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Parafoveal preview during reading: Effects of sentence position

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Abstract

Two experiments examined parafoveal preview for words located in the middle of sentences and at sentence boundaries. Parafoveal processing was shown to occur for words at sentence-initial, mid-sentence, and sentence-final positions. Both Experiments 1 and 2 showed reduced effects of preview on regressions out for sentence-initial words. In addition, Experiment 2 showed reduced preview effects on first-pass reading times for sentence-initial words. These effects of sentence position on preview could result from reduced parafoveal processing for sentence-initial words, or other processes specific to word reading at sentence boundaries. In addition to the effects of preview, the experiments also demonstrate variability in the effects of sentence wrap-up on different reading measures, indicating that the presence and time course of wrap-up effects may be modulated by text-specific factors. We also report simulations of Experiment 2 using version 10 of E-Z Reader (Reichle, Warren, & McConnell, 2009), designed to explore the possible mechanisms underlying parafoveal preview at sentence boundaries.

Key words / phrases

reading; eye movements; E-Z Reader; parafoveal preview; wrap-up effects

As we read, we preprocess upcoming words that fall in the parafovea, the area of vision just beyond the center of current fixation. Although text in the parafovea is visually degraded, reading proceeds more quickly for words that have received some preprocessing in the parafovea than for words that have not (see Rayner, 1998, 2009, for reviews). Previous work investigating parafoveal preview for individual words has only considered words located approximately in the middle of sentences. In the present article, we present two experiments examining parafoveal preprocessing of words in other locations; specifically words that start or end sentences. This work has important implications for understanding both the mechanisms of parafoveal preview during reading and the nature and time course of language processing at the beginning and ends of sentences.

Experiments investigating parafoveal processing generally use saccade-contingent display change techniques. One such technique is the *moving-window paradigm*, in which an area of text is made available contingent on the participant's eye position. This methodology has been used to show that approximately four characters to the left of fixation and 15 characters

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to the right of fixation can be processed during the reading of English text (McConkie & Rayner, 1975, 1976). Another technique is the *boundary paradigm*, in which the preview of a single word within the text is manipulated (Rayner, 1975). In this paradigm, a critical word in a sentence is initially presented either correctly or incorrectly. When the reader's eye crosses an invisible boundary just prior to the critical word, the display is changed such that the critical word is correct when the reader's eye lands on it. In conditions in which the preview (the word or characters available before the display change) provides useful information, parafoveal preprocessing leads to shorter reading times on the critical word (this shortening is known as "preview benefit"). Studies using this paradigm have shown that orthographic (e.g., Rayner, 1975) and phonological (e.g., Pollatsek, Lesch, Morris, & Rayner, 1992), but not semantic (e.g., Rayner, Balota, & Pollatsek, 1986) characteristics of mid-sentence words can be processed parafoveally (for a review, see Hyönä, 2011).

Notably for the present study, a reader's current processing load can modulate the amount of parafoveal processing he or she engages in. For example, Henderson and Ferreira (1990) and White, Rayner, and Liversedge (2005) found that readers showed reduced preview benefit of an upcoming critical word when they were fixating an infrequent, compared to a frequent, word (see also Drieghe, Rayner, & Pollatsek, 2005; Kennison & Clifton, 1995; Schroyens, Vitu, Brysbaert, & d'Ydewalle, 1999). Also, Rayner (1986) showed that children utilize less parafoveal information than skilled adult readers, which is consistent with this account if text imposes a higher processing load for children. According to the E-Z Reader model of eye movement control during reading (Reichle, Pollatsek, Fisher, & Rayner, 1998; Reichle, Rayner, & Pollatsek, 2003), the mechanism behind parafoveal processing is the following: sometimes processing on word n will complete, attention will shift to word $n+1$, and processing of word $n+1$ will begin, all while the eyes remain on word n due to delays in saccadic programming. In the model, the time between the attention shift and the saccade to word $n+1$ therefore corresponds to parafoveal processing. Critically, this mechanism accounts for effects of current processing load on parafoveal processing. When word n is difficult to process, the attention shift to $n+1$ is delayed, reducing the time for parafoveal processing.¹

The present study extends the examination of parafoveal processing by testing whether it is modified by the position of a word within a sentence. Critically for the present study, Henderson and Ferreira (1990) also showed reduced preview benefit when the pre-critical word was a point of high post-lexical (syntactic) processing complexity. This makes the investigation of preview benefit a potentially valuable tool for testing different mechanisms that have been proposed to account for reading effects at the ends of sentences, because some mechanisms assume an increased post-lexical processing load at the ends of sentences whereas others do not.

For example, many studies have shown that readers are slower to process words when they appear at the end rather than in the middle of a sentence (Aaronson & Scarborough, 1976; Green, Mitchell, & Hammond, 1981; Just & Carpenter, 1980; Mitchell & Green, 1978; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). This phenomenon is referred to as the sentence *wrap-up effect*, which has been assumed to reflect the time necessary to complete the semantic or discourse interpretation that remained unfinished at the end of the sentence, or the integration of information between clauses (Just & Carpenter, 1980; Rayner, Kambe,

¹In the E-Z Reader model, attention is allocated to a single word at a time. In other models, such as the SWIFT model (Engbert, Nuthmann, Richter, & Kliegl, 2005), attention can be allocated to multiple words in parallel. In parallel models, parafoveal processing is undertaken continually and is determined jointly by eccentricity from fixation and foveal load. Because the manipulations in the present paper relate to factors that are beyond the scope of parallel models (i.e. parallel models don't currently explain post-lexical processing difficulty), but within the scope of the most recent version of the E-Z Reader model (Reichle et al., 2009), the current paper focuses on the E-Z Reader model.

& Duffy, 2000). More recently, researchers have proposed that wrap-up effects may reflect implicit prosody (Hirotani, Frazier, & Rayner, 2006), or a response to the visual cues that occur at the ends of sentences (Hill & Murray, 2000). Recent experimental and modeling results suggest that both linguistic processing and visual cues likely contribute to wrap-up effects (Warren, White, & Reichle, 2009). The experiments in the current paper will provide evidence relevant to the debate regarding the causes of wrap-up effects, because different mechanisms may have different implications for the amount of parafoveal processing that can be done from a sentence-final word. For example, if wrap-up effects occur as a result of increased post-lexical processing, then sentence-final words will be difficult to process and hence there might be fewer resources to devote to parafoveal processing of upcoming sentence-initial words. On the other hand, if wrap-up effects simply reflect a pause of the eyes, due either to prosody or visual cues, then sentence-final words may allow increased time for parafoveal processing of upcoming sentence-initial words.

In addition to presenting new empirical examinations of the nature of parafoveal processing at the ends of sentences, the current paper will explore the mechanisms underlying parafoveal preview at these positions via simulations of the most recent version of the E-Z Reader model (Reichle et al., 2009). E-Z Reader has previously been shown to predict modulations of preview as a function of lexical difficulty (e.g. related to word frequency) (Pollatsek, Reichle, & Rayner, 2006a). In the present paper, we explore whether the model also predicts effects of sentence boundaries on preview, and use the model to generate hypotheses about the mechanisms underlying these effects (c.f. Warren et al., 2009).

To summarize, there is considerable evidence that individual words can be preprocessed prior to fixation, but this evidence comes from experiments examining preview for words positioned in the middle of sentences. The experiments presented here compare the parafoveal preview of words in the middle of sentences with those at sentence boundaries. If wrap-up effects reflect increased post-lexical processing, then preview benefit might be smaller for sentence-initial words than mid-sentence words. If wrap-up effects reflect a pause of the eyes unrelated to post-lexical processing load, then preview benefit might be larger for sentence-initial than mid-sentence words. If parafoveal preview at sentence boundaries is independent of the factors that induce sentence wrap-up effects, then preview benefits should be equal regardless of sentence position. Experiments 1 and 2 examine parafoveal preview for mid-sentence and sentence-initial words, and Experiment 2 additionally examines preview for sentence-final words.

Experiment 1

Experiment 1 was designed to: (1) test whether readers process sentence-initial words parafoveally, and (2) investigate the influence of sentence wrap-up effects on parafoveal processing in order to learn more about the mechanisms driving them. The items were designed such that a sentence boundary could be located in either of two positions within the same string of words. The same critical word could thus appear either in the middle of a sentence or as the first word in the second sentence. A saccade-contingent boundary was placed prior to the critical word, and the word was presented correctly or incorrectly prior to the display change. Given that wrap-up effects are generally present and robust, we expect to find longer fixations on, and more regressions from, sentence-final words than sentence-medial words.

Method

Participants—32 undergraduates at the University of Leicester participated for course credit. Participants were native English speakers with normal or corrected-to-normal vision and were naïve in relation to the purpose of the experiment.

Apparatus—Eye movements were monitored using an EyeLink 1000 eye tracker (SR Research Ltd.). Pupil location was sampled at a rate of 1000Hz with a spatial accuracy of <0.3 degrees. Viewing was binocular, though only movements of the right eye were recorded. The sentences were presented on a ViewSonic P227fb monitor with a refresh rate of 7ms (150Hz). Given data processing and refresh delays, the second display refresh commenced up to 10ms ($M = 6\text{ms}$) after the boundary was crossed. The viewing distance was 80cm and 3.2 characters subtended approximately one degree of visual angle.

Materials and design—There were 56 experimental items, each including a critical word for which parafoveal preview was examined. Two variables were manipulated in a 2 (sentence position: sentence-initial, mid-sentence) $\times$ 2 (preview: correct, incorrect) design. Sentences 1a and 1b show examples of an item in sentence-initial and mid-sentence conditions respectively (critical word in italics, incorrect preview in parentheses). A full list of experimental items is given in Appendix A.

- (1a) After dinner, Joe and Bob phoned. *Before* (Dctuzn) leaving they needed directions.
- (1b) After dinner, Joe and Bob phoned *before* (dctuzn) leaving. They needed directions.

