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Testing for Lexical Competition During Reading: Fast Priming With Orthographic Neighbors

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Recent studies have found that masked word primes that are orthographic neighbors of the target inhibit lexical decision latencies (Davis & Lupker, 2006; Nakayama, Sears, & Lupker, 2008), consistent with the predictions of lexical competition models of visual word identification (e.g., Grainger & Jacobs, 1996). In contrast, using the fast priming paradigm (Sereno & Rayner, 1992), orthographically similar primes produced facilitation in a reading task (H. Lee, Rayner, & Pollatsek, 1999; Y. Lee, Binder, Kim, Pollatsek, & Rayner, 1999). Experiment 1 replicated this facilitation effect using orthographic neighbor primes. In Experiment 2, neighbor primes and targets were presented in different cases (e.g., *SIDE–tide*); in this situation, the facilitation effect disappeared. However, nonword neighbor primes (e.g., *KIDE–tide*) still significantly facilitated reading of targets (Experiment 3). Taken together, these results suggest that it is possible to explain the priming effects from word neighbor primes in fast priming experiments in terms of the interactions between the inhibitory and facilitory processes embodied in lexical competition models.

Keywords: fast priming, masked priming, neighbor priming, orthographic neighbors, neighborhood frequency

Skilled reading requires the efficient processing and integration of orthographic, phonological, and semantic information for the meaning of the text to be understood. In an effort to better understand the skilled reading process, language researchers have proposed a number of models of orthographic representation and processing, each of them embodying certain assumptions about the nature of the word identification process. The purpose of the present research is to focus on a core assumption of one type of word identification model.

Most localist models of visual word identification assume that there is competition among the lexical units of orthographically similar words during word identification (e.g., the interactive-activation model proposed by McClelland & Rumelhart, 1981; the multiple read-out model proposed by Grainger & Jacobs, 1996). Exactly what is meant by "orthographically similar words" varies from theory to theory and from model to model; however, words that are regarded as *orthographic neighbors* according to the definition introduced by Coltheart, Davelaar, Jonasson, and Besner (1977) are assumed to qualify, and hence, are conventionally used in much of the relevant research (i.e., a word's neighbors are those words that can be created by changing a single letter of the word; for example, the neighbors of *corn* are *born*, *coin*, *cord*, *core*, *cork*, *horn*, *torn*, and *worn*).

The core assumption common to these localist, activation-based models is that the representations of a word and its neighbors will compete with one another when they are activated and that successful word identification depends on the resolution of the competition between the word and its neighbors. The frequency of the neighbors is important in determining how quickly the lexical competition is resolved. The presence of higher frequency neighbors will slow down the word identification process because higher frequency neighbors are presumed to be more powerful competitors. Thus, words with higher frequency neighbors (such as *corn*, with the higher frequency neighbor *born*) are predicted to be identified more slowly than words with similar normative frequencies but without higher frequency neighbors (e.g., *tube*).

Consistent with this prediction, Grainger, O'Regan, Jacobs, and Segui (1989) observed that lexical decision latencies to words with at least one higher frequency neighbor were slower than those to words without higher frequency neighbors. Grainger et al. referred to this phenomenon as the *neighborhood frequency effect*. Over the past two decades the neighborhood frequency effect has been observed in a number of studies using words from a number of different languages (e.g., Bijeljac-Babic, Biardeau, & Grainger, 1997; Carreiras, Perea, & Grainger, 1997; Grainger & Segui, 1990; Segui & Grainger, 1990; for reviews, see Andrews, 1997; Perea & Rosa, 2000). These results contrast with the typical result in English. Although fewer studies have used English materials (For-

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ster & Shen, 1996; Huntsman & Lima, 1996, 2002; Perea & Pollatsek, 1998; Sears, Campbell, & Lupker, 2006; Sears, Hino, & Lupker, 1995; Siakaluk, Sears, & Lupker, 2002), inhibitory neighborhood frequency effects have seldom been reported. The contrast between the results from the English studies and the studies in other languages has led some researchers to speculate that there may be important differences between languages in the role that inhibition plays in orthographic processing (Andrews, 1997; Sears et al., 2006; Siakaluk et al., 2002; Van Heuven, Dijkstra, & Grainger, 1998; Whitney & Lavidor, 2005).[1]

If this interpretation is correct, a possible implication is that a more powerful experimental paradigm may allow the lexical competition process to emerge more clearly with English stimuli. Two recent sets of experiments, using the masked priming paradigm (Forster & Davis, 1984), support this possibility (Davis & Lupker, 2006; Nakayama, Sears, & Lupker, 2008). In the masked priming paradigm, a trial consists of the presentation of a forward mask ("XXXX"), a prime word (typically presented for less than 60 ms), and a target word. Participants respond to the target, in most studies by making a lexical decision response. Segui and Grainger (1990) were the first to use the masked priming paradigm to study lexical competition. Using French stimuli, they found that lexical decision latencies were significantly slower when a word target was primed by a higher frequency neighbor (e.g., *avec–AVEU*) than when it was primed by an unrelated word of equivalent frequency (e.g., *puis–AVEU*). Segui and Grainger argued that this result is consistent with the lexical competition process embodied in models like the interactive-activation model (McClelland & Rumelhart, 1981). Because a word's higher frequency neighbors will be the word's strongest competitors, presenting one of them as a prime makes that word an even stronger competitor, thereby delaying the target word's identification. Thus, when the prime is a higher frequency neighbor of the target word, inhibitory priming is expected. (A similar inhibitory effect from higher frequency primes was reported by Bijeljac-Babic et al., 1997, using French stimuli; and De Moor & Brysbaert, 2000, using Dutch stimuli.)

Davis and Lupker (2006) and Nakayama et al. (2008), using English stimuli, also reported experiments in which target words were primed by higher frequency orthographic neighbors (e.g., *help–HEAP*). In both sets of experiments, lexical decision latencies were slower when the prime was a higher frequency neighbor of the target word (e.g., *help*) than when it was an unrelated word (e.g., *area*), replicating Segui and Grainger's (1990) results. Unlike Segui and Grainger, however, Nakayama et al. also found that lower frequency neighbor primes can delay responses to higher frequency targets (e.g., *heap–HELP*). These lower frequency primes delayed responses to higher frequency targets essentially as much as higher frequency neighbor primes delayed responses to lower frequency targets, as long as the target words had many neighbors. Apparently, when a word has many neighbors those neighbors can "gang up" and produce measurable inhibition even for high-frequency targets (see Nakayama et al., 2008, for a discussion). The important point is that Davis and Lupker's and Nakayama et al.'s results demonstrate that lexical competition plays a role in English word identification and that the masked priming paradigm is a sensitive tool for exploring this process.

Neighborhood Frequency Effects in Reading Tasks

Most of the studies discussed above involved responding to a single word in isolation (e.g., the lexical decision, word naming, and semantic categorization tasks); few studies have looked for evidence of lexical competition while people are reading normal text (Perea & Pollatsek, 1998; Pollatsek, Perea, & Binder, 1999; Sears et al., 2006; Williams, Perea, Pollatsek, & Rayner, 2006; note that all of these studies used English stimuli). In studies investigating the reading of text, the target is embedded in a short sentence and participants' eye movements are recorded while they read the sentence for comprehension. Because no overt decision making is required in this reading task (unlike in other tasks such as lexical decision or semantic categorization), one could argue that this methodology is better suited for investigating normal lexical processing. An effect of neighborhood frequency in a reading task, for example, would indicate that lexical competition affects the reading of words during normal silent reading and that competition effects are not artifacts of laboratory tasks.

The results from previous reading studies investigating the impact of a word having a higher frequency neighbor are mixed. Perea and Pollatsek (1998) compared the reading of targets with and without higher frequency neighbors and found a neighborhood frequency effect in some measures of eye movements. On the one hand, they reported that first fixation durations and gaze durations (the sum of all fixations on the target word) to words with higher frequency neighbors were no longer than first fixation and gaze durations to words without higher frequency neighbors. This finding indicates that a word's higher frequency neighbors did not have a direct and immediate effect on reading time. On the other hand, there were effects of neighborhood frequency on the probability of regressing back to the target word and on the duration of the first fixation after the target word fixation, two "spillover" variables that are assumed to mainly reflect processing that occurs after the reader has left the target word. Like Perea and Pollatsek, Sears et al. (2006) did not find an effect of neighborhood frequency on first fixation durations or on gaze durations (in contrast to the clear effects of word frequency on these variables). However, unlike Perea and Pollatsek, Sears et al. did not find an effect of neighborhood frequency on the spillover variables that Perea and Pollatsek measured (when they used their own stimuli or when they used Perea and Pollatsek's stimuli). All of these studies, like those studies using the lexical decision task, suggest that the effect of neighborhood frequency in lexical decision and other laboratory tasks in English is weak or nonexistent. Despite the expectation that a word's higher frequency neighbors should have a direct and obvious impact on first fixations and gaze durations, the previous research has provided little evidence of an effect of this sort during normal reading.

[1] Consistent with this possibility, there appear to be differences between languages in the neighborhood size effect. The results of the English studies are clear: in a wide variety of tasks, words with many neighbors are responded to more quickly than words with few neighbors (e.g., Andrews, 1997; Chateau & Jared, 2000; Forster & Shen, 1996; Lavidor & Ellis, 2001, 2002; Sears, Lupker, & Hino, 1999; Sears, Siakaluk, Chow, & Buchanan, 2008; Siakaluk et al., 2002; Whitney & Lavidor, 2005). This pattern contrasts with the results in Spanish, Italian, and French, in which facility effects of neighborhood size are often quite small or nonexistent (e.g., Arduino & Burani, 2004; Carreiras et al., 1997; Grainger & Jacobs, 1996; Mathey, 2001; Perea, Acha, & Fraga, 2008).

