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Phonological and Orthographic Overlap Effects in Fast and Masked Priming

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Phonological and Orthographic Overlap Effects in Fast and Masked Priming

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Abstract

We investigated how orthographic and phonological information is activated during reading, using a fast priming task, and during single word recognition, using masked priming. Specifically, different types of overlap between prime and target were contrasted: high orthographic and high phonological overlap (*track-crack*), high orthographic and low phonological overlap (*bear-gear*), or low orthographic and high phonological overlap (*fruit-chute*). In addition, we examined whether (orthographic) beginning overlap (*swoop-swoon*) yielded the same priming pattern as end (rhyme) overlap (*track-crack*). Prime durations were 32 and 50ms in the fast priming version, and 50ms in the masked priming version, and mode of presentation (prime and target in lower case) was identical. The fast priming experiment showed facilitatory priming effects when both orthography and phonology overlapped, with no apparent differences between beginning and end overlap pairs. Facilitation was also found when prime and target only overlapped orthographically. In contrast, the masked priming experiment showed inhibition for both types of end overlap pairs (with and without phonological overlap), and no difference for begin overlap items. When prime and target only shared principally phonological information, facilitation was only found with a long prime duration in the fast priming experiment, while no differences were found in the masked priming version. These contrasting results suggest that fast priming and masked priming do not necessarily tap into the same type of processing.

Orthographic features of a word are crucial for its correct identification and there is good evidence that the phonological features of words are also accessed during word identification (Ashby, 2010; Ashby, Sanders, & Kingston, 2009; Ferrand & Grainger, 1992, 1993, 1994; Perfetti & Bell, 1991; Rastle & Brysbaert, 2006; Rayner, Pollatsek, Ashby, & Clifton, 2012; Ziegler, Ferrand, Jacobs, Rey, & Grainger, 2000). In the present paper, we explored the extent to which pre-activation of orthographic and phonological features, either combined or in isolation, affects the recognition of a word. We will mainly focus on how words are read in context (fast priming paradigm), but will also compare these effects to results from a masked priming task in which the same words are read out of context.

A vast amount of research using single-word, out-of-context, word identification tasks has refined our views on what features facilitate/inhibit word recognition and when these influences come into play (see Ferrand, 2007 for a review). One such task is the *masked priming* task, in which a prime word is briefly presented on a computer screen (below conscious awareness) before being replaced by a target word (Forster & Davis, 1984). The rationale of such a manipulation is that information from the first word, even if presented extremely briefly, influences how the second word is processed. Words are presented in isolation on a computer screen and participants must provide an overt response (naming or a judgment of lexicality) after reading the second word. A related technique, *fast priming* (Sereno & Rayner, 1992), has also been adapted and used during normal reading. In fast priming, a target word in the text is first presented as a random letter string (see Figure 1). When the reader moves his/her eyes across an invisible boundary location (Rayner, 1975) and lands on the target word, the random letters are first replaced by a prime word, and then very quickly replaced by the target word. In general, readers are not aware of the prime word. Unlike masked priming tasks, no overt response (naming or button press) is necessary as

participants are only required to read the sentence silently for comprehension. While numerous masked priming experiments have been carried out, there are only a handful of fast priming experiments, and many of them focused on the processing of homophones (see below). However, notwithstanding the large overlap between the two tasks, their findings are not always in line with each other. In the remainder of the Introduction, we will first discuss research on orthographic priming in both tasks, and then discuss research on phonological priming.

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Insert Figure 1 here
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Orthographic Priming

Results from fast priming studies have consistently shown faster processing of the target word when it overlaps orthographically with the prime (Lee, Binder, Kim, Pollatsek, & Rayner, 1999a; Lee, Kambe, Pollatsek, & Rayner, 2005; Lee, Rayner, & Pollatsek, 1999b, 2002; Rayner, Sereno, Lesch, & Pollatsek, 1995). For example, when *house* is used as prime for *horse*, the target word is read faster than when the prime is an orthographically unrelated word (*thing-horse*). These orthographic priming effects have been found with prime durations in the time window (or prime-target SOA) between 24 and 42 ms. These results indicate that orthographic information can be extracted very quickly from the prime word, resulting in faster recognition of the target word when letters overlap.

It is unclear, however, whether any type of orthographic overlap will result in facilitation, and some evidence suggests that place and/or amount of overlap might affect the degree of facilitation. Lee et al. (1999a) conducted a sub-analysis of their data and found stronger priming when the first three letters overlapped with the target, compared to when the first two or only the first letter overlapped. A considerable amount of reading research (see Rayner & Kaiser, 1975;

Rayner, White, Johnson, & Liversedge, 2006) has indicated that the beginning of a word plays a more prominent role in recognition than the end or the middle. We will test this by contrasting two types of overlap, one in which the last letter is dissimilar (*swoop-swoon*) and one with a dissimilar first letter (*track-crack*).

While orthographic overlap results in faster processing in the fast priming task, a number of masked priming studies have shown the opposite effect: specifically, slower recognition is found when the prime and target are orthographic neighbors (i.e. words that overlap in all letters but one; Davis & Lupker, 2006; Grainger, 1990; Grainger & Ferrand, 1994; Segui & Grainger, 1990). Localist models of word recognition, like the interactive-activation (IA) model by McClelland and Rumelhart (1981; see Davis, 2003; Diependale, Ziegler & Grainger, 2010), explain the inhibitory effect by postulating competition between a word and its orthographic neighbors. Words are recognized by suppressing the activation of closely related competing candidate words. When an orthographic neighbor is primed, the prime word will become a strong competitor during the recognition of the target word, slowing down target word recognition. In addition, this effect is modulated by the prime and target frequencies so that when the neighbor prime is of higher frequency than the target, competition will be especially great, leading to stronger inhibition (see Segui & Grainger, 1990). For example words with a high-frequency neighbor take longer to recognize than words with a low-frequency neighbor (Grainger, O'Regan, Jacobs & Segui, 1989; Segui & Grainger, 1990; Carreiras, Perea & Grainger, 1997). However, when the prime is a pseudoword or nonword, and thus has no lexical representation, no competition between the prime and target ensues (though there can still be competition from other activated lexical representations). Since the nonword neighbor prime can pre-activate the target without entering in competition with it, facilitation effects are observed (Davis & Lupker, 2006; Ferrand & Grainger, 1992, 1993, 1994; Forster, 1987).

Given the large similarities between the masked priming and fast priming tasks, these conflicting results are remarkable. As noted by Nakayama, Sears, and Lupker (2010): “results from these fast priming studies are at odds not only with the research from the masked priming task but also with the core assumptions made by activation-based models” (p.480). They addressed this discrepancy by running a series of fast priming experiments using orthographic neighbors that previously yielded inhibition in masked priming experiments (Nakayama, Sears, & Lupker, 2008). In their first experiment, in which prime and target were presented in lower case (as is standard in fast priming), orthographic facilitation was found, contrary to the masked priming results. In their second experiment, in which the prime was presented in upper case (in masked priming, the prime and target are usually presented in different case), the effect disappeared, though no inhibition was observed. Their last experiment contained orthographic neighbor nonwords as primes and the facilitation effect returned, both when the prime was presented in lower case (Experiment 3a) and when it was in upper case (Experiment 3b). Contrary to the predictions from an IA account, no inhibition was found for the word primes, and no effect of prime frequency was observed in Experiments 1 and 2. Nevertheless, Nakayama et al. argued that these data were not necessarily incompatible with an interactive-activation account, and pointed to the difference observed between word and nonword primes: while facilitation disappeared when the word primes were presented in capitals, it remained for the nonword primes. They argued that while facilitation is expected for orthographically overlapping nonword primes (as they do not enter into competition with word targets), the expected inhibition for word primes was obscured due to low-level priming from visual overlap between the prime and target (Experiment 1) and priming from the larger syntactic, semantic, and conceptual context the words appeared in (Experiments 1 & 2). When the low-level overlap was prevented by using different case for primes and targets, the facilitation effect disappeared

and the authors argued that the contextual facilitation annulled the purported lexical inhibition effect.

There are a number of unresolved questions with these interpretations. First, as acknowledged by Nakayama et al., the concealing of inhibition due to low-level feature overlap would predict greater facilitation for nonwords presented in lower case compared to nonwords presented in different case as the former should also benefit from low-level visual overlap. However, the facilitation they observed was nearly identical for lower and upper case primes (20 and 21 ms priming overall). Additionally, and also identified by Nakayama et al., one would expect the priming effect to be greater for nonword primes presented in lower case compared to lower case word primes as only word primes are supposed to suppress candidate words. In fact, the word primes produced numerically greater facilitation (32 vs. 20 ms overall). Finally, it's unclear to what extent the larger context can facilitate processing with this prime duration. The idea is that upon processing the prime word, candidate words are not only being suppressed but also evaluated against the context, and if they fit well in the context, the activation level of the candidate words is increased. This, however, assumes that the semantics of all candidate words is recovered from the mental lexicon and evaluated against the larger context within 60 ms, the prime display time used by Nakayama et al. One could therefore make the prediction that during reading, words with many neighbors will take longer to process as more candidate words are being semantically evaluated against the context. While this effect has indeed been observed in reading (Pollatsek, Perea, & Binder, 1999), it appears to be restricted to later processing measures, in contrast to the early differences found in fast priming experiments. We will return to the issue of contextual facilitation in the General Discussion.

Taken together, Nakayama et al.'s (2010) results can be summarized as follows: in 3 out of 4 fast priming studies reported, facilitation was observed when prime and target overlapped orthographically (even when the prime was a nonword), in line with all previous fast priming

studies (see also Williams, Perea, Pollatsek, & Rayner, 2006, for converging evidence with the parafoveal preview paradigm). The only study that failed to show facilitation is Nakayama et al.'s second experiment in which the prime word was presented in upper case, and this study produced a null effect. Hence, it is safe to say that to date one of the core assumptions of IA-based models, i.e. that the presence of an orthographic neighbor word prime should lead to costly competition, has not received much experimental support from fast priming reading experiments.