Each experimental item was composed of two sentences in a single line of text (maximum 81 characters). The words in each item were identical across conditions. In the sentence-initial condition, the second sentence began at the critical word (“*Before*”). In the mid-sentence condition, the second sentence began one to three words after the critical word. The critical words were prepositions or conjunctions and were always five or six letters long ($M = 5.5$, $SD = 0.5$). The word prior to the critical word (“*phoned*”), referred to as word n-1, was always a five to seven letter long verb ($M = 5.7$, $SD = 0.5$). The incorrect previews matched the correct critical words in letter shape (ascender, descender, neutral). The sentences were presented in Courier (mono-spaced) bold font with text presented in black (1.3 cd/m^2) on a white background (102.6 cd/m^2). To control for parafoveal eccentricity, spacing was the same between every word in all stimuli, regardless of the presence or absence of a punctuation mark, as described and illustrated in Warren et al. (2009) (text in font size 14, punctuation in font size 10, spaces between words summed to font size 15).

The four conditions were manipulated within participants and items following a Latin square design. Four lists of 92 sentences were constructed and eight participants were randomly allocated to each list. Thirty-six of these sentences were filler items, consisting of single lines of one or two sentences with a range of syntactic constructions (with no saccade-contingent changes). Six filler items were always presented at the start of the experiment for practice. The sentences were presented in a fixed pseudo-random order. Fourteen experimental sentences and six filler sentences were followed by questions to test for comprehension.

Procedure—Participants were instructed to read the sentences for comprehension and to respond “yes” or “no” to question statements using a button response. A chinrest and

²Participants were replaced if more than a third of their data had to be excluded according to the criteria set out in the “Analyses” section of the Methods. Thirty-two participants were replaced in Experiment 1 and ten participants were replaced in Experiment 2 for these reasons. The trial exclusion rate was particularly high in Experiment 1 due to a large number of cases in which the contingent changes were triggered early; often this occurred when blinks at an earlier position within the sentence produced an erroneously high horizontal eye position value which triggered the change. In Experiment 2 the proportion of erroneously early-triggered changes is likely to have been reduced by requiring two consecutive samples to be beyond the boundary before triggering the change, and also by placing the contingent change boundary slightly further to the right (reducing the proportion of fixations close to the left of the boundary).

forehead rest minimized head movements. The eye tracker was calibrated using a three point horizontal calibration. The calibration was checked prior to every item at the three horizontal calibration positions; recalibrations were undertaken if necessary. Participants had to accurately fixate on a fixation cross at the position of the start of the line of text before each item was presented. Participants pressed a button to indicate when they had finished reading. An invisible boundary was set at the end of word n-1 (“*phoned*” in Sentence 1) just before the period. After the boundary was crossed the critical word was changed to the correct form for all of the conditions. Participants were given at least one break and the entire experiment lasted approximately 35 minutes.

On completion of the experiment participants were asked if they had noticed anything odd about the appearance of the text during the experiment. If the participants had noticed any display changes they were asked to estimate how many they saw. Participants were only included in the analyses detailed here if they reported that they noticed five or fewer changes³.

Analyses—For the 32 participants on whom the analyses presented here are based, 82% of trials were included in the analyses (ranging from 78 to 83% across conditions). 4% of trials were excluded due to blinks on first pass reading of word n-1 or the critical word. For each trial, regardless of the experimental condition, the time at which the display change occurred was compared to the time at which the first fixation after the boundary began. 10% of trials were excluded because the display change was triggered too early and 1% of trials were excluded because the display change occurred more than 4 ms into the start of the subsequent fixation. In addition, 3% of trials were excluded due to fixations at the position of the period after word n-1 (these fixations crossed the boundary and hence triggered the display change before the critical word was fixated).

Results

The average error rate on the comprehension questions was nine percent, indicating that participants read and understood the sentences. Analyses were undertaken for both word n-1 (“*phoned*”) and the critical word (“*before*”), including the following measures: (1) *first-fixation duration* (i.e., the duration of the first fixation, conditional upon it occurring during the first pass); (2) *gaze duration* (i.e., the sum of fixation durations on a word during first pass reading before leaving it); (3) the probability of making a regression out of the word on first pass; and (4) *go-past time* (i.e., summed fixation durations from first fixation of the word until moving to its right, also known as *regression-path duration*). Analyses are also presented for a spillover region, the word(s) between the critical word and the end of the first sentence in the mid-sentence condition (“*leaving*” in Sentence 1). For this spillover region, *first-pass reading time* (sum of fixations before leaving to the left or right), *go-past time*, and the probability of a first-pass regression out are reported. Repeated measures Analyses of Variance (ANOVAs) were undertaken using participants (F_1) and items (F_2) as random factors.

Word n-1—Reading measures for word n-1 (“*phoned*” in Sentence 1) are shown in Table 1. There were clear wrap-up effects. Reading times were longer on word n-1 when it was sentence-final (the sentence-initial condition) compared to mid-sentence for both first-fixation duration [$F_1(1,31) = 45.43$, $MSE = 1466$, $p < .001$; $F_2(1, 55) = 52.63$, $MSE = 1754$,

³Participants who are aware of display changes can produce substantially larger preview effects, distorting the pattern of results (White, Rayner, & Liversedge, 2005). Consequently, in addition to the participants replaced as described in Footnote 2, one participant in Experiment 1 and six participants in Experiment 2 were replaced because they noticed more than five display changes. Note that due to the potentially more distinctive visually dissimilar previews in Experiment 2, the contrast between text and background was lowered to minimize the number of changes noticed.

$p < .001$] and gaze duration [$F_1(1,31) = 33.26$, $MSE = 2723$, $p < .001$; $F_2(1, 55) = 61.10$, $MSE = 2274$, $p < .001$]. There were also more regressions out of and longer go-past times on word n-1 when it was sentence-final (sentence-initial condition) compared to mid-sentence [regressions out: $F_1(1,31) = 16.54$, $MSE = .007$, $p < .001$; $F_2(1, 55) = 33.68$, $MSE = .008$, $p < .001$; go-past: $F_1(1,31) = 29.77$, $MSE = 13917$, $p < .001$; $F_2(1, 55) = 56.07$, $MSE = 13123$, $p < .001$]. There were no effects of preview nor interactions involving preview in first-fixation durations or regressions out ($F_s < 1$). There was a marginally reliable effect of preview in gaze duration [$F_1(1,31) = 4.55$, $MSE = 2204$, $p < .05$; $F_2(1, 55) = 3.25$, $MSE = 4066$, $p = .077$] with a similar trend in go-past [$F_1(1,31) = 2.90$, $MSE = 7581$, $p = .098$; $F_2(1, 55) = 3.88$, $MSE = 9735$, $p = .054$], such that conditions with incorrect previews were read more slowly. These marginal effects did not interact with position [gaze duration: $F_1(1,31) = 2.47$, $MSE = 801$, $p = .126$; $F_2 < 1$; go-past: $F_s < 1$].

Critical word—Reading measures for the critical word (“before” in Sentence 1)⁴ are shown in Table 2. There was a reliable main effect of preview in all measures, with longer reading times and more regressions when the preview was incorrect compared to correct [first-fixation: $F_1(1,31) = 6.11$, $MSE = 1491$, $p < .05$; $F_2(1, 55) = 4.35$, $MSE = 2027$, $p < .05$; gaze duration: $F_1(1,31) = 8.89$, $MSE = 1659$, $p < .01$; $F_2(1, 55) = 6.05$, $MSE = 2865$, $p < .05$; regressions out: $F_1(1,31) = 22.16$, $MSE = .019$, $p < .001$; $F_2(1,55) = 32.95$, $MSE = .018$, $p < .001$; go-past: $F_1(1,31) = 22.17$, $MSE = 5599$, $p < .001$; $F_2(1,55) = 22.36$, $MSE = 7272$, $p < .001$]. These results indicate that participants engaged in parafoveal processing of the critical word. Position had generally weaker effects that were only fully reliable in regressions out, with shorter reading times and fewer regressions when the critical word was sentence-initial rather than sentence-medial [first-fixation: $F_1 < 1.1$, $p < .32$; $F_2(1,55) = 9.68$, $MSE = 1170$, $p < .01$; gaze duration: $F_1 < 1$; $F_2(1,55) = 4.00$, $MSE = 2265$, $p = .05$; regressions out: $F_1(1,31) = 12.35$, $MSE = .016$, $p < .01$; $F_2(1,55) = 21.83$, $MSE = .017$, $p < .001$; go-past: $F_1(1,31) = 2.05$, $MSE = 9959$, $p = .162$; $F_2(1,55) = 5.72$, $MSE = 8335$, $p < .05$]. The general trend towards faster reading of, and fewer regressions from, sentence-initial words might reflect the fact that they do not need to be integrated into a previous sentential context, unlike the mid-sentence words.

Regressions out was the only measure to show a reliable interaction between preview and position [$F_1(1,31) = 8.14$, $MSE = .015$, $p < .01$; $F_2(1,55) = 19.82$, $MSE = .009$, $p < .001$]. There were more regressions out when the preview was incorrect, compared to correct, for both conditions: sentence-initial [$t_1(31) = 2.24$, $p < .05$; $t_2(55) = 2.46$, $p < .05$; mid-sentence, $t_1(31) = 4.47$, $p < .001$; $t_2(55) = 6.29$, $p < .001$]. However, the effect of preview on the probability of making a regression out was significantly larger for mid-sentence than sentence-initial words [$t_1(31) = 2.85$, $p < .01$; $t_2(55) = 4.45$, $p < .001$]. The same pattern was evident in go-past time, but the interaction was not significant [$F_1(1,31) = 3.21$, $MSE = 7140$, $p = .083$; $F_2(1,55) = 1.56$, $MSE = 18358$, $p = .217$]. This interaction suggests that readers may have engaged in less parafoveal processing of sentence-initial than sentence-medial words, given that incorrect previews interfered more with the processing of sentence-medial words. There were no significant interactions for either first-fixation or gaze duration ($ps > .19$)⁵.

