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INTRODUCTION

During reading, the eyes make a series of movements called fixations and saccades. A fixation occurs when the eyes briefly stop on a word to process the available information, and a saccade occurs when the eyes jump to make a new fixation (Rayner, 1998). Occasionally, the eyes make a saccade over an entire word such that it is never fixated, which will be referred to as word skipping. Word skipping is a normal part of reading that occurs on about 30% of words (Rayner, 1998) and does not disrupt reading comprehension. However, there is a contemporary debate in the literature as to how deeply skipped words are processed during reading for comprehension (Reichle, Rayner, & Pollatsek, 2003; Engbert, Nuthmann, Richter, & Kliegl, 2005, Eskenazi & Folk, 2015a). The purpose of the current study is to investigate whether skipped words and fixated words receive the same amount of processing. The results of this research have important theoretical implications for understanding models of eye movement control and how words are identified during reading.

Word Skipping Effects

Although there is debate about how deeply skipped words are processed, much is known about the characteristics that influence word skipping during silent reading for comprehension. One of the most important factors that influences word skipping is word length, in that shorter words are skipped more often than longer words (Vitu, O’Regan, Inhoff, & Topolski, 1995). Vitu et al. observed skipping rates when participants read passages containing words ranging in
length from one-letter to ten-letters. The skipping rate on one-letter word was close to 80%. However, this rate dropped sharply to about 40% for four-letter words, and to less than 10% for seven-letter words and longer. One of the explanations for this effect involves the perceptual span during reading, which refers to the size of the perceptual window from which a reader can extract information during a fixation. In English, the perceptual span is asymmetrical and extends about 4 characters to the left of a fixation and 14 characters to the right of a fixation (McConkie & Rayner, 1976). Therefore, only a limited amount of information is available for processing on each fixation, but information can sometimes be extracted from more than just the currently fixated word. Further, the information in the perceptual span varies in its quality. A word in the center of a fixation, or the fovea, is processed with the best visual acuity. Words that are outside of the center of the fixation, or the parafovea, are processed with limited visual acuity. Therefore, words in the parafovea, and especially longer words, are less likely to be processed fully because of limits in visual acuity (Rayner, Pollatsek, Ashby, & Clifton, 2012). Thus, it is less likely that a longer word will be fully processed when it occurs in the parafovea during a fixation, resulting in less skipping of longer words.

While word length, a visual factor, plays an important role in word skipping, researchers have also demonstrated many linguistic factors that influence word skipping and reading times. One linguistic factor is word frequency in that fixation times are shorter for high frequency words compared to low frequency words (Rayner & Fischer, 1996; Inhoff & Rayner, 1986, Rayner & Duffy, 1986). A second linguistic factor is word predictability in that reading times are shorter on words that are predictable from the preceding context compared to words that are less predictable or unpredictable from the preceding context (Ehrlich & Rayner, 1981; Rayner &
Well, 1996). Together these effects indicate that when words are easier to process, they take less time to identify during reading.

The variables of word frequency and predictability affect skipping in a similar way that they affect fixation durations. High frequency words are skipped more often than low frequency words, and predictable words are skipped more often than unpredictable words (Rayner, Sereno, & Raney, 1996; Ehrlich & Rayner, 1981). Importantly, these effects still occur when controlling for word length; therefore, words are skipped because they are easier to process cognitively, and not only because they are short and easier to process visually. When there is sufficient time to process a word in the parafovea, it will be more likely to be skipped if it is high frequency and/or predictable because it will take less time to lexically process and identify the word. Word identification and lexical access will be used interchangeably. Lexical access is defined as the activation and selection of word meaning from long-term memory through its orthography (spelling) and phonology (sound) (Rayner et al., 2012).

**Word Skipping and Models of Eye Movement Control**

Given the amount of information that researchers know about the visual and linguistic factors that influence word skipping, models of eye movement control have incorporated explanations of this important aspect of reading (Reichle, et al., 2003; Engbert, et al., 2005). A model of eye movement control is a computational model that attempts to explain how cognitive processes control eye movement behavior during reading. Several models have been successfully implemented to account for many aspects of reading including the duration of fixations, the length of saccades, refixations or re-reading behavior, and word skipping. Keeping within the scope of this dissertation, I will focus on how the two most influential models of eye
movement control, the E-Z Reader Model and the SWIFT Model, explain word skipping. Although both of these models are able to account for word skipping, they disagree on the process by which a word is skipped and the amount of processing that occurs on a skipped word, which highlights the importance of the current research.

The E-Z Reader Model (Reichle et al., 2003) is a serial processing model of reading, which means that only one word is lexically processed at a time. Lexical processing is divided into two stages referred to as $L_1$ and $L_2$. In $L_1$, the reader reaches a “familiarity check” such that the fixated word (word$_n$) has been processed sufficiently that it is safe to program a saccade to the next word (word$_{n+1}$). This means that sufficient activation has occurred in long-term memory to indicate that lexical access is “imminent.” In $L_2$, lexical identification of word$_n$ is complete and a covert shift of attention occurs to word$_{n+1}$ so that the reader can begin processing that word. The eyes remain on word$_n$ while attention shifts forward to word$_{n+1}$. This covert shift of attention is critical to word skipping.

In the E-Z Reader model, word skipping occurs when the covert shift of attention results in imminent or complete lexical access of the word in the parafovea (word$_{n+1}$) while the eyes are still fixated on word$_n$. When lexical access is imminent or complete on word$_{n+1}$ then the saccade that is programmed to word$_{n+1}$ will be cancelled and reprogrammed to word$_{n+2}$. Therefore, word$_{n+1}$ has been identified without ever receiving a fixation. When word$_{n+1}$ is easy to process as a result of being high frequency and/or highly predictable from the context, it will be more likely to be skipped. The key to word skipping in the E-Z Reader Model is that words are skipped as a
result of lexical identification because lexical processing is the force that drives the eye movements forward.¹

What follows is a simplified explanation of word skipping in the E-Z Reader Model:

1. The fixated wordₙ is identified and a saccade is programmed to wordₙ₊₁.
2. A covert shift of attention occurs to wordₙ₊₁ before the eyes move to wordₙ₊₁.
3. Lexical access of wordₙ₊₁ is complete or imminent.
4. The programmed saccade to wordₙ₊₁ is cancelled and re-programmed to wordₙ₊₂.
5. The saccade is executed to wordₙ₊₂ and a fixation is not made on wordₙ₊₁.

This view of word skipping is in contrast to another prominent model of eye movement control, the SWIFT Model (Engbert, et al., 2005). The SWIFT Model is a parallel processing model in which up to four words are processed in a dynamic field of activation on each fixation. Each word in this field competes to be the target of the next saccade, and that saccade is directed to the word that is farthest from lexical identification. This means that, “…words need not to be fully identified in order to be skipped” (Engbert et al., 2005, p. 22). If wordₙ₊₁ is not yet fully identified while the reader is fixated on wordₙ, but wordₙ₊₂ is farther from identification, then wordₙ₊₁ will be skipped, and wordₙ₊₂ will be fixated. This explanation of word skipping raises an important question – are words fully identified when they are skipped? In other words, is the

¹ Occasionally, words are fixated even though they have been fully identified in the parafovea. This occurs because there is a labile and non-labile stage in saccade programming. After the saccade is programmed, there is a limited amount of time in which the saccade can be cancelled and re-programmed (labile stage). After this time passes, the saccade program enters a non-labile stage in which the saccade must be executed to its planned location, even though lexical processing is still occurring in the parafovea. If the parafoveal word reaches its full lexical access during the non-labile stage, then the saccade will be executed to the parafoveal word even though it has been fully identified.
orthographic, phonological, and semantic information of a lexical entry completely accessed when a word is skipped through parafoveal processing? If the answer to this question is yes, then the saccade targeting mechanisms of the SWIFT Model are implausible.

**Parafoveal Processing**

A common method for studying the amount of processing that occurs in the parafovea during silent reading is called the boundary change paradigm (McConkie & Rayner, 1975). In this paradigm, the word in the parafovea (when readers are fixated on word_{n}) changes after the eyes cross an invisible boundary so that there is a different word preview before the eyes cross the boundary. For example, the parafoveal preview might be \textit{cahc} and the target word might be \textit{cake}. When the readers’ eyes cross an invisible boundary, the target word \textit{cahc} will change to \textit{cake}. If reading times on the word \textit{cake} are faster when the parafoveal preview was \textit{cahc} compared to an orthographically dissimilar non-word such as \textit{troz}, this would provide evidence that readers can extract orthographic letter information from the parafovea. Faster reading time as a result of parafoveal processing is referred to as parafoveal preview benefit.

An interesting, although criticized eye tracking study, has provide some support for the SWIFT Model’s explanation of word skipping using the boundary change paradigm (Balota, Pollatsek, & Rayner, 1985). In this study, readers were presented with sentences that contained highly predictable target words. For example, the word \textit{cake} is highly predictable in the sentence, \textit{Since the wedding was today, the baker rushed the wedding \_\_\_\_ to the reception}. Balota et al. manipulated what information was presented in the parafovea before the presentation of the target word, \textit{cake} in this example, using different types of parafoveal previews. The preview word in the parafovea was either the correct word (\textit{cake}), a visually
similar non-word (*cahc*), an unpredictable related word (*pies*), or a non-word visually similar to the unpredictable related word (*picz*). The preview changed to the target word (*cake*) when readers’ eyes crossed the invisible boundary. In the example below, the * represents the fixation location and the | represents the invisible boundary, that, when readers’ eyes cross it, the target word preview (*cahc*) changes to the correct target word (*cake*). 

```
*Since the wedding was today, the baker rushed the |cahc to the wedding.*
```

Since the wedding was today, the baker rushed the |cahc to the wedding.

```
*Since the wedding was today, the baker rushed the |cake to the wedding.*
```

Since the wedding was today, the baker rushed the |cake to the wedding.

