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The Role of Inhibitory Competition in Activation-based Models of Word Identitification

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Role of Inhibitory Competition in Activation-based Models of Word Identification" submitted by Crystal R. Sharp in partial fulfillment of the requirements for the degree of Master of Science.

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Abstract

The role of inhibitory competition in the identification of English words was examined using lexical decision and reading tasks. According to activation-based models of word identification (e.g., J. Grainger & A. M. Jacobs, 1996), response latencies to words with higher frequency neighbors should be longer and less accurate than response latencies to words without higher frequency neighbors. This inhibitory neighborhood frequency effect has been observed only in one study using English stimuli (M. Perea & A. Pollatsek, 1998). The present experiments attempted to replicate and extend this finding, but inhibitory effects of higher frequency neighbors were not consistently observed. The implications for activation-based models of word identification are discussed.

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The Role of Inhibitory Competition in Activation-based Models of Word Identification

Phenomenologically, reading is an effortless process, and skilled readers seldom experience difficulty identifying individual words. But the ease and speed with which words are identified is misleading. Word identification is the culmination of a sequence of sophisticated information processing, the details of which are the focus of much empirical attention. Of particular interest in recent years is how the identification of a word is affected by its orthographic "neighbors". The orthographic neighbors of a word are defined as the set of different words that can be created by changing one letter of a word while maintaining letter positions (Coltheart, Davelaar, Jonasson, & Besner, 1977). For example, BASE, CASE, EAST, EASY, EAVE, ELSE, LASE, and VASE are all orthographic neighbors of EASE.

For many activation-based models of word identification, when a word is presented, the lexical representation of the word and the lexical representations of its orthographic neighbors are activated, which then play an important role in the lexical selection (i.e., word identification) process (Forster, 1976; Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981; Paap, Newsome, McDonald, & Schvandevelt, 1982). The frequency of a word's orthographic neighbors (usually referred to as neighborhood frequency) is especially important in these models. For many words, the neighbors of the word are higher in frequency than the word itself. For example, EASE has a Kucera and Francis (1967) normative frequency of 42, and the normative frequencies of its highest frequency neighbors (EASY, ELSE, EAST, and CASE) are 125, 176, 183, and 362, respectively. In the interactive-activation model (McClelland & Rumelhart, 1981) and the multiple read-out model (Grainger & Jacobs, 1996), selection of the target word occurs through a process of competitive inhibition. The lexical units that are activated during the presentation of a word compete against one another during the lexical selection process via mutual inhibitory connections. According to these models, high-frequency words have higher resting activation levels than low-frequency words, and hence can exert more inhibition on their low-frequency neighbors. As a result, the identification of words with higher frequency neighbors should be delayed due to this competitive inhibition. The specific prediction is that words with higher frequency neighbors should be responded to more slowly and less accurately than words without higher frequency neighbors, usually referred to as an *inhibitory neighborhood frequency effect* (e.g., Grainger, O'Regan, Jacobs, & Segui, 1989).

A number of investigators have examined the effect of a word's higher frequency neighbors upon its identification (e.g., Carreiras, Perea, & Grainger, 1997; Forster & Shen, 1996; Grainger, 1990; Grainger & Jacobs, 1996; Grainger et al., 1989; Grainger & Segui, 1990; Huntsman & Lima, 1996; Perea & Pollatsek, 1998; Sears, Hino, & Lupker, 1995; Siakaluk, Sears, & Lupker, 2002). Most of these studies show that lexical decision latencies to low-frequency words with higher frequency neighbors are slower than those to low-frequency words without higher frequency neighbors. In the original report of this effect (Grainger et al., 1989, Experiment 1), neighborhood frequency was manipulated by using words with no neighbors, words with some neighbors but none of higher frequency, words with exactly one higher frequency neighbor, and words with many higher frequency neighbors. Target word frequency was equated across these four conditions. Responses to words with at least one higher frequency neighbor were slower than responses to words with no higher frequency neighbors. This effect also has been reported in perceptual identification tasks (e.g., Carrieras et al., 1997; Grainger & Jacobs, 1996; Grainger & Segui, 1990), the semantic categorization task (Carrieras et al., 1997), the naming task (Carrieras et al., 1997), and with eye movements (Grainger et al., 1989; Perea & Pollatsek, 1998).

On the whole, the literature does seem to support this prediction of activation-based models. But as Andrews (1997) first noted, much of this support has come from studies in languages other than English; namely, French (Grainger & Jacobs, 1996; Grainger, O'Regan, Jacobs, & Segui, 1989; Grainger & Segui, 1990; Jacobs & Grainger, 1992), Spanish (Carreiras, et al., 1997), and Dutch (Grainger, 1990; van Heuven, Dijkstra, & Grainger, 1998). In contrast, in studies that have used English stimuli, the typical result is a null effect of neighborhood frequency or even a facilitatory effect (Forster & Shen, 1996; Sears, Hino, & Lupker, 1995, 1999; Siakaluk, Sears, & Lupker, 2002).

A notable exception is a study by Perea and Pollatsek (1998). In their Experiment 1, neighborhood frequency was manipulated by using words with higher frequency neighbors and words without higher frequency neighbors. Lexical decision latencies to words with higher frequency neighbors were 26 ms slower than the latencies to words without higher frequency neighbors (this difference was significant in a subject analysis, but not in an item analysis). In post hoc analyses, Perea and Pollatsek divided their stimuli into low-frequency words (with normative frequencies less than 10) and medium-frequency words (with normative frequencies greater than or equal to 10 but less than 58). In this analysis, the inhibitory neighborhood frequency effect was 42 ms for the low-frequency words and 2 ms for the medium-frequency words (for the low-frequency words, the effect was significant by subjects and by items). Perea and Pollatsek concluded that inhibitory effects of neighborhood frequency could be observed for English words, but only when they are very low in frequency.

In a second experiment, Perea and Pollatsek (1998) embedded the words used in Experiment 1 into sentences and monitored the eye movements of participants reading these sentences. They reported that first fixation durations and gaze durations to words with higher frequency neighbors were no longer than first fixation durations to words without higher frequency neighbors. Perea and Pollatsek suggested that the absence of an inhibitory neighborhood frequency effect on these measures indicates that a word's higher frequency neighbors do not affect early stages of lexical processing. Further analyses revealed that there were effects of neighborhood frequency in the probability of regressing back to the target word (13.5% for words with higher frequency neighbors and 6.9% for words without higher frequency neighbors), and in the duration of the first fixation following the target word (261 ms for words with higher frequency neighbors and 249 ms for words without higher frequency neighbors). According to Perea and Pollatsek, these results indicate that higher frequency neighbors affect relatively late stages of lexical selection (i.e., after a reader has already processed a word).

Perea and Pollatsek (1998) speculated that reader skill could affect the extent to which neighborhood frequency affects target identification latencies. To explore this possibility, they divided their participants into two groups based on the percentage of regressions made to the target words. In the group with more regressions, the neighborhood frequency effect was slightly facilitatory (12 ms) in the gaze duration data, whereas in the group with less regressions the neighborhood frequency effect was slightly inhibitory (15 ms). Perea and Pollatsek suggested that, for some readers, inhibitory effects of higher frequency neighbors occur relatively early in lexical processing, whereas for others the effects of higher frequency neighbors are delayed (and thus not easily measured in first fixation and gaze duration measures). They explained this in terms of the E-Z Reader model of eye movement control in reading (Reichle, Pollatsek, Fisher, & Rayner, 1998). In this model, lexical selection consists of two stages: a familiarity check stage and a lexical completion stage. According to Perea and Pollatsek's reasoning, the group with the larger number of regressions would have a shorter familiarity check stage and a longer lexical completion stage than would the group with fewer regressions. In the E-Z Reader model, the signal to move the eyes occurs when the total excitation in the lexicon reaches a threshold. Thus, for the group with more regressions (the "impulsive" readers), this threshold would be lower, and as a consequence, for these readers, detecting inhibitory effects of neighborhood frequency would be more difficult. In the end, however, because there was no independent measure of reading ability administered, the possibility that reader skill modulates the effect of neighborhood frequency could not be directly evaluated.

The Present Study

As many investigators have stressed (e.g., Forster & Shen, 1996; Paap & Johansen, 1994), orthographic neighborhood effects raise absolutely critical theoretical issues, the most important being the role played by competitive processes in word identification. The purpose of the present study is to re-examine the effect of neighborhood frequency in English. This was accomplished by using lexical decision and eye movement paradigms, as well as by carrying out simulations of experimental data.

My first experiment was a replication of Perea and Pollatsek's (1998) Experiment 1, using their exact word and nonword stimuli. In Experiment 1A, participants were given standard lexical decision instructions (i.e., respond as quickly and as accurately as possible). Perea and Pollatsek, however, stressed accuracy over speed in their study, and so in Experiment 1B participants were instructed to give preference to accuracy over speed (i.e., to make as few errors as possible). A comparison of the results of Experiments 1A and 1B permitted an evaluation of the influence that lexical decision instructions could have had in the Perea and Pollatsek study. In Experiment 2, the identical experimental design was used with a new and larger set of word and nonword stimuli. As with Experiment 1, one group of participants was asked to respond as quickly and as accurately as possible (standard instructions), and another group was asked to give preference to accuracy over speed (the modified instructions used by Perea & Pollatsek). This experiment should shed further light on the results of Experiment 1.

In Experiment 3, the eye movements of participants were recorded while they read sentences that contained the target words used in Experiments 1 and 2. Experiment 3A used the sentences Perea and Pollatsek (1998) created for their target words (the target words used in the present study's Experiment 1). In Experiment 3B a new set of sentences were created for the words used in Experiment 2. Together these experiments should settle the question of whether inhibitory neighborhood frequency effects occur in the English, and if not, what this means for activation-based models of word identification.

Finally, the possibility that reader skill could have an influence on the neighborhood frequency effect was examined by administering two measures of reader skill; namely the Author Recognition Test (ART; Stanovich & West, 1989), and the Nelson-Denny Reading Test (Brown, Fishco, & Hanna, 1993). (The ART was administered to participants in all of the experiments; the Nelson-Denny Reading Test to those in Experiments 3A and 3B.) These measures provided an assessment of reader skill independent of recognition performance (i.e., percentage of regressions while rereading text).

Experiment 1

This was a replication of Perea and Pollatsek's (1998) lexical decision experiment, using the identical word and nonword stimuli. In Experiment 1A, standard lexical decision instructions were given to participants (i.e., "respond as quickly and as accurately as possible"). In Experiment 1B, participants were instructed to give preference to accuracy over speed, as in the Perea and Pollatsek experiment (i.e., "make as few errors as possible when responding").

Method

Participants

Eighty University of Calgary undergraduate students participated in the experiment in exchange for partial course credit. There were 40 participants in Experiment 1A and 40 in Experiment 1B. All participants were native English speakers and reported normal or corrected-to-normal vision. None of these individuals participated in more than one experiment.

Stimuli

The descriptive statistics for the word stimuli are listed in Table 1. (The complete set of stimuli is presented in the Appendix.) There were 92 words presented in the experiment (66 five-letter words and 26 six-letter words). Half of the words had no neighbors higher in frequency than themselves, and half had at least one higher frequency neighbor. For the words with higher frequency neighbors, the mean Kucera and Francis (1967) normative frequency per million words of the highest frequency neighbor of each word was 179.4. For the words without higher frequency neighbors, the mean normative frequency of the highest frequency neighbor of each word was slightly lower than the mean target frequency. Perea and Pollatsek (1998) excluded four words from their data analysis due to high error rates.[1] These words were also excluded from the following analyses.

As can be seen in Table 1, there were 51 low-frequency words and 37 medium-frequency words according to Perea and Pollatsek's (1998) definitions. The low-frequency words had a mean Kucera and Francis (1967) normative frequency of 3.4 (range of 0 to 9), and the medium-frequency words had a mean normative frequency of 25.9 (range of 10 to 58). The subjective frequency of each word was determined to provide an alternative measure of word frequency, given that Kucera and Francis norms tend to be somewhat unreliable for low-frequency words (Gernsbacher, 1984; Gordon, 1985). In a separate study, 68 undergraduate students were asked to estimate how frequently they encountered 444 different words in print, using a scale from 1 (*Very Infrequently*) to 9 (*Very Frequently*). They were instructed that if they did not think that an item was a word, they should give it a rating of zero. The words were three, four, five, and six letters in length, and were listed in a random order on five sheets of paper. The 88 words used in the analyses of Experiment 1 were included in this list. The mean subjective frequencies for these stimuli are listed in Table 1.

These subjective frequency data were submitted to a 2 (Word Frequency: high, low) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) factorial analysis of variance (ANOVA). Not surprisingly, there was a main effect of word frequency, $F_i(1, 84) = 42.58$, $p < .001$, $MSE = 0.81$, with the medium-frequency words having higher subjective frequencies than the low-frequency words (4.0 vs. 2.7). The main effect of neighborhood frequency was not significant, $F_i(1, 84) = 1.80$, $p > .15$, $MSE = 0.81$, although there was a tendency for the words with higher frequency neighbors to have lower subjective frequencies than the words without higher frequency neighbors. There was no interaction ($F_i < 1$).

Apparatus and Procedure

Stimuli were presented on a 70 Hz color VGA monitor driven by a Pentium-class microcomputer. The presentation of stimuli was synchronized with the vertical retrace rate of the monitor (14 ms) and response latencies were measured to the nearest ms. At a viewing distance of 50 cm the stimuli subtended a visual angle of approximately 1.1 degrees.

Each trial was initiated by a 12,000 Hz warning tone, after which a fixation point appeared at the center of the video monitor. The fixation point was presented for 500 ms, was then erased, and 200 ms later a word or a nonword was presented (in lowercase letters). Participants indicated the lexicality of stimuli (word or nonword) by pressing one of two buttons on a response box. The participant's response terminated the stimulus display, and the next trial was initiated after a timed interval of 1.5 s.

In Experiment 1A, participants were instructed to respond as quickly and as accurately as possible. In Experiment 1B, participants were instructed to make as few errors as possible. Each participant completed 24 practice trials prior to the collection of data. The practice stimuli consisted of 12 words and 12 orthographically legal and pronounceable nonwords. (These practice stimuli were not used in the experiment, and the data from these practice trials were not analyzed.) Following the practice trials the participants were provided with feedback as to the mean latency and accuracy of their responses (percent correct). During the experimental trials this information was presented every 32 trials.

After completing the lexical decision task, each participant completed the Canadian version of the ART. The ART is a checklist of 86 names. The instructions ask participants to place a checkmark next to the names they know to be an author or a writer. The list consists of the names of 46 popular authors and 40 foils. Guesses are taken into account by subtracting incorrect responses from correct responses when calculating an overall score. The maximum possible score is 46.

The participants in Experiment 1B were also asked to estimate how frequently they encountered the 92 experimental words in print, using a scale from 1 (*Very Infrequently*) to 9 (*Very Frequently*). They were instructed that if they did not think that an item was a word, they should give it a rating of zero.

Design

A 2 (Word Frequency: low, medium) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) factorial design was used for each of the experiments. There were 27 low-frequency words without higher frequency neighbors, 28 low-frequency words with higher frequency neighbors, 18 medium-frequency words without higher frequency neighbors, and 19 medium-frequency words with higher frequency neighbors. There were also 92 nonwords presented in each experiment (66 five-letters in length and 26 six-letters in length; these were the same nonwords used in Perea and Pollatsek's experiment), for a total of 184 trials. The order in which the stimuli were presented in the experiments was randomized separately for each participant.

For the word data, the response latencies of correct responses and the error rates from each experiment were submitted to a 2 (Word Frequency: high, low) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) repeated-measures factorial ANOVA. Both subject (F_s) and item (F_i) analyses were carried out.

Results

Response latencies less than 300 ms or greater than 1,500 ms were considered outliers and were removed from the analyses. For Experiment 1A, 26 response latencies (0.7% of the data) were removed by this procedure, and for Experiment 1B, 29 response latencies (0.8% of the data) were removed. The mean response latencies of correct responses and the mean error rates in Experiment 1A and Experiment 1B are shown in Table 4.

Simulations

Simulations using the multiple read-out model (Grainger & Jacobs, 1996) were conducted to determine if the model would predict that responses to words with higher frequency neighbors would be slower than responses to words without higher frequency neighbors. In these simulations the same parameters adopted by Grainger and Jacobs were used, including setting the activation threshold (the M criterion) to 0.67 (the Σ criterion was not used in these simulations). According to the model, when the M criterion is exceeded lexical selection has occurred (i.e., a specific word has been identified). The four-letter, five-letter, and six-letter lexicons used in the simulations consisted of words with Kucera and Francis (1967) frequencies greater than zero. The four-letter lexicon consisted of 1,580 words, the five-letter lexicon consisted of 2,124 words, and the six-letter lexicon consisted of 2,661 words.

Word identification latencies were simulated by the number of processing cycles required for a word's lexical unit to reach the M criterion. The mean number of processing cycles required to reach the M criterion for the words used in Experiment 1 are shown in Table 2. These data were submitted to a 2 (Word Frequency: high, low) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) factorial analysis of variance (ANOVA). The main effect of word frequency was not significant, $F_i < 1$. The main effect of neighborhood frequency was significant, $F_i(1, 84) = 46.80$, $p < .001$, $MSE = 1.25$. Words with higher frequency neighbors required an average of 1.66 more processing cycles than words without higher frequency neighbors (18.10 vs. 16.44). There was no interaction between word frequency and neighborhood frequency, $F_i(1, 84) = 1.72$, $p > .15$, $MSE = 1.25$. The results of this simulation indicate that, for these stimuli, there should be an inhibitory neighborhood frequency effect, but no effect of word frequency.

Simulations using the Seidenberg and McClelland (1989) and the Plaut et al. (1996) PDP models were also conducted. The training set for the Seidenberg and McClelland model consisted of 2,897 monosyllabic words of three or more letters in length. In this model, orthographic and phonological error scores are generated. These scores are a measure of how close the model's output is to the desired (correct) output. According to the model, lower orthographic error scores correspond to shorter lexical decision latencies, and lower phonological error scores correspond to shorter pronunciation latencies. The training set for the Plaut at al. model consisted of the 2,897 words in the Seidenberg and McClelland model plus an additional 101 words. In this model the cross-entropy error scores represent how close the model's output is to the correct pronunciation, with lower scores representing shorter pronunciation latencies. The orthographic error scores, the phonological error scores, and the cross-entropy error scores were each submitted to a 2 (Word Frequency: high, low) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) factorial analysis of variance (ANOVA).

As shown in Table 3, the mean Seidenberg and McClelland (1989) orthographic error score for the low-frequency words (11.44) was significantly higher than that of the medium-frequency words (7.11), $F_i(1, 41) = 16.67$, $p < .001$, $MSE = 11.65$. Although the words with higher frequency neighbors had a lower mean orthographic frequency score (9.21) than the words without higher frequency neighbors (9.34), the effect of neighborhood frequency was not significant, $F_i < 1$, nor was the interaction between word frequency and neighborhood frequency, $F_i(1, 41) = 2.07$, $p > .15$, $MSE = 11.65$. Although not significant, for the low-frequency words, the mean orthographic error score for the words with higher frequency neighbors (12.14) was higher than the mean orthographic error scores for the words without higher frequency neighbors (10.74), and for the medium-frequency words, the mean orthographic error score for the words with higher frequency neighbors (6.28) was lower than the mean orthographic error score for the words without higher frequency neighbors (7.94).

Phonological error scores were also significantly higher for the low-frequency words (6.55) than for the medium-frequency words (4.19), $F_i(1, 41) = 14.44$, $p < .001$, $MSE = 3.99$. Neither the effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency were significant (both F's < 1). Although not significant, for the low-frequency words, the mean phonological error score for the words with higher frequency neighbors (6.80) was higher than the mean phonological error score for the words without higher frequency neighbors (6.31), and for the medium-frequency words, the mean phonological error score for the words with higher frequency neighbors (3.92) was lower than the mean phonological error score for the words without higher frequency neighbors (4.47). Taken together, these results suggest that for these stimuli there should be an effect of word frequency, but no overall effect of neighborhood frequency: for the low-frequency words the trend was towards an inhibitory effect, and for the medium-frequency words the trend was towards a facilitatory effect.

The mean Plaut et al. (1996) cross-entropy error scores for the low-frequency words (.077) were significantly higher than the error scores of the medium-frequency words (.047), $F_i(1, 41) = 5.21$, $p < .05$, $MSE = .00$. Neither the effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency were significant (both p's > .25). Although not significant, for the low-frequency words, the mean error score for the words with higher frequency neighbors (.085) was higher than for the words without higher frequency neighbors (.069), and for the medium-frequency words, the mean cross-entropy error score for the words with higher frequency neighbors (.042) was essentially identical to the mean error score for the words without higher frequency neighbors (.042).[2,3,4] Thus, these results also indicate that a word frequency effect, but not a neighborhood frequency effect, should occur for these stimuli.

Experiment 1A

In the analysis of response latencies, the main effect of word frequency was significant, $F_s(1, 39) = 84.45$, $p < .001$, $MSE = 1{,}529.26$; $F_i(1, 84) = 15.56$, $p < .001$, $MSE = 4{,}587.28$. Low-frequency words were responded to 57 ms slower than medium-frequency words. The main effect of neighborhood frequency was not significant, $F_s(1, 39) = 1.29$, $p > .20$, $MSE = 589.23$; $F_i < 1$, nor was the interaction between word frequency and neighborhood frequency (both F's < 1). As can be seen in Table 4, for both the low-frequency and the medium-frequency words responses to words with higher frequency neighbors were no slower than responses to words without higher frequency neighbors (all F's < 1).

In the analysis of error rates, there was a main effect of word frequency, $F_s(1, 39) = 37.01$, $p < .001$, $MSE = 18.36$; $F_i(1, 84) = 3.84$, $p = .05$, $MSE = 94.94$. The main effect of neighborhood frequency was not significant, $F_s(1, 39) = 1.90$, $p > .15$, $MSE = 9.55$; $F_i < 1$, nor was the interaction between word frequency and neighborhood frequency (both F's < 1). When the low-frequency and medium-frequency words were analyzed separately, only the latter showed a significant effect of neighborhood frequency, $F_s < 1$; $F_i < 1$, and $F_s(1, 39) = 5.25$, $p < .05$, $MSE = 7.12$; $F_i < 1$. Participants made fewer errors to the medium-frequency words with higher frequency neighbors than to the medium-frequency words without higher frequency neighbors (2.1% vs. 3.4%).[5] The mean response latency for the nonwords was 697 ms; the mean error rate was 8.4%.

Effect of reader skill. To assess the effect of reader skill, a median split of the ART scores (median = 15, range = 5 to 29) was used to create two groups of participants: a low ART group ($M = 10.4$) and a high ART group ($M = 20.1$), $F_s(1, 38) = 74.22$, $p < .001$, $MSE = 12.55$. The mean correct response latencies and error rates for the low and the high ART groups are shown in Table 5. In the analysis of the response latencies, the main effect of group was significant, $F_s(1, 38) = 9.14$, $p < .01$, $MSE = 21{,}063.43$; $F_i(1, 168) = 41.52$, $p < .001$, $MSE = 234{,}686.34$. On average, the low ART group responded 70 ms slower than the high ART group. The main effect of word frequency was significant, $F_s(1, 38) = 97.73$, $p < .001$, $MSE = 1{,}321.57$; $F_i(1, 168) = 27.53$, $p < .001$, $MSE = 5{,}652.12$, and in the subject analysis there was a significant interaction between word frequency and group, $F_s(1, 38) = 7.13$, $p < .05$, $MSE = 1{,}321.57$; $F_i(1, 168) = 2.40$, $p > .10$, $MSE = 13{,}567.34$. For the low ART group the word frequency effect was 67 ms; for the high ART group it was 41 ms. No other effects were significant (all p's > .25).

In the error rate analysis, the main effect of group was significant, $F_s(1, 38) = 14.57$, $p < .001$, $MSE = 28.52$; $F_i(1, 168) = 3.81$, $p = .053$, $MSE = 116.95$, with the low ART group making more errors on average than the high ART group (6.4% vs. 3.2%). The effect of word frequency was significant, $F_s(1, 38) = 39.13$, $p < .001$, $MSE = 17.37$; $F_i(1, 168) = 6.23$, $p < .05$, $MSE = 116.95$, and the interaction between group and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.23$, $p = .08$, $MSE = 17.37$; $F_i < 1$. The low ART participants made significantly more errors to the low-frequency words (9.1%) than to the medium-frequency words (3.8%), $F_s(1, 19) = 26.85$, $p < .001$, $MSE = 20.97$; $F_i(1, 84) = 3.29$, $p = .073$, $MSE = 183.62$, which was true of the high ART participants as well (4.7% vs. 3.5%), $F_s(1, 19) = 12.52$, $p < .01$, $MSE =$

13.77; $F_i(1, 84) = 3.68$, $p = .058$, $MSE = 50.28$, but the difference was much smaller. No other effects were statistically significant (all p's > .15).[6]

There was also an effect of group on the response latencies to the nonwords and on the errors to nonwords, $F_s(1, 38) = 6.59$, $p < .05$, $MSE = 12{,}475.63$; $F_i(1, 182) = 69.13$, $p < .001$, $MSE = 4{,}400.55$, and $F_s(1, 38) = 5.24$, $p < .05$, $MSE = 20.94$; $F_i(1, 182) = 3.00$, $p = .085$, $MSE = 168.29$, respectively. The participants in the low ART group responded to the nonwords an average of 90 ms slower than the participants in the high ART group (742 ms vs. 651 ms) and the low ART participants made significantly more errors than the high ART participants (10.1% vs. 6.7%).

Experiment 1B

There was a main effect of word frequency in the analysis of response latencies, $F_s(1, 39) = 166.24$, $p < .001$, $MSE = 918.40$; $F_i(1, 84) = 18.15$, $p < .001$, $MSE = 4{,}381.81$, as medium-frequency words were responded to 62 ms faster than low-frequency words (see Table 4). The main effect of neighborhood frequency was significant in the subject analysis, $F_s(1, 39) = 16.59$, $p < .001$, $MSE = 624.92$, but not in the item analysis, $F_i(1, 84) = 1.03$, $p > .30$, $MSE = 4{,}381.81$. The interaction between word frequency and neighborhood frequency was also significant in the subject analysis, $F_s(1, 39) = 4.10$, $p = .05$, $MSE = 575.08$, but not in the item analysis, $F_i < 1$. As can be seen in Table 4, responses to low-frequency words with higher frequency neighbors were 24 ms slower than responses to low-frequency words without higher frequency neighbors, $F_s(1, 39) = 17.23$, $p < .001$, $MSE = 656.04$; $F_i\,(1, 49) = 1.95$, $p > .15$, $MSE = 4{,}753.42$. Responses to medium-frequency words with higher frequency neighbors were 9 ms slower than responses to medium-frequency words without higher frequency neighbors, $F_s(1, 39) = 2.61, p > .10, MSE = 543.96$; $F_i < 1$.

In the analysis of error rates, there was a main effect of word frequency, $F_s(1, 39) = 25.54, p < .001, MSE = 20.44$; $F_i(1, 84) = 3.85, p = .05, MSE = 72.60$. The main effect of neighborhood frequency was not significant (both F's < 1), but there was an interaction between word frequency and neighborhood frequency in the subject analysis, $F_s(1, 39) = 5.10, p < .05, MSE = 19.29$, though not in the item analysis, $F_i < 1$. For the low-frequency words, there was no difference between the words with higher frequency neighbors and the words without higher frequency neighbors, $F_s(1, 39) = 2.40, p > .10$, $MSE = 30.87$; $F_i < 1$. For the medium-frequency words, fewer errors were made to words with higher frequency neighbors (1.8%) than to words without higher frequency neighbors (3.0%), $F_s(1, 39) = 4.13, p < .05, MSE = 7.13$; $F_i < 1$.[7] The mean response latency for the nonwords was 717 ms, and the mean error rate was 7.2%.

Effect of reader skill. As in the analysis of Experiment 1A, a low ART group ($M = 10.6$) and a high ART group ($M = 20.9$) were created by a median split on the ART scores (median = 14, range = 7 to 34), $F_s(1, 38) = 93.43, p < .001, MSE = 11.36$. In the analysis of response latencies, the main effect of group was marginally significant, $F_s(1, 38) = 3.31, p = .077, MSE = 40{,}287.03$; $F_i(1, 168) = 27.44, p < .001, MSE = 4{,}988.75$, as the low ART group took slightly longer to respond overall than the high ART group (see Table 5). The main effect of word frequency was significant, $F_s(1, 38) = 162.11, p < .001, MSE = 941.42$; $F_i(1, 168) = 32.06, p < .001, MSE = 4{,}988.75$, as was the main effect of neighborhood frequency (in the subject analysis only), $F_s(1, 38) = 16.91, p < .001, MSE = 612.84$; $F_i(1, 168) = 1.77, p > .15, MSE = 4{,}988.75$. The interaction between the neighborhood frequency and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 4.01$, $p = .052$, $MSE = 587.55$; $F_i < 1$. No other effect was significant (all p's > .15).

In the error rate analysis, the main effect of group was significant in the subject analysis, $F_s(1, 38) = 4.69$, $p < .05$, $MSE = 24.00$; $F_i(1, 168) = 1.53$, $p > .20$, $MSE = 78.63$, with the low ART group making significantly more errors than the high ART group (5.0% vs. 3.3%). The effect of word frequency was significant $F_s(1, 38) = 25.84$, $p < .001$, $MSE = 20.20$; $F_i(1, 168) = 7.11$, $p < .01$, $MSE = 78.63$. The word frequency by neighborhood frequency interaction was significant in the subject analysis, $F_s(1, 38) = 5.11$, $p < .05$, $MSE = 19.26$; $F_i < 1$. No other effects were statistically significant (all p's > .20).[8]

The low ART group's response latencies to nonwords were significantly longer than the high ART group (757 ms vs. 677 ms), $F_s(1, 38) = 4.13$, $p < .05$, $MSE = 15{,}196.21$; $F_i(1, 182) = 49.48$, $p < .001$, $MSE = 4{,}041.78$. The difference in the nonword error rates between the two groups was also significant in the subject analysis, $F_s(1, 38) = 4.36$, $p < .05$, $MSE = 23.25$; $F_i(1, 182) = 2.55$, $p > .10$, $MSE = 185.55$, as the low ART group made slightly more errors to the nonwords than did the high ART group (8.8% vs. 5.7%).

Subjective frequencies. As noted, after completing the lexical decision task, the participants were shown a list of the words presented during the experiment and were asked to estimate how frequently they encountered these words in print, using a scale from 1(*Very Infrequently*) to 9 (*Very Frequently*). These ratings are shown in Table 6. An analysis revealed an effect of word frequency, $F_s(1, 39) = 162.41$, $p < .001$, $MSE = .35$;

$F_i(1, 84) = 42.85$, $p < .001$, $MSE = .81$, and of neighborhood frequency, $F_s(1, 39) = 7.77$, $p < .001$, $MSE = .10$; $F_i(1, 84) = 1.80$, $p > .15$, $MSE = .81$, but no interaction (both F's < 1). Not surprisingly, participants indicated that the low-frequency words were less frequently encountered than the medium-frequency words. More interesting (and puzzling) was the fact that the words with higher frequency neighbors were rated as being more frequently encountered than the words without higher frequency neighbors (Table 6). Although this difference was fairly small, it is just the opposite of the data from the other group of participants who rated these words but who did not participate in the experiment (see Table 1). Also note that the participants in Experiment 1B judged the words to be more frequent than the other group of participants. This makes sense because for the participants in Experiment 1B, their ratings would have been influenced by a recency effect (i.e., having just seen the words during the lexical decision task, the words would not seem to be as low in frequency). One possibility is that the recency effect was larger for the words with higher frequency neighbors because these words were actually lower in frequency (as suggested by the data from the other group of participants who rated these words).

Combined Analysis

In a combined analysis of Experiment 1A and 1B, for the response latencies to words, the main effect of experiment was not significant in the subject analysis, $F_s < 1$, but was marginally significant in the item analysis, $F_i(1, 168) = 3.14$, $p = .08$, $MSE =$ 4,484.55. There was also a main effect of word frequency, $F_s(1, 78) = 229.87$, $p < .001$, $MSE = 1{,}223.65$; $F_i(1,168) = 33.62$, $p < .001$, $MSE = 4{,}484.55$, and a main effect of neighborhood frequency that was significant in the subject analysis, $F_s(1, 78) = 13.79$, $p < .001$, $MSE = 607.02$, but not in the item analysis, $F_i < 1$.

The only significant interaction was between experiment and neighborhood frequency, $F_s(1, 78) = 4.54$, $p < .05$, $MSE = 607.02$; $F_i < 1$, due to the fact, as noted, that there was an inhibitory effect of neighborhood frequency in Experiment 1B, but not in Experiment 1A. Although the three-way interaction between experiment, word frequency, and neighborhood frequency was not significant (both p's > .25), as can be seen in Table 4, it was only the responses to the low-frequency words that differed between the experiments. This was confirmed in separate analyses of the low-frequency and the medium-frequency words. In the analysis of the low-frequency words, there was a main effect of neighborhood frequency, $F_s(1, 78) = 10.22$, $p < .01$, $MSE = 803.22$; $F_i(1, 98) = 1.22$, $p > .25$, $MSE = 5{,}045.16$, and, more importantly, an interaction between experiment and neighborhood frequency, $F_s(1, 78) = 4.44$, $p < .05$, $MSE = 803.22$; $F_i < 1$. The neighborhood frequency effect in Experiment 1B was 5 ms, and in Experiment 3B it was 24 ms. In the analysis of the medium-frequency words there were no significant effects (all p's > .10)

In the error analysis, there was an effect of word frequency, $F_s(1, 78) = 61.64$, $p < .001$, $MSE = 19.40$; $F_i(1, 168) = 7.65$, $p < .01$, $MSE = 83.77$, and, in the subject analysis, an interaction between word frequency and neighborhood frequency, $F_s(1, 78) = 6.16$, $p < .05$, $MSE = 16.55$; $F_i < 1$. For the low-frequency words, as noted, there was no effect of neighborhood frequency in either experiment. For the medium-frequency words, in both experiments words with higher frequency neighbors were responded to more accurately than words without higher frequency neighbors, producing an overall facilitatory effect,

$F_s(1, 78) = 9.34, p < .01, MSE = 7.13; F_i < 1$. No other effects were statistically significant (all p's > .20).[9]

In the analysis of the nonword data, responses to nonwords were slower in Experiment 1B than in Experiment 1A (717 ms vs. 697 ms), but this difference was not statistically significant (both p's > .10). The nonword error rate was slightly lower in Experiment 1B (7.2%) than in Experiment 1A (8.4%), but this difference was not significant either (both p's > .25).