⁴The critical word was significantly more likely to be skipped when the preview was correct, compared to incorrect ($ps < .001$). There was a marginal effect of sentence position ($F_s > 4$, $ps < .054$) and no reliable interaction ($F_s < 6.1$, $ps > 0.02$). The incorrect previews were rarely skipped (0.03–0.04) but the correct words had numerically higher skipping rates when they were mid-sentence (0.2) compared to sentence-initial (0.15).

⁵Further analyses were undertaken to ensure that the pattern of results shown for the critical word was not affected by any potential differences in the location of the fixation preceding the first fixation on the critical word (e.g., if it was far away following a regression out of word n-1, or very near following a refixation on word n-1). For both Experiments 1 and 2, the results for the critical word were re-calculated only for cases in which there was a single first-pass fixation, and no regression out, of word n-1. The pattern of results for these restricted analyses was the same as for the data overall.

Spillover region—Table 3 shows the mean reading measures for the spillover region (“leaving” in Sentence 1). Consistent with the wrap-up effects on the critical word, the spillover region also showed wrap-up effects when it was sentence-final (in the mid-sentence condition). There were longer first-pass reading times [$F_1(1,31) = 16.29$, $MSE = 5174$, $p < .001$; $F_2(1,55) = 38.56$, $MSE = 4765$, $p < .001$], longer go-past times [$F_1(1,31) = 42.77$, $MSE = 14965$, $p < .001$; $F_2(1,55) = 57.18$, $MSE = 20722$, $p < .001$], and more regressions out [$F_1(1,31) = 57.98$, $MSE = .013$, $p < .001$; $F_2(1,55) = 46.10$, $MSE = .028$, $p < .001$] when the spillover region formed the end of the sentence in the mid-sentence condition, compared to the middle of a sentence in the sentence-initial condition. There were no effects of preview ($F_s < 1$) and no interaction between preview and position ($F_s < 1.91$, $p_s > .18$) in any of these measures.

Discussion

The results of Experiment 1 show that, similar to mid-sentence words, sentence-initial words can be preprocessed prior to fixation. Additionally, Experiment 1 showed clear wrap-up effects, with longer reading times on word $n-1$ (and the spillover region) when it was sentence-final compared to mid-sentence (Aaronson & Scarborough, 1976; Hill & Murray, 2000; Hirotani et al., 2006; Just & Carpenter, 1980; Rayner et al., 1989, 2000; Warren et al., 2009). For the critical words, the wrap-up effect was apparent even in first-fixation durations, in line with Warren et al. (2009)’s finding.

The effect of preview on first-pass reading time measures on the critical word occurred regardless of the position of the word within the sentence, indicating that preview effects were not modulated by differential reading times on word $n-1$. This is interesting because the wrap-up effects on word $n-1$ were comparable in size to the effects of word frequency and syntactic complexity which previous studies have shown to modulate parafoveal preview for mid-sentence words (Henderson & Ferreira, 1990; White, Rayner, & Liversedge, 2005; but c.f. Warren, Reichle, & Patson, *in press*). However, first-pass regressions out of the critical word did show such an interaction. The fact that incorrect previews led to more regressions from sentence-medial than sentence-initial words is consistent with accounts attributing wrap-up effects to increased post-lexical processing, because increased processing on the sentence-final word could have reduced the resources available for parafoveal processing of the upcoming sentence-initial word (Henderson & Ferreira, 1990). However, the fact that this effect was not evident in first pass fixation-based measures, but only in regressions out, leaves open the possibility that it might simply reflect a hypothesized lower propensity to regress across boundaries with punctuation (Hemforth, Konieczny, & Scheepers, 1994; Hirotani et al., 2006). Such a propensity might result if readers tend to chunk material in memory at punctuated boundaries and if they’re less likely to return to and reprocess already chunked material. We will provide another possible alternative account of this pattern of results in the General Discussion—an explanation couched within the framework of the E-Z Reader model of eye-movement control in reading (Reichle et al., 2009; Warren et al., 2009).

Finally, the results of Experiment 1 also demonstrate that it is possible for some measures of processing (first-pass reading times) to show no modulation of preview effects, whilst other measures (regressions out) are sensitive to such differences. These findings crucially highlight the importance of examining effects of preview on a wide range of different measures, as first-pass reading times may not reflect the full impact of incorrect parafoveal previews.

Experiment 2

Experiment 2 was designed to: (1) examine preview for sentence-final words, and (2) investigate whether the results of Experiment 1 generalize to stimuli with different syntactic structures. Given that sentence-final words are the locus of wrap-up processes, it is possible that the integration of parafoveal preview information for sentence-final words may differ from that for sentence-initial or sentence-medial words. Experiment 2 therefore compares parafoveal preview for all three positions.

In Experiment 1, word *n*-1 was a verb and the critical word was a preposition / conjunction. In Experiment 2, a different sentence structure was used to allow the sentence boundary to fall in one of three positions within the same string of words. This meant that word *n*-1 was always a noun and the critical word was always an adverb, which appeared either sentence initially, mid-sentence, or sentence finally.

A few additional changes were also made to the methodology of Experiment 2. First, Experiment 1 used visually similar incorrect previews. Although such previews control for overall letter / word shape, they tend to produce smaller preview effects than visually dissimilar previews (for a review, see Hyönä, Bertram, & Pollatsek, 2004). Therefore Experiment 2 used visually dissimilar incorrect previews. Second, in Experiment 1 the initial letter of the preview changed in the incorrect preview condition. Therefore the changed letters were always lower case in the mid-sentence condition, whereas one of the changed letters was always upper case in the sentence-initial condition. Changes to upper case letters could potentially be more salient or distinctive than changes to lower case letters. Therefore, in Experiment 2 the initial letter of the critical word remained correct for both preview conditions. Other minor changes are described below.

Method

Participants—36 undergraduates at the University of Leicester participated for course credit. Participants were native English speakers with normal or corrected-to-normal vision and were naïve in relation to the purpose of the experiment (none participated in Experiment 1).

Apparatus—The apparatus was the same as for Experiment 1 except that the sample rate was 2000 Hz and the contingent change was triggered when two consecutive samples crossed the boundary.

Materials and design—There were 66 experimental items, each including a critical word. Two variables were manipulated in a 3 (sentence position: sentence-initial, mid-sentence, sentence-final) $\times$ 2 (preview: correct, incorrect) design. Sentences 2a, 2b, and 2c show examples of an item in sentence-initial, mid-sentence, and sentence-final conditions respectively (critical word in italics, incorrect preview in parentheses). A full list of experimental items is given in Appendix B.

(2a) Liz ran to the green field. *Nearby* (Ntfjcv) along the river she saw some geese.

(2b) Liz ran to the green field *nearby* (ntfjcv) along the river. She saw some geese.

(2c) Liz ran to the green field *nearby* (ntfjcv). Along the river she saw some geese.

As in Experiment 1, all words in each item were identical, but the second sentence starts on a different word according to the variable of critical word position. The pre-critical word (word *n*-1, “*field*”) was always a four to six letter long noun ($M = 5.4$, $SD = 0.5$) and the critical word (“*nearby*”) was a four to six letter long adverb ($M = 5.3$, $SD = 0.5$). The initial letter of the incorrect preview was always correct; all other letters were visually dissimilar to

those in the correct preview for that item. Text presentation was the same as for Experiment 1, with equal spacing regardless of punctuation; the only difference being that the background was grey (45.6 cd/m²) to reduce the contrast and make it less likely that participants would notice the display changes.

The six conditions were manipulated within participants and items following a Latin square design. Thirty-nine filler items similar to those described for Experiment 1 were included, of which four were practice items at the beginning of the experiment. Six lists of 105 sentences were constructed and six participants were randomly allocated to each list. The sentences were presented in a random order. Twenty experimental sentences and fourteen filler sentences were followed by a comprehension question.

Procedure—The procedure was the same as for Experiment 1 except for the following. The invisible boundary was set at the end of word n-1 (“*field*” in Sentence 2), just after the period, instead of just before the period (as in Experiment 1). The calibration was checked prior to every trial with a central fixation target, and every third trial at each of the three horizontal calibration positions; recalibrations were undertaken if necessary.

Analyses—For the 36 participants on whom the analyses presented here are based, 84% of trials were included in the analyses (ranging from 83 to 85% across conditions). 3% of trials were excluded due to blinks on first pass reading of word n-1 or the critical word. For each trial, regardless of the experimental condition, the time at which the display change occurred was compared to the time at which the first fixation after the boundary began. 8% of trials were excluded because the display change was triggered too early and 5% of trials were excluded because the display change occurred more than 5 ms into the start of the subsequent fixation. As in Experiment 1, participants were replaced if more than a third of their data had to be excluded (see Footnote 2).

Results

The average error rate on the comprehension questions was five percent, indicating that participants read and understood the sentences. Similar to Experiment 1, analyses are presented for word n-1 (“*field*”, including the punctuation area), the critical word (“*nearby*”), and a spillover region encompassing the words between the critical word and the sentence-final word in the mid-sentence condition (“*along the*” in Sentence 2). Results were corrected for sphericity where necessary, with uncorrected degrees of freedom presented in the text to avoid confusion.

Word n-1—Reading measures for word n-1 (“*field*” in Sentence 2) are shown in Table 1. Word n-1 was sentence-final in the sentence-initial condition. In contrast to Experiment 1, first fixations and gaze durations on word n-1 did not show main effects of sentence position ($F_s < 1.1$), but both measures produced a main effect of preview [first-fixation: $F_1(1,35) = 6.41$, $MSE = 1478$, $p < .05$; $F_2(1,65) = 9.05$, $MSE = 1769$, $p < .01$; gaze duration: $F_1(1,35) = 4.62$, $MSE = 2358$, $p < .05$; $F_2(1,65) = 6.70$, $MSE = 3158$, $p < .05$] and no interaction ($F_s < 1.2$). Similarly, go-past time also showed a main effect of preview [$F_1(1,35) = 4.23$, $MSE = 6349$, $p < .05$; $F_2(1,65) = 3.91$, $MSE = 10704$, $p = .052$] and no interaction ($F_s < 1.11$). These preview effects are evidence for one type of “parafoveal-on-foveal” effect (Kennedy, 2000), in which parafoveal processing of difficult orthographic material (the incorrect preview in this case) inflates fixation durations on the current word.