While Balota et al. found typical predictability effects, that a preview of *cake* was skipped more often than a preview of an unpredictable word (*pies*), they found no difference in the skipping rates of the correct word *cake* (11%) and the visually similar non-word *cahc* (11%). If skipping is based on lexical identification, as the E-Z Reader Model suggests, then skipping of the word *cahc* should be less likely than skipping of the word *cake*. *Cahc* does not have a lexical entry to be accessed, so it does not meet the requirements to be skipped.

While this study appears to provide support for the notion that skipped words are not always fully identified, more recent eye tracking research has revisited this finding (Drieghe, Rayner, & Pollatsek, 2005). Drieghe et al. criticized the findings of Balota et al. because the
latter did not control the location of the fixation prior to the target word, referred to as “launch position.” When a word is skipped from a far launch position (a word before word$_n$), it is possible that the word was skipped as a result of coarse visual information from poor visual acuity.

*  

_Since the wedding was today, the baker rushed the cahc to the wedding._

*  

_Since the wedding was today, the baker rushed the cahc to the wedding._

For example, in the first line above, the reader is fixated too far from the preview _cahc_ to have sufficient lexical processing of this word in the parafovea as a result of reduced visual acuity. In the second line, the reader is fixated close enough to _cahc_ so that it can be processed with greater visual acuity. When a non-word such as _cahc_ is processed with sufficient visual acuity, skipping rates should be low because this word will not match any stored lexical entry in long-term memory to reach lexical identification. Indeed, this is what Drieghe et al. found when they only analyzed data from near launch positions. Non-word previews were skipped less often than real word previews (36% v 50%), indicating that lexical processing influences word skipping.

However, a question still remains: why was the skipping rate so high (36%) for non-words? Drieghe et al. (2005) explain this effect in several different ways. First, it is possible that mislocated saccades overshot the intended word, which would inflate the skipping rate. A mislocated saccade is the result of oculomotor error in saccade targeting. Occasionally the eyes overshoot or undershoot their intended target. When the eyes overshoot their intended target, it
would appear as though a word was skipped even though it was intended to be fixated. Second, it is possible that readers misidentified the non-word as the real word, which would result in a skip through accessing a lexical entry for *cake* even though *cahc* was presented. Third, it is possible that the non-word was guessed to be the highly predictable real word through top-down processing.

These explanations leave open the option that readers skip words based on incomplete lexical identification, as the SWIFT Model predicts. To investigate this hypothesis, Eskenazi and Folk (2015a) took a novel approach using both eye tracking and a lexical decision task. In this study, participants read sentences with target words that were low frequency, unpredictable, three-letter nouns. The eye-tracking portion of the study was used to determine whether a word was fixated or skipped. Immediately after the eye tracking portion of the study, participants completed a repetition priming lexical decision task (Scarborough, Cortese, & Scarborough, 1977). In this task, a prime is presented that is the exact same word as the subsequently presented target word. In the repetition priming effect, response times are fastest when a prime is identical to the target word (*dog:dog*) compared to some other weaker prime (*pen:dog*).

In Eskenazi and Folk’s adaptation of this paradigm, the target word from the eye tracking portion of the study functioned as the prime and was repeated as the target in the lexical decision task. Thus, we could measure the effects of response times in the lexical decision task to a repeated word when that word had been skipped or fixated previously in the eye tracking task. We found longer response times to the repeated words in the lexical decision task when a word was skipped (667ms) compared to when a word was fixated (602ms) in the reading portion of the study. Therefore, we concluded that skipped words are not always fully identified and
functioned as a weaker repetition prime than the fixated words that were fully identified. However, the data did indicate that skipped words are at least partially processed because lexical decision times were faster to words that had been skipped in the reading task compared to a non-repetition control word that had not been presented in the reading task. This indicates that some level of processing occurs on skipped words, but it is not the same level of processing as fixated words.

New Questions and Current Dissertation

Although Eskenazi and Folk (2015a) provided evidence that skipped words are not always fully identified during reading, they also raised some new questions. Was this effect the result of the use of a delayed offline measure of repetition priming effects (a lexical decision task that followed the reading session), or will it also appear online during reading? What does it mean that skipped words are not fully identified? Some processing has occurred on the skipped word, but what aspects of processing are missing or incomplete? These theoretical questions are important to answer in the context of the previously mentioned models of eye movement control. The E-Z Reader and SWIFT Models make different predictions about lexical access of skipped words, but scant research has investigated these predictions. Next, I will outline how the current dissertation seeks to answer these questions through two eye tracking experiments.

The first experiment addressed the question as to whether or not the findings of Eskenazi and Folk (2015a) represent real effects of online lexical processing during reading so that the results can be more directly applied to models of eye movement control. In this first experiment, participants read sentences that contained two identical target words in an intra-sentence repetition priming paradigm (Gordon, Plummer, & Choi 2013). The target words were the same
stimuli from Eskenazi and Folk (2015a) because they are known to result in a skipping rate of approximately 50%. This 50% skipping rate is important so that there will be a similar amount of data in the fixate and skipping conditions. For example, the target word *sky* was embedded in the sentence:

> I looked at the pretty *sky* when the *sky* turned gray before the storm.

In this sentence, the first target word *sky* functioned as the prime and the second target word *sky* functioned as the repetition prime target.

The independent variable was the skipping status of the prime word conditionalized as either skipped or fixated. The dependent variables were the eye movement behaviors on the second (repeated) target word including first fixation duration, gaze duration, total time, second pass time, skipping probability, and regression probability.\(^2\) I expected to find longer reading times, less skipping, and more regressions on the second target word when the first target word was skipped compared to when it was fixated. This would indicate that a skipped word was not fully identified and functioned as a weaker prime than a fixated word, replicating Eskenazi and Folk (2015a) in an online reading paradigm.

The second experiment was designed to answer new questions such as, what does it mean that skipped words are not fully identified, and what components of the word identification process are incomplete? To answer these questions, I must first review the research that has been conducted on parafoveal processing. There are three aspects of the word identification process that could explain incomplete lexical processing for skipped words – orthographic

\(^2\) These dependent variables will be defined in more detail in the results section.
processing, phonological processing, and semantic processing. I will review each aspect in order to guide the predictions and design of the second experiment.

In terms of orthographic processing, the data support the idea that orthographic information is extracted from the parafovea. In other words, readers are able to process letter information of words in the parafovea during the covert shift of attention to word \(n+1\) or during parallel processing of words. In a study using the boundary change paradigm, readers were presented with parafoveal previews that were either correct (sleet), a non-word made by transposing letters (selet), or a non-word made by substituting letters (satet) (Johnson, Perea, & Rayner, 2007). The transposed letter condition resulted in greater preview benefit than the substituted letter condition, which indicates that readers extracted orthographic letter information from the parafovea. Preview benefit occurs when processing that has gone on before a word is fixated reduces the fixation duration time when the word is subsequently fixated. For example, parafoveal processing of selet provided good orthographic information for sleet, so that fixation times were shorter when sleet was later fixated. Parafoveal processing of salet did not provide as good orthographic information for sleet, so fixation times were longer when sleet was subsequently fixated.

In a related study, participants read sentences with parafoveal previews that consisted of correct preview (angel), transposed letter previews that created a real word (angle), transposed letter previews that made a non-word (anegl), or substituted letter previews that made a non-word (anupl) (Johnson & Dunne, 2012). In this study, the researchers found preview benefits for both real words and non-words made from transposing letters compared to the substituted letter condition. Again, this suggests that readers extracted orthographic information from the
parafovea whether that information came from real words or non-words. Orthographic processing in the parafovea facilitates orthographic processing when a word is subsequently fixated. Presumably, the orthographic information extracted in the parafovea before the word is fixated is enough to begin activation of similar words in long-term memory, reducing processing time on the word when it is fixated. If orthographic information were not extracted from the parafovea, then *angle* and *anegl* would not result in preview benefit for *angel*.

Results from several studies also suggest that readers extract phonological information from parafoveal words. In other words, after readers access the letter information of words, readers are also able to process the sound information associated with those letters in the parafovea. To investigate the role that phonological information plays in parafoveal processing, Pollatsek, Lesch, Morris, & Rayner (1992) manipulated the type of information available to readers from parafoveal preview using the boundary change paradigm described previously. The parafoveal word was either identical (beach for beach) to the upcoming target word, a homophone of the target (beech for beach), orthographically similar but phonologically dissimilar to the target (bench for beach), or a control condition in which the preview was orthographically and phonologically dissimilar to the target word (house for beach). They found more preview benefit, that is, shorter processing times on the target word *beach* when it was fixated, for the homophone preview and the orthographic preview compared to the control preview. Importantly, the homophone preview benefit was larger than that of an orthographic preview alone. This indicates that not only orthographic, but also phonological information is extracted from the parafovea. Although the previous studies provide strong evidence that readers extract both orthographic and phonological information from the parafovea, the data are mixed as to whether or not semantic information is extracted from the parafovea.
To investigate whether readers extract semantic information from the parafovea, Rayner, Balota, and Pollatsek (1986) manipulated parafoveal preview by using semantically related previews (tune for song) and unrelated previews (door for song), once again employing the boundary change paradigm. They found no preview benefit for semantically related previews; however, readers gained preview benefit from an orthographically related non-word (sorp for song). In a related study, Altarriba, Kambe, Pollatsek, and Rayner (2001) included Spanish-English bilinguals as participants, and they presented previews that were varied to be identical (sweet for sweet), Spanish-English cognates (crema for cream), pseudocognates (grasa for grass), and noncognate translations (dulce for sweet). They found preview benefit for all conditions except for the noncognate translation condition, indicating that readers extract phonological and orthographic information from the parafovea, but not semantic information. If semantic information were to be extracted from the parafovea then *dulce* should have provided preview benefit for *sweet* because they are semantically the same word for Spanish-English bilinguals.