Effect of reader skill across experiments. When I compared the difference in response latencies between the low ART group and the high ART group across Experiments 1A and 1B, the main effect of experiment was significant in the item analysis, $F_s < 1$; $F_i(1, 336) = 4.53, p < .05, MSE = 5{,}320.44$. The interaction between group and experiment was not significant, $F_s < 1$; $F_i(1, 336) = 1.23, p > .25, MSE = 5{,}320.44$. There was a main effect of group $F_s(1, 76) = 10.54, p < .01, MSE = 30{,}675.22$; $F_i(1, 336) = 68.61, p < .001, MSE = 5{,}320.44$, with the low ART group responding an average of 64 ms slower than the high ART group (631 ms vs. 567 ms). The main effect of word frequency was significant, $F_s(1, 76) = 248.59, p < .001, MSE = 1{,}131.50$; $F_i(1, 336) = 59.31, p < .001, MSE = 5{,}320.44$, but the interaction between word frequency and experiment was not (both F's < 1), as the overall word frequency effect in both experiments was very similar. The interaction between group and word frequency was marginally significant in the subject analysis, $F_s(1, 76) = 3.71, p = .058, MSE = 1{,}131.50$; $F_i < 1$, with a 66 ms word frequency effect for the low ART group and a 52 ms word frequency effect for the high ART group. In the subject analysis, there was a significant main effect of neighborhood frequency, $F_s(1, 76) = 13.08, p < .01, MSE = 608.62$; $F_i < 1$, and a significant interaction between experiment and neighborhood frequency, $F_s(1, 76) = 4.16$, $p < .05$, $MSE = 608.62$; $F_i(1, 336) = 2.10$, $p > .10$, $MSE = 5{,}320.44$. The three-way interaction between experiment, group, and word frequency was also significant, $F_s(1, 76) = 4.64$, $p < .05$, $MSE = 1{,}131.50$, reflecting the fact that the low ART group exhibited a larger word frequency effect than the high ART group in Experiment 1A, but not in Experiment 1B. No other effects were statistically significant (all p's $> .10$).

In the error rate analysis, there was a main effect of group, $F_s(1, 76) = 18.26$, $p < .001$, $MSE = 26.26$; $F_i(1, 336) = 5.25$, $p < .05$, $MSE = 97.79$, with the low ART group averaging 5.7% errors and the high ART group averaging 3.3% errors. Neither the main effect of experiment, nor the interaction between experiment and group was significant (all p's $> .15$). There was a main effect of word frequency, $F_s(1, 76) = 63.65$, $p < .001$, $MSE = 18.78$; $F_i(1, 336) = 13.11$, $p < .001$, $MSE = 97.79$, and a group by word frequency interaction that was significant in the subject analysis, $F_s(1, 76) = 4.42$, $p < .05$, $MSE = 18.78$; $F_i < 1$, reflecting the fact that the effect of word frequency on error rates was larger for the low ART group than for the high ART group (4.9% vs. 2.9%). The interaction between word frequency and neighborhood frequency was also significant in the subject analysis, $F_s(1, 76) = 6.12$, $p < .05$, $MSE = 16.66$; $F_i(1, 336) = 1.12$, $p > .25$, $MSE = 97.79$. Averaged across the two experiments, the neighborhood frequency effect was larger for the low-frequency words than for the medium-frequency words. No other effects were significant (all p's $> .15$).[10]

For the nonwords, the effect of experiment was significant in the item analysis of the response latencies, $F_s < 1$; $F_i(1, 364) = 8.61$, $p < .01$, $MSE = 4{,}220.91$, but not in the analysis of errors (both F's < 1). There was an effect of group in the analysis of the response latencies, $F_s(1, 76) = 10.43$, $p < .01$, $MSE = 13{,}835.92$; $F_i(1, 364) = 118.16$, $p < .001$, $MSE = 4{,}220.91$, and in the analysis of errors, $F_s(1, 76) = 9.55$, $p < .01$, $MSE = 22.10$; $F_i(1, 364) = 5.53$, $p < .05$, $MSE = 176.92$. The low ART group was slower to respond to nonwords than the high ART group (749 ms vs. 664 ms), and also made significantly more errors than the high ART group (9.4% vs. 6.2%). No other effects were statistically significant (all p's > .25).

Discussion

A core assumption of activation-based models of word identification is that identification of a word occurs through a process of competitive inhibition (e.g., Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). According to these models, words with higher frequency neighbors will experience greater inhibition from their neighbors than words without higher frequency neighbors, which will produce longer identification latencies in word identification tasks. Simulations using the interactive activation model confirmed this prediction for the stimuli used in Experiment 1, but the effect was only observed in one of the two experiments. There was no effect of neighborhood frequency for either the low-frequency or the medium-frequency words in Experiment 1A, when standard lexical decision instructions were used. When participants were instructed to give preference to accuracy over speed (Experiment 1B) an inhibitory effect of neighborhood frequency was observed for the low-frequency words. This discrepancy between the experiments warranted further attention, and so in Experiment 2 the identical experimental design was used with a new and larger set of word and nonword stimuli.

Interestingly, the multiple read-out model did not predict that a word frequency effect should occur for these stimuli, however, in both Experiment 1A and Experiment 1B a word frequency effect was obtained in the behavioral data.

Simulations with the Seidenberg and McClelland (1989) model predicted a word frequency effect for these stimuli, but not a neighborhood frequency effect. The Plaut et al. (1996) model also predicted that a word frequency effect, but not a neighborhood frequency effect should occur. The Seidenberg and McClelland model seems best able to account for the results of Experiment 1. For the low-frequency words, recall that the trend was towards an inhibitory effect of neighborhood frequency, although the effect failed to reach significance.

Also of note was the fact that although participants who scored lower on the ART were slower overall to respond to the target words than those participants who scored higher on the ART, reader skill did not modulate the effect of neighborhood frequency. Nonetheless, possible effects of reader skill were again examined in Experiment 2.

Experiment 2

The stimuli used in Experiment 1 were far from an ideal manipulation of neighborhood frequency for a number of reasons. For one, many of these words are very infrequently encountered in print, even by university students (e.g., mosque had a mean subjective frequency of 1.80, and horde had a mean subjective frequency of 1.53, whereas the mean subjective frequency of all the low-frequency words was 3.34). In addition, several of these stimuli did not possess any neighbors (e.g., robin, marble), and so they possessed unusual orthographic sequences. Curiously, simulations with the multiple read-out model (Grainger & Jacobs, 1996) indicated that the model did not predict a word frequency effect for these stimuli (although it did predict a neighborhood frequency effect). This suggests that there was something unusual about this set of stimuli. My goal in Experiment 2 was to re-examine neighborhood frequency effects in English using a new set of stimuli that avoided these problems.

I also wished to examine the role of word-body neighbors in the neighborhood frequency effect. One explanation for the lack of an inhibitory neighborhood frequency effect in English is that word-body neighbors are critical mediators of the effect (Andrews, 1997; Ziegler & Perry, 1998). Word-body neighbors share the same orthographic rime (e.g., POUR-YOUR). Because English has a fairly inconsistent relationship between orthography and phonology (Trieman, Mullenix, Bijeljac-Babic, & Richmond-Welty, 1995), body units may help to regularize this relationship. It is possible that only higher frequency neighbors that are not word-body neighbors produce inhibition. An examination of the influence of word-body neighbors was not possible in Experiment 1 because none of the highest frequency neighbors shared a word-body with the experimental word (e.g., SPICE-SPACE). The stimuli used in Experiment 2 permitted such an examination because for many of the words with higher frequency neighbors, the highest frequency neighbor was a word-body neighbor (e.g., SKILL-STILL, KISS-MISS).

Finally, unlike the nonwords used in Experiment 1, the nonwords used in this experiment were very word-like (because they had many orthographic neighbors). In a lexical decision task, this creates a situation where participants cannot use "word-likeness" to make fast positive "word" responses, and thus makes it more likely that responses will be based on the completion of lexical selection.

Method

Participants

Eighty-one University of Calgary undergraduate students participated in the experiment in exchange for partial course credit. Forty participated in Experiment 2A and 41 participated in Experiment 2B. All Participants were native English speakers with normal or corrected-to-normal vision. None of these individuals participated in more than one experiment.

Word stimuli

The set of stimuli presented in the experiment is listed in the Appendix. The stimuli consisted of 60 four-letter words and 60 five-letter words. Ultimately, five words were excluded from all data analyses due to high error rates.[11] The descriptive statistics for the remaining stimuli are listed in Table 7. Each of these words had at least one neighbor. Neighborhood frequency and word frequency were factorially manipulated while controlling for neighborhood size (the number of neighbors ranged from 1 to 11, with a mean of 4.5 neighbors). Half of these words had no neighbors higher in frequency than themselves, and half had at least one neighbor of higher frequency. Half of the words were of low-frequency, with Kucera and Francis (1967) normative frequencies less than 10 per million words. The remainder of the words had normative frequencies of 10 to 54 (medium-frequency words).

To assess the impact of word-body neighbors, the experimental words in each of the conditions were categorized as to whether the highest frequency neighbor was a word-body neighbor or not. As can been seen in Table 7, for the low-frequency words with higher frequency neighbors, for 13 of the words the highest frequency neighbor was a word-body neighbor. Of these word-body neighbors, 12 shared a consistent phonology with the target word (e.g., HIKE-LIKE), and one had a different phonology (e.g., MOTH-BOTH). For the medium-frequency words with higher frequency neighbors, for 12 of the words the highest frequency neighbors was a word-body neighbor. Of these words, nine shared a consistent phonology with the target, and three had a different phonology (e.g., BEARD-HEARD).

Nonword stimuli

The nonword stimuli were orthographically legal and pronounceable (GARK), and were matched to the words on length (60 four-letter, 60 five-letter). The mean neighborhood size of the nonwords was 9.0 (range of 3 to 18).

Apparatus and Procedure

The apparatus and procedure was identical to that used in Experiment 1. In Experiment 2A, participants were instructed to respond as quickly and as accurately as possible. In Experiment 2B, participants were instructed to make as few errors as possible. Each participant completed 24 practice trials prior to the collection of data. The practice stimuli consisted of 12 words and 12 orthographically legal and pronounceable nonwords. Following the practice trials the participants were provided with feedback as to the mean latency and accuracy of their responses (percent correct). During the experimental trials this information was presented every 30 trials. The order in which 240 stimuli will be presented in the experiments was randomized separately for each participant.

The ART was administered to each participant after they completed the lexical decision task. Each participant was also asked to estimate how frequently they encountered the 120 target words in print, using a scale from 1 (*Very Infrequently*) to 9 (*Very Frequently*).

Design

For the word data, the response latencies of correct responses and the error rates from each experiment were submitted to a 2 (Word Frequency: high, low) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) repeated-measures factorial ANOVA. Both subject (F_s) and item (F_i) analyses were carried out.

Results

Response latencies less than 300 ms or greater than 1,500 ms were considered outliers and were removed from the analyses. For Experiment 2A, a total of 15 observations (0.3% of the data) were removed by this procedure, and for Experiment 2B, a total of 43 observations (0.9% of the data) were removed. The mean response latencies of correct responses and the mean error rates in Experiment 2A and Experiment 2B are shown in Table 8.

Simulations

Simulations with the multiple read-out model (Grainger & Jacobs, 1996) indicated that the model predicts slower responses to the words with higher frequency neighbors. The mean number of processing cycles required to reach the M criterion is shown in Table 2. These data were submitted to a 2 (Word Frequency: medium, low) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) factorial analysis of variance (ANOVA). In this analysis there was a main effect of word frequency, $F_i(1, 111) = 21.25, p < .001, MSE = .22$, and of neighborhood frequency, F_i(1,

111) = 83.89, $p < .001$, $MSE = .22$, but no interaction, $F_i(1, 111) = 2.67$, $p > .10$, $MSE =$ .22. Words with higher frequency neighbors required an average of 0.80 more processing cycles to reach the M criterion than words without higher frequency neighbors (18.06 vs. 17.26). For both the low-frequency and the medium-frequency words, an inhibitory neighborhood effect should occur, $F_i(1, 54) = 41.35$, $p < .001$, $MSE = .30$, and $F_i(1, 57) =$ 44.95, $p < .001$, $MSE = .14$, respectively. The model thus predicted that an inhibitory neighborhood frequency effect (and a word frequency effect) should occur in this experiment.

Simulations were also conducted using the Seidenberg and McClelland (1989) model and Plaut et al. (1996) model. The orthographic error scores, the phonological error scores, and the cross-entropy error scores were each submitted to a 2 (Word Frequency: high, low) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) factorial analysis of variance (ANOVA). The mean Seidenberg and McClelland (1989) and Plaut et al. (1996) error scores are shown in Table 3. The mean Seidenberg and McClelland orthographic error scores for the low-frequency words (10.84) were significantly higher than those for the medium-frequency words (6.43), $F_i(1, 93) = 32.50$, $p < .001$, $MSE = 14.11$. Neither the main effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency were significantly (both F's < 1).

There was an effect of word frequency in the phonological error scores, $F_i(1, 93)$ = 14.60, $p < .001$, $MSE = 4.33$, as the error scores for the low-frequency words (5.62) were higher than the error scores for the medium-frequency words (3.99). The neighborhood frequency effect was not significant, nor was the interaction between word frequency and neighborhood frequency (both *p*'s > .10).

For the cross-entropy scores (Plaut et al., 1996), the effect of word frequency was significant, $F_i(1, 93) = 10.17$, $p < .01$, $MSE = .00$. The mean error score for the low-frequency words (.070) was higher than the mean error score for the medium-frequency words (.042). There was also a significant effect of neighborhood frequency; the mean cross-entropy error score for the words with higher frequency neighbors (.069) was higher than the mean error score for the words without higher frequency neighbors (.043), $F_i(1, 93) = 8.62$, $p < .01$, $MSE = .00$. The interaction between word frequency and neighborhood frequency was not significant, $F_i(1, 93) = 1.78$, $p > .15$, $MSE = .00$. For the low-frequency words, the mean error score for words with higher frequency neighbors (.089) was significantly higher than for the words without higher frequency neighbors (.051), $F_i(1, 42) = 6.33$, $p < .05$, $MSE = .00$. There was no effect of neighborhood frequency for the medium-frequency words, $F_i(1, 51) = 1.91$, $p > .15$, $MSE = .00$.[12, 13, 14]

Experiment 2A

In the analysis of response latencies, the main effect of word frequency was significant, $F_s(1, 39) = 257.42$, $p < .001$, $MSE = 843.18$; $F_i(1, 111) = 81.06$, $p < .001$, $MSE = 2{,}042.57$. Low-frequency words were responded to 73 ms slower than medium-frequency words. The main effect of neighborhood frequency was not significant (both *F*'s < 1). The interaction between word frequency and neighborhood frequency was significant in the subject analysis, $F_s(1, 39) = 8.96$, $p < .01$, $MSE = 422.40$, but not in the item analysis, $F_i(1, 111) = 1.15$, $p > .25$, $MSE = 2{,}042.57$. As can be seen in Table 8, for the low-frequency words, responses to words with higher frequency neighbors were 12 ms faster than responses to words without higher frequency neighbors, $F_s(1, 39) = 5.48$, *p*

$< .05$, $MSE = 570.37$; $F_i < 1$, and for the medium-frequency words responses to words with no higher frequency neighbors were 7 ms slower than the responses to words with higher frequency neighbors, $F_s(1, 39) = 3.22$, $p = .08$, $MSE = 299.68$; $F_i < 1$.

In the analysis of error rates, there was a main effect of word frequency, $F_s(1, 39) = 62.82$, $p < .001$, $MSE = 16.16$; $F_i(1, 111) = 32.32$, $p < .001$, $MSE = 23.18$, with fewer errors to medium-frequency words than to low-frequency words (1.3% vs. 6.3%). The main effect of neighborhood frequency was not significant (both F's < 1). The interaction between word frequency and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 39) = 3.50$, $p = .069$, $MSE = 12.00$, but was not significant in the items analysis, $F_i < 1$. Consistent with the response latencies, for the low-frequency words there were fewer errors to words with higher frequency neighbors than to words without higher frequency neighbors, $F_s(1, 39) = 1.17$, $p > .25$, $MSE = 19.69$; $F_i < 1$, whereas for the medium-frequency words there were more errors to the words with higher frequency neighbors than to the words without higher frequency neighbors, $F_s(1, 39) = 3.78$, $p = .059$, $MSE = 5.05$; $F_i(1, 57) = 4.85$, $p < .05$, $MSE = 2.90$.[15] The mean response latency for the nonwords was 685 ms; the mean error rate was 4.8%.

Subjective frequencies. An analysis of the subjective frequency ratings revealed only a main effect of word frequency, $F_s(1, 39) = 261.38$, $p < .001$, $MSE = .32$; $F_i(1, 111) = 66.62$, $p < .001$, $MSE = .85$ (all other F's < 1). As expected, the low-frequency words were judged to be less frequently encountered than the medium-frequency words (see Table 9).

Word-body neighbor analysis. To determine whether word-body neighbors modulate the neighborhood frequency effect, the low-frequency and the medium-frequency target words with higher frequency neighbors were divided into two groups: namely, 1) words whose highest frequency neighbor was a word-body neighbor, and 2) words whose highest frequency neighbor was not a word-body neighbor. The response latencies and error rates to these words were compared to the response latencies and error rates to the words without higher frequency neighbors. The mean correct response latencies and error rates to these stimuli are shown in Table 10.

For the low-frequency words, in the subject analyses of the response latencies and error rates, there was an effect of neighborhood frequency condition that was marginally significant in the subject analysis, $F_s(2, 78) = 2.50$, $p = .088$, $MSE = 1{,}196.62$; $F_i < 1$ and $F_s(2, 78) = 5.80$, $p < .01$, $MSE = 35.83$; $F_i(2, 53) = 1.79$, $p > .15$, $MSE = 42.83$, respectively. Response latencies to words with a higher frequency neighbor that was a word-body neighbor were similar to the response latencies to words without higher frequency neighbors, $F_s(1, 39) = 1.05$, $p > .30$, $MSE = 1{,}108.31$; $F_i < 1$, as were the errors (both F's < 1). Response latencies to words with a higher frequency neighbor that was not a word-body neighbor were 9 ms faster than response latencies to words with a higher frequency neighbor was a word-body neighbor, but this difference was not significant, $F_s(1, 39) = 1.14$, $p > .25$, $MSE = 1{,}619.70$; $F_i < 1$. There were, however, significantly more errors to words with a higher frequency word-body neighbor than to words with a higher frequency neighbor that was not a word-body neighbor (8.2% vs. 3.8%), $F_s(1, 39) = 8.73$, $p < .01$, $MSE = 45.06$; $F_i(1, 26) = 3.42$, $p = .076$, $MSE = 40.02$. Responses to words with a higher frequency neighbor that was not a word-body neighbor were 17 ms faster than responses to words without higher frequency neighbors, $F_s(1, 39) = 6.92$, $p < .05$, $MSE = 861.87$; $F_i(1, 41) = 1.14$, $p > .25$, $MSE = 2{,}658.18$. Error rates were also lower to words without a higher frequency word-body neighbor compared to the errors made to words without higher frequency neighbors (6.9% vs. 3.8%), $F_s(1, 39) = 7.44$, $p < .05$, MSE = 26.37; $F_i(1, 41) = 2.82$, $p = .10$, $MSE = 33.91$.

The situation was different for the medium-frequency words. In the analysis of response latencies, there was an effect neighborhood frequency condition in the subject analysis, $F_s(2, 78) = 5.79$, $p < .01$, $MSE = 498.16$; $F_i(2, 56) = 1.13$, $p > .30$, $MSE =$ 1,070.58, and a marginally significant effect in the item analysis of error rates, $F_s(2, 78) =$ 1.23, $p > .25$, $MSE = 12.23$; $F_i(2, 56) = 2.86$, $p = .066$, $MSE = 2.91$. Response latencies to words with higher frequency word-body neighbors were 15 ms slower than the responses to words without higher frequency neighbors, $F_s(1, 39) = 8.45$, $p < .01$, $MSE = 551.52$; $F_i(1, 40) = 1.93$, $p > .15$, $MSE =$ 1,139.35, and responses to these words were also slightly more error prone than the responses to words without higher frequency neighbors (1.4% vs. 0.8%; both F's < 1). Response latencies to words with a higher frequency word-body neighbor were 14 ms slower than words with a higher frequency neighbor that was not a word-body neighbor, $F_s(1, 39) = 6.81$, $p < .05$, $MSE = 582.22$; $F_i(1, 45) = 1.45$, $p > .20$, $MSE =$ 1,199.67. There was no significant difference in the error rates to these conditions (both F's < 1). Response latencies to words with a higher frequency neighbor that was not a word-body neighbor were nearly identical to the response latencies to words without higher frequency neighbors (both F's < 1), however, the error rates were significantly higher (2.0% vs. 0.8%), $F_s(1, 39) = 4.41$, $p < .05$, $MSE = 6.81$; $F_i(1, 45) =$ 6.13, $p < .05$, $MSE = 2.66$.

Effect of reader skill. A low ART group ($M = 12.5$) and a high ART group ($M =$ 20.7) were created by a median split on the ART scores (median = 16, range = 5 to 29),

$F_s(1, 38) = 68.07$, $p < .001$, $MSE = 9.75$. The mean correct response latencies and error rates for the low and the high ART groups are listed in Table 11. In the analysis of response latencies, the main effect of group was significant in the item analysis only (611 ms for the low ART group and 586 ms for the high ART group), $F_s(1, 38) = 1.34$, $p > .25$, $MSE = 19{,}299.96$; $F_i(1, 222) = 14.67$, $p < .001$, $MSE = 2{,}336.54$. The main effect of word frequency was significant, $F_s(1, 38) = 254.83$, $p < .001$, $MSE = 829.96$; $F_i(1, 222) = 140.01$, $p < .001$, $MSE = 2{,}336.54$. The interaction between word frequency and neighborhood frequency was significant in the subject analysis, $F_s(1, 38) = 8.56$, $p < .01$, $MSE = 433.30$; $F_i(1, 222) = 2.06$, $p > .15$, $MSE = 2{,}336.54$. None of the interactions between group and word frequency, group and neighborhood frequency, or the three-way interaction between group, word frequency, and neighborhood frequency were statistically significant (all p's $> .20$).

In the analysis of error rates, the main effect of word frequency was significant, and the interaction between word frequency and neighborhood frequency was marginally significant (in the subject analysis), $F_s(1, 38) = 60.24$, $p < .001$, $MSE = 16.98$; $F_i(1, 222) = 47.36$, $p < .001$, $MSE = 31.33$, and $F_s(1, 38) = 3.48$, $p = .07$, $MSE = 12.29$; $F_i(1, 222) = 1.98$, $p > .15$, $MSE = 31.33$, respectively. The main effect of group was not significant (both F's < 1). As in the response latency analysis, none of the interactions between group and word frequency, group and neighborhood frequency, or the three-way interaction were significant (all F's < 1).[16]

In the analysis of the nonword data, the two groups differed from one another in response latencies only in the item analysis, $F_s(1, 38) = 2.65$, $p > .10$, $MSE = 5{,}993.36$;

$F_i(1, 238) = 30.13, p < .001, MSE = 3,134.32$. The two groups did not differ in their error rates to the nonwords (both F's < 1).

Experiment 2B

There was a main effect of word frequency in the analysis of response latencies, $F_s(1, 40) = 212.46, p < .001, MSE = 1,264.13$; $F_i(1, 111) = 71.73, p < .001, MSE =$ 2,533.86, as medium-frequency words were responded to 80 ms faster than low-frequency words. The main effect of neighborhood frequency was not significant, $F_s(1, 40) = 1.27, p > .25, MSE = 443.47$; $F_i < 1$, nor was the interaction between neighborhood frequency and word frequency, $F_s(1, 40) = 1.70, p > .15, MSE = 765.27$; $F_i < 1$.

In the analysis of error rates, there was a main effect of word frequency, $F_s(1, 40) = 50.54, p < .001, MSE = 13.28$; $F_i(1, 111) = 26.72, p < .001, MSE = 17.61$, as the error rates to the low-frequency words (4.8%) were higher than the error rates to the medium-frequency words (0.8%). The main effect of neighborhood frequency was not significant, $F_s(1, 40) = 1.33, p > .25, MSE = 8.10$; $F_i < 1$, nor was interaction between word frequency and neighborhood frequency, $F_s(1, 40) = 1.45, p > .20, MSE = 5.12$; $F_i < 1$. There was no significant difference in the error rates to the low-frequency words (both F's < 1), however, for the medium-frequency words, participants made significantly more errors to words with higher frequency neighbors than to words with no higher frequency neighbors, $F_s(1, 40) = 4.73, p < .05, MSE = 3.82$; $F_i(1, 57) = 6.44, p < .05, MSE = 2.02$.[17] The mean response latency for the nonwords was 742 ms; the mean error rate was 5.2%.

Subjective frequencies. As in Experiment 2A, only the main effect of word frequency was significant, $F_s(1, 40) = 269.50, p < .001, MSE = .30$; $F_i(1, 111) = 66.62, p$

< .001, $MSE = .85$ (all other F's < 1). The low-frequency words were judged to be less frequently encountered than the medium-frequency words (see Table 9).

Word-body neighbor analysis. The mean response latencies of correct responses and the mean error rates as a function of neighborhood frequency condition are shown in Table 10. For the low-frequency words, in the response latency analysis, there was no overall effect of neighborhood frequency condition, $F_s(2, 80) = 1.44$, $p > .20$, $MSE = 1{,}470.30$; $F_i < 1$. There was no effect of neighborhood frequency condition in the error analysis (both F's < 1).

As in Experiment 2A, the situation was different for the medium-frequency words. There was an effect of neighborhood frequency condition in the response latencies in the subject analysis, $F_s(2, 80) = 13.63$, $p < .001$, $MSE = 650.89$; $F_i(2,56) = 2.19$, $p > .10$, $MSE = 1{,}252.40$, and in the item analysis of the error rates, $F_s(2, 80) = 2.32$, $p > .10$, $MSE = 9.01$; $F_i(2, 56) = 4.52$, $p < .05$, $MSE = 1.97$. Words with higher frequency neighbors where the highest frequency neighbor was a word-body neighbor were responded to 19 ms slower than to words without higher frequency neighbors, $F_s(1, 40) = 10.97$, $p < .01$, $MSE = 680.68$; $F_i(1, 40) = 1.88$, $p > .15$, $MSE = 1{,}401.57$, and responses to these words were slightly more error prone than the responses to the words without higher frequency neighbors (1.8% vs. 0.4%), $F_s(1, 40) = 4.05$, $p = .05$, $MSE = 10.25$; $F_i(1, 40) = 9.40$, $p < .01$, $MSE = 1.85$. Response latencies to words with a higher frequency word-body neighbor were 29 ms faster than response latencies to words with a higher frequency neighbor that was not a word-body neighbor, $F_s(1, 40) = 21.90$, $p < .001$, $MSE = 783.63$; $F_i(1, 27) = 3.69$, $p = .065$, $MSE = 1{,}482.11$. The error rates in these two conditions were not significantly different (both p's > .20). Response latencies to medium-frequency words with higher frequency neighbors where the highest frequency neighbor was not a word body neighbor were 10 ms faster than the response latencies to the medium-frequency words without higher frequency neighbors, $F_s(1, 40) = 4.07$, $p = .05$, $MSE = 488.33$; $F_i(1, 45) = 1.18$, $p > .25$, $MSE = 981.98$. Responses to these words were also more error prone (1.0% vs. 0.4%), $F_s(1, 40) = 11.04$, $p < .01$, $MSE = 3.57$; $F_i(1, 45) = 2.85$, $p = .098$, $MSE = 1.36$.

Effect of reader skill. A median split on the ART scores (median = 14, range = 5 to 37) created a low ART group ($M = 11.7$) and a high ART group ($M = 19.7$), $F_s(1, 39) = 35.05$, $p < .001$, $MSE = 18.69$. In the analysis of response latencies, the main effect of group was not significant (both F's < 1). The main effect of word frequency was significant, $F_s(1, 39) = 219.10$, $p < .001$, $MSE = 1{,}197.90$; $F_i(1, 222) = 120.23$, $p < .001$, $MSE = 2{,}931.41$, and the interaction between word frequency and group was marginally significant, $F_s(1, 39) = 3.21$, $p = .081$, $MSE = 1{,}197.90$; $F_i(1, 222) = 3.65$, $p = .057$, $MSE = 2{,}931.41$. The main effect of neighborhood frequency was not significant, $F_s(1, 39) = 1.12$, $p > .25$, $MSE = 446.31$; $F_i < 1$. The interaction between word frequency and neighborhood frequency was not significant, $F_s(1, 39) = 1.81$, $p > .15$, $MSE = 774.21$; $F_i < 1$, nor were the interactions between group and neighborhood frequency and between group, word frequency, and neighborhood frequency (all F's < 1).

In the analysis of error rates, the main effect of group was not significant (both F's < 1). The main effect of word frequency was significant, $F_s(1, 39) = 48.92$, $p < .001$, $MSE = 13.61$ $F_i(1, 222) = 41.32$, $p < .001$, $MSE = 22.71$. No other effects were statistically significant (all p's > .10).[18] As in Experiment 2A, for the nonwords, the responses of the low ART participants were slower than the responses of the high ART participants, $F_s < 1$; $F_i(1, 238) = 8.03$, $p < .05$, $MSE = 3{,}323.27$, but there was no difference between the groups in terms of error rates (both F's < 1).

Combined Analysis

In a combined analysis of Experiment 2A and 2B, for the response latencies to words, the main of experiment was marginally significant in the subject analysis, F_s (1, 79) = 3.94, $p = .051$, MSE = 30, 301.95, and was significant in the item analysis, F_i(1, 222) = 32.42, $p < .001$, $MSE = 2{,}288.21$, as the response latencies in Experiment 2A were shorter than in Experiment 2B (see Table 8). There was a main effect of word frequency, $F_s(1, 79) = 458.12$, $p < .01$, $MSE = 1{,}056.32$; $F_i(1,222) = 151.70$, $p < .001$, MSE = 2,288.21. The main effect of neighborhood frequency was not significant in either analysis, $F_s(1, 79) = 1.91$, $p > .15$, $MSE = 445.53$; $F_i < 1$. The only significant interaction was between word frequency and neighborhood frequency, $F_s(1, 79) = 8.01$, $p < .01$, $MSE = 596.01$; $F_i(1, 222) = 1.27$, $p > .25$, $MSE = 2{,}288.21$. This is because, in both Experiment 2A and Experiment 2B, low-frequency words with higher frequency neighbors were responded to more rapidly than low-frequency words without higher frequency neighbors (662 ms vs. 651 ms), $F_s(1, 79) = 6.88$, $p < .05$, $MSE = 701.21$; F_i(1, 224) = 2.29, $p > .10$, $MSE = 2{,}538.40$. For the medium-frequency words a slightly inhibitory effect was observed with the words with higher frequency neighbors being responded to more slowly than those without any higher frequency neighbors, however this effect was not significant, $F_s(1, 79) = 2.34$, $p > .10$, $MSE = 340.33$; $F_i < 1$ (See Table 8).

In the error analysis, the effect of experiment was marginally significant, $F_s(1, 79)$ = 3.63, $p = .06$, $MSE = 21.25$; $F_i(1, 222) = 2.68$, $p > .10$, $MSE = 20.39$. There were more errors in Experiment 2A than in Experiment 2B (see Table 8). There was an effect of word frequency, $F_s(1, 79) = 113.67$, $p < .001$, $MSE = 14.92$; $F_i(1, 222) = 59.02$, $p < .001$, $MSE = 20.39$. There was no interaction between word frequency and neighborhood frequency, $F_s(1, 79) = 1.53$, $p > .25$, $MSE = 8.52$; $F_i < 1$. No other effects were statistically significant (all p's > .25).[19]

In the analysis of the nonword data, responses to nonwords were slower in Experiment 2B than in Experiment 2A (742 ms vs. 685 ms), $F_s(1, 79) = 6.70$, $p < .05$, $MSE = 9{,}787.73$; $F_i(1, 222) = 32.42$, $p < .001$, $MSE = 2{,}288.21$. The nonword error rate was slightly higher in Experiment 2B (5.2%) than in Experiment 2A (4.8%), but this difference was not significant, $F_s < 1$; $F_i(1, 222) = 2.68$, $p > .10$, $MSE = 20.39$.