In contrast to first-pass reading times on word n-1, the probability of first-pass regressions from word n-1 showed a main effect of position [$F_1(2,70) = 21.50$, $MSE = .020$, $p < .001$; $F_2(2,130) = 19.99$, $MSE = .027$, $p < .001$]. Consistent with Experiment 1 and previous

evidence for wrap-up, there were more first-pass regressions from word *n*-1 when it was sentence-final (in the sentence-initial condition) compared to when it was mid-sentence (sentence-final and mid-sentence conditions) ($ts > 2.6$, $ps < .01$). As in Experiment 1, this measure showed no effect of preview and no interaction ($F_s < 1.2$). Go-past time showed a similar pattern. There was a main effect of position [$F_1(2,70) = 12.43$, $MSE = 7415$, $p < .001$; $F_2(2,130) = 14.63$, $MSE = 10354$, $p < .001$], characterized by longer go-past times on word *n*-1 when it was sentence-final (sentence-initial condition) compared to when it was mid-sentence (sentence-final and mid-sentence conditions) for the correct preview conditions ($ts > 3.4$, $ps < .01$) with similar trends for the incorrect preview conditions ($ts > 1.6$, $ps < .12$).

Critical word—Reading measures for the critical word (“*nearby*” in Sentence 2)⁶ are shown in Table 4. There was no significant main effect of sentence position for first-fixation [$F_1(2,70) = 1.85$, $MSE = 1900$, $p = .166$; $F_2(2,130) = 2.83$, $MSE = 2258$, $p = .063$], but all other measures showed significant effects [gaze duration: $F_1(2,70) = 3.21$, $MSE = 2781$, $p < .05$; $F_2(2,130) = 4.62$, $MSE = 3289$, $p < .05$; regressions out: $F_1(2,70) = 25.95$, $MSE = .018$, $p < .001$; $F_2(2,130) = 36.48$, $MSE = .021$, $p < .001$; go-past: $F_1(2,70) = 14.74$, $MSE = 16086$, $p < .001$; $F_2(2,130) = 19.48$, $MSE = 15821$, $p < .001$]. All measures also showed significant effects of preview [first-fixation: $F_1(1,35) = 22.44$, $MSE = 1838$, $p < .001$; $F_2(1,65) = 35.20$, $MSE = 2162$, $p < .001$; gaze duration, $F_1(1,35) = 34.03$, $MSE = 2579$, $p < .001$; $F_2(1,65) = 40.58$, $MSE = 3978$, $p < .001$; regressions out: $F_1(1,35) = 25.19$, $MSE = .017$, $p < .001$; $F_2(1,65) = 38.86$, $MSE = .018$, $p < .001$; go-past: $F_1(1,35) = 44.64$, $MSE = 6986$, $p < .001$; $F_2(1,65) = 41.58$, $MSE = 12157$, $p < .001$]. In all measures, these main effects were qualified by interactions [first-fixation: $F_1(2,70) = 3.76$, $MSE = 1015$, $p < .05$; $F_2(2,130) = 3.35$, $MSE = 1792$, $p < .05$; gaze duration: $F_1(2,70) = 6.35$, $MSE = 1357$, $p < .01$; $F_2(2,130) = 4.42$, $MSE = 3508$, $p < .05$; regressions out: $F_1(2,70) = 7.45$, $MSE = .017$, $p < .001$; $F_2(2,130) = 9.27$, $MSE = .023$, $p < .001$; go-past: $F_1(2,70) = 7.90$, $MSE = 6107$, $p < .01$; $F_2(2,130) = 4.49$, $MSE = 17253$, $p < .05$].

In our first analysis of this interaction, the effect of sentence position in correct preview conditions was investigated. For the correct previews, sentence position affected neither first-fixation durations ($ts < 1$) nor gaze durations ($ts < 1.4$, $ps > .18$), but there were more first-pass regressions out of the critical word and longer go-past times when it was sentence-final compared to when it was mid-sentence [regressions out: $t_1(35) = 2.97$, $p < .01$; $t_2(65) = 3.34$, $p < .01$; go-past: $t_1(35) = 2.64$, $p < .05$; $t_2(65) = 2.70$, $p < .01$], with a similar pattern when comparing sentence-final to sentence-initial words [regressions out: $t_1(35) = 2.60$, $p < .05$; $t_2(65) = 3.02$, $p < .01$; go-past: $t_1(35) = 2.16$, $p < .05$; $t_2(65) = 1.93$, $p = .058$]. The effects in first-pass regressions out and go-past times are consistent with the effects of wrap-up on regressions out of word *n*-1 in both Experiments 1 and 2, and with previous work on wrap-up effects. The lack of reliable wrap-up effects in either first-fixation or gaze duration is unusual, but is consistent with the pattern on word *n*-1 in the current experiment.

Interestingly, reading times for the incorrect previews show standard wrap-up effects, but such differences might be better interpreted as differential preview effects. Although all sentence position conditions showed numerical preview effects, those for mid-sentence and sentence-final words were larger than those for sentence-initial words. Contrasts showed that preview effects for mid-sentence [first-fixation: $t_1(35) = 3.77$, $p < .01$; $t_2(65) = 3.17$, $p < .01$; gaze duration: $t_1(35) = 5.03$, $p < .001$; $t_2(65) = 4.36$, $p < .001$; regressions out: $t_1(35)$

⁶As in Experiment 1, the critical words in Experiment 2 were skipped more often when the previews were correct (0.05), compared to incorrect (0.02) ($F_s > 10.5$, $ps < 0.01$) and there was no interaction with position ($F_s < 1.5$, $ps > 0.2$). There was a significant main effect of position ($F_s > 6.2$, $ps < 0.01$) with sentence-initial words skipped numerically more often (0.06) than sentence-final (0.02) or mid-sentence (0.03) words.

= 3.85, $p < .001$; $t_2(65) = 4.13$, $p < .001$; go-past: $t_1(35) = 6.83$, $p < .001$; $t_2(65) = 4.56$, $p < .001$], and sentence-final [first-fixation: $t_1(35) = 5.35$, $p < .001$; $t_2(65) = 5.74$, $p < .001$; gaze duration: $t_1(35) = 6.73$, $p < .001$; $t_2(65) = 6.47$, $p < .001$; regressions out: $t_1(35) = 3.92$, $p < .001$; $t_2(65) = 5.13$, $p < .001$; go-past: $t_1(35) = 5.01$, $p < .001$; $t_2(65) = 4.24$, $p < .001$], words were reliable, whereas preview effects for sentence-initial words were not [first-fixation: $t_1(35) = 1.41$, $p = .169$; $t_2(65) = 2.08$, $p < .05$; gaze duration: $t_1(35) = 1.41$, $p = .168$; $t_2(65) = 1.39$, $p = .168$; regressions out: $ts < 1$; go-past: $ts < 1.2$, $ps > .24$]. Although the numerical preview effects for sentence-initial words were not reliable in this experiment, they were comparable in size to some of the main effects of preview found in Experiment 1 (see Table 2).

Spillover region—As in Experiment 1, first-pass reading time, regressions out and go-past time were analysed for the spillover region⁷ (“*along the*” in Sentence 2); means are reported in Table 3. There were no significant main effects of position for either first-pass reading time [$F_1(2,70) = 1.35$, $MSE = 4629$, $p = .265$; $F_2(2,128) = 1.18$, $MSE = 12581$, $p = .309$] or go-past time ($F_s < 1.1$) and no main effects of preview for either first-pass [$F_1 < 1$; $F_2(1,64) = 1.70$, $MSE = 7714$, $p = .197$] or go-past time [$F_1 < 1$; $F_2(1,64) = 1.21$, $MSE = 17173$, $p = .276$]. There was no significant interaction for first-pass time [$F_1(2,70) = 2.38$, $MSE = 2906$, $p = .100$; $F_2(2,128) = 2.77$, $MSE = 8352$, $p = .066$], but there was a significant interaction for go-past time [$F_1(2,70) = 5.83$, $MSE = 9778$, $p < .01$; $F_2(2,128) = 6.29$, $MSE = 18705$, $p < .01$]. For go-past time, the interaction was characterized by significantly longer reading times when the preview was correct, compared to incorrect, in the sentence-initial condition [$t_1(35) = 2.06$, $p < .05$; $t_2(64) = 2.39$, $p < .05$], and significantly longer reading times when the preview was incorrect, compared to correct, in the mid-sentence condition [$t_1(35) = 2.22$, $p < .05$; $t_2(65) = 2.31$, $p < .05$].

For the probability of making a first-pass regression out, there was a significant main effect of position [$F_1(2,70) = 4.95$, $MSE = .011$, $p < .05$; $F_2(2,128) = 5.97$, $MSE = .021$, $p < .01$], no effect of preview [$F_1(1,35) = 1.33$, $MSE = .010$, $p = .256$; $F_2 < 1$], and a marginally significant interaction [$F_1(2,70) = 4.08$, $MSE = .008$, $p < .05$; $F_2(2,128) = 2.76$, $MSE = .020$, $p = .067$]. The trend towards an interaction appeared to be characterized by significantly more regressions out when there was a correct, compared to an incorrect, preview for the sentence-initial condition [$t_1(35) = 2.57$, $p < .05$; $t_2(64) = 2.05$, $p < .05$] but no significant effects of preview for either the mid-sentence or sentence-final conditions ($ts < 1$).

The effect of preview on go-past times in the mid-sentence condition is consistent with continued disruption from processing the incorrect preview in the prior region. It is not clear why there was an inverted preview effect (more regressions and longer go-past times in the correct, compared to incorrect, condition) for the sentence-initial condition. However, these results at least indicate that the sentence-initial incorrect preview produced no delayed disruption, such that reading of the following spillover region was not disrupted by the earlier incorrect preview in this condition.