However, there is some data to support semantic parafoveal processing in other languages. A semantic preview benefit has been found in Chinese reading (Yan, Richter, Shu, & Kliegl., 2009). This finding is not surprising for a couple reasons. Chinese symbols are more directly related to their meaning, whereas the symbols that represent words in English are entirely abstract. Further, Chinese is a logographic writing system in which a single character can represent an entire word, and most Chinese words are represented by only one or two characters. These factors make it easier to extract information from the parafovea, and therefore these results are not directly applicable to alphabetic languages such as English. However, Hohenstein and Kliegl (2014) demonstrated the first evidence of semantic preview benefit in an alphabetic language, German. Finally, one study in English has demonstrated semantic preview
benefit when the preview word was a very closely related synonym (*start*) to the target word (*begin*) (Rayner & Schotter, 2014).

While it is clear that both orthographic and phonological information is easily extracted from the parafovea, the data are less clear as to whether or not semantic information is extracted from the parafovea. It appears as though only under certain circumstances and certain writing systems are people able to extract this information. Therefore, I hypothesized that skipped words in the parafovea are less likely to reach full semantic activation whereas fixated words processed in the fovea do. Further, the paradigm that all of the previous research has used to investigate parafoveal semantic processing may not be the best method to investigate this process.

Schotter, Angele, and Rayner (2012) pointed out that a potential reason that semantic preview benefit has not been found is that semantically related previews are “washed out” by the fact that they are orthographically different from the target words. In other words, *tune* may activate *song* when *tune* is processed in the parafovea, but the activation of *tune* does not facilitate the processing of *song* because *song* is so orthographically distinct from *tune*. For this reason, using the boundary change paradigm might not be the best method to study semantic activation in the parafovea, even though all of the previously mentioned studies have relied on this paradigm. Therefore, the second experiment took a novel approach to determine whether semantic information is accessed in the parafovea.

The second experiment used an intra-sentence semantic priming paradigm. Each sentence consisted of two semantically related target words. The first target words fit the same characteristics as the first experiment so that there would be a similar number of items in the fixate and skip conditions. The second target word was a four to seven-letter content word with
high semantic similarity to the first word. Thus, reading of the first target word would semantically prime the second target word. For example, in this sentence:

There was a little bee in the flower that I picked.

the first target word bee would prime the second target word flower. The sentences were controlled such that no other individual words in the sentence primed the second target word, and the sentence context would not prime the second target word. Therefore, differences in reading times, fixation probabilities, and regression probabilities could be explained by whether or not the first target word was skipped.
EXPERIMENT 1

The purpose of Experiment 1 was to replicate the findings of Eskenazi and Folk (2015a) that skipped words do not produce as much priming as fixated words. The original experiment measured reading times on the second target word in a repetition priming lexical decision task after the participant read sentences. The current experiment expands on this work to determine whether this effect occurs online during reading, rather than in a separate task after the participant has fixated or skipped the first target word. In Experiment 1, both target words were embedded into the same sentence using an intrasentence repetition priming paradigm so that there would be no need for a delayed offline lexical decision measure. Reading times on the second target word would determine the amount of priming from the first target word conditional on when the first target word was fixated or skipped.

The hypotheses for the first experiment are dependent on the predictions of the E-Z Reader Model and the SWIFT Model. Therefore, the hypotheses will be formed based on their predictions:

If skipped words are not always fully identified as the SWIFT Model predicts, then fixation times on the second target word should be longer when the first target word was skipped than when the first target word was fixated. I also expected the second target word to be regressed to (regressions in) more often and skipped less often when the first target was skipped compared to when the first target word was fixated. Taken together, this pattern of results would
indicate that the first target word was not processed as fully when it was skipped compared to when it was fixated.

If words are skipped as a result of lexical access as the E-Z Reader Model predicts, then fixation times on the second target word should be the same regardless of whether the first target word was skipped or fixated. The probability of making a regression and of skipping the target word will be the same when the first target was skipped compared to when the first target word was fixated. Taken together, this pattern of results would indicate that skipped words and fixated words were processed to the same degree and go through the same process of lexical identification.

Method

Participants. Fifty Kent State undergraduate students participated in this research for course credit. This number was confirmed to be more than sufficient by a power analysis to detect a small to medium effect size for a fixed effect with 2 levels and 15 observations at each level. This is also more participants than in Eskenazi and Folk (2015a) who conducted a similar experiment. All participants were at least 18 years old, had no reported reading disabilities, spoke English as their first language, and had either normal or corrected vision. I also recruited 25 separate participants who functioned as a control group and fit all of the same criteria as the original set of participants.

Stimuli. Thirty sets of two identical target words were embedded in sentences. Each target word was controlled to be a three-letter content word that was unpredictable from the previous sentence context, with low written word frequency ($M = 10.54$ counts per million from
To ensure that words were unpredictable from the previous context, a separate group of 50 participants completed a cloze task. In the cloze task, participants saw each sentence up until the target word and were instructed to write the next word that is most likely to come in the sentence. The same method was used for the second position of the target word, too, to ensure that it was not predictable in either position in the sentence. The two cloze tasks (first target word and second target word) were completed by two separate samples of 25 participants each. An a priori cut-off of 20% was used to ensure that no one word was correctly predicted in more than 20% of responses. It is important to control for word predictability so that words that are skipped will not be done so through top down predictability processing, but through lexical identification (Drieghe et al., 2005). Neither the first target word ($M = 2\%$ predictability) nor the second target word ($M = 5\%$ predictability) were selected more than the cut-off of 20% predictability; therefore, all target words were unpredictable.

The word prior to the first target word was also controlled so that it was a four to seven-letter content word. This control was used so that participants were likely to fixate word$_n$ prior to skipping the target word$_{n+1}$. It is important that participants fixated word$_n$ so that the target word was within a reader’s perceptual span so that it could be processed in the parafovea on a previous fixation. As Drieghe et al. (2005), pointed out, when words are skipped from a far launch position, it is unclear whether or not the target word was sufficiently processed to account for skipping or if skipping occurred because readers made a miscalculation in their saccade (i.e., mislocated saccade). Therefore, I only analyzed trials when the reader skipped or fixated the target word$_{n+1}$ after launching from the word prior to it, word$_n$. 

CELEX (Baayen, Piepenbrock, & van Run, 1995))
An example of a sentence from Experiment 1 is:

I just had a great fig from the fig tree in front of my house.

In this sentence fig is the repeated three-letter, low frequency target word. It is unpredictable from the previous context in both the first and second position. In the first position it is preceded by a five-letter content word that is likely to be fixated so that fig is within the average perceptual span so that it could be skipped when great is fixated as a result of parafoveal processing.

A final and important control is that the second target word (fig) was not related to any other word that was previously read in the sentence (I, just, had, a, great, from, the), so reading of the first target word is the only word that could activate the second target word. If any other word in the sentence were related to the second target word, then it would be unclear whether the priming came from the first target word or some other word in the sentence. To determine the degree of relatedness between all other words and the second target word I used Latent Semantic Analysis (LSA) (Landauer & Dumais, 1997). LSA is a statistical technique that determines the degree of semantic relatedness of words, phrases, and/or documents to each other. This technique uses 444 works of literature containing over 57 million words divided into 300 factors in a multidimensional semantic space. Semantic relatedness is reported from a scale of -1.0 to +1.0 with a score of +1.0 indicating perfect semantic relatedness (identical words). A score of +.30 or higher indicates strong semantic relatedness. Each word was compared to the target word to ensure that the LSA value was less than .10, and the entire preceding phrase (excluding the first target word) was compared to the second target word. For example, I analyzed the relationship between fig and I, just, had, a, great, from, the to ensure that the combination of words in addition to each individual word was not semantically related to the second target word.
The average relatedness of each individual word to the second target word was .04 and each phrase was .02. Therefore, only the first target word (repetition prime) was semantically related to the second target word.

I also created control sentences to determine if a skipped word primed significantly more than having no exposure to the first target word. This would allow for a comparison of reading times on the second target word when participants fixated, skipped, or did not read the first target word. Therefore, these sentences only contained the second target word, and the first half of the sentence was neutral up until that target word. For example, the control stimuli for the sample sentence above would have been:

There was so much shade from the *fig* tree in front of my house.

The second half of the sentence is exactly the same, but the first half of the sentence was created such that the first target word was removed, and no word in the sentence nor the entire sentence phrase was semantically related to the second target word. Again, I used LSA to ensure that no individual word nor the entire phrase was related to the second target word. The average relatedness of each individual word to the second target word was .06 and each phrase was .01. Again, no individual word nor the entire phrase was closely related to the second target word.

Thirty filler sentences were included in this reading task so that these participants read the same number of sentences as the experimental participants. Fifteen additional filler sentences were followed by a comprehension question. Therefore, control participants read a total of 75 sentences: 30 control sentences, 30 filler sentences, and 15 comprehension filler sentences.
**Apparatus.** Data were collected using an SR Research Eyelink 1000 Plus eye tracker with a sampling rate of 1000Hz. Sentences were presented in random order on a 21.5-inch iMac Retina Display video screen. Participants were seated approximately 60cm away from the screen. Reading was binocular, although eye movements were recorded only from the right eye. One degree of visual angle was equal to 2.4 letters.

**Procedure.** After each participant read and signed the consent form, the experimenter explained the eye tracking session to the participant. Participants were told to rest their head on a chin rest and lean their forehead against a stabilizing bar to reduce head movements. Prior to each sentence, participants looked at a fixation point and the experimenter controlled the onset of the reading by pressing a button to present the sentence. The first word of the sentence appeared where the fixation point was. Participants were instructed to read normally for comprehension at their own pace and to press a button when they were finished reading a sentence. To ensure that participants were reading for comprehension, 15 separate filler sentences were included and each was followed by a “yes” or “no” comprehension question. Participants pressed a button to answer this question, and no participant scored below 80% accuracy, with mean overall accuracy at 97%. Participants completed a practice session of six sentences to learn the procedure before reading the experimental items.