Word-body neighbor analysis across experiments. For the low-frequency words, in the analysis of response latencies, there was an effect of experiment, $F_s(1, 79) = 4.04$, $p < .05$, $MSE = 26{,}999.81$; $F_i(1, 106) = 10.38$, $p < .01$, $MSE = 3{,}481.59$, as the response latencies were faster in Experiment 2A than in Experiment 2B. There was no effect of experiment in the error analysis, $F_s(1, 79) = 2.47$, $p > .10$, $MSE = 47.52$; $F_i(1, 106) = 1.25$, $p > .25$, $MSE = 38.67$. In the subject analysis, there was an effect of neighborhood frequency condition in both the response latency analysis, $F_s(2, 158) = 3.79$, $p < .05$, $MSE = 1{,}335.19$; $F_i < 1$, and in the analysis of error rates, $F_s(2, 158) = 5.71$, $p < .01$, $MSE = 29.25$; $F_i(2, 106) = 1.54$, $p > .20$, $MSE = 38.67$. The interaction between experiment and neighborhood frequency condition was not significant (all p's > .10).

For the medium-frequency words, the effect of experiment was marginally significant in the response latency analysis, $F_s(1, 79) = 3.83$, $p = .054$, $MSE = 19{,}237.64$; $F_i(1, 112) = 25.35$, $p < .001$, $MSE = 1{,}161.49$, but not in the error rate analysis, $F_s < 1$;

$F_i(1, 112) = 1.44$, $p > .20$, $MSE = 2.44$. There was an effect of neighborhood frequency condition for the response latencies, $F_s(2, 158) = 18.20$, $p < .001$, $MSE = 575.49$; $F_i(2, 112) = 3.08$, $p = .05$, $MSE = 1{,}161.49$. The effect was marginally significant in the subject analysis, and significant in the item analysis for errors, $F_s(2, 158) = 2.41$, $p = .093$, $MSE = 10.60$; $F_i(2, 112) = 5.59$, $p < .01$, $MSE = 2.44$. For both the response latencies and errors, the interaction between experiment and neighborhood frequency condition was not significant, $F_s(2, 158) = 2.10$, $p > .10$, $MSE = 575.48$; $F_i < 1$ and $F_s < 1$; $F_i(2, 112) = 1.47$, $p > .20$, $MSE = 2.44$, respectively.

Effect of reader skill across experiments. When the response latencies of the low ART group and the high ART group were compared across Experiments 2A and 2B, the main effect of experiment was significant, $F_s(1, 77) = 4.19$, $p < .05$, $MSE = 30{,}707.70$; $F_i(1, 444) = 60.09$, $p < .001$, $MSE = 2{,}633.98$, as the participants in Experiment 2A were faster to respond to the target words than the participants in Experiment 2B (599 ms vs. 637 ms). Both the main effect of group and the interaction between group and experiment were significant in the item analysis, $F_s < 1$; $F_i(1, 444) = 4.82$, $p < .05$, $MSE = 2{,}633.98$ and $F_s < 1$; $F_i(1, 444) = 8.45$, $p < .01$, $MSE = 2{,}633.98$, respectively. The main effect of word frequency was significant, $F_s(1, 77) = 464.61$, $p < .001$, $MSE = 1{,}016.32$; $F_i(1, 444) = 257.91$, $p < .001$, $MSE = 2{,}633.98$, but the interaction between word frequency and experiment was not, $F_s(1, 77) = 1.01$, $p > .30$, $MSE = 1{,}016.32$; $F_i < 1$. The word frequency effect was 73 ms in Experiment 2A and 80 ms in Experiment 2B. The interaction between group and word frequency was significant, $F_s(1, 77) = 4.77$, $p < .05$, $MSE = 1{,}016.32$; $F_i(1, 444) = 8.45$, $p < .01$, $MSE = 2{,}633.98$. Overall, the word frequency effect was larger for the low ART participants (84 ms) than for the high ART participants

(69 ms). The three-way interaction between experiment, group, and word frequency was not significant (both *F*'s < 1). The interaction between neighborhood frequency and word frequency was significant in the subject analysis, $F_s(1, 77) = 8.01, p < .01, MSE = 605.97$; $F_i(1, 444) = 2.24, p > .10, MSE = 2{,}633.98$. None of the other main effects or interactions involving neighborhood frequency were significant (all *F*'s < 1).

In the analysis of errors, the main effect of experiment was marginally significant in the subject analysis, $F_s(1, 77) = 3.72, p = .057, MSE = 21.65$, and was significant in the item analysis, $F_i(1, 444) = 4.26, p < .05, MSE = 27.02$, as more errors were made in Experiment 2A than in Experiment 2B (3.8% vs. 2.8%). There was no main effect of group, nor was there an interaction between experiment and group (all *F*'s < 1). The main effect of word frequency was significant, $F_s(1, 77) = 464.61, p < .001, MSE = 1{,}016.32$; $F_i(1, 444) = 88.49, p < .001, MSE = 27.02$. There was a significant interaction between word frequency and neighborhood frequency, $F_s(1, 77) = 4.77, p < .05, MSE = 8.56$; $F_i(1, 444) = 2.16, p > .10, MSE = 27.02$. No other effects were significant (all *p*'s > .20).[20]

For the nonwords, there was an effect of experiment in the analysis of the response latencies, $F_s(1, 77) = 6.96, p < .05, MSE = 9{,}790.72$; $F_i(1, 476) = 106.58, p < .001, MSE = 3{,}228.82$. Overall, the nonwords in Experiment 2B were responded to more slowly than the nonwords in Experiment 2A (741 ms vs. 683 ms). The effect of group was significant in the item analysis, $F_s(1, 77) = 1.76, p > .15, MSE = 9{,}790.72$; $F_i(1, 476) = 34.30, p < .001, MSE = 3{,}228.82$, and the interaction between group and experiment was marginally significant in the item analysis, $F_s < 1$; $F_i(1, 476) = 3.21, p = .074, MSE = 3{,}228.82$. In the error analysis, there were no significant (all *p*'s > .20).

Discussion

As in Experiment 1, models that assume there is competitive inhibition amongst neighbors would have predicted inhibitory neighborhood frequency effects in these experiments. Simulations using the multiple read-out model confirmed this prediction, but the effect was not consistently found across the Experiments 2A and 2B. In Experiment 2A, where participants were given standard lexical decision instructions, there was no overall inhibitory effect of neighborhood frequency in either the response latencies or in the error rates. Indeed, for the low-frequency words the effect of higher frequency neighbors was facilitatory, not inhibitory. For the medium-frequency words, neighborhood frequency had no effect on response latencies or on errors. In Experiment 2B, where participants were asked to emphasize accuracy over speed, a small and statistically unreliable inhibitory effect of neighborhood frequency was observed in the error rates to the medium-frequency words. Taken together, these results lend no support to the notion that competitive activation processes play an important role during the identification of English words.

On the other hand, the word-body neighbor analyses did suggest that the processing of words with higher frequency neighbors could be delayed. For the medium-frequency words, words with a higher frequency word-body neighbor were responded to more slowly than the words without higher frequency neighbors, and responses to these words were more error prone than the responses to words without higher frequency neighbors. There was no word-body neighbor effect for the low-frequency words, however. This inhibitory effect of word-body neighbors requires further examination.

Because the identical stimuli were used in Experiment 3B, such an examination was possible.

Simulations with the Seidenberg and McClelland (1989) model indicated that the model predicted an effect of word frequency, no effect of neighborhood frequency in the orthographic error scores, and a marginally significant inhibitory effect in the phonological error scores for the medium-frequency words. The Plaut et al. (1996) model also predicted a word frequency effect, but it predicted an inhibitory effect of higher frequency neighbors, this time for the low-frequency words. Again, the Seidenberg and McClelland model was best able to account for the results of Experiment 2.

As was the case in Experiment 1, there was no indication that reader skill was associated with the neighborhood frequency effect. Nonetheless, the ART was once again administered to the participants in Experiment 3 in a final attempt to discern such an effect.

Experiment 3

Experiment 3A was a replication of Perea and Pollatsek's (1998) Experiment 2. In the experiment, participant's eye movements were monitored while they read sentences. The words from Perea and Pollatsek's lexical decision task (Experiment 1) were embedded in these sentences. The sentence frames were created so that one frame would create a pair of sentences. Both members of the pair were identical except for the target word – one would have a target with higher frequency neighbors, and one would have a target without higher frequency neighbors.

As in Experiment 1, these sentences were not an ideal manipulation. Recall that Perea and Pollatsek (1998) had separated these words into low-frequency and medium-frequency words in a post hoc analysis. As such, in eleven of these sentence pairs, a low-frequency word was paired with a medium-frequency word. Also, 24 of these sentence pairs were modified by adjectives (e.g., The naturalist encountered an immense [horde, swarm] of insects in the swamp). Rayner, Sereno, Morris, Schmauder, and Clifton (1989) found that fixation durations for modified nouns were longer than fixation durations for unmodified nouns.

The same methodology was used in Experiment 3B, but the target words from Experiment 2 were embedded into a new set of 60 sentences. The sentence pairs were created so that only low-frequency words were paired together, and only medium-frequency words were paired together. Only three sentences in this set were preceded by an adjective; for the remainder of the sentences the target word was not modified (e.g., Justin said that the [suite, lodge] was already booked for the weekend.). In addition, all of the sentences were constructed so that the preceding context was neutral and ambiguous with respect to each of the target words (e.g., The pamphlet outlined the [*risk, swim*] involved in the triathlon.). This ensured that contextual information would play little, if any, role in the processing of the target words.

Method

Participants

Eighty University of Calgary undergraduate students participated in the experiment in exchange for partial course credit. Forty participated in Experiment 3A and 40 participated in Experiment 3B. All participants were proficient English speakers with normal or corrected-to-normal vision. None of these individuals participated in more than one experiment.

Materials

The sentences used in Experiments 3A and 3B are listed in the Appendix. In Experiment 3A, the sentences were the same as those used by Perea and Pollatsek (1998). The target words from Experiment 1 were used in 46 pairs of sentences. The sentences in each pair were identical, except that one contained a target word with no higher frequency neighbors, and the other contained a target word with higher frequency neighbors. Each sentence was no more than 80 characters in length and was presented a single line of the display screen.

For Experiment 3B, a new set of 60 sentence pairs was created using the target words from Experiment 2. Word frequency and neighborhood frequency were again manipulated. The sentences were divided equally into two conditions (30 in each): sentences that contain low-frequency targets and sentences that contain medium-frequency targets. The sentences in each pair were identical, except that one contained a target word with no higher frequency neighbors, and the other contained a target word with at least one higher frequency neighbor. Each sentence was no more than 80 characters in length and was presented on a single line of a display screen.

Apparatus and Procedure

Eye movements were recorded by a Sensomotoric Instruments, Inc. (Boston, MA) EyeLink System, which has a sampling rate of 250 Hz (allowing for a temporal resolution of 4 ms). The system simultaneously uses IR video-based tracking technology for both eyes and head position compensation. The gaze and eye position resolution is 0.005 ° (20 seconds of arc), with an average error of 0.5° to 1.0°. Detection and analysis of saccades, fixations, and blinks occurs in real time.

When each participant arrived for the experiment, they were fitted with the headmount and the eye tracking system was calibrated. The calibration period lasted approximately 5 min. After the calibration was completed, the procedure used by Perea and Pollatsek (1998) in their Experiment 2 was followed. Participants were told that they would be silently reading sentences, presented one at a time, and that the purpose of the experiment was to determine what people look at while they read. They were asked to read the sentences for normal comprehension. After reading 25% of the sentences (i.e., after every 11-12 sentences in Experiment 3A and after every 15 sentences in Experiment 3B), the participants were asked a series of comprehension questions about what they just read. Accuracy in answering was extremely high. Before they read any experimental sentences, participants read 8 practice sentences in order to familiarize them with the procedure.

After completing the reading task, each participant completed the ART. A measure of each participant's reading rate was also collected using Form G of the Nelson-Denny Reading Test (Brown et al., 1993).

Design

In Experiment 3A, each participant read one of two lists. Each list contained 23 sentences with target words that had higher frequency neighbors and 23 sentences that had no higher frequency neighbors. The presence of the target word was counterbalanced across the two lists. That is, if a word with higher frequency neighbors (e.g., MARSH) appeared in one list, its corresponding target without higher frequency neighbors (e.g., CANAL) appeared in the other. In Experiment 3B, each participant also read one of two lists. Each list contained 30 sentences with target words that had higher frequency neighbors and 30 sentences that had no higher frequency neighbors. Again, the presence of the target word was counterbalanced across the two lists.

A 2 (Word Frequency: low, medium) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) repeated-measures design was used for each of the experiments. The dependent variables were first-fixation durations (the duration of the first fixation on the target word), gaze durations (the sum of the fixation durations on the target word before the reader left the target word), and the percentage of trials where the target word was initially skipped. For all these analyses, the target region was defined as the target word, the space that preceded it, and the last two characters of the previous word. For the above first pass measures, excluding percentage of target words skipped, trials were included in the analyses only when the reader initially fixated on the target word with a forward saccade (i.e., a trial was not counted when the target word was initially skipped).

Also of interest was the processing that occurred after the participant left the target word (i.e., spillover effects). The following variables were submitted to separate 2 (Word Frequency: high, low) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) repeated-measures factorial ANOVA: the duration of the first fixation after leaving the target word, the probability of making a regression back to the target word, the total time spent on the target word (the sum of all fixation durations on the target word, including regressions), and the total time spent on the target word and the immediate post-target region. (The immediate post-target region is defined as the two words subsequent to the target word.) Again, trials were included only when the target word was originally fixated.

Results

Experiment 3A

The data for the first pass variables for Experiment 3A are presented in Table 12. An analysis of the percentage of target words skipped during the readers' first pass revealed a significant main effect of word frequency, $F_s(1, 39) = 46.74$, $p < .001$, $MSE = 112.91$; $F_i(1, 84) = 16.25$, $p < .001$, $MSE = 171.78$, as the medium-frequency words were skipped much more often than the low-frequency words (20.8% vs. 9.3%). There was also a main effect of neighborhood frequency that was significant in the subject analysis only, $F_s(1, 39) = 4.50$, $p < .05$, $MSE = 107.77$; $F_i(1, 84) = 1.26$, $p > .25$, $MSE = 171.78$. Words with higher frequency neighbors were skipped slightly less often than words without higher frequency neighbors (13.3% vs. 16.8%). The interaction between word frequency and neighborhood frequency was not significant (both *p*'s > .25). Those trials where the target word was not fixated on the reader's first pass of the sentence were excluded from all subsequent analyses (251 trials, 14.2% of the data).

The effect of word frequency on the first fixation durations was marginally significant in the subject analysis, $F_s(1, 39) = 3.43$, $p = .07$, $MSE = 880.76$, and was significant in the items analysis, $F_i(1, 84) = 4.57$, $p < .05$, $MSE = 576.73$. On first fixation, low-frequency words were fixated an average of 8 ms longer than medium-frequency words. The main effect of neighborhood frequency was not significant (both *F*'s < 1), nor was the interaction between word frequency and neighborhood frequency, $F_s(1, 39) = 2.60$, $p > .10$, $MSE = 565.22$; $F_i(1, 84) = 1.05$, $p > .30$, $MSE = 576.73$.

A similar pattern of results was found for the gaze duration data. There was a significant main effect of word frequency, $F_s(1, 39) = 9.96$, $p < .01$, $MSE = 1{,}509.10$;

$F_i(1, 84) = 6.04$, $p < .05$, $MSE = 1{,}668.52$, as more time was spent fixating on the low-frequency words than on the medium-frequency words (257 ms vs. 238 ms). There was no effect of neighborhood frequency (both F's < 1), and there was no interaction between word frequency and neighborhood frequency, $F_s(1, 39) = 2.54$, $p > .10$, $MSE = 1{,}121.33$; $F_i < 1$.

The data for the spillover effects is shown in Table 13. For each of these measures there was a consistent effect of word frequency. There was an effect of word frequency on total time spent on the target word, $F_s(1, 39) = 13.18$, $p < .01$, $MSE = 2{,}249.67$; $F_i(1, 84) = 5.40$, $p < .05$, $MSE = 3{,}022.66$, with participants spending on average 18 ms more time on the low-frequency words than on the medium-frequency words. The effect of word frequency on the first fixation after leaving the target word was marginally significant in the subject analysis, $F_s(1, 39) = 3.66$, $p = .063$, $MSE = 1{,}738.35$, but was not significant in the item analysis, $F_i(1, 84) = 1.94$, $p > .15$, $MSE = 1{,}813.47$. There was a significant effect of word frequency on the total time spent on the target word and the immediate post-target region, $F_s(1, 39) = 11.90$, $p < .01$, $MSE = 15{,}734.09$; $F_i(1, 84) = 6.78$, $p < .05$, $MSE = 21{,}435.71$, as well as on the percentage of regressions back to the target word, $F_s(1, 39) = 7.64$, $p < .01$, $MSE = 139.39$; $F_i(1, 84) = 4.90$, $p < .05$, $MSE = 120.66$. Not only did participants spend more time on the target words plus the two following words when the target word was low in frequency than when the target word was of medium-frequency (719 ms vs. 650 ms), they also regressed more often to the low-frequency targets than the medium-frequency targets (16.3% vs. 11.2%). In contrast, there were no significant effects of neighborhood frequency on any of these spillover variables (all p's > .10).[21]

Low vs. high percentage of regressions. I replicated Perea and Pollatsek's (1998) reader skill analysis by performing a median split on the overall percentage of trials where participants regressed (median = 12.6%, range = 0% to 38.5%), distinguishing between the participants that made fewer regressions ($M = 7.6\%$) and the participants that made more regressions ($M = 19.9\%$), $F_s(1, 38) = 41.31$, $p < .001$, $MSE = 36.47$. Perea and Pollatsek reported significant effects of higher frequency neighbors in the gaze duration analysis, in the analysis of the first fixation after leaving the target word, and in the analysis of the percentage of regressions to the target word. Overall, their participants that made fewer regressions were more likely to exhibit inhibitory neighborhood frequency effects.

For the participants that made fewer regressions, there was a main effect of word frequency in the percentage of target words initially skipped, $F_s(1, 19) = 23.43$, $p < .001$, $MSE = 134.24$; $F_i(1, 84) = 15.03$, $p < .001$, $MSE = 209.44$. Low-frequency words were skipped less often than the medium-frequency words (9.0% vs. 21.6%). The main effect of neighborhood frequency was marginally significant, $F_s(1, 19) = 3.52$, $p = .076$, $MSE = 134.68$; $F_i(1, 84) = 1.91$, $p > .15$, $MSE = 209.44$, and there was an interaction between word frequency and neighborhood frequency in the subject analysis, $F_s(1, 19) = 5.95$, $p < .05$, $MSE = 79.21$; $F_i < 1$. For the low-frequency words, there was no effect of neighborhood frequency (both F's < 1), but for the medium-frequency words, participants skipped the words with higher frequency neighbors less often than the words without higher frequency neighbors (16.7% vs. 26.5%), $F_s(1, 19) = 7.30$, $p < .05$, $MSE = 129.48$; $F_i(1, 35) = 1.40$, $p > .20$, $MSE = 357.26$. For the participants that made more regressions, the low-frequency words were skipped less often than the medium-frequency words (9.7% vs. 20.1%), $F_s(1, 19) = 22.87$, $p < .001$, $MSE = 95.18$; $F_i < 1$, but no other effects were significant (all p's > .30).

In the first fixation duration analysis, for the participants that made fewer regressions, the main effects of word frequency and of neighborhood frequency were not significant (all F's < 1) but the interaction was marginally significant in the subject analysis, $F_s(1, 19) = 4.28$, $p = .052$, $MSE = 492.11$; $F_i(1, 84) = 2.00$, $p > .15$, $MSE =$ 792.80. First fixation durations for the low-frequency words with higher frequency neighbors were on average 12 ms slower than the first fixation durations for the low-frequency words without higher frequency neighbors, $F_s(1, 19) = 4.35$, $p = .051$, $MSE =$ 347.81; $F_i(1, 49) = 2.22$, $p > .10$, $MSE = 650.67$. For the medium-frequency words, the neighborhood frequency effect was reversed, but not significant. The first fixation durations for the words with higher frequency neighbors were on average 9 ms faster than the first fixation durations for the words without higher frequency neighbors, $F_s(1, 19) =$ 1.05, $p > .31$, $MSE = 641.88$; $F_i < 1$. For the participants that made more regressions, there was a significant main effect of word frequency, $F_s(1, 19) = 5.58$, $p < .05$, $MSE =$ 1,031.49; $F_i(1, 84) = 7.71$, $p < .01$, $MSE = 887.17$, with first fixation durations for the low-frequency words 17 ms slower than first fixation durations for medium-frequency words. The main effect of neighborhood frequency and the interaction between word frequency and neighborhood frequency were not significant (all F's < 1).

In the gaze duration analysis, for the participants that made fewer regressions, there were no significant effects (all p's > .10). For the participants that made more regressions, only the main effect of word frequency was significant, $F_s(1, 19) = 8.40$, $p <$ .01, $MSE = 2,183.08$; $F_i(1, 84) = 13.59$, $p < .05$, $MSE = 2,340.60$ (all other F's < 1). The gaze durations for the low-frequency words were 30 ms longer than the gaze durations for the medium-frequency words.

In the analysis of the total time spent on the target word, for the group that made fewer regressions, there was a main effect of word frequency, $F_s(1, 19) = 10.60$, $p < .01$, $MSE = 788.83$; $F_i(1, 84) = 5.05$, $p < .05$, $MSE = 2{,}136.17$, with participants spending 20 ms longer on the low-frequency words than the medium-frequency words. The main effect of neighborhood frequency was not significant (both F's < 1), but the interaction between word frequency and neighborhood frequency was significant, $F_s(1, 19) = 4.81$, $p < .05$, $MSE = 1{,}712.37$; $F_i(1, 84) = 4.73$, $p < .05$, $MSE = 2{,}136.17$. For the low-frequency words, words with higher frequency neighbors were examined an average of 29 ms longer than words without higher frequency neighbors, $F_s(1, 19) = 9.82$, $p < .01$, $MSE = 813.54$; $F_i(1, 49) = 4.62$, $p < .05$, $MSE = 2{,}049.98$. For the medium-frequency words, there was no neighborhood frequency effect, $F_s < 1$; $F_i(1, 35) = 1.07$, $p > .30$, $MSE = 2{,}256.84$. For the participants that made more regressions, there was a main effect of word frequency on the total time spent on the target word, $F_s(1, 19) = 6.20$, $p < .05$, $MSE = 3{,}732.19$; $F_i(1, 84) = 10.26$, $p < .01$, $MSE = 5{,}207.74$ (333 ms for the low-frequency words and 300 ms for the medium-frequency words), but no other effects were statistically significant (all p's $> .25$).

In the analysis of the first fixation duration after leaving the target word data, for the participants that made fewer regressions, there was a significant main effect of word frequency, $F_s(1, 19) = 8.02$, $p < .05$, $MSE = 668.15$; $F_i(1, 84) = 4.95$, $p < .05$, $MSE = 1{,}512.36$, but no main effect of neighborhood frequency and no interaction between word frequency and neighborhood frequency (all F's < 1). Fixation durations were 16 ms longer for low-frequency words than for medium-frequency words. For the participants that made more regressions, there were no statistically significant effects (all F's < 1).

In the analysis of the total time spent on the target word and the immediate post-target region, for the group that made fewer regressions, there was a significant main effect of word frequency, $F_s(1, 19) = 11.40, p < .01, MSE = 9{,}920.74$; $F_i(1, 84) = 6.98, p < .05, MSE = 21{,}505.18$ (661 ms for the low-frequency words and 586 ms for the medium-frequency words), but no other effects were significant (all F's < 1). For the participants that made more regressions, the main effect of word frequency was marginally significant, $F_s(1, 19) = 3.41, p = .08, MSE = 22{,}278.53$; $F_i(1, 84) = 3.67, p = .059, MSE = 33{,}782.47$ (777 ms for the low-frequency words and 716 ms for the medium-frequency words), but no other effects were significant (all p's > .20).

In the analysis of the percentage of regressions, for the participants that made fewer regressions, there was a main effect of word frequency in the subject analysis, $F_s(1, 19) = 11.64, p < .01, MSE = 52.88$; $F_i(1, 84) = 2.52, p > .10, MSE = 146.58$, with more regressions to low-frequency words than to medium-frequency words (10.3% vs. 4.8%), but there was no main effect of neighborhood frequency and no interaction (all p's > .15). For the participants that made more regressions, there were no significant effects (all p's > .10). [22]

Effect of reader skill. As a measure of reader skill, I administered the ART and also measured participants' reading rate using Form G of the Nelson-Denny Comprehension Test. The two measures were significantly correlated, $r(40) = .54, p < .001$. Median splits on the ART scores (median = 15, range = 6 to 32) and on the standardized reading rate scores (median = 204, range = 166 to 305), created a low ART group ($M = 10.8$) and a high ART group ($M = 20.9$), $F_s(1, 38) = 54.65, p < .001, MSE = 18.48$, and a low reading rate group ($M = 195.7$) and a high reading rate group ($M = 220.4$), $F_s(1, 38) = 20.46, p < .001, MSE = 297.76$. (See Table 14 for the first pass measures and Table 15 for the spillover effects.)

The low ART group did not regress to the target words significantly more often than the high ART group (10.7% vs. 16.0%), $F_s(1, 38) = 1.04, p > .30, MSE = 296.31$; $F_i(1, 168) = 2.61, p > .10, MSE = 174.74$. Participants with lower reading rate scores did not differ from participants with higher reading rate scores in the percentage of trials they regressed to the target word (13.9% vs. 12.8%; both F's < 1). This is inconsistent with the earlier regression analysis.

There was a main effect of ART group for the percentage of target words skipped, $F_s(1, 38) = 13.94, p < .01, MSE = 296.41$; $F_i(1, 168) = 20.58, p < .001, MSE = 258.42$, as participants in the low ART group skipped the target much less often than participants in the high ART group (9.8% vs. 19.9%). There was also a significant effect of word frequency, $F_s(1, 38) = 45.44, p < .001, MSE = 114.88$; $F_i(1, 168) = 21.66, p < .001, MSE = 258.42$, and of neighborhood frequency, $F_s(1, 38) = 4.30, p < .05, MSE = 105.70$; $F_i(1, 168) = 2.56, p > .10, MSE = 258.42$. There was no interaction between group and word frequency (both F's < 1). The interaction between neighborhood frequency and group was not significant, nor was the interaction between word frequency and neighborhood frequency were significant, nor was the three-way interaction (all p's > .20). Reading rate also had an effect on the percentage of target words skipped, $F_s(1, 38) = 6.91, p < .05, MSE = 342.87$; $F_i(1, 168) = 9.67, p < .01, MSE = 213.86$. The participants with lower scores on the Nelson-Denny reading rate measure skipped the target words less often than the participants with higher scores (11.4% vs. 19.1%). The main effect of word frequency was significant, $F_s(1, 38) = 46.39, p < .001, MSE = 114.58$; $F_i(1, 168) = 24.38, p < .01, MSE = 213.86$, and the main effect of neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 38) = 4.71, p < .05, MSE = 107.68$; $F_i(1, 168) = 2.27, p < .01, MSE = 213.86$. None of the other effects were significant (all p's > .30).

In the analysis of first fixation durations, the main effect of ART group was significant in the item analysis, $F_s(1, 38) = 1.13, p > .25, MSE = 3{,}854.57$; $F_i(1, 168) = 11.17, p < .01, MSE = 1{,}008.36$ (234 ms for the low ART group and 218 ms for the high ART group). The main effect of word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.67, p = .063, MSE = 872.30$, and was significant in the item analysis, $F_i(1, 168) = 4.19, p < .05, MSE = 1{,}008.36$, but there was no interaction between group and word frequency, $F_s(1, 38) = 1.38, p > .20, MSE = 872.30$; $F_i < 1$, or between group and neighborhood frequency (both F's < 1). The interaction between word frequency and neighborhood frequency and the three-way interaction between group, word frequency, and neighborhood frequency were marginally significant by subjects, $F_s(1, 38) = 3.04, p = .089, MSE = 534.82$; $F_i(1, 168) = 1.21, p > .25, MSE = 1{,}008.36$, and $F_s(1, 38) = 3.22, p = .081, MSE = 534.82$; $F_i < 1$, respectively. In the reading rate analysis of the first fixation durations, there was a significant effect of group in the item analysis, $F_s(1, 38) = 2.02, p > .15, MSE = 3{,}768.89$; $F_i(1, 168) = 5.34, p < .05, MSE = 875.29$. The participants with lower reading rate scores fixated an average of 14 ms longer than the participants with higher reading rate scores. The main effect of word frequency was also significant in the item analysis, $F_s(1, 38) = 3.30, p = .077, MSE = 903.16$; $F_i(1, 168) = 5.20, p < .05, MSE = 875.29$. No other effects were significant (all p's > .10).

In the analysis of gaze durations, the main effect of ART group was significant in the item analysis, $F_s(1, 38) = 2.04, p > .15, MSE = 6{,}584.50$; $F_i(1, 168) = 14.39, p < .001, MSE = 1{,}784.45$. Both the main effect of word frequency and the interaction between group and word frequency were significant, $F_s(1, 38) = 12.66, p < .01, MSE = 1{,}283.59$; $F_i(1, 168) = 11.72, p < .01, MSE = 1{,}784.45$ and $F_s(1, 38) = 7.85, p < .01, MSE = 1{,}283.59$; $F_i(1, 168) = 3.23, p = .074, MSE = 1{,}784.45$, respectively. For the low ART group the word frequency effect was 35 ms, $F_s(1, 38) = 26.75, p < .001, MSE = 924.32$; $F_i(1, 84) = 12.84, p < .01, MSE = 1{,}893.03$, whereas for the high ART group it was 5 ms, $F_s < 1$; $F_i(1, 84) = 1.41, p > .20, MSE = 1{,}675.86$. The main effect of neighborhood frequency and the interaction between group and neighborhood frequency were not significant (all F's < 1). The interaction between word frequency and neighborhood frequency was not significant, $F_s(1, 38) = 2.45, p > .10, MSE = 1{,}149.76$; $F_i < 1$, nor was the three-way interaction between group, word frequency, and neighborhood frequency (both F's < 1). Reading rate did have a significant effect on gaze duration, $F_s(1, 38) = 4.95, p < .05, MSE = 6{,}138.31$; $F_i(1, 168) = 11.25, p < .01, MSE = 1{,}729.54$. Gaze durations were 27 ms slower for the participants with lower reading rate scores than for participants with higher reading rate scores. There was also a significant effect of word frequency, $F_s(1, 38) = 9.60, p < .01, MSE = 1{,}542.25$; $F_i(1, 168) = 13.04, p < .001, MSE = 1{,}729.54$. No other effects were significant (all p's > .10).

There was no effect of ART group in the total time spent on the target word, $F_s < 1$; $F_i(1, 168) = 1.64, p > .20, MSE = 4{,}739.34$. The main effect of word frequency was significant, $F_s(1, 38) = 14.53, p < .001, MSE = 2{,}133.08$; $F_i(1, 168) = 8.45, p < .01, MSE = 4{,}739.34$, and the interaction between group and word frequency was marginally significant by subjects, $F_s(1, 38) = 3.13$, $p = .085$, $MSE = 2{,}133.08$; $F_i < 1$. The word frequency effect was 41 ms for the low ART group, $F_s(1, 18) = 16.18$, $p < .01$, $MSE = 1{,}955.97$; $F_i(1, 84) = 6.25$, $p < .05$, $MSE = 4{,}777.79$, and 15 ms for the high ART group, $F_s(1, 20) = 2.04$, $p > .15$, $MSE = 2{,}292.47$; $F_i(1, 84) = 2.58$, $p > .10$, $MSE = 4{,}700.89$. No other effects were significant (all p's > .10). The effect of reading rate on the total time on the target word was significant by items, $F_s < 1$; $F_i(1, 168) = 7.81$, $p < .01$, $MSE = 4{,}104.08$. Participants with lower reading rate scores spent longer on the target words than participants with higher reading rate scores (300 ms vs. 267 ms). The main effect of word frequency was significant, $F_s(1, 38) = 14.53$, $p < .001$, $MSE = 2{,}133.08$; $F_i(1, 168) = 10.41$, $p < .01$, $MSE = 4{,}104.08$. No other effects were significant (all F's < 1).

In the analysis of the duration of the first fixation after leaving the target word, there was no effect of ART group (both F's < 1). There was a main effect of word frequency, $F_s(1, 38) = 5.25$, $p < .05$, $MSE = 1{,}399.50$; $F_i(1, 168) = 2.72$, $p > .10$, $MSE = 2{,}705.00$, and a group by word frequency interaction, $F_s(1, 38) = 10.45$, $p < .01$, $MSE = 1{,}399.50$; $F_i(1, 168) = 3.87$, $p = .051$, $MSE = 2{,}705.00$. For the low ART group the word frequency effect was 32 ms, $F_s(1, 18) = 12.43$, $p < .01$, $MSE = 1{,}634.93$; $F_i(1, 84) = 5.75$, $p < .05$, $MSE = 3{,}074.43$, and 5 ms for the high ART group (both F's < 1). No other effects were significant (all p's > .20). The main effect of reading rate was significant by items, $F_s(1, 38) = 2.35$, $p > .10$, $MSE = 4{,}791.60$; $F_i(1, 168) = 3.88$, $p = .05$, $MSE = 3{,}368.33$. Participants with lower reading rate scores fixated longer than participants with higher reading rate scores (249 ms vs. 232 ms). The only other effects to approach significance were the main effect of word frequency, $F_s(1, 38) = 3.78$, $p = .059$, $MSE = 1{,}752.35$; $F_i(1, 168) = 2.50$, $p > .10$, $MSE = 3{,}368.33$, and the interaction between reading rate group and neighborhood frequency, $F_s(1, 38) = 3.28$, $p = .078$, $MSE = 1{,}740.26$; $F_i(1, 168) = 1.16$, $p > .25$, $MSE = 3{,}368.33$.

