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# Synonyms provide semantic preview benefit in English

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ABSTRACT

While orthographic and phonological preview benefits in reading are uncontroversial (see Schotter, Angele, & Rayner, 2012 for a review), researchers have debated the existence of semantic preview benefit with positive evidence in Chinese and German, but no support in English. Two experiments, using the *gaze-contingent boundary paradigm* (Rayner, 1975), show that semantic preview benefit can be observed in English when the preview and target are synonyms (share the same or highly similar meaning, e.g., *curlers-rollers*). However, no semantic preview benefit was observed for semantic associates (e.g., *curlers-styling*). These different preview conditions represent different degrees to which the meaning of the sentence changes when the preview is replaced by the target. When this continuous variable (determined by a norming procedure) was used as the predictor in the analyses, there was a significant relationship between it and all reading time measures, suggesting that similarity in meaning between what is accessed parafoveally and what is processed foveally may be an important influence on the presence of semantic preview benefit. Why synonyms provide semantic preview benefit in reading English is discussed in relation to (1) previous failures to find semantic preview benefit in English and (2) the fact that semantic preview benefit is observed in other languages even for non-synonymous words. Semantic preview benefit is argued to depend on several factors—attentional resources, depth of orthography, and degree of similarity between preview and target.



## Introduction

One of the most debated topics over the past decade in the field of eye movements during reading is whether or not semantic information can be obtained from an upcoming word while still fixating a prior word (see Hohenstein & Kliegl, 2013; Rayner, 1998, 2009; Schotter et al., 2012 for reviews). The debate centers on cases when a target word is not skipped; when it is skipped, it can be reasonably assumed that it had been sufficiently identified prior to fixation (Drieghe, Rayner, & Pollatsek, 2005; Ehrlich & Rayner, 1981; Rayner & Well, 1996). Throughout this debate researchers have used various tasks and languages to examine whether readers can obtain such information. The results of these studies have come to different conclusions: some claim positive evidence while others claim negative evidence. Some studies that have been used as evidence in the debate have not investigated the task of silent reading (e.g., "reading" lists of words, Dimigen, Kliegl, & Sommer, 2012) and, because the nature of the task is different from that of silent reading, will not be considered here. The perspective in the present paper is not to provide yet another piece of evidence to weigh on one side or another, but rather to attempt to reconcile various studies showing different results. I first discuss past studies on semantic preview benefit and develop a conceptual framework in which to reconcile them. A prediction of this framework was tested in two experiments showing that semantic preview benefit may be observed in English, but only if the preview and target are very similar in meaning—i.e., are synonyms of each other.

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To test what information about upcoming words readers can access and use while reading, researchers use the *gaze-contingent boundary paradigm* (Rayner, 1975). In this paradigm, a preview word is changed to a target word during the saccade to it (see Experiment 1 Method; Fig. 1). Reading time measures on the target are compared between various related preview conditions and an unrelated control condition. Faster processing in a related condition compared to the unrelated condition suggests *preview benefit*—that information was obtained from the preview word parafoveally and used to facilitate processing of the target. The evidence is clear that orthographically (e.g., Balota, Pollatsek, & Rayner, 1985; Drieghe et al., 2005; Johnson, Perea, & Rayner, 2007; McConkie & Zola, 1979; Rayner, 1975) and phonologically related previews (e.g. Ashby & Rayner, 2004; Miellet & Sparrow, 2004; Pollatsek, Lesch, Morris, & Rayner, 1992; Pollatsek, Tan, & Rayner, 2000) provide preview benefit, while preview benefits from other relationships (e.g., morphologically or semantically related previews) have mixed evidence and may depend on the language being considered (see Hohenstein & Kliegl, 2013; Rayner, 1998, 2009; Schotter et al., 2012 for reviews). Preview benefit is defined as facilitated processing of a target word (e.g., *beer*) when the reader had access to a related preview word/nonword (e.g., an orthographically similar letter string, *becn*) in that location compared to an unrelated preview condition (e.g., *rope*; Rayner, Balota, & Pollatsek, 1986). Rayner et al. did not find preview benefit for semantically related previews (e.g., *wine*, see below). Semantic preview benefit is one of a few effects that researchers believe distinguishes the two most prominent models of eye movement control in reading: E–Z Reader (Reichle, Pollatsek, Fisher, & Rayner, 1998; Reichle, Pollatsek, & Rayner, 2006; Reichle, Rayner, & Pollatsek, 2003; Reichle, Warren, & McConnell, 2009) and SWIFT (Engbert, Longtin, & Kliegl, 2002; Engbert, Nuthmann, Richter, & Kliegl, 2005; Schad & Engbert, 2012). Because of this, the presence of semantic preview benefit is of particular interest to the field.

Because, according to SWIFT, attention is allocated to multiple words in parallel (distributed as a gradient related to distance from fixation location) it is believed that semantic pre-activation of words naturally falls out of the model. In contrast, because attention is allocated serially in E–Z Reader, it is thought that the model is unable to account for lexical (and consequently, semantic) preprocessing of the upcoming word. However, according to the model, there is nothing barring lexical preprocessing of the upcoming word; it is just very unlikely, given that attention is only allocated to the upcoming word during a brief amount of time, after the current word has been identified but before the saccade to the upcoming word has been triggered. The robustly observed orthographic and phonological preview benefits reported throughout the literature are due to these features of words being processed parafoveally quickly during that brief attention shift. Thus, in E–Z Reader, if the preview duration is longer more time would allow for semantic pre-processing.

Semantic preview benefit likely arises because of a mechanism similar to that thought to cause *semantic priming* (e.g., spreading activation throughout a semantic network; Collins & Loftus, 1975; Quillian, 1967; but see Hutchinson, 2003; Lucas, 2000; and Neely, 1991 for reviews with other accounts, as well). Semantic priming is the finding that subjects respond faster to target words (generally presented in isolation) when a prime word (that was presented in its location briefly before the target) was semantically related to the target compared to when the prime was unrelated (see Neely, 1991). Semantic priming is generally assessed within a *lexical decision task* (where the response to the target is a decision about whether the target letter string is or is not a word), a *naming task* (where the response to the target is pronunciation of the word aloud) or a *categorization task* (where the response to the target is a decision about whether it belongs in a certain category (e.g., "animals")). In general in all of these tasks, subjects are facilitated by semantically related primes (as well as orthographically and/or phonologically related primes). In essence, semantic priming is generally accepted as being due to the prime providing a head-start on processing the target (e.g., Balota, Yap, Cortese, & Watson, 2008; Voss, Rothermund, Gast, & Wentura, 2013).

However, there are important differences between semantic priming and preview benefit; most notably, the fact that target words in sentences benefit from the sentence context putting constraints on (and making it easier to process) the meaning and syntactic class of the word (Hale, 2001; Levy, 2008). Furthermore, parafoveal preview allows for access to the visual form of the word before it is fixated (see Schotter et al., 2012). Regardless of which

| Condition | Sentence |
| --- | --- |
| Identical | Sarah tried using **curlers** on her stubborn straight hair before prom. |
| Synonym | Sarah tried using **rollers** on her stubborn straight hair before prom. |
| Unrelated | Sarah tried using **suffice** on her stubborn straight hair before prom. |
| Semantically related (Experiment 2 only) | Sarah tried using **styling** on her stubborn straight hair before prom. |
| Target | Sarah tried using **curlers** on her stubborn straight hair before prom. |

**Fig. 1.** Example sentences used in the experiments. Asterisks represent the location of the word being fixated. The first three lines represent the sentence during preview (i.e., before the display change) in the three conditions presented in both experiments, the fourth line represents the sentence during the preview in the semantically related condition (presented in Experiment 2 only), and the last line represents the sentence after the display change for all conditions in both experiments. For clarity, preview and target words are represented in boldface in the figure (but were presented normally in the experiments).

model of reading or semantic priming one considers, it is possible that semantic preview benefit would *not* be observed if activation from the preview has only a brief amount of time to provide a head-start on processing. Consequently, if activation does not need to spread as far in the network, semantic preview benefit might be more likely to be observed even with brief preview durations. While spreading activation is one account for semantic priming, an alternative explanation could be based on semantic features being activated (see Hutchinson, 2003; Lucas, 2000; Neely, 1991). Under this account, as well, semantic preview benefit would be more likely to be observed when the preview and target are more similar (i.e., when they share more features).