Discussion

The results of Experiment 2 can be summarized as follows. On word n-1, early fixation-based measures (e.g. first-fixation duration) did not show wrap-up effects, but did show parafoveal-on-foveal effects of the incorrect preview. Wrap-up effects were evident in first-pass regressions from both word n-1 and the critical word. On the critical word, first-pass reading time measures did not show wrap-up effects in conditions with correct previews,

⁷For the analysis of the Spillover region in Experiment 2, the items analysis was based on 65 items due to missing data for one of the items.

similar to the pattern on word n-1. Preview effects in both the mid-sentence and sentence-final conditions were larger than those observed for sentence-initial words. This is consistent with the pattern of preview effects shown for regressions out in Experiment 1.

Experiment 2 included a novel manipulation of parafoveal preview for sentence-final words. Consistent with previous research for words at other sentence positions, sentence-final words showed clear preview effects in all measures. Note also that preview effects on sentence-final words were numerically, but not reliably, larger than preview effects on sentence-medial words. It could be that the higher processing load associated with sentence-final words tended to exacerbate the difficulty induced by the incorrect previews in this condition.

In Experiment 2, reading times on word n-1 showed parafoveal-on-foveal preview effects that might have been driven by the orthographically unfamiliar letter sequences in the incorrect preview (White, 2008). Note that Experiment 1 showed similar numerical, but non-reliable, effects for word n-1 gaze durations. Although some researchers claim that such effects may be due to parallel processing of words (Kliegl, Nuthmann, & Engbert, 2006), other explanations, such as mislocated fixations, have also been proposed (Drieghe, Rayner, & Pollatsek, 2008). That is, some fixations targeted to the critical word may have landed on word n-1, such that attention may have been allocated to the critical word whilst fixating word n-1. In such cases, difficulty associated with processing the orthographically unfamiliar incorrect previews may have resulted in inflated fixation durations on word n-1.

In Experiment 2, standard wrap-up effects were evident in regressions out and go-past time for word n-1 and the critical word, as in Experiment 1. However, in contrast to Experiment 1, wrap-up effects were not evident in first-pass reading times on word n-1 or the critical word in the correct preview conditions. This is an unusual finding, as wrap-up effects are usually present in gaze durations (e.g. Hill & Murray, 2000; Hirotsani et al., 2006; Rayner et al., 2000; Warren et al., 2009). This lack of wrap-up effects in first-pass reading time measures could be related to the long string of adjuncts (i.e. “*nearby along the river*”) that was included in Experiment 2 to allow the sentence boundary to be placed in one of three positions. If wrap-up effects are related to prosody, and readers had a tendency to prosodically pause before or after each adjunct, or if readers sometimes anticipated the end of the sentence before or after the first adjunct and began to initiate wrap-up processing anticipatorily, this could have weakened or diffused fixation-based wrap-up effects in this experiment as compared to in previous ones. Importantly, the fact that first-pass reading time measures did not show wrap-up effects in this experiment does not mean that wrap-up effects don’t exist, aren’t important to study, or cannot be understood. Wrap-up effects have sometimes been characterized as simple, but are likely complex: they are probably driven by multiple mechanisms, both linguistic and visual (Warren et al., 2009); the engagement of different mechanisms is likely to depend on properties of the stimuli (e.g., the strength of an expectation for a clause boundary); and the relationship between the linguistic mechanisms and eye movements is likely to be complicated (e.g., Clifton, Staub, & Rayner, 2007). It should also be noted that the contrast between the text and background was lower in Experiment 2 than in Experiment 1. Although the text and punctuation were clearly visible, they may not have been quite as salient in Experiment 2 as in Experiment 1. Given that visual cues such as punctuation and capitalization are thought to be important in triggering wrap up (Hill & Murray, 2000; Warren et al., 2009), it is possible that the reduced wrap-up effects in Experiment 2 were due to less salient visual cues.

E-Z Reader Simulations

In order to further test the explanatory power of the E-Z Reader model (cf., Warren et al., 2009), and to explore the possible mechanisms underlying the effect of sentence word location on parafoveal preview, we simulated the results of Experiment 2 using the standard version of E-Z Reader (version 10: Reichle et al., 2009). Note that E-Z Reader was originally designed to account for the influence of visual and lexical variables on eye movement behavior during reading (Reichle et al., 1998, 2003) but version 10 extends these capabilities such that it now also incorporates post-lexical influences. We focused on Experiment 2 for brevity, and because it had a superset of the conditions from Experiment 1. Three dependent measures were simulated for word $n-1$ (“field” in Sentence 2) and the critical word (“nearby” in Sentence 2): first-fixation durations, gaze durations, and the probabilities of making regressions out. These measures were chosen because the model has only a superficial account of re-reading; it is best suited to explaining how our experimental manipulations might have influenced lexical and post-lexical processing during the first pass through the text, up to the point where readers moved their eyes from either word $n-1$ or the critical word. Similar to previous simulations of preview effects with other versions of E-Z Reader (Pollatsek, Reichle, & Rayner, 2006a, 2006b, 2006c; Reichle et al., 2003, 2008), the incorrect preview conditions were simulated by preventing any processing of the critical word before it was fixated. Although not ideal, this method was adopted because, in the absence of a detailed lexical processing mechanism, the model simply cannot process a nonword stimulus. Issues related to this limitation are discussed further below.

Note that in order to maximize the accuracy of the E-Z Reader predictions, the simulations are based directly on the set of materials from Experiment 2, using the frequency, length, and cloze predictability of each word, rather than an adjusted version of the standard corpus (taken from Schilling, Rayner, & Chumbley, 1998) that has most often been used for testing the model (see Reichle, 2011). The observed values of the three dependent measures (taken from Tables 1 and 4, using the full data sets) are plotted in Figures 1–3 to facilitate comparison with the simulated values.

Before generating the simulations reported in Figures 1–3, it was first necessary to adjust five of the model’s free parameters so that the overall performance of the model fit the performance of our participants. These parameters included: (1) α_1 , the intercept parameter that determines the maximal lexical processing time for a word; (2) α_2 , the parameter that attenuates the lexical processing time as a function of a word’s frequency; (3) α_3 , the parameter that attenuates the lexical processing time as a function of a word’s predictability; (4) I , the mean time required to complete the post-lexical integration of a word; and (5) p_N , the probability that an inter-word regression is directed back to the immediate source of processing difficulty (i.e., the word where integration failed), rather than some other location earlier in the sentence (i.e., which by default is always the preceding word). It is reasonable to expect that these parameters might vary as a function of the sample of readers and/or materials being simulated. We used parameter values that minimized the square root of the mean normalized deviations (error) between each of the observed and simulated means in the conditions involving mid-sentence critical words (as shown in Figure 1). (All other model parameters were set equal to their default values from Reichle et al., 2009. Although the parameter that controls the probability of integration failure on a word, p_F , has no default value per se, it was set equal to a value comparable to those used in previous simulations of “standard” sentences, $p_F = 0.1$.)

The logic of fitting the model to the mid-sentence conditions is that these conditions provide a baseline from which to gauge the effects of sentence location on preview effects. That is, by fitting the model to this condition, it is possible to infer the time required to complete

integration and the probability of it failing in the absence of visual cues (i.e., a period) that explicitly mark the ends of sentences. The best-fitting parameter values were found by completing four successive grid searches of the parameter space. In these searches, the values of the five parameters were orthogonally and incrementally varied across a “space” of possible values to assess how different permutations of parameters affected the model’s performance (as described in the Appendix of Reichle et al., 1998). The first search used 10 statistical subjects for each permutation of parameter values over the following parameter value domains and using the indicated step-size increments: $\alpha_1 \in [100, 120]$, increment = 5; $\alpha_2 \in [2, 4]$, increment = 1; $\alpha_3 \in [5, 25]$, increment = 5; $I \in [25, 95]$, increment = 10; $p_N \in [0.1, 0.8]$, increment = 0.1. The initial domain of possible parameter values were selected on the bases of plausibility (e.g., the first three parameters were constrained to give plausible word identification latencies). The second search used 100 statistical subjects per permutation across a domain that was centered on the best-fitting parameter values obtained from the first search and using the following increments: $\alpha_1 = 2$; $\alpha_2 = 1$; $\alpha_3 = 5$; $I = 5$; and $p_N = 0.05$. Likewise, the third search used 250 statistical subjects across a domain centered on the best-fitting parameter values from the second search and the following increments: $\alpha_1 = 1$; $\alpha_2 = 1$; $\alpha_3 = 2$; $I = 2$; and $p_N = 0.02$. The fourth and final search used 1,000 statistical subjects and was centered to the best-fitting parameter values from the third using the following increments: $\alpha_1 = 1$; $\alpha_2 = 1$; $\alpha_3 = 1$; $I = 1$; and $p_N = 0.01$.

The best-fitting parameter values from the final grid search ($\alpha_1 = 121$ ms; $\alpha_2 = 3$ ms; $\alpha_3 = 8$ ms; $I = 77$ ms; and $p_N = 0.83$) were comparable to those used in previous simulations (e.g., see Reichle et al., 2009; Warren et al., 2009). The simulation results shown in Figure 1 are based on these parameter values and 1,000 statistical subjects per condition. As Figure 1 shows, these parameters allowed the model to accurately simulate the observed pattern of first-fixation and gaze durations in the various conditions, as well as the overall probabilities of making regressions out of word n-1 and the critical word. However, the figure also indicates two discrepancies. First, the model over-predicted the gaze-duration cost that occurred on word n-1 when parafoveal processing of the critical words was prevented. The second is that the model under-predicted the proportion of regressions out of the critical words when parafoveal processing of those words was prevented.