In the analysis of the total time spent on the target word and the immediate post-target region, the main effect of ART group was not significant (both F's < 1). The main effect of word frequency was significant, $F_s(1, 38) = 12.37$, $p < .01$, $MSE = 15{,}602.19$; $F_i(1, 168) = 9.28$, $p < .01$, $MSE = 29{,}343.94$. There was no interaction between group and word frequency, $F_s(1, 38) = 1.33$, $p > .25$, $MSE = 15{,}602.19$; $F_i < 1$. The main effect of neighborhood frequency was not significant, $F_s(1, 38) = 1.32$, $p > .25$, $MSE = 12{,}025.78$; $F_i < 1$, but there was a significant interaction between group and neighborhood frequency in the subject analysis, $F_s(1, 38) = 4.75$, $p < .05$, $MSE = 12{,}025.78$; $F_i < 1$. For the low ART group, the amount of time spent on the target word and the post-target region was similar when the target had higher frequency neighbors and when it did not (669 ms vs. 687 ms; both F's < 1). On the other hand, the high ART group spent an average of 58 ms longer on the target word and the post-target region when the target had higher frequency neighbors, $F_s(1, 20) = 6.06$, $p < .05$, $MSE = 11{,}574.15$; $F_i < 1$. There were no significant interactions between word frequency and neighborhood frequency, or between group, word frequency, and neighborhood frequency (all F's < 1). The main effect of reading rate group was significant, $F_s(1, 38) = 8.49$, $p < .01$, $MSE = 66{,}142.13$; $F_i(1, 168) = 17.92$, $p < .001$, $MSE = 26{,}271.17$. Participants with lower reading rate scores spent on average 119 ms longer on the target word and the post-target region than participants with higher reading rate scores. There was a significant effect of word frequency, $F_s(1, 38) = 11.48$, $p < .01$, $MSE = 15{,}888.37$; $F_i(1, 168) = 10.63$, $p < .01$, $MSE = 26{,}271.17$, but no other comparisons were significant (all p's > .25).

As previously mentioned, the low ART group did not regress more to the target words significantly more often than the high ART group (10.7% vs. 16.0%), $F_s(1, 38) = 1.04$, $p > .30$, $MSE = 296.31$; $F_i(1, 168) = 2.61$, $p > .10$, $MSE = 174.74$. There was an effect of word frequency, $F_s(1, 38) = 7.34$, $p < .05$, $MSE = 140.40$; $F_i(1, 168) = 7.56$, $p < .01$, $MSE = 174.74$, but no other effects were significant (all p's > .25). Participants with lower reading rate scores also did not differ from participants with higher reading rate scores in the percentage of trials they regressed to the target word (13.9% vs. 12.8%; both F's < 1). The main effect of word frequency was significant, $F_s(1, 38) = 7.90$, $p < .01$, $MSE = 139.37$; $F_i(1, 168) = 7.24$, $p < .01$, $MSE = 171.65$, but there were no other effects (all p's > .30).[23, 24, 25]

Experiment 3B

The first pass data for Experiment 3B are presented in Table 16. When looking at the percentage of target words that were skipped during the readers' first pass, there were no significant effects of word frequency or of neighborhood frequency (all p's > .10). Those trials where the target word was not fixated on the first pass of the sentence were excluded from all subsequent analyses (431 trials, 17.9% of the data).

The was no effect of word frequency on the first fixation durations (both F's < 1). There was also no main effect of neighborhood frequency and no interaction between word frequency and neighborhood frequency (all p's > .10).

For the gaze duration data, there was a significant main effect of word frequency, $F_s(1, 39) = 5.50$, $p < .05$, $MSE = 628.69$; $F_i(1, 116) = 4.28$, $p < .05$, $MSE = 1{,}722.43$. More time was spent fixating on the low-frequency words than on the medium-frequency words (254 ms vs. 245 ms). There was no effect of neighborhood frequency, $F_s(1, 39) =$

1.71, $p > .15$, $MSE = 631.57$; $F_i < 1$, and no interaction between word frequency and neighborhood frequency (both F's < 1).

In the analyses of the spillover effects (see Table 17), there was an effect of word frequency on the total time spent on the target word, $F_s(1, 39) = 14.86$, $p < .001$, MSE = 992.23; $F_i(1, 116) = 3.74$, $p = .056$, $MSE = 3{,}372.10$, with participants spending on average of 19 ms longer on the low-frequency words than on the medium-frequency words. The effect of word frequency was not significant in any of the other spillover variables (all p's > .10), nor was there a significant effect of neighborhood frequency on any of these variables (all p's > .15). There was also no interaction between word frequency and neighborhood frequency (both F's < 1).[26]

Word-body neighbor analysis. Table 18 shows the first pass data and Table 19 shows the spillover data. For both the low-frequency and the medium-frequency words there were no significant effects for the percentage of trials where the target word was initially skipped (all p's > .25). Only those trials where participants fixated on the target word on the first pass were used in the following analyses.

In the first fixation duration analysis, there was no overall effect of neighborhood frequency condition (i.e., words without higher frequency neighbors, words with higher frequency neighbors but no higher frequency word-body neighbors, and words with a higher frequency word-body neighbor) for the low-frequency words, $F_s(2, 78) = 2.03$, $p >$ .10, $MSE = 1{,}208.01$; $F_i(2, 53) = 1.06$, $p > .30$, $MSE = 741.04$, or for the medium-frequency words (both F's < 1).

In the gaze duration analysis of the low-frequency words, there was an effect of neighborhood frequency condition in the subject analysis, $F_s(2, 78) = 3.78$, $p < .05$, MSE

= 1, 763.87; $F_i < 1$. As can be seen in Table 18, gaze durations to words with higher frequency word-body neighbors were no longer than gaze durations to words without higher frequency neighbors (both F's < 1). The gaze durations to the words with higher frequency neighbors where the highest frequency neighbor was not a word-body neighbor were 22 ms longer than the gaze durations to words with higher frequency word-body neighbors (or word-body neighbor, if there was only one), $F_s(1, 39) = 4.13$, $p < .05$, $MSE = 2, 288.26$; $F_i < 1$. Participants spent more time on the words with higher frequency neighbors where the highest frequency neighbor was not a word-body neighbor (272 ms) than on the words without higher frequency neighbors (249 ms), $F_s(1, 39) = 7.52$, $p < .01$, $MSE = 1, 373.66$; $F_i < 1$. For the medium-frequency words, the effect of neighborhood frequency condition was significant in the subject analysis, $F_s(2, 78) = 3.45$, $p < .05$, $MSE = 1, 447.20$; $F_i(2, 56) = 1.54$, $p > .20$, $MSE = 1{,}186.19$. Unlike the low-frequency words, gaze durations to words with higher frequency word-body neighbors were 13 ms shorter than the gaze durations for words without higher frequency neighbors. This difference approached significance in the subject analysis, $F_s(1, 39) = 3.59$, $p = .066$, $MSE = 912.85$; $F_i(1, 40) = 1.06$, $p > .30$, $MSE = 1{,}165.25$. The gaze durations to words with a higher frequency word-body neighbor were also longer than those to words with higher frequency neighbors, but no higher frequency word-body neighbor (255 ms vs. 232 ms), $F_s(1, 39) = 6.15$, $p < .05$, $MSE = 1{,}609.99$; $F_i(1, 27) = 2.97$, $p = .096$, $MSE = 1{,}219.10$. There was no significant difference between the gaze durations for the words with no higher frequency neighbors than for the words with higher frequency neighbors where the highest frequency neighbor was not a word-body neighbor, $F_s < 1$; $F_i(1, 45) = 1.04$, $p > .30$, $MSE = 1{,}185.05$.

In the analysis of the spillover variables (Table 19), for the low-frequency words, there was a significant main effect of neighborhood frequency condition in the total time spent on the target word in the subject analysis, $F_s(2, 78) = 4.40$, $p < .05$, $MSE =$ 3,303.79; $F_i < 1$. Participants spent less time on the words with higher frequency neighbors where the highest frequency neighbor was a word-body neighbor, but this difference was not significant (both F's < 1). There was a significant difference in the total time spent on the target words with higher frequency neighbors with (281 ms) and without (317 ms) a word-body neighbor as a highest frequency neighbor, $F_s(2, 78) =$ 7.19, $p < .05$, $MSE = 3{,}590.21$; $F_i(1, 26) = 1.53$, $p > .20$, $MSE = 3{,}853.87$. Participants spent 29 ms longer on the words where the highest frequency neighbor was not a word-body neighbor compared to words without higher frequency neighbors, $F_s(2, 78) = 5.24$, $p < .05$, $MSE = 3{,}209.71$; $F_i(1, 41) = 1.53$, $p > .20$, $MSE = 4{,}395.14$.There were no significant effects of neighborhood frequency condition for the medium-frequency words (all p's > .15).

In the percentage of regressions to the target word, there were significant effects of neighborhood frequency condition for the low-frequency words (all p's > .15). For the medium-frequency words, the main effect of neighborhood frequency condition was significant in the subject analysis, $F_s(2, 78) = 3.36$, $p < .05$, $MSE = 162.67$; $F_i < 1$. There was no significant difference in the percentage of trials where participants' regressed to the target word between words with no higher frequency neighbors and words with a higher frequency neighbor where the highest frequency neighbor was a word-body neighbor, $F_s(1, 39) = 1.11$, $p > .25$, $MSE = 193.71$; $F_i < 1$. When the target words had higher frequency neighbors, there were more regressions when the highest frequency neighbor was a word-body neighbor than when it was not (16.0% vs. 9.0%), $F_s(1, 39) = 5.13, p < .05, MSE = 212.33$; $F_i(1, 27) = 2.15, p > .15, MSE = 83.50$. Participants regressed less often to the target word in trials when the target word had higher frequency neighbor where the highest frequency neighbor was not a word-body neighbor (9.0%) than when the target word had no higher frequency neighbors (13.1%), $F_s(1, 39) = 2.03, p = .05, MSE = 81.97$; $F_i < 1$. No effects of neighborhood frequency condition were observed in any of the other spillover measures (all p's > .10).

There were no significant effects in the analyses of the first fixation after leaving the target word or in the total time spent on the target word and the immediate post-target region (all p's > .10).

Low vs. high percentage of regressions. A median split was performed on the percentage of trials where participants regressed to the target word (median = 12.9%, range = 0% to 28.3%), creating a low percent regression group (M = 7.3%) and a high percent regression group (M = 19.3%), $F_s(1, 38) = 70.65, p < .001, MSE = 20.29$. Perea and Pollatsek (1998) found a significant inhibitory effect of neighborhood frequency for their participants that made fewer regressions in the gaze duration data and in the duration of the first fixation after leaving the target word. They also found that both groups showed an inhibitory neighborhood frequency effect in the percentage of regressions to the target word.

In the analysis of the percentage of target words initially skipped, there were no significant effects for the group with fewer regressions (all p's > .15). For the group that made more regressions, the low-frequency words were skipped more often than the medium-frequency words (20.9% vs. 16.0%), $F_s(1, 19) = 6.10, p < .05, MSE = 77.18$; $F_i(1, 84) = 9.91, p < .01, MSE = 203.44$. No other effects were significant (all F's < 1).

In the first fixation duration analysis, for the participants that made fewer regressions, the main effect of word frequency was not significant (both F's < 1). The main effect of neighborhood frequency was significant, $F_s(1, 19) = 6.63, p < .05, MSE = 398.53$; $F_i(1, 111) = 2.31, p > .10, MSE = 1{,}085.69$. The first fixation durations for words with higher frequency neighbors were 12 ms shorter than the first fixation durations for words without higher frequency neighbors. The interaction between word frequency and neighborhood frequency was not significant (both F's < 1). For the participants that made more regressions, there were no significant effects on the first fixation durations (all p's > .15).

In the gaze duration analysis, there were no significant effects for the participants that made fewer regressions (all p's > .15). For the participants that made more regressions, only the main effect of word frequency was significant, $F_s(1, 19) = 5.19, p < .05, MSE = 569.65$; $F_i < 1$. The main effect of neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 19) = 4.03, p = .059, MSE = 685.09$; $F_i < 1$, as the gaze durations for words with higher frequency neighbors were 11 ms longer than the gaze durations for the words without higher frequency neighbors. The interaction between word frequency and neighborhood frequency was not significant (both F's < 1).

In the analysis of the total time spent on the target word, for the group that made fewer regressions, the main effect of word frequency was marginally significant in the subject analysis, $F_s(1, 19) = 3.78, p = .067, MSE = 869.96$; $F_i(1, 111) = 2.51, p > .10$, $MSE = 3{,}831.99$. The main effect of neighborhood frequency was not significant (both

F's < 1), but the interaction between word frequency and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 19) = 3.53$, $p = .076$, $MSE = 1{,}029.00$; $F_i < 1$. For the low-frequency words, there was no effect of neighborhood frequency, $F_s(1, 19) = 1.30$, $p > .25$, $MSE = 911.21$; $F_i < 1$. For the medium-frequency words, participants in this group spent an average of 16 ms less time on the words with higher frequency neighbors than on the words without higher frequency neighbors, $F_s(1, 19) = 4.62$, $p < .05$, $MSE = 556.73$; $F_i < 1$. For the participants that made more regressions, there was also a main effect of word frequency in the subject analysis, $F_s(1, 19) = 12.10$, $p < .01$, $MSE = 1{,}081.17$; $F_i(1, 111) = 2.23$, $p > .10$, $MSE = 5{,}384.13$, but no effect of neighborhood frequency, and no interaction (all F's < 1).

In the analysis of the first fixation duration after leaving the target word, there were no significant effects for either group (all p's > .10).

For the participants that made fewer regressions, in the analysis of the total time spent on the target word and the immediate post-target region, there was no effect of word frequency (both F's < 1). There was a significant main effect of neighborhood frequency in the subject analysis, $F_s(1, 19) = 9.35$, $p < .01$, $MSE = 1{,}962.51$; $F_i(1, 111) = 2.76$, $p > .10$, $MSE = 13{,}947.79$. Participants spent 30 ms less time on the words with higher frequency neighbors than on the words without higher frequency neighbors. The interaction between word frequency and neighborhood frequency was not significant (both F's < 1). For the participants that made more regressions, there were no significant effects (all p's > .15).

In the analysis of the percentage of regressions, there were no significant effects for either group (all p's > .15).[27]

Effect of reader skill. A median split on the ART scores (median = 14, range = 3 to 26), created a low ART group ($M = 9.1$) and a high ART group ($M = 18.5$), $F_s(1, 38) = 68.77$, $p < .001$, $MSE = 12.77$. A median spilt on the reading rate scores (median = 204, range = 183 to 244), created a low reading rate group ($M = 194.7$) and a high reading rate group ($M = 216.7$), $F_s(1, 38) = 68.63$, $p < .001$, $MSE = 68.78$. The two measures of reader skill were significantly correlated, $r(40) = .43$, $p < .01$.

The high ART group regressed more often to the target word than the low ART group (16.4% vs. 11.0%), $F_s(1, 38) = 5.36$, $p < .05$, $MSE = 203.37$; $F_i(1, 222) = 6.83$, $p < .05$, $MSE = 254.50$. The group with lower reading rate scores did not regress to the target more often than the group with the higher reading rate scores (13.9% vs. 12.8%; both F's < 1). Thus, only the ART analysis appears to be consistent with the low vs. high regression analysis in that it the two groups differed in their percentage of regressions.

In the analysis of the percentage of target words skipped, the main effect of ART group was not significant (both F's < 1). The interaction between ART group and word frequency was significant in the subject analysis, $F_s(1, 38) = 4.81$, $p < .05$, $MSE = 88.41$; $F_i < 1$. As can be seen in Table 20, the low ART group did not skip the low-frequency words any more often than the medium-frequency words (both F's < 1), whereas the high ART group did skip the low-frequency words more often than the medium-frequency words (22.6% vs. 16.6%), $F_s(1, 18) = 6.42$, $p < .05$, $MSE = 103.06$; $F_i(1, 111) = 1.30$, $p > .25$, $MSE = 210.35$. No other effects were statistically significant (all p's $> .25$). In the reading rate analysis, there were no significant effects (all p's $> .10$).

In the analysis of the first fixation durations, the only significant effect was the main effect of ART group, which was significant in the item analysis, but not the subject analysis, $F_s(1, 38) = 1.11$, $p > .25$, $MSE = 3{,}388.45$; $F_i(1, 222) = 9.24$, $p < .01$, $MSE =$ 1,009.99. The low ART group fixated longer than the high ART group (224 ms vs. 214 ms). There was a significant effect of reading rate group in the item analysis of the first fixation duration data, $F_s(1, 38) = 3.67$, $p = .063$, $MSE = 3{,}179.92$; $F_i(1, 222) = 16.43$, $p <$ .001, $MSE = 1{,}249.91$. The participants with lower reading rate scores fixated 17 ms longer than the participants with higher reading rate scores. There was no main effect of word frequency and no interaction between word frequency and reading rate group (both F's < 1). The main effect of neighborhood frequency and the interaction between neighborhood frequency and reading rate group both approached significance in the subject analysis, $F_s(1, 38) = 3.66$, $p = .063$, $MSE = 449.23$; $F_i(1, 222) = 1.41$, $p > .20$, $MSE = 1{,}249.91$ and $F_s(1, 38) = 2.90$, $p = .097$, $MSE = 662.41$; $F_i(1, 222) = 1.39$, $p > .20$, $MSE = 1{,}249.91$, respectively. The participants with lower reading rate scores showed a 13 ms facilitatory effect of neighborhood frequency, $F_s(1, 16) = 4.37$, $p = .058$, $MSE =$ 584.14; $F_i(1, 111) = 2.21$, $p > .10$, $MSE = 1{,}581.00$. There was no effect of neighborhood frequency for the participants with higher reading rate scores (both F's < 1). No other effects were significant (all p's > .10).

In the analysis of the gaze duration data, there was a main effect of ART group, $F_s(1, 38) = 4.21$, $p < .05$, $MSE = 6{,}603.07$; $F_i(1, 222) = 23.78$, $p < .001$, $MSE = 2{,}097.48$. The gaze durations of participants in the low ART group were 26 ms longer than the gaze durations of participants in the high ART group. The main effect of word frequency was significant, $F_s(1, 38) = 5.25$, $p < .05$, $MSE = 626.60$; $F_i(1, 222) = 3.29$, $p = .071$, $MSE =$ 2,097.48, but the interaction between group and word frequency was not, $F_s(1, 38) =$ 1.13, $p > .25$, $MSE = 626.60$; $F_i(1, 222) = 1.54$, $p > .20$, $MSE = 2{,}097.48$. No other effects were significant (all p's > .20). There was a significant effect of reading rate on the gaze duration data, $F_s(1, 38) = 6.64, p < .05, MSE = 6{,}242.88$; $F_i(1, 222) = 37.41, p < .001$, $MSE = 2{,}501.31$, as the gaze durations of the participants with lower reading rate scores were 32 ms longer than the gaze durations of the participants with high reading rate scores. There was also an effect of word frequency, $F_s(1, 38) = 5.52, p < .05, MSE = 642.80$; $F_i(1, 222) = 3.26, p = .072, MSE = 2501.31$. The only other effect to approach significance was the three-way interaction between reading rate group, word frequency, and neighborhood frequency in the subject analysis, $F_s(1, 38) = 3.15, p = .084, MSE = 1{,}147.97$; $F_i(1, 222) = 1.14, p > .25, MSE = 2{,}501.31$.

The measures of spillover effects for the low ART group and the high ART group are listed in Table 21. There was a main effect of ART group in the item analysis of the total time spent on the target word (290 ms for the low ART group and 269 ms for the high ART group), $F_s(1, 38) = 1.42, p > .20, MSE = 9023.54$; $F_i(1, 222) = 5.81, p < .05$, $MSE = 4{,}166.58$. The main effect of word frequency was also significant, $F_s(1, 38) = 14.37, p < .01, MSE = 1{,}003.78$; $F_i(1, 222) = 5.58, p < .05, MSE = 4{,}166.58$. No other effects were significant (all p's > .20). Reading rate had an effect on the total time spent on the target word, $F_s(1, 38) = 9.88, p < .01, MSE = 7{,}428.33$; $F_i(1, 222) = 26.08, p < .001, MSE = 5{,}084.54$. Participants with lower reading rate scores spent longer on the target words than participants with higher reading rate scores (268 ms vs. 236 ms). Again the effect of word frequency was significant, $F_s(1, 38) = 16.04, p < .001, MSE = 982.86$; $F_i(1, 222) = 4.07, p < .05, MSE = 5{,}084.54$, but no other effects were significant (all p's > .20).

In the analysis of the duration of the first fixation after leaving the target word, there was a significant effect of ART group in the item analysis (228 ms for the low ART group and 218 ms for the high ART group), $F_s < 1$; $F_i(1, 222) = 6.04$, $p < .05$, $MSE =$ 954.45. The group by neighborhood frequency interaction was significant, $F_s(1, 38) =$ 7.51, $p < .01$, $MSE = 432.21$; $F_i(1, 222) = 4.66$, $p < .05$, $MSE = 954.45$. For the low ART group, fixation durations to words with higher frequency neighbors were 11 ms faster than the fixations to words without higher frequency neighbors, $F_s(1, 20) = 4.74$, $p < .05$, $MSE = 490.13$; $F_i(1, 111) = 3.19$, $p = .077$, $MSE = 1{,}025.49$. There was no effect of neighborhood frequency for the high ART group, $F_s(1, 18) = 2.92$, $p > .10$, $MSE =$ 372.08; $F_i(1, 111) = 1.56$, $p > .20$, $MSE = 883.41$. No other effects were significant (all F's < 1). There was a significant effect of reading rate on the next fixation after the target word, $F_s(1, 38) = 7.16$, $p < .05$, $MSE = 3{,}386.62$; $F_i(1, 222) = 23.46$, $p < .001$, $MSE =$ 1,178.64. Participants with lower reading rate scores fixated on average 26 ms longer than the participants with higher reading rate scores. The effect of word frequency was significant in the item analysis, $F_s(1, 38) = 2.09$, $p > .15$, $MSE = 554.53$; $F_i(1, 222) =$ 4.06, $p < .05$, $MSE = 1{,}178.64$. There was also a significant interaction between word frequency and reading rate group, $F_s(1, 38) = 4.56$, $p < .05$, $MSE = 554.53$; $F_i(1, 222) =$ 4.09, $p < .05$, $MSE = 1{,}178.64$. This was due to a marginally significant effect of word frequency for the participants with lower reading rate scores, $F_s(1, 16) = 3.28$, $p = .089$, $MSE = 941.23$; $F_i(1, 111) = 5.54$, $p < .05$, $MSE = 1{,}733.80$, but no effect of word frequency for participants with higher reading rate scores (both F's < 1). The main effect of neighborhood frequency was not significant (both F's < 1) but there was an interaction between reading rate group and neighborhood frequency, $F_s(1, 38) = 4.49$, $p < .05$, MSE

$= 465.11$; $F_i(1, 222) = 3.73$, $p = .055$, $MSE = 1{,}178.64$. Unfortunately, the effect of neighborhood frequency was not significant for either reading rate group (all p's $> .15$). No other effects were significant (all F's < 1).

In the analysis of the total time spent on the target word and the immediate post-target region, the main effect of ART group was not significant, $F_s(1, 38) = 2.46$, $p > .10$, $MSE = 44{,}523.06$; $F_i(1, 222) = 9.66$, $p < .01$, $MSE = 17{,}110.76$, nor were any of the other effects (all p's $> .10$). The participants with lower reading rate scores spent more time on the target word and the immediate post-target region (691 ms vs. 576 ms), $F_s(1, 38) = 15.35$, $p < .001$, $MSE = 33{,}764.50$; $F_i(1, 222) = 57.38$, $p < .001$, $MSE = 18{,}449.69$. The effect of word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.18$, $p = .083$, $MSE = 3{,}538.97$; $F_i(1, 222) = 1.09$, $p > .25$, $MSE = 18{,}449.69$, but no other effects were significant (all p's $> .15$).

In the analysis of the regressions, the high ART group regressed more often to the target word than the low ART group (16.4% vs. 11.0%), $F_s(1, 38) = 5.36$, $p < .05$, $MSE = 203.37$; $F_i(1, 222) = 6.83$, $p < .05$, $MSE = 254.50$, but no other effects were significant (all p's $> .20$). For the reading rate analysis, the only effect to approach significance was the interaction between reading rate group and neighborhood frequency, $F_s(1, 38) = 2.95$, $p = .094$, $MSE = 106.33$; $F_i(1, 222) = 1.44$, $p > .20$, $MSE = 271.35$.[28, 29, 30]

Discussion

Recall that simulations using the multiple read-out model (Grainger & Jacobs, 1996) predicted that an inhibitory neighborhood frequency effect should occur for both sets of stimuli used in Experiment 3 (see Table 2). As a result, clear evidence of this effect should have been observed in the present experiments.

In Experiment 3A, there was a significant inhibitory effect of neighborhood frequency in the percentage of target words skipped, as words with higher frequency neighbors were skipped less often than words without higher frequency neighbors (13.3% vs. 16.8%), but the other first pass measures showed no effect of neighborhood frequency, nor did any of the spillover variables. In Experiment 3B, no effects on neighborhood frequency were observed in either the first pass variables or in the spillover variables. Taken together, the results of Experiment 3 lend little support to the idea that inhibitory competition is a fundamental component of visual word identification.

Experiment 3B also offered an opportunity to again examine the role of word-body neighbors in the process of identification of English words. In this experiment, and in contrast to the results of Experiment 2, higher frequency word-body neighbors provided facilitation in word identification, which directly challenges the assumption of competitive activation of activation-based models.

The possibility that the neighborhood frequency effect could be modulated by reader skill was explored in two ways. First, Perea and Pollatsek's (1998) analysis, in which participants were divided into two groups based on the overall percentage of trials they regressed to the target word, creating a low regression group and a high regression group, was replicated. Perea and Pollatsek found significant inhibitory neighborhood frequency effects for both groups in the percentage of regressions to the target words, and, for the participants that made fewer regressions, in the gaze durations and first fixation durations following the target word.

In Experiment 3A, the participants that made fewer regressions skipped the medium-frequency words with higher frequency neighbors less often than the medium-frequency words without higher frequency neighbors. Participants in this group also spent longer on the low-frequency words with higher frequency neighbors than the low-frequency words without higher frequency neighbors in terms of the total time spent on the target word. There were no significant effects of neighborhood frequency for the participants that made more regressions. Although not an exact replication, overall these results generally confirm those of Perea and Pollatsek (1998): participants who made fewer regressions during the experiment were more likely to exhibit inhibitory neighborhood frequency effects on the eye monitoring measures.

In Experiment 3B, in contrast, participants that made fewer regressions spent less time on the words with higher frequency neighbors than on the words without higher frequency neighbors in both the first fixation durations, and the total time spent on the target word and immediate post-target region. This group also spent less time on the medium-frequency target words that had higher frequency neighbors than the medium-frequency targets without higher frequency neighbors. For the participants that made more regressions, there were no significant effects of neighborhood frequency. These results are exactly the opposite of those of Experiment 3A: participants that made fewer regressions during the experiment were more likely to exhibit facilitatory neighborhood frequency effects.

The associations between reader skill and neighborhood frequency were also assessed by administering two measures of reader skill (the ART and the reading rate test of the Nelson-Denny Comprehension Test). This allowed an assessment of reader skill independent of word recognition performance. Median splits were conducted on both the ART scores and the reading rate scores, creating a low ART group and a high ART group, and a low reading rate group and a high reading rate group. In Experiment 3A, for the high ART group, there was an increase in the total time spent on target words and the immediate post-target region when the words had higher frequency neighbors relative to when they did not have. In Experiment 3B, for the low ART group, the duration of the first fixation following the target word was shorter for the words with higher frequency neighbors than for the words without higher frequency neighbors. In the reading rate analysis, there was a facilitatory neighborhood frequency effect in the first fixations of the participants with lower reading rate scores.

Together these results suggest that, in Experiment 3A, for participants that scored higher on standardized measures of reading proficiency, any effect of neighborhood frequency was likely to be inhibitory, whereas in Experiment 3B, for the participants that scored lower on these measures, any effect of neighborhood frequency was likely to be facilitatory.

Are the regression split and the reader skill analyses measuring the same thing? In Experiment 3A, neither the ART groups, nor the reading rate groups differed in the percentage of regressions to the target words. In Experiment 3B, the high ART group regressed more often than the low ART group, but the two reading rate groups did not differ in the percentage of regressions to the target word. Overall, it seems that the regression split and the reader skill analyses are measuring different aspects of reader skill. It is also possible that the percentage of regressions participants make is not related to reader skill.

General Discussion

The goal of the present research was to re-examine the question of whether inhibitory neighborhood frequency effects occur in English, and, in doing so, to re-evaluate its implications for activation-based models of lexical selection (Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981; Paap, Newsome, McDonald, & Schvandevelt, 1982).

As noted, Perea and Pollatsek's (1998) study is the only clear demonstration of an inhibitory neighborhood frequency effect in English. Perea and Pollatsek used a lexical decision task and a reading task to investigate neighborhood frequency effects. They modified the lexical decision instructions to stress accuracy over speed, and they obtained an inhibitory effect of neighborhood frequency, but only for words very low in frequency (i.e., Kucera and Francis normative frequencies < 10). The purpose of the present Experiment 1 was to replicate Perea and Pollatsek's results, and also to evaluate the influence that the lexical decision instructions could have had in the Perea and Pollatsek study. In Experiment 1, there was an inhibitory neighborhood frequency effect, but only when Perea and Pollatsek's modified lexical decision instructions were used.

The discrepancy in the results of Experiment 1 were further explored in Experiment 2, using a different set of stimuli. Again, the lexical decision instructions influenced the results, but in a qualitatively different manner. In Experiment 2A (standard instructions), a facilitatory neighborhood frequency effect was found for the low-frequency words, and in Experiment 2B, there was no inhibitory or facilitatory effect of neighborhood frequency (except for the error rates for the medium-frequency words, where there was a small and unreliable inhibitory effect).

In the end, in only one of the four lexical decision experiments was an inhibitory neighborhood effect observed (Experiment 1B, slow lexical decision instructions). The effect, therefore, appears to depend critically on the stimuli used and on the type of lexical decision instructions. Specifically, an inhibitory neighborhood frequency effect was observed only for Perea and Pollatsek's (1998) low-frequency words and only when the instructions emphasized accuracy over speed. Consequently, the significance of Perea and Pollatsek's (1998) result (an inhibitory neighborhood frequency effect for the processing of English words) is questionable. With these stimuli and under these conditions, participants may have adopted a more cautious decision-making strategy that may have had a large impact on the responses to the low-frequency words with higher frequency neighbors.

Experiment 3A was a replication of Perea and Pollatsek's (1998) Experiment 2. Recall that they found no effects of neighborhood frequency in their participants' first pass eye movement measures. As a result, Perea and Pollatsek concluded that a word's higher frequency neighbors affect lexical selection only after the reader has left the word. Indeed, they found an inhibitory effect of neighborhood frequency in two of their spillover effects: namely, 1) the probability of regressing back to the target word, and 2) the duration of the first fixation after leaving the target word. In contrast to Perea and Pollatsek's findings, there were no inhibitory neighborhood frequency effects on any of the eye movement measures in Experiment 3A. There was, however, an inhibitory neighborhood frequency effect in the percentage of target words that were initially skipped by readers. In Experiment 3B, a new set of stimuli was used and there were again no effects of neighborhood frequency on any of the eye movement measures.

In Perea and Pollatsek's (1998) Experiment 2, they found that the presence of higher frequency neighbors resulted in more regressions to the words with higher frequency neighbors than to words without higher frequency neighbors. There was an inhibitory neighborhood frequency effect in the gaze durations of the group that made fewer regressions, and an unreliable facilitatory effect for the group that made more regressions. They suggested that, at least for some readers (i.e., those that made more regressions) inhibitory neighborhood frequency effects may be delayed, whereas for other readers (i.e., those that make fewer regressions) the effects can be found relatively early in lexical processing. Perea and Pollatsek used the E-Z Reader model of eye movement control (Reichle et al., 1998) to explain this finding. The model consists of two stages: a familiarity check stage and a lexical completion stage. The total lexical selection time for the two groups remains constant. The group that made more regressions would have a shorter familiarity check stage and a longer lexical completion stage than the group with fewer regressions. In the model, the signal to move the eyes occurs when the total excitation of the lexicon reaches a threshold. For the group that made more regressions, this threshold would be lower and inhibitory effects would be difficult to detect (e.g., recall that an unreliable facilitatory effect was obtained for this group).

As in Perea and Pollatsek (1998), the participants in Experiment 3 were divided into two groups based on the overall percentage of trials where they regressed to the target word, creating a low regression group and a high regression group. In Experiment 3A, the effect of higher frequency neighbors tended to be inhibitory for the participants that made fewer regressions, and had no significant effects on the eye movements of the participants that made more regressions. For the group that made fewer regressions, higher frequency neighbors had a inhibitory effect on the percent of target words skipped. Also for this group, the total time spent on the target word was longer for the low-frequency words with higher frequency neighbors than for the words without higher frequency neighbors. In Experiment 3B, there was an opposite effect of neighborhood frequency for the group that made fewer regressions to the target word. In this experiment, this group showed a facilitatory neighborhood frequency effect for the first fixation durations, total time spent on the target word (for the medium-frequency words only), and total time spent on the target word and immediate post-target region. For the high regression group, there were again no significant effects.

The results of Experiment 3A are similar to Perea and Pollatsek's (1998) results. However, the results of Experiment 3B are not consistent with either Experiment 3A or Perea and Pollatsek. The implications of the results of Experiment 3B for the E-Z Reader model are unknown and are beyond the scope of this discussion.

