom contrasts specified to ensure orthogonal comparisons for the two contrasts of interest: non-word vs. identical and related, and identical vs. related and non-word. Two models were run on the data: One to estimate the effects of the preview condition with the non-word baseline and the other to estimate the preview effects with the identical preview as a baseline. The models were identical in regard to the fixed effects and random structure. The only difference was the baseline condition: identical vs. non-word. As a result, the control contrast (non-word vs. identical) is the same across both models and differs only with the sign (+/−). The related preview contrast allowed us to tease apart preview effects for related as compared to identical and non-word conditions, respectively.

For all models, the random effect structure was fitted using likelihood ratio tests; all final models reported below had random intercepts and slopes for participants and items. To reduce model complexity, the correlations between the random effects were set to zero. Some models failed to converge with subject and item random slopes for the preview condition. Item random slopes were removed from these models (see Appendix 3). The LME models were fitted to untransformed and log-transformed fixation durations. The latter are in agreement with the model assumption of normal distribution of residuals and are reported in Appendix 2. Since the pattern of results was identical for both log-transformed and untransformed models, we report only untransformed models below to facilitate interpretation. See Tables 4 and 5 for model summaries.

Table 3. Mean (and *SE*) for reading measures on the target across conditions with related condition compared against identical and non-word baselines.

Measure	Preview condition: Identical		Related		Non-word
Fixation duration measures					
FF duration	261 (5.4)		268 (6.0)		262 (5.7)
SF duration	282 (6.7)		286 (7.9)		276 (6.6)
GD	320 (8.0)	*	**358** (**10.0**)		338 (8.8)
Go-past duration	426 (14.4)	*	**482** (**17.1**)		477 (15.1)
TT duration	614 (20.0)	*	**693** (**22.3**)	*	626 (20.6)
Fixation probability measures					
First-pass fixation	0.94 (0.01)		0.93 (0.01)		0.93 (0.01)
Regressions out	0.19 (0.02)		**0.17** (**0.02**)	*	0.23 (0.02)
Regressions in	0.25 (0.01)		0.26 (0.01)		0.26 (0.01)

Notes: Significant ($p < .05$) effects are indicated in bold.
*Indicates the difference between the baseline (identical or non-word) and the related conditions.

Fixation duration measures

None of the manipulations yielded significant results in the SF and FF.

Gaze

The identical condition did not differ from the non-word in both models ($t = -1.56$, $p = .12$; $t = 1.56$, $p = .12$). Morphologically related preview elicited a preview cost compared with the identical baseline ($t = 3.24$, $p < .01$) but did not differ from the non-word baseline ($t = 1.62$, $p = .10$). The results suggest the preview of the morphologically related case marker interfered with the word identification of the target word while the root overlap in the non-word preview facilitated word identification (e.g. **лодк-д** for **лодк-а**). Because there was no morphosyntactic information communicated by the last letter in the non-word preview, no traditional preview benefit was observed between the identical condition and non-word baseline.

GPT

The identical condition elicited a preview benefit effect compared to the non-word in both models ($t = -2.28$, $p < .01$; $t = 2.28$, $p < .05$). The contrast between morphologically related and identical previews in the model with the identical baseline yielded a significant ($t = 2.67$, $p < .01$) preview cost for the morphologically related preview compared with the identical preview. Morphologically related

Table 4. Results of the LME models for fixation duration measures.

