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Do Visible Semantic Primes Preactivate Lexical Representations?

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Considerable research effort has been devoted to investigating semantic priming effects, particularly, the locus of those effects. Semantically related primes might activate their target's lexical representation (through automatic spreading activation at short stimulus onset asynchronies (SOAs), or through generation of words expected to follow the prime at longer SOAs). Alternately, semantically related primes might aid responding after target identification (i.e., postlexically). In contrast, masked orthographic priming effects appear to be lexical and automatic. Lexical processing of targets is facilitated by orthographically similar nonword primes and often inhibited by orthographically similar word primes (Davis & Lupker, 2006). Using the lexical-decision task (LDT), we found additivity between the facilitative effects of visible semantic primes and the facilitative effects of masked orthographically similar nonword primes at long and short SOAs, consistent with a postlexical locus of the semantic priming effects. Also consistent with this conclusion, semantic primes affected the skew of the distribution (larger effects on longer latency trials), whereas masked orthographic primes did not. In a final experiment, visible primes that were semantically related to the masked orthographic word primes did not make those primes more effective lexical inhibitors of orthographically similar targets (independent of SOA). Taken together, our findings suggest that the impact of a semantic prime is not to increase the lexical activation of related concepts. Rather, they suggest that the locus of semantic priming effects in LDTs is postlexical, in that discovering the existence of a relationship between the prime and target biases participants to make a "word" response.

Keywords: lexical processing/activation, masked orthographic priming, semantic priming

To successfully read a word, the correct lexical representation must be selected from among a set of candidate lexical representations. This lexical selection process appears to be affected not only by the nature of the word's orthography, but also by the nature of the word's semantic representation. For example, words with more semantic information associated with them are generally recognized faster (Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008; Pexman, Lupker, & Hino, 2002; Yap, Pexman, Wellsby, Hargreaves, & Huff, 2012). Findings that *word-based* semantic information influences a word's recognition are consistent with the ideas that (a) the lexical system at least partially activates information about the meaning of candidate words before the word itself is fully identified (i.e., the lexical and semantic systems work in an interactive fashion during word recognition) and (b) the activated semantic information feeds activation back to the lexical system enhancing the activation level of the target's lexical representation. The question examined in the present research is whether the semantic information *activated when processing a different word*, in particular, a visible context word (i.e., a prime) influences the lexical activation process for semantically related target words.

The task used in this investigation was the lexical-decision task (LDT). In the LDT, participants indicate whether a letter string is a word or a nonword. Although other tasks have been used to investigate the impact of semantically related primes (e.g., Balota, Yap, Cortese, & Watson, 2008; de Wit & Kinoshita, 2014, 2015b), the LDT is the task thought to provide the best tool for examining the lexical access process in word recognition. That is, LDT responses appear to be driven mainly by lexical-level activity (e.g., Hino & Lupker, 1996; Pexman et al., 2002), although it does appear that additional decision-making and response components, which occur after lexical selection has been essentially completed, also affect performance in the task (e.g., de Groot, 1984). In contrast, the other two tasks often used to investigate semantic priming, semantic categorization and pronunciation, require the activation/retrieval of additional information in order to be performed correctly, semantic information in the case of the former task, phonological information in the case of the latter task. Semantic priming effects in those tasks, therefore, may reflect the

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impact of a semantic prime on the retrieval of those types of information. We will return to this issue in the General Discussion.

Semantic Priming

The semantic priming effect (Meyer & Schvaneveldt, 1971) is the finding that responding to a target word is facilitated when it has an associative or featural relationship with a preceding prime. Whereas a number of mechanisms have been proposed to explain semantic priming effects, those mechanisms tend to involve two main distinctions (Neely & Keefe, 1989, see also Jones & Estes, 2012). The first, and the one most central to the present investigation, is whether the prime preactivates the target (i.e., semantic processing of the prime influences the lexical activation and, hence, speed of selection, of the target word) versus whether the prime and target are, in some way, evaluated together during a later processing stage. The second is whether the process(es) that produce(s) the priming is(are) automatic or strategic. The three main accounts of semantic priming exemplify these distinctions.

Automatic Spreading Activation

This type of process has often been used to explain semantic priming effects. In the original conceptualization of this process, Collins and Loftus (1975) simply proposed that the activation from the lexical representation of the prime spreads to the target's lexical representation, either through direct linkages or through connections within semantic memory. Information from the semantically related prime would thus influence the lexical processing of the target by preactivating the target's lexical representation. In general, spreading activation is assumed to be involved in producing semantic priming effects when the stimulus onset asynchronies (SOA) is short (i.e., under 300 ms; Neely, 1977).

Expectancy

Neely (1977) and Becker (1980) have proposed that participants predict (explicitly or implicitly) which word(s) are likely to follow the prime. As with the spreading activation account, the prediction process preactivates the lexical units of any expected target words (the expectancy set), facilitating recognition of those words if one of them is the presented target (Jones & Estes, 2012). The generation of expectancy sets is assumed to be a strategic process because it appears to be modulated by relatedness proportion (RP), that is, the proportion of trials on which the target actually is semantically/associatively related to the prime (Hutchison, 2007; Hutchison, Neely, & Johnson, 2001). Note also that the set of expected words would likely overlap with the words activated through automatic spreading activation. Expectancy can, therefore, be viewed as, in many circumstances, a strategic extension of the automatic spreading activation process. The central point is that these two accounts are based on the idea that the semantic information from the prime preactivates the lexical representation of the target, facilitating that target's lexical processing and, hence, producing a semantic priming effect.

Postlexical, Meaning Integration

Accounts of this sort posit that participants may determine whether the prime and the target are semantically related to one another following lexical access and semantic processing of the target word but prior to the overt LDT response (de Groot, 1984; de Wit & Kinoshita, 2014, 2015a, 2015b; Forster, 1981; Neely, Keefe, & Ross, 1989). That is, participants engage in some sort of semantic matching process. The detection of a relationship between the prime and the target biases participants to make a "word" response, facilitating responding to word targets following related primes (Neely et al., 1989). In contrast, when the prime and target are unrelated, participants will experience a bias to respond "nonword" because nonword targets are typically never semantically related to their primes. As a result, participants are slowed a bit in correctly responding to words following unrelated primes. Like expectancy set generation, the process of semantic matching is thought to be at least somewhat under strategic control, but, crucially for the present discussion, unlike expectancy and automatic spreading activation, semantic matching occurs after the lexical selection of the target word (i.e., it is not a preactivation process).

Note that the literature contains a number of ways of conceptualizing a postlexical decision process that could produce a semantic priming effect (e.g., Ratcliff & McKoon's [1988, 1994] compound-cue theory). Because the present experiments are designed to evaluate the contrast between lexically based versus post–lexically based accounts, the contrasts among the various postlexical accounts will not be explored. Rather, the semantic matching conceptualization, as described just above, will be treated as the prototypical postlexical account for the remainder of this paper.

