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Inhibitory neighbor priming effects in eye movements during reading

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Abstract

We report an eye movement experiment investigating whether prior processing of a word's orthographic neighbor in a sentence influences subsequent word processing during reading. There was greater difficulty in early word processing when a target word's neighbor rather than a control word appeared earlier in a sentence; and this effect was uninfluenced by the relative lexical frequency of the word and its neighbor. We discuss this inhibitory neighbor priming effect in terms of competitive network models of word recognition and the process of lexical identification in the E-Z Reader model of oculomotor control (e.g., Reichle, Pollatsek, Fisher, & Rayner, 1998).

Key words: Eye movements in reading; lexical processing; neighbor priming effects.

A wealth of research indicates that the speed with which a word can be identified is influenced by its orthographic neighborhood (see Andrews, 1997, for a review). Following Coltheart, Davelaar, Jonasson, and Besner (1977), orthographic neighbors are defined as those words formed from a target word by substituting one letter for another while preserving letter positions and length (but for an expanded definition see, e.g., Davis & Taft, 2005).

Research has shown that words that have higher frequency neighbors in the lexicon are identified more slowly than matched control words without higher frequency neighbors. This inhibitory neighborhood frequency effect has been widely observed in studies using the lexical decision task and related methodologies (e.g., Bowers, Davis, & Hanley, 2005a, 2005b; Carreiras, Perea, & Grainger, 1997; Davis & Taft, 2005; Grainger, 1990; Grainger, O'Regan, Jacobs, & Segui, 1989; Huntsman & Lima, 1996; but for failures to replicate this effect see, e.g., Forster & Shen, 1996). The effect has also been investigated by measuring eye movements during reading; where inhibitory effects have been observed both for words that have higher frequency neighbors and for words that have larger numbers of higher frequency neighbors (Perea & Pollatsek, 1998; Pollatsek, Perea, & Binder, 1999). These effects emerged relatively late in the eye movement record (i.e., in total reading times for the target word and in regressions and spill-over effects for following words), and have been attributed to readers initially misidentifying a word that has a higher frequency neighbor and subsequently making a regressive eye movement to re-fixate and re-process this word.

Particularly clear evidence of neighborhood interference comes from studies in which identification of a word (e.g., *blue*) is shown to be inhibited by prior processing of a word that is its orthographic neighbor (e.g., *blur*), relative to a control word that is not its neighbor (e.g., *gasp*). This inhibitory neighbor priming effect has been widely reported in research employing masked priming, where a forward mask is presented, followed by a briefly-presented prime that is in turn followed by a target word (or nonword) to which participants make a lexical decision response (Bijeljac-Babic, Biardeau, & Grainger, 1997; Brysbaert, Lange, & Wijnendaele, 2000; Davis & Lupker, 2006; De Moor & Brysbaert, 2000; Drews & Zwitserlood, 1995; Grainger, Colé, & Segui, 1991; Grainger & Ferrand, 1994; Segui & Grainger, 1990). Neighboring primes have also been shown to slow the recognition of target words in unmasked priming studies, where prime words are presented for longer durations and without a mask (Colombo, 1986; Lupker & Colombo, 1994; Segui & Grainger, 1990).

Inhibitory neighborhood effects have been interpreted within competitive network models of word recognition, such as interactive activation (IA) and SOLAR models (e.g., Davis, 2003; Grainger & Jacobs, 1996, McClelland & Rumelhart, 1981), where they are attributed to competition between lexical candidates. Specifically, during lexical identification, letters that comprise a word activate the lexical entry for that word, as well as for words sharing these letters, and activation of these lexical competitors can interfere with target word identification. The inhibitory neighbor priming effect observed in priming research is attributed to the prior presentation of a word's neighbor as a prime effectively giving a lexical competitor a head start in processing.

Masked priming research also has shown that larger inhibitory priming effects are observed when the prime word is of higher frequency than the target word (Davis & Lupker, 2006; Segui & Grainger, 1990). Competitive network models attribute this prime frequency effect to a higher frequency prime word supplying a strong competitor for a lower frequency target word during lexical identification, but not vice versa. However, the effect is reversed in unmasked priming, where inhibitory effects have been obtained only for primes that are of lower frequency than the target word (Colombo, 1986; Lupker & Colombo, 1994; Segui & Grainger, 1990). It is argued that in these studies conscious identification of the prime word results in inhibition of higher frequency lexical competitors, and that this interferes with subsequent identification of a higher frequency target word.

