

Lack of semantic parafoveal preview benefit in reading revisited

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Abstract

In contrast to earlier research, evidence for semantic preview benefit in reading has been reported by Hohenstein and Kliegl (2013) in an alphabetic writing system; they also implied that prior demonstrations of a lack of semantic preview benefit needed to be re-examined. In the present article we report a rather direct replication of an experiment reported by Rayner, Balota, and Pollatsek (1986). Using the *gaze-contingent boundary paradigm*, subjects read sentences that contained a target word (*razor*), but different preview words were initially presented in the sentence. The preview was either identical to the target word (i.e., *razor*), semantically related to the target word (i.e., *blade*), semantically unrelated to the target word (i.e., *sweet*), or a visually similar non-word (i.e., *razar*). When the reader's eyes crossed an invisible boundary location just to the left of the target word location, the preview changed to the target word. Like Rayner et al. (1986), we found that fixations on the target word were significantly shorter in the identical condition than in the unrelated condition, which did not differ from the semantically related condition; when an orthographically similar preview had been initially present in the sentence fixations were shorter than when a semantically unrelated preview had been present. Thus, the present experiment replicates the earlier data reported by Rayner et al. (1986) indicating evidence for orthographic preview benefit, but a lack of semantic preview benefit in reading English.

It is well established that readers obtain information from the word to the right of fixation (word $n+1$). The fact that they sometimes skip over word $n+1$ without making a regression back to the word is at least consistent with the argument that it is possible to obtain semantic information from word $n+1$ (Rayner, 2009). However, there is some controversy concerning the case in which word $n+1$ is not skipped. Here, the evidence is less clear, though much of it indicates that readers of English do not obtain morphological or semantic information from word $n+1$ (see Hohenstein & Kliegl, 2013; Rayner, 1998, 2009; Schotter, Angele, & Rayner, 2012 for reviews). When they have a valid preview of that word, fixation time on it, when it is subsequently fixated, is shorter than when there was an invalid preview; this effect of shorter fixation times on word $n+1$ is typically referred to as *preview benefit*. The effect has been examined numerous times by the use of the *gaze-contingent boundary paradigm* (Rayner, 1975). In this paradigm, readers' eye movements are monitored as they read text and a specified target word is changed from a preview word to the target word when the reader's eyes cross an invisible boundary located just to the left of the beginning of the target word. Because vision is suppressed during a saccade, and provided that the display change occurs during the saccade or shortly after it ends (within 10 ms of the end of the saccade; Slattery, Angele, & Rayner, 2011), readers typically do not notice the change.

It has been confirmed a number of times that both orthographically similar (see Balota, Pollatsek, & Rayner, 1985; Drieghe, Rayner, & Pollatsek, 2005; Inhoff, 1989; Rayner, 1975 for examples) and phonologically similar (see Ashby & Rayner, 2004; Miellel & Sparrow, 2004; Pollatsek, Lesch, Morris, & Rayner, 1992 for examples) previews yield preview benefit (see Rayner, 1998, 2009; Schotter et al., 2012 for reviews). Furthermore, prior research has largely indicated no reliable evidence for the effectiveness of morphological previews in alphabetic

writing systems (Bertram & Hyönä, 2007; Inhoff, 1989; Kambe, 2004; Lima, 1987) though morphological preview benefit has been demonstrated for Hebrew script (Deutsch, Frost, Peleg, Pollatsek, & Rayner, 2003; Deutsch, Frost, Pollatsek, & Rayner, 2000, 2005). More central for the present report, a number of studies have also failed to find evidence of semantic preview benefit (Altarriba, Kambe, Pollatsek, & Rayner, 2001; Dimigen, Kliegl, & Sommer, 2012; Hyönä & Häikiö, 2005; Rayner, Balota, & Pollatsek, 1986; Rayner, McConkie, & Zola, 1980) in alphabetic writing systems. It has generally been assumed that semantic preview benefit is difficult to observe because the properties of a semantically related preview and a given target word typically do not match on either orthography or phonology and hence this mismatch overrides any potential benefit that a reader might obtain from a semantically related preview (Schotter et al., 2012).