Manipulations of the prime–target stimulus onset asynchrony SOA are often used to investigate the factors driving semantic priming and to test predictions of the above theoretical accounts. Specifically, longer SOAs (e.g., over 300 ms) are typically assumed to be necessary to allow for the strategic use of the prime in generating expectancy sets (Becker, 1980). This idea is consistent with the finding that semantic priming effects are greater in lists with high (vs. low) RPs when the SOA is long. In contrast, with SOAs under 300 ms, RP has often been reported not to influence the semantic priming effect (e.g., Grossi, 2006; Hutchison et al., 2001; Neely et al., 1989; Neely, 1977; Pecher, Zeelenberg, & Raaijmakers, 2002; Perea & Rosa, 2000), suggesting that the effect in that situation is not attributable to expectancy generation. What is also possible, of course, is that both long and short SOA priming effects may be, at least in part, attributable a semantic matching-type process as the viability of using that process would not be affected by the prime–target SOA (Kahan, Neely, & Forsythe, 1999) unless the SOA was so short that it didn't allow sufficient semantic activation of the prime.

As just noted, at short SOAs (i.e., when expectancy sets do not have enough time to form), semantic priming effects have generally been explained as being attributable to automatic spreading activation owing to the fact that RP effects are usually not found at those SOAs. Recent findings by de Wit and Kinoshita (2014, 2015b; see also de Groot, 1984), however, have suggested that RP effects can be seen at shorter SOAs. Further, following a series of studies investigating semantic priming effects in both lexical decision and semantic categorization tasks, de Wit and Kinoshita (2014, 2015a, 2015b) have made the argument that semantic priming effects in LDTs with short SOAs (so that, presumably, expectancy sets cannot be formed) are solely driven by a retrospective semantic matching mechanism. Those authors' conclusion was based on three claims: (a) their demonstration that semantic priming can be modulated by RP in an LDT even with a short SOA, (b) when the visibility of the prime is carefully controlled, as it was in the authors' experiment, there has been little evidence that masked semantic priming effects exist (if spreading activation is a real process, one would expect to observe it even when the prime is masked), and (c) unlike in the semantic categorization task, the size of the priming effect in the LDT was larger for slower items. De Wit and Kinoshita argued that this latter result is especially telling because it indicates that, during slower trials, information from the prime has a greater impact on the response, a result that, they argue, should not occur if the priming were being driven by automatic spreading activation. That is, priming effects attributable to spreading activation preactivating the target's lexical representation would be expected to produce the same size priming effect for all targets (i.e., a distributional shift) because all the targets would get the same head start in processing (Balota et al., 2008; Gómez, Perea, & Ratcliff, 2013).

The main goal of the present research was to evaluate and expand on these ideas concerning the nature of the semantic priming effect. De Wit and Kinoshita's (2014, 2015a, 2015b) argument is that the process of spreading activation leading to the target's preactivation is not a real concept. As a result, semantic priming with a short SOA is being driven entirely by a semantic matching-type process. The stability of the three components of de Wit and Kinoshita's argument (described above) can certainly be challenged, however. For example, although those authors obtained an RP effect with a short SOA, others have not (Grossi, 2006; Pecher et al., 2002; Perea & Rosa, 2000). Second, a reasonable case can be made against their claim that *all* masked semantic priming experiments that showed a priming effect did not properly control for prime visibility (Van den Bussche, Van den Noortgate, & Reynvoet, 2009). Further, even though their claim that the size of the semantic priming effect increases with target latency does have reasonable support (at least when the SOA is short, see Balota et al., 2008), there is often a priming effect for even the fastest targets in the high RP condition and there is also a priming effect for targets even in the low RP condition. These effects would seem to support a lexical activation explanation (i.e., both spreading activation and semantic matching may be at work in the LDT). Nonetheless, de Wit and Kinoshita's arguments do raise a challenge for the conventional way of explaining semantic priming effects (Neely, 1991) that would seem to call for further investigation.

De Wit and Kinoshita's (2014, 2015a, 2015b) main claim is that the semantic priming effect in LDTs with short SOAs is not attributable to spreading activation preactivating the lexical representation of the target. The present experiments allowed us to examine the preactivation claim in general (i.e., at both short and long SOAs) by looking for an interaction between semantic priming and masked orthographic priming, a phenomenon that is generally accepted as being a lexical activation phenomenon (as will be explained in greater detail just below). Essentially, the argument is that because nonword primes preactivate the lexical representations of orthographically similar targets, if semantic primes do so as well, there should be an interaction between the two factors (Sternberg, 1969). A finding of additivity of the two factors would be consistent with de Wit and Kinoshita's position. The nature of the manipulation that allows orthographic and semantic priming to be investigated together is described below, following the section describing the nature of masked orthographic priming.

Lexical Facilitation/Inhibition From Masked Orthographic ("Neighbor") Primes

In the masked priming paradigm, the prime is preceded by a forward mask and is immediately followed by the target which serves as a backward mask. The prime is presented briefly and is rarely, if ever, consciously recognized by participants. Thus, the effects of the prime are typically assumed to be automatic, rather than strategic. Most importantly, because masked priming effects of the sort investigated here (i.e., orthographic priming effects, e.g., tafle-TABLE) do not involve a semantic relationship between the prime and target, they would appear to be lexically, rather than semantically, based.

In line with the proposal of the Interactive-Activation and Competition (IAC) Model (McClelland & Rumelhart, 1981) and its more recent extensions (e.g., Davis, 2010), the lexical activation process is assumed to be based on both facilitative and inhibitory processes. Therefore, masked orthographic primes can either facilitate or inhibit the recognition of target words. Specifically, consistent with IAC principles, masked word primes that are orthographically similar to their targets (orthographic neighbors, *lamp* – *LAMB*), the type of primes to be used in the present Experiment 3, typically slow down recognition of the target word (e.g., Davis & Lupker, 2006; Grainger, Colé, & Segui, 1991; Segui & Grainger, 1990). In contrast, masked nonword primes that are orthographically similar to their targets (i.e., nonword neighbors, *lkmb—LAMB*), the type of primes to be used in the present Experiments 1 and 2, typically facilitate target word recognition (e.g., Ferrand & Grainger, 1993; Forster & Davis, 1984; Perea & Rosa, 2000). As Davis and Lupker note, according to IAC principles, any orthographically similar prime should preactivate the target word's lexical representation, potentially resulting in some facilitation. However, *word* neighbor primes will also activate their own representation, which will cause it to act as a strong lexical competitor of the target which can lead to a delay in target recognition. *Nonword* neighbor primes do not have lexical representations and thus should not activate any lexical competitors of the target to an extent that would allow them to produce a level of competition that would overcome the facilitation produced by preactivating the target.