Williams et al. (2006) used a different reading task, one that is more akin to a priming manipulation, to study the effect of a word's orthographic neighbors on its identification. Williams et al. examined how a parafoveal preview of an orthographic neighbor of a target word affects the reading of the target word. Williams et al.'s task employed an eye movement contingent boundary technique (Rayner, 1975). The boundary technique allows a manipulation of the type of preview information that is available in the parafovea prior to the reader fixating on the target word. In this task, as a participant is reading a sentence, a preview of a word is presented in the parafovea. This preview of the word is then changed to the target word as the participant moves his or her eyes across an invisible boundary to fixate on the target word. In the critical condition of their Experiment 1, the preview word (e.g., *sweet*) was a higher frequency neighbor of the target word (*sleet*); for example, when reading the sentence "Mary was afraid of *sweet* when she had to drive in the winter," the preview word *sweet* was changed to the target word *sleet* during the participant's saccade to the target. Williams et al. reasoned that a higher frequency neighbor preview should have an inhibitory effect on the reading of a low-frequency target word because the preview of the higher frequency neighbor should activate that word's lexical representation, which should then compete with the lexical representation of the low-frequency word.

Williams et al. (2006) found no evidence of an inhibitory effect from higher frequency neighbor previews. In fact, they found that a preview of a higher frequency neighbor led to shorter first fixation and single fixation durations on low-frequency target words relative to a control condition that used unrelated nonword previews. Clearly, this beneficial effect of a higher frequency neighbor preview conflicts with the expectation that activating a higher frequency neighbor of a target word will create competition between the neighbor and the target and thereby interfere with the reading of the target. For the same reason, Williams et al.'s results also appear to conflict with the reports of inhibitory priming in the masked priming paradigm (Davis & Lupker, 2006; Nakayama et al., 2008; Segui & Grainger, 1990).

The Present Research

In the present research, we looked for evidence of lexical competition using a different reading paradigm, the fast priming paradigm (Sereno & Rayner, 1992). The fast priming paradigm also employs the boundary technique (Rayner, 1975). On each trial, a preset target region is embedded in a short sentence (see Figure 1). The target region is first occupied with random letters so that useful parafoveal information is unavailable. As readers' eyes cross an invisible boundary, landing on the target word, a prime word is briefly presented at the point of fixation (i.e., primes are presented in readers' foveal vision). The prime duration is typically the first 30 to 60 ms of the fixation duration. The prime word is then replaced by the target word, which remains visible until the participant finishes reading the sentence. The eye movements of participants are monitored and recorded the entire time that they read the sentence. Like Williams et al.'s (2006) parafoveal priming paradigm, one of the major advantages of the fast priming paradigm is that priming effects can be examined while participants are engaged in normal silent reading. An additional advantage of these online reading tasks is that fixation latencies to words are significantly shorter than manual and vocal latencies, and so the priming effects observed reflect the more immediate impact of prime words on the processing of targets.

Although both Williams et al.'s (2006) paradigm and the fast priming paradigm are paradigms involving normal reading processes, the fast priming paradigm would seem to be a superior paradigm to use in the present experiments. The main reason is that there are strong methodological parallels between the fast priming paradigm and the masked priming paradigm, the paradigm in which inhibitory priming was initially observed. That is, like the masked priming paradigm, the fast priming paradigm involves a visual mask, prime, and target, with the prime being presented foveally in the same location as the target. As such, the prime can be presented immediately before target processing begins, allowing for a direct assessment of its effect on target processing. In contrast, Williams et al.'s paradigm involves the presentation of prime information more than 250 ms prior to the target. Thus, much of the activation created by the prime may have changed by the time the target is viewed. In addition, prime information is presented in the periphery in Williams et al.'s paradigm, providing a much more impoverished view of the prime.

There are only a few studies that have examined the effect of orthographically similar primes on reading using the fast priming paradigm (H. Lee, Rayner, & Pollatsek, 1999, 2002; Y. Lee, Binder,

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      *---*----*------*--------*------
a) The girls walked under the beautifu | l gzfd moon that evening.
                                       ----*
b) The girls walked under the beautifu | l bull moon that evening.
                                           *
c) The girls walked under the beautifu | l full moon that evening.
                                           -----*----------*
d) The girls walked under the beautifu | l full moon that evening.
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Figure 1. An illustration of the sequence of events while a participant reads a sentence. An asterisk (*) represents the fixation point of the participant; the vertical line represents the invisible boundary within the sentence. The prime/target location is initially occupied by a random letter string (a). When the participant's gaze crosses the invisible boundary (b), the random letter string (*gzfd*) is replaced by the prime word (*bull*), which is presented for 60 ms. The prime word is then replaced by the target (*full*) during the same fixation (c). The target remains in place while the participant finishes reading the sentence (d). Note that the spacing within the sentence was not affected by the invisible boundary.

Kim, Pollatsek, & Rayner, 1999; Rayner, Sereno, Lesch, & Pollatsek, 1995). In none of these studies was the focus on orthographic neighbor priming specifically. Despite the similarities between fast priming and conventional masked priming, in these studies the effect of orthographically similar primes was facilitory—when a word was primed by an orthographically similar prime, reading times were faster than when the word was primed by an unrelated word. The finding that is particularly relevant to the present research comes from Y. Lee et al.'s Experiment 2. In this experiment, the relative frequencies of visually similar primes and targets were manipulated to create four critical conditions: (a) low-frequency primes and high-frequency targets (e.g., *pare–pain*), (b) high-frequency primes and high-frequency targets (e.g., *seat–sent*), (c) low-frequency primes and low-frequency targets (e.g., *foal–fowl*), and (d) high-frequency primes and low-frequency targets (e.g., *have–hare*). Most, but not all, of the primes were orthographic neighbors of the target (the focus of their study was phonological priming, not orthographic priming). When participants were asked simply to read sentences for comprehension, participants fixated for significantly less time on the targets (e.g., There was a *lone* rider on the trail) when they were primed by an orthographically similar prime (e.g., *line*) than when they were primed by an unrelated prime (e.g., *wind*). This was true regardless of the frequency difference between the primes and targets and the prime duration (32 ms or 38 ms). Y. Lee et al. also presented orthographically similar nonword primes and found a facilitation effect for both high- and low-frequency targets, indicating that the lexicality of the prime is not critical for producing the facilitation effect.

H. Lee et al. (1999) also used the fast priming paradigm to examine the effect of orthographically similar primes on reading. In their experiments three different types of primes were presented (orthographically similar, homophones, and semantically related) and five prime durations were employed (29 ms, 32 ms, 35 ms, 38 ms, and 41 ms). Like Y. Lee et al. (1999), H. Lee et al. (1999) found that orthographically similar primes (most of them orthographic neighbors of the target) facilitated reading of targets in comparison to control primes at all of the prime durations examined (homophone primes and semantically related primes facilitated reading times only at shorter prime durations of 29 to 35 ms). In a subsequent study, H. Lee et al. (2002) also manipulated the relative frequency of the orthographically similar primes (the primes were higher or lower in frequency than the target). With a prime duration of 45 ms, word targets were read significantly faster when primed by both higher frequency and lower frequency primes than when primed by unrelated primes.

The results from these fast priming studies are at odds not only with the research from the masked priming paradigm but also with the core assumptions made by activation-based models; namely, that visually similar words (i.e., orthographic neighbors) compete with each other during the word identification process. Thus, the theoretical question becomes: Are activation models, models incorporating inhibitory processes due to lexical competition, truly viable models of normal reading? The purpose of the present research was to address that question by looking for evidence of lexical competition using the fast priming paradigm; to our knowledge, the first time this technique has been used specifically for this purpose. That is, unlike the previous fast priming studies using orthographically similar primes, the focus of the present research was on inhibitory neighbor priming, and the present experiments were designed to maximize the likelihood of observing the predicted inhibition from neighbor primes. In order to accomplish this goal, the same critical stimuli used in Nakayama et al.'s (2008, Experiment 2) masked priming experiment were used in the present experiments. As noted, these stimuli have been shown to produce robust inhibition effects, irrespective of relative prime-target frequency, which is not the case for the stimuli used in any of the other fast priming experiments in the literature. We also used a longer prime duration (60 ms) than most previous fast priming studies (in these previous studies the prime durations were 45 ms or less, with the exception of Sereno and Rayner, 1992, who used a 60 ms prime in one of their experiments). We speculated that the absence of inhibitory priming effects in the previous studies may have been due to the fact that the prime duration was too short to activate the target's neighbors sufficiently for them to become potent competitors. In the previous masked neighbor priming studies showing inhibitory effects (Davis & Lupker, 2006; Nakayama et al., 2008; Segui & Grainger, 1990) prime durations were approximately 60 ms. Thus, to maximize the possibility of observing inhibition in the present experiments, a 60 ms prime duration was used here.

Experiment 1

Method

Participants. Thirty-six undergraduate students from the University of Calgary volunteered to participate in exchange for extra course credit. All participants were native speakers of English and reported having normal or corrected to normal vision.

Materials. The critical stimuli were 40 pairs of orthographic neighbors (e.g., *side–tide*); these were the same pairs used in Experiment 2 in Nakayama et al. (2008). All of these words had many orthographic neighbors ($M = 10.2$). For each orthographic neighbor pair, one word was much higher in frequency than the other. The mean normative frequency (Kucera & Francis, 1967) of the higher frequency words of the pairs was 507.9 occurrences per million; the mean normative frequency of the lower frequency words of the pairs was 12.6 occurrences per million. (The frequency counts from the CELEX English linguistic database were 571.7 and 3.6 occurrences per million, respectively; Baayen, Piepenbrock, & van Rijn, 1995.) Both members of the pair were used as targets. Of the 40 pairs of neighbors, the two neighbors differed from one another at the first letter position in 14 of the pairs, the neighbors differed at one of the middle letter positions in 15 of the pairs, and the neighbors differed at the last letter position in 11 pairs. For each neighbor pair, two four-letter unrelated primes with similar neighborhood sizes were selected ($M = 9.4$). Forty unrelated primes were of high frequency (with a mean normative frequency of 495.3) and the other 40 unrelated primes were of low frequency (with a mean normative frequency of 13.3). Thus, each member of the pair (e.g., *tide*) could be paired with either a neighbor (e.g., *side*) or an unrelated word (e.g., *need*) of similar frequency.