The above-mentioned priming research has used word recognition tasks (usually lexical decision) to investigate the recognition of isolated words. However, a natural extension of this research is to investigate if inhibitory neighbor priming effects also occur between words during normal sentence comprehension. This was the approach taken in the present experiment, which used measures of eye movements to investigate whether prior exposure to a word's orthographic neighbor earlier in a sentence affects the processing of that word. A related study that used a different technique to investigate neighbor priming effects during reading was recently reported by Williams, Perea, Pollatsek, and Rayner (2006). These researchers used the boundary technique (Rayner, 1975) to investigate the effects of parafoveal preview of a word's neighbor on subsequent word recognition. This can be considered a form of priming in which a preview word (or nonword) in the parafovea acts in a similar way to a prime, by changing into the target word as the reader's point of fixation crosses an invisible boundary. Previews in this experiment were identical to the target word (e.g., *sleet*) or a neighboring word (e.g., *sweet*) of higher or lower frequency than the target word (or a neighboring nonword, e.g., *speet*). The results revealed a facilitatory preview effect for higher frequency neighbors on target word processing, in contrast to the inhibitory priming effects observed in studies of single word recognition.

Williams et al. (2006) explained their results in terms of the account of lexical identification that is integral to the E-Z Reader model of oculomotor control (e.g., Reichle, Pollatsek, Fisher, & Rayner, 1998; Reichle, Rayner, & Pollatsek, 2003; Pollatsek, Reichle & Rayner, 2006). In this model, lexical identification is the primary determinant of when a reader moves their eye, and occurs in two stages; an initial familiarity check where likely lexical candidates become activated, followed by a verification stage when full lexical identification occurs. Williams et al. suggested that parafoveal preview of a word's neighbor principally affects the familiarity check by activating letter representations that are mostly shared with the target word and perhaps by also weakly activating the neighbor word's lexical entry. The benefit occurs for high frequency neighbors only, as their increased familiarity produces more effective letter activation. Williams et al. argued that inhibitory neighborhood effects in other eye movement experiments (e.g., Perea & Pollatsek, 1998; Pollatsek et al., 1999), that emerge relatively late in the eye movement record, are due to competition between lexical entries during the verification stage of lexical identification.

By contrast to the technique employed by Williams et al. (2006), in the present experiment sentences were presented entirely normally without the use of the boundary paradigm. In this experiment the neighbor prime appeared earlier in the sentence than the target word and we were interested to determine whether the presence of the prime influenced subsequent processing of the target. We used sentences like 1-4 (see Figure 1). Prime and target words were orthographic neighbors, one higher in frequency than the other (e.g., *blue* vs. *blur*), or a control word matched for length and frequency that had no orthographic overlap with the target word appeared in place of the neighbor prime (e.g., *town* & *gasp*).

-----------------Figure 1 about here-----------------

Inhibitory effects at the target word would be consistent with results from priming studies (e.g., Davis & Lupker, 2006; Segui & Grainger, 1990), demonstrating that competition between lexical candidates impedes target word identification during normal reading as well as in the lexical decision task. Inhibitory effects would also be consistent with findings of Williams et al. (2006) as, despite having observed facilitatory effects of parafoveal preview of a neighbor word in their study, their account predicts that a neighboring word that is fully identified prior to a reader fixating the target word will inhibit target word identification as it provides a lexical competitor for the target during the verification stage of lexical identification. On some occasions this may result in misidentification of the target word.

We also manipulated the relative lexical frequency of the prime and target words. As discussed earlier, masked priming research has shown a prime frequency effect, whereby higher frequency neighbor primes exert a greater inhibitory influence on lower frequency target words than vice versa (Davis & Lupker, 2006; Segui & Grainger, 1990). However, in these experiments participants were not consciously aware of the prime. In contrast, Segui and Grainger found the opposite effect in an unmasked priming study when primes were consciously identified prior to target word identification. We investigated whether a prime frequency effect is observed in normal reading. As prime words will clearly have been fully identified prior to fixation on a target word, it seems reasonable to anticipate a similar inversion of the prime frequency effect as obtained by Segui and Grainger, with greater inhibition for neighbor primes that are lower rather than higher in frequency than the target word.

Method

Participants: Thirty-two native English speakers were recruited from the University of Leicester.