When the prime is a word neighbor, the relative prime–target frequency is also relevant because of the fact that, because representations of higher frequency words are activated more quickly and more strongly, higher frequency primes should be more effective lexical competitors. Davis and Lupker (2006; Experiment 1) provide what is probably the most comprehensive evaluation of these ideas. In their related prime condition, each target was preceded by either a word or a nonword neighbor (see also Segui & Grainger, 1990). When word primes were used, in one condition the prime was higher in frequency than the target whereas in the other condition, the words were switched so that the target was the higher frequency word. Inhibitory effects were found in both cases, however, they were stronger when the prime was high frequency and the target was low frequency in comparison to when the frequency relationship was reversed. Davis and Lupker also found that, although word neighbor primes produced this inhibition effect, nonword neighbor primes produced a facilitation effect for the same targets. This contrast between the effects of word versus nonword primes is referred to as the "prime lexicality effect" (Forster & Veres, 1998). Davis and Lupker ultimately argued that the demonstration of both inhibition and facilitation for the same set of word targets suggests that masked orthographic priming effects are automatic rather than a result of strategic processing and that those effects are consistent with lexical processing models based on the IAC framework.

Although nonword neighbor primes do not activate lexical competitors to a sufficient degree to delay target processing, they should activate lexical competitors to some degree which produces some amount of lexical competition. The result is that the total amount of target facilitation produced somewhat underestimates the target activation provided by a nonword neighbor prime. In an attempt to address the idea that lexical competition may diminish masked orthographic priming effects, even from nonword primes, Lupker and Davis (2009) introduced the *sandwich priming* paradigm. In this paradigm, each target word is preceded by two masked primes. The initial prime is always identical to the target. The second is the prime of interest (either a neighbor or a non-neighbor). The brief presentation of the initial prime should raise the activation level of the target word. Consequently, at least some of the lexical competitors of the target word that are activated by a neighbor prime would have a reduced capacity to inhibit the target. In addition, the subsequent presentation of a neighbor prime as the prime of interest helps maintain the target's activation for a longer time period. Consistent with these ideas, although Lupker and Davis found no facilitation from certain types of orthographically similar primes in a conventional masked priming task (see also Guerrera & Forster, 2008), many of those primes did produce significant facilitation in their sandwich priming task.

The Present Experiments

As noted, the main goal of the present experiments was to provide a new evaluation of the locus of the semantic priming effect in the LDT, particularly the idea that priming is a lexical activation phenomenon, by combining a semantic priming manipulation with masked orthographic priming manipulations, manipulations that are believed to influence only lexical-level representations. Lexical activation of the target was manipulated by using a masked neighbor or non-neighbor prime. Prior to the presentation of that prime, a semantically related or unrelated visible prime was presented. Following Sternberg's (1969) additive factors logic, an interaction between the semantic priming and orthographic priming factors would support the idea that those factors influence a common stage of processing during word recognition in an LDT (see Borowsky and Besner (2006); O'Malley and Besner (2008) and Robidoux and Besner (2018) for recent examples of the use of additive factors logic). Thus, an interaction between visible semantic and masked orthographic neighbor priming would clearly indicate that the visible semantic primes influence the lexical activation of the target. In contrast, additive semantic and masked orthographic neighbor priming effects would be supportive of the idea that semantic priming and orthographic neighbor priming influence separate stages in word recognition in an LDT. In particular, additivity would suggest a (potentially strategic) postlexical locus of any semantic priming effect which occurs after lexical selection but prior to the response (Neely et al., 1989) in line with the claims of de Wit and Kinoshita (2014, 2015a, 2015b).

In addition, the effects of visible semantic primes and masked orthographic neighbor primes on the latency distributions of their targets were examined via quantile plots. Masked neighbor primes, having their impact at the lexical level, would be expected to produce a head start for their targets, resulting in a shift in the latency distribution. Thus, the masked neighbor priming effects should be similar across quantiles. The effects of visible semantic primes on latency distributions will help evaluate the locus of the semantic priming effect. Specifically, an increase in the semantic priming effect across quantiles as found by de Wit and Kinoshita (2015a, 2015b; see Balota et al., 2008 for a more complete explanation of this logic) would be consistent with there being a strategic and postlexical locus (e.g., semantic matching). A constant semantic priming effect across quantiles would be consistent with the idea that semantic primes give their targets a head start by preactivating their lexical representations.

Experiment 1 examined how the facilitative effect of a masked nonword neighbor prime was influenced by visible semantic primes presented at both a short SOA (267 ms) and a long SOA (1,467 ms). A 267-ms SOA was used in an attempt to prevent the generation of expectancy sets by not allowing enough time to do so (Hutchison et al., 2001) and, therefore, should provide an examination of de Wit and Kinoshita's (2014) claims concerning the reality of spreading activation.[1] A 1,467-ms SOA, in contrast, should certainly allow for the generation of expectancy sets based on the visible semantic prime which would lead to a preactivation of the expected targets' lexical representations and, hence, a lexically based priming effect. Hence, in both cases, an interaction between semantic and orthographic neighbor priming would be expected. On the other hand, regardless of the SOA, semantic priming could, of course, have a postlexical locus (Kahan et al., 1999). If that were the only locus, additivity of effects would be expected.

Experiment 2 examined the effects of semantic primes on the facilitation from orthographic neighbor primes using the sandwich priming paradigm (Lupker & Davis, 2009). As in Experiment 1, semantic primes were presented with both short (283 ms) and long (1,483 ms) SOAs between those primes and the first masked prime in the sequence. As noted, there is typically a somewhat larger facilitation effect in the sandwich priming paradigm which should allow for a more sensitive test of whether there is an interaction between the masked orthographic neighbor and visible semantic priming effects than that allowed by the conventional masked priming paradigm used in Experiment 1.

[1] As will be discussed in the General Discussion, there are data (e.g., Hutchison, 2007; Hutchison, Heap, Neely, & Thomas, 2014) suggesting that it is possible for at least some participants to generate expectancy sets with an SOA of 267 ms.

Whereas Experiments 1 and 2 examined whether semantic primes influence lexical processing using additive factors logic (Sternberg, 1969), Experiment 3 more directly examined the notion of semantic priming being a lexical preactivation process. As noted, masked word neighbor primes typically inhibit target processing (or, at the very least, severely diminish the priming provided by masked nonword neighbor primes). The question is whether the (inhibitory) impact of those primes can be enhanced as a result of lexical preactivation from a visible semantic prime. Therefore, rather than being semantically related to the target word, the visible primes in Experiment 3 were either semantically related or unrelated to the masked word neighbor primes. If a visible semantic prime influences the lexical activation of the masked neighbor prime's lexical representation, one would expect that word neighbor primes would become more effective inhibitors of target processing.