		Model with non-word baseline			Model with identical baseline		
Measure	Contrast	*b*	*SE*	*t*	*b*	*SE*	*t*
FF duration	Intercept	**260.66**	**9.50**	**27.42**	**260.94**	**8.13**	**32.10**
	Control preview	0.28	7.98	0.03	−0.28	7.98	−0.03
	Related preview	6.56	7.86	0.83	6.28	7.37	0.85
SF duration	Intercept	**278.86**	**9.47**	**29.43**	**284.38**	**10.49**	**27.12**
	Control preview	5.52	9.48	0.58	−5.52	9.48	−0.58
	Related preview	11.38	11.12	1.02	5.85	9.63	0.61
GD	Intercept	**336.75**	**16.20**	**20.79**	**318.68**	**13.71**	**23.24**
	Control preview	−18.07	11.60	−1.56	18.07	11.60	1.56
	Related preview	18.32	11.29	1.62	**36.39**	**11.23**	**3.24***
Go-past duration	Intercept	**474.89**	**22.43**	**21.17**	**425.23**	**22.83**	**18.62**
	Control preview	**− 49.66**	**21.81**	**− 2.28**	**49.66**	**21.81**	**2.28**
	Related preview	4.97	22.16	0.22	**54.63**	**20.43**	**2.67***
Total duration	Intercept	**624.54**	**38.15**	**16.37**	**612.40**	**38.44**	**15.93**
	Control preview	−12.14	25.54	−0.47	12.14	25.54	0.47
	Related preview	**65.38**	**27.92**	**2.34**	**77.53**	**26.90**	**2.88***

Note: Significant ($p < .05$) effects are indicated in bold.
*$p < .01$.

Table 5. Results of the generalised LME models for fixation probability measures.

		Model with non-word baseline			Model with identical baseline		
Measure	Fixed effect	*b*	*SE*	*z*			
First-pass fixation	Intercept	**3.74**	**0.45**	**8.26**	**3.89**	**0.46**	**8.41**
	Control preview	0.15	0.31	0.48	−0.15	0.31	−0.48
	Related preview	−0.01	0.31	−0.05	−0.27	0.31	−0.53
Regressions out	Intercept	**− 1.30**	**0.16**	**− 8.12**	**− 1.55**	**0.17**	**− 9.25**
	Control preview	−0.28	0.18	−1.37	0.28	0.18	1.37
	Related preview	**− 0.38**	**0.18**	**− 2.06**	−0.13	0.19	−0.70
Regressions in	Intercept	**− 1.12**	**0.11**	**− 9.99**	**− 1.17**	**0.11**	**− 10**
	Control preview	−0.05	0.05	−1.04	0.05	0.05	1.04
	Related preview	0.01	0.05	0.30	0.07	0.05	1.49

Note: Significant ($p < .05$) effects are indicated in bold.

previews did not differ from non-word previews ($t = 0.22$, $p = .36$), suggesting that at this point both the related and non-word previews were equally disruptive.

TT

A significant preview cost for the morphologically related condition (non-word baseline: $t = 2.32$, $p < .05$; identical baseline $t = 2.88$, $p < .01$) indicates that the related preview elicited significantly longer viewing times than the non-word and identical conditions, which did not differ from each other ($t = -0.47$, $p = .81$; $t = 0.47$, $p = .81$). TT on targets were on average 67 ms longer in the related condition (accusative case) compared to non-word condition. This result represents "a preview cost", rather than benefit, as the effect was inhibitory, not facilitatory. Previously only preview *benefit* for an identical condition has been reported in TT across different languages (e.g. Schotter & Jia, 2016; Yang, Li, Wang, Slattery, & Rayner, 2014; synonymous preview benefit Schotter, Lee, Reiderman, & Rayner, 2015; orthographic control preview benefit Veldre & Andrews, 2015) and preview *cost* for an unrelated word as compared with an identical baseline (Risse & Kliegl, 2014). To our knowledge this is the first time preview *cost* for morphologically related preview is reported as late as TT, calling for more targeted investigation of syntactic context on word identification in silent reading. We speculate on the interplay between lexical identification, morphological processing, and syntactic structure-building in the Conclusion and General discussion sections.

Fixation probability measures

First-pass fixation probability and regressions in did not yield significant results.