Researchers have accounted for the lack of evidence for semantic preview benefit in English (e.g., Rayner et al., 1986; see also Altarriba, Kambe, Pollatsek, & Rayner, 2001) by suggesting that lexical and semantic representations are activated after (likely as a consequence of) orthographic and phonological information and there is simply not enough time during parafoveal preview for information to feed up to semantics. Support for this idea comes from studies showing that orthographic preview benefit is larger when the pretarget word is high frequency (i.e., requires less processing to identify; Henderson & Ferreira, 1990; Kennison & Clifton, 1995), allowing for more preprocessing of the upcoming word prior to fixation, and consequently more preview benefit. Importantly, this should be a larger issue in a language like English than in other languages because of its deep orthography (i.e., there is an inconsistent connection between letters and sounds) and accessing phonological representations may be more effortful than in other languages. As a consequence, there may be less opportunity in English to observe semantic preview benefit, but languages with shallower orthographies may have a greater opportunity to produce semantic preview benefit (because semantic information would have a greater likelihood of being activated, either by activation spreading further in the network or by semantic features becoming more activated) even with only brief preview durations. In fact, a language (German) that does show evidence for semantic preview benefit does have a shallower orthography than English (Hohenstein & Kliegl, 2013; Hohenstein, Laubrock, & Kliegl, 2010). Relatedly, semantic preview benefit has also been reported in Chinese (Yan, Richter, Shu, & Kliegl, 2009; Yang, Wang, Tong, & Rayner, 2010), which more directly represents semantics without necessarily requiring phonological mediation (Hoosain, 1991). For a more detailed account, see the General Discussion.

One of the problems complicating the study of semantic preview benefit (and semantic priming, in general) is the fact that there are many possible ways in which words can be related in meaning. In fact, a review by Hutchinson (2003) identified 14 different types of relationships observed in association norm databases. Because these categories represent a whole range of types of relationships (e.g., perceptual property—*canary-yellow*, phrasal associates—*baby-boy*, supraordinate category—*dog-animal*, antonyms—*hot–cold*, etc.), it is likely that combining all (or many) of them in an experiment will obscure different and nuanced effects that vary between the different types. The seminal semantic preview benefit study (Rayner et al., 1986) did, in fact, investigate this to a small extent. Rayner et al.'s (1986) overall data showed no semantic preview benefit. In a post hoc analysis, they compared the magnitude of the preview benefit for semantically related previews that altered the meaning of the sentence (measured by a norming procedure) compared to all sentences. They found the same pattern of data, regardless of whether the preview constituted a change in the meaning of the sentence. However, even words that were not rated to have significantly changed the meaning of the sentence may have actually changed the meaning of the sentence to enough of a degree that semantic preview benefit may have been eliminated.

For this reason, it is necessary to assess the degree to which previews that are semantically related, and do *not* change the meaning of the sentence, provide preview benefit. For instance, *synonyms* (words with the same or very similar meaning; e.g., *curlers—rollers*) may show a different type of preview benefit than purely related items (e.g., *curlers—styling*). Because synonyms share the same meaning, in a reading task in which the goal of the cognitive-linguistic processing system is to access word meanings, they may actually provide preview benefit even though the various semantic relationships tested in previous studies in English did not.

Given this, an argument could be made that *translation equivalents*—words that have the same meaning across two languages (e.g., *strong* in English and *fuerte* in Spanish) should provide substantial preview benefit to proficient bilinguals because they should not significantly alter the meaning of the sentence. However, a study by Altarriba et al. (2001) found that words such as these, which are *non-cognates* (i.e., only share meaning, and not orthography or phonology, e.g., *strong—fuerte*) did not provide any preview benefit compared to an unrelated word, but those that shared meaning, phonology and orthography (*cognates*, e.g., *cream—crema*) and those that only shared orthography and phonology but not meaning (*pseudocognates*, e.g., *grass—grasa*) did. Altarriba et al. explained this by proposing that preview benefit is based on parafoveal processing of orthographic and phonological information, but not semantic information; alternatively, as suggested above, when orthographic and phonological information changes between preview and target any semantic information that had been obtained is discarded. However, because these words were only semantically related across languages, it is possible that Altarriba et al. failed to find a semantic preview benefit because information obtained from the preview may have not spread quickly enough to their other lexicon (i.e., Spanish) after reading words exclusively in one language (i.e., English).

Given the evidence reviewed above, it is possible that when a preview and a target are dissimilar enough that information obtained from the preview parafoveally will either not have time to become activated or will be discarded and word identification on the target will start again, from scratch (see Altarriba et al., 2001; Schotter et al., 2012). However, if there is enough shared information between the preview and target to facilitate processing of the target, parafoveally obtained preview information may be retained and used to identify the target. This account makes two specific predictions about whether preview benefit will be observed and the relative magnitude of preview benefits in different conditions. First, the more levels of representation that are shared between preview and target, the larger the preview benefit should be. Prior research demonstrates that phonological preview benefit is larger when both orthography and phonology are shared between preview and target compared to when only one representation is shared (e.g., Miellet & Sparrow, 2004) and preview benefit is observed for bilinguals reading cognates (words that share orthographic/phonological *and* semantic representations across languages), but not non-cognate translations (words that only share semantic representations across languages; Altarriba et al., 2001). Second, and most importantly for the current experiments, the greater degree of similarity between preview and target *within* a level of representation (e.g., orthography, phonology, semantics), the larger the observed preview benefit should be. In fact, prior research has demonstrated that the degree of orthographic similarity is positively related to the magnitude of orthographic preview benefit (e.g., Miellet & Sparrow, 2004; Pollatsek et al., 1992). Given these two predictions, one would expect that (1) synonyms should provide preview benefit while other semantic relationships (i.e., semantic associates) should not and (2) preview benefit should be positively related to the similarity in meaning between preview and target.

To test these predictions, two experiments examined the presence and magnitude of semantic preview benefit during reading. To test for semantic preview benefit, both experiments utilized the gaze-contingent boundary paradigm (Rayner, 1975) and compared reading time measures on the target between various related preview conditions: (1) identical (e.g., *curlers—curlers*), (2) synonym (e.g., *rollers—curlers*), (3) semantically related (e.g., *styling—curlers* in Experiment 2 only), and (4) an unrelated control condition (e.g., *suffice—curlers*).[1]

## Experiment 1

### Method

*Subjects*. Thirty-six undergraduates at the University of California San Diego participated in the experiment for course credit. All subjects were native English speakers with normal or corrected-to-normal vision and were naïve to the purpose of the experiment.

*Apparatus*. Eye movements were recorded with an SR Research Ltd. Eyelink 1000 eye tracker (with a sampling rate of 1000 Hz) in a tower setup that restrains head movements with forehead and chin rests. Viewing was binocular, but only the movements of the right eye were recorded. Subjects were seated approximately 60 cm away from an Iiyama Vision Master Pro 454 CRT monitor with a screen resolution of 1024 × 768 pixels and a refresh rate of 150 Hz. The sentences were presented in the center of the screen with black Courier New 14-point font on a white background and were always presented in one line of text with 3.8 characters subtending 1° of visual angle. Following calibration, eye position errors were (maximally) less than 0.3°. The display change was completed, on average, within 4 ms (range = 0–7 ms) of the tracker detecting a saccade crossing the boundary.