Experiment 1

Because the aim of Experiment 1 was to examine whether a visible semantic prime influences the lexical processing of its target, a set of prime–target pairs (e.g., *mutton–lamb*) that yielded a semantic priming effect compared with unrelated pairs (e.g., *corporation–lamb*) at both long and short SOAs was obtained. Prime–target pairs were selected with the goal of maximizing the semantic priming effect, so as to increase the sensitivity for detecting an interaction between the semantic priming effect and the masked orthographic neighbor priming effect. Thus, various prime–target relationships (i.e., synonyms, antonym, etc.) were included, and prime–target pairs varied in forward and backward association strengths. To create the nonword neighbor primes, nonword neighbors were then generated from the targets (e.g., *lkmb* generated from *LAMB*) and their lexical facilitation of the targets, compared with unrelated primes (e.g., *dvsk*), was first established (this group of participants will be referred to as the *masked prime* group). Note that, as is often the case in masked neighbor priming manipulations (e.g., Davis & Lupker, 2006), the generation of the nonword primes did not take into account whether those primes were orthographically legal or pronounceable.

In the main part of this experiment, the visible semantic prime, related or unrelated to each target, was presented preceding the masked prime (e.g., *mutton-####-lkmb-LAMB* vs. *mutton-####-trmd-LAMB*), so as to observe the effects of the visible semantic prime on the orthographic neighbor prime facilitation effect (see Figure 1). The effect of a visible semantic primes was examined at a 267-ms SOA in the *short SOA visible prime group* and at a 1,467-ms SOA in the *long SOA visible prime group* to separately test the potential effects of automatic spreading activation (267-ms SOA) and expectancy generation (1,467-ms SOA) from the visible semantic primes. The key question is whether a visible semantic prime influences the lexical activation of the target which would be demonstrated

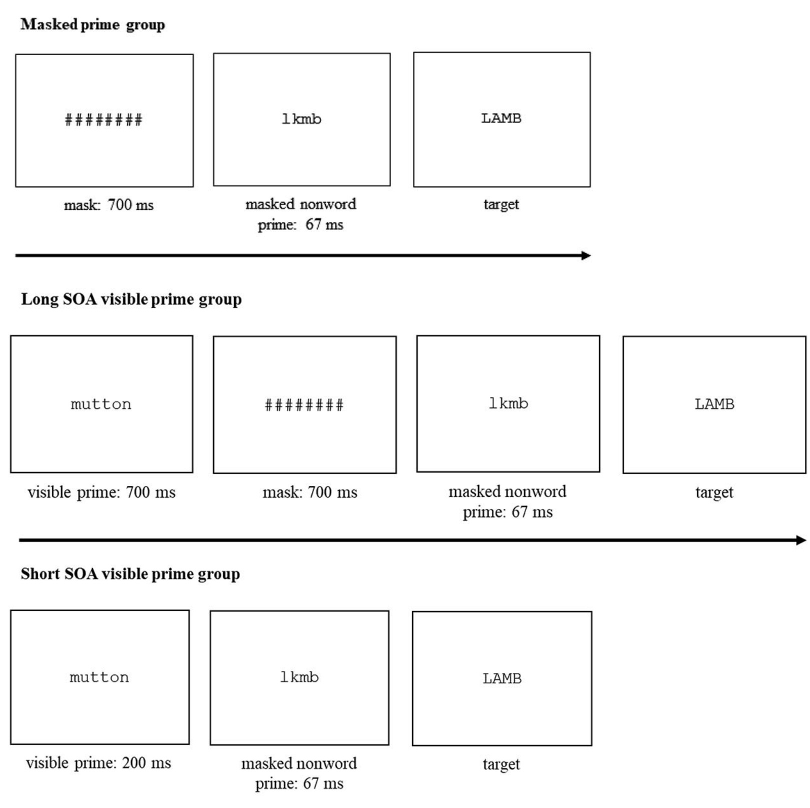

Figure 1. Trial sequence presented to the masked prime group (top panel), the long SOA visible prime group (middle panel), and the short SOA visible prime group (bottom panel) in Experiment 1.

by the observation of an interaction between the visible semantic and the masked orthographic neighbor priming effects.

Method

Participants. A total of 179 undergraduate students who self-identified as fluent English-speakers participated in Experiment 1 for course credit. Because of their high rates of errors and outlier responses on nonword trials (>20%), data from one participant of 37 in the *masked prime* group, nine participants of 57 in the *short SOA visible prime group*, and 13 participants of 85 in the *long SOA visible prime group* were excluded from the analyses. Error rates on nonword trials were used as the core exclusion criterion so as to remove participants displaying a tendency to make *word* responses as a default (i.e., without processing the target sufficiently), a strategy that may minimize the sizes of our priming effects.

Fewer participants were tested in the masked prime group than in the other two groups. The purpose of the masked prime group was to confirm the presence of the masked neighbor priming effect and to provide a general basis of comparison to the effect sizes in the short and long SOA visible prime groups. Additionally, no interactions were examined in the masked prime group, thus the statistical power from additional participants was not necessary once the masked neighbor priming effect was established. Note also that more participants were tested in the long (vs. short) SOA visible prime group. The reason is that the long SOA visible prime group was the initial group that was investigated and hence, the first time that the present double priming paradigm was examined. Therefore, because we had no clear knowledge of effect sizes, we felt it advisable to use a larger sample size than one would typically use in these types of experiments.

Stimuli. Sixty-four prime–target word triplets were selected from Hutchison et al.'s (2013) semantic priming project database. Each triplet contains the target word (e.g., *lamb*), an associatively or featurally related prime (*mutton*), and an unrelated prime (*corporation*). The forward and backward associative strengths and the LSA values for the related primes and targets are .27, .14, and .36, respectively. The semantic priming project is an online repository (http://spp.montana.edu) which contains lexical decision data for 1661 target words, following semantically related and unrelated primes, based on 768 participants with priming effects being available for each target word. The related semantic prime–target pairs and various properties of these pairs (i.e., forward and backward associative strengths as well as LSA values) in the semantic priming project were taken from the University of South Florida free association norms database (Nelson, McEvoy, & Schreiber, 1999). Half of the targets were five-letter words, and half were four-letter words. The targets were selected to be low frequency words (CELEX frequency = 16.33) and to have moderate neighborhood sizes (Coltheart, Davelaar, Jonasson, and Besner (1977) $N = 6.53$). The frequency and N values were obtained using N-Watch software (Davis, 2005). Sixty-four nonword targets (half four letters and half five letters) were generated using the English Lexicon Project (Balota et al., 2007) database found on the website elexicon.wustl.edu. The nonwords were selected to be word-like ($N = 15.98$). Primes for the nonword targets were words from the semantic priming project that were unrelated to any of the selected word targets.