For the reading task, 80 sentence frames were created to embed the targets. Half of the sentences were embedded with high-frequency targets and half were embedded with low-frequency targets (see the Appendix for a list of the materials). The targets were always in the second half of the sentences but were never the last word of a sentence (e.g., "I am always really busy during the first [*week*] of every month"). Each participant was presented with 40 experimental sentences in total and with only one member of each neighbor pair (e.g., if a participant saw a sentence containing *tide* with either the prime *side* or the prime *need*, the sentence containing *side* was not presented to the same participant). Four lists of presentation materials were created so that the assignment of the stimuli to conditions was counterbalanced across participants. For each presentation list, four different random trial sequences were created and these were assigned to participants in a random fashion.

Apparatus. Stimulus presentation was controlled by an Eyelink I System eye tracking system (SR Research Ltd., Mississauga, Ontario, Canada). An EyeLink I eye tracker (SR Research Ltd.) was used to collect eye movement data. The eye tracker has a sampling rate of 250 Hz and an average gaze error of less than 0.5° of visual angle. The EyeLink eye tracker does event parsing using an automatic saccadic detection algorithm based on a velocity threshold of 30°/s and an acceleration threshold of $8{,}000°/s^2$. Stimuli were presented on a ViewSonic G225fb monitor with a vertical retrace rate of 160 Hz. The sentences were presented on the center of the screen in a single line. All sentences were presented in white Courier New font on a black background. The words in each sentence were presented in lower case letters, with the exception of the first letter of the first word of each sentence and proper names. The primes and targets were always presented in lower case letters. The participants were seated approximately 60 cm from the monitor; at this distance 2.5 letters subtended approximately 1° of visual angle. Viewing was binocular and eye movements were recorded from the right eye. A custom fast priming program was provided by SR research. The program was created based on the description of the procedure in Sereno and Rayner's (1992) report.

Procedure. Participants were seated and asked to adjust a chinrest so that their eyes were level with the center of the computer screen. Although a chinrest is not required for the Eye Link I system because it automatically adjusts its tracking to accommodate the natural head movements made by participants, we elected to use one to prevent large head movements and thereby further improve the calibration accuracy. Next, the eye tracker was calibrated for each participant. The participants were asked to fixate on dots presented at 5 different points on the computer screen. Three of the five *x*- and *y*-coordinates of dots roughly corresponded to the beginning, middle, and end of the experimental sentences. The calibration process took 5 to 10 min to complete. The calibration was repeated after every 20 sentences and at any other time it was deemed necessary.

A trial sequence was as follows. First, participants were asked to fixate on the dot that was presented on the middle left of the computer screen. When the experimenter confirmed that the participant's fixation had been stabilized on the dot, a sentence was presented for reading. Participants then made a saccade to the beginning of the sentence to begin reading. For each sentence, random letters first occupied the target region (e.g., *tqpd*) so that no parafoveal information relevant to the prime word was available. An invisible boundary had been set for each sentence (left of the last letter of the word immediately preceding the target) and as soon as the participant's eyes crossed the invisible boundary the random letters were replaced by the prime word. This display change was triggered by the participant's saccade to the target region to prevent the participant from detecting the transformation. As soon as the participant fixated on the target, it triggered a timer for the next display change. After 60 ms had elapsed since the start of the fixation (this was the prime duration) the target replaced the prime word.[2] This second display change occurred during the fixation. Participants continued reading the sentence and indicated that they had finished reading by looking down and away from the sentence, at which point the experimenter cleared the display. The existence of the prime words was not mentioned to participants. Participants were asked to carefully read each sentence because a comprehension question would be asked occasionally. Questions were asked on approximately 25% of the trials (participants had no difficulty answering these questions).

Each participant read six practice sentences to familiarize themselves with the procedures. During the practice trials participants were informed that they might sometimes notice a flash in the display (corresponding to the presentation of the prime word) but were instructed to ignore it and to read normally. During pilot testing we noted that a few participants sometimes noticed a flicker when the target was presented (due to the target overwriting the prime). At the end of each experimental session we asked participants to estimate how many of these events they had noticed and whether they had noticed anything else about the events. Most participants noticed a prime-target display change occasionally but none of the participants reported being able to identify the primes on any more than a handful of trials (similar to the situation in masked priming experiments).

Results

The dependent variables were first fixation durations, gaze durations, and total fixation durations on the target. First fixation duration is the duration of the reader's initial fixation on the target. Gaze duration is the sum of all fixations on the target before the reader's eyes move to another word. Regressive fixations are not included in either of these measures. Both first fixation duration and gaze duration are believed to reflect relatively early lexical processing. In contrast, the total fixation duration (the sum of all fixations the target receives, including fixations following regressions) is assumed to reflect a combination of early and later lexical processing. In previous fast priming studies, priming effects were assessed primarily using first fixation and gaze durations. We thought it would be important to also use total fixations durations because a number of researchers (e.g., Perea & Rosa, 2000; Pollatsek et al., 1999; Williams et al., 2006) have suggested that, in online reading tasks, the impact of lexical competition is apparent only at a later point in time. If so, then inhibitory priming effects would be more likely to be observed in the total fixation duration measure.

Several criteria that have been developed to trim data in reading experiments were used here (e.g., Ashby & Rayner, 2004; Y. Lee, et al., 1999; Sereno & Rayner, 1992). First, fixations that were shorter than 100 ms and longer than 700 ms were considered outliers and excluded from all analyses (two consecutive fixations that were within five pixels of each other were merged into one

[2] As with previous fast priming studies (e.g., H. Lee et al., 1999), the prime duration of 60 ms was nominal. The actual prime interval was 60 to 67 ms depending on the beginning screen location of the raster display device (the vertical retrace rate of the display was 160 Hz).

fixation). This procedure excluded 2.5% of the data. Data from trials were also excluded if (a) there was a tracking loss, (b) the target was initially skipped, (c) the reader fixated on the final letter of the word preceding the target region (in which case a parafoveal preview was likely), (d) the prime presentation did not coincide with the onset of the fixation, and (e) the first fixation on the target was removed as an outlier. In addition, consistent with previous fast priming studies (e.g., Sereno & Rayner, 1992), if less than 60% of a participant's data was usable the participant was replaced. Three participants were replaced for this reason; these participants were replaced with three new participants who were shown the same presentation lists so that the proper counterbalancing of lists could be maintained across participants. As a result of the data trimming, 81% of all the data collected were subject to data analyses.

The first fixations, gaze durations, and total fixation durations were analyzed separately with a 2 (prime type: neighbor prime vs. unrelated prime) × 2 (target frequency: high frequency vs. low frequency) analysis of variance (ANOVA). Both subject (F_s) and item (F_i) analyses were carried out. In the subject analysis, all factors were within-subject factors; in the item analysis, prime type was a within-item factor and target frequency was a between-item factor. The means for first fixation durations, gaze durations, and total fixation durations from the subject analysis are listed in Table 1.

First fixation durations. The effect of prime type was significant, $F_s(1, 35) = 28.68$, $p < .001$, $MSE = 1{,}308.9$, partial $\eta^2 = .45$; $F_i(1, 78) = 31.60$, $p < .001$, $MSE = 1{,}301.2$, partial $\eta^2 = .29$. The priming effect was facilitory, not inhibitory—first fixations to targets primed by orthographic neighbors were shorter than first fixations to targets primed by unrelated words (321 ms vs. 354 ms). As can be seen in Table 1, the interaction between prime type and target frequency was not significant (both Fs < 1): There were similar priming effects for low-frequency targets primed by higher frequency neighbors (27 ms) and high-frequency targets primed by lower frequency neighbors (37 ms). There was no effect of target frequency (both Fs < 1), consistent with Inhoff and Rayner's (1986) finding that there is no effect of word frequency on first fixation durations when no parafoveal preview of the target is available.

Gaze durations. The effect of prime type was significant, $F_s(1, 35) = 19.21$, $p < .001$, $MSE = 1{,}703.8$, partial $\eta^2 = .35$; $F_i(1, 78) = 16.20$, $p < .001$, $MSE = 2{,}192.4$, partial $\eta^2 = .17$. The priming effect was again facilitory, with shorter gaze durations to targets primed by orthographic neighbors (382 ms) than to targets primed by unrelated words (413 ms). The effect of target frequency was also significant, $F_s(1, 35) = 9.32$, $p < .01$, $MSE = 1{,}155.1$, partial $\eta^2 = .21$; $F_i(1, 78) = 4.14$, $p < .05$, $MSE = 2{,}833.9$, partial $\eta^2 = .05$. Gaze durations to high-frequency targets were shorter than gaze durations to low-frequency targets (389 ms vs. 406 ms). The interaction between target frequency and prime type was not significant (both Fs < 1). The priming effects for the targets primed by higher frequency neighbors (26 ms) and the targets primed by lower frequency neighbors (34 ms) were of similar magnitude.

Total fixation durations. The effect of prime type was significant, $F_s(1, 35) = 16.96$, $p < .001$, $MSE = 2{,}460.2$, partial $\eta^2 = .33$; $F_i(1, 78) = 17.20$, $p < .001$, $MSE = 2{,}775.5$, partial $\eta^2 = .18$. Like the first fixation and gaze durations, total fixation durations were shorter when targets were primed by orthographic neighbors than when they were primed by unrelated words (415 ms vs. 449 ms). There was also an effect of target frequency, $F_s(1, 35) = 25.00$, $p < .001$, $MSE = 1{,}592.9$, partial $\eta^2 = .42$; $F_i(1, 78) = 8.93$, $p < .01$, $MSE = 4{,}262.7$, partial $\eta^2 = .10$; with shorter total gaze durations to high-frequency targets (415 ms) than low-frequency targets (448 ms). Consistent with the first fixation and gaze duration data, the interaction between prime type and target frequency was not significant, $F_s(1, 35) = 1.79$, $p > .10$, $MSE = 2{,}589.1$; $F_i < 1$, although numerically facilitation from lower frequency neighbor primes was larger (46 ms) than facilitation from higher frequency neighbor primes (23 ms).[3]

Discussion

In Experiment 1, we attempted to maximize the possibility of obtaining an inhibitory neighbor priming effect in the fast priming paradigm. Essentially, the critical question was whether the prime-target pairs that produced inhibition in the lexical decision task (Nakayama et al., 2008, Experiment 2) would produce the same effect in a reading task when using a longer prime duration (60 ms) than previous fast priming studies (to allow the lexical units of primes time to receive sufficient activation to become strong competitors for the targets). We found that they did not. Instead, consistent with previous fast priming studies (H. Lee et al., 1999, 2002; Y. Lee et al., 1999; Rayner et al., 1995), targets were read faster when they were primed by word neighbor primes than when they were primed by unrelated

Table 1
Experiment 1: Mean FFD, GD, and TFD for Target Words as a Function of Relative Prime-Target Frequency

	Prime-target frequency					
	High–low			Low–high		
Prime type	FFD	GD	TFD	FFD	GD	TFD
Neighbor	326	393	437	317	372	392
Unrelated	353	419	460	354	406	438
Difference	27	26	23	37	34	46

Note. Means include the prime duration of 60 ms. All means given in milliseconds. FFD = first fixation duration; GD = gaze duration; TFD = total fixation duration.