*Materials and design*. Stimuli consisted of 123 target words that were paired with one synonym and one unrelated item to create the three preview conditions: identical (*curlers – curlers*), synonym (*rollers – curlers*), and unrelated (*suffice – curlers*; see Table 1, Appendix A). Each target item was presented in a sentence context that was designed to be neutral and not predict either the target or either of the previews (all cloze scores < .05; see normative data section, below). The target word was always preceded and followed by a minimum of three words. The target and all previews were matched on length (number of letters), ranging from 3 to 10 letters (mean = 5.61). The synonym and unrelated previews were matched with each other on word shape (e.g., ascenders and descenders) and number of initial letters shared with the target ($M_{\text{synonym-target}}$ = 0.09, SE = .03, $M_{\text{unrelated-target}}$ = 0.09, SE = .03). Number of initial letters shared with the target was calculated by counting the number of letters, starting with the leftmost letter, shared between the preview and target (e.g., for *rollers-curlers* this number would be 0, for *drab-dull* this number would be 1). In addition to the lexical characteristics, a series of norming experiments assessed the degree to which the target and previews were (1) predictable in the sentence context, (2) related in meaning, and (3) changed the meaning of the sentence. Lastly, the previews were coded for whether or not they were anomalous in the sentence context (see Results and Discussion section of Experiment 2, below).

*Normative data*. Fifteen UCSD students, who did not participate in the reading experiment, participated in a cloze norming task to evaluate the predictability of the target and preview words. This norming task revealed that the sentences were very neutral, with (on average) the target only being produced 2% of the time, the synonym being produced 5% of the time and the unrelated word being produced 0% of the time.

A separate set of thirty UCSD students participated in a semantic relatedness judgment task to evaluate the degree to which each of the previews were similar in meaning to the target (on a 1–9 point rating scale). This norming task revealed that the target and synonym were rated as very similar in meaning (*M* = 7.5) whereas the unrelated preview was very different in meaning (*M* = 2.4).

To assess the degree to which replacing the target with a preview changed the meaning of the sentence, an additional norming task was conducted with yet another set

[1] It must be noted that expectations about what word will appear next in the sentence may affect how the encountered word is processed (Hale, 2001; Levy 2008; Roland, Yun, Koenig, & Mauner, 2012). Mainly, words that are semantically similar to the expected word are processed more easily than those that are dissimilar. However, the purpose of the present experiments is to test for semantic preview benefit—whether semantic information can be obtained from the *word itself*, in the absence of support from context. For this reason, all sentences were created to have very low cloze probabilities for all target and preview words so that any preview benefit observed is attributable to parafoveal preprocessing, rather than similarity between the preview and the expected word.

**Table 1**
Lexical characteristics of and normative data for target and preview words used in Experiment 1 (all conditions except semantically related) and Experiment 2 (all conditions). Standard errors are in parentheses.

| Variable | Target | | Preview condition | |
|---|---|---|---|---|
| | Identical | Synonym | Semantic | Unrelated |
| Length | 5.61 (1.46) | 5.61 (1.46) | 5.61 (1.46) | 5.61 (1.46) |
| Log frequency (HAL) | 8.31 (1.86) | 10.26 (1.46) | 8.99 (2.11) | 10.04 (1.53) |
| Total letters shared with target | – | .72 (.09) | .81 (.10) | .55 (.07) |
| Initial letters shared with target | – | .09 (.03) | .15 (.05) | .09 (.03) |
| Cloze predictability | .02 (.05) | .05 (.12) | .00 (.02) | .00 (.01) |
| Word relatedness to target (1–9 scale) | – | 7.5 (.97) | 5.6 (1.5) | 2.4 (.97) |
| Sentence fragment relatedness to target (1–9 scale) | – | 7.2 (1.3) | 4.9 (1.8) | 1.9 (.72) |
| Proportion of items that are semantically anomalous | .00 | .00 | .17 | .70 |
| Proportion of items that are syntactically anomalous | .00 | .00 | .13 | .40 |

of thirty UCSD students. Subjects were given one sentence fragment (including the beginning of the sentences up to, and including, the target) and a second fragment where the target was replaced by one of the previews, and asked to judge how much the meaning of the sentence fragments differed (on a 1–9 point rating scale).[2] This norming task revealed results quite similar to the relatedness judgments of the isolated words. The sentence fragments that changed from target to synonym were rated as very similar ($M = 7.2$), whereas the sentence fragments with the unrelated preview were rated as very different ($M = 1.9$).

*Procedure*. Subjects were instructed to read the sentences for comprehension and to respond to occasional comprehension questions, pressing the left or right trigger on the response controller to answer yes or no, respectively. At the start of the experiment (and during the experiment if calibration error was greater than .3 degrees of visual angle), the eye-tracker was calibrated with a 3-point calibration scheme. At the beginning of the experiment, subjects received five practice trials, each with a comprehension question, to allow them to become comfortable with the experimental procedure.

Each trial began with a fixation point in the center of the screen, which the subject was required to fixate until the experimenter started the trial. Then a fixation box appeared on the left side of the screen, located at the start of the sentence. Once a fixation was detected in this box, it disappeared and the sentence appeared. The sentence was presented on the screen until the subject pressed a button signaling they had completed reading the sentence. The target replaced the preview once the subject's gaze crossed an invisible boundary located before the space before the target (see Fig. 1). Subjects were instructed to look at a target sticker on the right side of the monitor beside the screen when they finished reading to prevent them from looking back to a word (in particular, the target, which was often located in the center of the sentence, near the location of the fixation point that started the next trial) as they pressed the button. Comprehension questions followed 30 (41%) of the sentences, requiring a "yes" or "no" response. The experimental session lasted approximately thirty minutes.

### *Results and discussion*

Comprehension accuracy was very high (on average 96%). Fixations shorter than 80 ms within one character of a previous or subsequent fixation were combined. All remaining fixations shorter than 80 ms were eliminated. Trials in which there was a blink or track loss on the target word or on an immediately adjacent word during first pass reading were excluded, as were trials in which the display change was triggered by a saccade that landed to the left of the boundary or trials in which the display change was completed late. These data exclusions left 3637 trials (82% of the original data) available for analysis. Additionally, for each measure, durations that were beyond 3 standard deviations from each subject's mean were excluded.

Data were analyzed using inferential statistics based on generalized linear mixed-effects models (LMMs) with preview entered as a fixed effect with planned contrasts (see below) and subjects and items as crossed random effects (see Baayen, Davidson, & Bates, 2008), using the maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013).[3] There were two planned contrasts built into the model: the first tested for a difference between the identical condition and the unrelated condition (i.e., an identical preview benefit) and the second tested for a difference between the synonym and the unrelated condition (i.e., a synonym preview benefit). These contrasts were achieved by setting the unrelated condition to the baseline (intercept) in the model and using the default contrasts for the comparisons of each of the other conditions to the unrelated condition. 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 fixation duration measures, linear mixed-effects regressions were used, and regression

[2] Data were also collected from 15 subjects that did not participate in any of the other experiments in which the order of the sentence fragments was reversed (i.e., the subjects were asked to judge the extent to which the meaning of the fragment changed when the *preview* was replaced by the *target*) because, in the reading experiment, the preview was presented first. The data from these two tasks were highly correlated (Pearson's $r = .92$), indicating that there was no difference, based on the direction of association.

[3] Log transforming the fixation durations lead to more normally distributed data (because fixation durations generally have a heavy tail) but this transformation did not change the results so untransformed data are used for transparency of the effect sizes.

coefficients (b), which estimate the effect size (in milliseconds) of the reported comparison, and the *t*-value of the effect coefficient are reported. For binary dependent variables (fixation probability data), logistic mixed-effects regression were used, and regression coefficients (b), which represent effect size in log-odds space, and the *z* value and *p* value of the effect coefficient are reported. Absolute values of the *t* and *z* statistics greater than or equal to 1.96 indicate an effect that is significant at approximately the .05 alpha level.