Nonword neighbor primes were then constructed for each target. The neighbor primes for word targets ($N = 4.84$) and nonword targets ($N = 7.05$) were constructed by arbitrarily replacing a single letter in the target with another letter not contained in the prime or target and, as noted, were thus sometimes orthographically and phonologically illegal. To provide non-neighbor primes for the targets, the masked neighbor prime–target pairs were repaired. However, in a few instances an additional letter in the prime had to be replaced so that the non-neighbor prime had no orthographic overlap with the target. All stimuli used in Experiment 1 are shown in Appendix A.

Two counterbalancing conditions were created for the masked prime group. Word and nonword targets were each divided into two sets, and half of the participants saw the first set preceded by its neighbor prime and the second set preceded by its non-neighbor prime. The other half of the participants received the opposite assignment. Four counterbalancing conditions were created for both the short and long SOA visible prime groups. Word targets were divided into four sets, such that each set of targets was preceded by semantically related and unrelated visible primes as well as neighbor and non-neighbor masked primes across four groups of participants. The nonword targets were split into two sets as each nonword was paired with both a neighbor prime and an unrelated prime (in a counterbalanced fashion) but with only one visible prime.

Semantic priming effects. The visible prime–target triplets were initially selected based on their ability to produce a semantic priming effect at a short SOA according to the semantic priming project database. However, because of the length and frequency restrictions imposed on the target words owing to the plan to use them as masked neighbor primes in Experiment 3, the selected triplets had a much weaker facilitation effect at a long (4.18 ms) than at a short (101.52 ms) SOA according to that database. Therefore, in a pilot experiment (different participants were used) we tested whether the selected stimuli would provide semantic facilitation at both a short SOA (267 ms) and a long SOA (1,467 ms) for members of the present participation pool. Semantic priming was confirmed as there was a 29-ms facilitation effect at a 267-ms SOA ($N = 30$), significant in both subject and item analyses, both $F\text{s} > 8.73$, and a 28-ms facilitation effect at a 1,467-ms SOA ($N = 38$) that was also significant in both subject and item analyses, both $F\text{s} > 7.66$.

Although it isn't at all clear what could account for the discrepancy in the semantic priming effect sizes for the selected stimuli as reported in the semantic priming project database versus those obtained in the present pilot experiment (i.e., 4.18 ms vs. 28 ms at a 267-ms SOA, and 101.52 ms vs. 29 ms at a 1,467-ms SOA), there were a couple of procedural differences between those experiments and the present pilot experiment. For example, although the overall SOAs used in the present experiment were comparable with those used by Hutchison et al. (2013), the composition of the trials was a somewhat different. In contrast to the trial composition used in the present experiment, all semantic primes were shown for 150 ms in both the short and long SOA conditions by Hutchison et al. and a blank interstimulus interval between the prime and target was varied to create the short and long SOA conditions.

Experimental procedure. Participants were tested individually in a quiet and well-lit room. For the masked prime group, each trial began with a mask which consisted of 8 hashtags (########), presented for 700 ms, followed by the masked nonword prime, presented in lowercase for 67 ms,[2] followed by the target. The target appeared in uppercase and remained on the screen until a response was made or 2,500 ms had elapsed. The short SOA visible prime group saw the visible (related or unrelated) semantic prime for 200 ms, which was immediately followed by the 67-ms masked (neighbor or non-neighbor) prime, followed by the target as presented to the masked prime group. The long SOA visible prime group first saw the visible prime for 700 ms, then the mask for 700 ms, the 67-ms masked prime, and the target as presented to the masked prime and short SOA groups. All experiments were run using DMDX (Forster & Forster, 2003) software.

All stimuli appeared in the center of the screen in black Courier New font on a white background. Each participant was instructed to indicate whether the uppercase letter string was a word or nonword by pressing one of two buttons on the keyboard. Each participant received 12 practice trials, followed by 128 experimental trials (which were presented in a different randomized order for each participant). The experiment took approximately 5 min for the masked prime group to complete, about 8 min for the short SOA visible prime group and about 12 min for the long SOA visible prime group. The practice trials for each group had the same structure as the experimental trials. This research was approved by the Western University REB (Protocol # 109670).

Results

Combining the masked prime and the short and long SOA groups, of the word target trials, 4.7% were incorrect responses and 0.8% were faster than 250 ms or slower than 1,750 ms (outliers). Of the nonword target trials, 11.3% were incorrect responses, and 2.0% were correct response outliers. Analyses of latencies excluded outliers and incorrect responses, and analyses of error rates excluded outliers. Table 1 shows the latencies and error rates for word targets for the masked prime group, and as a function of visible semantic and masked orthographic prime types for the short and long SOA groups. The latencies and error rates for the nonword targets are shown in Appendix D.

Quantiles of word trials used in the latency analyses were generated. For each participant, the word trials used in latency analyses were first split by condition of interest. Specifically, to examine the semantic priming effect, word trials were split based on whether the preceding visible semantic prime was related (vs. unrelated), resulting in 32 trials in each condition. Likewise, to examine the masked orthographic priming effect, trials were split based on the preceding masked prime (neighbor vs. non-neighbor), again resulting in 32 trials per condition. In each condition, trials were then sorted from slowest response time to fastest, then divided into five quantiles, where the first four quantiles would have seven trials each and the fifth quantile would have the remaining four trials, accounting for the 32 trials. However, because most participants had at least some missing responses in each condition, the fifth quantile often had fewer than four trials. The fifth quantile was thus not used in the quantile analyses.

Not using the fifth quantile resulted in the loss of 9.0% of the word trials in the masked prime group. Likewise, in the short SOA visible prime group, not using the fifth quantile resulted in the loss of 6.6% of the word trials when investigating the effect of visible prime type, and 6.7% of the word trials when investigating the effect of masked prime type. Finally, in the long SOA visible prime group, not using the fifth quantile resulted in a loss of 8.5% of the word trials when investigating the effect of visible prime type, and 8.4% of the word trials when investigating the effect of masked prime type. The mean of each quantile was then calculated. Figure 2 shows the quantile plot for the word targets as a function of masked prime type for the masked prime group. Figure 3 shows the quantile plots for the word targets as a function of masked (neighbor or non-neighbor) prime type (top panel) and visible (semantic or related) prime type (bottom panel) for the combined data for the short and long SOA groups.