[3] An alternative analysis technique is to use multivariate analysis of variance (MANOVA) to analyze the first fixation duration, gaze duration, and total fixation duration data together, given that these variables are typically correlated and MANOVA is designed to handle correlated dependent variables. Using MANOVA to analyze the data produced results equivalent to those of the ANOVA analyses. Specifically, a MANOVA analysis of the subject means produced an effect of prime type, Wilk's $\Lambda = .50$, $F(3, 33) = 10.81$, $p < .001$, partial $\eta^2 = .50$; an effect of target frequency, Wilk's $\Lambda = .54$, $F(3, 33) = 9.41$, $p < .001$, partial $\eta^2 = .46$; and no interaction, Wilk's $\Lambda = .92$, $F < 1$, $p > .10$. A MANOVA analysis of the item means also produced an effect of prime type, Wilk's $\Lambda = .67$, $F(3, 76) = 12.45$, $p < .001$, partial $\eta^2 = .30$; an effect of target frequency, Wilk's $\Lambda = .86$, $F(3, 76) = 2.98$, $p < .05$, partial $\eta^2 = .11$; and no interaction, Wilk's $\Lambda = .96$, $F < 1$, $p > .10$.

words. This was true for first fixation and gaze durations and for total fixation durations, the latter measure assumed to reflect relatively later processing and suggested to be more sensitive to a lexical inhibition effect (e.g., Perea & Pollatsek, 1998; Williams et al., 2006). (The facilitory priming effect was of similar magnitude for all of these measures, however.) Also consistent with Y. Lee et al.'s and H. Lee et al.'s (2002) results was that the facilitation effects were observed irrespective of relative prime-target frequency.[4]

The facilitation effects observed in Experiment 1 contrast sharply with the inhibition effects observed in previous masked neighbor priming studies (e.g., Davis & Lupker, 2006; Nakayama et al., 2008), despite the fact that the prime-target pairs used in Experiment 1 were the same stimuli used by Nakayama et al. in one of their masked priming experiments (Experiment 2). The obvious question is how could the same stimuli produce an inhibition effect in one task and a facilitation effect in what seems to be a fairly parallel task? One possibility has to do with the cases of the primes and targets. In the masked priming paradigm, primes and targets are normally presented in different cases (e.g., *tide–SIDE*) to ensure effects reflect lexical processing rather than visual integration. In the fast priming paradigm, on the other hand, the prime and target are typically presented in the same font and in the same case and therefore have a large perceptual overlap with one another (e.g., *tide–side*). A large perceptual overlap between the prime and target likely aids target processing on neighbor prime trials, which may make it difficult to observe an impact of the competition that is presumed to occur at the lexical level. Experiment 2 was conducted to investigate this idea by reducing the perceptual overlap between the primes and targets: all the primes were presented in upper case letters and all the targets were presented in lower case letters (*TIDE–side*). (Note the case relationship is the opposite of that used in masked priming experiments because the words in the sentences in the present experiments are presented in lower case.) If a large perceptual overlap between the prime and target makes it difficult to observe inhibition effects, then reducing the perceptual overlap in this manner should allow these effects to emerge.

Experiment 2

Method

Participants. Thirty-six undergraduate students from the University of Calgary volunteered to participate in exchange for extra course credit. All participants were native speakers of English and reported having normal or corrected to normal vision. None of these individuals participated in Experiment 1.

Apparatus and procedure. The apparatus and procedure were identical to those in Experiment 1.

Materials. The materials were the same as those used in Experiment 1, except that the primes were presented in upper case letters. The sizes of the primes and targets were matched to each other so that the upper case primes would be efficiently backward masked by lower case targets.

Results

As in Experiment 1, fixations that were shorter than 100 ms or longer than 700 ms were removed as outliers (2.6% of the data). Data were also excluded according to the previously established criteria described in Experiment 1. Four participants were replaced because they did not meet the 60% usable-data criterion. As a result of the data trimming, 82% of all the data collected were subject to data analyses. The mean first fixation durations, gaze durations, and total fixation durations from the subject analysis are listed in Table 2. These data were analyzed in the same manner as in Experiment 1.

First fixation durations. There was no effect of prime type on first fixation durations (both Fs < 1). First fixation durations to targets primed by orthographic neighbors (335 ms) were essentially the same as first fixation durations to targets primed by unrelated words (334 ms). The effect of target frequency was significant, $F_s(1, 35) = 4.62$, $p < .05$, $MSE = 1{,}013.9$, partial $\eta^2 = .12$; $F_i(1, 78) = 4.14$, $p < .05$, $MSE = 1{,}491.6$, partial $\eta^2 = .05$; with shorter fixations to high-frequency targets (329 ms) than to low-frequency targets (340 ms). The interaction between prime type and target frequency was not significant (both Fs < 1).

Gaze durations. There was no effect of prime type (both Fs < 1). Gaze durations to targets primed by orthographic neighbors (390 ms) were very similar to gaze durations to targets primed by unrelated words (395 ms). There was an effect of target frequency, $F_s(1, 35) = 6.77$, $p < .05$, $MSE = 1{,}040.5$, partial $\eta^2 = .16$; $F_i(1, 78) = 4.14$, $p < .05$, $MSE = 2{,}260.3$, partial $\eta^2 = .05$; with shorter gaze durations to high-frequency targets than to low-frequency targets (386 ms vs. 400 ms). The interaction between prime type and target frequency was not significant (both Fs < 1).

Total fixation durations. There was no effect of prime type on total fixation durations (both Fs < 1). Like the first fixation and gaze durations, total fixation durations to targets primed by orthographic neighbors (451 ms) were nearly identical to total fixation durations to targets primed by unrelated words (452 ms). The effect of target frequency was marginally significant, $F_s(1, 35) = 3.21$, $p = .08$, $MSE = 2{,}819.5$, partial $\eta^2 = .08$; $F_i(1, 78) = 1.39$, $p > .10$, $MSE = 6{,}622.1$, partial $\eta^2 = .02$. Again, the interaction between prime type and target frequency was not significant (both Fs < 1).[5]

Discussion

The purpose of Experiment 2 was to investigate the possibility that the facilitation effects observed in Experiment 1 (and, pre-

[4] There is a possibility that the facilitation effect in Experiment 1 could have been due not only to orthographic similarly, but also to phonological similarly between primes and targets, given that neighbor primes and targets would sound more similar than unrelated primes and targets. On the other hand, previous fast priming studies (H. Lee et al., 1999; Y. Lee et al., 1999) reported that phonologically similar primes (i.e., homophones) facilitate reading over orthographically similar primes at short prime durations (e.g., 29 to 35 ms) but not at longer prime durations (e.g., 38 to 42 ms). (Nonword primes were not found to produce any phonological priming.) Thus, it seems likely that the facilitation in the present experiment (with a prime duration of 60 ms) was an orthographic priming effect, although we cannot rule out the possibility that phonological similarity contributed to the priming effects.

[5] MANOVA analyses of the subject and item means produced equivalent results, with significant effects of target frequency, no effects of prime type, and no interactions.

Table 2
Experiment 2: Mean FFD, GD, and TFD for Target Words as a Function of Relative Prime-Target Frequency

	Prime-target frequency					
	High–low			Low–high		
Prime type	FFD	GD	TFD	FFD	GD	TFD
Neighbor	342	397	458	327	384	444
Unrelated	338	402	461	330	387	444
Difference	–4	5	3	3	3	0

Note. Means include the prime duration of 60 ms. All means given in milliseconds. FFD = first fixation duration; GD = gaze duration; TFD = total fixation duration.

sumably, in a number of similar studies; e.g., H. Lee et al., 1999; Y. Lee et al., 1999) were caused by the large perceptual overlap between the prime and target, which may have counteracted the effects of the competition process at the lexical level. In Experiment 2, the physical overlap between the prime and target was reduced by presenting primes in upper case and targets in lower case (e.g., *TIDE–side*). All the stimuli and the remainder of the procedures were identical to those in Experiment 1.

When upper case primes were used in Experiment 2 the facilitation effects observed in Experiment 1 completely disappeared.[6] Instead, null priming effects were found for all three fixation measures. These results suggest that the facilitation effects in Experiment 1 were the result of the large perceptual overlap between the primes and targets. The null effects in Experiment 2, however, also imply that there was no impact of lexical competition in the reading task (i.e., the primes essentially had no impact at all on target processing). However, in offering this conclusion we feel that it is important to consider an alternative interpretation of the results of Experiment 2.

As Davis (2003) outlined (see also Perry, Lupker, & Davis, 2008), according to activation-based models, neighbor primes do more than produce added competition within the lexicon, inhibiting target processing (the process producing inhibition effects). In particular, they also facilitate target processing because they preactivate the lexical representation of the target and help inhibit neighbors of the target that are not neighbors of the prime. That is, *slap* and *claw* are both neighbors of the target *clap*. If *slap* is presented as a prime for *clap*, it will help to inhibit *claw*, diminishing the ability of *claw* to compete with the target *clap* when *clap* is presented. In a masked priming situation, the inhibition of *clap* created by lexical competition from *slap* seems to be more potent than the benefit to *clap* due to pre-activation of its lexical unit and the inhibition of *claw*-type neighbors. Such might not be the case, however, in a reading task. In a reading task, inhibition and facilitation may more closely balance themselves out and produce an overall null effect such as the one observed in Experiment 2.