*Eye movement measures*. To assess the degree to which semantic information was obtained from the target words parafoveally, standard *local reading time measures* (see Rayner, 1998, 2009; Schotter et al., 2012) on the target word across conditions were compared: *first fixation duration* (the duration of the first fixation on the word, regardless of how many fixations are made), *single fixation duration* (the duration of a fixation on a word when it is the only fixation on that word in first pass reading), *gaze duration* (the sum of all fixations on a word prior to leaving it, in any direction), *total viewing time* (the sum of all fixations on a word, including regressions) and *go past time* (the sum of all fixations on a word and any words to the left of it before going past it to the right). The fixation probability measures reported are *fixation probability* (the probability of making a fixation on the target during first pass reading), *regressions out of the target* (probability of making a regression out of the target, to a word to the left of it) and *regressions into the target* (probability of making a regression into the target from one of the words to its right). Note that, because of the display change, readers never fixated the preview (i.e., the target was present upon fixation in all conditions) and the only access they had to the preview was parafoveally. Thus, any differences across conditions are due to the information readers had obtained from the preview prior to fixating it and the facilitation that information provided to processing the target during fixation on it. There were no differences across condition for gaze duration on the pretarget word (all ts < .45), indicating no parafoveal-on-foveal effects (effects of the subsequent word affecting reading time on the currently fixated word); pretarget gaze durations were 234 ms, 231 ms, and 233 ms in the identical, synonym, and unrelated conditions, respectively. Means and standard errors (aggregated by subject) for local reading time measures on the target word are reported in Table 2.

**Table 2**
Means and standard errors (aggregated by subjects) for reading measures on the target across condition in Experiment 1.

| Measure | Preview | | |
|---|---|---|---|
| | Identical | Synonym | Unrelated |
| *Fixation duration measures* | | | |
| First fixation duration | 223 (4.3) | 220 (4.3) | 234 (5.4) |
| Single fixation duration | 227 (4.7) | 227 (5.1) | 244 (6.4) |
| Gaze duration | 247 (5.6) | 251 (6.7) | 267 (7.0) |
| Total viewing time | 286 (9.4) | 294 (8.1) | 320 (12.0) |
| Go past time | 277 (9.0) | 281 (8.6) | 308 (13.0) |
| *Fixation probability measures* | | | |
| Fixation probability | .81 (.03) | .83 (.02) | .85 (.02) |
| Regressions into the target | .14 (.02) | .18 (.02) | .19 (.02) |
| Regressions out of the target | .09 (.02) | .09 (.01) | .13 (.02) |

*Fixation duration measures*. Results of the LMMs for fixation duration measures are reported in Table 3. Across all measures there was a significant preview benefit in the identical condition; reading times were significantly shorter on the target when the preview was identical, than when it was unrelated (FFD: $b = 12.51$, $t = 3.05$; SFD: $b = 18.23$, $t = 3.72$; GZD: $b = 21.75$, $t = 4.22$; TVT: $b = 39.90$, $t = 5.32$, Go-Past: $b = 31.50$, $t = 3.84$). Similarly, there was a significant preview benefit in the synonym condition: reading times were significantly shorter on the target when the preview was a synonym of the target than when it was unrelated (FFD: $b = 14.84$, $t = 3.61$; SFD: $b = 17.81$, $t = 3.63$; GZD: $b = 16.63$, $t = 3.10$; TVT: $b = 27.19$, $t = 3.14$, Go-Past: $b = 29.54$, $t = 3.28$). These results suggest that semantic information can be extracted from the parafovea and used to facilitate processing of the target, once it is fixated (see General discussion).

*Fixation probability measures*. Results of the LMMs on fixation probability measures are reported in Table 4. There was no effect of preview condition on the probability of fixating the target: both the difference between the identical and unrelated conditions and the difference between the synonym and unrelated conditions were not significant (both $ps > .65$). For regressions, the difference between the identical and unrelated conditions was significant, with lower probabilities in the identical condition for both regressions into the target ($z = 4.16$, $p < .001$) and regressions out of the target ($z = 4.14$, $p < .001$) whereas the difference between the synonym and unrelated conditions was not significant for regressions into the target ($z < 1$) but was marginally significant (a lower probability in the synonym condition) for regressions out of the target ($z = 1.71$, $p = .09$).

Taken together, these results suggest that semantic information can be obtained from an upcoming word during silent reading and, if that semantic information is similar enough to that of the target (i.e., if preview and target are synonyms) the information will be used to facilitate processing of the target. Note that the orthographic similarity between the synonym preview and target and the unrelated preview and target was well-matched and very low (on average almost no similar letters) so that a perceptually-based account of these data is unlikely.

## Experiment 2

To further test the predictions laid out in the introduction, a second experiment was conducted using the boundary paradigm to test for semantic preview benefit. This experiment contained the same sentences and conditions as Experiment 1, but also included a semantically related (but not synonymous) condition (e.g., *styling—curlers*). This experiment is important to (1) replicate the finding of preview benefit provided by synonyms from Experiment 1 and (2) replicate the finding of a lack of preview benefit for semantically related, but not synonymous words (Rayner et al., 1986). This experiment directly tests whether the reason why semantic preview benefit was observed in

**Table 3**
Results of the linear mixed effects models for reading time measures on the target across condition in Experiment 1. Preview benefit refers to the difference in processing between the unrelated condition and either the identical or synonym, separately. Significant effects are indicated by boldface.

| Measure | Preview benefit comparison | *b* | SE | T |
|---|---|---|---|---|
| First fixation duration | **Identical** | **12.51** | **4.10** | **3.05** |
| | **Synonym** | **14.84** | **4.11** | **3.61** |
| Single fixation duration | **Identical** | **18.23** | **4.90** | **3.72** |
| | **Synonym** | **17.81** | **4.91** | **3.63** |
| Gaze duration | **Identical** | **21.75** | **5.16** | **4.22** |
| | **Synonym** | **16.63** | **6.01** | **3.10** |
| Total time | **Identical** | **39.90** | **7.50** | **5.32** |
| | **Synonym** | **27.19** | **8.66** | **3.14** |
| Go-past time | **Identical** | **31.50** | **8.20** | **3.84** |
| | **Synonym** | **29.54** | **9.00** | **3.28** |

**Table 4**
Results of the linear mixed effects regression model for fixation probability measures on the target across condition in Experiment 1. Preview benefit refers to the difference in processing between the unrelated condition and either the identical or synonym, separately. Significant effects are indicated by boldface.

| Measure | Preview benefit comparison | *b* | *z* | *p* |
|---|---|---|---|---|
| Fixation probability | Identical | .08 | 0.44 | .66 |
| | Synonym | −.05 | 0.26 | .79 |
| Regressions into the target | **Identical** | **.83** | **4.16** | **<.001** |
| | Synonym | .14 | .98 | .33 |
| Regressions out of the target | **Identical** | **.89** | **4.14** | **<.001** |
| | Synonym | .35 | 1.71 | .09 |

Experiment 1, here, but not by Rayner et al. (1986) is due to the degree of semantic similarity between preview and target. That is, many of their semantically related previews changed the meaning of the sentence (as do many of the semantically related previews in Experiment 2) while synonyms do not. Thus, we should not see preview benefit from the semantically related previews in Experiment 2, but we should still see preview benefit from the synonym previews.

### Method

The method was identical to that of Experiment 1 with the following exceptions.

*Subjects*. Forty undergraduates at the University of California San Diego participated in the experiment for course credit. None of them participated in any of the other experiments and were chosen using the same inclusion criteria as Experiment 1.

*Materials and design*. Stimuli were identical to those used in Experiment 1, except for the inclusion of an additional condition—semantically related but not synonymous words—which were matched in length to the target (see Table 1 and Appendix). Because of the requirement to match the semantically related preview to the target in terms of length, finding related words in a database (e.g., the South Florida norms) proved too difficult. Rather, these items were selected by the experimenter and confirmed via norming (see below). In the cloze norming task (see Experiment 1 Method), the semantically related word was never produced (cloze probability = 0%). In the relatedness norming procedure to test for similarity in meaning between the preview and target, the semantically related words were rated as related to the target ($M = 5.6$ on a 9 point scale), but not as related as the synonyms were ($M = 7.5$). Additionally, in the norming procedure to test for similarity in meaning of the sentence when the preview was replaced by the target, these items were somewhat similar in meaning to the fragment with the target ($M = 4.9$), but not as similar as the fragment with the synonym ($M = 7.2$).

### Results and discussion

Comprehension accuracy was very high (on average 97%). The same data processing procedure used in Experiment 1 was used in Experiment 2. These data exclusions left 4048 trials (82% of the original data) available for analysis. The same analysis procedure used in Experiment 1 was used in Experiment 2, with an additional planned contrast (semantically related vs. unrelated) entered into the models. Means and standard errors (aggregated by subject) of local reading measures on the target are presented in Table 5. There were no differences across condition for gaze duration on the pretarget word (all $ts < 1.28$), indicating no parafoveal-on-foveal effects (pretarget gaze durations were 241 ms, 243 ms, 244 ms, and 238 ms in the identical, synonym, semantically related, and unrelated conditions, respectively).