To examine facilitation from masked (neighbor or non-neighbor) primes, word latencies and error rates from the masked prime group were submitted to 2 (masked prime type: neighbor vs. non-neighbor) × 2 (group/set: 1 vs. 2) separately using subjects (F_s) and items (F_i) as random factors in split-plot ANOVAs. *Masked prime type* was a within-subject and within-item factor, whereas *group* was a between-subjects factor and *set* was a between-item factor.[3] The analyses of latencies and errors from the short and long SOA visible prime groups were carried out via a 2 (SOA: short vs. long) × 2 (visible prime type: related vs. unrelated) × 2 (masked prime type: neighbor vs. non-neighbor) × 4 (group/set: 1 vs. 2 vs. 3 vs. 4) separately using subjects (F_s) and items (F_i) as random factors in split-plot ANOVAs. SOA was a between-subjects and within-item factor. The analyses of nonword latencies and error rates for the masked prime, short, and long SOA visible prime groups are presented in Appendix E.

In the masked prime group, the latencies selected for quantile analyses were submitted to a 2 (masked prime type: neighbor vs. non-neighbor) × 4 (quantile: 1 vs. 2 vs. 3 vs. 4) × 2 (group/set: 1 vs. 2) split-plot ANOVA to examine the effects of masked neighbor primes on the latency distributions (i.e., whether the priming effect varied across quantiles). To investigate the effect of semantic primes on the latency distributions in the double prime groups, a 2 (visible prime type: related vs. unrelated) × 2 (SOA: short vs. long) × 4 (quantile: 1 vs. 2 vs. 3 vs. 4) × 4 (group/set: 1 vs. 2 vs. 3 vs. 4) split-plot ANOVA was used.[4] Because some word targets were generally responded to faster (or slower) by most participants, many word targets often did not have responses in all four retained quantiles. Item analyses thus often excluded many word targets and were considered underpowered. As a result, only subject analyses are reported for the

[2] Although masked prime durations are typically between 50 and 60 ms, a slightly longer duration (67 ms), but one that still does not make the prime available to consciousness, was used in both Experiments 1 and 3 to maximize the effectiveness of the masked neighbor primes. In Experiment 2, because the experimental technique itself, sandwich priming, maximizes the effectiveness of the masked neighbor primes, a more standard 50-ms prime duration was used. A second reason for the use of a 50-ms prime duration in Experiment 2 was that at least some letters in the (longer) masked primes used in that experiment were visible to both the experimenter and other lab members when a 67-ms prime duration was used. The primes were not visible to the experimenter and other lab members with a 67-ms duration in Experiments 1 and 3, or with a 50-ms duration in Experiment 2. No visibility data from a separate set of participants was collected.

[3] In all these experiments group/set was included as a factor in the ANOVA following the suggestion of Pollatsek and Well (1995). However, because that factor has no theoretical implications, we do not report F values for either the main effect of, or any interactions involving, that factor.

[4] Both experimental factors were not included in these analyses because to do so would have reduced the number of trials per distribution to no more than 16.

Table 1
Latencies (Milliseconds) and Error Rates (Percentages) for Word Targets as a Function of Visible Semantic Prime and Masked Orthographic Nonword Prime Types for the Masked Prime, Long, and Short SOA Visible Prime Groups in Experiment 1

Group/Visible semantic prime type	Masked orthographic nonword prime type		
	Neighbor	Non-neighbor	Orthographic priming effect
Masked prime	625	643	18 [2.13, 33.87]
	4.5	3.1	−1.4 [−2.77, −0.03]
Short SOA visible prime			
Related	653	677	24 [5.35, 42.65]
	5.9	4.9	−1.0 [−3.23, 1.23]
Unrelated	680	699	19 [0.35, 37.65]
	7.0	7.9	0.9 [−1.33, 3.13]
Semantic priming effect	27 [6.73, 47.27]	22 [1.73, 42.27]	
	1.1 [−1.17, 3.37]	3.0 [0.73, 5.27]	
Long SOA visible prime			
Related	636	646	10 [−3.87, 23.87]
	2.3	2.9	0.6 [−0.85, 2.05]
Unrelated	662	681	19 [5.13, 32.87]
	5.0	5.9	0.9 [−0.55, 2.35]
Semantic priming effect	26 [12.19, 39.81]	35 [21.19 48.81]	
	2.7 [1.26, 4.14]	3.0 [1.56 4.44]	

Note. SOA = stimulus onset asynchronies. Error rates are shown in the rows below latencies, and 95% confidence intervals for orthographic and semantic priming effects are shown in brackets.

quantile analyses. When sphericity was violated, the Greenhouse-Geisser correction was applied to the degrees of freedom.

Masked prime group.

Word latencies. An 18-ms priming effect was found which was significant in both the subject $F_s(1, 34) = 5.69$, $p = .03$, $\eta^2 = .14$, and item analyses, $F_i(1, 62) = 9.90$, $p = .003$, $\eta^2 = .14$.

Word errors. The error rate was significantly greater following masked neighbor (vs. non-neighbor) primes in the subject analysis, $F_s(1, 34) = 4.50$, $p = .041$, $\eta^2 = .12$, but only marginally greater in the item analyses, $F_i(1, 62) = 3.18$, $p = .079$, $\eta^2 = .05$.

Effects of masked orthographic prime type across quantiles. An effect of quantile was observed, with later quantiles having slower latencies, $F_s(1, 34) = 158.52$, $p < .001$, $\eta^2 = .82$. The priming effect was now marginal, $F_s(1, 34) = 3.84$, $p = .06$, $\eta^2 = .10$. Importantly, as shown in Figure 2, this masked neighbor priming effect remained constant throughout quantiles as there was no interaction between prime type and quantile, $F_s < 1$.

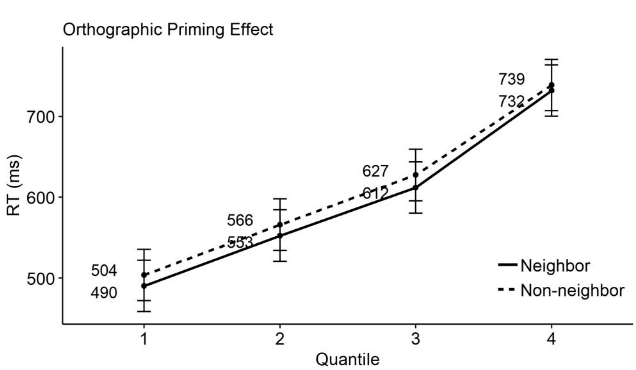

Figure 2. Effect of masked orthographic prime type on word targets across quantiles for the masked prime group in Experiment 1. Error bars represent 95% confidence intervals for each mean.

Analyses of the short and long SOA groups.