However, there might be other factors contributing to the lack of an inhibition effect in fast priming: prime duration and type of overlap. Experiments using the fast priming task typically present the prime for between 24 and 36 ms (Lee et al., 1999a, 1999b; Rayner et al., 1995; Sereno & Rayner, 1992), which is shorter than most experiments using masked priming (see Rastle & Brysbaert, 2006, for a review). The first issue we will address is whether the longer prime duration (60 ms) used by Nakayama et al. (2010) was responsible for the observed facilitation effect. By using a short (32 ms) and a longer (50 ms) prime duration we tested whether inhibition by orthographic neighbors is shorter-lived in reading than in masked priming tasks. The shorter prime duration has previously shown to be sensitive to orthographic overlap effects in fast priming, while the longer prime duration is in line with those used in masked priming.

The second issue, and the main focus of the present article, is related to type and amount of shared information between primes and targets. Due to design considerations, previous fast priming experiments, with the exception of Nakayama et al. (2010), have not systematically used orthographic neighbors as primes. For example, in Lee et al. (1999b) orthographically similar primes were orthographic neighbors of the target only 40% of the time. In contrast, masked priming experiments showing inhibition from orthographic overlap were restricted to orthographic neighbors as stimuli (e.g., Davis & Lupker, 2006; Nakayama et al., 2008). We therefore restricted our prime-target pairs to orthographic neighbors. Masked priming experiments however have not taken into account the *kind* of overlap that exists between primes and targets, with dissimilar letters appearing

anywhere in the word (e.g., *tide-side*, *lung-long*, *tire-time*, and *plank-plane*; from Nakayama et al., 2008, 2010, who had 14/40 prime-target pairs with a different first letter, 11/40 with a different last letter, and the rest with a different letter elsewhere). As discussed above, reading experiments have shown that begin and end letters of a word do not necessarily have the same status in processing, and inhibition might be greater when, for example, the first letters of the prime and target overlap.

Finally, we also addressed the idea of low-level visual priming. Nakayama et al. (2010) applied the practice of different case to the fast priming task (which causes an unnatural and disturbing presentation). We will test the reverse and examine whether having both prime and target in lower case results in facilitation in the masked priming task, as expected on a low-level visual overlap account.

Orthographic overlap also involves varying degrees of phonological overlap (Peereman & Content, 1997; see also Lee et al., 1999a). Typically, orthographic primes are chosen which have a specific number of overlapping letters, without much regard for how the prime relates phonologically to the target. For example (examples again taken from Nakayama et al., 2008, 2010), some primes preserve the rime (e.g., *mate-rate*) while others don't (*weep-week*), some conserve the spelling of the vowel but change its pronunciation (*fork-work*), some change the characteristics of the vowel (e.g., from a monophthong to a diphthong: *shoe-show* or from a long to a short vowel: *heap-help*), some preserve the onset (*laser-later*) while others don't (*bind-find*), and some change the consonant cluster (*class-clash*). One of the aims of the present experiments is to contrast primes that have both high orthographic and phonological overlap (*track-crack*) with primes that have high orthographic but low phonological overlap (*bear-gear*) in order to test whether orthographic priming also occurs in the presence of inconsistent phonological overlap. While inconsistency has not been examined in the fast priming task, it has received quite some attention in single-word experiments. Naming experiments have shown that when a target word is

preceded by an inconsistent neighbor (PINT preceding MINT), naming times increase (Burt & Humphreys, 1993; Pexman, Trew, & Holyk, 2005; Taraban & McClelland, 1987).

Phonological Priming

One reason why inhibitory orthographic neighbor effects are not found in fast priming might be due to facilitation coming from the phonological overlap between the prime and target (see Nakayama et al., 2010, footnote 4). Fast priming experiments examining phonological activation have typically compared priming of homophone pairs (*beech–beach*) to priming by a control word with a similar degree of orthographic overlap (*bench–beach*). Rayner et al. (1995; see also Lee et al., 1999a, 1999b, 2005) found shorter gaze durations on the target when the prime was a homophone than when the prime was an orthographic control word. Comparable results were found when the prime was a pseudohomophone (*brane–brain*). These results indicate an early involvement of phonology in reading, with phonological priming effects observable with prime durations between 29 and 35 ms (see Lee et al., 1999a, 1999b; Rayner et al., 1995). By using prime durations of 32 and 50 ms in the present experiments, we contrasted a short prime duration that has been shown to be sensitive to phonological priming in fast priming to a longer prime duration that has shown facilitation in masked priming (see Rastle & Brysbaert, 2006).

In the fast priming task, phonological priming has only been assessed using (pseudo)homophones, which tend to have large orthographic overlap. Hence, in order to examine whether phonological priming effects can be found in the absence of large orthographic overlap, we included a condition in which the prime and target rhymed but had a different spelling (*fruit–chute*). Masked priming experiments testing rhyme priming have produced a range of different effects, dependent on the task (naming vs. lexical decision), the prime presentation time, and the lexical status of the prime (word vs. nonword). For example, using word primes in a naming experiment, Lukatela and Turvey (1996) found inhibitory rhyme priming at short SOAs of 36 and 70ms. In

contrast, lexical decision and naming tasks using nonword primes tend to show facilitation for rhymes, though not with all prime exposures (e.g., Bélanger, Baum & Mayberry, 2012; Grainger & Ferrand, 1996; Lukatela, Frost & Turvey, 1998; Ziegler et al., 2000;).

Homophone priming is measured against the priming effect from an orthographic control word. As a consequence, the control word needs to be chosen carefully. For example, if one calculates the number of overlapping end letters in the (otherwise well-controlled) item set of Lee et al. (1999b), the homophone primes have a significantly larger number of overlapping end letters than their orthographic control words. On the other hand, orthographic priming effects are measured by subtracting the fixation times of a visually similar word from those of a dissimilar word (e.g., subtracting the fixation times of *house-horse* from those of *thing-horse*). Because it is not clear what the best baseline is for the different conditions in our experiments, we used pronounceable nonwords as control primes, which did not contain any overlapping letters in the same position. Given that the pseudowords constituted less than 3% of the number of words in the experiment, it is unlikely that the inclusion of these pseudowords would have led to strategic effects (even when assuming that each pseudoword is noticed at both prime durations, which in itself is highly doubtful). We therefore believe that using pseudowords as control words provides the most appropriate baseline condition.¹

Predictions

In order to test the differential activation and timing influences of orthographic and phonological information, along with the notion of place of overlap, we employed two prime durations, 32 and 50 ms, and four sets of item pairs: P+O+ (rhyme) primes and targets with high orthographic and high phonological end overlap (*track-crack*); P+O+ (non-rhyme) item pairs with high orthographic and high phonological beginning overlap (*swoop-swoon*); P-O+ prime and targets with low phonological, high orthographic non-rhyming end overlap (*bear-gear*); and P+O- item pairs with high phonological (rhyming) and low orthographic overlap (*fruit-chute*). For the P-O+

item pairs, the prime words were exception words (Glushko, 1979) that do not follow simple spelling-sound correspondences and do not rhyme with (the majority of) the other words with a similar orthographic ending.

On the basis of other fast priming experiments (Lee et al., 1999a, 1999b; Rayner et al., 1995), we expected to find both orthographic and phonological priming effects for the P+O+ sets at the short prime duration. Predictions for the long prime duration are less straightforward. Since orthographic priming has been found for all prime durations that have been tested previously (24 to 42 ms), we expected to find facilitatory orthographic priming at the longer duration as well. Since no phonological priming has been observed for homophones with prime durations between 38 and 42 ms (Lee et al., 1999a, 1999b), one might expect phonological priming to have disappeared at the 50 ms prime duration. For the P-O+ item pairs, we expected to find facilitatory priming due to the orthographic overlap (see Lesch & Pollatsek, 1998), though possibly attenuated due to the lack of phonological overlap. Finally, if the results from masked priming lexical decision tasks (e.g., Grainger & Ferrand, 1996; Ziegler et al., 2000) translate to fast priming effects, then we expect to find facilitatory priming for the P+O- set. Following Ziegler et al. (2000), this facilitation might be less than the P+O+ and the P-O+ sets at the shorter duration, and less than the P+O+ set at the longer duration.

This set of four types of orthographic and phonological overlap allowed us to examine a number of contrasts. By comparing the magnitude of the priming effect for P+O+ (rhyme) to that of the priming effect for P+O+ (non-rhyme) item pairs, it was possible to establish whether rhyme has a special status in early processing or whether beginning overlap was more advantageous. Another way of testing this prediction is by comparing the fixation times on the target word itself rather than the magnitude of the priming effect. Given that the target words were well controlled, which was the case since no differences between them were found when primed by the control nonword (see below), then differences in fixation times when primed can be related to the type of prime used.

Another possible comparison is between the P-O+ set and both P+O+ sets. If the main priming effect is determined by orthographic overlap only, then no difference would be expected between these sets. However, if the interplay between orthographic and phonological overlap affected priming, then P-O+ item pairs, with their inconsistent phonological mapping, would lead to a smaller priming effect. Again, analyzing fixation times on the target words, rather than the priming effect sizes, can be revealing. In this case we would expect longer fixations on the P-O+ targets primed by an inconsistent prime relative to P+O+ targets primed by a consistent prime.

Finally, P+O- item pairs were compared to P-O+ item pairs to investigate whether (“pure”) orthographic or (“pure”) phonological overlap led to a stronger effect. P+O- item pairs were also be compared to P+O+ (rhyme) item pairs to determine whether the rhyme effect was mediated by orthographic overlap.

EXPERIMENT 1: FAST PRIMING

Method

Participants

Fifty-six students from the University of California, San Diego, participated for remuneration. All were native speakers of English and had either normal or corrected vision.