To examine this issue more fully, in Experiment 3 we used nonword neighbor primes, with the primes presented in lower case (*kide–tide*) in Experiment 3A (as they were in Experiment 1) and in upper case (*KIDE–tide*) in Experiment 3B (as they were in Experiment 2). The targets and their sentences were the same as those in Experiments 1 and 2. Nonword neighbors do not have the same ability to produce lexical competition because they do not have a representation in the lexicon. However, they do have the ability to pre-activate the target. Thus, they tend to produce facilitation effects in masked priming experiments (Davis & Lupker, 2006; Forster, 1987; Forster, Davis, Schoknecht, & Carter, 1987; Forster & Veres, 1998). If our interpretation of the lack of inhibition in Experiment 2 is correct, then nonword neighbor primes should produce facilitation in Experiment 3. If this is the case, then it implies that inhibitory processes were active in Experiment 2 but were not powerful enough to overcome the facilitory processes that were also present in that situation.

Experiment 3

Nonword primes were presented in lower case (*kide–tide*) in Experiment 3A and in upper case (*KIDE–tide*) in Experiment 3B. In all other respects the two experiments were identical.

Method

Participants. Participants were undergraduate students from the University of Calgary who volunteered to participate in exchange for extra course credit. There were 36 participants in Experiment 3A and 36 participants in Experiment 3B. All participants were native speakers of English and reported having normal or corrected to normal vision. None of these individuals participated in the previous experiments.

Apparatus and procedure. The apparatus and procedure were identical to those used in Experiments 1 and 2.

Stimuli. For each target (e.g., *side*) two types of nonwords were chosen: one was an orthographic neighbor of the target (e.g., *kide–side* in Experiment 3A and *KIDE–side* in Experiment 3B) and the other was orthographically unrelated to the target (e.g., *cust*–side in Experiment 3A and *CUST–side* in Experiment 3B). The same nonword primes were paired with both low-frequency and high-frequency targets (for example, both *kide* and *cust* were paired with both *side* and *tide*) because the normative frequency of the nonwords could not be manipulated. Nonword neighbor primes and targets thus differed at the exact letter position at which the original neighbor pairs differed (e.g., for the *side–tide* neighbor pair, *kide* was selected as a prime; likewise, for the *door–doom* neighbor pair, *doof* was selected as a prime). These nonword primes had a mean neighborhood size that was the same as that for the word neighbor primes in Experiments 1 and 2 ($M = 10.2$). For the nonword primes presented in upper case (Experiment 3B) the

[6] Combined analyses of the data from Experiments 1 and 2 were carried out to determine if there was an Experiment (lower case prime vs. upper case prime) × Prime Type (neighbor prime vs. unrelated prime) interaction for any of the fixation measures, which would be expected if there was a priming effect in Experiment 1 but not in Experiment 2. This interaction was significant for all fixation measures: first fixation durations, $F_s(1, 70) = 17.23$, $p < .001$, $MSE = 1{,}144.4$, partial $\eta^2 = .20$; $F_i(1, 78) = 13.34$, $p < .001$, $MSE = 1{,}382.6$, partial $\eta^2 = .15$; gaze durations, $F_s(1, 70) = 8.49$, $p < .01$, $MSE = 1{,}436.7$, partial $\eta^2 = .11$; $F_i(1, 78) = 6.77$, $p < .05$, $MSE = 1{,}785.2$, partial $\eta^2 = .08$; total fixation durations, $F_s(1, 70) = 8.08$, $p < .01$, $MSE = 2{,}410.7$, partial $\eta^2 = .10$; $F_i(1, 78) = 7.72$, $p < .01$, $MSE = 3{,}045.3$, partial $\eta^2 = .09$. The Experiment × Prime Type interaction was also significant in a MANOVA analysis.

size of the primes and targets were matched (e.g., CUST–*side*) as they were in Experiment 2.

Results

Table 3 shows the mean first fixation durations, gaze durations, and total fixation durations in Experiments 3A; Table 4 shows the same data from Experiment 3B.

Experiment 3A: Nonword primes presented in lower case. Data from seven participants did not satisfy the 60% usable data criterion and those participants were replaced with new participants while maintaining the proper counterbalancing of lists across participants. Outliers were removed using the same criteria used in Experiments 1 and 2, resulting in 4.6% of the data being removed. The data trimming procedures described in Experiment 1 left 78% of the data usable. The mean first fixation durations, gaze durations, and total fixation durations were analyzed separately with a 2 (prime type: neighbor prime vs. unrelated prime) × 2 (target frequency: high frequency vs. low frequency) ANOVA.

First fixation durations. The effect of prime type was marginally significant in the subject analysis, $F_s(1, 35) = 3.79$, $p = .06$, $MSE = 1{,}110.6$, partial $\eta^2 = .10$; $F_i(1, 78) = 2.54$, $p > .10$, $MSE = 1{,}708.9$. First fixation durations to targets primed by nonword neighbors were 11 ms shorter than first fixation durations to targets primed by unrelated nonwords (321 ms vs. 332 ms). There was no effect of target frequency, $F_s(1, 35) = 1.69$, $p > .10$, $MSE = 1{,}043.8$; $F_i\ (1, 78) = 1.93$, $p > .10$, $MSE = 2{,}025.9$. The interaction between prime type and target frequency was not significant, $F_s(1, 35) = 1.77$, $p > .10$, $MSE = 1{,}362.1$; $F_i(1, 78) = 2.88$, $p = .09$, $MSE = 1{,}708.9$.

Gaze durations. The effect of prime type was significant, $F_s(1, 35) = 10.07$, $p < .01$, $MSE = 1{,}668.5$, partial $\eta^2 = .22$; $F_i(1, 78) = 9.35$, $p < .01$, $MSE = 1{,}900.8$, partial $\eta^2 = .11$. Gaze durations to targets primed by nonword neighbors were shorter (379 ms) than gaze durations to targets primed by unrelated nonwords (400 ms). The effect of target frequency was also significant, $F_s(1, 35) = 9.30$, $p < .01$, $MSE = 1{,}900.4$, partial $\eta^2 = .21$; $F_i(1, 78) = 8.14$, $p < .01$, $MSE = 2{,}827.7$, partial $\eta^2 = .09$. Gaze durations to high-frequency targets were shorter than gaze durations to low-frequency targets (378 ms vs. 401 ms). The interaction between prime type and target frequency was not significant, $F_s(1, 35) = 1.24$, $p > .10$, $MSE = 1{,}813.8$; $F_i(1, 78) = 1.49$, $p > .10$, $MSE = 1{,}900.8$.

Total fixation durations. There was an effect of prime type, $F_s(1, 35) = 6.17$, $p < .05$, $MSE = 4{,}391.5$, partial $\eta^2 = .15$; $F_i(1, 78) = 7.52$, $p < .01$, $MSE = 4{,}568.1$, partial $\eta^2 = .09$, with shorter total fixation durations when targets were primed by nonword neighbors (441 ms) than when primed by unrelated nonwords (468 ms). The effect of target frequency was marginally significant, $F_s(1, 35) = 3.88$, $p = .06$, $MSE = 4{,}057.9$, partial $\eta^2 = .10$; $F_i(1, 78) = 3.33$, $p = .07$, $MSE = 4{,}947.9$, partial $\eta^2 = .04$. Gaze durations to high-frequency targets were 21 ms shorter than gaze durations to low-frequency targets (444 ms vs. 465 ms). Consistent with the first fixation data and gaze duration data, the interaction between prime type and target frequency was not significant, $F_s(1, 35) = 1.03$, $p > .10$, $MSE = 2{,}389.9$; $F_i < 1$.[7]

Experiment 3B: Nonword primes presented in upper case. Outliers were removed using the same criteria described previously and resulted in 2.9% of the data being removed. The data trimming procedure left 83% of the data usable. The mean first fixation durations, gaze durations, and total fixation durations were analyzed separately with a 2 (prime type: neighbor prime vs. unrelated prime) × 2 (target frequency: high frequency vs. low frequency) ANOVA.[8]

First fixation durations. There was no effect of prime type, $F_s(1, 35) = 1.69$, $p > .10$, $MSE = 1{,}544.0$; $F_i(1, 78) = 1.50$, $p > .10$, $MSE = 1{,}723.4$; no effect of target frequency, $F_s(1, 35) = 1.93$, $p > .10$, $MSE = 1{,}326.1$; $F_i < 1$; and no interaction (both Fs < 1).

Gaze durations. The effect of prime type was significant, $F_s(1, 35) = 9.87$, $p < .01$, $MSE = 1{,}767.3$, partial $\eta^2 = .22$; $F_i(1, 78) = 12.78$, $p < .01$, $MSE = 1{,}595.6$, partial $\eta^2 = .14$. Gaze durations to targets primed by nonword neighbors were shorter (389 ms) than gaze durations to targets primed by unrelated

Table 3
Experiment 3A: Mean FFD, GD, and TFD for the Target Words Primed by Lower Case Nonword Primes as a Function of Target Frequency

	Target frequency					
	Low			High		
Prime type	FFD	GD	TFD	FFD	GD	TFD
Neighbor	329	394	447	313	364	434
Unrelated	331	407	483	332	393	454
Difference	2	13	36	19	29	20

Note. Means include the prime duration of 60 ms. All means given in milliseconds. FFD = first fixation duration; GD = gaze duration; TFD = total fixation duration.

Table 4
Experiment 3B: Mean FFD, GD, and TFD for Target Words Primed by Upper Case Nonword Primes as a Function of Target Frequency

	Target frequency					
	Low			High		
Prime type	FFD	GD	TFD	FFD	GD	TFD
Neighbor	339	405	450	325	373	415
Unrelated	342	422	472	339	400	455
Difference	3	17	22	14	27	40

Note. Means include the prime duration of 60 ms. All means given in milliseconds. FFD = first fixation duration; GD = gaze duration; TFD = total fixation duration.

[7] MANOVA analyses of the subject and item means produced equivalent results, with significant effects of prime type and target frequency and no interactions.

[8] Primes for three targets (*hands*, *help*, *tire*) were not properly presented in Experiment 3B and therefore the data for these items were not included in the analyses. For the item analyses missing data was replaced with cell means.

nonwords (411 ms). The effect of target frequency was also significant, $F_s(1, 35) = 24.88$, $p < .001$, $MSE = 1{,}049.9$, partial $\eta^2 = .42$; $F_i(1, 78) = 10.01$, $p < .01$, $MSE = 1{,}979.9$, partial $\eta^2 = .11$; with shorter gaze durations to high-frequency targets than to low-frequency targets (387 ms vs. 414 ms). The interaction between prime type and target frequency was not significant (both Fs < 1).