To further explore the role of reader skill, two measures of reader skill were used. The ART was used in each experiment to measure participants' exposure to print and Form G of the Nelson-Denny Comprehension Test was used in Experiment 3 to provide a measure of each participant's reading rate. For the most part, reader skill did not modulate the effect of neighborhood frequency, except for two small effects in Experiment 3. In Experiment 3A, the participants who scored higher on the ART showed an inhibitory neighborhood frequency effect in the total time spent on the target word and the immediate post-target region. In Experiment 3B, there was a facilitatory neighborhood frequency effect on the duration of the first fixation following the target word, but only for participants in the low ART group. For the group with lower Nelson-Denny reading rate scores, there was also a facilitatory effect of neighborhood frequency on first fixation durations.

Taken together, the results of the present experiments are problematic for activation-based models of lexical selection (Forster, 1976; Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981; Paap, Newsome, McDonald, & Schvandevelt, 1982). These models assume that identification of words with higher frequency neighbors should be delayed due to competitive inhibition. Indeed, simulations using Grainger and Jacobs' (1996) multiple read-out model predicted that an inhibitory neighborhood frequency effect should occur in each experiment, however, as shown above the effect was not consistently found. The results from the reader skill analyses are no more than suggestive at this stage of research, and a great deal more attention to this issue will be required before its impact can be properly assessed.

Implications for Other Models of Word Recognition

Simulations using the Seidenberg and McClelland's (1989) and the Plaut et al. (1996) PDP models were completed to examine their predictions with regard to the presence of higher frequency neighbors. In these models, lexical representations are embodied in the pattern of activation across an interconnected network of units, instead of in single word units like the multiple read-out model (Grainger & Jacobs, 1996) and the interactive-activation model (McClelland & Rumelhart, 1981). Recently, Sears, Hino, and Lupker (1999) found that with the models' full corpi, for low-frequency words the presence of higher frequency neighbors should be beneficial to processing. They also examined the stimuli from Perea and Pollatsek's (1998) study and found that the

Seidenberg and McClelland model would predict an overall inhibitory neighborhood frequency effect.

The present simulations using the PDP model of Seidenberg and McClelland (1989) predicted that a word frequency effect, but not a neighborhood frequency effect should occur for the stimuli in Experiments 1 and 3A (see Table 3). For the stimuli in Experiments 2 and 3B, the model predicted an effect of word frequency, no effect of neighborhood frequency in the orthographic error scores, and a small unreliable inhibitory neighborhood frequency effect for the medium-frequency words. Simulations using the Plaut et al. (1996) model predicted that a word frequency effect, but not a neighborhood frequency effect, should occur for the stimuli in Experiments 1 and 3A. In Experiments 2 and 3B, the model again predicted that a word frequency effect should occur, but this time it also predicted an inhibitory effect of neighborhood frequency for the low-frequency words. Overall, the Seidenberg and McClelland (1989) model was better able to account for the behavioral data.

The results of the PDP simulations should be interpreted with caution for two reasons. One, the results are based on a restricted stimulus set. The Seidenberg and McClelland (1989) model was trained with only 51% of the stimuli. The Plaut et al. (1996) model was trained with only 48% of the stimuli. Two, as Sears et al. (1999) pointed out, the predictions of these models with respect to the effects a word's orthographic neighbors must be established if these models are to be regarded as providing a superior account of the word identification process.

Future Research

There may be important language differences in the role competitive inhibition plays in orthographic processing. It is becoming clear that there are strong effects of inhibition in languages such as French, Spanish, and Dutch (Carreiras, et al. 1997; Grainger, 1990; Grainger & Jacobs, 1996; Grainger et al., 1989; Grainger & Segui, 1990; Jacobs & Grainger, 1992; van Heuven et al., 1998) but not in English (Forster & Shen, 1996; Sears, Hino, et al., 1995, 1999; Sears, Lupker, et al. 1999; Siakaluk et al., 2002). One explanation for this language difference is that, in English, word-body neighbors (i.e., orthographic rimes) may play a special role in regularizing the inconsistent relationship between orthography and phonology (Andrews, 1997; Ziegler & Perry, 1998; Trieman et al., 1995).

In their examination of the neighborhood size effect (i.e., the finding that words with many neighbors are responded to more rapidly than words with few neighbors; see Andrews, 1997, for a review), Ziegler and Perry (1998) found a facilitatory effect of word-body neighbors in a lexical decision task: responses to words with many word-body neighbors were faster than responses to words with few body neighbors. Facilitatory neighborhood frequency effects for English words could arise in a similar fashion. That is, for English words, the higher frequency neighbors of a word are frequently word-body neighbors. Because those word-body neighbors are high frequency, they may have a strong influence on word identification processes.

To test this hypothesis, the target words with higher frequency neighbors from Experiment 2 and Experiment 3B were divided into two groups: 1) those that have a word-body neighbor as their highest frequency neighbor, and 2) those who did not have a higher frequency word-body neighbor. In the lexical decision task, words with a higher frequency word-body neighbor were responded to more slowly than words without higher frequency neighbors (for the medium-frequency words only). In the reading task, however, reading latencies were facilitated by the presence of a higher frequency word-body neighbor.

These contrasting findings are puzzling. The reading task is probably more indicative of true lexical processing than the lexical decision task, as it has already been established that the lexical decision task is sensitive to decision-making strategies (see Andrews, 1997). Further studies that control for and/or factorially manipulate the word frequency of the word-body neighbor and body neighborhood size (Ziegler & Perry, 1998) of the target words are necessary before any concrete explanation can be made.

There was an inhibitory neighborhood frequency effect for words with higher frequency neighbors where the highest frequency neighbor was not a word-body neighbor. Assuming that the reading task closely approximates true lexical selection processes, this effect may partly explain the discrepancies in the results of Perea and Pollatsek's (1998) Experiment 2 and the results of the current Experiment 3B. Perea and Pollatsek found an inhibitory neighborhood frequency effect in the total time on the target word and in the percentage of regressions to the target words. Recall that an investigation of the role that higher frequency word-body neighbors play in the identification of English words was not possible for these stimuli. In Experiment 3B there were words with and without higher frequency word-body neighbors. There were no effects of neighborhood frequency in this experiment. Thus, the presence of higher frequency word-body neighbors could have supplied sufficient facilitation to nullify any inhibitory effects.

Is the effect of higher frequency word-body neighbors orthographic or phonological? In the present experiments, all but four of the word-body neighbors were phonologically consistent with the target word. A test of whether or not the effect is due to the similarity in spelling patterns or due to shared phonology was not possible for these stimuli. Again, in order to draw any concrete conclusions, further research should explore the difference between higher frequency neighbors that are word-body neighbors and higher frequency neighbors that do not share the same orthographic rime as the target word.

Endnotes

[1] The words removed from Perea and Pollatsek's (1998) analysis because of their high error rates (33% or more) were *lasso*, *noose*, *verve*, and *villa*. In Experiment 1A, the error rates for lasso, noose, verve, and villa were 57%, 22%, 62%, and 45%, respectively. In Experiment 1B the error rates were 52%, 31%, 44%, and 34%, respectively.

[2] There is a substantial body of research that has shown that response latencies to homophones are delayed relative to matched control words (e.g., Pexman & Lupker, 1999; Pexman, Lupker, & Jared, 2001; Pexman, Lupker, & Reggin, 2002). As such, *bread*, *draft*, *flair*, *flour*, *flyer*, *horde*, *manor*, *mayor*, *medal*, *miner*, *route*, *waist*, and *whale* were removed from the analyses. The simulation results excluding these stimuli were as follows.

Simulations using the multiple read-out model (Grainger & Jacobs, 1996) revealed a significant effect of neighborhood frequency $F_i(1, 71) = 42.26$, $p < .001$, $MSE = 1.34$. Words with higher frequency neighbors required on average 1.76 more processing cycles than words without higher frequency neighbors (18.10 vs. 16.34). The main effect of word frequency was not significant, $F_i < 1$, nor was the interaction between word frequency and neighborhood frequency, $F_i < 1$.

The mean Seidenberg and McClelland (1989) orthographic error scores for the low-frequency words were substantially larger than the error scores for the medium-frequency words (11.4 vs. 7.0), $F_i(1, 35) = 12.28$, $p < .01$, $MSE = 13.26$. Both the neighborhood frequency effect and the interaction between word frequency and neighborhood frequency were not significant (both p's > .15). There was also a word frequency effect in the phonological error scores, with the low-frequency words having larger error scores than the medium-frequency error scores (6.64 vs. 4.29). As in the orthographic error scores, neither the effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency was significant (both F's < 1). When the low-frequency and the medium-frequency words were analyzed separately, however, only the medium-frequency words showed a marginally significant effect of neighborhood frequency, $F_i(1, 18) = 3.24$, $p = .089$, $MSE = 1.13$. This was a facilitatory effect as the average phonological error score for the words with higher frequency neighbors was lower than the error score for the words without higher frequency neighbors.

The mean Plaut et al. (1996) cross-entropy error scores for the low-frequency words (.081) were significantly higher than the error scores of the medium-frequency words (.044), $F_i(1, 35) = 6.58$, $p < .05$, $MSE = .00$. Neither the effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency were significant (both F's < 1). When the low-frequency words were analyzed separately, the mean error score for the words with higher frequency neighbors (.085) was higher than for the words without higher frequency neighbors (.077), but this effect was not significant, $F_i < 1$. The neighborhood frequency effect was also not significant for the medium-frequency words alone, $F_i < 1$, as the mean cross-entropy error score for the words with higher frequency neighbors (.043) was comparable to the mean error score for the words without higher frequency neighbors (.046).

3 The data from Plaut et al.'s (1996) Simulation 3 was also examined for these stimuli. The Simulation 3 was a fully interactive recurrent network that generated settling times for items rather than error scores. In this simulation, after a word is presented to the

network, the unit activations eventually settle into a stable pattern representing the phonological output, with the settling times analogous to pronunciation latency. The mean Plaut et al. (1996) settling time for the low-frequency words (1.75) was not significantly different from the mean settling time for the medium-frequency words (1.73), $F_i < 1$. Neither the effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency were significant (both p's > .30). When the low-frequency words were analyzed separately, the mean settling time for the words with higher frequency neighbors (1.79) was higher than for the words without higher frequency neighbors (1.72), but this difference was not significant, $F_i < 1$. The neighborhood frequency effect was also not significant for the medium-frequency words alone, $F_i < 1$, as the mean settling time for the words with higher frequency neighbors (1.74) was very similar to the mean settling time for the words without higher frequency neighbors (1.73).

4 The effects of word frequency, neighborhood frequency, and the interaction between word frequency and neighborhood frequency for Plaut et al. (1996) Simulation 3 settling times were not significant when the homophones were removed from the analyses (all F's < 1).

5 The analyses with the homophones excluded were as follows. In the analysis of response latencies, the main effect of word frequency was significant, $F_s(1, 39) = 72.69$, $p < .001$, MSE =1,927.28; $F_i(1, 71) = 12.76$, $p < .01$, MSE = 4,660.79. Low-frequency words were responded to 59 ms slower than medium-frequency words. The main effect of neighborhood frequency was not significant, nor was the interaction between word frequency and neighborhood frequency (all F's < 1). For both the low-frequency words

and the medium-frequency words, responses to words with higher frequency neighbors were no slower than responses to words without higher frequency neighbors (all p's > .25). In the analysis of error rates, there was a main effect of word frequency in the subject analysis, $F_s(1, 39) = 21.13$, $p < .001$, $MSE = 21.10$; $F_i(1, 71) = 2.24$, $p > .10$, $MSE = 82.13$. The main effect of neighborhood frequency was significant in the subject analysis, $F_s(1, 39) = 13.66$, $p < .001$, $MSE = 11.45$; $F_i < 1$, but not the interaction between word frequency and neighborhood frequency (both F's < 1). The error rates to words with higher frequency neighbors were lower than the error rates to words without higher frequency neighbors (3.6% vs. 5.5 %). When the low-frequency words and the medium-frequency words were analyzed separately, however, only the latter showed a significant effect of neighborhood frequency, $F_s(1, 39) = 2.65$, $p > .10$, $MSE = 18.29$; $F_i < 1$, and $F_s(1, 39) = 11.87$, $p < .01$, $MSE = 9.72$; $F_i < 1$, respectively. Participants made less errors to the medium-frequency words with higher frequency neighbors than to the medium-frequency words without higher frequency neighbors (1.7% vs. 4.1%).

[6] The reader skill analyses excluding the homophones were as follows. In the analysis of the response latencies, the main effect of ART group was significant, $F_s(1, 38) = 9.07$, $p < .01$, $MSE = 21{,}278.68$; $F_i(1, 142) = 36.51$, $p < .001$, $MSE = 5{,}593.07$. On average, the low ART group responded 70 ms slower than the high ART group. The main effect of word frequency was significant, $F_s(1, 38) = 89.20$, $p < .001$, $MSE = 1{,}570.39$; $F_i(1, 142) = 22.74$, $p < .001$, $MSE = 5{,}593.07$, and in the subject analysis there was a significant interaction between word frequency and group, $F_s(1, 38) = 9.86$, $p < .01$, $MSE = 1{,}570.39$; $F_i(1, 142) = 2.62$, $p > .10$, $MSE = 5{,}593.07$. For the low ART group the word frequency effect was 79 ms, $F_s(1, 19) = 53.02$, $p < .001$, $MSE = 2{,}345.52$; $F_i(1, 71) =$

16.00, $p < .001$, $MSE = 7{,}136.57$. For the high ART group it was 40 ms, $F_s(1, 19) = 39.24$, $p < .001$, $MSE = 795.26$; $F_i(1, 71) = 6.85$, $p < .05$, $MSE = 4{,}049.57$. No other effects were significant (all p's > .25).

In the error rate analysis, the main effect of group was significant, $F_s(1, 38) = 15.68$, $p < .001$, $MSE = 24.68$; $F_i(1, 142) = 3.09$, $p = .081$, $MSE = 102.93$, with the low ART group making more errors than the high ART group (6.1% vs. 3.0%). Again, the effect of word frequency was significant, $F_s(1, 38) = 21.69$, $p < .001$, $MSE = 20.56$; $F_i(1, 142) = 3.58$, $p = .06$, $MSE = 102.93$, but not the interaction between group and word frequency, $F_s(1, 38) = 2.04$, $p > .15$, $MSE = 20.56$; $F_i < 1$. The main effect of neighborhood frequency was significant in the subject analysis, $F_s(1, 38) = 13.88$, $p < .01$, $MSE = 11.29$; $F_i(1, 142) = 1.18$, $p > .25$, $MSE = 102.93$, but the interaction between neighborhood frequency and group was not, $F_s(1, 38) = 1.64$, $p > .20$, $MSE = 11.29$; $F_i < 1$. Overall, errors were lower to words with higher frequency neighbors than to words without higher frequency neighbors (3.6% vs. 5.5%).

[7] With the homophones removed from the analyses, the results were as follows. There was a main effect of word frequency in the analysis of response latencies, $F_s(1, 39) = 119.39$, $p < .001$, $MSE = 1{,}083.80$; $F_i(1, 71) = 12.13$, $p < .01$, $MSE = 4{,}447.75$, as medium-frequency words were responded to 57 ms faster than low-frequency words. The main effect of neighborhood frequency was significant in the subject analysis, $F_s(1, 39) = 20.91$, $p < .001$, $MSE = 604.73$, but not in the item analysis, $F_i < 1$. The interaction between word frequency and neighborhood frequency was not significant, $F_s(1, 39) = 1.73$, $p > .15$, $MSE = 795.50$; $F_i < 1$. The neighborhood frequency effect was inhibitory for both the low-frequency words and the medium-frequency words. Responses to low-

frequency words with higher frequency neighbors were 24 ms slower than responses to low-frequency words without higher frequency neighbors, $F_s(1, 39) = 13.96$, $p < .01$, $MSE = 800.55$; $F_i(1, 41) = 1.49$, $p > .20$, $MSE = 4{,}629.06$. Responses to medium-frequency words with higher frequency neighbors were 12 ms slower than responses to medium-frequency words without higher frequency neighbors, $F_s(1, 39) = 4.74$, $p < .05$, $MSE = 599.69$; $F_i < 1$.

In the analysis of error rates, there was a main effect of word frequency in the subject analysis, $F_s(1, 39) = 10.33$, $p < .01$, $MSE = 22.55$; $F_i(1, 71) = 2.07$, $p > .15$, $MSE = 51.11$. The main effect of neighborhood frequency was not significant (both p's > .25), nor was the interaction between word frequency and neighborhood frequency, $F_s(1, 39) = 1.50$, $p > .20$, $MSE = 17.40$; $F_i < 1$.

[8] In the analysis of response latencies that excluded the homophones, the main effect of group was marginally significant, $F_s(1, 38) = 3.12$, $p = .085$, $MSE = 41{,}394.21$; $F_i(1, 142) = 22.73$, $p < .001$, $MSE = 5{,}113.05$, as the low ART group took longer to respond than the high ART group (641 ms vs. 585 ms). The main effect of word frequency was significant, $F_s(1, 38) = 116.66$, $p < .001$, $MSE = 1{,}109.16$; $F_i(1, 142) = 21.18$, $p < .001$, $MSE = 5{,}113.05$, as was the main effect of neighborhood frequency (in the subject analysis only), $F_s(1, 38) = 21.30$, $p < .001$, $MSE = 593.52$; $F_i(1, 142) = 1.51$, $p > .20$, $MSE = 5{,}113.05$. No other effect was significant (all p's > .15).

In the error rate analysis excluding homophones, the main effect of group was significant in the subject analysis, $F_s(1, 38) = 4.59$, $p < .05$, $MSE = 25.50$; $F_i(1, 142) = 1.85$, $p > .15$, $MSE = 57.39$, with the low ART group making significantly more errors than the high ART group (4.7% vs. 3.0%). Again, the effect of word frequency was significant $F_s(1, 38) = 10.32$, $p < .01$, $MSE = 22.54$; $F_i(1, 142) = 3.69$, $p = .057$, $MSE = 57.39$, but no other effects were statistically significant (all p's $> .20$).

9 In a combined analysis of Experiment 1A and 1B that excluded the homophones, for the response latencies to words, the main effect of experiment was not significant in the subject analysis, $F_s(1, 78) = 1.05$, $p > .30$, $MSE = 34{,}665.95$, but was marginally significant in the item analysis, $F_i(1, 142) = 3.01$, $p = .085$, $MSE = 4{,}554.27$. There was also a main effect of word frequency, $F_s(1, 78) = 178.92$, $p < .001$, $MSE = 1{,}505.54$; $F_i(1,142) = 24.89$, $p < .001$, $MSE = 4{,}554.27$, and a main effect of neighborhood frequency that was significant in the subject analysis, $F_s(1, 78) = 13.10$, $p < .01$, $MSE = 636.61$, but not in the item analysis, $F_i < 1$.

The only significant interaction was between experiment and neighborhood frequency, $F_s(1, 78) = 7.20$, $p < .01$, $MSE = 636.61$; $F_i < 1$, due to the fact, as noted, that there was an inhibitory effect of neighborhood frequency in Experiment 1B, but not in Experiment 1A.

In the error analysis, there was an effect of word frequency, $F_s(1, 78) = 30.33$, $p < .001$, $MSE = 21.80$; $F_i(1, 142) = 4.28$, $p < .05$, $MSE = 66.62$, and, in the subject analysis, a significant effect of neighborhood frequency, $F_s(1, 78) = 10.11$, $p < .01$, $MSE = 15.07$; $F_i < 1$. For the low-frequency words, as noted, there was no effect of neighborhood frequency in either experiment (all p's $> .20$). For the medium-frequency words, in both experiments words with higher frequency neighbors were responded to more accurately than words without higher frequency neighbors, producing an overall facilitatory effect, $F_s(1, 78) = 16.20$, $p < .001$, $MSE = 9.83$; $F_i < 1$. No other effects were statistically significant (all F's < 1).

[10] In the combined analysis of reader skill that excluded homophones, the main effect of experiment was significant in the item analysis, $F_s(1, 76) = 1.16, p > .25, MSE =$ 31,336.45; $F_i(1, 284) = 4.65, p < .05, MSE =$ 5,353.06. The interaction between group and experiment was not significant, $F_s < 1$; $F_i(1, 284) = 1.15, p > .25, MSE =$ 5,353.06. There was a main effect of group $F_s(1, 76) = 10.19, p < .01, MSE =$ 31,336.45; $F_i(1, 284) = 58.70, p < .001, MSE =$ 5,353.06, with the low ART group responding an average of 63 ms slower than the high ART group (631 ms vs. 568 ms). The main effect of word frequency was significant, $F_s(1, 76) = 201.06, p < .001, MSE =$ 1,339.78; $F_i(1, 284) = 43.93, p < .001, MSE =$ 5,353.06, but the interaction between word frequency and experiment was not (both F's < 1), as the overall word frequency effect in both experiments was very similar. The interaction between group and word frequency was significant in the subject analysis, $F_s(1, 76) = 4.81, p < .05, MSE =$ 1,339.78; $F_i < 1$, with a 68 ms word frequency effect for the low ART group and a 50 ms word frequency effect for the high ART group. In the subject analysis, there was a significant main effect of neighborhood frequency, $F_s(1, 76) = 13.07, p < .01, MSE = 637.94$; $F_i < 1$, and a significant interaction between experiment and neighborhood frequency, $F_s(1, 76) = 7.18, p < .01, MSE = 637.94$; $F_i(1, 284) = 1.28, p > .25, MSE =$ 5,353.06. The three-way interaction between experiment, group, and word frequency was also significant, $F_s(1, 76) = 6.84, p < .05, MSE =$ 1,339.78; $F_i(1, 284) = 2.16, p > .10, MSE =$ 5,353.06, reflecting the fact that the low ART group exhibited a larger word frequency effect than the high ART group in Experiment 1A, but not in Experiment 1B. No other effects were statistically significant (all p's > .10).

In the error rate analysis, there was a main effect of group, $F_s(1, 76) = 18.52, p < .001, MSE = 25.08$; $F_i(1, 284) = 4.94, p < .05, MSE = 80.16$, with the low ART group averaging 5.4% errors and the high ART group averaging 3.0% errors. Neither the main effect of experiment, nor the interaction between experiment and group were significant (all p's $> .15$). There was a main effect of word frequency, $F_s(1, 76) = 30.69, p < .001, MSE = 21.54$; $F_i(1, 284) = 7.11, p < .01, MSE = 80.16$, and a group by word frequency interaction that was marginally significant in the subject analysis, $F_s(1, 76) = 2.85, p = .096, MSE = 21.54$; $F_i < 1$, reflecting the fact that the effect for word frequency on error rates was larger for the low ART group than for the high ART group (3.8% vs. 2.0%). The effect of neighborhood frequency was also significant in the subject analysis, $F_s(1, 76) = 10.02, p < .01, MSE = 15.21$; $F_i(1, 284) = 1.54, p > .20, MSE = 80.16$. No other effects were significant (all p's $> .15$).

11 *Bred, farce, gown, mulch,* and *tote* were removed from the analyses. Bred, farce, mulch, and tote were removed because of their high error rates (30% or greater). In Experiment 2A, the error rates to these words were 32%, 32%, 20%, 50%, and 37%, respectively. In Experiment 2B, they were 39%, 37%, 18%, 57%, and 42%, respectively.

12 In Experiment 2 the homophones were also removed. The stimuli removed were: *gene, dense, pair, pour, reel, roam, scent, steel,* and *suite.* Simulations with the multiple read-out model (Grainger & Jacobs, 1996) indicated that the model predicts slower responses to the words with higher frequency neighbors. In this analysis there was a main effect of word frequency, $F_i(1, 102) = 21.98, p < .001, MSE = .22$, and of neighborhood frequency, $F_i(1, 102) = 84.64, p < .001, MSE = .22$, and a marginally significant interaction, $F_i(1, 102) = 3.11, p = .081, MSE = .22$. For both the low-frequency and the

medium-frequency words, words with higher frequency neighbors require more processing cycles to reach the M criterion than words without higher frequency neighbors, although this difference was slightly larger for the low-frequency words (1.0 cycles for the low-frequency words and 0.7 cycles for the medium-frequency words), $F_i(1, 48) = 40.45$, $p < .001$, $MSE = .30$, and $F_i(1, 54) = 45.66$, $p < .001$, $MSE = .14$, respectively. The model thus predicts that an inhibitory neighborhood frequency effect (and a word frequency effect) should occur in this experiment.

The mean Seidenberg and McClelland orthographic error scores for the low-frequency words (11.05) were significantly higher than those for the medium-frequency words (6.38), $F_i(1, 84) = 32.58$, $p < .001$, $MSE = 14.60$. Neither the effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency were significantly (both F's < 1). The neighborhood frequency effect was not significant when the low- and the medium-frequency words were analyzed separately (both F's < 1).

There was an effect of word frequency in the phonological error scores, $F_i(1, 84) = 18.35$, $p < .001$, $MSE = 4.31$, as the error scores for the low-frequency words (5.87) were higher than the error scores for the medium-frequency words (3.96). The neighborhood frequency effect was significant, $F_i(1, 84) = 3.99$, $p < .05$, $MSE = 4.31$, but not the interaction between word frequency and neighborhood frequency, $F_i < 1$. The mean phonological error score for the words with higher frequency neighbors (5.36) was higher than that for the words without higher frequency neighbors (4.47).

The effect of word frequency was significant in the analysis of the Plaut et al. (1996) cross-entropy error scores, $F_i(1, 84) = 14.74$, $p < .001$, $MSE = .00$. The mean error score for the low-frequency words (.072) was higher than the mean error score for the medium-frequency words (.040). The mean cross-entropy error score for the words with higher frequency neighbors (.069) was higher than the mean error score for the words without higher frequency neighbors (.043), $F_i(1, 84) = 9.42, p < .01, MSE = .00$. The interaction between word frequency and neighborhood frequency was also significant, $F_i(1, 84) = 4.04, p < .05, MSE = .00$. For the low-frequency words, the error scores for words with higher frequency neighbors (.094) were significantly higher than those for the words without higher frequency neighbors (.051), $F_i(1, 36) = 7.63, p < .01, MSE = .00$. There was no effect of neighborhood frequency for the medium-frequency words, $F_i(1, 48) = 1.02, p > .30, MSE = .00$, as the mean cross-entropy error scores for the words with higher frequency neighbors (.045) was not significantly different than the mean error score for the words without higher frequency neighbors (.036).

[13] The effect of word frequency was marginally significant in the analysis of the Simulation 3 Plaut et al. (1996) settling times, $F_i(1, 93) = 2.86, p = .094, MSE = .02$. The mean settling time for the low-frequency words (1.77) was higher than the mean settling time for the medium-frequency words (1.71). The effect of neighborhood frequency was not significant, $F_i < 1$, but the interaction between word frequency and neighborhood frequency was marginally significant, $F_i(1, 93) = 3.68, p = .058, MSE = .02$. For the low-frequency words, the mean settling time for words with higher frequency neighbors (1.82) was slightly longer than the mean settling time for the words without higher frequency neighbors (1.72), $F_i(1, 42) = 2.86, p = .098, MSE = .03$. There was no effect of neighborhood frequency for the medium-frequency words, $F_i < 1$, as the mean settling

time for the words with higher frequency neighbors (1.70) was comparable to the mean settling time for the words without higher frequency neighbors (1.73).

14 With the homophones removed, the analysis was comparable. The effect of words frequency was marginally significant in the analysis of the Simulation 3 Plaut et al. (1996) settling times, $F_i(1, 84) = 4.26$, $p < .05$, $MSE = .02$. The mean settling time for the low-frequency words (1.78) was higher than the mean settling time for the medium-frequency words (1.72). The effect of neighborhood frequency was not significant, $F_i(1, 84) = 1.85$, $p > .15$, $MSE = .02$, but the interaction between word frequency and neighborhood frequency was significant, $F_i(1, 84) = 6.46$, $p < .05$, $MSE = .02$. For the low-frequency words, the mean settling time for words with higher frequency neighbors (1.85) was slightly higher than the mean settling time for the words without higher frequency neighbors (1.72), $F_i(1, 36) = 4.75$, $p < .05$, $MSE = .03$. There was no effect of neighborhood frequency for the medium-frequency words, $F_i(1, 48) = 1.17$, $p > .25$, $MSE = .02$, as the mean settling time for the words with higher frequency neighbors (1.70) was comparable to the mean settling time for the words without higher frequency neighbors (1.74).

15 In the analysis of response latencies excluding the homophones, the main effect of word frequency was significant, $F_s(1, 39) = 211.48$, $p < .001$, $MSE = 1{,}110.06$; $F_i(1, 102) = 79.66$, $p < .001$, $MSE = 2{,}052.44$. Low-frequency words were responded to 76 ms slower than medium-frequency words. The main effect of neighborhood frequency was not significant (both F's < 1). The interaction between word frequency and neighborhood frequency was significant in the subject analysis, $F_s(1, 39) = 4.28$, $p < .05$, $MSE = 413.00$, but not in the item analysis, $F_i < 1$. For the low-frequency words,

responses to words with higher frequency neighbors were 9 ms faster than responses to words without higher frequency neighbors, $F_s(1, 39) = 2.54, p > .10, MSE = 701.54$; $F_i < 1$. The effect of neighborhood frequency was 4 ms for the medium-frequency words, $F_s(1, 39) = 1.02, p > .30, MSE = 292.72$; $F_i < 1$.

In the analysis of error rates, there was a main effect of word frequency, $F_s(1, 39) = 66.18, p < .001, MSE = 17.69$; $F_i(1, 101) = 31.33, p < .001, MSE = 24.25$, with fewer errors to medium-frequency words than to low-frequency words (1.2% vs. 6.6%). The main effect of neighborhood frequency was not significant (both F's < 1), nor was the interaction between word frequency and neighborhood frequency, $F_s(1, 39) = 1.61, p > .20, MSE = 15.06$; $F_i < 1$.

[16] When the homophones were removed from the analyses, the results were as follows. In the analysis of response latencies, the main effect of group was significant in the item analysis only, $F_s(1, 38) = 1.20, p > .25, MSE = 19{,}455.42$; $F_i(1, 204) = 12.09, p < .001, MSE = 2{,}365.81$. The main effect of word frequency was significant, $F_s(1, 38) = 206.80, p < .001, MSE = 1{,}107.81$; $F_i(1, 204) = 138.87, p < .001, MSE = 2{,}365.81$. The interaction between word frequency and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.97, p = .054, MSE = 421.53$; $F_i < 1$. None of the interactions between group and word frequency, group and neighborhood frequency, or the three-way interaction between group, word frequency, and neighborhood frequency were significant (all p's > .30).

In the analysis of error rates, the main effect of word frequency was significant, $F_s(1, 38) = 63.46, p < .001, MSE = 18.05$; $F_i(1, 204) = 46.41, p < .001, MSE = 32.41$. The interaction between word frequency and neighborhood frequency was not significant,

$F_s(1, 38) = 1.61, p > .20, MSE = 15.43; F_i(1, 204) = 1.07, p > .30, MSE = 32.41$. The main effect of group was not significant (both F's < 1). As in the response latency analysis, none of the interactions between group and word frequency, group and neighborhood frequency, or the three-way interaction were significant (all F's < 1).

17 With the homophones removed, there was a main effect of word frequency in the analysis of response latencies, $F_s(1, 40) = 202.82, p < .001, MSE = 1{,}379.39; F_i(1, 101) = 67.71, p < .001, MSE = 2{,}540.20$, as medium-frequency words were responded to 82 ms faster than low-frequency words. The main effect of neighborhood frequency was marginally significant, $F_s(1, 40) = 2.92, p = .095, MSE = 480.95; F_i < 1$, but the interaction between neighborhood frequency and word frequency was not, $F_s(1, 40) = 1.61, p > .20, MSE = 758.30; F_i < 1$.

In the analysis of error rates, there was a main effect of word frequency, $F_s(1, 40) = 49.02, p < .001, MSE = 16.02; F_i(1, 101) = 27.43, p < .001, MSE = 18.14$. The main effect of neighborhood frequency was marginally significant, $F_s(1, 40) = 2.87, p = .098, MSE = 7.37; F_i < 1$. The interaction between word frequency and neighborhood frequency was not significant, $F_s(1, 40) = 1.45, p > .20, MSE = 5.12; F_i < 1$.

18 In the analysis of response latencies with the homophones removed, the main effect of group was not significant (both F's < 1). The main effect of word frequency was significant, $F_s(1, 39) = 205.98, p < .001, MSE = 1{,}329.38; F_i(1, 204) = 114.21, p < .001, MSE = 2{,}936.04$, and the interaction between word frequency and group was marginally significant in the item analysis, $F_s(1, 39) = 2.50, p > .10, MSE = 1{,}329.38; F_i(1, 204) = 3.06, p = .082, MSE = 2{,}936.04$. The main effect of neighborhood frequency was not significant, $F_s(1, 39) = 2.64, p > .10, MSE = 475.48; F_i < 1$. The interaction between word

frequency and neighborhood frequency was also not significant, $F_s(1, 39) = 1.67, p > .20$, $MSE = 772.38$; $F_i < 1$. Neither the interaction between group and neighborhood frequency, nor the three-way interaction between group, word frequency, and neighborhood frequency were significant (all p's > .20).

In the analysis of error rates, the main effect of group was not significant (both F's < 1). The main effect of word frequency was significant, $F_s(1, 39) = 47.47, p < .001$, $MSE = 16.43$ $F_i(1, 204) = 41.43, p < .001, MSE = 23.43$, but no other effects reached significance (all p's > .10).