Materials and Design

A total of 160 target words were selected for the experiment. Each target word (*gear*) was paired with a prime word (*bear*) and a prime control nonword (*qulk*; see Appendix for a complete set of stimuli). Both the prime word and the prime control nonword were of equal length as the target word. The prime control nonword followed English spelling rules, was pronounceable, and did not contain any letters of the prime word or the target word in the same position (see Table 1). A preview nonword (i.e. a nonword that was presented before the eyes fixated the target area) was also created for each target word (*dnlw*). The preview nonword only contained consonants and was of

the same length as the target word (and the two possible primes). None of the consonants appeared in the same position as those in either the prime or the target word. This manipulation ensured that no preview benefit was possible for the target word.

The prime/target relations varied in the amount of orthographic overlap between them. Four types of overlap were distinguished, each type being represented by 40 item pairs.² P+O+ (rhyme) item pairs comprised end overlap (rhyme), and thus had high phonological and orthographic overlap (*track-crack*). P+O+ (non-rhyme) item pairs comprised similar sounding beginning overlap (*swoop-swoon*). P-O+ primes had the same orthographic end overlap as their targets, but were pronounced differently (*bear-gear*). Finally, P+O- primes and targets shared the same phonological rhyme, but were spelled differently (*fruit-chute*).

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 Insert Table 1 here
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The prime words were on average 9.8 times more frequent than the target words (45.2 vs. 4.6 per million, based on the CELEX database, Baayen, Piepenbrock, & Van Rijn, 1993; $t(158) = 9.28, p < .001$). While the P-O+ prime words were slightly shorter due to the limited set of possible words to choose from, the four types did not differ significantly in either length [$F(3, 155) < 1$] or frequency [$F(3, 155) < 1$]. Similarly, even though the P-O+ target words were slightly shorter and lower in frequency, the four types did not show a significant difference in either length [$F(3, 155) < 1$] or frequency [$F(3, 155) = 1.39; p > .24$].

The sentences were divided over four lists, with an equal number of items from each type (word, nonword) and each condition (P+O+, etc.) in each list without repetition of the target word. Hence, a participant would see a specific target word only once, either with a word or a nonword prime, with either a 32 or a 50ms prime duration. The first three items of each list were practice items. Presentation of the lists was counterbalanced. The 160 critical sentences were intermixed

with 48 filler sentences from a different experiment (which did not contain a prime-target change). Yes/no questions were asked after 40% of the sentences. Accuracy was 94%.

Procedure and Apparatus

The participants were tested on an Eyelink 1000 running the Eyetrack software (<http://www.psych.umass.edu/eyelab/software/>). The participants were seated 60 cm from a 22 inch NEC MultiSync FP1370 monitor with a refresh rate of 150Hz and a resolution of 1024 x 768 pixels. Sentences were presented in Courier New 14 pt on a single-line with a maximum of 100 characters per sentence. There were 2.9 characters per degree of visual angle.

At the beginning of the experiment, the eyetracking system was calibrated. Viewing was binocular but only data from the right eye were collected. In the experimental task, each sentence was preceded by a black rectangular box to the left of the first letter of the upcoming sentence. This box acted as an automatic trigger and only if a fixation was detected in this area did the sentence appear. Participants then read each sentence silently, while their eye movements were recorded, and ended each trial with a button press.

All target items contained a change from a random consonant preview to a word/nonword prime to the target word (see Figure 1). The first change (from the consonant preview to the prime) was triggered when the participant moved his/her eyes across an invisible boundary that was placed immediately following the end of the preceding word and before the space. Display changes were carried out immediately and took approximately 8 ms on average. The prime was presented for either 32 or 50 ms, and was then replaced (via a second display change) by the target word, which remained on the screen until the participant finished reading the sentence. Because the first display change occurred during the saccade, participants were not aware of it (due to saccadic suppression, Rayner, 1998).

After the reading task, a short questionnaire was given in order to assess to what extent the participants were aware of the experimental manipulation. The results from this questionnaire

showed that while participants noticed a change between primes and targets, only 32% of them thought that “something” was presented during the change. However, what had been presented was not always clear to them (e.g., “a square image”, “fuzzy lines”) and they greatly underestimated how often a prime had been presented when a change had occurred (on average, they estimated 13% rather than the actual 100%).

Results

We analyzed two eye movement measures that are considered to capture early effects: *single fixation duration* (the fixation on the target word when only one fixation is made during first pass reading; 60% of the first-pass data on the target word were single fixations) and *gaze duration* (the sum of fixations on the target word before the eyes move away from the target). Trials on which the prime was triggered too early, too late (later than 7 ms after crossing the invisible boundary), or not at all, trials on which the participant blinked on or around the target words, and trials in which the prime was displayed for too short or too long a time, were eliminated. Short and long fixations were also removed based on cutoffs of 80 and 800 ms, respectively. In total, 7% of the trials were taken out.

All analyses were carried out using R 2.15.2 (R Development Core Team, 2010) and the lme4 package, version 0.999999-0 (Bates, Maechler, & Bolker, 2012). The fixed effects were Prime (word vs. nonword), Duration (32 vs. 50 ms), and Type (P+O+, rhyme; P+O+, non-rhyme; P-O+, P+O-). We used maximally-appropriate random effects structures (see Barr, Levy, Scheepers, & Tily, 2013) whenever possible, unless otherwise stated. For example, for analyses with one fixed effect, we compared a base model including fixation times as the dependent variable, the fixed effect, and random intercepts and slopes for both participants and items to the same model without the fixed effect, using a likelihood ratio test. The results of these tests are reported in Tables 2-4.

Priming effects.

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 Insert Table 2 here
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We first tested whether a priming effect was found at each duration interval, i.e. the difference in reading time for the target word when preceded by a word vs. a nonword prime. As seen in Table 2, for both P+O+ conditions (rhyme and non-rhyme), significant facilitatory priming effects, with faster reading times when primed by a word prime compared to a nonword prime, were found at all durations for both measures. P-O+ (*bear-gear*) item pairs also showed a facilitatory priming effect for single fixation duration when the prime was presented for 32 ms, and for both prime durations for the gaze duration measure. The effect, however, was of a somewhat smaller magnitude than for the two P+O+ conditions, where both orthographic and phonological information overlap. Although there was conflicting phonological information from the prime word to the target, this did not result in inhibition. P+O- item pairs (*fruit-chute*) showed a significant priming effect for the single fixation measure, though only when the prime was presented for 50 ms. No effects were observed for the gaze duration analyses.

In order to test the possibility that these results were driven by a number of outliers, we performed the same analyses on the log-transformed fixation data. These analyses showed the exact same pattern of results, with the same significance levels, except for the P+O- single fixation measure with 50 ms priming. While the non-transformed data showed a significant priming effect, the log-transformed data revealed only a borderline significant effect ($\chi^2(1) = 3.22, p < .08$). We will therefore treat this result cautiously.³

We also ran separate analyses for each overlap type including the factors Prime Lexicality and Duration, and its interaction. All models contained random intercepts and slopes. For both measures, adding the factor Prime Lexicality improved the model for the two P+O+ and for the P-

O+ conditions ($ps < .02$), but adding the interaction term did not ($ps > .16$), indicating that the priming effects were comparable for both prime durations.⁴ For the P+O- overlap, the main effect of Prime was not significant ($ps > .36$), and the Prime Lexicality x Duration interaction was significant for the single fixation data ($p < .05$) but not for the gaze data ($p > .44$). Again, this significant effect for P+O- disappeared when the data were log-transformed ($p < .08$).

Together, these results indicate that the priming effect could be detected on the earliest measure when the prime overlapped both phonologically and orthographically with the target, but also for words spelled similarly but with inconsistent pronunciations (P-O+). When the overlap was only phonological (P+O-), the priming effect was only observable with the long prime duration in single fixation durations, and became non-significant when the fixation times were log-transformed. This suggests that the existence of similar orthography helps in the identification of the target while having inconsistent phonology does not seem to inhibit much; in contrast similar phonology alone did not immediately aid recognition.

Comparisons between overlap types.

In order to address the predictions above, we compared the magnitude of the priming patterns between relevant types. The analyses were performed as follows: A full model including Overlap Type, Prime Lexicality, and Duration was constructed and compared using an ANOVA with another model excluding the 3-way interaction (see Table 3 for the results of model comparisons). This tested whether the 3-way interaction contributed significantly to the full model. Then, the three 2-way interactions (Overlap Type x Prime Lexicality, Overlap Type x Duration, Prime Lexicality x Duration) were evaluated against the full model minus the 3-way interaction, also using ANOVAs. If an interaction was significant, follow-up comparisons were performed on the relevant subsets. Since none of the 3-way or the Overlap Type by Duration interactions approached significance (all $ps > .14$), only the analyses for the main effect of Overlap Type and for

the interaction between Overlap Type and Prime Lexicality are listed in Table 3. Finally, the main effects (Overlap Type, Prime Lexicality, and Duration) were compared against the full model, again using ANOVAs. For the full model, maximal random slope structure did not converge. We therefore used a model that fitted all terms of the conditions but assumed one covariance rather than estimating the covariance between all conditions.⁵ For the follow-up comparisons, random intercepts and slopes for the fixed effects were added to the model.

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 Insert Table 3 here
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P+O+ (*rhyme*) vs. *P+O+* (*non-rhyme*). This comparison allowed us to test whether rhyme has a special status early in processing. If so, we would expect a main effect of Overlap Type and/or an interaction with the variables Overlap Type and Prime Lexicality. The results showed that the pattern of results for both overlap types were very comparable for both measures, suggesting that end overlap (rhyme) does not help or hinder more than beginning overlap, at least in the context of fast priming.

P+O+ (*rhyme*) vs. *P-O+* and *P+O+* (*non-rhyme*) vs. *P-O+*. These comparisons test whether orthographic overlap alone is sufficient to provide a priming effect even in the absence of phonological overlap. For the single fixation duration analyses, an Overlap Type by Prime Lexicality interaction was evident (marginal when comparing *P+O+* (rhyme) to *P-O+*). Follow-up comparisons revealed that the priming effect for *P+O+* item pairs was greater than for *P-O+* item pairs. In short, while the gaze durations did not reveal a difference between the two types, the single fixation data pattern suggests that the presence of both orthographic and phonological overlap aids target word processing more during the earliest stages than orthographic overlap alone.