Prior to both the practice and experimental sessions, the experimenter calibrated the eye tracker. Participants focused on a white circle that moved to nine different positions on the screen to determine gaze positions. Calibration was considered acceptable when degree of visual angle error was less than .50 degrees. Prior to each trial, the experimenter checked the degree of visual angle error. If the error increased beyond .50 degrees then the experimenter recalibrated.
After participants finished reading all items, they were thanked for their time and debriefed on the purpose of the study. Participants read a total of 75 sentences: 30 experimental sentences, 30 filler sentences, and 15 filler comprehension sentences. Presentation was completely randomized. The entire session took roughly 20-30 minutes.

**Results**

The data were analyzed using Linear Mixed-Effects Models (LMM), a type of hierarchical linear model, with the statistical program R version 2.11.1 (R Project, 2011). The models were structured such that items were nested within participants. The fixed effect of skipping status was an item-level variable. The model included both random intercepts and random slopes to provide maximum power as supported by recent research (Barr, Levy, Scheepers, & Tily, 2013). Alpha levels were set at .05, and statistical significance was inferred when \(t\) or \(z\) values were greater than 1.96. When the dependent variable was a dichotomous variable, such as word skipping or regressions into the word, then we conducted logistic LMMs.

Fixation durations below 100ms and above 1,000ms were excluded from analyses because they are generally caused by eye blink or track loss and are thus not relevant to lexical processing (Rayner, 1998). This made up 2.3% of all trials. The target word region was defined as every letter of the target word. We only analyzed data when the first target word \(w_n\) was either skipped or fixated when launching from the previous word \(w_{n-1}\). This was done to ensure that if a word was skipped it was done so as a result of at least partial lexical processing. If a word was skipped when launching from a word prior to \(w_{n-1}\), then it would have been unlikely that any lexical processing could have occurred on that word and thus artificially decreasing the level of priming. This pattern of eye movements occurred on 78% of all trials. Finally, as predicted, the
controls used to create the first target word resulted in a roughly even proportion of stimuli in the fixated and skipped conditions in that the target word was skipped on 45% of trials and fixated on 55% of trials. Participants’ skipping rates ranged from 27% to 73%, so no participant had fewer than eight items in each condition.

The dependent variables included measures of early and late processing on the second target word. Measures of early processing are generally highly correlated and all are indicative of lexical processing or the activation of a word’s representation in long-term memory. Therefore, converging evidence from all three measures is taken as evidence for the ease or difficulty of lexical processing. Late processing measures are indicative of text integration and overall comprehension of the sentence meaning. These measures are listed and defined below:

**Early Processing.**

*First Fixation Duration:* The duration of time of the first fixation in a region from when the eyes first enter a target region until when they first leave the target region regardless of the number of fixations that are made on a word, measured in milliseconds (ms).

*Gaze Duration:* The sum of all fixation times on a word from when the eyes first enter the target region until when they first leave the target region, measured in ms.

*Word Skipping:* A word is considered skipped when zero fixations are made in the target region. Critically, a word will only be considered skipped if the fixation prior to the skip is on the word prior to the target word. This ensures that the target word was within the perceptual span so that it was processed on a previous fixation. This variable is measured as a percentage.

**Late Processing.**
Regression In: A regression into the word occurs when the eyes have already moved past the word, but then move back to the word. Regressions in will be conditionalized by whether or not the word was fixated or skipped on the first pass through the sentence. This variable is measured as a percentage.

Second Pass Time: This is a measure of the second gaze duration on the word, or the sum of all fixations from when the eyes entered the target region for a second time until they left the target region for a second time. This is a measure of re-reading time on a word in ms.

Total Reading Time: This is the sum of the durations of all fixations that were made in the target region. If a reader made a regression to the word or re-read the word from the beginning of the sentence, then the durations of all of those fixations would be included in this measure. This is a measure of late processing because it includes all fixations that were made after initial processing of the word and is measured in ms.

Finally, I conducted several planned comparisons. The inclusion of the control group allowed for a determination of whether there was any priming of the second target word when the first target word was skipped compared to when there was no exposure to the first target word. Therefore, each analysis was conducted as follows: I first analyzed dependent measures on the second target word when the first target word was either fixated or skipped. If there were differences between the two, I then compared the skipped condition to the control condition to determine whether the skipped word provided any priming compared to the control condition.

Fixation Durations. All fixation durations on the second target word are reported in Figure 1 conditionalized by when the first target word was skipped, fixated, and when there was
no first target word in the control condition. There are four different fixation measures listed including first fixation duration, gaze duration, total reading time, and second pass time. The overall pattern of results was that reading times on the second target word were significantly faster when the first target word was fixated compared to when it was skipped. Planned comparisons also indicated that reading times on the second target word were faster when the first target word was skipped compared to the control condition where there was no first target word. The details of the analyses for each fixation duration measure are listed below.

**First Fixation Duration.** First fixation durations on the second target word were significantly faster when the first target word was fixated \((M = 214\text{ms}, SE = 3.29)\) compared to when the first target word was skipped \((M = 227\text{ms}, SE = 3.28), \beta = 12.61, SE = 5.01, t = 2.52\). Fixated words provided more priming than skipped words; however, it is still unclear whether skipped words provided any priming compared to having not read the first target word. Therefore, a planned comparison was conducted on the first fixation duration on the second target word when the first target word was skipped compared to the control sentences where there was no first target word. When the first target word was skipped first fixation durations on the second target word were significantly faster \((M = 227\text{ms}, SE = 3.28)\) compared to the no-prime control condition \((M = 239\text{ms}, SE = 2.14), \beta = 11.29, SE = 4.36, t = 2.59\).

**Gaze Duration.** Gaze durations on the second target word were significantly faster when the first target word was fixated \((M = 216\text{ms}, SE = 3.45)\) compared to when the first target word was skipped \((M = 236\text{ms}, SE = 3.64), \beta = 17.71, SE = 5.53, t = 3.20\). Once again, fixated words provided more priming than skipped words. As in first fixation duration, the planned comparison revealed that when the first target word was skipped gaze durations on the second target word
Figure 1. Reading times on the second target word conditional on when the first target word was skipped, fixated, or never read in the control group in Experiment 1.
were significantly faster \((M = 236\text{ms}, \ SE = 3.64)\) compared to the control condition \((M = 251\text{ms}, \ SE = 2.23)\), \(\beta = 15.49, \ SE = 5.21, \ t = 2.97\).

**Total Time.** Total reading time on the second target word was significantly faster when the first target word was fixated \((M = 233\text{ms}, \ SE = 4.71)\) compared to when the first target word was skipped \((M = 257\text{ms}, \ SE = 4.81)\), \(\beta = 19.09, \ SE = 7.13, \ t = 2.68\). As found in the measures of early processing reported previously, fixated words provided more priming than skipped words. Once again, the planned comparison indicated that when the first target word was skipped, total reading time on the second target word was significantly faster \((M = 257\text{ms}, \ SE = 4.81)\) compared to the control condition \((M = 298\text{ms}, \ SE = 3.98)\), \(\beta = 31.53, \ SE = 8.46, \ t = 3.73\).

**Second Pass Time.** Second pass time on the second target word was not significantly faster when the first target word was fixated \((M = 198\text{ms}, \ SE = 9.83)\) compared to when the first target word was skipped \((M = 204\text{ms}, \ SE = 11.93)\), \(\beta = 1.74, \ SE = 3.95, \ t = .44\). Fixated words did not provide any priming on the second target word compared to skipped words during the second pass through the second target word.

**Word Skipping.** As reported in Figure 2, readers were significantly more likely to skip the second target word if the first target word was fixated \((M = 46\%, \ SE = 2.23)\) compared to when the first target word was skipped \((M = 37\%, \ SE = 1.75)\), \(\beta = .28, \ SE = .13, \ z = 2.13\). The planned comparison indicated that when the first target word was skipped readers, there was a numerical trend such that readers were more likely to skip the second target word \((M = 37\%, \ SE = 1.75)\) compared to the control sentences \((M = 30\%, \ SE = 1.65)\), \(\beta = .24, \ SE = .13, \ z = 1.85\).
Figure 2. Probability of skipping the second target word conditional on when the first target word was skipped, fixated, or never read in the control group in Experiment 1.
**Regressions In.** As reported in Figure 3, readers were significantly less likely to make a regression into the second target word if the first target word was fixated ($M = 5\%, SE = 1.16$) compared to when the first target word was skipped ($M = 10\%, SE = .88$), $\beta = -.43, SE = .21, z = -2.05$. Planned comparisons indicated that when the first target word was skipped readers were not more likely to make a regression to the second target word ($M = 10\%, SE = .88$) compared to the control sentences ($M = 12\%, SE = .92$), $\beta = -.17, SE = .22, z = -.77$.

**Post-Hoc Conditional Analyses.** In addition to the traditional eye movement measures, I also conducted three post-hoc analyses to investigate three additional questions. The first question was whether the amount of time spent on the first target word would predict the amount of time spent on the second target words. In other words, if a reader spent more time processing the first target word, does that result in better priming of the second target word, which would manifest as faster reading time on the second target word? To answer this question, I predicted the total reading time on the second target word from the gaze duration time on the first target word. I used gaze duration because it is a more complete measure of initial processing than first fixation duration. I used total reading time on the second target word because it would encompass both initial and later processing of that word. The analysis revealed a significant effect in that the more time a participant spent on the first target word, the less time they spent on the second target word, $\beta = -.09, SE = .04, z = 2.32$. This effect is not very large and indicates that for every 1 millisecond spent on the first target word, readers spent about 1 less millisecond on the second target word.