19 In a combined analysis of Experiment 2A and 2B with the homophones removed, for the response latencies to words, the main of experiment was marginally significant in the subject analysis, F_s (1, 79) = 3.60, $p = .061$, $MSE = 29{,}923.20$, and was significant in the item analysis, $F_i(1, 202) = 26.33, p < .001, MSE = 2{,}296.32$, as the participants in Experiment 2A were faster to respond to the words than the participants in Experiment 2B (599 ms vs. 635 ms). There was a main effect of word frequency, $F_s(1, 79) = 411.77$, $p < .001, MSE = 1{,}246.43$; $F_i(1,204) = 146.08, p < .001, MSE = 2{,}296.32$. The main effect of neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 79) = 2.85, p = .095, MSE = 530.47$; $F_i < 1$. The only significant interaction was between word frequency and neighborhood frequency, $F_s(1, 79) = 5.05, p < .05, MSE = 587.83$; $F_i < 1$. This is because, in both Experiment 2A and Experiment 2B, low-frequency words with higher frequency neighbors were responded to more rapidly than low-frequency words without higher frequency neighbors (662 ms vs. 652 ms), $F_s(1, 79) = 5.45, p < .05$, $MSE = 799.23$; $F_i < 1$, whereas there was no neighborhood frequency effect for the medium-frequency words (both F's < 1).

In the error analysis, the effect of experiment was marginally significant, $F_s(1, 79) = 3.50$, $p = .065$, $MSE = 22.75$; $F_i(1, 204) = 2.40$, $p > .10$, $MSE = 21.20$, as participants made more errors in Experiment 2A than in Experiment 2B (3.8% vs. 2.9%). There was an effect of word frequency, $F_s(1, 79) = 115.12$, $p < .001$, $MSE = 16.85$; $F_i(1, 204) = 58.67$, $p < .001$, $MSE = 21.20$. There was no interaction between word frequency and neighborhood frequency, $F_s(1, 79) = 1.65$, $p > .20$, $MSE = 10.88$; $F_i < 1$.

[20] When the homophones were removed from the analyses, the main effect of experiment was marginally significant, $F_s(1, 77) = 3.43$, $p = .068$, $MSE = 30{,}625.95$; $F_i(1, 408) = 48.27$, $p < .001$, $MSE = 2{,}650.92$. Both the main effect of group and the interaction between group and experiment were significant in the item analysis, $F_s < 1$; $F_i(1, 408) = 3.46$, $p = .064$, $MSE = 2{,}650.92$ and $F_s < 1$; $F_i(1, 408) = 7.76$, $p < .01$, $MSE = 2{,}650.92$, respectively. Overall, the low ART group responded more slowly than the high ART group (621 ms vs. 612 ms). The difference between the two groups in Experiment 2A was 23 ms, and in Experiment 2B the difference was 5 ms. The main effect of word frequency was significant, $F_s(1, 77) = 401.34$, $p < .001$, $MSE = 1{,}234.70$; $F_i(1, 408) = 246.82$, $p < .001$, $MSE = 2{,}650.92$, but the interaction between word frequency and experiment was not (both F's < 1). The interaction between group and word frequency was marginally significant in the item analysis, $F_s < 1$; $F_i(1, 408) = 2.97$, $p = .085$, $MSE = 2{,}650.92$. The three-way interaction between experiment, group, and word frequency was not significant, $F_s(1, 77) = 1.72$, $p > .15$, $MSE = 1{,}234.70$; $F_i < 1$. The interaction between neighborhood frequency and word frequency was significant in the subject analysis, $F_s(1, 77) = 5.06$, $p < .05$, $MSE = 600.20$; $F_i(1, 408) = 1.28$, $p > .25$, $MSE = 2{,}650.92$. None of

the other main effects or interactions involving neighborhood frequency were significant (all F's < 1).

In the error rate analysis, the main effect of experiment was marginally significant, $F_s(1, 77) = 2.98, p = .088, MSE = 22.92$; $F_i(1, 408) = 3.63, p = .058, MSE = 27.92$. Neither the main effect of group, nor the interaction between group and experiment was significant (all p's > .25). The interaction between word frequency and neighborhood frequency was not significant, $F_s(1, 77) = 1.21, p > .25, MSE = 10.85$; $F_i < 1$. The main effect of word frequency was significant, $F_s(1, 77) = 108.14, p < .001, MSE = 17.18$; $F_i(1, 408) = 87.60, p < .001, MSE = 27.92$. No other effects were significant (all p's > .20).

[21] When the homophones were removed from the analyses, an examination of the percentage of target words skipped in the readers' first pass revealed a significant effect of word frequency, $F_s(1, 39) = 19.99, p < .001, MSE = 117.91$; $F_i(1, 71) = 8.90, p < .01, MSE = 126.54$. The medium-frequency words were skipped (17.2%) much more often than the low-frequency words (9.6%). The main effect of neighborhood frequency was not significant (both F's < 1). Words without higher frequency neighbors were skipped no more often than words with higher frequency neighbors (12.7% vs. 14.1%). The interaction between word frequency and neighborhood frequency was not significant (both F's < 1).

The effect of word frequency on the first fixation durations was not significant, $F_s(1, 39) = 1.37, p > .20, MSE = 906.82$; $F_i(1, 71) = 1.36, p > .20, MSE = 558.13$. The main effect of neighborhood frequency was not significant (both F's < 1). The interaction between word frequency and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 39) = 3.04$, $p = .089$, $MSE = 643.97$; $F_i(1, 71) = 1.05$, $p > .30$, $MSE = 558.13$.

For the gaze duration data, there was a significant main effect of word frequency, $F_s(1, 39) = 6.23$, $p < .05$, $MSE = 1{,}565.48$; $F_i(1, 71) = 2.53$, $p > .10$, $MSE = 1{,}765.85$, as gaze durations were longer for the low-frequency words than for the medium-frequency words (255 ms vs. 240 ms). There was no effect of neighborhood frequency, $F_s(1, 39) = 1.24$, $p > .25$, $MSE = 804.59$; $F_i < 1$. The interaction between word frequency and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 39) = 3.17$, $p = .083$, $MSE = 1{,}375.50$; $F_i < 1$.

For the spillover effects, there was an effect of word frequency on the total time spent on the target word that was significant in the subject analysis, $F_s(1, 39) = 6.85$, $p < .05$, $MSE = 2{,}359.53$; $F_i(1, 71) = 1.67$, $p > .20$, $MSE = 3{,}125.21$, as participants spent an average of 20 ms more time on the low-frequency words than on the medium-frequency words. The effect of word frequency on the first fixation after leaving the target word was marginally significant in the subject analysis, $F_s(1, 39) = 4.01$, $p = .052$, $MSE = 1{,}839.24$, but not in the item analysis, $F_i(1, 71) = 1.60$, $p > .20$, $MSE = 2{,}004.63$. There was a significant effect of word frequency on the total time spent on the target word and the immediate post-target region, $F_s(1, 39) = 6.03$, $p < .05$, $MSE = 19{,}805.50$; $F_i(1, 71) = 2.79$, $p = .099$, $MSE = 21{,}593.53$, and a marginally significant effect on the percentage of regressions back to the target word, $F_s(1, 39) = 3.59$, $p = .065$, $MSE = 158.97$; $F_i(1, 71) = 2.44$, $p > .10$, $MSE = 128.77$. Not only did participants spend more time on the target words and the two following words when the target word was of low-frequency than when it was of medium-frequency (720 ms vs. 665 ms), they also regressed more often to the low-frequency targets (16.6% vs. 13.0%). There were no effects of neighborhood frequency and no interactions (all p's > .20).

[22] These analyses were conducted with the homophones removed. The results were as follows. For the participants that made fewer regressions, there was a main effect of word frequency in the percentage of target words initially skipped, $F_s(1, 19) = 8.84$, $p < .01$, $MSE = 158.34$; $F_i(1, 71) = 7.79$, $p < .01$, $MSE = 159.07$. Low-frequency words were skipped less often than the medium-frequency words (9.2% vs. 17.6%). The main effect of neighborhood frequency was not significant, nor was the interaction between word frequency and neighborhood frequency, $F_s(1, 19) = 1.15$, $p > .25$, $MSE = 164.57$; $F_i < 1$, and $F_s(1, 19) = 1.19$, $p > .25$, $MSE = 125.49$; $F_i < 1$, respectively. For the participants that made more regressions, the low-frequency words were skipped less often than the medium-frequency words (9.9% vs. 16.9%), $F_s(1, 19) = 11.81$, $p < .01$, $MSE = 82.68$; $F_i(1, 71) = 4.12$, $p < .05$, $MSE = 175.63$, and no other effects were significant (all p's > .10).

In the first fixation duration analysis, for the participants that made fewer regressions, the main effects of word frequency and of neighborhood frequency were not significant (all F's < 1) but the interaction was significant in the subject analysis, $F_s(1, 19) = 6.78$, $p < .05$, $MSE = 521.67$; $F_i(1, 71) = 3.09$, $p = .083$, $MSE = 769.12$. First fixation durations for the low-frequency words with higher frequency neighbors were on average 17 ms longer than the first fixation durations for the low-frequency words without higher frequency neighbors, $F_s(1, 19) = 6.87$, $p < .05$, $MSE = 392.33$; $F_i(1, 41) = 4.28$, $p < .05$, $MSE = 561.60$. For the medium-frequency words, the neighborhood frequency effect was reversed but not statistically significant: the first fixation durations for the words with higher frequency neighbors were on average 10 ms shorter than the first fixation durations for the words without higher frequency neighbors, $F_s(1, 19) = 1.24$, $p > .25$, $MSE = 836.53$; $F_i < 1$. For the participants that made more regressions, the main effect of word frequency was not significant, $F_s(1, 19) = 2.78$, $p > .10$, $MSE = 1{,}143.30$; $F_i(1, 71) = 3.01$, $p = .087$, $MSE = 892.78$. The first fixation durations for the low-frequency words were 13 ms longer than the first fixation durations for the medium-frequency words. Neither the main effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency were significant (all F's < 1).

In the gaze duration analysis, for the participants that made fewer regressions, neither the main effect of word frequency, nor the main effect of neighborhood frequency were significant (all p's $> .10$). The interaction between word frequency and neighborhood frequency did approach significance, $F_s(1, 19) = 3.41$, $p = .08$, $MSE = 1{,}744.57$; $F_i(1, 71) = 3.32$, $p = .073$, $MSE = 1{,}229.71$. The gaze durations for the low-frequency words with higher frequency neighbors were 18 ms longer than the gaze durations for the low-frequency words without higher frequency neighbors, $F_s(1, 19) = 5.73$, $p < .05$, $MSE = 580.20$; $F_i(1, 41) = 3.72$, $p = .061$, $MSE = 995.40$. For the medium-frequency words, the neighborhood frequency effect was reversed: the gaze durations for the words with higher frequency neighbors were 16 ms shorter than the gaze durations for the words without higher frequency neighbors, $F_s(1, 19) = 1.54$, $p > .20$, $MSE = 1{,}719.80$; $F_i < 1$. For the high percentage of regressions group, only the main effect of word frequency was significant, $F_s(1, 19) = 5.29$, $p < .05$, $MSE = 2{,}290.68$; $F_i(1, 71) = 7.76$, $p < .01$, $MSE = 2{,}412.28$ (all other p's $> .10$). The gaze durations for the low-frequency words were 24 ms longer than the gaze durations for the medium-frequency words.

In the analysis of the total time spent on the target word, for the participants that made fewer regressions, there was a main effect of word frequency in the subject analysis, $F_s(1, 19) = 4.41, p < .05, MSE = 895.27$; $F_i(1, 71) = 1.98, p > .15, MSE = 2{,}170.39$. The main effect of neighborhood frequency was not significant (both F's < 1), but the interaction between word frequency and neighborhood frequency was significant, $F_s(1, 19) = 5.28, p < .05, MSE = 1{,}865.50$; $F_i(1, 71) = 4.15, p < .05, MSE = 2{,}170.39$. Participants in this group spent an average of 28 ms longer on the low-frequency words with higher frequency neighbors than on the low-frequency words without higher frequency neighbors, $F_s(1, 19) = 7.90, p < .05, MSE = 1{,}035.86$; $F_i(1, 41) = 4.54, p < .05, MSE = 1{,}991.43$. There was no neighborhood frequency effect for the medium-frequency words (both F's < 1). For the participants that made more regressions, the effect of word frequency on the total time spent on the target word was marginally significant in the subject analysis, $F_s(1, 19) = 3.53, p = .076, MSE = 3{,}870.82$; $F_i(1, 71) = 5.08, p < .05, MSE = 5{,}568.16$. Neither the main effect of neighborhood frequency, nor the Word Frequency x Neighborhood Frequency interaction were significant (all F's < 1).

In the analysis of the first fixation duration after leaving the target word, for the participants that made fewer regressions, there was a significant main effect of word frequency, $F_s(1, 19) = 7.01, p < .05, MSE = 955.84$; $F_i(1, 71) = 3.59, p = .062, MSE = 1{,}584.99$. The fixation durations were 19 ms longer when the target word was of low-frequency than when it was of medium-frequency. Neither the main effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency were significant (all F's < 1). There were no significant effects for the participants that made more regressions (all F's < 1).

For the participants that made fewer regressions, there was a significant main effect of word frequency on the total time spent on the target word and the immediate post-target region, $F_s(1, 19) = 7.69$, $p < .05$, $MSE = 10{,}698.11$; $F_i(1, 71) = 2.91$, $p = .092$, $MSE = 22{,}228.58$. Participants in this group spent on average 64 ms longer on the low-frequency words than on the medium-frequency words. No other effects were significant (all p's > .15). For the participants that made more regressions, no effects were significant (all p's > .25).

In the percentage of regressions, there were no significant effects for the participants that made fewer regressions (all p's > .10). There were also no significant effects on the percentage of regressions for the participants that made more regressions (all p's > .15).

[23] These same analyses were conducted with the homophones removed. In the analysis of the percentage of target words initially skipped, there was a main effect of ART group, $F_s(1, 38) = 14.53$, $p < .001$, $MSE = 267.20$; $F_i(1, 142) = 18.36$, $p < .001$, $MSE = 201.35$, as the low

ART group skipped the target words less often than the high ART group (8.2% vs. 18.0%). There was also a main effect of word frequency, $F_s(1, 38) = 19.41$, $p < .001$, $MSE = 121.00$; $F_i(1, 142) = 10.05$, $p < .01$, $MSE = 201.35$, as the low-frequency words were skipped less often than the medium-frequency words (9.3% vs. 16.9%). No other effects were significant (all p's > .25). There was also a significant effect of reading rate group on the percentage of target words skipped, $F_s(1, 38) = 6.34$, $p < .05$, $MSE = 316.52$; $F_i(1, 142) = 10.95$, $p < .001$, $MSE = 171.03$. Participants with lower reading rate scores skipped the target words less often than the participants with higher reading rate scores

(10.0% vs. 17.1%). There was a main effect of word frequency, $F_s(1, 38) = 20.17$, $p < .001$, $MSE = 118.78$; $F_i(1, 142) = 11.22$, $p < .01$, $MSE = 171.03$, but no other effects were significant (all p's > .25).

In the analysis of the first fixation durations, the main effect of ART group was not significant, $F_s(1, 38) = 1.72$, $p > .15$, $MSE = 4{,}209.93$; $F_i(1, 142) = 14.48$, $p < .001$, $MSE = 959.73$. The main effect of word frequency was not significant, $F_s(1, 38) = 1.48$, $p > .20$, $MSE = 909.71$; $F_i(1, 142) = 1.48$, $p > .20$, $MSE = 959.73$, nor was the main effect of neighborhood frequency (both F's < 1). The interaction between word frequency and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.34$, $p = .076$, $MSE = 630.31$; $F_i(1, 142) = 1.04$, $p > .30$, $MSE = 959.73$, but neither the low-frequency words, nor the medium-frequency words showed a significant neighborhood frequency effect (all p's > .20). No other effects were significant (all F's < 1). There effect of reading rate group on the first fixation durations was significant in the item analysis (234 ms for the participants with lower reading rate scores and 221 ms for the participants with higher reading rate scores), $F_s(1, 38) = 2.47$, $p > .10$, $MSE = 4{,}131.68$; $F_i(1, 142) = 7.39$, $p < .01$, $MSE = 864.31$. The only other effect to approach significance was the word frequency by neighborhood frequency interaction, $F_s(1, 38) = 2.91$, $p = .096$, $MSE = 659.93$; $F_i(1, 142) = 1.55$, $p > .20$, $MSE = 864.31$ (all other p's > .20). Neither the low-frequency, nor the medium-frequency words showed a significant neighborhood frequency effect (all p's > .20).

For the gaze durations, the main effect of ART group was significant in the item analysis (259 ms for the low ART group and 233 ms for the high ART group), $F_s(1, 38) = 2.28$, $p > .10$, $MSE = 6{,}916.68$; $F_i(1, 142) = 13.75$, $p < .001$, $MSE = 1{,}813.57$. Both the main effect of word frequency and the interaction between ART group and word frequency were significant, $F_s(1, 38) = 7.68$, $p < .01$, $MSE = 1{,}387.57$; $F_i(1, 142) = 5.78$, $p < .05$, $MSE = 1{,}813.57$, and $F_s(1, 38) = 6.00$, $p < .05$, $MSE = 1{,}387.57$; $F_i(1, 142) = 1.90$, $p > .15$, $MSE = 1{,}813.57$, respectively. There was a significant effect of word frequency for the low ART participants, $F_s(1, 18) = 23.70$, $p < .001$, $MSE = 759.96$; $F_i(1, 71) = 6.91$, $p < .05$, $MSE = 1{,}876.80$, but not for the high ART participants (both F's < 1). The only other effect to approach significance was the Word Frequency x Neighborhood Frequency interaction, $F_s(1, 38) = 3.02$, $p = .09$, $MSE = 4{,}237.77$; $F_i < 1$ (all other p's > .25). There was an effect of reading rate group in the analysis of the gaze durations, $F_s(1, 38) = 5.94$, $p < .05$, $MSE = 6{,}340.01$; $F_i(1, 142) = 16.65$, $p < .001$, $MSE = 1{,}573.92$. The gaze durations for the participants with lower reading rate scores were on average 31 ms longer than the gaze durations for the participants with higher reading rate scores. The main effect of word frequency was significant, $F_s(1, 38) = 6.09$, $p < .05$, $MSE = 1{,}606.27$; $F_i(1, 142) = 6.41$, $p < .05$, $MSE = 1{,}573.92$, but the interaction between reading rate group and word frequency was not (both F's < 1). The main effect of neighborhood frequency, the two-way interaction between reading rate group and neighborhood frequency, and the three-way interaction between reading rate group, word frequency and neighborhood frequency were not significant (all p's > .25). The interaction between word frequency and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.01$, $p = .091$, $MSE = 1{,}401.42$; $F_i(1, 142) = 1.94$, $p > .15$, $MSE = 1{,}573.92$.

There was no effect of ART group in the total time spent on the target word, $F_s < 1$; $F_i(1, 142) = 1.99$, $p > .15$, $MSE = 5{,}071.77$. The main effect of word frequency was significant, $F_s(1, 38) = 7.83$, $p < .01$, $MSE = 2{,}208.05$; $F_i(1, 142) = 3.08$, $p = .081$, $MSE = 5{,}071.77$, and the interaction between ART group and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.68$, $p = .063$, $MSE = 2{,}208.05$; $F_i < 1$. The low ART group showed a significant word frequency effect, $F_s(1, 18) = 12.96$, $p < .01$, $MSE = 1{,}803.90$; $F_i(1, 71) = 3.10$, $p = .083$, $MSE = 5{,}143.86$, but the high ART group did not (both F's < 1). The main effect of neighborhood frequency was not significant, nor was the interaction between neighborhood frequency and ART group (all F's < 1). The interaction between word frequency and neighborhood frequency was not significant, $F_s(1, 38) = 1.21$, $p > .25$, $MSE = 2{,}639.45$; $F_i < 1$. The three-way interaction was also not significant (both F's < 1). Reading rate group had a significant effect on the total time spent on the target word, $F_s(1, 38) = 4.13$, $p < .05$, $MSE = 14{,}393.85$; $F_i(1, 142) = 9.57$, $p < .01$, $MSE = 4{,}280.55$, as the low reading rate group spent longer on the target words than the high reading rate group (303 ms vs. 265 ms). There was a main effect of word frequency, $F_s(1, 38) = 6.67$, $p < .05$, $MSE = 2{,}421.46$; $F_i(1, 142) = 4.11$, $p < .05$, $MSE = 4{,}280.55$, but no interaction between reading rate group and word frequency (both F's < 1). No other effects were significant (all p's > .30).

ART group had no effect on the first fixation after leaving the target word (both F's < 1). Both the main effect of word frequency and the interaction between ART group and word frequency were significant, $F_s(1, 38) = 5.61$, $p < .05$, $MSE = 1{,}501.40$; $F_i(1, 142) = 2.18$, $p > .10$, $MSE = 2{,}863.81$ and $F_s(1, 38) = 9.78$, $p < .01$, $MSE = 1{,}501.40$; $F_i(1, 142) = 4.26$, $p < .05$, $MSE = 2{,}863.81$, respectively. The low ART group showed a significant word frequency effect, $F_s(1, 18) = 16.83$, $p < .01$, $MSE = 1{,}283.41$ $F_i(1, 71) = 5.14$, $p < .05$, $MSE = 3{,}490.59$, but the high ART group did not (both F's < 1). No other effects were significant (all F's < 1). Reading rate group did not have a significant effect on the first fixation after the target word, $F_s(1, 38) = 1.46$, $p > .20$, $MSE = 5{,}531.30$; $F_i(1, 142) = 1.92$, $p > .15$, $MSE = 3{,}630.89$. The main effect of word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.98$, $p = .053$, $MSE = 1{,}880.64$; $F_i(1, 142) = 1.86$, $p > .15$, $MSE = 3{,}630.89$, but there was no interaction between reading rate group and word frequency (both F's < 1). The only other effect to approach significance was the Reading Rate Group x Neighborhood Frequency interaction, $F_s(1, 38) = 2.85$, $p = .099$, $MSE = 1{,}927.12$; $F_i < 1$ (all other F's < 1). When analyzed separately, however, neither the low reading rate group, nor the high reading rate group showed a significant neighborhood frequency effect (all p's > .20).

With respect to the total time spent on the target word and the immediate post-target region, there was no effect of ART group (both F's < 1). The main effect of word frequency was significant, $F_s(1, 38) = 6.11$, $p < .05$, $MSE = 20{,}065.22$; $F_i(1, 142) = 4.40$, $p < .05$, $MSE = 30{,}334.46$, but there was no interaction between ART group and word frequency (both F's < 1). The main effect of neighborhood frequency was not significant, $F_s(1, 38) = 1.57$, $p > .20$, $MSE = 14{,}958.05$; $F_i < 1$, but the interaction between ART group and neighborhood frequency was significant in the subject analysis, $F_s(1, 38) = 4.12$, $p < .05$, $MSE = 14{,}958.05$; $F_i < 1$. For the low ART group, the neighborhood frequency effect was 15 ms (both F's < 1), and the neighborhood frequency effect for the high ART was 64 ms, $F_s(1, 38) = 6.28$, $p < .05$, $MSE = 13{,}483.54$; $F_i < 1$. No other effects were significant (all p's > .20). There was an effect of reading rate group, $F_s(1, 38) = 9.91$, $p < .01$, $MSE = 65{,}629.28$; $F_i(1, 142) = 18.38$, $p < .001$, $MSE = 25{,}934.69$, as the participants with lower reading rate scores spent 128 ms longer on the target word and immediate post-target region than the participants with higher reading rate scores. There was a main effect of word frequency, $F_s(1, 38) = 5.76, p < .05, MSE = 19{,}980.28$; $F_i(1, 142) = 4.30, p < .05, MSE = 25{,}934.69$, but no interaction between reading rate group and word frequency (both F's < 1). No other effects were significant (all p's > .25).

There was no effect of ART group on the percentage of regressions, $F_s < 1$; $F_i(1, 142) = 1.51, p > .20, MSE = 185.09$. Only the main effect of word frequency approached significance, $F_s(1, 38) = 3.42, p = .072, MSE = 162.06$; $F_i(1, 142) = 3.21, p = .075, MSE = 185.09$. No other effects were significant (all p's > .30). Reading rate did also not have an effect on the percentage of regressions (both F's < 1). Again, the only effect to approach significance was that of word frequency effect, $F_s(1, 38) = 3.76, p = .06, MSE = 159.32$; $F_i(1, 142) = 3.32, p = .07, MSE = 178.05$. No other effects were significant (all p's > .30).

[24] To combine the two reader skill scores, a composite reader skill score was created for each participant. Participants were ranked both on their ART scores and their Nelson-Denny reading rate scores. The ranks were then added together to obtain the composite reader score. A median split was performed on these skill scores (median = 17, range = 1 to 31) creating a low skill group ($M = 11.1$) and a high skill group ($M = 21.4$), $F_s(1, 38) = 58.32, p < .001, MSE = 18.40$. The data were submitted to separate 2 (Word Frequency: low, medium) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) x 2 (skill group: low, high) repeated measures ANOVAs for each of the first pass and spillover variables.

In the percentage of target words initially skipped, reader skill was not significantly correlated with the word frequency effect, $r(40) = -.20, p > .20$. Reader skill was significantly correlated with the neighborhood frequency effect, $r(40) = -.38$, $p < .05$. As reader skill increased, the magnitude of the neighborhood frequency effect decreased. When analyzed separately, reader skill was significantly correlated with the low-frequency neighborhood frequency effect, $r(40) = -.40$, $p < .05$, but not with the medium-frequency neighborhood frequency effect, $r(40) = -.19$, $p > .20$. For the low-frequency words, as reader skill increased, the magnitude of the neighborhood frequency effect decreased. In the ANOVA, there was a significant effect of reader skill group, $F_s(1, 38) = 13.72$, $p < .01$, $MSE = 297.72$; $F_i(1, 168) = 21.38$, $p < .001$, $MSE = 230.40$. The low skill group skipped the target words less often than the high skill group (9.9% vs. 20.0%). There was a significant effect of word frequency, $F_s(1, 38) = 47.55$, $p < .001$, $MSE = 108.11$; $F_i(1, 168) = 22.59$, $p < .001$, $MSE = 230.40$, but no interaction between skill group and word frequency, $F_s(1, 38) = 2.73$, $p > .10$, $MSE = 108.11$; $F_i(1, 168) = 2.44$, $p > .10$, $MSE = 230.40$. The effect of neighborhood frequency was significant in the subject analysis, $F_s(1, 38) = 4.38$, $p < .05$, $MSE = 100.86$; $F_i(1, 168) = 2.71$, $p > .10$, $MSE = 230.40$, and the interaction between skill group and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.67$, $p = .063$, $MSE = 100.86$; $F_i(1, 168) = 1.70$, $p > .15$, $MSE = 230.40$. For the low skill group, there was no effect of neighborhood frequency (9.8% for the words with higher frequency neighbors and 10.1% for the words without higher frequency neighbors; both F's < 1). For the high skill group, there was an inhibitory effect of neighborhood frequency, $F_s(1, 38) = 3.67$, $p = .063$, $MSE = 100.86$; $F_i(1, 168) = 1.70$, $p > .15$, $MSE = 230.40$. The words with higher frequency neighbors were skipped more often than the words without higher frequency neighbors (23.2% vs. 16.8%). No other effects were significant (all p's > .20).

In the analysis of the first fixation durations, skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = .15$, $p > .30$ and $r(40) = -.12$, $p > .40$, respectively. In the ANOVA, reader skill did not have a significant effect, $F_s(1, 38) = 2.38$, $p > .10$, $MSE = 3{,}735.02$; $F_i(1, 168) = 10.50$, $p < .01$, $MSE = 972.16$. The main effect of word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.67$, $p = .063$, $MSE = 872.50$, and significant in the item analysis, $F_i(1, 168) = 4.49$, $p < .05$, $MSE = 972.16$, but the interaction between word frequency and skill group was not significant, $F_s(1, 38) = 1.37$, $p > .20$, $MSE = 872.50$; $F_i < 1$. No other effects were significant (all p's > .10).

For the gaze durations, reader skill was significantly correlated with the word frequency effect, $r(40) = .42$, $p < .01$, but was not significantly correlated with the neighborhood frequency effect, $r(40) = -.007$, $p > .95$. As reader skill increased, the magnitude of the word frequency effect also increased. In the ANOVA, reader skill did have a significant effect, $F_s(1, 38) = 6.05$, $p < .05$, $MSE = 5{,}985.42$; $F_i(1, 168) = 21.39$, $p < .001$, $MSE = 1{,}693.51$. The gaze durations for the low skill group were on average 30 ms longer than the gaze durations for the high skill group. The main effect of word frequency was significant, $F_s(1, 38) = 11.28$, $p < .01$, $MSE = 1{,}409.11$; $F_i(1, 168) = 10.83$, $p < .01$, $MSE = 1{,}693.51$, and the interaction between skill group and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.77$, $p = .06$, $MSE = 1{,}409.11$; $F_i(1, 168) = 2.43$, $p > .10$, $MSE = 1{,}693.51$. No other effects were significant (all *p*'s > .10).

In the total time spent on the target word, reader skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect,

$r(40) = .23$, $p > .10$ and $r(40) = .12$, $p > .45$, respectively. In the ANOVA, the main effect of skill group was marginally significant, $F_s(1, 38) = 3.24$, $p = .08$, $MSE = 13{,}732.89$; $F_i(1, 168) = 11.79$, $p < .01$, $MSE = 4{,}428.96$. The low skill group spent 33 ms longer on the target words than the high skill group. The main effect of word frequency was significant, $F_s(1, 38) = 14.86$, $p < .001$, $MSE = 2{,}095.98$; $F_i(1, 168) = 9.55$, $p < .01$, $MSE = 4{,}428.96$, and the interaction between skill group and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.86$, $p = .057$, $MSE = 2{,}095.98$; $F_i(1, 168) = 1.52$, $p > .20$, $MSE = 4{,}428.96$. No other effects were significant (all p's > .30).

For the durations of the first fixation after leaving the target word data, reader skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = .25$, $p > .10$ and $r(40) = -.04$, $p > .75$, respectively. In the ANOVA, the main effect of skill group was marginally significant in the item analysis, $F_s(1, 38) = 2.64$, $p > .10$, $MSE = 4{,}757.69$; $F_i(1, 168) = 3.65$, $p = .058$, $MSE = 3{,}173.83$. The main effect of word frequency was significant in the subject analysis, $F_s(1, 38) = 4.28$, $p < .05$, $MSE = 1{,}628.50$; $F_i(1, 168) = 1.55$, $p > .20$, $MSE = 3{,}173.83$, and the interaction between skill group and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.63$, $p = .064$, $MSE = 1{,}628.50$; $F_i < 1$. The effect of word frequency was significant for the low skill group, $F_s(1, 18) = 6.67$, $p < .05$, $MSE = 1{,}836.41$; $F_i(1, 84) = 1.52$, $p > .20$, $MSE = 4{,}488.64$, but not for the high skill group (both F's < 1). No other effects were significant (all p's > .20).

For the total time spent on the target word and the immediate post-target region, reader skill was significantly correlated with the word frequency effect, $r(40) = .39$, $p < .05$, but was not correlated with the neighborhood frequency effect, $r(40) = -.00$, $p > .95$.

As reader skill increased, so did the magnitude of the word frequency effect. In the ANOVA, the main effect of reader skill was significant, $F_s(1, 38) = 5.63$, $p < .05$, $MSE =$ 70,488.41; $F_i(1, 168) = 15.18$, $p < .001$, $MSE =$ 28,378.30. The low skill group spent 100 ms longer on the target word and the immediate post-target region than the high skill group. Both the main effect of word frequency and the interaction between skill group and word frequency were significant, $F_s(1, 38) = 13.67$, $p < .01$, $MSE =$ 14,470.58; $F_i(1, 168) = 9.65$, $p < .01$, $MSE =$ 28,378.30 and $F_s(1, 38) = 4.41$, $p < .05$, $MSE =$ 14,470.58; $F_i(1, 168) = 3.18$, $p = .076$, $MSE =$ 28,378.30, respectively. The main effect of word frequency was significant for the low skill group, $F_s(1, 18) = 29.66$, $p < .001$, $MSE =$ 7,804.09; $F_i(1, 84) = 9.95$, $p < .01$, $MSE =$ 34,092.05, but not for the high skill group, $F_s < 1$; $F_i(1, 84) = 1.10$, $p > .25$, $MSE =$ 22,664.55. No other effects were significant (all p's > .20).

For the percentage of regressions data, reader skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = .10$, $p > .50$ and $r(40) = -.26$, $p > .10$, respectively. In the ANOVA, there was no effect of reader skill (both F's < 1). The main effect of word frequency was significant, $F_s(1, 38) = 7.37$, $p < .05$, $MSE = 142.78$; $F_i(1, 168) = 7.10$, $p < .01$, $MSE = 187.80$, but there was no interaction between skill group and word frequency (both F's < 1). No other effects were significant (all p's > .15).

In this experiment, the composite skill score analysis provided no more information than the ART analysis. In the ART analysis, for the high ART group, there was a significant inhibitory neighborhood frequency effect in the total time spent on the target word and immediate post-target region. The only significant effect in the composite skill score analysis was an inhibitory neighborhood frequency effect for the high skill group in the percentage of target words skipped.

25 The analyses of the composite reader skill scores were conducted with the homophones removed from the stimulus set. The results were as follows. For the percentage of target words initially skipped, reader skill was not significantly correlated with the word frequency effect, $r(40) = .09$, $p > .50$. The negative correlation between skill and the neighborhood frequency effect was marginally significant, $r(40) = -.28$, $p = .078$. When analyzed separately, reader skill was significantly correlated with the low-frequency neighborhood frequency effect, $r(40) = -.30$, $p = .053$, but not with the medium-frequency neighborhood frequency effect, $r(40) = -.15$, $p > .30$. For the low-frequency words, as reader skill increased, the magnitude of the neighborhood frequency effect decreased. In the ANOVA, there was a significant effect of skill group in the percentage of target words skipped, $F_s(1, 38) = 9.81$, $p < .01$, $MSE = 293.55$; $F_i(1, 142) = 15.21$, $p < .001$, $MSE = 177.75$, as the low skill group skipped target words less often than the high skill group (8.9% vs. 17.4%). There was a significant effect of word frequency, $F_s(1, 38) = 19.41$, $p < .001$, $MSE = 118.95$; $F_i(1, 142) = 10.86$, $p < .01$, $MSE = 177.75$, but no interaction between skill group and word frequency (both F's < 1). The effect of neighborhood frequency was not significant (both F's < 1), nor was the interaction between skill group and neighborhood frequency, $F_s(1, 38) = 1.80$, $p > .15$, $MSE = 145.74$; $F_i(1, 142) = 1.43$, $p > .20$, $MSE = 177.75$. No other effects were significant (all p's $> .20$).