P+O+ (*rhyme*) vs. *P+O-*. This comparison tests whether phonological overlap alone results in comparable priming as phonological plus orthographic overlap. In both the single fixation

and gaze duration analyses, a significant interaction was found between Prime Lexicality and Overlap Type, with priming only significant for P+O+ (rhyme). Hence, orthographic and phonological overlap is more effective than simple phonological overlap (a similar pattern was found when comparing P+O+ (non-rhyme) item pairs to P+O- item pairs.)

P-O+ vs. P+O-. This final comparison allowed us to test whether orthographic or phonological overlap results in stronger priming. No differences were found for the single fixation analyses. In the gaze duration analyses, a significant interaction between Prime Lexicality and Overlap Type was apparent, with significant priming found only for the P-O+ item pairs. In short, this comparison suggests that whether the target overlapped either solely at the orthographic level or solely at the phonological level did not affect the earliest reading measure (though see below). The gaze duration measure revealed that the orthography of the prime is more beneficial for target processing than the phonology of the prime.

Target word reading time comparisons.

Finally, we tested whether it is indeed the prime word that is responsible for the main effects of Overlap Type found in the previous comparisons, rather than a difference between the target words and/or differences from the preceding contexts. In order to test this, we compared the reading times for the target words when primed by a nonword and, separately, when primed by a word prime. If the contexts were comparably neutral across the type of overlap conditions, then no differences should be observed for the nonword prime, but significant differences are expected when preceded by a word prime. Separate models were constructed for word and nonword primes with Overlap Type and Duration as predictor variables. Since none of the interactions between Overlap Type and Duration were significant, and since the effect of Duration is of no interest for these comparisons, only the result of the variable Overlap Type are reported in Table 4. All model fits contained the maximal random intercept and slope effects.

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Insert Table 4 here
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As seen in Table 4, when the prime was a nonword, there were no significant differences between the different types for both measures. On the other hand, the reading time comparisons showed that, when primed by a word, the P+O- target words were read slower than any of the other sets (see Table 2 for means). In addition, the single fixation data comparisons also indicated that the P-O+ target words were processed slower than the P+O+ target words.

The target word reading time comparisons indicated that words that overlap at the orthographic level with their prime are processed faster than words that only overlap at the phonological level. In addition, the single fixation duration measure showed that words which only overlap orthographically are processed slower than orthographically and phonologically overlapping words. In other words, contrary to what is found in the masked priming literature, we find that orthographic neighbors (if we put aside the notion that all words are a combination of orthographic and phonological overlap), produce facilitation in a fast priming task. However, one difference between the masked priming and fast priming tasks is that in fast priming, both primes and targets are presented in lower case, whereas in masked priming, the prime is typically presented in lower case and the target in upper case. It has been suggested (Nakayama et al., 2010) that at least part of the facilitation found in fast priming for orthographic neighbors stems from low-level visual overlap (because primes and targets are presented in the same case). In Experiment 2, we tested this possibility.

The predictions for Experiment 2 are straightforward: inhibition is expected for orthographic neighbors irrespective of where the letter change occurs, and phonological overlap should not play a role (given that prior experiments have not controlled this variable, yet have found consistent inhibitory effects from word neighbors). However, note that none of the previously

reported experiments systematically contrasted the different types of overlap we distinguish. In addition, if the low-level visual overlap account is correct, then we would expect to find facilitation rather than inhibition in a masked priming version of our prime-target pairs when using the same degree of low-level visual overlap (concretely, when both prime and target are presented in lower case). However, if the opposite pattern (i.e. facilitation) is observed, then this would argue against a low-level visual overlap explanation of the fast priming data. For the O-P+ overlap, the prediction is less clear, with previous naming experiments using word primes showing inhibition, and lexical decision experiments using nonword primes showing facilitation.

EXPERIMENT 2: MASKED PRIMING

Method

Participants

Seventy-eight students from the University of Birmingham participated in the experiment for credit. The data from ten participants (5 per list, see below) were discarded as they had an accuracy score of less than 70%.

Materials and Design

The same 160 prime-target pairs, 40 per overlap condition, as in Experiment 1 were used. In order to mirror more closely the prime duration used in masked priming, and to allow for a higher number of observations per cell, we only employed a 50 ms prime duration. This is also the only duration that showed an effect (borderline for the log-transformed data) for the P+O- condition (Table 2).

The item pairs from Experiment 1 were divided over two lists so that each participant saw half of the targets preceded by its word prime and the other half preceded by its nonword prime. Nonword filler items were added for task purposes and resembled the target pairs in a number of

ways: half of them were preceded by a nonword prime, half by a word prime. In addition, the word primes for the nonword targets exhibited the same type of overlap as for the target pairs: 40 had end overlap (*sleep-cleep*), 40 beginning overlap (*trunk-trunt*), 40 end overlap with possible inconsistent phonology (*spear-slear*), and 40 low-orthographic overlap but rhyming (*slain-frane*). This ensured that a word prime was equally likely to be followed by a word target as a nonword target, and that the 4 overlap types were presented equally often with a word as a nonword target. The 20 practice trials at the start of the experiment exhibited the same type of constraints as in the actual experiment.

Procedure, apparatus, and analyses

Each trial went as follows: first, a fixation asterisk was shown for 500 ms, followed by a mask consisting of the same number of hashes (#) as there are letters in the prime and target; after 500 ms, the prime was presented for 50 ms, immediately followed by the target. The target stayed on the screen for 1,500 ms and participants were instructed to answer as fast as possible without compromising accuracy. Up to four participants could be tested at the same time in a sound-attenuated room, each at their own table with a screen between the tables.

Items were presented on Samsung SyncMaster 753S 17 inch CRT monitors with a refresh rate of 60 Hz, and presentation was controlled by a PC computer running E-Studio 2.0. Items were presented in Courier New font size 18 in white on a black background. Participants were offered a break midway through the experiment. The entire experiment lasted about 30 minutes.

Only trials in which a correct response was made to the target were included in the reaction times analyses. We also deleted responses that were less than 300 ms (< 1%) and over 1,200 ms (> 1%). The reaction times were analyzed using R 2.15.2 and the lme4 package, version 0.999999-0. We analyzed the priming effects in the same way as for the fast priming experiment, with Prime as a fixed effect and the inclusion of random intercepts and slopes.

Results and Discussion

Reaction times and statistical analyses can be found in Table 5.

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The results showed inhibitory priming for 2 out of the 3 orthographically overlapping prime-target pairs which had revealed facilitatory priming in fast priming. Specifically, when prime and target overlapped in all letters except the beginning and did or did not overlap phonologically, slower reaction times were observed than when the target was preceded by a non-overlapping nonword. If the facilitation in fast priming had been due to low-level visual overlap, then one would not have expected to find inhibition in the masked priming version. Whether the inhibition was somewhat attenuated compared to a different case masked priming set-up remains to be tested, but the data clearly indicate that orthographic neighbors which show inhibition in masked priming can exhibit facilitation in fast priming, even when presented in exactly the same way (lower case-lower case).

No priming effect was found for the beginning overlap item pairs (*strain-strait*). In this case, the only thing changing from prime to target was the last letter of the word. However, even this overlap did not provide faster reaction times than when the word was preceded by a nonword that had no overlapping letters with the target word. According to an IA-based account, beginning overlap item pairs should provide as much inhibition as the other orthographically overlapping conditions, which was not supported. However, as indicated above, previous masked priming experiments investigating orthographic neighbors have not systematically taken into account place of overlap, so it's unclear whether this result will replicate with a standard different case presentation.

Finally, the phonological-only overlap condition showed a trend towards inhibition, in line with Lukatela and Turvey's (1996) findings in naming with a short SOA. While it is difficult to draw any strong conclusions from a non-significant result, the inhibitory trend found in the P+O-masked priming results contrasts with the numerical advantage found in the fast priming results for this overlap condition. In general, the masked priming data show different, and in some cases the exact opposite, results from the fast priming data, suggesting that low-level visual overlap was not the determining factor for the observed facilitation in the fast priming experiments.

General Discussion

The main results of Experiment 1 (fast priming) are as follows: (1) significant facilitatory priming (word vs. nonword primes for each condition) was observed for both measures (single fixation and gaze duration) at both prime durations (32 and 50 ms) when the prime and target overlapped both phonologically and orthographically (P+O+, i.e. when primes were neighbors of the targets), (2) there was no difference between the place of overlap for the P+O+ items (end/rhyming vs. begin/non-rhyming overlap), though there was a slight numerical advantage for the non-rhyming condition, (3) the single fixation analyses indicated that the priming effect was greater, and the target word reading times faster, when the overlap was both orthographically and phonologically related compared to only orthographically or only phonologically related, (4) when the overlap between prime and target was only phonological, no priming was observed at the short prime duration (and only on one analysis of the single fixation data for the long prime duration), and (5) the two prime durations, 32 and 50 ms, did not affect the priming pattern.

Experiment 2 (masked priming) tested the hypothesis that the facilitation found in Experiment 1 could be explained by low-level visual overlap. Given that the same prime-target pairs that showed facilitation in Experiment 1 revealed inhibition (P+O+, rhyme; P-O+) or no

significant difference (P+O+, non-rhyme; P+O-) in Experiment 2, our results do not support this hypothesis. In fact it was striking, and perhaps surprising, that compared to a legal nonword that had no letters overlapping with the target word, orthographically overlapping word primes did not facilitate processing. One would have expected that when none of the letters overlapped, the change would be more noticeable and disruptive, but our data did not confirm this since it was the overlapping condition that was responded to more slowly. While the null result for the P+O+, non-rhyme condition could be partially explained by visual overlap – it is harder to notice the change at the end of the word - it still did not show any facilitatory effect compared to the nonword baseline. Moreover, it remains to be tested whether this condition will show an inhibition effect in a different case masked priming task.