Regressions out

The non-word preview condition did not differ from the identical condition ($t = -1.04$, $p = .13$; $t = 1.04$, $p = .13$). A significant preview *benefit* for the morphologically related condition as compared with the non-word baseline ($t = -2.19$, $p < .05$) was observed (identical baseline: $t = 1.49$, $p = .16$). The related preview elicited significantly fewer regressions out of the target to the earlier parts of the sentence than the non-word or identical previews. The morphologically related preview elicited cost over the identical baseline as early as GD that persisted through the second-pass measures of GPT and TT. These results suggest that the related inflection was processed fully in the parafovea and the disruption to the processing observed as early as GD persisted through later measures of reading and reached significance in the TT. Participants moved their eyes to the earlier parts of the sentence significantly less in the morphologically related condition possibly *because* they spent more time on the target trying to work out the discrepancy between the preview and the target. However such a causal relationship is speculative and needs to be studied further in the future. Inhibition in TT and facilitation manifested in reduced regression rates suggest that these measures might reflect syntactic structure-building processes, calling for further examinations of later measures of visual word identification across languages.

Conclusions and general discussion

The experiment reported here examined whether Russian nominal inflectional morphology is processed parafoveally during silent reading. The results reported above provide the first demonstration that inflectional morphology can be processed parafoveally in an Indo-European language with linear morphology and a shallow alphabetic script.

Effects of the preview condition were not seen in SF or FF duration measures. GD revealed a preview cost for the morphologically related preview as compared with the identical condition, while the non-word preview did not differ from the identical or morphologically related conditions. A typical preview benefit effect for the identical condition was observed in go-past times. The morphologically related preview yielded significant effects in late second-pass measures: TT, where the related condition generated strong inhibitory effects compared to the non-word condition, and a preview benefit in regressions out. This pattern of results suggests a much stronger association between bottom-up low-level word identification processing and top-down anticipatory syntactic processing than have been previously assumed.

There is emerging evidence in the literature that higher-level linguistic information, such as the semantic predictability of the words, can yield preview benefit effects in late second-pass reading measures. Schotter (2013) showed that a highly predictable semantic context might facilitate semantic parafoveal processing of word *n* while the eyes are still on the word $n - 1$. Furthermore, Schotter et al. (2014) account for such higher-level parafoveal processing on the not-yet fixated word within E-Z Reader, assuming there is enough time to do so prior to the saccade off of word *n*. Syntactic context represents another higher-level processing cue that readers are quite successful in anticipating (Luke & Christianson, 2016). In fact, recent models of language processing employ structural prediction as the lynchpin of fluent, real-time comprehension (cf. Christiansen & Chater, 2016).

In a language like Russian, in which word orders are flexible and nearly every word in every grammatical class is inflected in some way, structural anticipation, to the extent to which it occurs, may require parafoveal examination of those inflections. Moreover, the inflections, when salient, might be used to facilitate lexical word identification. Based on the results here, we speculate that across word boundaries, structural anticipation modulates lexical identification processes. For this reason, a structurally acceptable preview interfered with the target word identification as early as GD. The preceding word, a transitive verb, required two arguments. The morphologically related preview was identified lexically in the parafoveal visual field while the eyes were still fixating the verb (word $n - 1$). Lexical access of word *n* included a thematic role that was different from the target thematic role. Then, upon fixation of the target, its correct morphosyntactic features indicated a conflict between preview and current case marking that needed to be resolved. The related case marker had been integrated completely (or nearly completely): "boat" was activated along with the information that the boat was the recipient of the action. This information was integrated parafoveally, but then yielded a cost in GD because the case marking on the target identified "boat" as the agent of the action denoted by the preceding verb.

We propose the non-word prime facilitated the activation of the target word due to the four letter overlap; however, critical morphosyntactic information that indicates the thematic role of the target word in the sentence (agent or patient/recipient) was not available in the non-word preview. As a result this generated inhibitory effects in go-past durations only because that prime, consisting of non-morphology, was not differentiated at the morphological level from the stem and thus did not enter into any predictions about upcoming structure and thus did not need to be inhibited later. The non-word also activated the lexical semantics of "boat", but the informative inflectional case marker was a letter that did not carry any morphosyntactic information with it. Therefore, the non-word did not elicit a cost in GD as compared with the identical baseline because no attempt was made to integrate the target into the unfolding syntactic structure until later—specifically, a cost for the non-word as compared with the identical preview did arise in GPT. It remains to be seen whether this is true for all word orders and all nouns in Russian. But for short Russian nouns with very salient (unambiguous) case markers (e.g. first class feminine gender), this seems to be the case.