For the first fixation duration data, reader skill was not significantly correlated with either the word frequency effect or with the neighborhood frequency effect, $r(40) =$

.02, $p > .85$ and $r(40) = -.15$, $p > .30$, respectively. In the ANOVA, skill group did not have a significant effect on the first fixation durations, $F_s(1, 38) = 2.56$, $p > .10$, $MSE = 4{,}122.30$; $F_i(1, 142) = 11.35$, $p < .01$, $MSE = 917.39$. The main effect of word frequency was not significant, $F_s(1, 38) = 1.40$, $p > .20$, $MSE = 925.76$; $F_i(1, 142) = 1.54$, $p > .20$, $MSE = 917.39$, nor was the interaction between word frequency and skill group (both F's < 1). The interaction between word frequency and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.02$, $p = .09$, $MSE = 658.91$; $F_i < 1$; however, when the low-frequency and the medium-frequency words were analyzed separately, neither showed a neighborhood frequency effect (all p's > .20). No other effects were significant (all p's > .10).

For the gaze durations, reader skill was significantly correlated with the word frequency effect, $r(40) = .31$, $p < .05$, but not with the neighborhood frequency effect, $r(40) = -.05$, $p > .70$. As reader skill increased, so did the magnitude of the word frequency effect. In the ANOVA, the effect of skill group was significant, $F_s(1, 38) = 6.87$, $p < .05$, $MSE = 6{,}209.30$; $F_i(1, 142) = 23.53$, $p < .001$, $MSE = 1{,}665.54$. The gaze durations for the low skill group were 33 ms longer than for the high skill group. The main effect of word frequency was significant, $F_s(1, 38) = 6.74$, $p < .05$, $MSE = 1{,}526.41$; $F_i(1, 142) = 5.46$, $p < .05$, $MSE = 1{,}665.54$, but the interaction between skill group and word frequency was not, $F_s(1, 38) = 2.00$, $p > .16$, $MSE = 1{,}526.41$; $F_i < 1$. No other effects were significant (all p's > .10).

For the total time spent on the target word, skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = .19$, $p > .20$ and $r(40) = .05$, $p > .75$, respectively. In ANOVA, the main effect of skill group was marginally significant, $F_s(1, 38) = 3.94$, $p = .054$, $MSE = 14{,}457.70$; $F_i(1, 142) = 12.11$, $p < .01$, $MSE = 4{,}674.99.96$. The low skill group spent 38 ms longer on the target words than the high skill group. The main effect of word frequency was significant, $F_s(1, 38) = 7.63$, $p < .01$, $MSE = 2{,}249.09$; $F_i(1, 142) = 3.58$, $p = .06$, $MSE = 4{,}674.99$, and the interaction between skill group and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 2.91$, $p = .096$, $MSE = 2{,}249.09$; $F_i < 1$. The main effect of word frequency was significant for the low skill group, $F_s(1, 18) = 10.84$, $p < .01$, $MSE = 1{,}973.40$; $F_i(1, 71) = 3.29$, $p = .074$, $MSE = 5{,}770.51$, but not for the high skill group (both F's < 1). No other effects were significant (all p's > .30).

For the duration of the first fixation after leaving the target word data, reader skill was significantly correlated with the word frequency effect, $r(40) = .34$, $p < .05$, but not the neighborhood frequency effect, $r(40) = -.08$, $p > .55$. As reader skill increased, so did the magnitude of the word frequency effect. In the ANOVA, the main effect of skill group was marginally significant in the item analysis, $F_s(1, 38) = 2.46$, $p > .10$, $MSE = 5{,}393.76$; $F_i(1, 142) = 2.96$, $p = .088$, $MSE = 3{,}403.79$. The main effect of word frequency was significant in the subject analysis, $F_s(1, 38) = 4.74$, $p < .05$, $MSE = 1{,}705.41$; $F_i(1, 142) = 1.11$, $p > .25$, $MSE = 3{,}403.79$, and the interaction between skill group and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 4.06$, $p = .051$, $MSE = 1{,}705.41$; $F_i < 1$. The main effect of word frequency was significant for the low skill group, $F_s(1, 18) = 10.29$, $p < .01$, $MSE = 1{,}387.15$; $F_i(1, 71) = 1.36$, $p > .20$, $MSE = 5{,}148.63$, but not for the high skill group (both F's < 1). No other effects were significant (all p's > .20).

For the total time spent on the target word and the immediate post-target region, reader skill was significantly correlated with the word frequency effect, $r(40) = .32, p < .05$, but was not correlated with the neighborhood frequency effect, $r(40) = -.03, p > .80$. As reader skill increased, so did the magnitude of the word frequency effect. In the ANOVA, the main effect of skill was significant, $F_s(1, 38) = 6.93, p < .05, MSE = 69{,}983.83$; $F_i(1, 142) = 15.69, p < .001, MSE = 28{,}859.88$. On average, the low skill group spent 111 ms longer on the target word and the immediate post-target region than the high skill group. The main effect of word frequency was significant, $F_s(1, 38) = 6.51, p < .05, MSE = 19{,}342.25$; $F_i(1, 142) = 4.25, p < .05, MSE = 28{,}859.88$, but the interaction between skill group and word frequency was not, $F_s(1, 38) = 1.93, p > .15, MSE = 19{,}342.25$; $F_i(1, 142) = 1.72, p > .15, MSE = 28{,}859.88$. No other effects were significant (all p's > .20).

In the percentage of regressions data, reader skill was not significantly correlated with the word frequency effect, $r(40) = .09, p > .50$. The negative correlation between skill and the neighborhood frequency effect was marginally significant, $r(40) = -.28, p = .078$. As reader skill increased, the magnitude of the neighborhood frequency effect decreased. In the ANOVA, the main effect of skill was significant in the subject analysis, $F_s(1, 38) = 9.81, p < .01, MSE = 293.55$; $F_i < 1$. The main effect of word frequency was significant, $F_s(1, 38) = 19.41, p < .001, MSE = 118.95$; $F_i(1, 142) = 7.10, p = .09, MSE = 199.87$, but there was no interaction between skill group and word frequency (both F's < 1). No other effects were significant (all p's > .15).

[26] With the homophones removed from the analyses, the results were as follows. For the percentage of target words that were skipped during the readers' first pass, there was a

significant effect of word frequency in the subject analysis, with participants skipping the low-frequency words more often than the medium-frequency words (21.1% vs. 17.5%), $F_s(1, 39) = 4.78, p < .05, MSE = 111.51$; $F_i(1, 101) = 1.34, p > .25, MSE = 156.64$. No other effects were significant (all F's < 1).

The was no effect of word frequency on the first fixation durations (both F's < 1). The facilitatory effect of neighborhood frequency was significant in the subject analysis, as the first fixation durations for words with higher frequency neighbors were shorter (211 ms) than the first fixation durations for words without higher frequency neighbors (223 ms), $F_s(1, 39) = 10.93, p < .01, MSE = 514.60$; $F_i(1, 101) = 1.36, p > .20, MSE =$ 944.07. The interaction between word frequency and neighborhood frequency was not significant, $F_s(1, 39) = 1.94, p > .15, MSE = 931.49$; $F_i(1, 101) = 1.35, p > .20, MSE =$ 944.07, however, the neighborhood frequency effect was larger for the low-frequency words. For the low-frequency words, the first fixation durations for words with higher frequency neighbors (206 ms) were shorter than the first fixation durations for words without higher frequency neighbors (225 ms), $F_s(1, 39) = 8.67, p < .01, MSE = 764.99$; $F_i(1, 48) = 3.98, p = .052, MSE = 610.42$. For the medium-frequency words, the first fixation durations for words with higher frequency neighbors (216 ms) were very similar to the first fixation durations for the words without higher frequency neighbors (221 ms), $F_s(1, 39) = 1.04, p > .30, MSE = 581.10$; $F_i < 1$.

For the gaze duration data, the effect of word frequency was not significant, $F_s(1, 39) = 1.20, p > .25, MSE = 666.26$; $F_i(1, 101) = 1.79, p > .15, MSE = 1{,}605.44$. There was also no effect of neighborhood frequency, nor was there an interaction between word frequency and neighborhood frequency (all F's < 1).

For the spillover effects, there was a marginally significant effect of word frequency on the total time spent on the target word in the subject analysis, $F_s(1, 39) = 3.82$, $p = .058$, $MSE = 1{,}379.30$; $F_i(1, 101) = 1.27$, $p > .25$, $MSE = 3{,}189.78$, with participants spending on average 11 ms more time on the low-frequency words than the medium-frequency words. There was a significant effect of word frequency on the duration of the first fixation after leaving the target word, $F_s(1, 39) = 5.65$, $p < .05$, $MSE = 924.03$; $F_i(1, 101) = 3.43$, $p = .067$, $MSE = 536.99$. Participants' fixation durations were 11 ms longer when the target word was of low-frequency than when it was of medium-frequency. The effect of word frequency was not significant in any of the other spillover variables (all p's > .10). No effects of neighborhood frequency were significant in the analysis of the total time spent on the target word and the immediate post-target region (all p's > .15). There was also no significant interactions between word frequency and neighborhood frequency (all p's > .20).

[27] These analyses were conducted with the homophones removed. In the analysis of the percent of target words initially skipped, there were no significant effects for the participants that made fewer regressions (all F's < 1). For the participants that made more regressions, the low-frequency words were skipped more often than the medium-frequency words (21.9% vs. 15.5%), $F_s(1, 19) = 10.15$, $p < .01$, $MSE = 80.37$; $F_i(1, 102) = 1.34$, $p > .25$, $MSE = 212.60$. No other effects were significant (all p's > .25).

In the first fixation duration analysis, for the participants that made fewer regressions, the main effect of word frequency was not significant (both F's < 1). The main effect of neighborhood frequency was significant, $F_s(1, 19) = 14.04$, $p < .01$, $MSE = 507.58$; $F_i(1, 102) = 4.83$, $p < .05$, $MSE = 1{,}065.90$. The first fixation durations for words with higher frequency neighbors were 18 ms shorter than the first fixation durations for words without higher frequency neighbors. The interaction between word frequency and neighborhood frequency was not significant (both *F*'s < 1). For the participants that made more regressions regressions, there were no significant effects (all *p*'s > .20).

In the gaze duration analysis, for the participants that made fewer regressions, the main effect of word frequency was not significant (both *F*'s < 1). The neighborhood frequency effect was marginally significant in the subject analysis, $F_s(1, 19) = 4.10$, $p = .057$, $MSE = 624.62$; $F_i(1, 102) = 1.41$, $p > .20$, $MSE = 2,135.06$. The gaze durations to the words with higher frequency neighbors were 12 ms shorter than the gaze durations to the words without higher frequency neighbors. The interaction between word frequency and neighborhood frequency was not significant (both *F*'s < 1). For the participants that made more regressions, the main effect of word frequency was not significant, $F_s(1, 19) = 2.21$, $p > .15$, $MSE = 723.93$; $F_i < 1$. The main effect of neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 19) = 3.09$, $p = .095$, $MSE = 688.81$; $F_i < 1$, as the gaze durations for words with higher frequency neighbors were 10 ms longer than the gaze durations for the words without higher frequency neighbors. The interaction between word frequency and neighborhood frequency was not significant (both *F*'s < 1).

In the analysis of the total time spent on the target word, for the participants that made fewer regressions, the main effect of word frequency was not significant (both *F*'s < 1). The main effect of neighborhood frequency was not significant, $F_s(1, 19) = 2.11$, $p > .15$, $MSE = 637.38$; $F_i < 1$, nor was the interaction between word frequency and neighborhood frequency (both *F*'s < 1). For the participants that made more regressions, there was a main effect of word frequency, $F_s(1, 19) = 5.93$, $p < .05$, $MSE = 1{,}150.19$; $F_i(1, 102) = 1.08$, $p > .30$, $MSE = 5{,}490.32$. Participants in this group spent on average 18 ms longer on the low-frequency words than on the medium-frequency words. Neither the main effect of neighborhood frequency, nor the interaction between word frequency and neighborhood frequency were significant (all *F*'s < 1).

In the analysis of the first fixation duration after leaving the target word, for the participants that made fewer regressions, the main effect of word frequency was marginally significant, $F_s(1, 19) = 3.53$, $p = .076$, $MSE = 1{,}141.04$; $F_i(1, 102) = 3.84$, $p = .053$, $MSE = 1{,}036.31$. Neither the main effect of neighborhood frequency, nor the interaction were significant (all *p*'s > .10). For the participants that made more regressions, there were no significant effects (all *p*'s > .15).

For the group that made fewer regressions, there was no effect of word frequency on the total time spent on the target word and the immediate post-target region (both *F*'s < 1). There was a significant main effect of neighborhood frequency, $F_s(1, 19) = 6.84$, $p < .05$, $MSE = 2{,}996.02$; $F_i(1, 102) = 4.63$, $p < .05$, $MSE = 13{,}130.65$. Participants spent less time on the words with higher frequency neighbors than on the words without higher frequency neighbors (607 ms vs. 639 ms). The interaction between word frequency and neighborhood frequency was not significant (both *F*'s < 1). There were no significant effects on the total time spent on the target word and immediate post-target region for the group that made more regressions (all *p*'s > .15).

In the analysis of the percentage of regressions, there were no significant effects for either group (all *p*'s > .10).

[28] The reader skill analyses were conducted with the homophones removed and the results were as follows. There was no effect of ART group in the percentage of target words skipped (both F's < 1). The effect of word frequency was significant, as the low-frequency words were skipped more often than the medium-frequency words (21.2% vs. 17.4%), $F_s(1, 38) = 5.48$, $p < .05$, $MSE = 105.10$; $F_i(1, 204) = 1.92$, $p > .15$, $MSE = 217.02$. The interaction between ART group and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.38$, $p = .074$, $MSE = 105.10$; $F_i < 1$. The low ART group did not skip the low-frequency words any more often than the medium-frequency words (both F's < 1), whereas the high ART group skipped the low-frequency words more often than the medium-frequency words (23.8% vs. 17.0%), $F_s(1, 18) = 8.00$, $p < .05$, $MSE = 109.23$; $F_i(1, 102) = 1.78$, $p > .15$, $MSE = 218.22$. None of the effects involving neighborhood frequency were significant (all p's $> .25$). In the reading rate analysis, the effect of word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.84$, $p = .057$, $MSE = 106.59$; $F_i(1, 204) = 1.34$, $p > .20$, $MSE = 220.12$. The low-frequency words were skipped more often than the medium-frequency words (20.6% vs. 17.4%). No other effects were significant (all p's $> .10$).

There was a significant effect of ART group in the item analysis of the first fixation durations, $F_s < 1$; $F_i(1, 204) = 6.67$, $p < .05$, $MSE = 975.34$. There was a significant effect of neighborhood frequency, $F_s(1, 38) = 10.72$, $p < .01$, $MSE = 500.96$; $F_i(1, 204) = 3.84$, $p = .051$, $MSE = 975.34$. The first fixation durations for the words with higher frequency neighbors were 11 ms shorter than the first fixation durations for the words without higher frequency neighbors. No other effects were significant (all p's $>$ .10). The main effect of reading rate group on the first fixation duration data was significant in the item analysis (228 ms for the participants with lower reading rate scores and 210 ms for the participants with higher reading rate scores), $F_s(1, 38) = 2.37$, $p > .10$, $MSE = 3{,}338.78$; $F_i(1, 204) = 14.34$, $p < .001$, $MSE = 1{,}199.59$. There was no main effect of word frequency and no interaction between word frequency and reading rate group (all p's > .20). The main effect of neighborhood frequency and the interaction between neighborhood frequency and reading rate group were both significant in the subject analysis, $F_s(1, 38) = 15.04$, $p < .001$, $MSE = 450.28$; $F_i(1, 204) = 4.46$, $p < .05$, $MSE = 1{,}199.59$ and $F_s(1, 38) = 6.57$, $p < .05$, $MSE = 450.28$; $F_i(1, 204) = 1.87$, $p > .15$, $MSE = 1{,}199.59$, respectively. Participants with lower reading rate scores showed a 22 ms facilitatory effect of neighborhood frequency, $F_s(1, 16) = 16.48$, $p < .01$, $MSE = 493.01$; $F_i(1, 102) = 4.76$, $p < .05$, $MSE = 1{,}523.34$. There was no effect of neighborhood frequency for the participants with high reading rate scores, $F_s(1, 22) = 1.09$, $p > .30$, $MSE = 419.21$; $F_i < 1$. No other effects were significant (all p's > .10).

In the analysis of the gaze duration data, the main effect of ART group was marginally significant in the subject analysis, $F_s(1, 38) = 3.73$, $p = .061$, $MSE = 7{,}036.57$; $F_i(1, 204) = 21.31$, $p < .001$, $MSE = 2{,}046.23$. The main effect of word frequency was not significant, $F_s(1, 38) = 1.09$, $p > .30$, $MSE = 668.96$; $F_i < 1$, nor was the interaction between group and word frequency, $F_s < 1$; $F_i(1, 204) = 1.21$, $p > .25$, $MSE = 2{,}046.23$. No other effects were significant (all F's < 1). There was a significant effect of reading rate on the gaze duration data, $F_s(1, 38) = 5.92$, $p < .05$, $MSE = 6{,}684.71$; $F_i(1, 204) = 34.35$, $p < .001$, $MSE = 2{,}440.57$, as the gaze durations for the participants with lower reading rate scores were 32 ms longer than the gaze durations for the participants with higher reading rate scores. There was no effect of word frequency, $F_s(1, 38) = 1.25$, $p >$

.25, $MSE = 382.00$; $F_i < 1$. The only other significant effect was the three-way interaction between reading rate group, word frequency, and neighborhood frequency in the subject analysis, $F_s(1, 38) = 4.91$, $p < .05$, $MSE = 1{,}253.10$; $F_i(1, 204) = 1.08$, $p > .30$, $MSE = 2{,}440.57$. For the participants with lower reading rate scores, the gaze durations for the low-frequency words with higher frequency neighbors were 22 ms shorter than the gaze durations for the low-frequency words without higher frequency neighbors, $F_s(1, 38) = 5.08$, $p < .05$, $MSE = 802.79$; $F_i < 1$. There were no significant effects of neighborhood frequency for the medium-frequency words (both F's < 1). There were no significant effects for the participants with higher reading rate scores (all p's > .20).

There was a main effect of ART group in the item analysis of the total time spent on the target word, $F_s < 1$; $F_i(1, 204) = 5.12$, $p < .05$, $MSE = 4{,}043.03$ (288 ms for the low ART group and 268 ms for the high ART group). The main effect of word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.63$, $p = .064$, $MSE = 1{,}402.12$; $F_i(1, 204) = 2.17$, $p > .10$, $MSE = 4{,}043.03$, but the interaction between group and word frequency was not (both F's < 1). No other effects were significant (all F's < 1). Reading rate had an effect on the total time spent on the target word, $F_s(1, 38) = 8.01$, $p < .01$, $MSE = 8{,}382.71$; $F_i(1, 204) = 23.79$, $p < .001$, $MSE = 4{,}885.53$. Participants with lower reading rate scores spent more time on the target words than the participants with higher reading rate scores (307 ms vs. 265 ms). In addition, the effect of word frequency was significant in the subject analysis, $F_s(1, 38) = 4.72$, $p < .05$, $MSE = 1{,}343.93$; $F_i(1, 204) = 1.23$, $p > .25$, $MSE = 4{,}885.53$. No other effects were significant (all p's > .15).

In the analysis of the duration of the first fixation after leaving the target word, there was a significant effect of ART group in the item analysis (228 ms for the low ART group and 218 ms for the high ART group), $F_s < 1$; $F_i(1, 204) = 6.14$, $p < .05$, $MSE =$ 943.35. There was a significant effect of word frequency in the subject analysis, $F_s(1, 38) = 5.41$, $p < .05$, $MSE = 939.30$; $F_i(1, 204) = 3.75$, $p = .054$, $MSE = 943.35$, and no group by word frequency interaction, $F_s < 1$; $F_i(1, 204) = 1.61$, $p > .20$, $MSE = 943.35$. The group by neighborhood frequency interaction was significant, $F_s(1, 38) = 6.27$, $p < .05$, $MSE = 659.00$; $F_i(1, 204) = 3.05$, $p = .082$, $MSE = 943.35$. For the low ART group, fixation durations to words with higher frequency neighbors were not significantly different than fixation durations to words without higher frequency neighbors, $F_s(1, 20) = 2.36$, $p > .10$, $MSE = 413.14$; $F_i(1, 102) = 4.71$, $p < .05$, $MSE = 1{,}027.33$. The effect of neighborhood frequency was marginally significant for the high ART group in the subject analysis, $F_s(1, 18) = 3.74$, $p = .069$, $MSE = 932.19$; $F_i(1, 102) = 1.55$, $p > .20$, $MSE =$ 859.37. For this group, fixation durations were longer for words with higher frequency neighbors (229 ms) than for words without higher frequency neighbors (215 ms). No other effects were significant (all p's > .20). There was a significant effect of reading rate on the next fixation after the target word, $F_s(1, 38) = 5.31$, $p < .05$, $MSE = 4{,}078.86$; $F_i(1, 204) = 30.66$, $p < .001$, $MSE = 981.34$, as the fixations for participants with lower reading rate scores were 23 ms longer than the fixations for the participants with higher reading rate scores. The effect of word frequency was significant, $F_s(1, 38) = 7.12$, $p < .05$, $MSE = 879.42$; $F_i(1, 204) = 6.40$, $p < .05$, $MSE = 981.34$, and the interaction between word frequency and reading rate group was marginally significant in the subject analysis, $F_s(1, 38) = 2.98$, $p = .093$, $MSE = 879.42$; $F_i(1, 204) = 4.80$, $p < .05$, $MSE = 981.34$. This was due to a significant effect of word frequency for the participants with lower reading rate scores, $F_s(1, 16) = 8.01$, $p < .05$, $MSE = 921.93$ $F_i(1, 102) = 8.08$, $p < .01$, $MSE =$

1,353.64, but no effect of word frequency for the participants with higher reading rate scores (both F's < 1). The main effect of neighborhood frequency was not significant (both F's < 1), but the interaction between reading rate group and neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 38) = 4.01, p = .052$, $MSE = 694.45$; $F_i(1, 204) = 2.06, p > .15$, $MSE = 981.34$. For the participants with lower reading rate scores, the effect of neighborhood frequency was not significant (both p's > .15). For the participants with higher reading rate scores, the fixations following words with higher frequency neighbors were 10 ms longer than the fixations following word without higher frequency neighbors, $F_s(1, 38) = 3.25, p = .085$, $MSE = 711.10$; $F_i < 1$. No other effects were significant (all p's > .15).

In the analysis of the total time spent on the target word and the immediate post-target region, the main effect of ART group was not significant, $F_s(1, 38) = 2.34, p > .10$, $MSE = 45{,}069.61$; $F_i(1, 204) = 8.78, p < .01$, $MSE = 16{,}173.19$. The main effect of word frequency was not significant, $F_s(1, 38) = 1.81, p > .15$, $MSE = 4{,}543.69$; $F_i < 1$, nor was the interaction between group and word frequency, $F_s(1, 38) = 1.18, p > .25$, $MSE = 4{,}543.69$; $F_i < 1$. The main effect of neighborhood frequency was not significant, $F_s(1, 38) = 1.95, p > .15$, $MSE = 6{,}185.39$; $F_i < 1$, nor was the interaction between group and neighborhood frequency (both F's < 1). Both the word frequency by neighborhood frequency interaction and the three-way interaction between group, word frequency, and neighborhood frequency were not significant (all F's < 1). The participants with lower reading rate scores spent more time on the target word and the immediate post-target region (692 ms vs. 574 ms), $F_s(1, 38) = 16.26, p < .001$, $MSE = 33{,}502.61$; $F_i(1, 204) = 56.50, p < .001$, $MSE = 17{,}186.94$. No other effects were significant (all p's > .10).

The high ART group regressed more often to the target word compared to the low ART group (17.8% vs. 12.7%), $F_s(1, 38) = 3.10, p = .086, MSE = 322.57$; $F_i(1, 204) = 5.42, p < .05, MSE = 257.58$. No other effects were significant (all p's > .25). For the reading rate analysis, the only effects to approach significance were the interaction between reading rate group and neighborhood frequency, $F_s(1, 38) = 2.85, p = .099, MSE = 176.35$; $F_i < 1$, and the three-way interaction between reading rate group, word frequency, and neighborhood frequency, $F_s(1, 38) = 3.38, p = .074, MSE = 185.29$; $F_i < 1$.

[29] As in Experiment 3A, a composite reader skill score was created for each participant. Participants were ranked both on their ART scores and their Nelson-Denny reading rate scores. The ranks were then combined to create a composite reader skill score. A median split was performed on these skill scores (median = 17, range = 1 to 31) creating a low skill group ($M = 10.5$) and a high skill group ($M = 22.0$), $F_s(1, 38) = 81.86, p < .001, MSE = 17.39$. The data were submitted to separate 2 (Word Frequency: low, medium) x 2 (Neighborhood Frequency: no higher frequency neighbors, higher frequency neighbors) x 2 (skill group: low, high) mixed model ANOVAs for each of the first pass and spillover variables.

For the percentage of target words initially skipped, the correlation between reader skill and the word frequency effect was marginally significant, $r(40) = -.29, p = .062$. As reader skill increased, the magnitude of the word frequency effect decreased. Reader skill was not significantly correlated with the neighborhood frequency effect, $r(40) = -.17, p > .25$. In the ANOVA, the effect of skill group was not significant, $F_s < 1$; $F_i(1, 222) = 2.06, p > .15, MSE = 226.24$. The effect of word frequency was not significant, $F_s(1, 38) = 2.39$, $p > .10$, $MSE = 90.51$; $F_i < 1$, but the interaction between skill group and word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.82$, $p = .058$, $MSE = 90.51$; $F_i(1, 222) = 1.31$, $p > .25$, $MSE = 226.24$. The effect of neighborhood frequency was not significant, $F_s(1, 38) = 1.13$, $p > .25$, $MSE = 86.44$; $F_i < 1$, and the interaction between skill group and neighborhood frequency was significant in the subject analysis, $F_s(1, 38) = 5.48$, $p < .05$, $MSE = 86.44$; $F_i < 1$. The low skill group did not exhibit a significant neighborhood frequency effect (both F's < 1), whereas the high skill group did, $F_s(1, 20) = 5.68$, $p < .05$, $MSE = 92.86$; $F_i(1, 111) = 1.19$, $p > .25$, $MSE = 203.35$. The high skill group skipped the target words with higher frequency neighbors less often than the target words without higher frequency neighbors (15.9% vs. 18.8%). No other effects were significant (all p's > .20).

In the analysis of the first fixation durations, reader skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = -.05$, $p > .70$ and $r(40) = .23$, $p > .10$, respectively. In the ANOVA, the effect of skill group was significant in the item analysis, $F_s(1, 38) = 2.00$, $p > .15$, $MSE = 3{,}312.68$; $F_i(1, 222) = 9.73$, $p < .01$, $MSE = 1{,}276.00$. The main effect of word frequency was not significant, $F_s < 1$; $F_i(1, 222) = 1.13$, $p > .25$, $MSE = 1{,}276.00$, and the interaction between word frequency and skill group was not significant (both F's < 1). The main effect of neighborhood frequency was marginally significant in the subject analysis, $F_s(1, 38) = 2.92$, $p = .095$, $MSE = 464.06$; $F_i(1, 222) = 1.45$, $p > .20$, $MSE = 1{,}276.00$. No other effects were significant (all p's > .20).

In the gaze duration analysis, reader skill was not significantly correlated with the word frequency effect, $r(40) = .17$, $p > .25$, nor with the neighborhood frequency effect,

$r(40) = .009$, $p > .95$. In the ANOVA, reader skill did have a significant effect, $F_s(1, 38) = 4.36$, $p < .05$, $MSE = 6{,}579.18$; $F_i(1, 222) = 29.27$, $p < .001$, $MSE = 2{,}483.81$. The main effect of word frequency was significant, $F_s(1, 38) = 5.29$, $p < .05$, $MSE = 644.18$; $F_i(1, 222) = 3.84$, $p = .051$, $MSE = 2{,}483.81$, but the interaction between skill group and word frequency was not (both F's < 1). No other effects were significant (all p's > .20).

In the total time spent on the target word, reader skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = .18$, $p > .20$ and $r(40) = .01$, $p > .90$, respectively. In the ANOVA, the main effect of skill group was significant, $F_s(1, 38) = 5.07$, $p < .05$, $MSE = 8{,}257.21$; $F_i(1, 222) = 20.29$, $p < .001$, $MSE = 4{,}589.74$. The main effect of word frequency was significant, $F_s(1, 38) = 14.44$, $p < .001$, $MSE = 1{,}018.33$; $F_i(1, 222) = 5.24$, $p < .05$, $MSE = 4{,}589.74$, but the interaction between skill group and word frequency was not (both F's < 1). No other effects were significant (all p's > .30).

In the analysis of the duration of the first fixation after leaving the target word, reader skill was significantly correlated with both the word frequency effect and the neighborhood frequency effect, $r(40) = .38$, $p < .05$ and $r(40) = .54$, $p < .001$, respectively. As reader skill increased, so did the magnitude of the word frequency effect and the magnitude of the neighborhood frequency effect. In the ANOVA, the main effect of reader skill was significant, $F_s(1, 38) = 4.18$, $p < .05$, $MSE = 3{,}625.71$; $F_i(1, 222) = 25.12$, $p < .001$, $MSE = 989.12$. The main effect of word frequency was not significant, $F_s(1, 38) = 1.39$, $p > .20$, $MSE = 586.31$; $F_i(1, 222) = 2.57$, $p > .10$, $MSE = 989.12$, nor was the interaction between skill group and word frequency, $F_s(1, 38) = 2.25$, $p > .10$, $MSE = 586.31$; $F_i(1, 222) = 2.10$, $p > .10$, $MSE = 989.12$. The group by neighborhood frequency interaction was significant, $F_s(1, 38) = 7.56$, $p < .01$, $MSE = 433.70$; $F_i(1, 222) = 5.03$, $p < .05$, $MSE = 989.12$. The neighborhood frequency effect was marginally significant for the low skill group, $F_s(1, 38) = 3.68$, $p = .071$, $MSE = 676.88$; $F_i(1, 111) = 3.23$, $p = .075$, $MSE = 1{,}255.61$. The duration of the first fixation after leaving the target word was an average of 11 ms shorter for the words with higher frequency neighbors than for the words without higher frequency neighbors (a facilitatory neighborhood frequency effect). The effect of neighborhood frequency was also significant for the high skill group, $F_s(1, 38) = 4.37$, $p = .05$, $MSE = 214.85$; $F_i(1, 111) = 1.80$, $p > .15$, $MSE = 722.62$. The fixation durations for words with higher frequency neighbors were 6 ms longer than the fixations for the words without higher frequency neighbors (an inhibitory neighborhood frequency effect). No other effects were significant (all F's < 1).

For the total time spent on the target word and the immediate post-target region, reader skill was not correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = .11$, $p > .45$, and $r(40) = .02$, $p > .85$, respectively. In the ANOVA, the main effect of skill was significant, $F_s(1, 38) = 9.21$, $p < .01$, $MSE = 38{,}153.07$; $F_i(1, 222) = 38.30$, $p < .001$, $MSE = 17{,}780.93$. Neither the main effect of word frequency, nor the interaction between skill group and word frequency were significant, $F_s(1, 38) = 2.72$, $p > .10$, $MSE = 3{,}598.28$; $F_i < 1$ and $F_s < 1$; $F_i < 1$, respectively. No other effects were significant (all p's > .15).

In the analysis of the percentage of regressions, reader skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = -.0028$, $p > .95$ and $r(40) = .0005$, $p > .95$, respectively. In the ANOVA, there were no significant effects (all p's > .15).

In this experiment, the composite skill score analysis appeared to be slightly better than the ART analysis. In the ART analysis, the only significant effect was a facilitatory neighborhood frequency effect, for the low ART participants, in the duration of the first fixation after the target word. In the composite skill score analysis, for the high skill participants, there was an inhibitory effect of neighborhood frequency in the percentage of target words skipped and in the duration of the first fixation following the target word. Also, there was again a facilitatory neighborhood frequency effect for the duration of the first fixation after leaving the target word for the low skill participants.

30 The analyses of the composite reader skill scores were conducted with the homophones removed from the stimulus set. The results were as follows. For the percentage of target words initially skipped, the correlation between reader skill and the word frequency effect was not significant, $r(40) = -.25$, $p > .10$. Reader skill was also not correlated with the neighborhood frequency effect, $r(40) = -.12$, $p > .40$. In the ANOVA, the effect of skill group was not significant, $F_s < 1$; $F_i(1, 204) = 1.61$, $p > .20$, $MSE = 231.87$. In the subject analysis, both the effect of word frequency and the interaction between skill group and word frequency were significant, $F_s(1, 38) = 4.66$, $p < .05$, $MSE = 104.89$; $F_i(1, 204) = 1.15$, $p > .25$, $MSE = 231.87$, and $F_s(1, 38) = 3.46$, $p = .071$, $MSE = 104.89$; $F_i < 1$. The effect of neighborhood frequency was not significant (both F's < 1), but the interaction between skill group and neighborhood frequency was significant in the subject analysis, $F_s(1, 38) = 4.47$, $p < .05$, $MSE = 102.42$; $F_i < 1$. The low skill group did not exhibit a significant neighborhood frequency effect (both F's < 1), whereas the high skill group did, $F_s(1, 20) = 8.10$, $p < .05$, $MSE = 110.07$; $F_i < 1$. The high skill group skipped the target words with higher frequency neighbors less often than the words

without higher frequency neighbors (16.7% vs. 18.8%). No other effects were significant (all *p*'s > .20).