Design & Materials: Twenty-six sets of 5-letter words and 22 sets of 4-letter words were selected from the stimuli of Davis and Lupker (2006; see Appendix). Each set comprised two neighbors (e.g., *blue* & *blur*) and two orthographically unrelated control words of the same length (e.g., *gasp* & *town*). Neighboring words differed by one letter and the letter position that was changed varied across the materials. Each neighbor was matched for frequency (counts per million words) with a control word using CELEX (Baayen, Piepenbrock, & Gulikers, 1995). The only significant difference in frequency was between high and low frequency pairs (e.g., high frequency neighbor = 313, low frequency neighbor = 9, high frequency control word = 318, low frequency control word = 7, $F(1,47) = 6.26$, $p=.02$; other Fs<1).

Prime and target pairs were inserted into pairs of identical sentence frames. In neighbor priming conditions, either the lower frequency neighbor preceded the higher frequency neighbor (e.g., *blur–blue*) or vice-versa (e.g., *blue–blur*). We created non-neighbor priming conditions by substituting appropriate control words for neighbor primes (e.g., *gasp–blue* & *town–blur*). Thus, four sentences were constructed for each set, manipulating orthographic-relatedness and prime-target frequency. Sentences were presented in counterbalanced lists such that each participant saw only one of the four. The average separation of prime and target words was 1.8 words (7.4 characters). Textual distance between primes and targets was identical for sentences containing the same target and did not differ significantly for sentences containing different targets. Sentences were matched for plausibility: Ten participants supplied plausibility ratings for each version of the sentences, which did not differ significantly (F<1).

Procedure: Eye movements were recorded using a Fourward Technologies Generation 6 DPI eye-tracker at the University of Leicester, employing standard stimulus presentation and data acquisition procedures.

Results

Regions: Five scoring regions were used (see Figure 1). Region 1 contained text preceding the prime. Region 2 was the prime word. Region 3 contained words between the prime and target words. Region 4 was the target word. Region 5 contained the next word (or two words if the next word was a short function word).

Analysis: An automatic procedure pooled or deleted short or long fixations. Analyses for each region excluded trials with zero first-pass reading times. We report first fixation duration (duration of the first fixation on a word, gaze duration (sum of all fixations on a word before a saccade from it), and total reading time (sum of all fixations) for Regions 2 and 4, and single fixation duration (duration of the fixation on a word receiving only one first-pass fixation) for Region 4 only. First fixation duration and first-pass reading time (equivalent to gaze duration for regions containing several words) are reported for Regions 3 and 5, and the frequency of regressions and regression path reading times (sum of first-pass fixations within a region along with fixations that re-inspect earlier portions of text before a fixation is made to the right of this region; e.g., Liversedge, Paterson, & Pickering, 1998) are reported for Regions 2-5.

We conducted two 2 (lexical frequency: high or low) X 2 (orthographic similarity: neighbors or non-neighbors) repeated measures ANOVAs, computing error variance over participants (F_1) and sentences (F_2). Mean reading times are shown in the Table.

----------------------Table about here----------------------

Region 2 (prime word): There was a 17 msec lexical frequency effect in gaze durations for prime words, $F_1(1,31) = 8.62$, $p<.01$, $F_2(1,47) = 4.81$, $p<.05$. Total reading times were longer for primes that were neighbors of the target word than for controls, $F_1(1,31) = 5.88$, $p<.05$, $F_2(1,47) = 4.04$, $p=.05$. No other effects were reliable (Fs<3.1).

Region 3 (*intervening text*): No effects were significant (Fs<3.0).

Region 4 (target word): Inhibitory priming effects were observed for first fixation duration, gaze duration, and total reading times (12 msec first fixation effect, $F_1(1,31) = 5.79$, $p<.05$, $F_2(1,47) = 6.29$, $p<.05$; 15 msec gaze duration effect, $F_1(1,31) = 4.31$, $p<.05$, $F_2(1,47) = 5.98$, $p<.05$; 45 msec total reading time effect, $F_1(1,31) = 9.48$, $p<.01$, $F_2(1,47) = 8.83$, $p<.01$). The effect for single fixation durations was marginal (9 msec effect, $F_1(1,31) = 2.95$, $p=.10$, $F_2(1,47) = 4.95$, $p<.05$). In addition, regression path reading times were longer for target words that followed a neighbor prime rather than a control word (38 msec effect, $F_1(1,31) = 10.31$, $p<.01$, $F_2(1,47) = 3.76$, $p=.06$). Despite a trend for larger inhibitory priming effects in first fixation durations when prime words were lower in frequency than target words (16 msec vs. 9 msec), this interaction was not significant (Fs<1). No other effects were significant (Fs<2.5). Thus, there was clear evidence of an inhibitory neighbor priming effect for target words but no significant modulation of this effect by the relative lexical frequency of prime and target words.