While the evidence for semantic preview benefit is not clear with alphabetic writing systems (especially English), evidence for it has been obtained in non-alphabetic writing systems such as Chinese (see Hohenstein & Kliegl, 2013 for an excellent review). Because the Chinese writing system is more densely packed than English, the preview word is generally much closer to the fixation point (or foveal vision) than is typically the case with alphabetic writing systems. Furthermore, semantic/morphological information is more directly coded in the writing system in non-alphabetic writing systems like Chinese.

Critically, semantic preview benefit has also recently been demonstrated across seven different experiments in German (Hohenstein & Kliegl, 2013; Hohenstein, Laubrock, & Kliegl, 2010). Specifically, Hohenstein and Kliegl¹ (2013) utilized the boundary paradigm as subjects read sentences containing a critical target noun for which a parafoveal preview was either semantically related or unrelated to the target. They found that fixation times on the target word

were shorter when there was a semantically related preview word than when there was an unrelated preview. More importantly for present purposes, in a very thorough analysis of studies failing to demonstrate semantic preview benefit, Hohenstein and Kliegl (2013) raised doubts about most of these prior studies because (1) they did not really involve subjects in the task of reading (Dimigen et al., 2012; Rayner et al., 1980), (2) they relied on emotion words and didn't really manipulate semantic relatedness (Hyönä & Häikiö, 2005), or (3) they involved presenting a preview in one language and the target word in another language (i.e., a Spanish word as a preview for an English word; Altarriba et al., 2001) and hence involved code switching that could have influenced the results. Their analysis thus renders these studies as somewhat questionable as evidence against semantic preview benefit, leaving Rayner et al. (1986) as the only study in which semantic preview benefit was not obtained while subjects were actually reading. This raises the question, very much implied in Hohenstein and Kliegl's analysis, as to whether or not Rayner et al.'s results are replicable. Here, we examined this specific issue via a rather direct replication (i.e., same subject pool, same eye-tracking system, and same stimuli) of Rayner et al. (1986). More specifically, in the Drieghe et al. (2005) study, which focused on word skipping of predictable words, 36 out of the 40 stimuli from the original Rayner et al. (1986) were analyzed here, allowing for a nearly perfect replication.

Method

Subjects. Twenty-four members of the University of Massachusetts at Amherst community participated in the experiment. All were native speakers of English and had 20/20 vision or contacts. They either received extra credit in a psychology course or were paid \$8 for their participation.

Apparatus. Eye movements were recorded via a Fourward Technologies Dual Purkinje Eyetracker (Generation V) interfaced with a Pentium computer, which in turn was interfaced with a 15-inch NEC MultiSync FGE color monitor. The display monitor used in the present investigation was much better than that used by Rayner et al. (1986) and led to much sharper resolution of the letters in the sentences (and hence the preview, see Drieghe et al., 2005 for further discussion). Subjects were seated 61 cm from the monitor; at this distance 3.8 character spaces equaled 1 deg of visual angle. Display changes occurred within 5 ms of detection of when the invisible boundary was crossed; the boundary was located between the last letter of the prior word and the space preceding the target word. Although reading was binocular, eye movements were only recorded from the subject's right eye (which was sampled every millisecond).

Materials. The stimuli consisted of 36 sentences from Rayner et al. (1986)². Within each sentence, we focused on four possible previews for the target word. For example, for the target word *razor*, the previews could be *razor* (Identical – ID), *blade* (Semantically Related – SR), *sweet* (Semantically Unrelated – UR), or *razar* (Visually Similar non-word – VSN). The VSN preview was created by replacing the penultimate letter with a visually similar letter. The average word length of the target word was 4.83 letters (with a range of 4-6 letters) and the average word frequency (based on Francis & Kučera, 1982) was 96.8 per million for the target word, 70.4 per million for the SR preview, and 115.6 per million for the UR preview. The SR preview word fit easily into the sentence context, whereas the UR preview word typically did not. To confirm this, twenty subjects who did not participate in the eye movement experiment were given the sentence frames up to and including the preview words. The ID and SR previewers were rated as good continuations, respectively 4.5 and 4.4 (on a scale of 1-5 with 5