These two discrepancies are related and stem from the fact that a key aspect of the experimental manipulation is outside of the theoretical scope of E-Z Reader. The model does not include a precise description of lexical processing (e.g., it does not contain a computational model of word identification) and simply assumes that lexical processing halts when random letter strings (of the type used in our previews) are encountered, so that the critical word is the recipient of no processing from word n-1 in the no-preview condition. Hence early processing of the critical word, whilst fixating word n-1, is less likely to eliminate any pending saccadic program to refixate word n-1, thereby increasing both the likelihood of making a refixation and the gaze duration on word n-1. The absence of preview also reduces the probability that the critical word will be identified before word n-1 has been fully integrated, which in turn reduces the probability that a regression out of the critical word will be initiated. These two discrepancies thus reflect an inherent limitation of the model that is unlikely to be remedied without more detailed assumptions regarding lexical processing and how it proceeds when provided with useless or misleading input (as occurs in the no-preview condition). Of course, it is important to acknowledge that the specific details of how the model would have to be modified to handle this limitation are yet to be worked out. Of particular interest is whether these discrepancies can be explained within the framework of the current model (by specifying more precisely what happens to lexical processing when the preview is an illegal letter string) or whether the discrepancies might instead require new assumptions. For example, the presence of an illegal preview may

simply override the normal “routines” that—according to the model—determine when and where the eyes move during reading.

Interestingly, although the current simulations over-estimate the effect of an incorrect preview of word *n* on gaze durations on word *n-1*, they also highlight a possible alternative account of the observed parafoveal-on-foveal effect. The simulation results indicate that parafoveal lexical processing might interact with on-going foveal post-lexical processing, modulating the probability of making a refixation on the foveal word and thereby modulating the gaze duration on that word. As will be seen below, this limitation of the model is not specific to the mid-sentence conditions and manifests itself in the other reported simulations.

Figure 2 reports two attempts to simulate reading behavior when the critical word is sentence-initial. The first of these simulations used exactly the same parameter values as the simulation of the mid-sentence conditions (i.e., Figure 1) and accounted for the overall patterns of first-fixation and gaze durations in these conditions reasonably well, which indicates that the model is not over-fitting the data from the mid-sentence conditions (see Myung, 2000.) However, the model again over-predicted the gaze durations on word *n-1* in the no-preview condition. In addition, the model markedly under-predicted the proportion of regressions out of word *n-1*, which would have been sentence-final in this condition. This is unsurprising because this wrap-up effect is likely to result from a modulation of post-lexical processing. We therefore tested this by completing a second simulation in which the values of the p_F and p_N parameters for the last word in the sentence (i.e., word *n-1*, “field” in Sentence 2) were varied to maximize the model’s overall fit to the data⁸. Recall that p_F reflects the probability of integration failure and p_N reflects the probability that any resulting regressive saccades are subsequently directed to the source of difficulty (earlier in the sentence). If the hypothesis that post-lexical processing modulates parafoveal processing is correct, then making post-lexical processing of the end-of-sentence word more difficult should improve the model’s performance. Similarly, if integration failure on the sentence-final word specifically reflects a wrap-up effect that is associated with processing the overall sentence, then any inter-word regressions that are initiated from this word might be predicted to be directed further back into the sentence. Consistent with both of these hypotheses, the best-fitting parameter values (obtained via grid-searches using 1,000 statistical subjects and increment sizes of $p_F = 0.01$ and $p_N = 0.01$) were ones that made: (a) post-lexical processing of the end-of-sentence words more prone to error ($p_F = 0.18$) than post-lexical processing of the other words in the sentences, and (b) inter-word regressions more likely to move the eyes further back into the sentence than the immediate source of integration difficulty ($p_N = 0.34$). These two changes allowed the model to more accurately simulate the observed proportion of regressions out of word *n-1*. However, for the reason already mentioned, the model still over-predicted the gaze-duration cost on word *n-1* in the no-preview condition.

Figure 3 shows two attempts to simulate reading behavior when the critical word is sentence-final. Again, we first used the parameter values from the simulation of the mid-sentence conditions (Simulation 1), and then varied the values of the post-lexical parameters for the last word in the sentences (i.e., the critical word “nearby” in Sentence 2) to optimize the model’s fit to the data (as was done in Simulation 2). The first simulation was

⁸Because E-Z Reader does not include a detailed account of the post-lexical processing that occurs with each word and how this processing varies across the words in a sentence, one might argue that different values of p_F and p_N should be selected for each word in each sentence. For example, one might posit that, on average, the values of both parameters would increase across the words in a sentence as the processing load that accrues with each additional word increases. Because this “solution” would be intractable, we have instead opted to adjust these two parameters for a specific word in a manner that might be expected on both a priori empirical and theoretical bases—the final word in each sentence.

completely consistent with the previous ones in that the model demonstrated both a robust capacity to capture the overall pattern of results and the same systematic discrepancies. In the second simulation, the best-fitting parameter values were obtained in exactly the same manner as in the second simulation of the sentence-initial conditions and resulted in parameter values (for the last word of the sentence) that were almost identical: $p_F = 0.24$ ms and $p_N = 0.37$. As Figures 2 and 3 show, these changes were sufficient for the model to more accurately simulate the observed proportions of regressions out of the end-of-sentence words (word $n-1$ in Figure 2, word n in Figure 3) in three of the four conditions, although (for reasons already discussed) the model still under-predicted the number of regressions out of the critical word in the no-preview condition. This under-prediction meant that the simulations failed to capture the observed interaction between preview and sentence position in the proportion of regressions out.

These simulations were useful in demonstrating that the basic assumptions of the E-Z Reader model can capture the general patterns observed in first-pass measures when parafoveal preview of the critical words was available versus not, and when those critical words occurred at the beginnings, middles, or ends of sentences. This conclusion cannot be made without a few caveats, however. For example, if one uses the difference between gaze durations on the critical words in the normal preview conditions when those words occur in the middle (269 ms) versus ends (281 ms) of sentences as a pure measure of sentence wrap up, then the observed wrap-up effect (12 ms) is smaller than the simulated value (i.e., $327 - 287 = 40$ ms). However, it is worth noting that the observed wrap-up effect is also smaller in magnitude than the 46-ms effect observed in gaze durations by Warren et al. (2009). And although one might undoubtedly improve the model's performance by varying its parameters across conditions, the fact that the model was able to simulate these results using a single set of parameter values (obtained by fitting the model to the mid-sentence conditions) suggests that the model is not over-fitting the data (Myung, 2000). Taken together, this suggests that the basic model assumptions provide a useful description of how post-lexical processing might be modulated by sentence position, but that this description is less useful in elucidating the ways that post-lexical processing manipulations might influence the extraction of parafoveal information. This is likely related to an important limitation of the model as discussed earlier—namely its simplified assumptions about what occurs during parafoveal lexical processing in conditions involving non-word parafoveal previews. For example, it is possible that incorrect parafoveal previews may actively interfere with lexical processing (thereby inducing regressions) rather than simply removing any benefit that might otherwise be obtained with correct preview information (as assumed in the model).

General Discussion

The current paper reports two experiments examining the nature of parafoveal preview for words located at different positions within a sentence. Consistent with previous studies (e.g., Rayner, 1975), both experiments showed that mid-sentence words are processed parafoveally prior to fixation. The experiments reported here are the first to specifically examine and demonstrate preview for sentence-initial and sentence-final words. The results showed that although sentence-initial words can be preprocessed prior to fixation, the preview effect for sentence-initial words is sometimes smaller than that shown for mid-sentence words. There were no significant differences in preview for words in sentence-final compared to mid-sentence positions.

The reduced preview effect for sentence-initial compared to mid-sentence words was evident in first-pass reading times in Experiment 2, and in regression measures in both Experiments 1 and 2. As previously noted, there are several possible mechanisms that could

drive the reduced preview effects for sentence-initial words. First, sentence-initial words may receive less parafoveal processing than words in other positions. This could result if wrap-up effects on the previous sentence-final word reflect an increase in processing load, given that increases in lexical and syntactic foveal load reduce parafoveal preview (Henderson & Ferreira, 1990; White et al., 2005). Note that in Experiment 2 there were no reliable wrap-up effects in first-pass reading times to support such a suggestion. However, regression-based measures did indicate that wrap-up impacted on processing load, suggesting that wrap-up did incur processing difficulty, even if gaze durations were not sensitive to it in this case. Nevertheless, it could be that reading measures showed smaller preview effects for the sentence-initial word for reasons other than modulation of preview by processing load, as outlined below.

A second possibility is that preview effects may be reduced for sentence-initial words, not because of any difference in parafoveal preview, but simply because they are easier to process (in both experiments there were trends towards shorter reading times on sentence-initial words). However, this possibility is contrary to other research showing greater (rather than smaller) preview effects for higher frequency (Inhoff and Rayner, 1986) or higher predictability (Balota, Pollatsek, & Rayner, 1985) words. Also note that preview effects in these previous studies were characterized by differences in reading measures for the correct previews, whereas in the current studies the effects are driven by differences for the incorrect previews. Hence it seems unlikely that the differential preview effects were related to lower processing load for the sentence-initial words.

A third possibility is that reduced preview effects for sentence-initial words may result because eye behavior on sentence-initial words could be less sensitive to processing load. That is, sentence-initial fixation durations might be less influenced by post-lexical processing than fixation durations on other words, and there may be a generally lower propensity to make regressions out of sentence-initial words (or perhaps just across sentence boundaries, see Hirotani et al., 2006). Although models of eye movement control during reading make no special predictions for the nature of eye movement control at sentence-initial locations, it seems possible that following a “reset” of the post-lexical processes resolved at the end of the previous sentence, not all of the standard mechanisms controlling when and where the eyes move for mid-sentence words may be operational. Further empirical work is needed to examine this issue, for example, to identify whether sentence-initial words are influenced by variables such as word frequency in the same manner as for mid-sentence words.

Simulations of Experiment 2 using the E-Z Reader 10 model of eye-movement control in reading were able to capture the broad patterns of wrap-up effects and preview effects, but were not able to capture subtleties like the interaction of wrap-up and preview. This is probably because the model has very simple and likely incorrect assumptions about what occurs during the parafoveal processing of a non-word letter string. It would likely be possible to improve the model's simulations of the current data by introducing new assumptions, such as decreasing the sensitivity of the eyes to post-lexical processing load on sentence-initial words or incorporating a word processing mechanism that is sensitive to the presence of nonwords (rather than just absence of preview). However, at the current time, we think it is most important to investigate what the model can accomplish within its basic framework, without the addition of specifically tailored assumptions.