Region 5 (spillover region): There were more regressions and longer regression path reading times when target words followed a neighbor prime than a control word (5.1% regression frequency effect, $F_1(1,31) = 6.28$, $p<.05$, $F_2(1,47) = 4.92$, $p<.05$; 113 msec regression path reading time effect, $F_1(1,31) = 9.41$, $p<.01$, $F_2(1,47) = 6.85$, $p<.05$). No other effects were significant (Fs<2.8).

Discussion

The results reveal that prior exposure to a word's neighbor earlier within a sentence slows subsequent processing of that word during normal reading. As this effect emerged in early reading time measures (i.e., first fixation duration and gaze duration), we can conclude that the inhibitory influence of a previously identified neighbor is present by the time the target word is fixated. This effect is consistent with findings from priming research showing that presentation of a word's neighbor as a prime impedes that word's recognition. Our results therefore extend a phenomenon observed in studies of isolated word recognition into the domain of silent reading, and form a bridge between these two literatures. The effect seemingly differs from that observed in other research on eye movements during reading (e.g., Perea & Pollatsek, 1998; Pollatsek et al., 1999) where the neighborhood characteristics of a word have a relatively late influence on lexical processing that has been attributed to readers often misidentifying words that have higher frequency neighbors. By contrast with this finding, the present results suggest that prior activation of a word's neighbor can influence early stages of lexical processing.

Competitive network models (e.g., Davis, 1999, 2003; Grainger & Jacobs, 1996, McClelland & Rumelhart, 1981) would explain the inhibitory priming effect in the present experiment in terms of prior exposure to a word's neighbor providing activation for a lexical competitor that interferes with subsequent target word identification. A fundamental assumption of these models is that activation of a lexical entry decays over time and is inhibited when other lexical entries become activated as other words are read. Therefore, the models can explain the present findings in terms of competition between lexical entries so long as activation of the prime word's lexical entry has not decayed or been inhibited substantially in the interval between identification of the prime word and fixation on the target word. As clear inhibitory priming effects were observed, it could be argued that there was sufficient ongoing activation of the prime word's lexical entry for this to interfere with target word identification when prime words were separated from target words by only one or two (often function) words.

However, this inhibitory priming effect might also be explained by an episodic account of lexical priming (e.g., Tenpenny, 1995). According to this approach, when prime and target words are read separately (as in the present experiment), and these words are orthographically similar, then the processing of the target word will evoke an episodic memory trace encoded during the processing of the prime word. It is argued that in repetition priming, the evoked memory of a prime word that was processed earlier can facilitate subsequent target word identification. However, it seems likely that when the prime is a neighbor of the target, this evoked memory will interfere with target word identification. It has been argued (e.g., Tenpenny, 1995) that episodic approaches have an advantage in explaining longer-term priming effects (but, see Bowers, 2000, and Davis, 1999, for discussions of how an abstractionist account offered by competitive network models can also explain such effects). However, which account provides the best explanation for inter-sentential intra-lexical priming effects during reading remains to be determined.

Consider now how the present findings relate to the account of neighbor priming effects proposed by Williams et al. (2006). Williams et al. accounted for the parafoveal effects in their experiment in terms of the two-stage account of lexical identification in the E-Z Reader model (e.g., Reichle et al., 1998), proposing that virtually all processing in the parafovea is associated with an initial familiarity check stage of identification during which lexical and orthographic representations become activated. They argued that preview of a word's neighbor activates the neighboring word's lexical entry and associated letter representations. As almost all these letters are shared with the target word, this increased letter activation facilitates target word identification. However, Williams et al. suggested that, because prime word identification is only partially completed before the target word is fixated, its lexical entry does not become as active as it would if the prime word was actually fixated, and therefore does not provide a strong lexical competitor for the target word. Consequently, lexical competition is not observed during the familiarity check, and parafoveal preview of a word's neighbor can, on balance, facilitate lexical identification. Williams et al. also argued that inhibitory neighborhood effects that emerge after parafoveal processing of a word (e.g., Perea & Pollatsek, 1998; Pollatsek et al., 1999) are attributable to competition between lexical entries during the second, verification stage of identification, which may result in misidentification of the word. The present findings are consistent with Williams et al.'s account of lexical identification in the E-Z Reader model as they indicate that prior exposure to a word's neighbor can give rise to effects of lexical competition in early measures of eye movements (i.e., first fixation duration, gaze duration) as soon as the word is fixated.