The finding that during fast priming significant facilitation is observed for words primed by an orthographic neighbor is the opposite of what one would expect on the basis of single word masked priming lexical decision experiments (Davis & Lupker, 2006; Grainger, 1990; Grainger & Ferrand, 1994; Segui & Grainger, 1990), but in line with Nakayama et al.'s (2010) Experiment 1 results. Our results extend Nakayama et al.'s findings in several ways. First, the item pairs used by Nakayama et al. (2010) did not take into account that the orthographic neighbors can overlap phonologically to different degrees. By manipulating the type of overlap between the prime and target in a consistent way we could rule out the possibility that the expected inhibition effect was reversed due to phonological overlap as even for the P-O+ item pairs facilitation was found (though slightly less strongly than for the P+O+ item pairs). Second, since facilitation was found both for the short and longer prime durations in Experiment 1, we can conclude that Nakayama et al.'s results were not the result of using (compared to other fast priming experiments) an exceptionally long prime duration. In other words, there seems to exist a genuine difference in how words are processed in reading and in isolation, at least with respect to how orthographic neighbors impact word recognition, which is again confirmed by the contrasting results of the present Experiments 1

and 2. In fact, except for Nakayama et al.'s (2010) null result when the prime was presented in capitals (and thereby arguably introducing a more visually striking change than found in same case fast priming experiments), all fast priming experiments containing orthographically overlapping pairs have shown facilitation.

While the results of Experiment 2 suggest that low-level visual overlap cannot explain the reversal of effects between masked and fast priming, Nakayama et al. (2010) identified a second mechanism which could facilitate target processing, i.e. the larger context that the word appears in. Concretely, it was suggested that upon reading a prime word, some of its orthographic neighbors will receive priming from the context (e.g., when the context only allows a noun, neighbors that are nouns will receive extra activation). Hence, when the prime is *bear*, all its neighbors (*gear, dear, fear, hear, lear, near, pear, rear, sear, tear, wear, year, bead, beak, beam, beat, bean, beau, beer*) will receive bottom-up activation, but the syntactic context (*John picked up the*) will provide extra activation for nouns and adjectives (*gear, dear, fear, near, pear, rear, bead, beak, beam, beat, bean, beau, beer*) while the semantic context further increases activation for more likely continuations (e.g., *gear, dear, fear, near, rear, bead, beat, bean, beau, beer*). Given that we found facilitation at 32 ms, it suggests that the pruning of syntactically unacceptable candidate words and the evaluation of how well the remaining words fit in the preceding context is an extremely fast process.

It is difficult to argue against this hypothesis without carrying out more experiments specifically designed to test whether, for example, having only one contextually plausible, though non-predictable, neighbor word leads to larger facilitation than having several candidates. However, it should be noted that we tried to keep our preceding contexts semantically neutral so that in most instances quite a few orthographic neighbor words could still fit in the context (see example above). Moreover, given that the context will not only prime certain orthographic neighbors but rather *all* words that semantically/conceptually fit the context well, one would expect more rather than less competition between lexical candidates. In addition, while we do not doubt that (supra)lexical

processes influence reading, as is evident from, for example, predictability effects in reading (Ehrlich & Rayner, 1981; Frisson, Rayner, & Pickering, 2005; Rayner & Well, 1996), more subtle fit-in-context effects tend to show up only in later eye-tracking measures (e.g., Rayner, Warren, Juhasz, & Liversedge, 2004). Of course, one can still argue that *any* form of context is more constraining than the random words presented in a lexical decision task and that the interaction between such contexts and target word recognition might mask or override effects found in single-word experiments. While this might be a valid argument, it makes any comparison between single-word experiments and word recognition in text quite problematic.

What other differences between masked priming and fast priming might account for the conflicting results? One reason might be related to task demands: in masked priming lexical decision tasks, the main objective is to indicate whether a string of letters is a word or not, and information from the prime can make this decision harder. Word primes are lexically represented and, when activated, will compete with the recognition of the target word. For a participant it makes sense therefore to try and disregard or suppress the prime, especially when the prime is harder to dismiss, i.e. when it's an existing word. Indeed, there is some evidence that inhibition effects are greater when participants are more aware of the prime (Zimmerman & Gomez, 2012), possibly indicating some degree of (sub)conscious strategy. Similarly, De Moor, Van der Herten, and Verguts (2007) have shown that the effect of word neighbor primes becomes increasingly inhibitory with longer prime durations.

A second reason, which is not incompatible with the first, is concerned with the large difference between fixation and reaction times. In fast priming we obtained priming effects in the single fixation duration, around 350 ms after crossing the invisible boundary.⁶ Since this includes the presentation of the prime itself, this means that priming had a facilitatory effect close to 300 ms after the appearance of the target. In contrast, the masked priming reaction times are about twice as long. It is therefore not inconceivable that both methodologies are tapping into different stages of

processing. Concretely, in fast priming, candidate words might still be accruing lexical activation, and orthographic overlap will be helpful at this stage. In contrast, at the moment of decision-making in masked priming, the candidate words might have been activated strongly enough to provide competition, resulting in lateral inhibition. Evidence from ERP experiments are compatible with the view of different stages of processing in masked (and probably fast) priming. Massol Grainger, Dufau, and Holcomb (2010) distinguished two different ERP components, the N250 (a negative going signal 250 ms post-target onset) and the N400 (peaking approximately 400 ms post-target) component. According to the bi-modal interactive activation model (BIAM, Grainger & Holcomb, 2009; see also Diependaele et al., 2010), the earlier component is thought “to reflect the mapping of prelexical orthographic representations onto whole-word orthographic representation” and the latter component to “reflect the mapping of lexical form onto meaning” (Massol et al., 2010, pp. 163-164). By combining masked priming with ERP recording, they found that word neighbor primes elicited a different pattern of activation than nonword neighbor primes, arguably reflecting the inhibitory vs. facilitatory priming effects found in behavioral studies, but only at the temporally later N400 component. At the N250 component, all types of prime (word, nonword, and repetition) produced similar patterns of effect. It is not inconceivable that fast priming is more reflective of this earlier processing stage while masked priming exposes the latter stage (when competition between whole-word representations is thought to occur, see Massol et al., 2010). If this view is correct, then any direct comparison between fast and masked priming experiments will remain tenuous.

The second main finding of the fast priming experiment, no differences between the two P+O+ conditions (rhyming vs. non-rhyming item pairs), indicates that there is no special status for rhyming words during reading, notwithstanding their great importance in learning to read (Bradley & Bryant, 1983). The numerical advantage found for beginning overlap item pairs, however, is in line with eye-tracking results on letter transposition and letter substitution, where it has been shown

that changes at the beginning of a word cause greater disruption than changes at the end of a word (Rayner et al., 2006; White, Johnson, Liversedge, & Rayner, 2008). However, given that this difference did not reach significance, it is difficult to draw any strong conclusions regarding beginning and end overlap. Interestingly, the masked priming results do show a difference, with inhibition for rhyming pairs but not for non-rhyming P+O+ pairs. This result suggests that inhibition from visual or orthographic features might be stronger than a possible advantage one could get from the phonological rhyme overlap.

The P+O- condition (*fruit-chute*) allowed us to investigate whether phonological overlap in the absence of orthographic overlap primes or not. The results showed an advantage for mere phonological overlap, but only on the single fixation duration measure and only for the longest prime duration (and when log-transformed, this effect became non-significant). In other words, presenting a prime word that rhymes with the target word for 32 ms does not speed up processing any more than having a string of random letters.⁷ Compared to single word tasks, these results are more in line with those found in naming (e.g., Forster & Davis, 1991, failed to find a priming effect for orthographically dissimilar rhyming words like *stake-BREAK*; see also Carreiras et al., 2005) than with masked priming lexical decision tasks (e.g., Lukatela & Turvey, 1996, found rhyme inhibition in lexical decision; Ziegler et al., 2000, found facilitation with a 29 ms prime duration). Our own masked priming data are inconclusive: while there was a numerical trend towards inhibition, it failed to reach significance.

With respect to the third main finding of the fast priming experiment, greater facilitation when both phonology and orthography overlapped relative to when either orthography or phonology alone overlapped between primes and targets, it needs to be pointed out that this was most clearly in the single fixation data, an earlier measure than the gaze duration measure usually reported in previous research because gaze duration times also include the duration of refixations on a word, leading to longer reading times (Lee et al., 1999a, 1999b, Rayner et al., 1995). By including a

condition in which the spellings of the prime and target, but not their sound, overlapped (P-O+, *bear-gear*), as is the case when the pronunciation of the prime is inconsistent, we were able to examine whether orthographic overlap is in itself sufficient to produce priming. This was indeed the case, and contrary to evidence from single word naming experiments (e.g., Burt & Humphreys, 1993; Pexman et al., 2005; Taraban & McClelland, 1987), the effect was facilitatory rather than inhibitory. When the prime and target only overlapped at the phonological level (P+O-, *fruit-chute*), facilitation was only found with the longer prime duration.⁸ Together, this pattern of results, i.e. orthography being used immediately during reading and phonology coming into play only at a somewhat later stage, supports findings in the masked priming and electrophysiological literature (Bélanger, et al., 2012; Ferrand & Grainger, 1994; Grainger & Holcomb, 2009; Grainger, Kiyonaga, & Holcomb, 2006).

However, the picture is more complicated than this. The prime effect size and the target word reading time comparisons between the P+O+ conditions and the P-O+ and P+O- conditions show that orthographic or phonological overlap alone is less beneficial than when orthography and phonology combine. Given that none of the interactions with prime duration were significant, this benefit does not seem to be restricted to the longer prime duration. This pattern suggests that when there is orthographic overlap, the prime's phonology can very quickly speed up target word recognition, a result that is also in line with findings in the masked priming literature (Bélanger et al., 2012; Ferrand & Grainger, 1994; Frost, Ahissar, Gotesman & Tayeb, 2003; Ziegler et al., 2000).