being highly acceptable and 1 being unacceptable) whereas the UR previews were rated as 1.1. The target sentences were embedded in 108 other sentences that the subjects read. For the SR, UR, and target words used in the Rayner et al. (1986) study, they reported a 20 ms priming effect in a standard priming study in which subjects named target words (i.e., *razor*) preceded by either a SR prime (i.e., *blade*) or an UR prime (i.e., *sweet*); the prime words were presented for 200 ms, followed by a blank screen, and then the target word (which remained visible until the subjects responded).

Procedure. When subjects arrived for the present experiment, a bite bar was prepared, which served to eliminate head movements. Subjects were first given general instructions about the task and the eyetracking system was calibrated; the initial calibration took about 5 min. Each subject read 10 practice sentences followed by the entire set of 144 sentences. Prior to the presentation of each sentence, a series of 5 fixation points (extending from the first to the last letter position of an 80-letter space line) appeared on the monitor and subjects looked at each point to verify that eye position was accurately recorded; if it was not, the tracker was recalibrated. If calibration was accurate, the subject looked at the first fixation point and the experimenter displayed the sentence. Questions were asked about the meaning of sentence after 25% of the sentences; subjects answered the questions correctly 96% of the time.

Results

For details on data cleaning prior to running the analyses, Drieghe et al. (2005) should be consulted. Given that the target word received a single fixation 92% of the time, the primary dependent variable reported is *single fixation duration* (the duration of a fixation on a word when it receives only one fixation). However, given that Rayner et al. (1986) reported *gaze duration*

(the sum of all fixations on a word prior to moving to another word), we also report that measure. In addition, fixation probabilities are reported as there were differences in fixation probability on the target word across conditions. The means for each of these measures are presented in Table 1. Data were analyzed using inferential statistics based on generalized linear mixed-effects models (LMMs) with preview entered as a fixed effect with default contrasts (see below) and subjects and items as crossed random effects (see Baayen, Davidson, & Bates, 2008). Following Barr, Levy, Scheepers and Tily (2013), we used the maximal random effects structure possible: random intercepts for subjects and items as well as random slopes for each of the preview contrasts and correlations between all of these effects³. To assess preview benefit, the unrelated condition was set as the intercept (baseline condition) and each of the other conditions were compared to it, individually. In order to fit the LMMs, the lmer function from the lme4 package (Bates, Maechler & Bolker, 2011) was used within the R Environment for Statistical Computing (R Development Core Team, 2012). For single fixation duration and gaze duration, linear mixed-effects regressions were used, and regression coefficients (b), which estimate the effect size (in milliseconds) of the comparison, and the t-value of the effect coefficient are reported⁴. Absolute values of the *t* statistic greater than or equal to 1.96 indicate an effect that is significant at approximately the .05 alpha level. For fixation probability (a binary dependent measure) we conducted a logistic mixed-effects regression and report regression coefficients (b), which represent effect size in log-odds space, and the z value and p value of the effect coefficient. Importantly, fixations on the pre-target word were unaffected by any of the preview conditions (all *ts* < 1) indicating no evidence of parafoveal-on-foveal effects (i.e., the notion that characteristics of word *n*+1 can influence the amount of time readers look at word *n*).