A second question addressed in the present experiment was whether relative prime-target frequency influenced target word recognition. Normal reading more closely resembles unmasked than masked priming, as in both normal reading and unmasked priming the prime word will have been consciously identified prior to the target word being processed. Recall that unmasked priming showed that lower frequency neighbor primes produced greater inhibitory effects than higher frequency neighbor primes (Segui & Grainger, 1990). Therefore, we might have expected to see a similar modulation of neighborhood priming effects by prime frequency in the present experiment. While it was the case that the inhibitory neighbor priming effect was numerically greater for targets that followed lower rather than higher frequency prime words, this modulatory effect of frequency fell far short of statistical significance. Note also that we did not obtain any basic effect of lexical frequency for the target word itself (and that this was true even when the target words followed control words). The lack of such an effect at the target word is especially notable given the robustness of the frequency effect observed at the prime word. Clearly, there has to be some reason for the lack of such an effect.

One possible explanation that has been raised previously (e.g., Rayner & Duffy, 1986; see also Reichle et al., 2003) is that the absence of frequency effects at the target word may be due to a spillover frequency effect from the prime word. Note that lower frequency target words always followed higher frequency prime or control words in the present experiment, and vice versa. This raises the possibility that participants were continuing to process a more costly lower frequency prime or control word as they fixated the following higher frequency target word. If this were the case, then recognition of a higher frequency target word would be impeded by this spillover effect, thereby substantially reducing the likelihood of observing frequency effects at the target word.

Turning to the prime word data: here, as expected, we obtained a standard lexical frequency effect (for neighbor and non-neighbor primes) in gaze durations, confirming the effectiveness of the manipulation of prime word frequency. A separate effect was observed in total reading times, which were longer for primes that were neighbors of the target word than for control words. As this effect occurred exclusively in total reading times for the prime word (with concomitant increases in regressions and regression path reading times occurring only at the target word and post-target region), it is readily explained in terms of readers making a regressive fixation from the target word or post-target region in order to re-inspect and re-process the prime word.

Such regressive eye movements were most likely to be due to readers having increased difficulty in processing the target word, and possibly even misidentifying this word, when it followed a neighbor word prime. However, it could be argued that these effects are instead due to a delayed influence of neighborhood characteristics of the prime words spilling over onto target word processing. That is to say, rather than reflecting neighbor priming, the effect may have been attributed to an inhibitory neighborhood effect during prime word processing, due to neighbor primes having more higher frequency neighbors than the control words, and this effect emerging relatively late in processing (e.g., Perea & Pollatsek, 1998; Pollatsek et al., 1999). Fortunately, this alternative explanation of the effect can easily be ruled out by demonstrating that the prime and control words did not differ significantly in terms of the number of neighbors that were higher in frequency. We used the N-Watch program (Davis, 2005) to carry out such a computation, and indeed, there were no such differences (neighbor primes = 0.84, control words = 1.03, $F<1.4$). Therefore, the total reading time effect at the prime word cannot be due to a delayed inhibitory neighborhood frequency effect.

In conclusion, the present results demonstrate that exposure to a word’s orthographic neighbor earlier in a sentence interferes with word identification during normal sentence comprehension. The fact that this phenomenon occurred between words of a sentence that was read normally indicates that eye movements during reading are sensitive to intra-sentential, inter-lexical influences that occur naturally within sentences. Furthermore, such relationships have implications for the process of lexical identification that occurs as we read sentences. The results are consistent with research employing priming methodologies using isolated words and can be accommodated within a two-stage account of lexical identification as per the E-Z Reader model. Thus, the current experimental findings extend a phenomenon observed in studies of single word recognition, and therefore form a bridge between the domains of isolated word recognition and silent reading. Future research has to establish how orthographic information from earlier in a sentence carries across intervening words to affect the lexical processing of words read later in the sentence.