To a large extent, our fast priming data can be accounted for in a model of word recognition such as the bi-modal interactive activation model (BIAM; Diependaele et al., 2010; Grainger & Holcomb, 2009). This model assumes that as soon as letter-level information becomes available, sublexical orthography is being mapped onto sublexical phonology via a sublexical interface. This processing is reflected in the N250 component discussed above. Sublexical orthographic and phonological information then activate lexical orthographic and phonological

levels of representation, respectively, and these whole-word representations are then related to their meanings in the so-called “form-meaning interface.” This is thought to be reflected in the N400 component, and is also the assumed locus of the inhibition effects found in masked orthographic priming. Our finding that phonological overlap can speed up processing, as evidenced by the larger priming effects and faster reading times for P+O+ item pairs compared to P-O+ item pairs, indicates that orthographic and phonological information interacts, as assumed to happen at the sublexical level in the BIAM. However, our data also indicate that the feedback from the phonological node to the orthographic one must be rather feeble, at least in fast priming experiments. Support for this comes from the P-O+ data, which did not show inhibition effects when the prime and target had mismatching phonology, and from the P+O- data, which did not show facilitation at the shorter prime duration notwithstanding the large phonological overlap.

In conclusion, our experiments tested different kinds of phonological and orthographic overlap between a prime and its target using the fast priming and the masked priming lexical decision task. We showed opposing orthographic neighbor effects, with facilitation during reading and inhibition (or no effect) in lexical decision, even when low-level visual overlap was kept constant. We also found that processing was fastest when prime and target overlapped at both the orthographic and phonological level. Our data suggest that fast priming results reflect an earlier stage of processing than masked priming results, compatible with assumptions in the BIAM account.

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Footnotes

¹ Confirmation that our priming effects are very much in line with previous research comes from a comparison with previous research: the priming effects reported in Experiment 1 are comparable to those reported by Rayner et al. (1995) and slightly smaller than those found by Lee et al. (1999a, 1999b).

² One P+O- item pair (*crook-stalk*) was mistakenly classified as rhyming and therefore deleted from all analyses, together with the data from the control nonword prime.

³ We also examined whether the P+O- condition showed an effect in other eye movement measures. To this end, we checked whether there was a main effect of priming overall, an interaction between Prime and Duration, or a priming effect at each duration interval separately for the following measures (see Pickering, Frisson, McElree, & Traxler, 2004): percentage of first-pass regressions out, regression-path duration, percentage of regressions in, second pass duration, and total gaze duration. None of the comparisons approached significance (all $ps > .22$), again emphasizing the need to treat the single fixation finding for this condition cautiously.

⁴ There were also near significant main effects of Duration for some of the different types, due to longer fixation times in general for the longer prime duration. We will not discuss this further.

⁵ In R, this means that instead of a model such as $(F1 * F2 * F3 + (1 + F1:F2:F3|ppt) + (1 + F1:F2:F3|item))$ we used $(F1 * F2 * F3 + (1|ppt) + (1|ppt:F1:F2:F3) + (1|item) + (1|item:F1:F2:F3))$.

⁶ Note that these fixation times are somewhat longer in the present experiment than observed in normal reading experiments, which is due to the absence of a parafoveal preview, though in line with other fast priming experiments (e.g., Lee et al., 1999a, b).

⁷ One could argue that the P+O- primes also overlap more with the targets than the nonword primes. While this is indeed the case for most primes (e.g., the prime target pair *greet-bleat* have two letters in common, while *nuxin-bleat* do not), research by Humphreys, Evett, and Quinlan (1990) and Humphreys, Evett, Quinlan, and Besner (1987) has shown that orthographic priming with primes that only have 2 out of 4, or 2 out of 5, letters overlapping is comparable to having a row of x's as prime. We also calculated whether the relative Levenshtein distance between the prime and target (Levenshtein distance divided by the number of letters), which measures degree of orthographic overlap, was a significant predictor of the reading times. This was not the case, all $ps > .10$.

⁸ Note that this prime duration is longer than the prime durations used in homophone fast priming experiments, in which no homophone priming has been found for durations longer than 36 ms.

Appendix

Stimuli by Type.

P+O+, rhyme (*track-crack*)

Experimental sentence (target italicized)	Prime	
	Nonword	P+O+ word
The secret agents said that the foreign <i>kings</i> were a pain to look after.	groft	wings
At the market, Julie bought a <i>bream</i> and a salmon for dinner that evening.	whelg	dream
When Susan revealed she had a <i>crush</i> on Kenneth, her best friend became worried.	zaind	brush
The woman was happy that the <i>lotion</i> was on sale in the drug store.	stupen	motion
The TV report was about a <i>clash</i> between two rival motorcycle gangs.	grukt	flash
Elisabeth was worried that the <i>frail</i> pensioner started to feel lonely.	penpy	trail
The children were waiting for the <i>clown</i> to make his entrance.	ghuif	crown
Students are expected to reread and <i>refine</i> their draft of the paper on thermo-dynamics.	attyph	define
Jonathan bought the wrong <i>brand</i> of breakfast cereal yesterday.	flith	grand
The new, ugly office block is a <i>blight</i> on the surrounding landscape.	crousk	flight
Dorothy decided to replace the <i>lard</i> with sunflower oil, which ruined the cake recipe.	tufs	card
The hunter was annoyed when the <i>flock</i> of geese suddenly changed	trens	clock

direction.

The little girl wanted the *trunk* to be taken down from the attic.

As described in the log, a *mayday* was transmitted after the collision with the iceberg.

The ascent was dangerous because of the *sleet* and rain that suddenly appeared.

The realtor noticed a *crack* in the ceiling and had it replastered.

The bulky man tried to *detain* the suspect but was pushed aside.

Robert noticed that the *flame* was slowly dying in the fireplace.

Patricia was happy that she could *dwell* at the fair for a bit longer.

Tony insisted that his *quest* for an eligible bride would take as long as necessary.

It became clear that the horrible *shrew* needed to be dealt with asap.

Barbara always loves to *glide* down the snow-covered hills.

The shy girl tried to *slink* away in the corner during the boisterous office party.

The animal started to *cluck* annoyingly until the dog disappeared.

It has turned into the longest *slump* of the last century, due to a shortage in lending.

George was delighted that the *rink* was reopened so quickly.

When walking on this forest path, avoid the *snare* that has been set out for rabbits.

The captain mentioned that a *barge* and a tugboat were both in trouble on the icy river.

To Paul's relief, his worst *dread* turned out to be unfounded and he

slagh drunk

vunkel payday

prumd fleet

luigh track

whoppy retain

zyrth blame

traph swell

narph guest

plick threw

kronk slide

graxt blink

heirl pluck

drynt plump

jorf wink

luind spare

jymis large

nuigh bread

could end his race.		
The lower management faced the <i>brunt</i> of the reorganization of the company.	lazip	grunt
After a while, the powerful <i>rector</i> had enough and quickly disappeared.	muighs	sector
It quickly became clear that the <i>chore</i> of window cleaning was going to take its toll.	kleth	shore
It was formed by the crushing of <i>shale</i> and sandstone, and covered the whole backyard.	exynd	whale
I was concerned that the heavy food would <i>bloat</i> the bellies of the sheep.	miers	float
It is still unclear to what degree people are <i>faking</i> when they're hypnotized.	blixir	waking
The smart student was on the <i>brink</i> of a promising career when disaster struck.	whyls	drink
To many people, however <i>trite</i> it may sound, much joy is to be found in a Spring day.	glenp	write
The instructions indicate that you have to <i>tick</i> the appropriate box on the form.	gomp	sick
Every individual, whatever <i>creed</i> or color, is entitled to freedom of expression.	lanph	breed
The slow, insistent, rhythmic <i>clank</i> of two metal rods started the composition.	dwebs	flank

P+O+, non-rhyme (*swoop-swoon*)

Experimental sentence (target italicized)	Prime	
	Nonword	P+O+ word
They navigated the narrow <i>strait</i> between the Turkish peninsula and the mainland.	cheelk	strain
Mark was asked to <i>steer</i> the fishing vessel into the harbor.	krunk	steel
The investigators made a <i>sweep</i> for hidden devices.	blaph	sweet
After the alarm, I could see helicopters <i>scour</i> the countryside for the missing hikers.	leynd	scout
Donna pretended that the <i>bland</i> dish made by her husband was an utter delight.	sweis	blank
After some planning, the crew decided to just <i>steal</i> the blueprints from the office.	vrynk	steam
The player was upset when he saw that his <i>cleat</i> was dirty and ripped beyond repair.	whibb	clear
Margaret made sure that the <i>braid</i> was fastened with a red, white and blue ribbon.	clush	brain
The young prodigy told me that he disliked <i>chess</i> but that he played for his parents.	noork	chest
She told me that Shawn's most annoying <i>trait</i> was impatience with his colleagues.	boufs	train
After a fruitless outing, the cat <i>slunk</i> back into the warm kitchen.	frich	slung
Instead of cream cheese, Lisa used <i>quark</i> in her delicious cheese soufflé.	voong	quart
The reporter could <i>glean</i> information from the illegal recordings	scrit	gleam

but did not to use it.

It was evident that there was a *stark* contrast between the two presidential candidates.

It is expected that the young man will *slay* the dragon and marry the princess.

Whenever I work on my car's engine, I *stink* of gasoline and oil.

This product provides a natural *sheen* to leather equipment and increases suppleness.

Betty made certain that the *spool* was wound up tight before switching on the machine.

The poor old man had a *stoop* and a wavering voice, but still commanded respect.

Derek could not believe that the *chain* had come off his bicycle.

When things become difficult, Lou starts to *droop* his shoulders and become very quiet.

Matthew swiftly approached the *mound* from which he would be throwing the snowballs.

Those silly girls would *swoon* if they were to meet Brad Pitt in real life.

It will take time and effort to *repeal* the offensive and discriminatory legislation.

Jackson had an adventurous *streak* in him that made him scale terrifying rock cliffs.