Word latencies. A main effect of semantic priming was obtained in both the subject and item analyses, $F_s(1, 112) = 42.78$, $p < .001$, $\eta^2 = .28$; $F_i(1, 60) = 32.12$, $p < .001$, $\eta^2 = .35$. Facilitation from masked neighbor primes was also observed in both the subject and item analyses, $F_s(1, 112) = 20.84$, $p < .001$, $\eta^2 = .16$; $F_i(1, 60) = 13.13$, $p < .001$, $\eta^2 = .18$. Responses were longer in the short (vs. long) SOA condition (see Table 1); however, the main effect of SOA was not significant in the subject analysis, $F_s(1, 112) = 1.14$, $p = .29$, $\eta^2 = .01$, although it was in the item analysis $F_i(1, 60) = 21.53$, $p < .001$, $\eta^2 = .26$. SOA did not modulate the semantic priming effect, the orthographic neighbor priming effect, or the interaction between these two effects, all Fs < 1. Importantly, the Visible Semantic Prime × Masked Orthographic Neighbor Prime interaction was not significant, both Fs < 1.

To further investigate the null interaction between visible semantic prime type and masked neighbor prime type, we evaluated the evidence for the null interaction using a Bayes factor analysis, where evidence for a model assuming a null effect is compared against evidence for a model assuming a true effect. The method of carrying out this analysis is outlined in Masson (2011) and requires only the transformation of the sum-of-squares values generated by an ANOVA. The number of independent observations is defined as the number of subjects/items multiplied by one less than the number of conditions. For the null interactions between visible semantic prime type and masked neighbor prime type in the subject and item analyses, the posterior probabilities of the null hypothesis being true were $P_{sBIC} = .95$ and $P_{iBIC} = .92$, respectively.

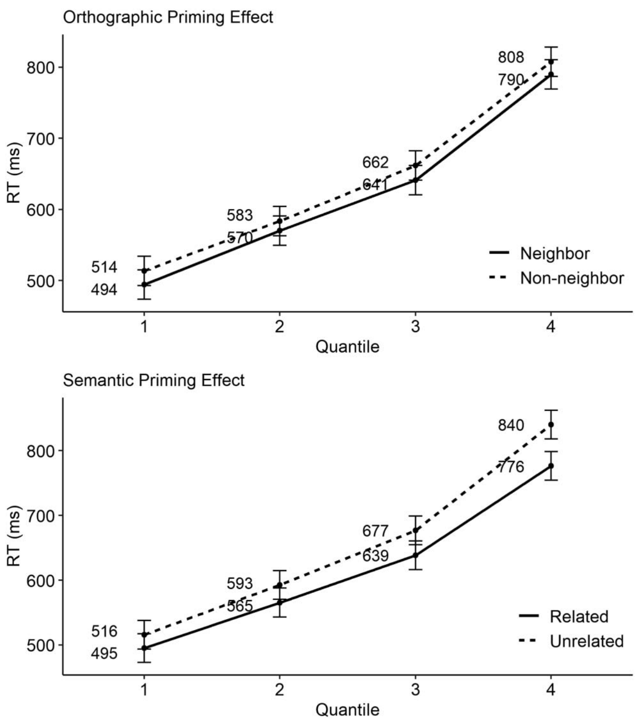

Figure 3. Effect of masked orthographic prime type (top panel) and visible semantic prime type (bottom panel) on word targets across quantiles for the combined SOA visible prime groups in Experiment 1. Error bars represent 95% confidence intervals for each mean.

Word errors. Subject and item analyses showed a significant reduction in errors following related (vs. unrelated) visible semantic primes, $F_s(1, 112) = 21.77$, $p < .001$, $\eta^2 = .16$; $F_i(1, 60) = 9.87$, $p < .01$, $\eta^2 = .14$. No effect of masked neighbor prime type was observed, both Fs < 1. There was a smaller error rate at a long (vs. a short) SOA (see Table 1) as the main effect of SOA was significant in both the subject and item analyses, $F_s(1, 112) = 8.21$, $p < .01$, $\eta^2 = .07$; $F_i(1, 60) = 18.75$, $p < .001$, $\eta^2 = .24$. As with the latency analyses, SOA did not interact with visible semantic prime type, masked neighbor prime type, or the Visible Semantic × Masked Neighbor prime type interaction, all Fs < 1.20, $ps > .28$. The Visible Semantic × Masked Orthographic Neighbor prime interaction was not significant in either the subject or the item analysis, $F_s(1, 112) = 2.38$, $p = .13$, $\eta^2 = .02$; $F_i(1, 60) = 1.16$, $p = .29$, $\eta^2 = .02$.

As discussed further below, the additive factors logic proposed by Sternberg (1969) does not necessarily apply to error rates as it does to latencies. However, Schweickert (1985) has suggested that factors which have additive effects on latencies should also have additive effects on logarithms of the percentages of responses that are correct. Schweickert further recommends using a chi-square test based on log-linear models to test the hypothesis that the factors of interest have additive effects on the logarithm of percent correct responses. Specifically, expected frequencies of correct responses in each experimental condition generated by various log-linear models can be compared against observed frequencies of correct responses.

To examine whether visible semantic and masked neighbor primes exerted additive effects on the log percent correct, frequencies of correct and incorrect responses (excluding outliers) were generated for Experiment 1, by SOA, visible semantic prime type, and masked neighbor prime type. Log-linear models were then fitted to the resulting frequencies of correct responses and then compared in terms of fit to the data. Specifically, a model assuming the main effects of SOA, visible semantic prime type, and masked neighbor prime type was compared with a model assuming these main effects as well as an interaction between the visible semantic prime factor and the masked neighbor prime factor. The two models did not differ, $\chi^2(1) < 1$.

Effects of masked orthographic neighbor priming across quantiles. The mean latency increased across quantiles, $F_s(1.11, 124.15) = 599.62$, $p < .001$, $\eta^2 = .84$. The facilitation from masked neighbor primes was significant, $F_s(1, 111) = 19.29$, $p < .001$, $\eta^2 = .15$. There was no main effect of SOA, nor did SOA interact with any variables or interactions, all Fs < 1.59. Importantly, paralleling the findings from the masked neighbor prime group, the priming effect was constant across quantiles as shown in Figure 3 (top panel), $F_s < 1$.