The findings in the current paper also provide evidence relevant to the debate about what mechanisms underlie sentence wrap-up effects. The results are inconsistent with the hypothesis that wrap-up effects reflect a simple pause of the eyes, unassociated with any increase in processing (Hirotani et al., 2006). The wrap-up effects observed in Experiment 2

appeared not as inflated fixations but instead as increased regression probability and re-reading. This finding does not mean that pauses associated with implicit prosody do not exist or do not contribute to wrap-up effects, but it does suggest that such a pause in linguistic processing does not manifest in a corresponding stationary pause of the eyes. Perhaps the pauses proposed by Hirotsu et al. can instead be characterized by re-reading, even if information does not need to be re-sampled from those parts of the text (see Ferreira, Apel, & Henderson, 2008). In addition, the finding of reduced preview effects for sentence-initial words is consistent with the hypothesis that wrap-up effects are caused by increased post-lexical processing at the end of a sentence (though see other possible explanations detailed above).

It has also been proposed that the eye-movement system might learn that visual cues at sentence boundaries are a good predictor of increased processing and anticipatorily take steps to reduce the likelihood that highly inefficient eye-movement patterns will occur (Hill & Murray, 2000; Warren et al., 2009). The fact that Experiment 1 showed effects of wrap-up from first fixation through all other measures is consistent with this hypothesis, but the fact that Experiment 2 showed no effects of wrap up in first-fixation or gaze durations is unexpected under this hypothesis. Note that this pattern of results indicates that the first-fixation wrap-up effects in Warren et al. (2009) and Experiment 1 are not likely due to the controlled spacing, given that Experiment 2 had the same visual layout. It is interesting and potentially relevant that the experiments which have shown wrap-up effects in first-fixation durations (Experiment 1 and the experiment reported in Warren et al., 2009) have had verbs as their critical words, unlike Experiment 2, which looked at wrap-up on both nouns and adverbs, and most other studies, which have investigated wrap-up on nouns. This pattern could indicate that the use of visual cues in the hypothesized way is contingent on how difficult post-lexical processing is anticipated to be. If the system parafoveally detects the upcoming end of a sentence (via the visual cues of punctuation and capitalization in this case) and has not yet processed a verb or created a proposition, it could anticipate a higher post-lexical processing load and in effect “put on the brakes” earlier than it would if it had processed either a full or almost full proposition and was either anticipating an adjunct or single argument. To summarise, it is not obvious why wrap-up effects on first-pass reading times occurred in Experiment 1, but not Experiment 2, but one possibility is that post-lexical difficulty contributes to the effect of wrap-up on first pass reading times, and it is likely that this was greater in the first experiment compared to the second.

Finally, in both Experiments 1 and 2, regression-based measures indicated that readers were more sensitive to the nature of the parafoveal preview for mid-sentence words than sentence-initial words. Notably, in Experiment 1 the effects of preview were statistically equal across conditions for the first-pass reading time measures, whereas the regression based measures did show significant differences. These findings highlight the importance of also examining regression-based measures of processing in studies of preview, as first-pass reading time measures may not necessarily reflect the complete impact of manipulations. Note that preview effects in regressions out are likely to reflect interference from the unusual previews, and as such therefore do not reflect a pattern of behavior that occurs in normal reading. Similarly, longer gaze durations associated with incorrect preview conditions may reflect interference from the incorrect preview, as well as lack of benefit from a correct parafoveal preview. Importantly, although incorrect previews can cause unique disruption to eye movement behavior, these measures are still highly informative in terms of evaluating the extent of processing of parafoveal previews (see White, Bertram, & Hyönä, 2008).

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Appendix A

Experimental sentences used in Experiment 1. In the sentence-initial condition the second sentence begins at the critical word, as shown in italics. In the mid-sentence condition the second sentence begins at the position marked *.

1. After dinner, Joe and Bob phoned *before* leaving* they needed directions.
2. Last night, Mary and Dan hugged *around* ten* they decided to go to the cinema.
3. At the spa, Gaby and Emma bathed *after* lunch* they also wanted massages.
4. On their third shot, Sue and Nick missed *after* pausing* they tried again.
5. Last night, Jen and Greg phoned *before* bed* they had a long chat.
6. Yesterday, Liz and Seb fought *among* the damage* everyone was upset.
7. At the interview, Bill and Stan probed *before* relenting* they were exhausted.
8. In most modules, Fred and Josh copied *during* finals* they failed their exams.
9. Because of the insult, Sam and Lucy cried *after* lunch* they met in a café.
10. To avoid flooding, Nicky and Don moved *after* July* the weather was perfect.
11. In the cafeteria, Emma and Neil choked *while* eating* they had been talking.
12. On the boat, Alex and Chris rowed *while* fishing* they moored on an island.
13. At the shoot, Beth and Meg posed *before* turning* they smiled many times.
14. At the studio, Matt and Todd filmed *before* editing* they wanted six solid scenes.
15. In the park, Greg and Ryan itched *after* lunch* they had touched some nettles.
16. In the morning, Jo and Rob rushed *before* leaving* they had to make their lunch.
17. In the hotel, Jay and Beth awoke *before* sunrise* they took a walk on the beach.
18. On the pitch, Brad and Doug kicked *during* training* they improved their aim.
19. In September, Abby and Carl moved *before* term began* they wanted to be settled.
20. For fun, Meg and Cara raced *after* gym* they declared it a tie.
21. In the car, Tim and Tom turned *after* Queen Street* they realized they were lost.
22. In the crowd, Doug and Sean pushed *among* the students* they were disliked.
23. At sunset, Anne and Steve kissed *while* talking* they decided to go out together.
24. Yesterday, Barb and Jon kissed *after* dinner* they went to a romantic movie.
25. At karate, Jen and Rob kicked *while* waiting* they wanted to be warmed up.
26. At the studio, Lynn and Tara posed *while* smiling* they modelled clothes.
27. That morning, Sue and Joe awoke *before* sunrise* they went running.

28. At ballet, Ed and Kate tired *before* class ended* they sat down.
29. Yesterday, Ted and Nina hugged *before* leaving* they exchanged phone numbers.
30. At the bar, Tim and Lee served *before* closing* they counted their tips.
31. Last night, Joy and Ed fought *before* bedtime* they apologized to one another.
32. At the restaurant, Alf and Lee served *before* leaving* they wiped the tables.
33. At the corner, John and Kim turned *after* signaling* they continued riding.
34. At the sink, Rob and Tony shaved *before* going out* they wanted to look nice.
35. At the track, Anna and Jill raced *before* sunset* they wanted to exercise.
36. In maths, Ted and Sue copied *every* time* they forgot to do their homework.
37. At football, Eva and Ben kicked *while* practicing* they hoped to improve.
38. In the smashed car, Dave and Andy shook *after* the accident* they were in shock.
39. In the woods, Deb and Ian itched *while* camping* they got mosquito bites.
40. In the park, Sam and Kara kissed *before* leaving* they took a walk together.
41. Yesterday, Mark and Jim called *before* visiting* they wanted to make plans.
42. At the meeting, Jesse and Vic fought *before* leaving* they did not apologize.
43. At the supermarket, Gwen and Amy rushed *while* shopping* they were in a hurry.
44. On the lake, Bill and Joey rowed *around* the shore* there were many fish.
45. At the meeting, Ron and Sara asked *while* taking notes* they learned a lot.
46. On the beach, Liz and Jess posed *while* standing* they looked at the camera.
47. On the highway, Geoff and Erica drove *among* the lorries* there were few cars.
48. On the test, Mat and Nell cheated *before* leaving* they were very nervous.
49. On holiday, Josh and Pete wrote *while* away* they missed their mothers.
50. In class, Mike and Tom wrote *while* reading* they were taking notes.
51. In school, Sara and Ann taught *before* leaving* they put the books away.
52. Last night, Jen and Leo raced *around* the track* they overtook the others.
53. On the pitch, Adam and Ben choked *while* running* they'd swallowed some flies.
54. At Scouts, Sam and Mary taught *during* the session* they focused on crafts.
55. According to Mum, Linda and Jen bathed *later* that night* they were still dirty.
56. According to Jim, Bill and Sam called *later* that day* everyone had heard.

Appendix B

Experimental sentences used in Experiment 2. In the sentence-initial condition the second sentence begins at the critical word, as shown in *italics*. In the mid-sentence condition, the second sentence begins at the position marked *. In the sentence-final condition, the second sentence begins at the word after the critical word.

1. Liz ran to the green field *nearby* along the river* she saw some geese.
2. Nick hung out with his wacky cousin *often* in the summer* he had free time.