Total fixation durations. There was an effect of prime type, $F_s(1, 35) = 20.29$, $p < .001$, $MSE = 1{,}704.1$, partial $\eta^2 = .37$; $F_i(1, 78) = 16.58$, $p < .001$, $MSE = 2{,}120.0$, partial $\eta^2 = .18$; with total fixation durations to targets being shorter when primed by nonword neighbors (432 ms) than when primed by unrelated nonwords (463 ms). There was also a 26 ms effect of target frequency, $F_s(1, 35) = 10.21$, $p < .01$, $MSE = 2{,}320.9$, partial $\eta^2 = .23$; $F_i(1, 78) = 4.33$, $p < .05$, $MSE = 4{,}376.0$, partial $\eta^2 = .05$, with shorter total fixation durations to high-frequency targets. Once again, the interaction was not significant, $F_s(1, 35) = 1.98$, $p > .10$, $MSE = 1{,}619.4$; $F_i(1, 78) = 1.22$, $p > .10$, $MSE = 2{,}120.0$.[9,10]

Discussion

For gaze durations and total fixation durations there were clear facilitation effects from nonword neighbor primes. In both experiments gaze durations were shorter when targets were primed by nonword neighbors than when primed by unrelated nonwords and the magnitude of the priming effects for high-frequency targets and low-frequency targets were not significantly different. The same was true for total fixation durations, with significant facilitory priming effects and statistically equivalent priming for high-frequency and low-frequency targets. These results are consistent with the proposed interpretation of the lack of inhibition in Experiment 2—that word primes in that experiment produced both facilitation and inhibition, with those two effects counteracting each other and leading to an overall null result.

Curiously, the magnitude of the facilitation effect was very similar for the lower case nonword primes (20 ms overall) and the uppercase nonword primes (21 ms overall); one might have expected the lower case primes to produce more facilitation given their larger perceptual overlap with the targets. Although this comparison may turn out to be theoretically important, it also is possible that fixation durations can be reduced by a prime only so much in a reading task because some minimum amount of time is necessary for a word to be processed and for the next saccade to be programmed. Ultimately, therefore, what we may be observing is something of an upper limit on the amount of priming that can be produced in these situations.

One other result of note is that similar facilitation effects were also produced by lower case word primes in Experiment 1 (a 32 ms priming effect overall) and lower case nonword primes in Experiment 3A (a 20 ms priming effect overall). One might predict that lower case nonword primes would produce more facilitation than lower case word primes because nonword primes do not have the ability to produce lexical competition. Nonetheless, note that Y. Lee et al. (1999) also found that lower case nonword primes produced no more facilitation than lower case word primes (in two separate experiments). Hence, the pattern we observed is quite consistent with Y. Lee et al.'s. (Unfortunately, H. Lee et al., 1999, 2002, did not use nonword primes in their fast priming experiments and thus, there are no other data available allowing us to examine this particular contrast.) Again, this result could merely be due to there being a limitation on how short fixations can actually be. On the other hand, it is also conceivable that visual and lexical priming effects interact in a way that is not yet well understood. A thorough understanding of what is producing the similar levels of priming from upper and lowercase nonword primes and lowercase word primes in the fast priming paradigm will have to await further study.

General Discussion

Recent research using English stimuli in the masked priming paradigm (Davis & Lupker, 2006; Nakayama et al., 2008) has established that there is an inhibitory neighbor priming effect similar to that found in other alphabetical languages (e.g., French, Dutch, Italian). The present research was an attempt to determine whether this effect also exists in a parallel task involving normal reading processes, namely, the fast priming paradigm (Sereno & Rayner, 1992). To make across-task comparisons easier, the critical neighbor prime-target pairs were taken from Nakayama et al. (Experiment 2), an experiment showing a clear inhibitory priming effect with the lexical decision task. In the present experiments, targets were embedded in short sentences and readers' fixation times to the targets were compared when the targets were primed by their orthographic neighbors and unrelated words.

Experiment 1 replicated the results of previous fast priming experiments that used orthographically similar primes (H. Lee et al., 1999, 2002; Y. Lee et al., 1999; Rayner et al., 1995). Consistent with previous experiments, fixation times were shorter to target words primed by their orthographic neighbors than to target words primed by unrelated words. Also consistent with previous experiments was the finding of statistically equivalent facilitation when high-frequency words primed low-frequency targets and when low-frequency words primed high-frequency targets (Y. Lee et al., 1999). Further, these patterns emerged in all three of our measures (first fixation duration, gaze duration, and total fixation duration). Taken together, the results of all of these studies suggest that in silent reading orthographic neighbor primes generally help target processing rather than hinder it.

Facilitation and Inhibition in Fast Priming

The facilitation found in Experiment 1 is, of course, exactly the opposite of the results reported in masked neighbor priming studies (Davis & Lupker, 2006; Nakayama et al., 2008). One methodological factor that could have produced this difference was how the primes and targets were presented. Traditionally, although primes and targets are presented in different cases in masked priming studies (e.g., *side–TIDE*), they are presented in the same case in fast priming studies (e.g., *side–tide*). The large physical overlap between primes and targets in the reading experiments may have allowed the neighbor primes to facilitate the visual

[9] MANOVA analyses of the subject and item means produced equivalent results, with significant effects of prime type and target frequency and no interactions.

[10] Combined analyses of the data from Experiments 3A and 3B produced no interactions between experiment and prime type (neighbor prime vs. unrelated prime) for any of the fixation measures (all ps $> .10$).

processing of the targets, effectively canceling out any effects of competition during lexical processing. This possibility was examined in Experiment 2 by presenting primes in upper case letters. The results of Experiment 2 provided reasonable support for this idea. When the physical overlap between primes and targets was minimized by varying their letter case, there was no facilitation in any of the fixation measures.

Although the case change for the primes eliminated the facilitation effect in Experiment 2, it did not produce the expected inhibition. Thus, the question remains as to whether activation models incorporating inhibitory processes and lexical competition are viable as models of normal reading. Experiment 3 was our final attempt to address this question. As Davis (2003) and Perry et al. (2008) described, according to activation models, orthographically similar primes both facilitate and inhibit their targets. Thus, it is possible that in Experiment 2 these processes merely counteracted each other. Nonword primes, however, are presumed to provide facilitation due to the fact that they activate the target's lexical unit, while creating much less lexical inhibition because nonwords do not have lexical representations. Thus, if the word primes were producing facilitation and inhibition (due to lexical competition) in Experiment 2, nonword primes would be expected to produce only facilitation in Experiment 3 regardless of whether the primes and targets were in the same case (Experiment 3A) or in different cases (Experiment 3B). The results of Experiment 3 confirmed this expectation. Thus, the absence of an inhibition effect in the fast priming task is not necessarily inconsistent with activation-based models that incorporate a lexical competition mechanism (e.g., Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). It is the case, of course, that we did not actually observe an inhibitory priming effect in our experiments, but rather inferred an effect from our data (in particular, the contrast between Experiments 2 and 3). Support for activation models would be strengthened considerably if a clear inhibitory priming effect could be demonstrated in the fast priming paradigm.

One remaining issue that should be discussed concerns the absence of an interaction between prime type and relative prime-target frequency in either Experiment 1 or 2. According to activation models, lower frequency targets receive stronger inhibition from higher frequency neighbor primes than vice versa. Thus, one would predict that the low-frequency targets would have experienced more inhibition than the high-frequency targets in both Experiments 1 and 2, leading to different priming effects for low- and high-frequency targets and hence an interaction. Nakayama et al. (2008) were able to confirm this prediction for these stimuli in their simulations with the interactive-activation model (Davis, 2003; McClelland & Rumelhart, 1981); they showed that the model predicts a substantially larger inhibitory priming effect from the higher frequency neighbor primes than from the lower frequency neighbor primes. Nonetheless, both types of primes produced statistically equivalent priming effects in the present experiments, which was true in Nakayama et al.'s masked priming experiments as well. Assuming the same principles are applicable in the masked priming paradigm and the fast priming paradigm, the lack of a prime type by relative target frequency interaction for the same set of words is not unexpected. However, both results do challenge one of the key assumptions of the activation-based models, namely, that only higher frequency neighbor primes can inhibit target identification. Contrary to the predictions of these models, it would seem that inhibitory neighbor priming effects do not depend solely on the frequency relationship between the prime and the target (see Nakayama et al., 2008, for a discussion).

Explaining Differences Between Masked Priming and Fast Priming

As discussed in the preceding section, a reasonable interpretation of the null priming effect from the upper case neighbor primes in Experiment 2 is that it was the outcome of a mixture of facilitation and inhibition effects created by word primes. This conclusion still leaves one major question unanswered: Why do the same primes that significantly inhibit target processing in masked neighbor priming using a lexical decision task (Nakayama et al., 2008, Experiment 2) produce a null effect in fast priming during reading? In attempting to account for this difference, we can rule out uncontrolled stimulus characteristics as a possibility because the same critical stimuli were used in the two experiments. We can also rule out perceptual overlap as being responsible because primes and targets were presented in different cases in Experiment 2 (as they are in masked priming experiments).

An obvious possibility for why it is more difficult to observe inhibition in our reading task (fast priming) and, possibly, in reading tasks in general, is that the words in the sentence also receive priming through syntactic, semantic, and conceptual processes. Consider, for example, the sentence "There is nothing that students *love* more than a hot cup of coffee," where *love* is the target word and *lone* is the prime. Of all the words activated by the prime *lone* (i.e., *love*, *tone*, *line*, *lane*, etc.), most of them receive little or no support from the syntactic, semantic, or conceptual constraints imposed by the first part of the sentence, with the exception of the word *love*. Because *love* is the only word that would benefit from priming from these sources, the impact would be to increase the relative activation level of the lexical unit for *love* (i.e., in comparison to most of its neighbors), which should decrease the ability of its neighbors to compete with it. As a result, the factors producing facilitation, in particular the pre-activation that the prime *lone* provides for the target *love,* should be dominant.