Daniel is impressed that his professional *guild* sponsors so many noble causes.

fleid start

juid slap

zoorf sting

jorck sheep

gruix spoon

hukdy stool

toung chair

meesk drool

prags mount

blydt swoop

jyfdun repeat

ulping stream

brabs guilt

It is two weeks now since the <i>stork</i> appeared in the marsh lands outside the city.	laper	storm
Kate told everyone that Brian was a <i>cheat</i> and did not think about anyone else.	hilsk	cheap
Joseph was afraid that the <i>creak</i> of the wooden steps would wake up his parents.	vuins	cream
The youngest son thought he could find the <i>grail</i> of truth, but he never did.	mouk	grain
The apprentice was told to bring the <i>plank</i> of wood to the dining room.	ruswy	plant
Deborah told me that the <i>stair</i> was very slippery and likely to splinter.	louck	stain
The language student observed that the <i>adverb</i> and the subject were spelled incorrectly.	klumph	advert
Madison was astonished when a <i>cheer</i> rose up from the stiff audience members.	blums	cheek
The intricate machinery started to <i>bleep</i> and shriek and then fell silent.	houth	bleed
Michael lost out to a rival driven by <i>greed</i> and money and without compassion.	zumth	green
After thinking hard, David removed the <i>rook</i> from the board and put it in his pocket.	gurg	roof
Harriet could not believe that the <i>marker</i> she had just bought was of the wrong color.	bilsug	market
Olivia had never felt such a <i>queer</i> sensation before and it made her	phamt	queen

sad.		
Mr Matthews asked for a <i>towel</i> as there was none in his hotel room.	chizy	tower
P-O+ (<i>bear-gear</i>)		
Experimental sentence (target italicized)	Prime	
	Nonword	P-O+ word
Joshua picked up the <i>gear</i> that he needed for his surfing trip.	qulk	bear
Hannah cleaned up while the <i>dough</i> was rising in the fridge.	inwer	cough
Isabelle put a couple of <i>cloves</i> in the simmering roasting pot.	praump	gloves
Alfie opted to go with a <i>tint</i> of yellow or orange for the dining room.	cesh	pint
It is upsetting that we have to <i>shear</i> the animal with rusty clippers.	noomp	swear
Lewis stumbled upon a <i>wallet</i> lying in the middle of the mountain trail.	ghochs	ballet
The husband saw that the house was <i>aglow</i> with lights when he pulled up in the driveway.	vrubs	allow
The nasty manager tried to <i>abash</i> everyone who didn't agree with him.	elkym	awash
Dylan was ecstatic when he caught a <i>snook</i> on his line during his holidays.	frymt	spook
We discovered that there was a <i>crow</i> sitting on the top branch of the willow tree.	halx	brow
We could clearly hear the <i>gull</i> screeching as it flew away.	toft	bull

We could all hear the <i>laughter</i> coming from the play room.	byloosks	daughter
Thomas decided to lower the <i>doses</i> of medication prescribed to the patient.	raimk	loses
Liam takes some tools and then <i>sneaks</i> out of the garage in broad daylight.	druimp	steaks
The shop attendant pointed out that all the <i>rasps</i> came with a one year warranty.	nueel	wasps
Amelia gazed upon her <i>brood</i> performing at the theatre.	jenth	blood
Here is a picture of my dog licking his <i>jowls</i> and looking very pleased with himself.	nirck	bowls
Ella was not happy when I told her about a <i>bleak</i> future in her chosen profession.	snoms	break
Last night, there was a <i>hush</i> of expectancy when the orchestra came on stage.	dald	bush
Samuel had to collect the <i>tolls</i> from all cars using the parking.	wrymp	dolls
The decorator made sure that the <i>gloss</i> paint was applied after the priming was done.	fuint	gross
Jake was told that the <i>beard</i> had to go if he wanted to look cool.	flomp	heard
Charlie carefully explored the <i>coves</i> of Brighton Bay on his own.	bliak	moves
I watch while the chef <i>sears</i> the meat quickly on both sides.	vonth	pears
It has been suggested that time <i>dulls</i> all memories, but some seem to be very resilient.	gromt	pulls
After the explosion, a <i>gush</i> of water spewed out of the pipe.	dylm	push
Although time is pressing, we <i>stall</i> in front of the entrance and then hail a taxi.	puirt	shall

The man enters the building, then <i>roves</i> around his desk, and leaves again.	klurk	doves
I watch Daisy when she <i>combs</i> her long blond locks in front of the mirror.	kralp	tombs
Harvey has a little <i>pouch</i> that he uses for carrying around money.	zears	touch
Jim was in an apple tree, sitting on a <i>bough</i> that could barely hold his weight.	plaun	tough
In one episode the actress <i>rants</i> and raves about Facebook and Twitter.	q Eich	wants
Phoebe made the decision to <i>mash</i> the potatoes and add some butter and milk.	lirt	wash
Suddenly, Harrison waved a <i>batch</i> of papers at her to sign.	jyrpe	watch
In this species, the male <i>rears</i> the young without help from the mother.	qinth	wears
It was difficult to see, but there were some <i>fives</i> and sixes and a list of letters.	laurn	gives
Henry collected all of the <i>cords</i> that were used in the exercise.	plyth	words
Little Jimmy has been collecting <i>corks</i> and bottles from vineyards around the world.	meemps	works
Megan told us that the <i>dorms</i> needed a good cleaning.	naibo	worms
Edward claimed he knew <i>morse</i> code, but he couldn't translate the message.	glink	worse

P+O- (*fruit-chute*)

Experimental sentence (target italicized)

Prime

	Nonword	P-O+ word
The tired crew did their best to stay <i>afloat</i> in the choppy waters, but to no avail.	iskwig	remote
Caitlin was annoyed when she saw that the <i>aisle</i> was blocked by unattended luggage.	wropt	smile
Jasmine quickly found the <i>booth</i> where her friends had been waiting for her.	vlaik	truth
Suddenly while driving, there was a <i>groan</i> coming from the engine of the old car.	huelq	stone
These data are based on <i>prewar</i> troop levels and are not relevant anymore.	nulzus	indoor
The designer was wearing a <i>fleece</i> while inspecting the blueprints.	phuith	grease
I acquired this at a <i>retail</i> price far above its real value.	opguph	female
Luckily, the condition turned out to be <i>benign</i> and the patient soon started walking.	molpat	divine
The police officer described the <i>baboon</i> that had escaped from the local zoo.	drykly	immune
When Holly found out that the <i>brute</i> had moved in next door, she moved out.	flein	shoot
The archaeologist found some kind of <i>canine</i> skull that was of no interest.	broult	design
Emma looked up when John started to <i>croak</i> and grunt before turning blue.	teelf	smoke
Ellie decided to sell the <i>lute</i> she inherited from her aunt.	magh	boot
The gang carefully hid the <i>loot</i> of their latest robbery in a locker.	aiph	suit

Max couldn't believe that the <i>bail</i> was set at over a million.	quef	male
Using a shovel, Tyler tried to <i>uproot</i> the weeds in his back garden.	ipchym	salute
Charlotte explained that the <i>chute</i> was used for bagged rubbish.	neelk	fruit
Wherever she goes, Nicola <i>draws</i> unwanted attention from men.	plenx	cause
When the animal started to <i>bleat</i> and make funny noises, the child ran away.	nuxin	greet
An accident was only just avoided when the <i>crane</i> dropped the heavy wooden boxes.	mouks	drain
Ian concealed the item in his <i>cloak</i> and tiptoed out of the expensive shop.	truim	spoke
Apparently some wasps will <i>flail</i> about while looking for a place to sting.	qunth	scale
It is not acceptable to <i>impugn</i> or question someone's integrity for nothing.	terbef	saloon
It's ridiculous to call this a <i>ghetto</i> or a slum just because it's not affluent.	juyrra	follow
These horrible devices can still <i>maim</i> or even kill innocent people.	fruq	tame
Sophia worked long hours to <i>attain</i> a position of creative independence.	vroffu	insane
Kinsey and colleagues had broken a <i>taboo</i> by openly discussing classified information.	meiph	screw
Oscar made sure there always was a <i>pleat</i> in his pants when he ironed them.	gruin	sheet
Joan's sister helped the <i>bride</i> into her intricate wedding dress.	jaulg	cried
The teacher would always <i>chide</i> her pupils, whether they were	jeags	guide

disobedient or not.

Ryan has a distinctive *gait* because a horse kicked him when he was small.

Alexander could not cope with the *shame* of being outed as a fraud.

The wounded man would *lurch* and stagger up the incline.

Ralph said that these claims are just a *crock* of something very smelly.

Once inside, we tried to *unzip* our jackets but our hands were too cold.

The officials were afraid of the *uproar* that was certain to follow the tax increase.

Elena was concerned about her *waist* after eating nothing but donuts for three days.

Although we could see the *bison* in the distance, approaching it was impossible.

Georgia showed us her *hoop* earrings made out of silver.

Keira quickly grabbed the *cello* and disappeared down the road.

wies fate

breex claim

daink perch

puimb stalk

argaw equip

jymlys ignore

goulk taste

yeemt cabin

gilk soup

zaity elbow

FIGURE CAPTION

Figure 1. Example of the fast-priming paradigm.

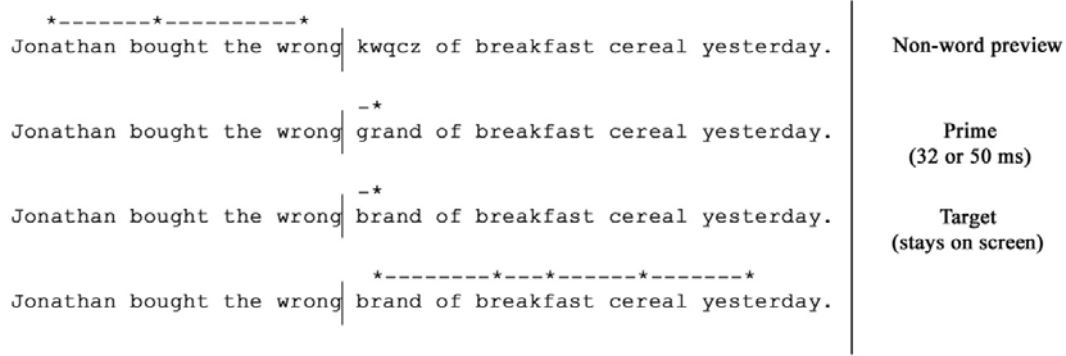


Table 1: Item characteristics.