3. Ed began hiking the rocky trail *early* in the evening* he reached the lake.
4. Greg held office events *often* for new staff members* this was exciting.
5. Pat ran around the uneven track *twice* after work* she had been called fat.
6. Jim tried on a black tuxedo *slowly* tying his tie* he looked in the mirror.
7. Lewis played with a music group *once* at the nightclub* he felt nervous.
8. Jan sang along to the blues music *often* in her car* she blasted the radio.
9. Kit walked her lovely poodle *often* in the morning* there was nice weather.
10. Karen drew rural scenes *often* in the morning* the lighting was just right.
11. John trained for the boxing match *early* in the morning* the gym was empty.
12. The teacher graded the latest exams *slowly* at her desk* she fell asleep.
13. Toby got a short break *today* in maths class* he finished his work early.
14. Charlie made a severe error *today* in the shop* he had to fix his mistake.
15. The DJ played the latest single *twice* on the air* he thanked his listeners.
16. Bob wrote his annual report *alone* in his office* he got some work done.
17. Li put on a black dress *sadly* in the afternoon* she had to go to a funeral.
18. The dog dirtied the suede couch *again* for the third time* Val scrubbed it.
19. Ann left her small house *often* in the summer* she'd go to the park.
20. Al danced with his pretty friend *twice* at the party* he tried to kiss her.
21. Joy sang to her weary family *daily* for a year* she had tortured them.
22. Dan saw the list of Latin books *today* on campus* he swapped modules.
23. Jon ironed his white shirt *today* at the hotel* a luncheon was being held.
24. John helped his dazed sister *calmly* in the corridor* he looked for a nurse.
25. Jo texted her squash buddy *often* in the evening* her phone was almost dead.
26. Jack visited the pizza place *nearby* on the street* two kids were fighting.
27. Zoe groped for the light switch *slowly* from the hall* she entered the room.
28. The bear raised his giant claws *higher* in the tree* he spotted some honey.
29. Dave searched for a tricky puzzle *today* in his bag* he had a few Sudokus.
30. Pete whined to his tired mother *sadly* at the park* a mean boy had hit him.
31. Faye opened her empty wallet *once* before class* she had bought a few DVDs.
32. Alf emailed his stingy bosses *often* in a panic* he threatened to quit.
33. Jo noticed the new street lamps *lately* on her walks* they seemed brighter.
34. Liz recited the Greek words *slowly* during the class* she began to catch on.
35. Sam saw a blurry figure *hazily* from across the bar* he also spotted a gun.
36. Jen calls her silly friend *often* in the morning* they meet at the cafe.
37. Jess bought a pretty dress *today* at the shops* she dreamed of a cute boy.

38. Rita finished the tough texts *today* after dinner* she had almost given up.
39. Tim goes to the tennis court *daily* after lunch* he works on his serve.
40. Beth returned to her empty house *alone* in her van* she cried to herself.
41. Phil answered the office phone *rudely* before hanging up* he laughed.
42. Nick put down the quiet infant *softly* in its crib* it cooed to itself.
43. Tom grilled tasty steaks *often* in the summer* he would entertain his pals.
44. Bea sells fresh fruit *yearly* at the fair* people flock to her berry stand.
45. Julie babysat the happy child *alone* for a few hours* they played peek-boo.
46. Meg typed the vague report *lazily* at her desk* she brewed a pot of coffee.
47. Guy drove the broken truck *oddly* after his accident* nobody stopped him.
48. Bob trained the small ferret *slowly* over time* Shari began to like the pet.
49. Tracy washed the dirty dishes *calmly* after lunch* her son played nearby.
50. Rick chased the quick train *sadly* in the rain* he fell on the wet platform.
51. Gabby read the famous plays *alone* in her room* she pretended to be Juliet.
52. Stan stood in the stone tower *warily* for a moment* he paused and listened.
53. Mae cheered for the local team *loudly* after each point* she blew a horn.
54. Barb ruined her white shirts *often* at meals* she would drip sauce on them.
55. Mo campaigned for better rules *openly* with her mates* she planned a strike.
56. Joe met the grumpy artist *today* at the gallery* they discussed modern art.
57. Dave ate at the greasy spoon *often* in the morning* the food was quite bad.
58. Ben went to the local cinema *alone* on the bus* he counted his money.
59. Kev bathed a scared puppy *gently* with his hands* he washed the dog's ears.
60. Brad went to the fancy eatery *twice* in one week* he spent nearly £50.
61. Kim mocked the weird loner *rudely* with her pals* she joked about his acne.
62. Leon sang the opera tunes *sadly* before the audition* he had caught a cold.
63. Amy wanted to make a yummy pizza *later* in the evening* she'd eat it all.
64. Jill sanded the wooden table *slowly* with Matt's help* she finished the job.
65. Mark watched famous movies *often* in the evening* he would rent several.
66. Fido sniffed the meaty treat *lazily* with his nose* he pushed it away.

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Figure 1.

Observed (*Obs*) and simulated (*Sim*) means for (Panel A) first-fixation durations (*FFD*), gaze durations (*GD*), and (Panel B) regression-out probabilities (*PrRO*) for word *n*-1 (*N-1*) and critical (*N*) words with and without parafoveal preview of mid-sentence critical words. (The error bars show the standard errors of the observed means.)

Figure 2.

Observed (*Obs*) and simulated (*Sim*) means for (Panel A) first-fixation durations (*FFD*), gaze durations (*GD*), and (Panel B) regression-out probabilities (*PrRO*) for word *n*-1 (*N-1*) and sentence-initial critical (*N*) words with and without parafoveal preview. The parenthetical numbers (1 vs. 2) in the legend indicate the simulation number: Simulation 1 used the same parameters as in the simulation shown in Figure 1, whereas Simulation 2 also included parameters that made post-lexical processing more prone to error ($p_F = 0.18$) and made long-distance inter-word regressions more likely ($p_N = 0.34$) for the last word in the sentences (i.e., word *n*-1). (The error bars show the standard errors of the observed means.)

Figure 3.

Observed (*Obs*) and simulated (*Sim*) means for (Panel A) first-fixation durations (*FFD*), gaze durations (*GD*), and (Panel B) regression-out probabilities (*PrRO*) for word *n*-1 (*N-1*) and sentence-final critical (*N*) words with and without parafoveal preview. The parenthetical numbers (1 vs. 2) in the legend indicate the simulation number: Simulation 1 used the same parameters as in the simulation shown in Figure 1, whereas Simulation 2 also included parameters that made post-lexical processing more prone to error ($p_F = 0.24$) and made long-distance inter-word regressions more likely ($p_N = 0.37$) for the last word in the sentences (i.e., word *n*). (The error bars show the standard errors of the observed means.)

First-Fixation Durations (FFD), Gaze Durations (GD), First Pass Regression Out Probabilities (FPRO) and Go-Past Time (GPT) for Word n-1 for Experiments (Exp.) 1 and 2. The Preview Effect (PE) is Shown as the Difference Between the Incorrect and Correct Preview Conditions for Each Sentence Position Condition. Standard Deviations in Parentheses.

Table 1

Exp.	Word n-1 Measure	Condition: Position of critical word									
		Sentence-initial		Mid-sentence		Sentence-final					
		Correct	Incorrect	PE	Correct	Incorrect	PE	Correct	Incorrect	PE	PE
1	FFD	294 (102)	294 (119)	0	250 (85)	252 (104)	2	-	-	-	-
	GD	345 (153)	366 (176)	21	283 (113)	294 (137)	11	-	-	-	-
	FPRO	0.12	0.12	0	0.05	0.06	0.01	-	-	-	-
	GPT	418 (349)	443 (304)	25	308 (160)	328 (211)	20				
2	FFD	237 (86)	256 (95)	19	237 (90)	254 (103)	17	240 (109)	246 (94)	6	6
	GD	278 (122)	295 (127)	17	268 (127)	290 (145)	22	276 (139)	280 (117)	4	4
	FPRO	0.24	0.2	-0.04	0.1	0.12	0.02	0.09	0.1	0.01	0.01
	GPT	383 (263)	389 (259)	6	313 (188)	358 (251)	45	314 (195)	325 (187)	11	11

Table 2

Mean First-Fixation Duration, Gaze Duration, Go-Past Time, and the Probability of First-pass Regressions Out (FPRO) for the Critical Word in Experiment 1. Mean Differences Between the Incorrect and Correct Preview Conditions are Labeled as Preview Effect (PE). Standard Deviations in Parentheses.

Critical Word Measure	Condition: Position of critical word				
	Sentence-initial		Mid-sentence		
	Correct	Incorrect	PE	Correct	Incorrect
First-fixation duration	246 (86)	268 (96)	22	268 (130)	273 (96)
Gaze duration	270 (119)	297 (137)	27	291 (141)	298 (128)
FPRO	0.05	0.1	0.05	0.07	0.24
Go-past time	312 (279)	343 (213)	31	317 (181)	397 (260)
					80

Mean First-Pass Reading Time / Gaze Duration (FPRT), Go-Past Time (GPT), and the Probability of First-pass Regressions Out (FPRO) for the Spillover Region in Experiments 1 and 2. Mean Differences Between the Incorrect and Correct Preview Conditions are Labeled as Preview Effect (PE). Standard Deviations in Parentheses.

Table 3

Exp.	Measure	Condition: Position of critical word									
		Sentence-initial		Mid-sentence				Sentence-final			
		Correct	Incorrect	PE	Correct	Incorrect	PE	Correct	Incorrect	PE	
1	FPRT	265 (136)	259 (128)	-6	315 (174)	324 (172)	9	-	-	-	
	FPRO	0.08	0.07	-0.01	0.23	0.23	0	-	-	-	
	GPT	301 (193)	293 (209)	-8	436 (339)	453 (326)	17	-	-	-	
2	FPRT	357 (201)	348 (187)	-9	328 (188)	352 (215)	24	373 (241)	350 (215)	-23	
	FPRO	0.13	0.07	-0.06	0.06	0.07	0.01	0.05	0.06	0.01	
	GPT	424 (281)	380 (218)	-44	356 (220)	421 (378)	65	403 (301)	384 (281)	-19	

Table 4

Mean First-Fixation Durations (FFD), Gaze Durations (GD), Go-Past Time (GPT) and the Probability of First-pass Regressions Out (FPRO) for the Critical Word in Experiment 2. Mean Differences Between the Incorrect and Correct Preview Conditions are Labeled as Preview Effect (PE). Standard Deviations in Parentheses.

Critical Word Measure	Condition: Position of critical word							
	Sentence-initial				Mid-sentence			
	Correct	Incorrect	PE		Correct	Incorrect	PE	
FFD	252 (104)	266 (91)	13	250 (92)	280 (98)	30	250 (91)	293 (43)
GD	285 (137)	300 (114)	15	269 (108)	319 (121)	50	281 (120)	341 (117)
FPRO	0.07	0.07	0	0.06	0.16	0.1	0.14	0.3
GPT	321 (221)	339 (229)	18	300 (191)	396 (267)	96	369 (335)	481 (338)
								112