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Appendix: Prime and target word stimuli

Neighbors		Non-neighbors	
High frequency	Low frequency	High frequency	Low frequency
royal	loyal	fresh	timid
blue	blur	town	gasp
able	axle	high	thug
iron	icon	edge	chef
club	clue	desk	mask
jury	fury	taxi	whip
thus	thud	else	howl
from	frog	with	grub
queen	queer	coast	moist
turn	turf	oval	clip
unit	knit	body	chef
both	moth	away	clip
inch	itch	food	knee
piece	niece	music	shrug
motor	rotor	chain	scalp
knock	knack	alarm	flute
fault	vault	siren	crime
media	medic	crowd	fluff
cruel	gruel	nasty	poppy
step	stew	task	loaf
magic	manic	teeth	fiery
lady	lazy	desk	numb
thumb	thump	rival	spark
chief	thief	woman	badge
anger	angel	shock	relic
tree	trek	film	lava
leave	weave	front	dodge
sign	sigh	army	atom
house	mouse	thing	drill
dance	lance	shirt	beret
outer	otter	brass	flock
deny	defy	chat	gulp
under	udder	among	mango
angle	ankle	rugby	thigh
onion	union	table	chalk
force	farce	sight	stunt
even	oven	just	folk
only	oily	most	vile
legal	regal	ended	suave
reply	repay	argue	kneel
hurt	hurl	bent	skim
drug	drum	sofa	jazz

open	omen	rest	saga
burn	burp	rage	pant
about	abort	pilot	halve
aside	abide	loose	dodge
solar	polar	furry	magic
state	skate	power	canoe

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Figure Legend

Example of sentence stimuli. Vertical lines delineate regions of analysis

Figure

Low frequency prime word (e.g., blur / gasp) - high frequency target word (e.g., blue)

1. There was a| blur $_{prime}$| as the| blue $_{target}$| lights $_{spillover}$| of the police car whizzed down the street.

2. There was a| gasp $_{prime|}$ as the| blue $_{target}$| lights $_{spillover}$| of the police car whizzed down the street.

High frequency prime word (e.g., blue / town) - low frequency target word (e.g., blur)

3. In the photograph, the| blue $_{prime}$| lights were a| blur $_{target}$| against $_{spillover}$| the cold night sky.

4. In the photograph, the| town $_{prime}$| lights were a| blur $_{target}$| against $_{spillover}$| the cold night sky.

Table: Eye movement data for (a) Regions 2 and 3 and (b) Regions 4 and 5. Reading times are given in msec (with standard errors in parentheses).

Table (a)

	Orthographic Relatedness of Prime and Target Words							
	Neighbors				Non-Neighbors			
	Prime word frequency							
Measures of Reading	Low (e.g., *blur*)		High (e.g., *blue*)		Low (e.g., *gasp*)		High (e.g., *town*)	
	Target word frequency							
	High (e.g., *blue*)		Low (e.g., *blur)*		High (e.g., *blue*)		Low (e.g., *blur*)	
Region 2 (prime word)	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
First fixation duration	226	6.4	220	6.1	224	4.8	216	5.3
Gaze duration	258	10.3	248	8.3	261	7.9	236	6.4
Regressions (%)	17.8	3.2	16.8	2.6	17.9	3.0	20.3	3.2
Regression path reading time	347	19.3	321	16.8	338	18.5	344	22.5
Total reading time	385	25.7	346	20.9	334	14.4	328	14.7
Region 3 (intervening text)								
First fixation duration	231	6.2	223	6.5	218	5.1	229	8.1
First pass reading time	299	13.1	296	12.0	291	11.2	312	14.2
Regressions (%)	16.3	2.6	11.7	2.5	15.8	2.9	16.2	2.9
Regression path reading time	271	21.9	236	16.9	269	21.7	297	27.7

Table (b)

	Orthographic Relatedness of Prime and Target Words							
	Neighbors				Non-Neighbors			
	Prime word frequency							
Measures of Reading	Low (e.g., *blur*)		High (e.g., *blue*)		Low (e.g., *gasp*)		High (e.g., *town*)	
	Target word frequency							
	High (e.g., *blue*)		Low (e.g., *blur)*		High (e.g., *blue*)		Low (e.g., *blur*)	
Region 4 (target word)	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
First fixation duration	233	6.4	237	7.0	224	6.0	221	4.9
Single fixation duration	236	5.9	239	7.3	227	6.7	230	6.3
Gaze duration	264	8.8	266	7.7	248	7.1	253	8.5
Regressions (%)	15.2	2.3	15.7	2.8	11.1	1.8	16.8	2.1
Regression path reading time	292	22.8	292	21.5	261	17.1	248	13.7
Total reading time	383	19.9	383	19.0	324	14.3	353	18.4
Region 5 (spillover)								
First fixation duration	228	6.4	228	6.0	218	5.8	230	6.1
First pass reading time	593	24.3	581	30.4	583	24.0	592	25.2
Regressions (%)	19.7	2.7	23.2	2.7	16.3	2.4	16.2	2.4
Regression path reading time	1022	64.3	1041	62.4	899	59.8	937	58.4