Insert Table 1 about here

Fixation probability. The target word was less likely to be fixated in the ID condition (.81) than in the UR condition (.88; $z = 2.66, p < .01$); it was also less likely to be fixated in the SR condition (.79) than in the UR condition ($z = 3.47, p < .001$). The fixation probability in the VSN condition (.89) was not significantly different from the UR condition ($p > .78$). It is interesting that fixation probabilities in the ID condition and SR condition were quite similar (81% and 79%, respectively). To further investigate this, we examined regression rates as a function of preview condition and whether the target word was skipped during first pass reading. Formal analyses were not possible because of very low skipping rates, but the qualitative pattern of data suggests that skipping did influence the likelihood of a regression to the target. When the target word was fixated (the majority of the time), regression rates were quite low and varied very little across conditions (.02 in the ID condition, .02 in the SR condition, .08 in the VSN condition and .00 in the UR condition). When the target word was skipped, regression rates were overall higher and varied more across condition (.13 in the ID condition, .47 in the SR condition, .02 in the VSN condition and .33 in the UR condition).

The fixation/skipping data seem consistent with the following view. On about 20% of the trials in both the ID and SR conditions, the target/preview word was identified and skipped since in both cases the word fits into the sentence context. However, on nearly half of the skips in the SR condition, the reader regressed to the target region after skipping it. This was most likely due to the processing system noticing that the word to the left of fixation in the target location differed from the preview (see Binder, Pollatsek, & Rayner, 1999). It may also be the case that on a small percentage of the trials, the reader identified the SR preview word and went with that meaning since it fit into the sentence context (see Schotter, Reichle, & Rayner, 2014). In the UR and VSN conditions, readers skipped the target word less frequently, but regressed quite often in

the UR condition. However, while interesting, the primary focus of the present study is the fixation time on the target word when it was not skipped (since preview benefit is assessed from this time).

Fixation Time Measures. Single fixation durations on the target word in the ID condition ($M = 252$ ms) were significantly shorter than in the UR condition ($M = 307$ ms; $b = -57.70$, $SE = 12.20$, $t = 4.73$). Single fixations were also shorter in the VSN condition ($M = 278$ ms) than in the UR condition ($b = -25.48$, $SE = 11.98$, $t = 2.13$). Single fixations in the SR condition ($M = 293$) were not significantly different than in the UR condition ($t = 1.32$)⁵. Similarly, gaze durations on the target word in the ID condition ($M = 267$ ms) were significantly shorter than in the UR condition (314 ms; $b = -51.38$, $SE = 15.25$, $t = 3.37$). Neither the comparison between the VSN condition (292 ms) and the UR condition, nor the comparison between the SR condition (311 ms) and the UR condition were significant (both $ts < 1.21$)⁶.

The fixation time measures were both very consistent in showing no evidence for semantic preview benefit. Fixation times were shorter in the ID condition than the other conditions, and fixation times did not differ between the SR and UR conditions.

Discussion

In a close replication of Rayner et al. (1986), we found no evidence of semantic preview benefit. Thus, with respect to the issue implicitly raised by Hohenstein and Kliegl (2013), the results reported by Rayner et al. are replicable. The present results are also quite consistent with two other recent reports using the boundary paradigm to investigate semantic preview benefit. First, Rayner and Schotter (2013) found that when target words were presented normally in

lower case (i.e., *navy*, *church*) there was no evidence of semantic preview benefit. However, when the first letter of the target word was capitalized (i.e., *Navy*, *Church*), there was evidence of semantic preview benefit in later eye movement measures (reflecting refixations on the target word or regressions from the target word). This latter result is consistent with the findings reported by Hohenstein and Kliegl given that the first letter of German nouns (which were target words in their study) were capitalized. We will return to this finding later in this section.

Second, Schotter (2013) found no evidence for semantic preview benefit when the previews were semantic associates of the target word. However, when the preview was a synonym of the target word, she did find preview benefit.

Together, the present results and those of Rayner and Schotter (2013) and Schotter (2013) suggest that semantic preview benefit in English might be rather difficult to observe. Actually, the stimuli used by Rayner et al. (1986), and therefore in the present study as well, are a mix of synonyms, antonyms, and semantic associates. Schotter's results demonstrate that synonyms yield semantic preview benefit, but semantic associates do not. Clearly, other types of semantic relationships between words should be investigated, as well perhaps as the relationship between the prior context and the preview/target words.