The second analysis was to determine whether the launch position on the word prior to the first target word (i.e., the prime) affected the amount of priming on the second target word.
Figure 3. Probability of making a regression to the second target word conditional on when the first target word was skipped, fixated, or never read in the control group in Experiment 1.
This question was motivated by the fact that more parafoveal information can be extracted when the fixation position on the foveal word is towards the end of that word. For example, if a reader fixates on the letter \( t \) in *great*, then that reader will be able to access more information from the parafoveal word *fig* than if the reader were to fixate the letter \( g \) (Yan et al., 2009). Therefore, I analyzed the gaze duration on the second target word conditional on the launch position of the word prior to the first target word. The launch position on the word prior to the first target word was coded as either a “near” or a “far” launch position. A launch position was considered “near” if the last fixation on the word was on either the last, second-to-last, or third-to-last letter. A launch position was considered “far” if the last fixation on the word was on either the first, second, or third letter of the word. For five-letter words a fixation on the third letter was considered a “near” launch position.\(^3\)

The analysis indicated that gaze durations on the second target word were significantly shorter for near launch positions (\( M = 214.64, SE = 3.80 \)) than for far launch positions (\( M = 234.49, SE = 3.71 \)), \( \beta = -16.95, SE = 5.21, t = 3.25 \). Therefore, readers were able to process the parafoveal word more when their eyes were closer to that word. This extra processing may allow for more activation on that word, in this case, the first presentation of the target word, which then resulted in greater priming of the second target word.

The third analysis was conducted to differentiate between different types of skipping. Occasionally, when a word is skipped it is followed by an immediate regression, and the originally skipped word is fixated via re-reading. This most often happens when a word is

\(^{3}\) The data were also analyzed when the third letter was considered a “far” launch position, and the results did not change.
skipped as a result of oculomotor error. The reader intended to fixate the word, but instead overshot the word and had to make a corrective regressive saccade. In these cases, the reader would have fixated the first target word prior to skipping the second target word even though it was considered to be “skipped.” In contrast, most of the time when a word is skipped it is never fixated (through either a forward or regressive saccade) prior to fixating the second target word, which I will refer to as a “pure skip.” One might wonder whether these non-pure skips prime as well as fixated words. To answer this question, I separated pure skips from non-pure skips (skips that were followed by an immediate regression). Non-pure skips made up 18% of the trials from the skipping condition.

On these 18% of trials the gaze duration on the second target word was 218ms, which was not different from the 216ms gaze duration on the second target word when the first target word was fixated. Therefore, when the first target word was skipped as a result of oculomotor error and subsequently refixated, the reading times on the second target word were the same as when the first target word was fixated. This finding should not be surprising because the reader was able to fixate and fully process the first target word (even though it was originally skipped) prior to encountering the second target word. Therefore, the fixation through a regression allowed for full processing of the first target word before encountering the second target word.

Summary

The results of Experiment 1 provided clear evidence that a fixated word functions as a better repetition prime than a skipped word. However, a skipped word still primes better than a word that was never read in the sentence (i.e., no-prime control). Therefore, all words that are processed in a sentence through fixations or skipping receive some level of activation, but
fixated words achieve a higher level of activation. This finding is supported by converging evidence from measures of both early and late processing on the second target word. For measures of early processing, readers showed facilitated processing of the second target word in first fixation durations, gaze durations, and probability of skipping the second target word when the first target word was fixated compared to when it was skipped. For measures of late processing, readers were faster to process the second target word in total reading time and were less likely to make a regression to that word when the first target word was fixated compared to when it was skipped. The only measure that did not reveal any differences between the two was second pass time. This is not surprising because second pass time occurs after the second word has already been fixated. Therefore, even though the first target word was skipped, that same word was fixated as the second target word. This would allow for full activation of the word, thus eliminating any differential priming effect from originally skipping it.

The post-hoc analyses provided further supporting evidence that skipped words do not achieve the same level of activation as fixated words. First, the longer that a reader spent processing the first presentation of a target word, the less time that reader had to spend processing the second presentation of that word. When a word is skipped there is only minimal time to process that word during a covert shift of attention. Therefore, the fact that less attentional time is directed towards the word in the parafovea could explain why that word does not prime as well. This is also supported by the finding that there was more priming of the second target word when readers were fixated closer to the first target word prior to skipping or fixating that word. The quality of information that is processed in the parafovea is dependent upon how close the eyes are to that word. For near launch positions, readers are able to spend
more time and attention processing the parafoveal word, which results in more activation of that word and better priming of the second target word.
EXPERIMENT 2

Although the results from Experiment 1 provide clear evidence for the first hypothesis, there is still an open question: What does it mean that skipped words do not prime as well as fixated words? As previously discussed, there are several possible explanations for this question including incomplete orthographic, phonological, or semantic activation. Based on previous evidence, I hypothesized that incomplete semantic activation is the driver of incomplete activation of skipped words. This research question was investigated in Experiment 2 using an intrasentence semantic priming task. Two target words were embedded into sentences that were semantic associates. The first target word followed the same characteristics as the first target word from Experiment 1, and the second target word was a semantic associate of that word. Therefore, processing of the first target word would result in semantic priming of the second target word. If readers do not achieve full semantic activation of skipped words, then reading times should be longer on the second target word when the first target word was skipped compared to when the reader fixated the first target word.

Method

Participants. Fifty Kent State undergraduate students participated in this research for course credit, and none had participated in Experiment 1. This sample size was determined to be sufficient by the same power analysis as the first experiment. The same participant characteristics were used in
this experiment as the first. The same group of 25 control participants as Experiment 1 participated as a control group in Experiment 2.

**Stimuli.** Experiment 2 also used 30 pairs of target words embedded into sentences. The first target word followed the same controls as those from Experiment 1 (low-frequency, unpredictable, three-letter content word). This target word was always preceded by a four to seven-letter content word in order to achieve a roughly 50% skipping rate as in Experiment 1. The second target word was a four to six-letter content word that is semantically related to the first target word. The degree of semantic relatedness was again determined by LSA. A score of +.30 or higher indicates strong semantic relatedness, so I set an a priori cut-off score of +.50 or higher so that all stimuli in this experiment were strongly related to each other. The average LSA between the two target word was .60.

Below is a sample sentence stimulus from experiment two:

There was a little *bee* in the *flower* that I picked.

In this sentence, the three-letter low frequency target word *bee* is semantically related to the six-letter second target word *flower* with an LSA of +.70. Both target words are unpredictable from the previous sentence context. Additionally, the second target word is not semantically related to any other individual word in the sentence context so that differences in reading times are directly related to priming from the first target word and no other word or phrase. LSA was also used to ensure no semantic relatedness between the second target word and any other word in the sentence. The average LSA between each word and the second target word was .04, and the average LSA for the entire preceding sentence context and the second target word was .02.
To ensure that there was sufficient semantic relatedness between the two target words to cause priming, a pilot study was conducted with 59 different participants. This pilot study used the moving window paradigm. In this paradigm, readers press a button to move through the sentence while only seeing a single word or a phrase at a time. Reading times were measured on each phrase or individual word. I was interested in reading times on the first and second target word, so each of these words was presented in isolation while the rest of the sentence was presented in phrases. For example, a sentence was divided as follows:

There was a little | bee | in the | flower | that I picked.

The words between each | were presented in isolation and disappeared after the reader pressed a button. Reading times were used as a measure of how long it took to identify the target words.

To measure the amount of priming caused by the first target word on the second target word, each sentence was paired with a non-priming control match. For example, the previous sentence was matched with the sentence, *She was happy when I gave her the flower that I picked.* Therefore, I was able to compare reading times on *flower* when it was preceded by *bee* compared to when it was preceded by an unrelated context. In both instances *flower* was unpredictable from the previous context. Fifty-nine undergraduate students participated in this pilot study for course credit. Items were counterbalanced so that participants would read either the control or the prime sentence and sentence presentation was randomized. Reading times were faster for primed words (\(M = 723.13\)ms) than for words with no prime (\(M = 758.53\)ms), indicating that the first target word worked as a prime for the second target word, \(t (58) = 3.71, p < .05\). Thus, in addition to the LSA values, I also had empirical evidence that the first target word would prime the second target word. However, the question still remains as to whether the same level of
priming occurs when the first target word is skipped or fixated. The control sentences from the moving window pilot experiment were the same control sentences read by the separate set of 25 control participants in the eye tracking study. These sentences did not have a prime word in them, which would allow for comparison between reading times on the second target word when it was preceded by a fixated or skipped prime word compared to no prime word.

**Apparatus and Procedure.** The apparatus and procedure were the same as in Experiment 1. Participants read a total of 75 sentences: 30 experimental sentences, 30 filler sentences, and 15 filler comprehension sentences. No participant scored below and 80% on the comprehension questions with an average accuracy of 96%.

**Results**

The same analysis plan and data trimming method as Experiment 1 was used. Trimming the data by eliminating fixations below 100ms and above 1,000ms eliminated 3.1% of the total data. I also only included trials in which the first target word was fixated or skipped after launching from the word prior to the first target word to ensure sufficient parafoveal processing when the word was skipped. This pattern of eye movements occurred on 81% of all trials. The tightly controlled sentence structure resulted in roughly even proportions of items in the skip and fixate conditions. The first target word skipped on 44% of all trials and fixated on 56%. Participants’ skipping rates ranged from 23% to 73%, so no participant had fewer than seven items in each condition. I also conducted planned comparisons as in Experiment 1. If there was a significant difference between the fixate and skip conditions, then I compared the skip condition to the control condition to determine if there was any significant semantic priming
when the first target word was skipped compared to when there was no semantically related target word in the sentence.

**Fixation Durations.** All fixation durations on the second target word are reported in Figure 4 conditionalized by when the first target word was skipped, fixated, and when there was no first target word in the control condition. There are four different fixation measures listed including first fixation duration, gaze duration, total reading time, and second pass time. The overall pattern of results was that reading times on the second target word were significantly faster when the first target word was fixated compared to when it was skipped. Planned comparisons also indicated that reading times on the second target word were faster when the first target word was skipped compared to the control condition where there was no first target word. The details of the analyses for each fixation duration measure are listed below.

**First Fixation Duration.** First fixation durations on the second target word were significantly faster when the first target word was fixated ($M = 217ms, SE = 3.97$) compared to when the first target word was skipped ($M = 231ms, SE = 4.89$), $\beta = 12.14, SE = 5.38, t = 2.57$. Fixated words provided more semantic priming than skipped words; however, it is still unclear whether skipped words provided any semantic priming compared to having not read the first target word. Therefore, a planned comparison was conducted on the first fixation duration on the second target word when the first target word was skipped compared to the control sentences where there was no first target word. When the first target word was skipped first fixation durations on the second target word were significantly faster ($M = 231ms, SE = 4.89$) compared to the control words ($M = 248ms, SE = 2.29$), $\beta = 13.78, SE = 4.69, t = 2.94$.  