Due to the confounding of linear order and grammatical function in the present materials, however, we cannot say for certain whether the observed effects would be found on all syntactic subjects, no matter their position (perhaps in order to check subject-verb agreement morphology), or on all first nouns (in support of structural prediction), or whether such effects are restricted to the feminine nouns (due to a more salient/marked morphological paradigm). An additional limitation of the study is the lack of a more typical non-word control that does not include root overlap (e.g. *лодка-псцнв*) as an additional baseline to track pure orthographic processing. This was an intentional restriction motivated by the limited pool of participants that affected the scope of our study. Future research, possibly with collaborators in Russia, will address this limitation of the present work.

The experiment reported here reveals a highly interactive relationship between higher-level factors and word identification processes during silent reading in Russian. Readers use parafoveally integrated nominal inflectional morphology for lexical identification of short Russian nouns and for subsequent message-level integration. Our experiment suggests that Russian readers can do so largely in contexts in which the upcoming structure cannot be reliably predicted based on previous context.

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Appendix 1. Experimental stimuli

Stimuli are created from the base sentence (VSO), different previews for the target word are in bold.

В доке загородила **лодка** доску у мостка.

"In the dock, **a boat** blocked a log by the bridge"

Identical preview: В доке загородила **лодка** доску у мостка.

Morphologically related preview: В доке загородила **лодку** доску у мостка.

Non-word preview: В доке загородила **лодкд** доску у мостка.

The rest of the stimuli are given in the base (SVO) form with a target word in bold. Translations are given in two forms: word for word with arguments marked for the syntactic role and following English SVO word order.

Item	Sentence
1	Еле-еле задержала **стена** крышу от распада в разрушенном доме. Barely stopped wall$_{NOM}$ roof$_{ACC}$ from collapsing in the demolished building. "A wall barely stopped a roof from collapsing in a demolished building."
2	Он верил, что прекратила **наука** войну и старался всех в этом убедить. He believed that ended science$_{NOM}$ war$_{ACC}$ and tried to persuade everybody. "He believed that science ended war and tried to persuade everybody to agree with him."
3	В коридоре прикрыла **сумка** шапку лежащую на стуле. In the hall covered bag$_{NOM}$ hat$_{ACC}$ lying on the table. "In the hall, a bag covered a hat that was lying on the table."
4	В этой сказке пригласила **цифра** букву померяться силами. In this tale invited number$_{NOM}$ letter$_{ACC}$ to test who is stronger. "In this tale, a number invited a letter to test who is stronger."
5	По легенде попросила **волна** скалу спрятать её от ветра. According to the legend asked wave$_{NOM}$ cliff$_{ACC}$ to hide it from the wind. "According to the legend, a wave asked a cliff to hide it from the wind."
6	В кухне догнала **мышка** крысу и первая схватила сыр. In the kitchen raced mouse$_{NOM}$ rat$_{ACC}$ and first took the cheese. "In the kitchen a mouse raced a rat and took the cheese first."
7	У малыша достала **ручка** ножку очень легко. Baby's touched hand$_{NOM}$ foot$_{ACC}$ easily. "A baby touched his own foot easily."
8	Все считали, что продолжила **пьеса** книгу очень удачно. Everybody believed that continued play$_{NOM}$ book$_{ACC}$ very successfully. "Everybody believed that a play was a good sequel to the book."
9	В сарае заслонила **труба** печку в углу у стены. In a shed blocked pole$_{NOM}$ oven$_{ACC}$ in the corner by the wall. "In a shed, a pole blocked an oven in a corner by the wall."
10	Все видели, что задела **бомба** плиту во дворе разрушенного дома. Everybody saw that touched bomb$_{NOM}$ block$_{ACC}$ in the yard of a demolished house. "Everybody saw that a bomb touched a block in the backyard of a demolished house."
11	Из-за несогласованности прервала **пауза** песню в прямом эфире. Due to a lack of coordination interrupted pause$_{NOM}$ song$_{ACC}$ on the air. "Due to a lack of coordination, a pause interrupted a song on the air."
12	В тот вечер остановила **толпа** банду на площади перед банком. That evening stopped crowd$_{NOM}$ gang$_{ACC}$ in the square by the bank. "That evening a crowd stopped a gang in a square by the bank."
13	На яхте соединила **кухня** каюту с выходом на палубу. On a yacht connected kitchen$_{NOM}$ bedroom$_{ACC}$ with an exit to the deck. "On a yacht the kitchen is connected to a bedroom with an exit to the deck."
14	Было слышно, как задела **ложка** чашку и покатилась по столу. It could be heard how touched spoon$_{NOM}$ cup$_{ACC}$ and rolled on a table. "It could be heard how a spoon touched a cup and rolled on a table."
15	В темноте осветила **лампа** свечу на окне и стул в углу. In the dark lit up lamp$_{NOM}$ candle$_{ACC}$ in the window and a chair in the corner. "In the darkness, a lamp shed light on a candle in the window and a chair in the corner."
16	С моря загородила **башня** сосну на горе у леса. From the sea blocked tower$_{NOM}$ pine tree$_{ACC}$ on a mountain by the forest. "A tower blocked from the sea a pine tree on a mountain by the forest."
17	На фоне плаща оттенила **шляпа** ленту бирюзового цвета. On the background of a cloak contrasted hat$_{NOM}$ ribbon$_{ACC}$ of teal colour. "A hat contrasted a ribbon of teal color with the background of a cloak."
18	Он понимал, что усилила **суета** злобу и надо было уединиться. He realised that increased commotionNOM hatredACC and he had to withdraw. "He sensed that a commotion increased hatred and he needed to seek solitude."