*Fixation duration measures*. Results of the LMMs on fixation duration measures are reported in Table 6. Across all measures there was a significant preview benefit such that reading times were significantly shorter on the target when the preview was identical than when it was unre-

**Table 5**
Means and standard errors (aggregated by subjects) for reading measures on the target across condition in Experiment 2.

| Measure | Preview | | | |
|---|---|---|---|---|
| | Identical | Synonym | Semantic | Unrelated |
| *Fixation duration measures* | | | | |
| First fixation duration | 225 (5.2) | 230 (5.7) | 241 (6.7) | 236 (5.9) |
| Single fixation duration | 232 (5.2) | 239 (6.1) | 252 (7.5) | 246 (6.4) |
| Gaze duration | 253 (6.3) | 261 (7.4) | 273 (8.1) | 270 (8.0) |
| Total viewing time | 326 (13) | 345 (13) | 354 (14) | 351 (12) |
| Go past time | 294 (9) | 302 (11) | 317 (12) | 323 (11) |
| *Fixation probability measures* | | | | |
| Fixation probability | .88 (.02) | .86 (.02) | .88 (.02) | .89 (.02) |
| Regressions into the target | .17 (.02) | .24 (.02) | .23 (.02) | .24 (.02) |
| Regressions out of the target | .12 (.01) | .12 (.02) | .13 (.02) | .15 (.02) |

**Table 6**
Results of the linear mixed effects models for reading time measures on the target across condition in Experiment 2. Preview benefit refers to the difference in processing between the unrelated condition and either the identical, synonym, or semantically related, separately. Significant effects are indicated by boldface.

| Measure | Preview benefit comparison | *b* | SE | *t* |
|---|---|---|---|---|
| First fixation duration | **Identical** | **11.15** | **3.63** | **3.07** |
| | Synonym | 6.18 | 3.27 | 1.89 |
| | Semantic | −4.98 | 3.59 | 1.39 |
| Single fixation duration | **Identical** | **14.93** | **4.32** | **3.46** |
| | **Synonym** | **9.78** | **3.74** | **2.61** |
| | Semantic | −4.47 | 3.91 | 1.14 |
| Gaze duration | **Identical** | **16.35** | **5.39** | **3.03** |
| | **Synonym** | **9.46** | **4.60** | **2.06** |
| | Semantic | −3.41 | 4.65 | .73 |
| Total time | **Identical** | **24.36** | **8.78** | **2.77** |
| | Synonym | 5.66 | 8.03 | .71 |
| | Semantic | −4.11 | 7.54 | .54 |
| Go-past time | **Identical** | **27.66** | **7.88** | **3.51** |
| | **Synonym** | **21.23** | **8.70** | **2.44** |
| | Semantic | 5.77 | 7.33 | .79 |

lated (FFD: $b = 11.15$, $t = 3.07$; SFD: $b = 14.93$, $t = 3.46$; GZD: $b = 16.35$, $t = 3.03$; TVT: $b = 24.36$, $t = 2.77$, Go-Past: $b = 27.66$, $t = 3.51$). There was a significant preview benefit in the synonym condition; reading times were significantly shorter on the target when the preview was a synonym of the target than when it was unrelated in all measures (SFD: $b = 9.78$, $t = 2.61$; GZD: $b = 9.46$, $t = 2.06$; Go-Past: $b = 21.23$, $t = 2.44$) except first fixation duration, where it was marginal ($b = 6.18$, $t = 1.89$) and total viewing time ($b = 5.66$, $t < 1$).[4] Importantly, none of the measures showed a significant preview benefit in the semantically related condition (all *ts* < 1.4).

*Fixation probability measures*. Results of the LMMs on fixation probability measures are reported in Table 7. Only the synonym preview condition significantly differed from the unrelated condition, with a lower probability of fixating the target in the synonym condition ($z = 3.27$, $p < .005$), likely because the synonym had slightly higher cloze probability (.05) than the other conditions (0 for the unrelated and semantically related and .02 for the identical condition). Neither the identical nor the semantically related condition were significantly different from the unrelated condition (both *ps* > .23) in terms of fixation probability. For the probability of making regressions into the target, the difference between the identical and unrelated conditions was significant, with a lower probability of regressing into the target in the identical condition ($z = 4.22$, $p < .001$) but neither the difference between the synonym nor the semantically related condition and unrelated condition were significant (both *ps* > .78). For regressions out of the target, all three preview contrast were significant, indicating that subjects were less likely to make a regression from the target to prior words in the text when the preview was identical to ($z = 1.99$, $p < .05$), a synonym of ($z = 2.17$, $p < .05$) or semantically related to the target ($z = 2.61$, $p < .01$) than when it was unrelated.

Taken together these data replicate the lack of semantic preview benefit reported by Rayner et al. (1986) using semantically related items that do not share the same meaning with the target. Importantly, these data contrast with the finding (replicated across two experiments in this study) that synonyms do provide semantic preview benefit. These results suggest that semantic information can be extracted from the parafovea and used to facilitate processing

[4] Note that these non-significant effects in the synonym condition do not perfectly replicate the effects seen in Experiment 1. Importantly, though the effects on the hallmark measures of preview benefit (gaze duration and single fixation duration) are replicated and the discrepancy between the results for first fixation and total time are likely due to noise.

**Table 7**
Results of the linear mixed effects regression model for fixation probability measures on the target across condition in Experiment 2. Preview benefit refers to the difference in processing between the unrelated condition and either the identical, synonym or semantically related, separately. Significant effects are indicated by boldface.

| Measure | Preview benefit comparison | *b* | *z* | *p* |
|---|---|---|---|---|
| Fixation probability | Identical | .19 | 1.18 | .24 |
| | **Synonym** | **.56** | **3.27** | **<.005** |
| | Semantic | .12 | .69 | .49 |
| Regressions into the target | **Identical** | **.54** | **4.22** | **<.001** |
| | Synonym | −.03 | .27 | .79 |
| | Semantic | .01 | .12 | .91 |
| Regressions out of the target | **Identical** | **.31** | **1.99** | **<.05** |
| | **Synonym** | **.31** | **2.17** | **<.05** |
| | **Semantic** | **.38** | **2.61** | **<.01** |

of the target, once it is fixated, but only if the meaning of the word does not change between preview and target.

## Does similarity in meaning drive semantic preview benefit in English?

The planned contrasts between conditions suggest that synonyms provide semantic preview benefit but that semantic associates do not. The results of the norming procedure reveal that the previews in these conditions lead to different degrees of similarity to the meaning of the sentence when replaced by the target (7.2, 4.9, and 1.9 for the synonym, semantically related and unrelated previews on a 9-point scale, respectively). Thus, to more directly test this hypothesis, follow-up analyses were conducted using the normative data results as a continuous predictor in the LMMs (see Tables 8, 9). Because the identical condition represents a case in which the preview and target are the same, relatedness norming data were not collected and reading time data for this condition were not used. Thus, the following analyses were only conducted on the synonym, semantically related and unrelated preview conditions and the estimated effects are likely to be smaller than they would be if the identical condition were included (because the identical condition exhibited the fastest reading times and including these data points in the regression would have made the fit line steeper).

These analyses reveal that the degree to which the meaning *changes* (10 minus the mean rating from the norming procedure in which subjects rated how *similar* the meaning is) between preview and target is positively related to all fixation duration measures (FFD: $b = 1.32$, $t = 2.29$; SFD: $b = 1.91$, $t = 2.82$; GZD: $b = 1.64$, $t = 1.98$; Go-Past: $b = 3.95$, $t = 3.58$) except total time ($t < 1$). There were also significant effects on the probability of fixating the target (fixation was more likely when the preview was more different in meaning from the target; $z = 2.34$, $p < .05$), and the probability of making a regression out of the target (regressions were more likely when the preview was more different in meaning from the target; $z = 3.53$, $p < .005$), but not the probability of making a regression into the target ($p = .59$). These data suggest that the difference between synonyms providing preview benefit and semantically related but not synonymous words not providing benefit may be due to the fact that synonyms preserve the meaning of the sentence while other semantically related words do not (see Fig. 2).