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Figure 4. Reading times on the second target word conditional on when the first target word was skipped, fixated, or never read in the control group in Experiment 2.
Gaze Duration. Similar to the first fixation data, gaze durations on the second target word were significantly faster when the first target word was fixated \((M = 232ms, SE = 4.80)\) compared to when the first target word was skipped \((M = 249ms, SE = 5.50)\), \(\beta = 15.46, SE = 6.16, t = 2.51\), indicating, once again, that fixated words provided more semantic priming than skipped words. The planned comparison revealed that when the first target word was skipped gaze durations on the second target word were significantly faster \((M = 249ms, SE = 5.50)\) compared to the control words \((M = 271ms, SE = 3.58)\), \(\beta = 18.58, SE = 7.93, t = 2.34\).

Total Time. Total reading time on the second target word was also significantly faster when the first target word was fixated \((M = 282ms, SE = 7.22)\) compared to when the first target word was skipped \((M = 301ms, SE = 7.52)\), \(\beta = 18.37, SE = 8.11, t = 2.27\). A planned comparison indicated that when the first target word was skipped total reading time on the second target word was significantly faster \((M = 301ms, SE = 7.52)\) compared to the control words \((M = 352ms, SE = 7.31)\), \(\beta = 36.35, SE = 11.86, t = 2.98\).

Second Pass Time. Second pass time on the second target word was not significantly faster when the first target word was fixated \((M = 210ms, SE = 4.96)\) compared to when the first target word was skipped \((M = 212ms, SE = 7.21)\), \(\beta = 1.33, SE = 3.33, t = .39\). Fixated words did not provide any semantic priming on the second target word compared to skipped words during the second pass through the second target word.

Word Skipping. As reported in Figure 5, readers were significantly more likely to skip the second target word if the first target word was fixated \((M = 24\%, SE = 1.91)\) compared to when the first target word was skipped \((M = 17\%, SE = 2.74)\), \(\beta = .50, SE = .21, z = 2.42\). Fixated words provided more semantic priming than skipped words. Planned comparisons
Figure 5. Probability of skipping the second target word conditional on when the first target word was skipped, fixated, or never read in the control group in Experiment 2.
indicated that when the first target word was skipped there was a numerical trend in that readers were more likely to skip the second target word \((M = 17\%, SE = 2.74)\) compared to the control sentences \((M = 12\%, SE = 1.84)\), \(\beta = .30, SE = .16, z = 1.89\).

**Regressions In.** As reported in Figure 6, readers were significantly less likely to make a regression into the second target word if the first target word was fixated \((M = 9\%, SE = 1.52)\) compared to when the first target word was skipped \((M = 15\%, SE = 2.81)\), \(\beta = -.78, SE = .27, z = -2.89\). Planned comparisons indicated that when the first target word was skipped readers were less likely to make a regression to the second target word \((M = 15\%, SE = 2.81)\) compared to the control sentences \((M = 21\%, SE = 1.60)\), \(\beta = -.67, SE = .23, z = -2.82\).

**Post-Hoc Conditional Analyses.** As in Experiment 1, I also conducted two post-hoc analyses to investigate two additional questions. The first question was whether the amount of time spent on the first target word would predict the amount of time spent on the second target words. In other words, if a reader spent more time processing the first target word, does that result in better semantic priming of the second target word, which would manifest in faster reading time on the second target word? To answer this question, I predicted the total reading time on the second target word from the gaze duration on the first target word. As in Experiment 1, I used gaze duration on the first target word as the predictor, and total time on the second target word as the outcome. The analysis revealed a significant effect in that the more time a participant spent on the first target word, the less time they spent on the second target word, \(\beta = -.09, SE = .04, z = -1.99\). This effect is the same size as that from Experiment 1 in that for every one millisecond spent on the first target word, readers spent about one millisecond less on the second target word.
Figure 6. Probability of making a regression to the second target word conditional on when the first target word was skipped, fixated, or never read in the control group in Experiment 2.
The second analysis was to determine whether the launch position on the word prior to the target word affected the amount of semantic priming on the second target word, similar to the analysis from Experiment 1. I analyzed the gaze duration on the second target word conditional on the launch position of the word prior to the first target word, defining “near” and “far” as in Experiment 1. A launch position was considered “near” if the last fixation on the word was on either the last, second-to-last, or third-to-last letter. A launch position was considered “far” if the last fixation on the word was on either the first, second, or third letter of the word. For five-letter words a fixation on the third letter was considered a “near” launch position.

The analysis indicated that gaze durations on the second target word were significantly shorter for near launch positions ($M = 234.71, SE = 4.94$) than for far launch positions ($M = 256.04, SD = 4.41$), $\beta = -12.89, SE = 4.53, t = -2.85$. Therefore, readers were able to process the parafoveal word more fully when their eyes were closer to that word. This extra processing may allow for more semantic activation on that word, which then resulted in greater priming of the second target word.

The third analysis was conducted to differentiate between when words were skipped as a result of sufficient processing (pure-skipping), and when word were skipped as a result of oculomotor error (non-pure skipping), as in Experiment 1. Similarly, words were skipped as the result of oculomotor error on 15% of trials (18% in Experiment 1). On these 15% of trials where the word was skipped and immediately regressed to, gaze durations on the second target word were not different from when the first target word was fixated (236ms v 232ms, respectively). Again, this result is not surprising, because the first target word received a direct fixation prior to encountering the second target word. This direct fixation, even though the word was originally
skipped, allowed for sufficient processing to prime the second target word better than when the first target word was originally skipped.

**Summary**

Experiment 1 demonstrated that skipped words function as weaker repetition primes than fixated words, even though they are processed to some degree. The purpose of Experiment 2 was to determine whether incomplete semantic processing could explain the weaker priming from skipped words. The results clearly indicate that skipped words function as weaker semantic primes than fixated words, although skipped words provide at least some semantic priming compared to control sentences. Multiple converging pieces of data support this conclusion. First fixations, gaze durations, and total processing time on the second target word were longer when the first target word was skipped compared to when it was fixated. However, the slowest processing times came from the control sentences, which indicates that a word that is skipped achieves at least some level of semantic activation. The second target word was also more likely to be the target of a regression and less likely to be skipped when the first target word was skipped providing further evidence for weaker processing of skipped words.

Post-hoc analyses provided further evidence for this conclusion, and replicated the findings of Experiment 1. First, when readers spent more time processing the first target word, they spent less time processing the second target word. This effect was very small and potentially meaningless, as the amount of time that a reader spends processing a word is mostly determined by the difficulty of processing that word. Second, the closer that the reader fixated to the first target word before skipping or fixating it resulted in faster processing (more priming) of the second target word. As a reader is fixated closer to the parafovea they are able to extract
more information from the parafoveal word to achieve a higher level of lexical activation. Finally, the investigation into different types of skipping revealed that only “pure skipping” resulted in weaker priming of the second target word. When a word was skipped, but immediately regressed to before reading the second target word, reading times were similar to when the first target word was originally fixated. Therefore, any type of fixation, even if the word was originally skipped, results in full lexical processing of that fixated word. If the word is skipped, and never regressed to, then the word does not reach full lexical semantic access.
GENERAL DISCUSSION

The purpose of the current research was to determine whether skipped words are processed and identified in the same way as fixated words during silent reading. This work was motivated by conflicting theories that skipped words do and do not need to be fully identified (Engbert et al., 2005, Reichle et al., 2003) and by empirical work showing that skipped words do not prime as well as fixated words in a repetition priming lexical decision task (Eskenazi & Folk, 2015a). Further, given that skipped words are processed differently than fixated words, I wanted to investigate what is driving this difference in processing, and what it might mean to incompletely identify a word. Assumptions are often made about word skipping and certain phrases such as “full identification” and “incomplete identification” are often used without clear definitions or evidence. This results of this research provided evidence for these untested assumptions and clear definitions for these undefined terms.

The results of Experiments 1 and 2 are the first to show in a silent reading task that skipped words are not processed in the same way as fixated words and that the difference can be localized to incomplete semantic activation. The results make several novel and important contributions to our understanding of how readers identify words during silent reading and the relationship between eye movement behavior and cognitive processing. First, this research has provided a novel method for studying semantic parafoveal processing, which addresses a potential problem with the boundary change paradigm. Second, the results have implications for the two prominent models of eye movement control, the E-Z Reader Model and the SWIFT
Model, and their explanations of word skipping. Third, the results have expanded our understanding of how and why readers skip words during silent reading, and I will present a new hypothesis to explain word skipping called the Efficient Skipping Hypothesis (ESH). I will discuss each of these areas individually and will finish with proposing several future directions for this work.

A New Paradigm

First, the methodology used in these two experiments of intra-sentence repetition priming, and intra-sentence semantic priming may serve as a new way of studying parafoveal processing that eliminates some of the problems of the boundary change paradigm. While the boundary change paradigm has been used in countless experiments and has contributed greatly to our understanding of the perceptual span, preview benefit, word order processing, foveal load, and other effects – it might not be the best method to study parafoveal semantic processing. For example, the research on parafoveal semantic processing has produced conflicting results, with several studies showing no semantic parafoveal preview benefit (Rayner et al., 1986; Altarriba et al., 2001), and others showing the effect (Yan et al., 2009; Hohenstein & Kliegl, 2014; Rayner & Schotter, 2014). On the other hand, the research on orthographic and phonological parafoveal processing has clearly and consistently shown that letter and sound information is extracted from the parafovea (Johnson et al., 2007; Pollatsek et al., 1992).