In the analysis of the first fixation durations, reader skill was not significantly correlated with the word frequency effect, $r(40) = -.10$, $p > .50$, but was correlated with the neighborhood frequency effect, $r(40) = .32$, $p < .05$. As reader skill increased, so did the magnitude of the neighborhood frequency effect. In the ANOVA, skill group did not have a significant effect, $F_s(1, 38) = 1.06$, $p > .30$, $MSE = 3{,}451.05$; $F_i(1, 204) = 7.34$, $p < .01$, $MSE = 1{,}233.05$. The main effect of word frequency was not significant, nor was the interaction between word frequency and skill group (all *F*'s < 1). The main effect of neighborhood frequency was significant, $F_s(1, 38) = 12.73$, $p < .001$, $MSE = 469.06$; $F_i(1, 204) = 4.29$, $p < .05$, $MSE = 1{,}233.05$. The interaction between skill group and neighborhood frequency was also significant in the subject analysis, $F_s(1, 38) = 4.79$, $p < .05$, $MSE = 469.06$; $F_i(1, 204) = 2.59$, $p > .10$, $MSE = 1{,}233.05$. No other effects were significant (all p's > .15).

In the gaze duration analysis, reader skill was not significantly correlated with the word frequency effect, $r(40) = .21$, $p > .15$, or with the neighborhood frequency effect, $r(40) = .10$, $p > .50$. In the ANOVA, skill group did have a significant effect, $F_s(1, 38) = 4.22$, $p < .05$, $MSE = 6{,}953.86$; $F_i(1, 204) = 28.58$, $p < .001$, $MSE = 2{,}437.24$. The main effect of word frequency was not significant, $F_s(1, 38) = 1.17$, $p > .25$, $MSE = 683.73$; $F_i(1, 204) = 1.37$, $p > .20$, $MSE = 2{,}437.24$, but the interaction between skill group and word frequency was not (both *F*'s < 1). No other effects were significant (all *p*'s > .20).

In the total time spent on the target word, reader skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect,

$r(40) = .22$, $p > .15$ and $r(40) = -.04$, $p > .75$, respectively. In the ANOVA, the main effect of skill group was significant, $F_s(1, 38) = 4.29$, $p < .05$, $MSE = 9{,}120.33$; $F_i(1, 204) = 19.11$, $p < .001$, $MSE = 4{,}458.03$. The main effect of word frequency was marginally significant in the subject analysis, $F_s(1, 38) = 3.82$, $p = .058$, $MSE = 1{,}408.27$; $F_i(1, 204) = 1.83$, $p > .15$, $MSE = 4{,}458.03$, but the interaction between skill group and word frequency was not (both F's < 1). No other effects were significant (all p's > .30).

In the analysis of the durations of the first fixation after leaving the target word, reader skill was not correlated with the word frequency effect, $r(40) = .18$, $p > .25$. Skill was correlated with the neighborhood frequency effect, $r(40) = .54$, $p < .001$. As reader skill increased, so did the magnitude of the neighborhood frequency effect. In the ANOVA, the main effect of skill group was not significant, $F_s(1, 38) = 2.71$, $p > .10$, $MSE = 4{,}340.24$; $F_i(1, 204) = 22.46$, $p < .001$, $MSE = 1{,}132.53$. The main effect of word frequency was significant, $F_s(1, 38) = 5.91$, $p < .05$, $MSE = 920.90$; $F_i(1, 204) = 6.45$, $p < .05$, $MSE = 1{,}132.53$, but the interaction between skill group and word frequency was not, $F_s(1, 38) = 1.13$, $p > .25$, $MSE = 920.90$; $F_i(1, 204) = 1.88$, $p > .15$, $MSE = 1{,}132.53$. The group by neighborhood frequency interaction was significant, $F_s(1, 38) = 8.02$, $p < .01$, $MSE = 634.02$; $F_i(1, 204) = 5.65$, $p < .05$, $MSE = 1{,}132.53$. The neighborhood frequency effect was not significant for the low skill group, $F_s(1, 38) = 2.98$, $p > .10$, $MSE = 516.13$; $F_i(1, 102) = 2.23$, $p > .10$, $MSE = 1{,}214.06$. The effect of neighborhood frequency was significant for the high skill group, $F_s(1, 38) = 5.23$, $p < .05$, $MSE = 740.12$; $F_i(1, 102) = 3.55$, $p = .062$, $MSE = 1{,}051.00$. The fixation durations for words with higher frequency neighbors were 13 ms longer than the fixations for the words without higher frequency neighbors. No other effects were significant (all F's < 1).

In the total time spent on the target word and the immediate post-target region, reader skill was not correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = .10$, $p > .50$, and $r(40) = .02$, $p > .85$, respectively. In the ANOVA, the main effect of skill was significant, $F_s(1, 38) = 9.01$, $p < .01$, $MSE =$ 38,667.90; $F_i(1, 204) = 36.83$, $p < .001$, $MSE =$ 16,402.14. Neither the main effect of word frequency, nor the interaction between skill group and word frequency were significant, $F_s(1, 38) = 2.12$, $p > .15$, $MSE =$ 4,530.34; $F_i < 1$ and $F_s(1, 38) = 1.30$, $p >$ .25, $MSE =$ 4,530.34; $F_i < 1$, respectively. No other effects were significant (all p's > .15).

In the percentage of regressions analysis, reader skill was not significantly correlated with either the word frequency effect or the neighborhood frequency effect, $r(40) = .02$, $p > .85$ and $r(40) = -.02$, $p > .85$, respectively. In the ANOVA, there were no significant effects (all p's > .20).

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Table 1
Stimulus Characteristics of the Words Used in Experiment 1

Stimulus Characteristic	Neighborhood Frequency	
	No HF N	HF N
	Low-frequency Words	
Word Frequency	3.8	3.0
Subjective Frequency	2.8	2.6
Number of Neighbors	1.0	2.7
Number of HF Neighbors	0.0	1.3
Highest Frequency Neighbor	1.9	121.1
N	25	26
	Medium-frequency Words	
Word Frequency	25.2	26.5
Subjective Frequency	4.1	3.9
Number of Neighbors	1.8	3.4
Number of HF Neighbors	0.0	1.3
Highest Frequency Neighbor	7.9	269.5
N	18	19

Note. HF = higher frequency neighbor(s). Highest frequency neighbor refers to the mean frequency of the highest frequency neighbor.

Table 2

Simulation Using the Multiple Read-out Model (Grainger & Jacobs, 1996) of Experiment 1 and Experiment 2 (Mean Number of Processing Cycles)

	Neighborhood Frequency	
Word Frequency	No HF N	HF N
	Experiment 1	
Low-frequency Words	16.37	18.35
Medium-frequency Words	16.51	17.85
	Experiment 2	
Low-frequency Words	17.39	18.33
Medium-frequency Words	17.14	17.79

Note. HF N = higher frequency neighbor(s).

Table 3

Mean Orthographic and Phonological Error Scores From the Seidenberg and McClelland (1989) Model, and Mean Cross-entropy Error Scores From the Plaut et al. (1996) Model for Experiment 1 and Experiment 2

	Low-frequency words		Medium-frequency words	
Error Score	No HF N	HF N	No HF N	HF N
		Experiment 1		
Orthographic	10.74	12.14	7.94	6.28
Phonological	6.31	6.80	4.47	3.92
Cross-entropy	.069	.085	.053	.042
		Experiment 2		
Orthographic	11.04	10.65	6.57	6.29
Phonological	5.31	5.94	3.62	4.36
Cross-entropy	.051	.089	.035	.049

Note. HF N = higher frequency neighbor(s).

Table 4

Mean Response Latencies (in Milliseconds) and Error Rates (in %) in Experiment 1A (Standard Lexical Decision Instructions) and Experiment 1B (Modified Lexical Decision Instructions)

	Neighborhood Frequency	
Word Frequency	No HF N	HF N
	Experiment 1A	
Low-frequency Words	616 (6.9)	621 (6.9)
Medium-frequency Words	560 (3.4)	563 (2.1)
	Experiment 1B	
Low-frequency Words	628 (5.1)	652 (7.0)
Medium-frequency Words	574 (3.0)	583 (1.8)

Note. HF N = higher frequency neighbor(s). Error rates appear in parentheses.

Table 5

Mean Response Latencies (in Milliseconds) and Error Rates (in %) for the Low ART Group and the High ART Group in Experiment 1A (Standard Lexical Decision Instructions) and Experiment 1B (Modified Lexical Decision Instructions)

		Neighborhood Frequency	
Word Frequency		No HF N	HF N
		Experiment 1A	
Low-frequency Words	Low ART	657 (9.0)	665 (9.2)
	High ART	575 (4.8)	577 (4.6)
Medium-frequency Words	Low ART	585 (4.7)	592 (2.8)
	High ART	534 (2.2)	532 (1.3)
		Experiment 1B	
Low-frequency Words	Low ART	653 (5.8)	684 (8.8)
	High ART	603 (4.4)	620 (5.1)
Medium-frequency Words	Low ART	602 (3.6)	614 (2.1)
	High ART	547 (2.5)	552 (1.5)

Note. HF N = higher frequency neighbor(s). Error rates appear in parentheses.

Table 6
Mean Subjective Frequency Ratings for Words in Experiment 1B (Modified Lexical Decision Instructions)

	Neighborhood Frequency	
Word Frequency	No HF N	HF N
Low-frequency Words	3.2	3.4
Medium-frequency Words	4.4	4.5

Note. HF N = higher frequency neighbor(s).

Table 7
Stimulus Characteristics of the Words Used in Experiment 2

Stimulus Characteristic	Neighborhood Frequency	
	No HF N	HF N
	Low-frequency Words	
Word Frequency	4.8	5.0
Number of Neighbors	4.5	4.5
Number of HF Neighbors	0	1.3
Highest Frequency Neighbor	4.8	344.3
Word Body Neighbors	12	13
	Medium-frequency Words	
Word Frequency	29.3	29.4
Number of Neighbors	4.4	4.4
Number of HF Neighbors	0	1.2
Highest Frequency Neighbor	12.9	270.9
Word Body Neighbors	17	12

Note. HF = higher frequency neighbor(s). Highest frequency neighbor refers to the mean frequency of the highest frequency neighbor.

Table 8

Mean Response Latencies (in Milliseconds) and Error Rates (in %) in Experiment 2A (Standard Lexical Decision Instructions) and Experiment 2B (Modified Lexical Decision Instructions)

	Neighborhood Frequency	
Word Frequency	No HF N	HF N
	Experiment 2A	
Low-frequency Words	642 (6.9)	630 (5.8)
Medium-frequency Words	559 (0.8)	566 (1.8)
	Experiment 2B	
Low-frequency Words	682 (4.8)	673 (4.9)
Medium-frequency Words	596 (0.4)	598 (1.3)

Note. HF N = higher frequency neighbor(s). Error rates appear in parentheses.

Table 9

Mean Subjective Frequency Ratings for Experiment 2A (Standard Lexical Decision Instructions) and Experiment 2B (Modified Lexical Decision Instructions)

	Neighborhood Frequency	
Word Frequency	No HF N	HF N
	Experiment 2A	
Low-frequency Words	3.6	3.7
Medium-frequency Words	5.1	5.1
	Experiment 2B	
Low-frequency Words	3.7	3.8
Medium-frequency Words	5.1	5.2

Note. HF N = higher frequency neighbor(s).

Table 10

Mean Response Latencies (in Milliseconds) and Error Rates (in %) in Experiment 2A (Standard Lexical Decision Instructions) and Experiment 2B (Modified Lexical Decision Instructions) as a Function of Neighborhood Frequency Condition

	Neighborhood Frequency		
Word Frequency	No HF N	HF N	HF NB
		Experiment 2A	
Low-frequency Words	642 (6.9)	625 (3.8)	634 (8.2)
Medium-frequency Words	559 (0.8)	560 (2.0)	574 (1.4)
		Experiment 2B	
Low-frequency Words	682 (4.8)	668 (4.3)	678 (5.6)
Medium-frequency Words	596 (0.4)	586 (1.0)	615 (1.8)

Note. HF N = higher frequency neighbor(s); HF NB = higher frequency neighbor where highest frequency neighbor is word-body neighbor. Error rates appear in parentheses.

Table 11

Mean Response Latencies (in Milliseconds) and Error Rates (in %) for the Low ART Group and the High ART Group in Experiment 2A (Standard Lexical Decision Instructions) and Experiment 2B (Modified Lexical Decision Instructions)

		Neighborhood Frequency	
Word Frequency		No HF N	HF N
		Experiment 1A	
Low-frequency Words	Low ART	655 (6.8)	644 (6.1)
	High ART	626 (7.1)	611(5.5)
Medium-frequency Words	Low ART	566 (0.6)	673 (5.1)
	High ART	549 (1.1)	553 (1.9)
		Experiment 1B	
Low-frequency Words	Low ART	682 (5.1)	673 (5.1)
	High ART	682 (4.5)	673 (4.6)
Medium-frequency Words	Low ART	590 (0.1)	586 (2.0)
	High ART	603 (0.7)	611 (0.5)

Note. HF N = higher frequency neighbor(s). Error rates appear in parentheses.

Table 12
First Pass Eye Movement Measures for Experiment 3A

	Neighborhood Frequency	
Word Frequency	No HF N	HF N
	Target Words Skipped (%)	
Low-frequency Words	10.2	8.5
Medium-frequency Words	23.5	18.2
	First Fixation Duration (ms)	
Low-frequency Words	229	236
Medium-frequency Words	227	222
	Gaze Duration (ms)	
Low-frequency Words	255	260
Medium-frequency Words	244	232

Note. HF N = higher frequency neighbor(s).

Table 13
Eye Movement Measures of Spillover Effects for Experiment 3A

Word Frequency	Neighborhood Frequency: No HF N	HF N
	Total Time on Target Word (ms)	
Low-frequency Words	293	304
Medium-frequency Words	272	271
	First Fixation After Target Word (ms)	
Low-frequency Words	252	243
Medium-frequency Words	232	239
	Total Time on Target Word And Immediate Post-target Region (ms)	
Low-frequency Words	704	735
Medium-frequency Words	644	657
	Target Words Regressed (%)	
Low-frequency Words	16.0	16.7
Medium-frequency Words	10.1	12.3

Note. HF N = higher frequency neighbor(s).

Table 14

First Pass Eye Movement Measures for the Low ART Group and the High ART Group in Experiment 3A

		Neighborhood Frequency	
Word Frequency		No HF N	HF N
		Target Words Skipped (%)	
Low-frequency Words	Low ART	4.9	4.2
	High ART	15.0	12.5
Medium-frequency Words	Low ART	15.9	14.2
	High ART	30.4	21.9
		First Fixation Duration (ms)	
Low-frequency Words	Low ART	234	249
	High ART	225	225
Medium-frequency Words	Low ART	233	221
	High ART	222	222
		Gaze Duration (ms)	
Low-frequency Words	Low ART	273	277
	High ART	238	244
Medium-frequency Words	Low ART	245	234
	High ART	243	230

Note. HF N = higher frequency neighbor(s).

Table 15

Eye Movement Measures of Spillover Effects for the Low ART Group and the High ART Group in Experiment 3A

		Neighborhood Frequency	
Word Frequency		No HF N	HF N
		Total Time on Target Word (ms)	
Low-frequency Words	Low ART	306	310
	High ART	281	298
Medium-frequency Words	Low ART	274	261
	High ART	270	279
		First Fixation After Target Word (ms)	
Low-frequency Words	Low ART	266	251
	High ART	240	237
Medium-frequency Words	Low ART	222	230
	High ART	240	247
		Total Time on Target Word And Immediate Post-target Region (ms)	
Low-frequency Words	Low ART	723	725
	High ART	687	743
Medium-frequency Words	Low ART	651	613
	High ART	638	698
		Target Words Regressed (%)	
Low-frequency Words	Low ART	14.7	13.3

	High ART	17.2	19.7
Medium-frequency Words	Low ART	10.8	10.3
	High ART	9.4	14.1

Note. HF N = higher frequency neighbor(s).

Table 16
First Pass Eye Movement Measures for Experiment 3B

Word Frequency	Neighborhood Frequency	
	No HF N	HF N
	Target Words Skipped (%)	
Low-frequency Words	21.1	18.6
Medium-frequency Words	17.9	16.9
	First Fixation Duration (ms)	
Low-frequency Words	225	217
Medium-frequency Words	220	217
	Gaze Duration	
Low-frequency Words	249	260
Medium-frequency Words	245	245

Note. HF N = higher frequency neighbor(s).

Table 17
Eye Movement Measures of Spillover Effects for Experiment 3B

Word Frequency	Neighborhood Frequency: No HF N	HF N
	Total Time on Target Word (ms)	
Low-frequency Words	288	299
Medium-frequency Words	276	272
	First Fixation After Target Word (ms)	
Low-frequency Words	226	223
Medium-frequency Words	221	220
	Total Time on Target Word And Immediate Post-target Region (ms)	
Low-frequency Words	637	630
Medium-frequency Words	630	606
	Target Words Regressed (%)	
Low-frequency Words	12.2	16.1
Medium-frequency Words	13.0	11.8

Note. HF N = higher frequency neighbor(s).

Table 18

First Pass Eye Movement Measures as a Function of Neighborhood Frequency Condition for Experiment 3B

		Neighborhood Frequency	
Word Frequency	No HF N	HF N	HF NB
		Target Words Skipped (%)	
Low-frequency Words	20.2	19.7	18.0
Medium-frequency Words	18.5	17.8	16.2
		First Fixation Duration (ms)	
Low-frequency Words	225	226	212
Medium-frequency Words	220	218	215
		Gaze Duration	
Low-frequency Words	249	272	250
Medium-frequency Words	245	255	232

Note. HF N = higher frequency neighbor(s); HF NB = higher frequency neighbor where highest frequency neighbor is word-body neighbor.

Table 19

Eye Movement Measures of Spillover Effects as a Function of Neighborhood Frequency Condition for Experiment 3B

Word Frequency	Neighborhood Frequency: No HF N	HF N	HF NB
	Total Time on Target Word (ms)		
Low-frequency Words	288	317	281
Medium-frequency Words	276	278	265
	First Fixation After Target Word (ms)		
Low-frequency Words	226	220	225
Medium-frequency Words	221	221	218
	Total Time on Target Word And Immediate Post-target Region (ms)		
Low-frequency Words	637	638	617
Medium-frequency Words	630	609	599
	Target Words Regressed (%)		
Low-frequency Words	12.2	17.2	13.7
Medium-frequency Words	13.0	9.0	16.4

Note. HF N = higher frequency neighbor(s); HF NB = higher frequency neighbor where highest frequency neighbor is word-body neighbor.

Table 20
First Pass Eye Movement Measures for the Low ART Group and the High ART Group in Experiment 3B

		Neighborhood Frequency	
Word Frequency		No HF N	HF N
		Target Words Skipped (%)	
Low-frequency Words	Low ART	18.1	16.6
	High ART	24.3	20.9
Medium-frequency Words	Low ART	18.9	17.0
	High ART	16.7	16.6
		First Fixation Duration (ms)	
Low-frequency Words	Low ART	233	220
	High ART	215	215
Medium-frequency Words	Low ART	224	220
	High ART	216	213
		Gaze Duration (ms)	
Low-frequency Words	Low ART	263	275
	High ART	234	243
Medium-frequency Words	Low ART	255	257
	High ART	235	233

Note. HF N = higher frequency neighbor(s).

Table 21

Eye Movement Measures of Spillover Effects for the Low ART Group and the High ART Group in Experiment 3B

		Neighborhood Frequency	
Word Frequency		No HF N	HF N
		Total Time on Target Word (ms)	
Low-frequency Words	Low ART	297	310
	High ART	279	286
Medium-frequency Words	Low ART	284	278
	High ART	268	266
		First Fixation After Target Word (ms)	
Low-frequency Words	Low ART	237	225
	High ART	215	221
Medium-frequency Words	Low ART	225	216
	High ART	216	224
		Total Time on Target Word And Immediate Post-target Region (ms)	
Low-frequency Words	Low ART	675	655
	High ART	594	602
Medium-frequency Words	Low ART	647	625
	High ART	611	585
		Target Words Regressed (%)	
Low-frequency Words	Low ART	9.9	12.5

	High ART	14.7	20.1
Medium-frequency Words	Low ART	11.9	8.8
	High ART	14.1	15.2

Note. HF N = higher frequency neighbor(s).

Appendix

Items used in Experiment 1A and 1B

Low-Frequency/No Higher Frequency Neighbors: ASPEN, CAMEL, CANAL, DRYER, FLAIR, JEWEL, LASSO*, POPPY, PUPPY, ROBIN, SCARF, SCOUT, SIEGE, SPOON, SWARM, TUNIC, URINE, VILLA*, WHEAT, CASINO, FAMINE, HAMMER, MENACE, PARCEL, PARDON, TASSEL, WAFFLE

Low-Frequency/Higher Frequency Neighbors: BIRCH, CHICK, DAISY, FILTH, FLOUR, FLYER, FROST, HORDE, MANOR, MARSH, MEDAL, MINER, NOOSE*, SHAWL, SPICE, STORK, TORCH, TRUCE, VERVE*, WHALE, BRUNCH, CARTON, CASTLE, CREASE, DAGGER, RANSOM, STRIFE, STRIPE

Medium-Frequency/No Higher Frequency Neighbors: ANGER, BRICK, DRAFT, FOCUS, FRUIT, LABEL, PILOT, ROUTE, SAUCE, STEAM, TOOTH, VERSE, WAIST, CANCER, FRINGE, MARBLE, MOSQUE, TICKET

Medium-Frequency/Higher Frequency Neighbors: ANKLE, BREAD, CHEEK, MAYOR, PLATE, PROSE, RIDER, SHADE, SHAME, SHIRT, STONE, STOVE, THEME, TRACK, BALLOT, RESORT, STRING, STROKE, THREAT

Nonwords: ADOGE, BAMON, BEETH, BLANT, BLONK, BRANK, BREND, CHOLE, CHURM, CLOAD, CLOME, CRESS, DERAY, DUNTY, FAMOR, FLUSE, GLOFE, GROTE, GUIRE, HAFEN, IMOGE, IDIAM, IROTY, JUIRE, JULOR, LEATE, MENON, METEL, MOREL, MOSEL, MUNTH, NASAL, NOIME, NUNSE, NYTON, OTTAR, PANLY, PHOSE, PRAME, PRINE, PROME, PRORY, QUALL, RESEN, RIMAL, ROMER, SCOLE, SHART, SLITE, SMICK, SPAVE, STIGE, STROW, STUKE, STUNF, SWASS, THEMB, THYSE, TRENK, VALNE, VAROR, VEXUS, VOWAL, WANER, WRENG, ARCODE, BEARON, BUTHON, CARPOT, CHRODE, COLEDY, DEBECT, DELIME, DENADE, ENTYLY, FLOMER, GARLEN, HEASEN, LESTON, MARNEL, MERTER, MONION, MONTEY, NOGICE, ORASGE, PALAME, PISCOL, RIBBAN, SILMER, STIBLE, TRAFLE

*These words were not included in the analyses.

Items used in Experiments 2A and 2B

Low-Frequency/No Higher Frequency Neighbors: ACRE, BRAG, BRED*, BUFF, CLOG, CUFF, EMIT, GLEE, HAZY, RAFT, ROMP, SLAB, SNAG, SNUG, SODA, ALLEY, BLOAT, BULKY, COMIC, CRAMP, CRANE, CROAK, MULCH*, PETTY, SCOOP, SCRAP, SLANG, SUPER, TRIBE, WRECK

Low-Frequency/Higher Frequency Neighbors: DORM, GENE, GLUE, HARP, HERB, HIKE, MOTH, POUR, REEL, ROAM, ROBE, SURF, TOTE*, WORM, YELP, BARGE, BASIN, DENSE, FARCE*, FOCAL, HEAVE, LEASH, SCENT, SNEAK, SNORT, SPEAR, STOOL, THIEF, VALVE, WOVEN

Medium-Frequency/No Higher Frequency Neighbors: ACID, BOMB, BOWL, COPY, DIRT, DRUG, GIFT, GLAD, JUMP, PUSH, SOAP, SPAN, SUIT, SWIM, TUBE, BLAME, CLOUD, CRAWL, CURVE, DELAY, GUILT, LODGE, LOOSE, MERGE, MOIST, RELAX, SHIFT, STEEL, STRAW, TRUST

Medium-Frequency/Higher Frequency Neighbors: CALF, FOAM, FUEL, GOWN*, HERO, HORN, KISS, KNEE, NOON, PAIR, RISK, SHOE, TOOL, WOOL, YARD, BEARD, BLOND, BLOOM, CHILL, FLOOD, PRIME, PRIZE, SKILL, SMART, SMELL, SPEND, STALL, STORM, SUITE, WORSE

Nonwords: ATON, BACE, BALT, BELD, BIRE, BOAD, BOPE, BORT, BOWN, BRAB, CHEP, CING, CLAR, DACE, DAST, DOSS, DUTE, FAIE, FAND, FANK, FARG, FING, FORP, FOST, FURE, GARK, GOST, GULM, HELT, JAME, LAPE, LECK, MANT, MARL, NIME, NOOT, NUSH, PAIT, PEAN, PLEM, PUEL, REAN, RIBE, RIST, SARK, SKIB, SLAN, SORK, SUND, SURL, SWID, TEAN, TOND, TORD, TUNK, VADE, VIRE, WEND WHOT, WULL, BARCH, BEGEN, BLACE, BLATE, BLICK, BRACK, CRAKE, CREAT, CRILL, DATCH, EATCH, FATCH, GLAKE, GOUGH, GRASE, GREEP, GRESS, GRIED, GROME, HERRY, HETCH, HOWER, JAKED, LITCH, MAKEN, MARTH, MATER, MIRED, MORTH, NASTE, NATCH, NEVEL, PARTH, PELCH, PLAKE, PORSE, PRIBE, RABLE, REACE, SEAVE, SHAFE, SHART, SHAZE, SMILL, SNOCK, SOUNT, SPIDE, STABE, STAPE, STARM, STECK, STORT, SWART, SWEFT, TOUTH, TRAVE, TROWN, VIRED, WHARE, WHONE

* These words were not used in the analyses.

Sentences used in Experiment 3A

The store didn't sell John's favorite [*spice, sauce*] any more.
Everything was clean except for one [*plate, spoon*] that had egg on it.
She was delighted to see the first [*daisy, poppy*] coming up in her garden.
It took a lot of effort, but the old [*stove, dryer*] was finally fixed.
The gift he liked most was the blue [*shirt, scarf*] from his girlfriend.
She was surprised to see a young [*stork, robin*] fly by the window.
In six months, the price of [*flour, wheat*] had risen very little.
The tailor finished the fancy [*shawl, tunic*] that the star would wear.
Because of the sudden change in temperature, the [*frost, steam*] turned to water.
The picture reminded him of the big [*birch, aspen*] tree in his front yard.
The troops were slowed down by the wide [*marsh, canal*] that was in their way.
The bullet hit the woman in the [*cheek, waist*], but she wasn't seriously hurt.
He was appalled to see a [*stone, brick*] come flying through the window.
After twenty years on the job, the [*miner, flyer*] was suddenly out of work.
When the children saw the picture of the [*whale, camel*] in their book, they laughed.
The prince usually went to his beautiful [*manor, villa*] in the summer.
The children liked the [*chick, puppy*] best of all the animals on the farm.
The award was given to the [*mayor, pilot*] with the longest record of service.
The settlers were glad to see a [*rider, scout*] who told them that the path was safe.
The best place for buying [*bread, fruit*] is the little market on the corner.
In order to be safe, he placed the [*torch, jewel*] out of reach.
The pain coming from his [*ankle, tooth*] was almost unbearable.
To make way for the new [*track, route*], the workers had to blast through solid rock.
Learning to tie a [*noose, lasso*] is harder than it looks.
The old house had an unbelievable amount of [*filth, urine*] on the bathroom floor.
The two month [*truce, siege*] was broken by a surprise attack.
David thought that [*prose, verse*] allowed him to express himself best.
At the conference, the major [*theme, focus*] was the role of women in society.
It was cold because of the [*shade, draft*], so he decided to put on a sweater.
The naturalist encountered an immense [*horde, swarm*] of insects in the swamp.
Mary expressed her extreme [*shame, anger*] by turning beet red.
The best part about the new play was the [*verve, flair*] with which it was acted.
From across the room Jim couldn't see the [*medal, label*] on Sam's jacket very well.
The secretary didn't know where to put the large [*carton, parcel*] that was delivered.
The corrupt official accepted a thousand dollars for the [*ransom, pardon*] of the prisoner.
Because of the dim lighting, the [*ballot, ticket*] was very difficult to read.
According to the statistics, [*stroke, cancer*] is one of the leading causes of death.
John was very proud of the new [*stripe, tassel*] on his uniform.
In some parts of the world, continual [*strife, famine*] causes widespread misery.
He saw it as a distinct [*threat, menace*] when the burglar picked up a knife.
The large [*crease, fringe*] made ironing the dress much more difficult.
On Sundays, he usually had a big [*brunch, waffle*] before going out to play golf.
Mary warned her son about playing with the [*dagger, hammer*] he just found.

The high point of her trip was the beautiful [*castle, mosque*] that they saw in Spain.
The car pulled up to the elegant [*resort, casino*] in the mountains.
The only thing left in the desk was a blue [*string, marble*] in the bottom drawer.

Note: The word with the higher frequency neighbor is listed first.

Sentences used in Experiment 3B

Low-frequency Words:
Patricia said that the [*hike, romp*] would benefit us all.
David learned to [*surf, raft*] while on vacation last summer.
That was a [*sneak, petty*] attack and he should be ashamed.
Samantha started to [*pour, buff*] the wax on to the hood of the car.
Mary said that the [*harp, slab*] was too heavy for her to lift alone.
They thought the [*snort, croak*] came from behind that tree.
She forgot her [*tote, soda*] on the kitchen counter at home.
She returned the [*worm, mulch*] to the compost heap.
My dad said that the [*spear, tribe*] came from an area of Brazil.
The guide said that the [*barge, wreck*] was at the bottom of the ocean.
The [*stool, comic*] was in the center of the stage.
She made a [*focal, super*] point in her speech on health care.
He started to [*yelp, cramp*] as he neared the finish line.
Martin said that the [*valve, clog*] was not allowing the water to drain.
Justin said that the [*dorm, alley*] was not a comfortable place to sleep.
The [*basin, acre*] was located next to the Pacific Ocean.
The [*moth, snag*] made a large hole in the camper curtains.
The fashion editor said that the [*robe, cuff*] made the garment look cheap.
The [*woven, bulky*] jacket was her favorite on rainy days.
The [*dense, hazy*] air made it difficult to finish the race.
They [*roam, bred*] the ponies at a large ranch in the foothills.
The [*farce, slang*] that was added to the script made the play more enjoyable.
He left the [*reel, scoop*] in the bottom of the boat.
He started to [*brag, glue*] but then he realized his mistake.
The [*gene, crane*] took years of engineering to modify.
The ground started to [*heave, emit*] molten lava on to the highway.
The [*herb, snug*] garden had just enough room for everything she wanted to grow.
The [*leash, scrap*] was made out of iron and aluminum.
She found the [*thief, glee*] from her first case difficult to restrain.
The [*bloat, scent*] of the carcass made Hank feel nauseous.

Medium-frequency Words:
Sara said that the [*gown, suit*] in the store window looked expensive.
Tommy liked to play in the [*yard, dirt*] on hot summer days.
Mrs. Mackie made John another [*pair, copy*] in case he lost his.

Matthew said that a [*horn, bomb*] went off a couple blocks away.
Donna said that the [*foam, tube*] was for packaging a parcel.
My professor said that [*tool, drug*] use is common amongst animals.
The pamphlet outlined the [*risk, swim*] involved in the triathlon.
The mayor said that Nicholas was a [*hero, gift*] to the community.
The fireman said there was [*fuel, acid*] spilled all over the road ahead.
The boys like to [*kiss, push*] the girls during recess.
Justin said that the [*suite, lodge*] was already booked for the weekend.
The [*knee, jump*] had to be repaired before her next competition.
The [*storm, cloud*] rolled in from the north end of the lake.
The [*calf, straw*] grew to be four feet tall in just one season.
The salesman said the [*wool, steel*] his company makes lasts a lifetime.
The [*shoe, bowl*] was made in England during the Victorian Period.
His [*beard, soap*] lathered up nicely, making shaving easier.
The [*noon, shift*] meeting was rescheduled for later in the day.
Her [*skill, span*] for remembering numbers greatly improved with practice.
She looked [*worse, glad*] after the eight hour operation was over.
Andrew wanted to [*spend, relax*] all day reading his favorite book.
Nancy said that the [*blond, moist*] cake from the bakery was delicious.
The lawyer wanted to [*prime, trust*] her client before the trial.
The [*smell, delay*] was almost unbearable.
He knew the [*prize, blame*] was eventually going to him.
The [*bloom, curve*] along the garden path was beautiful and graceful.
A numbing [*chill, guilt*] seemed to grip her entire body.
The cat was not [*smart, loose*] enough to wiggle free from inside the pipe.
Just as he began to [*stall, merge*] he was hit by another car.
The [*flood, crawl*] of cars on the freeway made David take another route.

Note: The word with higher frequency neighbors is listed first.