**Table 8**
Results of the linear mixed effects models for reading time measures on the target as a function of degree to which the meaning of the sentence fragment changes between preview and target in Experiment 2 (excluding items from the identical condition). Significant effects are indicated by boldface.

| Measure | *b* | SE | *t* |
|---|---|---|---|
| First fixation duration | **1.32** | **0.58** | **2.29** |
| Single fixation duration | **1.91** | **0.68** | **2.82** |
| Gaze duration | **1.64** | **0.83** | **1.98** |
| Total time | 0.81 | 1.19 | 0.68 |
| Go-past time | **3.95** | **1.10** | **3.58** |

**Table 9**
Results of the linear mixed effects regression model for fixation probability measures on the target as a function of degree to which the meaning of the sentence fragment changes between preview and target in Experiment 2. Significant effects are indicated by boldface.

| Measure | *b* | *z* | *p* |
|---|---|---|---|
| Fixation probability | **.06** | **2.34** | **<.05** |
| Regressions into the target | .01 | 0.54 | .59 |
| Regressions out of the target | **.08** | **3.53** | **<.001** |

Obviously, because the different preview conditions represent different points along the continuous predictor, the analysis in which only the continuous predictor is entered may capture variance in reading times that actually represents differences across condition. Because of collinearity, when both predictors (the continuous predictor and the coded contrasts used in the previous analyses) are entered into a model, the model cannot decide to which it should attribute the effect, and thus neither yield significant effects (and the model with both predictors does not significantly improve the model's fit to the data above either the model with just the continuous predictor or the condition contrasts). Thus, while these data are not conclusive on the issue, they suggest that degree of change in meaning between preview and target may be what is driving the differences we see across conditions.

Additionally, it is possible that the inflated reading times on the target in the semantically related and unrelated conditions were due to items that were anomalous, given the preceding sentence context. To test this, the items in these conditions were coded by the author (with binary predictors) for (1) whether they were semantically anomalous in the sentence context (i.e., whether the *meaning* of the word was strange—17% of the semantically related previews and 70% of the unrelated previews) and (2) whether

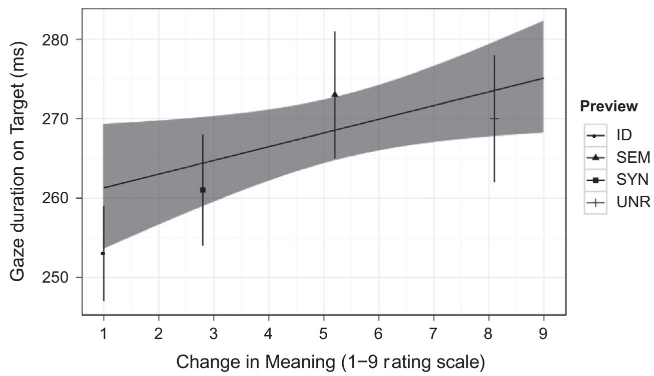


**Fig. 2.** Linear trend for the relationship between the degree to which the sentence changes meaning when the preview is replaced by the target (results of a norming study) and gaze duration on the target in Experiment 2. Linear fit was calculated without the identical condition. Data points and error bars represent the means and standard errors for each preview condition (mean gaze duration and mean norming score) and are plotted for reference (i.e., were not used in fitting the LMM or the regression line in the figure).

they were syntactically anomalous in the sentence context (i.e., whether their part of speech (e.g., noun, verb, adjective, etc.) or number (singular vs. plural) was not allowed by the preceding context—13% of the semantically related previews and 40% of the unrelated previews; Table 1).

First, note that there was always a substantially higher proportion of anomalous items (for either measure) in the unrelated condition than the semantically related condition. But the fact that we do not see any differences between these two conditions in the reading time measures (except for regressions out—see also further analyses, below) suggests that this variable is not what is driving the lack of preview benefit for the semantically related condition. Furthermore, to test this possibility, these variables were used as predictors in LMMs for each of the reading measures for the semantically related and unrelated conditions only (because there was no variability in the identical or synonym conditions because neither were anomalous). Neither of these predictors significantly affected reading times on the target except for in go-past time where reading times were longer when the preview was semantically anomalous ($M_{SEM} = 326$, $M_{UR} = 329$) than not semantically anomalous ($M_{SEM} = 322$, $M_{UR} = 312$: $b = 16.92$, $t = 2.19$). There was also an effect of syntactic anomaly on go-past times, with longer reading times when the preview was syntactically anomalous ($M_{SEM} = 343$, $M_{UR} = 342$) than not syntactically anomalous ($M_{SEM} = 313$, $M_{UR} = 314$: $b = 31.31$, $t = 2.94$). Similarly, there were effects of anomaly on the probability of making a regression out of the target with higher probabilities when the preview was semantically anomalous ($M_{SEM} = .17$, $M_{UR} = .17$) than when it was not semantically anomalous ($M_{SEM} = .14$, $M_{UR} = .13$: $z = 3.38$, $p < .001$) and higher probabilities when it was syntactically anomalous ($M_{SEM} = .22$, $M_{UR} = .20$) than when it was not syntactically anomalous ($M_{SEM} = .12$, $M_{UR} = .13$: $z = 2.97$, $p < .005$).[5] None of the above effects differed across preview conditions (all interactions < 1).

Importantly, none of these effects on the other early reading time measures were significant (all $t$s < 1.41). Because the only measures to demonstrate this effect (go-past time and regressions out) are generally assumed to reflect later, integrative processing (see also the effect of semantic anomaly on the N400 component (see Kutas & Federmeier, 2011 for a review) and the effect of syntactic anomaly on the P600 component (e.g., Osterhout & Holcomb, 1992) in the EEG signal), it is unlikely that anomalousness is driving the presence or lack of semantic preview benefit seen in first pass measures, which reflect word identification, rather than integration (Rayner, 1998, 2009; Schotter et al., 2012). In fact, this lack of an effect of anomaly on early reading measures fits nicely with other data showing that readers will skip high frequency words like "the" (Angele & Rayner, 2013) even when that word is syntactically anomalous in the sentence context. Angele and Rayner (2013) showed that readers will skip the word "the" (when it is a syntactically anomalous preview for the target verb "ace" in the sentence "She was sure she would **the/ace** all the tests.") approximately 50% of the time—as frequently as they skip "the" when it is in a syntactically appropriate location. In their study, there were also strong effects on go-past time on the post-target word, which is similar to the effect in go-past time on the target in the present study (since it is rarely skipped).

## General discussion

In two experiments using the gaze-contingent boundary paradigm, preview benefit was observed for previews that were synonymous with the target (Experiments 1 and 2) but not for previews that were semantically related to the target, but not synonymous (Experiment 2; see also Rayner et al., 1986). Further analyses revealed that reading times on the target were influenced by the degree to which the preview significantly changed the meaning of the sentence; previews that were similar in meaning produced faster reading on the target than previews that were different. Returning to the prior literature on semantic preview benefit discussed in

[5] There was also an effect on skipping the target, but this went in the opposite direction of what might be expected (a higher proportion of fixating the target when the preview was not anomalous) and is therefore likely due to noise or lack of data—there were very low skipping rates.

the introduction, it becomes apparent that semantic preview benefit is possible, but is not ubiquitous, and may depend on the right conditions to support it. I discuss each of these influences, in turn.