(*Continued*)

Continued.

Item	Sentence
19	В избе отгородила **лавка** койку от занавешенного окна. In the house separated bench$_{NOM}$ cot$_{ACC}$ from a blinded window. "In the house a bench separated a cot from a window with curtains."
20	При голосовании поддержала **Литва** Корею на последней встрече. During voting supported Lithuania$_{NOM}$ Korea$_{ACC}$ at the last meeting. "During voting Lithuania supported Korea at the last meeting."
21	В зоопарке рассмотрела **чайка** галку с заметным удивлением. At the Zoo examined sea gull$_{NOM}$ robin$_{ACC}$ with noticeable surprise. "At the Zoo a sea gull examined a robin with a noticeable surprise."
22	При крушении задела **пушка** мачту и скатилась с палубы. During a shipwreck touched canon$_{NOM}$ pole$_{ACC}$ and rolled off the deck. "During a shipwreck a canon touched a pole and rolled off the deck."
23	В открытом море обошла **шхуна** акулу и скрылась из виду. In the open sea passed boat$_{NOM}$ shark$_{ACC}$ and disappeared from sight. "In the open sea a boat passed a shark and disappeared from sight."
24	В чулане загородила **метла** щётку и совок за ящиком. In the closet blocked broom$_{NOM}$ mop$_{ACC}$ and a shovel behind the box. "In the closet a broom blocked a mop and a shovel behind the box."
25	Хорошо дополнила **груша** ягоду и лимон на натюрморте. Very well complemented pear$_{NOM}$ berry$_{ACC}$ and lemon on a picture. "On a painting a pear complemented a berry and a lemon very well."
26	Ранней весной отгородила **балка** пойму после разлива реки. Early spring separated ditch$_{NOM}$ shallow water$_{ACC}$ after the ice melted on the river. "A ditch separated shallow waters after the river ice melted away in the early spring."
27	В новой декорации заменила **шпага** саблю на левой стене. In the new decoration replaced sword$_{NOM}$ dagger$_{ACC}$ on the left wall. "For the new stage set up, a sword replaced a dagger on the left wall."
28	Все услышали как задела **фляга** финку упав со стола. Everybody heard that touched fluskNOM knifeACC as it fell off the table. "Everybody heard that a flask touched a knife as it fell off the table."
29	В спальне прикрыла **майка** кепку на краю кровати. In the bedroom covered undershirtNOM hatACC at the edge of the bed. "In the bedroom at the edge of a bed a tank top covered a hat."
30	Над камином дополнила **каска** маску с синим пером. Above the fireplace matched hat$_{NOM}$ mask$_{ACC}$ with the blue feather. "Above the fireplace a hat matched a mask with the blue feather."
31	После бури нашла **пчела** матку у разрушенного улья. After the storm found bee$_{NOM}$ queen bee$_{ACC}$ by the broken beehive. "After the storm a bee found the queen bee by the broken beehive."
32	Упав с ветки задела **почка** шишку лежавшую на земле. Falling off the branch touched bud$_{NOM}$ pine cone$_{ACC}$ lying on the ground. "A bud that was falling off the branch touched a pine cone that was lying on the ground."
32	С берега отделила **вилла** горку от леса. From the shore separated villa$_{NOM}$ hill$_{ACC}$ from the forest. "A villa separated a hill from the forest on the shore."
33	На востоке соединила **сопка** бухту с полуостровом. On the east connected mountain$_{NOM}$ bay$_{ACC}$ with the peninsular. "On the east a mountain connected a bay with the peninsula."