Overlap	Example	Prime log-frequency	Prime length	Target log-frequency	Target length
P+O+, rhyme	<i>track-crack</i>	2.6 (0.5)	5.1 (0.5)	1.7 (0.5)	5.1 (0.5)
P+O+, non-rhyme	<i>swoop-swoon</i>	2.6 (0.6)	5.1 (0.4)	1.7 (0.6)	5.1 (0.4)
P-O+	<i>bear-gear</i>	2.6 (0.6)	5.0 (0.7)	1.4 (0.7)	5.0 (0.7)
P+O-	<i>fruit-chute</i>	2.7 (0.5)	5.15 (0.7)	1.65 (0.5)	5.15 (0.7)
<i>Total</i>		<i>2.6 (0.6)</i>	<i>5.1 (0.6)</i>	<i>1.6 (0.6)</i>	<i>5.1 (0.6)</i>

Notes. P+ = high phonological overlap, P- = low phonological overlap, O+ = high orthographic overlap, O- = low orthographic overlap. Log-frequency is based on the CELEX database, length is expressed in number of letters. Standard deviations can be found between brackets.

Table 2. Fixation time results and priming analyses by Type.

P+O+, rhyme (*track-crack*)

	nonword prime	word prime	priming effect	Model comparison
Single Fixation				
32 ms	340	321	19	$\chi^2(1) = 5.79, p < .05$ $\beta = 20.5, SE = 8.2, t = 2.49$
50 ms	357	321	36	$\chi^2(1) = 19.60, p < .001$ $\beta = 36.4, SE = 7.3, t = 5.00$
Gaze Duration				
32 ms	382	363	19	$\chi^2(1) = 4.63, p < .05$ $\beta = 19.4, SE = 8.9, t = 2.18$
50 ms	398	379	19	$\chi^2(1) = 5.81, p < .05$ $\beta = 17.7, SE = 7.1, t = 2.50$

P+O+, non-rhyme (*swoop-swoon*)

	nonword prime	word prime	priming effect	Model comparison
Single Fixation				

32 ms	346	310	36	$\chi^2(1) = 18.72, p < .001$ $\beta = 36.0, SE = 7.5, t = 4.77$
50 ms	342	311	31	$\chi^2(1) = 16.02, p < .001$ $\beta = 34.7, SE = 7.9, t = 4.41$
Gaze Duration				
32 ms	383	357	26	$\chi^2(1) = 11.51, p < .001$ $\beta = 27.3, SE = 7.5, t = 3.65$
50 ms	390	366	24	$\chi^2(1) = 8.03, p < .01$ $\beta = 24.6, SE = 8.5, t = 2.89$

P-O+ (*bear-gear*)

	nonword prime	word prime	priming effect	Model comparison
Single Fixation				
32 ms	348	331	17	$\chi^2(1) = 4.01, p < .05$ $\beta = 15.3, SE = 7.6, t = 2.01$
50 ms	351	340	11	$\chi^2(1) = 2.65, p < .11$ $\beta = 13.1, SE = 8.0, t = 1.64$
Gaze Duration				

32 ms	387	372	15	$\chi^2(1) = 4.07, p < .05$ $\beta = 15.2, SE = 7.4, t = 2.04$
50 ms	395	381	14	$\chi^2(1) = 4.17, p < .05$ $\beta = 14.5, SE = 7.0, t = 2.08$

P+O- (*fruit -chute*)

	nonword prime	word prime	priming effect	Model comparison
Single Fixation				
32 ms	342	348	-6	$\chi^2(1) < 1$
50 ms	363	346	17	$\chi^2(1) = 4.49, p < .05$ $\beta = 16.8, SE = 7.6, t = 2.21$
Gaze Duration				
32 ms	386	391	-5	$\chi^2(1) < 1$
50 ms	406	402	4	$\chi^2(1) < 1$

Notes. Fixation times are in milliseconds.

Table 3. Comparisons between overlap Types.

	<i>Single fixation duration</i>	<i>Gaze duration</i>
P+O+ (rhyme) vs. P+O+ (non-rhyme)		
Type	$\chi^2(4) = 4.73, p > .31$	$\chi^2(4) = 5.96, p > .20$
Type:Prime	$\chi^2(1) = 1.02, p > .31$	$\chi^2(1) < 1$
P+O+ (rhyme) vs. P-O+		
Type	$\chi^2(4) = 6.29, p > .17$	$\chi^2(4) = 2.01, p > .73$
Type:Prime	$\chi^2(1) = 3.38, p < .07$ $\beta = 12.8, SE = 6.9, t = 1.85$	$\chi^2(1) < 1$
P+O+ (rhyme) Prime	$\chi^2(1) = 21.85, p < .001$ $\beta = 28.0, SE = 5.3, t = 5.31$	
P-O+ Prime	$\chi^2(1) = 5.05, p < .05$ $\beta = 13.5, SE = 5.8, t = 2.32$	
P+O+ (non-rhyme) vs. P-O+		
Type	$\chi^2(4) = 12.98, p < .05$ $\beta = 12.9, SE = 6.3, t = 2.04$	$\chi^2(4) = 5.98, p > .20$
Type:Prime	$\chi^2(1) = 7.59, p < .01$ $\beta = 19.7, SE = 7.1, t = 2.77$	$\chi^2(1) = 2.25, p > .13$

P+O+ (rhyme) Prime	$\chi^2(1) = 31.90, p < .001$ $\beta = 34.8, SE = 5.2, t = 6.66$	
P-O+ Prime	$\chi^2(1) = 5.05, p < .05$ $\beta = 13.5, SE = 5.8, t = 2.32$	
P+O+ (rhyme) vs. P+O-		
Type	$\chi^2(4) = 17.74, p < .01$ $\beta = 17.4, SE = 6.0, t = 2.89$	$\chi^2(4) = 19.70, p < .001$ $\beta = 18.1, SE = 6.3, t = 2.86$
Type:Prime	$\chi^2(1) = 9.35, p < .01$ $\beta = 20.5, SE = 6.8, t = 3.02$	$\chi^2(1) = 8.69, p < .01$ $\beta = 19.6, SE = 6.4, t = 3.05$
P+O+ (rhyme) Prime	$\chi^2(1) = 21.85, p < .001$ $\beta = 28.0, SE = 5.3, t = 5.31$	$\chi^2(1) = 8.78, p < .01$ $\beta = 15.6, SE = 6.0, t = 3.09$
P-O+ Prime	$\chi^2(1) = 1.06, p > .30$	$\chi^2(1) < 1$
P-O+ vs. P+O-		
Type	$\chi^2(4) = 5.96, p > .20$	$\chi^2(4) = 12.55, p < .05$ $\beta = 13.8, SE = 6.3, t = 2.19$
Type:Prime	$\chi^2(1) = 1.35, p > .24$	$\chi^2(1) = 6.05, p < .05$ $\beta = 15.8, SE = 6.4, t = 2.47$
P-O+ Prime		$\chi^2(1) = 7.76, p < .01$

		$\beta = 15.1, SE = 5.2, t = 2.92$
P+O- Prime		$\chi^2(1) < 1$

Table 4. Target word reading time comparisons.

	<i>Single fixation duration</i>	<i>Gaze duration</i>
P+O+ (rhyme) vs. P+O+ (non-rhyme)		
Nonword prime	$\chi^2(1) < 1$	$\chi^2(1) < 1$
Word prime	$\chi^2(1) < 1$	$\chi^2(1) = 1.36, p > .24$
P+O+ (rhyme) vs. P-O+		
Nonword prime	$\chi^2(1) < 1$	$\chi^2(1) < 1$
Word prime	$\chi^2(1) = 3.54, p < .06$ $\beta = 14.2, SE = 7.4, t = 1.91$	$\chi^2(1) = 1.09, p > .29$
P+O+ (non-rhyme) vs. P-O+		
Nonword prime	$\chi^2(1) < 1$	$\chi^2(1) < 1$
Word prime	$\chi^2(1) = 8.07, p < .01$ $\beta = 22.3, SE = 7.6, t = 2.96$	$\chi^2(1) = 4.27, p < .05$ $\beta = 17.3, SE = 8.0, t = 2.15$
P+O+ (rhyme) vs. P+O-		
Nonword prime	$\chi^2(1) < 1$	$\chi^2(1) = 1.23, p > .26$
Word prime	$\chi^2(1) = 14.04, p < .001$ $\beta = 27.7, SE = 7.1, t = 3.88$	$\chi^2(1) = 15.30, p < .001$ $\beta = 28.4, SE = 6.7, t = 4.22$

P-O+ vs. P+O-		
Nonword prime	$\chi^2(1) < 1$	$\chi^2(1) < 1$
Word prime	$\chi^2(1) = 3.72, p < .06$ $\beta = 14.2, SE = 7.2, t = 1.98$	$\chi^2(1) = 8.34, p < .01$ $\beta = 20.9, SE = 7.0, t = 2.97$

Table 5. Reaction times and priming analyses for the masked priming experiment.

	nonword prime	word prime	priming effect	Model comparison
P+O+ (rhyme)	624	642	-18	$\chi^2(1) = 6.56, p < .05$ $\beta = 21.2, SE = 7.7, t = 2.74$
P+O+ (non-rhyme)	625	621	4	$\chi^2(1) < 1$
P-O+	636	652	-16	$\chi^2(1) = 4.79, p < .05$ $\beta = 17.0, SE = 7.6, t = 2.25$
P+O-	644	653	-9	$\chi^2(1) = 2.68, p < .11$ $\beta = 9.5, SE = 5.6, t = 1.71$