Schotter et al., (2012), pointed out one explanation for the conflicting data on semantic preview benefit. She noted that it might be possible that words in the parafovea truly are processed semantically and should provide semantic preview benefit. However, the problem is that the difference between the spellings and sounds of the preview word are so different from
the target word that the effect is wiped away. For example, the preview word *tulip* might prime the target word *flower*, but since the spellings and sounds of the parafoveal word *tulip* are so different from eventual target word *flower*, any benefit from semantic processing has been lost. The reader will have no pre-processing of the spellings and sounds of the eventual foveal target that they will have to begin processing the target word from its basic visual characteristics. This is not a problem for orthographic and phonological preview benefit, because the basic sound and letter information matches the eventual foveal target, even though the meaning is different.

The intra-sentence semantic priming paradigm eliminates this problem but still allows the researcher to investigate the effect of semantic parafoveal processing. Rather than measuring the difference between reading times on a target word when there is a semantically related or unrelated preview, this method works by measuring reading times on the target word when there is a semantically related or unrelated prime just before the target word. LSA allows the researcher to ensure that no other word or entire phrase prior to the target word could have caused any priming. Therefore, any differences in reading time are likely to be due to the presence or absence of a semantic prime.

The results of the current work also have implications for understanding the conflicting data from the studies of parafoveal semantic preview. The results from both of the current experiments show a clear parafoveal preview benefit. In other words, when readers are exposed to a prime word, even if it is only processed in the parafovea, it leads to faster processing of a semantically related target compared to a control condition with no prime. This is essentially the same process as taken by traditional boundary change experiments – a reader is presented with a semantically related word in the parafovea, which should result in faster processing of a
subsequent target word. The inclusion of a control group in this experiment allowed us to verify that even when a prime word is skipped and any information about the prime was extracted from the parafovea, this still results in faster processing of the related target word compared to when there was no prime word in the sentence. The current results are more consistent with the most recent data indicating an effect of semantic preview benefit.

A question remains as to why earlier work using the boundary technique did not find an effect of semantic preview benefit. One potential explanation involves the variable of launch position. Launch position is how close the eyes were to the parafoveal word prior to fixating or skipping it. More recent investigations of semantic preview benefit have included this variable and consistently found that when the eyes are closer to the parafoveal word, the semantic preview benefit increases (Yan et al., 2009; Hohenstein & Kliegl, 2014). The data from the current experiments support this idea. In Experiment 1, readers spent 20ms less on the second target word when their eyes were within 4 characters of the first target word, which acted as the prime. This effect was a similar 22ms in Experiment 2. Therefore, readers were able to extract more semantic information from the parafoveal word than when the eyes were closer to that word. Earlier research indicating no semantic preview benefit did not investigate the variable of launch position, nor did they control the word prior to the boundary change word. It is possible that the prior word was too long and the eyes were fixated too far from the parafoveal word to extract enough information from it (Rayner et al., 1986).

Models of Eye Movement Control

Although a skipped word provides more semantic priming than a non-related control word, the skipped word still does not prime as well as a fixated word. Therefore, one cannot
conclude that skipped words are fully identified or processed in the same way that a fixated word is. This conclusion has important implications for models of eye movement control. The SWIFT Model (Engbert et al., 2005) can easily explain this pattern of results. According to SWIFT, multiple words are lexically processed at a time and each word competes to be the target of the next saccade. The word that is farthest from lexical activation is most likely to be targeted. For example, if word \( n+2 \) is much farther from being identified than word \( n+1 \), then word \( n+1 \) will be skipped and word \( n+2 \) will be targeted even though word \( n+1 \) has not been fully identified. This explanation fits with the idea that sometimes skipped words are not fully identified, which would result in them being a weaker prime compared to a fixated word.

The explanation of word skipping in the E-Z Reader Model is not as consistent with the current data. In E-Z Reader attention is directed at only one word at a time, and, therefore, only one word is processed at a time. The purpose of reading is to identify words and comprehend the text, so word identification is the driver of eye movements and the default target of the next saccade is the next written word in this model. Based on the idea that word identification is the driver of eye movements, it is inconsistent to find that skipped words are not always processed to the same degree as fixated words. However, as I will outline in the Efficient Skipping Hypothesis (ESH), it is very simple for the E-Z Reader Model to fit the current data.

Although the current data are more consistent with the SWIFT Model’s explanation of word skipping, the results do not support nor reject either model and should not be interpreted as support for parallel processing of words during silent reading. Parallel processing of words is still a controversial topic as it necessarily implies the existence of two unlikely effects. First, it suggests that parafoveal processing can influence foveal processing, which is referred to as
parafoveal on foveal effects. For example, if the parafoveal word is difficult to process, that should increase reading times on the foveal word if both are being processed at the same time. However, most evidence suggests that this is not the case (Drieghe, Rayner & Pollatsek, 2008).

Second, it also implies that words can be processed out of order. For example, if we process three words at once, it is possible that the third word can be identified before the first word if that word is very easy to process. This could lead to overall comprehension breakdown for a reader, and again there is no evidence to support the idea that words are ever processed outside of their written order (Rayner, Angele, Schotter, & Bicknell, 2013).

Efficient Skipping Hypothesis

Although these models of eye movement control can be a helpful framework to conceptualize and theorize about word skipping, I am going to present a new perspective on word skipping that breaks away from the serial-parallel dichotomy. This hypothesis posits that word skipping is a developed skill that readers must acquire as they learn to read. The acquisition of the ability to skip over words helps make the reading process more efficient so that readers can extract a sufficient amount of information from the text as quickly as possible. This hypothesis is based on another developmental oculomotor-linguistic skill, and is supported by research on the time course of lexical processing of words, evidence from the current experiment, and research on developmental changes in eye movement behavior. I will first outline another developed skill before explaining the Efficient Skipping Hypothesis (ESH).

A skilled reader is able to process an incredible amount of information in a very short period. For example, in about a quarter of a second a reader is able to (1) identify the spelling, sound, and meaning of a word, (2) preview an upcoming word, (3) scan the layout of a sentence
to determine the locations of spaces, and (4) plan, program, and execute an eye movement, all with minimal effort. These acquired skills take time to develop and transition from a slow and controlled behavior to an essentially automatic behavior. As these skills develop, they are done so in a way that allows for maximal efficiency so that readers can extract the most amount of information in the shortest period of time. One skill that must be developed is the ability to extract information from words while planning eye movements at the same time.

The planning of eye movements while concurrently processing words is the only way that so much processing can happen in such a short amount of time. For example, it takes about 150-175ms to plan and execute an eye movement and about 200ms to extract meaning from a word (Rayner, Slowiaczek, Clifton, & Bertera, 1983). Together, this would imply that each fixation duration on a word should be about 350-375ms, which far exceeds the typical observed reading time on a word, which is about 200-250ms. To reconcile this conflict, both serial and parallel processing models of eye movement control assume that readers begin to program their eye movements soon after lexical processing of a word begins. This allows for maximal efficiency so that a reader does not have to wait to plan an eye movement until after word processing is complete. Rayner et al., (2012) hypothesize that this is a skill that develops as part of reading skill development, and that early readers may not be able to concurrently plan eye movements while lexically processing a word. This could partially explain the finding that developing readers have significantly longer fixation durations than skilled readers, although much of the difference is likely a result of developing readers’ poor lexical quality and word knowledge (Blythe, 2014; Perfetti, 2007).
In the ESH I propose that concurrent planning of eye movements during lexical processing is not the only developed skill for maximal efficiency in reading. It is possible that word skipping developed so that readers could increase the efficiency of the reading process. For example, when a word is skipped in the parafovea, reading times on the foveal word increase by about 30ms (Drieghe et al, 2005; Rayner, Ashby, Pollatsek, & Reichle, 2004). This 30ms cost would end up saving about 170-220ms because the skipped word would not need to be the target of a fixation. Rather, than spending an extra 200-250ms on the target word, readers are able to extract a sufficient, but incomplete amount of information from the word in the parafovea so that reading can continue uninterrupted by any disruption of comprehension. I will outline three pieces of evidence to support this hypothesis: (1) the time course of lexical processing, (2) results from the current experiments, and (3) evidence from developing readers.

First, as outlined above, there was a dilemma in matching what is known about how long it takes to plan eye movements and extract information from words with how long eye movements actually last. A similar dilemma exists with word skipping. The time course of lexical processing and planning of eye movements does not leave sufficient time for complete lexical access of skipped words. Two recent simulations have estimated that readers have about 110ms for parafoveal processing after identifying the currently fixated word (Reingold, Reichle, Glaholt, & Sheridan, 2012; Sheridan & Reichle, 2016). Sheridan and Reichle (2016) also provided a detailed description of every process that happens during lexical access and the time course for how long those processes take, according to a computer simulation. I will outline this process as it fits within the 110ms available for parafoveal processing. First, the information that is extracted from visual encoding must get to the brain for processing, which takes 60ms, and is referred to as the retina-brain lag. Next, lexical processing occurs in two stages referred to as $L_1$
and $L_2$. $L_1$ is a stage after which sufficient processing of a word has occurred so that it is safe to begin programming a saccade to the next word while lexical processing finishes in stage $L_2$.

These stages are based on equations that take into account the predictability and the frequency of the word being processed. Frequency and predictability are two robust effects in that the more frequent and more predictable a word, the faster that word will be processed. For example, for a high frequency and predictable word, $L_1$ will take 75ms and $L_2$ will take 26ms. Taken together, full lexical processing of the parafoveal word would take 161ms ($60 + 75 + 26$).

One can already see that this presents a dilemma because the reader only has 110ms for parafoveal processing, but it would take 161ms to fully process this high frequency and predictable word parafoveally. The problem becomes worse when processing low-frequency and unpredictable words as in the current experiment. The time to complete $L_1$ for a low frequency unpredictable word would be 96ms and $L_2$ would be 33ms. Therefore, the total amount of time necessary for parafoveal processing would be 189ms. This far exceeds the amount of time that readers have for parafoveal processing, and would make full processing of parafoveal skipped words impossible. Therefore, I propose that words that are skipped in the parafovea are done so as a result of partial lexical activation, at least some of the time, as part of an efficient reading strategy.