34	После обвала поддержала **глыба** вышку довольно долго. After the collapse supported rock$_{NOM}$ tower$_{ACC}$ for quite some time. "After the collapse a rock supported a tower for quite some time."
35	Из-за беспорядка загородила **миска** банку на столе. Due to the mess covered plate$_{NOM}$ jar$_{ACC}$ on the table. "A plate covered a jar on the table because of the mess."
36	На столе закрыла **афиша** карту в стопке бумаг. At the table covered bulletin$_{NOM}$ map$_{ACC}$ at the pile of papers. "At the table a bulletin covered a map in the pile of papers."
37	На поляне отгородила **шахта** тропу от обрыва. It the field separated mine$_{NOM}$ path$_{ACC}$ from the cliff. "It the field a mine separated a path from the cliff."
38	В кабинете закрыла **рамка** папку на столе. In the study blocked frame$_{NOM}$ folder$_{ACC}$ on the table. "In the study a frame blocked a folder on the table."
39	На севере отгородила **аллея** речку от шоссе. In the north divided alley$_{NOM}$ river$_{ACC}$ from the highway. "In the north an alley divided a river from the highway."
40	В шкафу накрыла **шапка** кепку на полке. In the armoire covered hat$_{NOM}$ cap$_{ACC}$ on a shelf. "In the armoire a hat covered a cap on a shelf."

(*Continued*)

Continued.

Item	Sentence
41	Он не заметил как задела **вилка** чашку на кухонном столе. He did not notice how touched forkNOM cupACC at the kitchen table. "He did not notice that a fork scraped a cup at the kitchen table."
42	Вчера поддержала **элита** фирму благодаря хорошим связям. Yesterday supported the elite$_{NOM}$ company$_{ACC}$ due to good communication. "Yesterday the elite supported the corporation due to good rapport."
43	Утром увидела **кошка** мышку во дворе. In the morning saw cat$_{NOM}$ mouse$_{ACC}$ in the yard. "In the morning a cat saw a mouse in the yard."
44	На снимке загородила **плетка** сетку около стула. On a photo blocked whip$_{NOM}$ net$_{ACC}$ by the chair. "On a photo a whip blocked a net by the chair."
45	В лесу сойка услышала **белку** поздно вечером. In a forest heard jay$_{NOM}$ squirrel$_{ACC}$ late at night. "In a forest a jay bird heard a squirrel late at night."
46	В новой квартире разделила **кухня** ванну и коридор расширяя жилую комнату. In the new apartment divided kitchen$_{NOM}$ bathroom$_{ACC}$ and hallway widening the living room. "In the new apartment a kitchen was placed between a bathroom and a hallway, widening the living space."
47	Поздно вечером заметила **лайка** кошку около порога. Late at night saw dog$_{NOM}$ cat$_{ACC}$ by the door. "Late at night a dog saw a cat by the door."
48	Кое-где покрыла **глина** землю в этой части тундры. In some spots covered clayNOM groundACC in this part of the tundra. "In some spots clay covered ground in this part of the tundra."
49	Днем заметила **белка** кошку у берёзы. During the day noticed squirrel$_{NOM}$ cat$_{ACC}$ by a birch tree. "During the day a squirrel noticed a cat by a birch tree."
50	ʹОни услышали как задела **ложка** вилку в кухне. They heard that touched spoon$_{NOM}$ fork$_{ACC}$ in the kitchen. "They heard that a spoon touched a fork in the kitchen."