This situation contrasts, of course, with the situation in a standard masked priming, lexical decision experiment in which any of the neighbors of the prime *lone* could legitimately appear as a target. In that case, the lexical unit for *love* would receive no added benefit when primed by *lone*, as all of *lone*'s neighbors would receive the same degree of pre-activation. A potential implication is that in fast priming experiments, the syntactic, semantic, or conceptual nature of the prime's neighbors might be important. For example, if the target is the only prime neighbor that is a verb and a verb is required at that point in the sentence, none of the other neighbors would be viable candidates to occupy the target's position in the sentence. Thus, inhibition would be less likely than if many of the other prime neighbors were verbs, and hence, were viable candidates to occupy the target's position in the sentence. (If a difference of this sort were observed in a fast priming experiment, it should, of course, then disappear when these same stimuli are used in a standard masked priming, lexical decision task.)

Preliminary evidence along these lines was reported by Slattery, Pollatsek, and Rayner (2007). Slattery et al. had participants read target words with and without higher frequency neighbors that were embedded in two types of sentence frames. In one sentence type the target and its higher frequency neighbor fit equally well with the prior sentence context (e.g., "The brand new *choir* sounded much better than the old one," in which the higher frequency neighbor of *choir* is *chair*). In the other sentence type the target fit much better with the prior sentence context than did the target's higher frequency neighbor (e.g., "The beautiful sound from the new *choir* echoed through the room"). In their initial experiment, Slattery et al. reported that gaze durations to words with higher frequency neighbors were longer than those to control words without higher frequency neighbors only when the higher frequency neighbor fit with the prior sentence context. Slattery et al.'s findings, if replicated, would demonstrate the importance of semantic constraints in investigations of the neighborhood frequency effect in reading tasks, including the fast priming task.[11]

Conclusions

In the present experiments we looked for evidence of lexical competition between orthographically similar words during word identification, a key prediction of activation-based models of lexical selection (Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). Using the fast priming paradigm (Sereno & Rayner, 1992), we embedded word targets in sentences and assessed the impact of the presentation of one of the word's neighbors on the target's processing. Our results are consistent with the results of previous studies that have primed word targets with orthographically similar words while participants read sentences (H. Lee et al., 1999; Y. Lee et al., 1999; Williams et al., 2006): targets were read faster when they were primed by word neighbor primes than when they were primed by unrelated words. This facilitory neighbor priming effect contrasts sharply with the inhibition observed in masked neighbor priming studies (Davis & Lupker, 2006; Nakayama et al., 2008; Segui & Grainger, 1990). Our subsequent experiments and analyses, however, suggest that priming effects in the fast priming paradigm are due to interactions between facilitory and inhibitory processes like those embodied in activation-based models. Subsequent research using the fast priming paradigm should shed additional light on the nature of those interactions in a normal reading situation.

[11] Paterson, Liversedge, and Davis (2009) demonstrated that it is possible to get inhibitory effects of the sort we were looking for in an online reading task using a quite different experimental situation. In their task, the prime word was actually a word appearing earlier in the sentence; for example, for the sentence "In the photograph, the blue lights were a *blur* against the cold night sky," with *blue* being the orthographically related (unmasked) prime for *blur*. In contrast to a control sentence (e.g., replacing *blue* with *town*), Paterson et al. observed increases in a number of measures (e.g., first fixation time, total reading time, number of regressions) for the *blue–blur* sentences, effects that were independent of the frequency relationship between the prime and target (i.e., primes higher in frequency than the target produced as much priming as primes lower in frequency than the target). These results imply that even the facilitory effects of context can be overcome if the inhibiting prime is activated sufficiently.

References

Andrews, S. (1997). The effect of orthographic similarity on lexical retrieval: Resolving neighborhood conflicts. *Psychonomic Bulletin and Review, 4,* 439–461.

Arduino, L. S., & Burani, C. (2004). Neighborhood effects on nonword visual processing in a language with shallow orthography. *Journal of Psycholinguistic Research, 33,* 75–95.

Ashby, J., & Rayner, K. (2004). Representing syllable information during silent reading: Evidence from eye movements. *Language and Cognitive Processes, 19,* 391–426.

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1995). *The CELEX lexical database* (CD–ROM). Philadelphia: University of Pennsylvania, Linguistic Data Consortium.

Bijeljac-Babic, R., Biardeau, A., & Grainger, J. (1997). Masked orthographic priming in bilingual word recognition. *Memory & Cognition, 25,* 447–457.

Carreiras, M., Perea, M., & Grainger, J. (1997). Effects of the orthographic neighborhood in visual word recognition: Cross-task comparisons. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 857–871.

Chateau, D., & Jared, D. (2000). Exposure to print and word recognition processes. *Memory and Cognition, 28,* 143–153.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance 6* (pp. 535–555). Hillsdale, NJ: Erlbaum.

Davis, C. J. (2003). Factors underlying masked priming effects in competitive network models of visual word recognition. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 121–170). New York: Psychology.

Davis, C. J., & Lupker, S. J. (2006). Masked inhibitory priming in English: Evidence for lexical inhibition. *Journal of Experimental Psychology: Human Perception and Performance, 32,* 668–687.

De Moor, W., & Brysbaert, M. (2000). Neighborhood frequency effects when primes and targets are of different lengths. *Psychological Research, 63,* 159–162.

Forster, K. I. (1987). Form-priming with masked primes: The best-match hypothesis. In M. Coltheart (Ed.), *Attention and Performance XII.* (pp. 127–146). Hillsdale, NJ: Erlbaum.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10,* 680–698.

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation? *Quarterly Journal of Experimental Psychology, 39*A, 241–251.

Forster, K. I., & Shen, D. (1996). No enemies in the neighborhood: Absence of inhibitory neighborhood frequency effects in lexical decision and semantic categorization. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 696–713.

Forster, K. I., & Veres, C. (1998). The prime lexicality effect: Form-priming as a function of prime awareness, lexical status, and discrimination difficulty. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 498–514.

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple-read out model. *Psychological Review, 103,* 518–565.

Grainger, J., O'Regan, J. K., Jacobs, A. M., & Segui, J. (1989). On the role of competing word units in visual word recognition: The neighborhood frequency effect. *Perception and Psychophysics, 45,* 189–195.

Grainger, J., & Segui, J. (1990). Neighborhood frequency effects in visual word recognition: A comparison of lexical decision and masked identification latencies. *Perception and Psychophysics, 47,* 191–198.

Huntsman, L. A., & Lima, S. D. (1996). Orthographic neighborhood structure and lexical access. *Journal of Psycholinguistic Research, 25,* 417–429.

Inhoff, A. W., & Rayner, K. (1986). Parafoveal word processing during fixations in reading: Effects of word frequency. *Perception and Psychophysics, 40,* 431–439.

Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

Lavidor, M., & Ellis, A. W. (2001). Orthographic neighborhood effects in the right but not in the left cerebral hemisphere. *Brain and Language, 80,* 63–76.

Lavidor, M., & Ellis, A. W. (2002). Word length and orthographic neighborhood size effects in the left and right cerebral hemispheres. *Brain and Language, 80,* 45–62.

Lee, H., Rayner, K., & Pollatsek, A. (1999). The time course of phonological, semantic, and orthographic coding in reading: Evidence from the fast priming technique. *Psychonomic Bulletin and Review, 6,* 624–634.

Lee, H., Rayner, K., & Pollatsek, A. (2002). The processing of consonants and vowels in reading: Evidence from the fast priming paradigm. *Psychonomic Bulletin and Review, 9,* 766–772.

Lee, Y., Binder, K. S., Kim, J., Pollatsek, A., & Rayner, K. (1999). Activation of phonological codes during eye fixations in reading. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 948–964.

Mathey, S. (2001). L'influence du voisinage orthographique lors de la reconnaissance des mots écrits [The influence of orthographic neighbors on the recognition of written words]. *Canadian Journal of Experimental Psychology, 55,* 1–23.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88,* 375–407.

Nakayama, M., Sears, C. R., & Lupker, S. J. (2008). Masked priming with orthographic neighbors: A test of lexical competition assumption. *Journal of Experimental Psychology: Human Perception and Performance, 34,* 1236–1260.

Paterson, K. B., Liversedge, S. P., & Davis, C. J. (2009). Inhibitory neighbor priming effects in eye movements during reading. *Psychonomic Bulletin & Review, 16,* 43–50.

Perea, M., Acha, J., & Fraga, I. (2008). Lexical competition is enhanced in the left hemisphere: Evidence from different types of orthographic neighbors. *Brain and Language, 105,* 199–210.

Perea, M., & Pollatsek, A. (1998). The effects of neighborhood frequency in reading and lexical decision. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 767–779.

Perea, M., & Rosa, E. (2000). The effects of orthographic neighbourhood in reading and laboratory word identification tasks: A review. *Psicológica, 21,* 327–340.

Perry, J. R., Lupker, S. J., & Davis, C. J. (2008). An evaluation of the interactive-activation model using masked partial-word priming. *Language and Cognitive Processes, 23,* 36–68.

Pollatsek, A., Perea, M., & Binder, K. (1999). The effects of "neighborhood size" in reading and lexical decision. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 1142–1158.

Rayner, K. (1975). The perceptual span and peripheral cues in reading. *Cognitive Psychology, 7,* 65–81.

Rayner, K., Sereno, S. C., Lesch, M. F., & Pollatsek, A. (1995). Phonological codes are automatically activated during reading: Evidence from an eye movement priming paradigm. *Psychological Science, 6,* 26–32.

Sears, C. R., Campbell, C. R., & Lupker, S. J. (2006). Is there a neighborhood frequency effect in English? Evidence from reading and lexical decision. *Journal of Experimental Psychology: Human Perception and Performance, 32,* 1040–1062.

Sears, C. R., Hino, Y., & Lupker, S. J. (1995). Neighborhood size and neighborhood frequency effects in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 876–900.

Sears, C. R., Lupker, S. J., & Hino, Y. (1999). Orthographic neighborhood effects in perceptual identification and semantic categorization tasks: A test of the multiple read-out model. *Perception and Psychophysics, 61,* 1537–1554.