First, it is clear that attentional resources must be available for preview benefit to be robust. Henderson and Ferreira (1990; Kennison & Clifton, 1995) demonstrated that preview benefit is modulated by foveal load—preview benefit is larger when the pre-target word is easier to process (e.g., high frequency) than when it is more difficult. This finding is not controversial and can be accounted for by both the models of eye movements during reading mentioned in the introduction. SWIFT accounts for this effect by modulating the breadth of the *zoom lens of attention* such that more difficult words narrow the distribution of attention to focus on few words (or even just the fixated word) and easier words allow attention to be distributed over more words (Schad & Engbert, 2012). E-Z Reader accounts for this effect in that more difficult words are identified more slowly, leading to less time between the completion of word identification and the execution of the saccade, which constitutes the duration of preview benefit (White, Rayner, & Liversedge, 2005). As mentioned in the introduction, there are differences across languages in terms of whether semantic preview benefit is observed, and depth of orthography (for German, or a more direct connection between orthography and semantics for Chinese) may be a potential source for these cross language differences. This hypothesis relates to the above idea that attention modulates preview benefit, since a language with a deeper orthography (e.g., English) might require more resources to be allocated to phonological decoding, allowing for fewer resources to be allocated to pre-processing the upcoming word. The influence of foveal processing on preview benefit of the upcoming word is clear. But are there properties of the upcoming word that might make semantic preview benefit more or less possible?

Prior research has revealed that phonological preview benefit is modulated by the orthographic similarity between the preview and target: phonological preview benefit is larger when orthography is more similar (e.g., beach-beech) than when it is less similar (e.g., shoot-chute; Miellet & Sparrow, 2004; Pollatsek et al., 1992). Thus it may be reasonable to assume that orthographic properties of words would have an effect on semantic preview benefit, as well. Comparisons between existing studies across different languages (with different orthographic properties) help to demonstrate this point. Prior to the present study, semantic preview benefit has been observed for German (Hohenstein & Kliegl, 2013; Hohenstein et al., 2010), a shallower orthography than English, which may lead to faster foveal word identification and consequently more parafoveal preview benefit.[6] Furthermore studies using Chinese have also observed semantic preview benefit (Yan et al., 2009; Yang et al., 2010). Semantic preview benefit might be more likely in Chinese because of the density of the script—there are no spaces between words and words are generally one or two characters long, leading to a higher probability that the upcoming word lies within the fovea and can be processed in the higher acuity foveal region than target words in English studies. Additionally, rather than the orthography representing phonology (as in alphabetic languages), Chinese more directly represents semantics (via semantic radicals), potentially leading to a higher likelihood of semantic access, which would explain the semantic preview benefit. These orthographic influences on semantic preview benefit are not yet accounted for by either SWIFT or E-Z Reader and pose interesting avenues for future research.

The above account suggests that semantic preview benefit should not be (or is very unlikely to be) observed in English. However, the present study demonstrates that semantic preview can be observed in English when the preview and target are synonyms, and the degree to which the preview facilitates target processing may be related to how much the meaning changes between the two versions of the sentence. Taken together, these data and data from the prior literature suggest that preview benefit in English is a sensitive effect. If the preview represents a meaning that is identical or close to the target, this speeds processing of the target once it is fixated. Once meaning is sufficiently different, semantic preview benefit is not observed. However, the studies demonstrating semantic preview benefit in German and Chinese did not use exclusively synonyms, suggesting that this is not a necessary condition. Rather, it may be that the orthographic properties of these languages, mentioned above, make word processing efficient enough that there is more time for semantic information to spread throughout the network (or semantic features to become more activated), leading to semantic preview benefit for even non-synonymous previews. In English, however, orthographic and phonological processing may be sufficiently slow that there is not enough time for spreading activation in a semantic network to activate semantic associates. Synonyms may either be stored together or have stronger connections to the target than other semantic relationships in the network and thus provide semantic preview benefit.

In summary, the present experiments and the prior literature suggest that semantic preview benefit is possible—readers may be able to obtain meaning-based information from upcoming words before they move their eyes to it (in fact, this is the reason why readers skip words; Drieghe et al., 2005; Ehrlich & Rayner, 1981; Rayner & Well, 1996). However, there are certain circumstances (e.g., when foveal processing load is high, depth of orthography interferes with rapid preprocessing of the upcoming word, or when the meaning changes too drastically between preview and target) that work against preview benefit, making semantic information either not accessible or causing semantic information to be discarded.

The results reported here suggest that, in English, semantic information can be obtained from the upcoming word before it is fixated, but such information only

[6] This account might suggest that people would be faster readers overall in German than in English (because the shallow orthography would lead to faster processing; Seidenberg, 2011). However, testing this would be quite difficult because reading speed is greatly influenced by proficiency in the language and amount of experience (practice) reading, as well as properties of the language such as word length and syntactic complexity, which might not be able to be carefully controlled and these other cross-language differences may trade-off with the benefits of a shallow orthography.

facilitates target processing if the preview and target are synonyms. Whether these effects are better accounted for by failure to activate semantic information parafoveally or by parafoveally obtained information being discarded after the target is encountered is still an open question. Furthermore, the sentences used in the present study were created to not constrain the meaning of the target or preview (cloze probabilities for the target and preview words were 0–5%). This design feature was chosen so that any preview benefit observed could be attributed to parafoveal pre-processing, rather than facilitated processing from semantic similarity between the expected word and the encountered word (see Hale, 2001; Levy, 2008; Roland et al., 2012). It will be interesting to see whether the effects observed in the present study change when the sentence constrains the meaning and the target word (and consequently synonym) is more expected.

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## Appendix A

Stimuli used in the experiments. Target words (identical previews) are presented in boldface (not in boldface in the experiments). Columns to the right represent the synonym, semantically related and unrelated previews.

| Sentence | Synonym | Semantic | Unrelated |
|---|---|---|---|
| My friends have the same favorite **movie** that they watch every week. | video | audio | water |
| Dave admired his well kept **turf** while driving home. | lawn | yard | lava |
| Samantha was very **prudent** about not making a mistake in her drawing. | careful | precise | invited |
| Some students cannot **comprehend** the topics covered in lecture. | understand | assimilate | individual |
| The company did not realize the harsh **impact** their products had on the environment. | effect | result | attack |
| Jenna loved how her necklace would **sparkle** on sunny days. | glitter | flicker | platter |
| In kindergarten the kids would loudly **notify** the teacher when someone cut in line. | inform | update | actors |
| The teacher thought most of the reports were too **brief** and needed more content. | short | empty | stand |
| The well trained **scout** led the group along the cliff. | guide | guard | quote |
| We had to read many **surveys** in our psychology class. | reviews | breadth | measure |
| Rain makes it difficult to properly **steer** the vehicle safely. | drive | wheel | times |
| Last week, Alexander **totaled** his car on his way to school. | wrecked | skidded | awaited |
| Elizabeth goes to the store **nearly** every weekend to buy groceries. | almost | always | street |
| The soccer ball hit the shelf and made the vase **smash** into many pieces. | break | clean | heart |
| Boris needed a loyal **sponsor** to begin his campaign trail. | support | advisor | suggest |
| Gary thought if he put on a costume he could **excite** the children in the class. | thrill | arouse | thrift |
| Next week, we must **propose** a new financial plan to the executive board. | suggest | present | support |
| I have always wanted to attend **academy** meetings down the hall. | society | seminar | variety |
| Kenny told his longtime **rival** to meet him outside for a fight after school. | enemy | fists | array |
| The committee said the plan should be approved **contrary** to the president's advice. | opposite | rejected | appendix |
| Peter was asked to point out on the large **globe** where Antarctica was. | world | earth | small |
| The teacher tried to plan **artful** activities for the children. | crafty | pretty | verily |
| The little girl complained about her upset **tummy** and asked to skip soccer practice. | belly | torso | daddy |
| I always stay at the same **cabin** in Tahoe for vacation. | house | shack | known |
| The student was very **astute** because she answered the tricky question. | clever | brains | cheese |
| Brad thought his project idea was incredibly **ingenious** and wanted to tell everyone. | brilliant | inventive | fortified |
| The salesman said the car would hold its original **worth** for many years. | value | price | sites |
| Many people are extremely **committed** to recycling their waste. | dedicated | betrothed | liberated |
| Jill goes for a long **jog** in the morning. | run | leg | own |
| In ancient times, the pharaoh needed **warriors** to defend his kingdom. | soldiers | strength | millions |
| After witnessing the theft, many **guards** chased the thief. | police | cadets | palace |
| Although having a car may seem **essential** there are many other ways to commute. | necessary | requisite | remaining |
| Chris is always told that he should **relax** after playing a soccer game. | sleep | chill | cheap |