Appendix 2. Results of the LME models for fixation duration measures (log-transformed)

		Model with non-word baseline			Model with identical baseline		
Measure	Contrast	*b*	*SE*	*t*	*b*	*SE*	*t*
FF duration	Intercept	**5.48**	**0.03**	**159.57**	**5.49**	**0.03**	**182.14**
	Control preview	0.01	0.03	0.21	−0.02	0.03	−0.21
	Related preview	0.02	0.03	0.80	0.02	0.03	0.59
SF duration	Intercept	**5.58**	**0.04**	**156.04**	**5.58**	**0.04**	**153.04**
	Control preview	0.01	0.04	0.21	−0.01	0.04	−0.21
	Related preview	0.02	0.04	0.51	0.01	0.03	0.36
GD	Intercept	**5.70**	**0.05**	**124.83**	**5.66**	**0.04**	**147.67**
	Control preview	−0.04	0.03	−1.33	0.04	0.03	1.39
	Related preview	0.04	0.03	1.20	**0.09**	**0.03**	**2.77***
Go-past duration	Intercept	**6.00**	**0.04**	**130.97**	**5.89**	**0.05**	**121.64**
	Control preview	**− 0.11**	**0.04**	**− 2.81***	**0.11**	**0.04**	**2.81***
	Related preview	−0.01	0.04	−0.41	**0.10**	**0.04**	**2.62***
Total duration	Intercept	**6.25**	**0.06**	**109.16**	**6.23**	**5.73**	**108.81**
	Control preview	−0.02	0.04	−0.46	0.02	0.04	0.46
	Related preview	**0.09**	**0.04**	**2.50**	**1.11**	**3.79**	**2.95***

Note: Significant ($p < .05$) effects are indicated in bold; *$p < .01$.

Appendix 3. Random effects for the LME models

		LME models					Generalised LME models		
Group	Random effect	FF	SF	GD	Go-past duration	Total duration	First-pass fixation	Regression out	Regression in
Subject	Intercept	0.01	0.00	0.00	0.00	52.49	0.01	0.36	0.04
	Identical preview	39.46	50.42	68.08	106.11	200.81	2.29	0.82	0.60
	Related	44.40	49.68	78.37	125.24	220.93	1.82	0.90	0.50
	Non-word	43.46	39.36	87.13	101.39	198.53	1.40	0.01	0.04
Item	Intercept	0.00	0.00	28.03	49.65	79.33	0.01	0.61	0.00
	Identical preview	8.36	25.68	–	–	–	0.04	–	–
	Related	10.38	34.73	–	–	–	0.68	–	–
	Non-word	31.64	21.18	–	–	–	0.29	–	–
Residual		100.68	91.08	153.33	278.22	354.42	0.12	0.40	0.43
		Log transformed							
Subject	Intercept	9.12	0.00	0.00	1.51	1.29			
	Identical preview	1.42	0.17	1.92	2.45	3.07			
	Related	1.55	0.16	1.98	2.36	3.31			
	Non-word	1.55	0.15	2.39	2.22	3.28			
Item	Intercept	0.00	0.00	2.63	1.06	1.28			
	Identical preview	5.28	0.09	7.90	–	–			
	Related	4.33	0.08	6.89	–	–			
	Non-word	1.13	0.11	1.07	–	–			
Residual		3.71	0.32	1.83	5.11	5.28			

Note: Values are *SD*s. Missing values indicate the model did not specify the random effect because of nonconvergence.