We suspect that preview benefit is most likely to occur when there is some type of match between the preview word and the target word. Thus, with orthographically and phonologically related previews, there are matches between the preview and the target word; even when phonologically related previews do not match on orthography, but do match on phonology (i.e., *shoot*, *chute*) preview benefit is obtained (Pollatsek et al., 1992). Likewise, given that synonyms match on meaning, this results in preview benefit (Schotter, 2013). However, with semantic associates there is no match in terms of orthography, phonology, or meaning.

Another factor that is likely to be quite relevant is the nature of the writing system. With Chinese, for example, semantic information is more transparently encoded in the writing system. Likewise, German is a more shallow writing system than the deep orthography of English. As noted earlier, Hohenstein and Kliegl (2013) obtained semantic preview benefit for German readers. One reason for this may be that the first letter of their target words were capitalized, and this may draw more attention to the preview word than is the case with standard lower case (as in English). However, Hohenstein and Kliegl (their Experiment 2) also reported preview benefit even when the first letter of the target word was not capitalized (even though this violates German rules of orthography). Thus, preview benefit may simply be easier to demonstrate in shallow orthographies (see Schotter, 2013 for a discussion).

Finally, it may be the case that evidence for semantic preview benefit can be obtained for a deep orthography like English given the right circumstances⁷. Of course, this remains to be seen. However, as indicated by the present results, as well as the results of Rayner et al. (1986), Rayner and Schotter (2013), and Schotter (2013), semantic preview benefit in English seems to be rather elusive.

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Footnotes

1. We will focus on Hohenstein and Kliegl (2013) since it is most similar to Rayner et al. (1986) in using the boundary paradigm. Hohenstein et al. (2010) used a somewhat different paradigm.
2. Because Drieghe et al. (2005) focused on word skipping and long words are only rarely skipped, four of the sentences used in the original study by Rayner et al. (1986) were not used to ensure that all target words were between 4-6 letters and not longer.
3. For fixation probability, the model with the maximal random effects structure did not converge so we removed the correlation between the contrast for the VSN condition from the other contrasts in the random effects structure for items.
4. Log transforming the dependent variables increased the t-values of the comparisons, generally, but did not change the patterns of significance.
5. One could interpret the numerical difference between the means of the single fixation durations for the SR and UR condition as a suggestion of a semantic preview benefit. However, a post hoc power analysis revealed that on the basis of the mean difference, the effect size observed in the present study ($d = 0.25$) would require 128 subjects to obtain statistical power at the recommended .80 level (Cohen, 1988). This high number of required subjects casts doubts on whether this suggestion of an effect has the potential of becoming significant in eye movement experiments run on subject numbers remotely typical for the field. Moreover, close examination of the difference scores for the subjects revealed that for 12 out of 24 subjects the sign of the difference score was positive and for the remaining 12 was negative. Again, this casts doubt on whether our design was failing to pick up an existing effect.

6. We also ran additional models on the fixation duration data including the length of the incoming saccade and the duration of the fixation preceding the fixation on the target word. There was no indication that a semantic preview was observed for those instances when the eyes were close to the target word on the prior saccade and/or when this preceding fixation was long.
7. While it is widely assumed that semantic preview benefit effects are more consistent with the SWIFT model (Engbert, Nuthmann, Richter, & Kliegl, 2005) than with the E-Z Reader model (Reichle, Pollatsek, Fisher, & Rayner, 1998), it is the case that the latter model can account for semantic preview benefit effects (see Hohenstein & Kliegl, 2013 for discussion, and especially Schotter et al., 2014 for simulations demonstrating this).

Table 1. Means and standard errors (aggregated by subjects) for reading measures on the target word across conditions. ID = identical condition; SR = semantically related condition; VSN = visually similar nonword condition; UR = unrelated condition.

Measure	Preview			
	ID	SR	VSN	UR
Single Fixation Duration	252 (10)	293 (11)	278 (10)	307 (12)
Gaze Duration	267 (11)	311 (13)	292 (12)	314 (13)
Fixation Probability	.81 (.05)	.79 (.05)	.89 (.02)	.88 (.04)