Sears, C. R., Siakaluk, P. D., Chow, V., & Buchanan, L. (2008). Is there an effect of print exposure on the word frequency effect and the neighborhood size effect? *Journal of Psycholinguistic Research, 37,* 269–291.

Segui, J., & Grainger, J. (1990). Priming word recognition with orthographic neighbors: Effects of relative prime-target frequency. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 65–76.

Sereno, S. C., & Rayner, K. (1992). Fast priming during eye fixations in reading. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 173–184.

Siakaluk, P. D., Sears, C. R., & Lupker, S. J. (2002). Orthographic neighborhood effects in lexical decision: The effects of nonword orthographic neighborhood size. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 661–681.

Slattery, T., Pollatsek, A., & Rayner, K. (2007, November). *Neighbor frequency effects during reading: Is there a parallel with lexical ambiguity?* Poster presented at the 48th annual meeting of the Psychonomic Society, Long Beach, CA.

Van Heuven, W. J. B., Dijkstra, A., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language, 39,* 458–483.

Whitney, C., & Lavidor, M. (2005). Facilitative orthographic neighborhood effects: The SERIOL model account. *Cognitive Psychology, 51,* 179–213.

Williams, C. C., Perea, M., Pollatsek, A., & Rayner, K. (2006). Previewing the neighborhood: The role of orthographic neighbors as parafoveal previews in reading. *Journal of Experimental Psychology: Human Perception and Performance, 32,* 1072–1082.

(*Appendix follows*)

Appendix

Sentences used in Experiments 1 and 2[a]	Prime type	
	Neighbor	Unrelated
Lower frequency primes—Higher frequency targets		
I was not sure which [*side*] he was playing for in the baseball game.	*tide*	doll
The president of the company quickly [*told*] me to leave his office.	*toll*	*link*
I am always really busy during the first [*week*] of every month.	*weep*	*grim*
Linda realized she had walked [*long*] past the end of the trail.	*lung*	*cube*
Everyone who spent time with Ben's [*wife*] likes her a lot.	*wipe*	*scar*
Most passengers did not enjoy the rough [*plane*] ride in the storm.	*plank*	*wires*
Ray was angry when the child put his dirty [*hands*] on him.	*sands*	*clock*
The girls walked under the beautiful [*full*] moon that evening.	*bull*	*rope*
The girl packed up her things because it was a perfect [*time*] to go.	*tire*	*mess*
There is nothing the students [*love*] more than a hot cup of coffee.	*lone*	*tear*
The overweight man was not able to finish [*half*] of the marathon.	*halt*	*coin*
Sam was in trouble when his boss caught him leaving [*work*] early.	*fork*	*lawn*
The banker settled the deal when the interest [*rate*] was low.	*mate*	*tent*
Tom did not know how many boxes there were [*back*] at the house.	*bark*	*pine*
Kathy did not realize that everyone had already [*left*] the hotel.	*lift*	*mode*
Family feuds occurred as a result of an unfair [*will*] from a mother.	*pill*	*cake*
My cousin's husband gets very [*cold*] in the winter.	*colt*	*kick*
It was nice that the new couple could meet [*later*] for coffee.	*laser*	*blank*
The students learned a lot when they attended [*class*] with Dr. Jones.	*clash*	*sting*
There are a lot of people in this city that do many [*good*] things.	*hood*	*lure*
Before visiting the farm the boy had never touched a [*real*] pony.	*meal*	*sand*
They are not allowed to punch the opponent's [*head*] in the game.	*heal*	*slip*
Most people are eager to go straight [*home*] after a hard day.	*hose*	*math*
Older men are always attracted to intelligent women [*like*] Julia.	*lime*	*bass*
Simon could save money if he could [*make*] his own lunch.	*maze*	*pout*
Antique collectors often [*find*] treasures at garage sales.	*bind*	*swan*
The newlyweds did not think if pale [*brown*] was a nice house color.	*crown*	*silly*
Everyone was in panic when the building's [*power*] suddenly failed.	*tower*	*bitch*
Jenny was very excited when the police [*found*] the little girl.	*wound*	*slave*
The dog appeared to be afraid of the murky [*water*] down below.	*wager*	*spice*
Kathy did not know how to properly hang the glass [*door*] in her house.	*doom*	*babe*
This year's profits have been the oil company's [*best*] ever.	*nest*	*jail*
Mary took a while to pack the wooden [*case*] before her journey.	*cage*	*slab*
Although it was late they decided to watch the comedy [*show*] on TV.	*shoe*	*burn*
John really appreciated the extra [*help*] his friends gave.	*heap*	*grin*
The girl almost drowned after falling into the deep [*well*] by accident.	*bell*	*pint*
Liz was certain the skinny boy would [*take*] all day to finish his lunch.	*tame*	*mink*
Ann's bike is in the storage [*room*] downstairs in the basement.	*root*	*sing*
The dog jumped out of the dark when John [*least*] expected it.	*lease*	*brick*
It would have been nice if the welcome [*party*] was held earlier.	*pasty*	*snare*
Higher frequency primes—Lower frequency targets		
The fisherman had to dock his boat before the rising [*tide*] came in.	*side*	*need*
Commuters are frustrated by the increasing [*toll*] fee on the bridge.	*told*	*fact*
Sara is tired of seeing her friends [*weep*] after silly arguments.	*week*	*miss*
The doctor detected a tumor in the patient's [*lung*] after the test.	*long*	*same*
The chef used a cloth to quickly [*wipe*] up much of the spill.	*wife*	*cost*
No one has climbed to the top of the radio [*tower*] near the summit.	*power*	*light*
The man was killed when a loose [*plank*] from above fell on his head.	*plane*	*taken*
Many gas companies are exploring oil [*sands*] to increase their profits.	*hands*	*moral*
Bill was injured when the vicious [*bull*] attacked him.	*full*	*west*
Mary drove two miles before noticing her front [*tire*] was flat.	*time*	*said*
The young boy never stole from [*lone*] travelers in his village.	*love*	*turn*
The trading company put a [*halt*] on the shipment from China.	*half*	*seem*
You should stop when you come to the next [*fork*] in the road.	*work*	*life*
Jonathan could not find his first [*mate*] anywhere on board.	*rate*	*says*
This old tree may die if you peel all the thick [*bark*] off of it.	*back*	*just*
Peter could not possibly [*lift*] the heavy couch out of the house.	*left*	*mind*
The pharmacist instructed Jim to chew one green [*pill*] every 2 hr.	*will*	*some*
It's sad when a promising [*colt*] has to be put down due to sickness.	*cold*	*rest*
The doctor used a technologically advanced [*laser*] to remove the tumor.	*later*	*means*
Those two students always have ideas that [*clash*] with one another.	*class*	*sound*
He was afraid to check under the smoking [*hood*] of his truck.	*good*	*made*

Appendix (*continued*)

	Prime type	
Sentences used in Experiments 1 and 2[a]	Neighbor	Unrelated
Kate and Matt shared a wonderful [*meal*] at the new restaurant.	*real*	*sure*
Carl hoped his broken bone would eventually [*heal*] itself.	*head*	*part*
She washed her car using the plastic [*hose*] she borrowed from Tim.	*home*	*went*
They served Walter his favorite beer with a fresh [*lime*] in it.	*like*	*them*
The boy could not come out of the large [*maze*] without assistance.	*make*	*felt*
To build this raft you have to tightly [*bind*] these logs together.	*find*	*look*
There are many jewels set in this beautiful [*crown*] from France.	*brown*	*horse*
The hunter returned to camp with a serious [*wound*] on his leg.	*found*	*night*
The man was not one to carelessly [*wager*] away his hard-earned money.	*water*	*shall*
After the first explosion a sense of imminent [*doom*] hung in the air.	*door*	*name*
Many species of birds normally [*nest*] in the dead trees around here.	*best*	*face*
No wild animal should be put in a small [*cage*] in captivity.	*case*	*kind*
Kim was not happy after pulling up a dirty [*shoe*] with her rod.	*show*	*five*
The children threw their old clothes into a huge [*heap*] on the floor.	*help*	*form*
The whole town could hear the brass [*bell*] ringing in the church.	*well*	*must*
The trainer was not afraid of the beautiful [*tame*] lions.	*take*	*less*
Kelly tripped over the thick [*root*] protruding from the grass.	*room*	*seen*
There are 3 months remaining on the annual [*lease*] for the house.	*least*	*times*
Hal usually avoids the sun so he has a white [*pasty*] complexion.	*party*	*right*
Targets and nonword primes (neighbor and unrelated) used in Experiment 3		
side/tide	*kide*	*cust*
told/toll	*tolt*	*kime*
week/weep	*weem*	*bute*
long/lung	*lang*	*gest*
wife/wipe	*wice*	*tark*
power/tower	*fower*	*betch*
plane/plank	*plang*	*sheed*
hands/sands	*pands*	*datch*
full/bull	*jull*	*yone*
time/tire	*tike*	*lorn*
love/lone	*lote*	*pess*
half/halt	*halg*	*brax*
work/fork	*mork*	*pice*
rate/mate	*yate*	*clow*
back/bark	*bafk*	*meep*
left/lift	*laft*	*ruge*
will/pill	*yill*	*yock*
cold/colt	*colp*	*wast*
later/laser	*laper*	*steck*
class/clash	*clask*	*brone*
good/hood	*lood*	*cill*
real/meal	*leal*	*parn*
head/heal	*heak*	*ging*
home/hose	*hote*	*fids*
like/lime	*lipe*	*beal*
make/maze	*mape*	*fump*
find/bind	*nind*	*grat*
brown/crown	*prown*	*rands*
found/wound	*nound*	*shase*
water/wager	*waber*	*sharf*
door/doom	*doof*	*nilt*
best/nest	*dest*	*loke*
case/cage	*cade*	*leat*

(*Appendix continues*)

Appendix (*continued*)

show/shoe	*shoa*	*mong*
help/heap	*herp*	*sool*
well/bell	*rell*	*marn*
take/tame	*tave*	*shan*
room/root	*roop*	*dray*
least/lease	*leasy*	*crunk*
party/pasty	*palty*	*snall*

[a] Target words are in brackets. Primes were presented in lower case in Experiment 1 and in upper case in Experiment 2.

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