This is most likely the case with low frequency and unpredictable words, but it is not always the case that skipped words are only partially identified. For example, I will present the time course of processing the word that is skipped more often than any other word, the word *the*. This is the highest frequency word in the English language and is often extremely predictable. The time to complete $L_1$ on this word is 27ms, and $L_2$ is 9ms, which would result in total
parafoveal processing of 96ms, based on equations from the Sheridan and Reichle (2016) simulation. This is within the amount of time for parafoveal processing of 110ms. Therefore, it is not always the case that a word is skipped based on partial lexical identification. Extremely high frequency and predictable function words such as the or and are likely to be fully identified, but when content words are skipped such as fig or bee as in the current experiment, it is likely to be done as a result of incomplete processing.

The second piece of evidence to support this hypothesis comes from the current research. The main finding of these two experiments is that skipped words did not prime the second target word as well as fixated words through both repetition and semantic priming. This is consistent with the ESH, because it suggests that when a word is processed in the parafovea and does not receive a direct fixation, then it does not reach the same level of lexical activation as a fixated word. A word that is fixated is processed from two different sources. First, before the word is directly fixated it receives up to 100ms of parafoveal pre-processing before it is fixated. Second, the word is processed foveally through a fixation. These two sources of processing allow enough time for completion of both $L_1$ and $L_2$ so that the word can reach full lexical activation. This necessarily results in different levels of processing for fixated and skipped words as the skipped word only has about 100ms for parafoveal processing, which most often, is less than the amount of time necessary to fully process this word. About half the time that this word was processed in the parafovea, it did not reach sufficient activation for the eye movement control system to decide to skip over the word. Furthermore, even when the word was skipped, it was still not done as the result of complete lexical activation.
The third piece of evidence to support this hypothesis comes from developmental research on children’s eye movement behavior. Developing children’s eye movement behavior is markedly different from that of skilled adults in several ways. Children have longer average fixation durations, make more frequent regressions, are more likely to refixate words, and are less likely to skip over words (Blythe, 2014). Much of this can be attributed to two reasons. First, children have smaller perceptual spans and are therefore unable to extract as much information from the parafovea as skilled adult readers (Blythe & Joseph, 2011). Second, children’s knowledge of the spelling, sounds, and meanings of words is not fully developed. This makes it more difficult for them to quickly and efficiently extract information from words. As their knowledge of words increases their fixation durations decrease (Perfetti, 2007).

The increases in word knowledge and perceptual span size are likely to be the main causes of developmental changes in eye movement behavior. However, there is another potential factor that contributes to changes in how readers decide when and where to move the eyes – heuristics based on statistical learning. Reichle and Laurent (2006) created a computer program to study how eye movement behavior changes through development. The computer program learned to read with the typical constraints that human readers have: limited visual acuity and perceptual span, retina-brain lag of 60ms, delayed onset of saccade execution of 150ms, saccadic error, and the difficulty of processing words was based on frequency and predictability. The program learned to read through 100 iterations of reading 20 different eight-word sentences. After the 100th iteration, the program’s eye movement behavior was remarkably similar to normal human behavior.
The results are consistent with a view that across time, readers develop eye movement behaviors that allow them to become efficient readers so that they can process as much information as possible in the shortest amount of time. One example of this from Reichle and Laurent was that the program learned to begin programming a saccade before lexical processing was complete. As discussed before, if a reader waits to program a saccade until after lexical processing is complete, then fixation durations would be about 350-375ms, when in reality they are 200-250ms on average. Therefore, readers are able to become more efficient with figuring out when and where to move their eyes with repeated exposure to identifying words during silent reading. In their simulation, the program’s fixation durations significantly decreased across time. In a developing reader much of this change can be attributed to learning the spelling and meanings of words so that information can be extracted more quickly from long-term memory. However, this program was not learning spellings and meanings of words, but was simply responding to constraints and adapting its behaviors after repeated exposures. It is possible that developing readers are also developing more efficient eye movement behaviors in addition to learning how to extract information from words more quickly.

A similar argument can be made for word skipping. Much of the change in word skipping from a developing reader to a skilled reader can be attributed to increases in word knowledge. That is, readers are skipping words more often in the parafovea because they are better able to identify them quickly enough to skip them. It is possible that some of the change can also be attributed to learning an efficient decision making strategy in determining where to move the eyes. After repeated exposures to words, a reader may be able to make a quick decision that a word can be skipped based on partial lexical information. In other words, if a reader can extract a sufficient amount of information during the $L_1$ stage, then the reader might...
decide to skip over that word even though lexical processing might not be complete. Developing readers may be relying on a more inefficient process that requires a higher threshold of activation in order to decide that a word can be skipped.

**Incomplete Semantic Processing**

This hypothesis is consistent with an account of shallow semantic processing in discourse processing. A well-known example of shallow semantic processing occurs when a participant is asked “How many animals of each kind did Moses take on the ark?” Most participants respond by saying “two” without realizing that it was Noah and not Moses who took animals onto the ark. This is referred to as the “Moses Illusion” and can indicate shallow or incomplete semantic processing of words during discourse processing (Erickson & Mattson, 1981). Other research has also found that readers are unlikely to notice semantically anomalous noun phrases such as “tranquilizing stimulant” or “surviving dead” when there is strong global coherence of the entire discourse (Daneman, Lennertz, & Hannon, 2007). Therefore, readers are not always processing each word to full lexical semantic identification before moving on to process other words.

A question still remains as to what it means to have incomplete semantic processing. Several computational models of word identification have been implemented that can serve as a guide to answering this question. These models fall into two main categories – threshold and cascaded. In a threshold model, activation of one module must be complete before activation of another module can begin (Coltheart, Rastle, Perry, Langdon, Ziegler, 2001). For example, a reader must have completely processed the orthographic information of a word before beginning

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4 The decision to skip a word is not a conscious deliberate decision, but rather an implicit decision based on reaching a certain level of lexical activation on parafoveal words.
to process the phonological information of a word. On the other hand, in a cascaded model, any activation in one module allows for immediate activation in another module. For example, as soon as a reader begins to process the orthographic information of a word, then phonological processing begins.

A cascaded processing model has been implemented in the Dual Route Cascaded (DRC) Model, and can potentially explain incomplete processing of skipped words (Coltheart et al., 2001). One implementation of this model attempted to explain how orthographic, phonological, and semantic information are processed during reading through cascaded processing (Coltheart Woollams, Kinoshita, & Perry, 1999). In this model, the processing of letter units begins to activate processing in the orthographic and phonological lexicon. This processing continues to build, and after a delay begins to activate information in the semantic lexicon. The delay in semantic activation is to ensure that a sufficient amount of orthographic and phonological processing has occurred, even though it has not yet been completed. It is possible that the decision to skip a word is based on the extraction of sufficient orthographic and phonological information that has activated some semantic information. Processing has occurred up to a point where a reader has enough, but incomplete, information to decide that the word can be skipped in order to maintain an efficient rate of reading. Under normal circumstances, processing would continue until all modules have reached their identification threshold. However, with this efficient strategy of word skipping a decision can be made to terminate lexical processing so that attention and the eyes can move forward to process new information. This can be viewed as a similar process to the $L_1$ “familiarity check” in which the reader decides that it is safe to begin programming a saccade. This implicit decision, based on sufficient lexical processing, allows
the reader to continue reading at a rate that allows for extracting the most information in the shortest amount of time without disrupting reading comprehension.

**Future Directions**

While the current experiments have provided further evidence that skipped words are not processed to the same degree as fixated words, there are important follow-up experiments that can build on these findings and to test the efficient skipping hypothesis. First, an experiment should be conducted that manipulates the foveal load of the word prior to the first target word. Foveal load is a variable that influences the difficulty of processing the fixated word and is often manipulated by varying the frequency of the fixated word. Low frequency words would be considered high foveal load, and high frequency words would be considered low foveal load. Foveal load is an important variable because it influences two factors. First, as foveal load increases, the amount of time spent processing the fixated word increases. Second, as foveal load increases, the amount of time left over to process the parafoveal word decreases (Henderson & Ferreira, 1990).

Since foveal load can influence the amount of time available for parafoveal processing it should also influence the amount of semantic information that can be extracted from the parafoveal word when it is skipped. In the current experiments, the foveal load was controlled so that it was always low. This was done to ensure that there would be enough time for parafoveal processing so that words could be skipped at a high enough rate. However, when foveal load is high there should be less semantic priming on the second target word compared to when foveal load is low according to the ESH. Under conditions of high foveal load, readers will have less time to extract information from the parafovea, and will have less time to achieve full semantic
processing. The ESH suggests that some level of semantic processing always occurs on skipped words, so skipped words should still provide more priming than control words, even when they are skipped from a high foveal load word.

A second area that should be investigated is whether low skill and high skill readers have different efficient skipping procedures. Eskenazi and Folk (2015b) found that low skill readers are less likely to skip words when launching from a high foveal load word, but high skill readers’ skipping is not affected by foveal load. However, this experiment did not investigate whether low skill and high skill readers have different levels of priming from skipped words, nor if foveal load influenced priming. If high skill and low skill readers both use the same efficient skipping procedure then there should be the same level of priming for both skill levels, even though low skill readers will skip fewer words. However, it is possible that one group takes a riskier approach to word skipping in that they skip decide to skip a word at an even earlier time point, which would result in even less semantic processing.

Conclusion

In conclusion, the current work has demonstrated that skipped words and fixated words are processed differently during silent reading. Skipped words are processed such that the decision to skip the word is sometimes based on incomplete semantic activation. These results have expanded our understanding of how words are identified during silent reading, provided evidence for untested assumptions in models of eye movement control, and I have proposed a new theory that incomplete processing of skipped words can sometimes be the result of an efficient skipping strategy. Future work should investigate if the assumptions of the ESH can be
substantiated in other work and whether models of eye movement control can account for incomplete semantic processing of skipped words.
REFERENCES