| Sentence | Synonym | Semantic | Unrelated |
|---|---|---|---|
| Dan needed to have his **molar** replaced after many years of eating candy. | tooth | crown | tenth |
| George was afraid of a possibly **lethal** bite while handling the snake at the zoo. | deadly | mortal | kindly |
| The surgeon promised an extremely **rapid** to start bubbling. | quick | brisk | giant |
| The road signs inform drivers when **hazardous** terrain is approaching. | dangerous | turbulent | diagnosis |
| Dave wore his favorite **hat** to the baseball game. | cap | bag | cry |
| His father is a proud **physics** teacher in my school district. | science | biology | various |
| The man was a notorious **murderer** responsible for many deaths. | assassin | killings | enormous |
| After the party the couch felt **grimy** from all the guests sitting on it. | dirty | filth | lucky |
| Every year the children **wish** for new toys. | hope | pray | days |
| The response Tom received was not a very **fair** representation of his effort. | just | good | post |
| Sally forgot the specific **tune** she would always sing in the shower. | song | note | warp |
| Steven made a mean **quip** about his sister's hair. | joke | jest | gate |
| At the zoo I saw the giant **adult** panda eating bamboo leaves. | older | aging | album |
| The teacher always posted a relevant **topic** to start a discussion. | issue | theme | music |
| The dishes are stored **below** the sink in the kitchen. | under | handy | order |
| Tommy decided he would **fling** the stone into the pond later that day. | throw | chuck | floor |
| Jack saw more **unusual** sightings in the woods last week. | strange | startle | storage |
| Max had to have the teacher **clarify** when the homework assignment was due. | explain | discuss | captain |
| Jen thought it was a terrible **omen** that she had a nightmare before the exam. | sign | mark | nope |
| The sons were quite **lousy** at doing their chores before dinner. | awful | great | rated |
| James agreed to meet in the front **foyer** of the hotel before dinner. | lobby | doors | fifty |
| Fred and Will ordered nine **super** burritos after the little league game. | great | ample | point |
| Laura had strong **ache** in her tooth after eating too much candy. | pain | ouch | join |
| The sisters could not **name** all their favorite movies because there were too many. | list | cite | best |
| The students must **save** all their homework until the quarter is over. | keep | mass | long |
| Everyone was pleased that the talented **chef** prepared such a wonderful meal. | cook | food | acid |
| Last night my dreams were very **lucid** so I wrote about them in my journal. | clear | stark | class |
| The church received a beautiful **piano** from an anonymous donor. | organ | flute | argue |
| Felix likes to wear clean **boots** to his line dancing party. | shoes | socks | chess |
| I noticed that there was a small stone **spire** on top of the tower. | tower | point | horse |
| The Johnson family fell in love with the beautiful **vast** backyard at their new home. | huge | open | dogs |
| The children must **mow** the lawn every Friday. | cut | dig | net |
| The noise caused Tim to suddenly **fall** to his knees and cover his ears. | drop | down | king |
| The police were **alert** on patrol when they got a call from dispatch. | ready | vigil | early |
| My dog can always **select** the correct bowl with the treat inside. | choose | reject | chance |
| The decorator loved the detailed **lip** of the new vase. | rim | top | zoo |
| It appeared that the symphony **lacked** the true emotion the guests were expecting. | missed | showed | animal |
| Tammy noticed many items were left **blank** when grading the exam. | empty | clear | imply |
| Children are often very **obdurate** when it comes to cleaning up. | stubborn | outburst | stitches |
| After dinner Wendy always **rinsed** the dishes before putting them in the dishwasher. | washed | soaked | socket |
| Some animals eat from very **tall** trees in the zoo. | high | long | kept |
| Steph noticed a torn **bill** in her wallet and looked for the other half. | note | card | side |
| The team captain tried to establish **concord** between the rivals. | harmony | rapport | forming |
| After working out, Shelley felt a sudden **acute** pain in her calves. | sharp | quick | strip |
| Shelia would never **utter** a word about what happened. | speak | vocal | equal |
| The notorious gang **defaced** the statue in front of city hall. | damaged | wrecked | foreign |
| Ian auctioned an antique **clock** to raise money for a charity. | watch | timer | match |
| Howard was extremely **envious** of my new game boy. | jealous | zealous | gardens |
| The dog would always **sniff** the grass in front of the house. | smell | whiff | vault |
| Rita had a very strong **feeling** about the political candidates. | opinion | thought | species |
| Callie and her coworker must **evade** the office because their boss is mad at them. | avoid | greet | round |
| Her perfume was very **aromatic** and caught the attention of many men. | fragrant | distinct | linguist |
| The ring had a beautiful **jewel** in the center. | stone | pearl | clean |
| Although the apartments decor was very **drab** the owners felt it suited their needs. | dull | grey | hulk |
| I got a really cool **gadget** for my seventeenth birthday. | device | iphone | drives |
| I received a very important **prize** for my hard work at the company. | award | stars | weird |

(*continued on next page*)

| Sentence | Synonym | Semantic | Unrelated |
|---|---|---|---|
| Tim wanted to be more than **buddies** with Stacey, but she had a boyfriend. | friends | hugging | towards |
| After a week the messy family started to create a heaping **rubbish** pile in their yard. | garbage | rummage | postage |
| The losing team's **rebuttal** was so legendary that it went viral on YouTube. | response | reaction | congress |
| The horse race will **begin** in a couple minutes. | start | ready | check |
| Cops need to be aware of a possible **ambush** while on the job. | attack | battle | effort |
| Betty enjoys going to the nearby **town** to go shopping on the weekends. | city | area | only |
| Carter is always **bothering** Lisa in class when she tries to take notes. | harassing | involving | burrowing |
| Joel made a rapid **halt** when the light turned red. | stop | skid | ship |
| After a while Kim noticed a weird **scent** coming from the trash can. | smell | noses | vault |
| Will keeps a large **knife** in his backpack to protect himself. | blade | rifle | flute |
| Carla had a pleasant **chat** with her friend at the salon. | talk | rant | half |
| Despite living at the beach, George **seldom** goes surfing. | rarely | cannot | nicely |
| The weatherman predicted that a dangerous **tornado** might hit the town this week. | twister | cyclone | booster |
| Sarah tried using **curlers** on her stubborn straight hair before prom. | rollers | styling | suffice |
| Some people think a heavy **brick** could break a window. | stone | block | clean |
| My old nanny made me a bracelet with **string** for my fifth birthday. | thread | strand | threat |
| The crowd could only see the very **rear** of the stage from the discounted seats. | back | side | find |
| The class complained about the long **exam** to the professor. | test | quiz | kind |
| The loving couple looked at the peaceful **shore** while on vacation. | beach | ocean | trust |
| My roommate will continuously **scrub** the dishes until they are clean. | clean | bathe | alone |
| My neighbor took out his vintage **satan** costume for Halloween. | devil | demon | trend |
| The community thought of Amy with the highest **esteem** after her work at the shelter. | regard | praise | expand |
| Some people thought the parrot was **mute** but it just did not want to talk. | dumb | talk | loud |
| Erin fell asleep for a mere **moment** while driving on the highway. | second | period | around |
| I wrote down the incorrect **avenue** and got lost on my way to the restaurant. | street | suburb | client |
| My neighbor made a majestic **portrait** of my family as a Christmas present. | painting | panorama | pounding |
| Nadine goes to the gym because she wants to look **lean** in a swimsuit at the beach. | thin | slim | kiss |
| The chemist did not realize the reaction could **arise** without a spark. | occur | start | seven |
| Sheldon could not hear their **answers** over the loud music. | replies | opinion | replace |
| Julie watched the birds **flock** together in the sky. | group | bunch | going |
| Frank always sits in the exact **middle** of the classroom. | center | corner | member |
| In the morning Jessica **tallied** up all of the sales from last weekend. | counted | rounded | existed |
| Andrew enjoyed the interesting **tome** he borrowed from the library. | book | read | fact |
| In the pond a frog **leaped** across a lily pad and landed on a log. | jumped | hopped | gospel |

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