Effects of visible semantic priming across quantiles. Mean latency increased across quantiles, $F_s(1.11, 124.31) = 552.07$, $p < .001$, $\eta^2 = .83$. A semantic priming effect was also found, $F_s(1, 112) = 65.16$, $p < .001$, $\eta^2 = .37$. There was also a marginal effect of SOA reflecting longer latencies for the long (vs. short) SOA visible prime group, $F_s(1, 112) = 2.71$, $p = .10$, $\eta^2 = .02$. Additionally, there was a significant interaction between SOA and quantile, $F_s(1.11, 124.31) = 5.85$, $p = .01$, $\eta^2 = .05$, reflecting a greater overall increase in latency across quantiles in the long (vs. short) SOA visible prime group. There was also a marginal interaction between SOA and the Semantic Priming Effect × Quantile interaction, $F_s(1.33, 149.21) = 2.79$, $p = .09$, $\eta^2 = .02$, indicative of the larger Semantic Priming Effect × Quantile interaction in the long SOA visible prime group. Importantly, an increase in the semantic priming effect across quantiles (Figure 3, bottom panel) was found as indexed by the visible semantic prime by SOA interaction, $F_s(1.33, 149.21) = 14.78$, $p < .001$, $\eta^2 = .12$.

Discussion

Experiment 1 was an examination of whether a visible semantic prime influences the lexical activation/processing of its target by determining whether there was an effect of the visible semantic prime on the lexical facilitation from masked nonword neighbor primes. Further, the SOA of the visible semantic prime was varied to examine this question in the context of the different processes that have been presumed to drive semantic priming at different SOAs. An interaction between visible semantic and masked orthographic neighbor priming effects would suggest that the effect of visible semantic primes occurs at the same stage as the effect of masked nonword neighbor primes (i.e., during lexical selection, because of the prime influencing the lexical activation of the target). In contrast, additive effects would be more supportive of the idea that the effects of visible semantic and masked orthographic neighbor primes arise at different points in processing.

There were clear semantic priming effects with both 287-ms and 1,487-ms SOAs, effects that were similar in magnitude to the effects found in pilot testing, confirming the existence of semantic facilitation for our visible semantic prime–target pairs in our double priming paradigm. Additionally, the orthographic neighbor priming effect found in the masked prime group was also observed in the double prime groups. Importantly, the semantic and masked orthographic priming effects were additive in both the double prime groups. Further, chi-square analyses showed that semantic and orthographic primes had statistically additive effects on the log percent correct, suggesting that the additivity found in latencies was not the product of a speed–accuracy trade-off (Schweickert, 1985). These patterns suggest that the observed semantic priming in both SOA groups was not a lexical activation phenomenon but rather was attributable to a postlexical process such as semantic-matching (Neely & Keefe, 1989).

Posterior probabilities of the null hypothesis (Masson, 2011) produced by our Bayes factor analyses provided an additional source of evidence for a null interaction between the visible semantic and masked orthographic priming effects in the latency data. Raftery (1995) has provided categories to label the strength of evidence for a hypothesis based on the posterior probabilities generated by these types of analyses. These categories are based on the rules of thumb provided by Jeffreys (1961), but are more conservative. Specifically, Raftery defines posterior probabilities of 20:1 (P_{BIC} values of 95–99) as corresponding to strong evidence, whereas Jeffreys considered a 10:1 probability as constituting strong evidence. According to Raferty's convention, the posterior probabilities of the null hypothesis observed here (i.e., $P_{sBIC} = .95$ and $P_{iBIC} = .92$, in the subject and items analyses, respectively) constitute positive evidence for a null interaction between the visible semantic and masked orthographic neighbor priming effects.

Experiment 1 also examined the effects of masked neighbor primes and visible semantic primes on the latency distributions using quantile plots. An influence only on the lexical activation of the target and, hence, the lexical selection stage in word recognition, would be expected to produce a shift in the entire latency distribution, consistent with a head-start to processing the target word (i.e., the effect should thus remain constant across quantiles). In contrast, a postlexical effect would be expected to affect the skew of the distribution and thus result in a larger effect in the later quantiles (Balota et al., 2008; de Wit & Kinoshita, 2015a, 2015b). The effect of masked nonword neighbor primes was similar across quantiles, consistent with the notion that the effect of these primes is to offer a head-start to the processing of the target words (i.e., presumably through activation of lexical representations). Importantly, the effect of visible semantic primes increased in later quantiles, an effect that was marginally larger for the 1,487-ms SOA group. This pattern indicates that, as more time is required to process the target (i.e., during the slower trials) prime information facilitates the LDT response to a greater extent. Such a pattern is consistent with postlexical accounts of priming, where the impact of using information from the prime to aid target processing is greater later in target processing.

The 18-ms masked neighbor priming effect in Experiment 1, while similar in magnitude to the 26-ms effect found in Davis and Lupker (2006; Experiment 1), was not large which means that Experiment 1 may not have allowed for a very sensitive test for the existence of an interaction with the semantic priming effect. Experiment 2 addressed this issue by increasing the size of the masked neighbor priming effects through the use of the sandwich priming paradigm, thus providing a more sensitive test for the interaction. In addition, new sets of prime–target pairs were selected involving longer targets which should also lead to an increase in the size of the neighbor priming effects (e.g., Forster, Davis, Schoknecht, & Carter, 1987).

Experiment 2

As in Experiment 1, a set of visible semantic prime–target pairs, which yielded a semantic priming effect at both short and long SOAs in the semantic priming project (Hutchison et al., 2013), was obtained. Nonword neighbor primes were then generated for the target words (again, not taking into account whether those primes were orthographically legal or pronounceable).

As in Experiment 1, there was a masked (sandwich) priming group in Experiment 2 to establish the degree of facilitation provided by the nonword neighbor primes in this paradigm (e.g., *aluminum—alxminum—ALUMINUM*—the sandwich prime group). The effect of visible semantic primes on the lexical facilitation from the nonword neighbor primes in the sandwich priming paradigm was then examined (*e.g., foil—aluminum—alxminum—ALUMINUM*) at a 283-ms SOA in the *short SOA visible prime group*, and at a 1,483-ms SOA in the *long SOA visible prime group*. Consistent with the logic set up in Experiment 1, an interaction between the visible semantic and masked orthographic neighbor priming effects would indicate that the semantic prime influences the lexical activation of its target (through automatic spreading activation at the 283-ms SOA or expectancy generation at the 1,483-ms SOA). Additivity would imply that the effects of the semantic prime are more likely to be attributable to a postlexical process. As in Experiment 1, the effects of both masked orthographic neighbor primes and visible semantic primes on the latency distribution were examined through quantile plots. The fact that stimuli in Experiment 2 were entirely different from those in Experiment 1 means that these analyses will provide a second, independent examination of the question of whether visible semantic and masked orthographic neighbor priming effects do behave differently across quantiles.

Method

Participants. A total of 147 undergraduate students participated in Experiment 2 for course credit. Because of a high rate of errors and outlier responses on nonword trials (>20%), data from 11 of the 41 participants in the *sandwich prime group*, 11 of the 47 participants in the *short SOA visible prime group*, and seven of the 59 participants in the *long SOA visible prime group* were excluded from the analyses.

Stimuli. As in Experiment 1, primes and target words were selected from the semantic priming project database (Hutchison et al., 2013). The forward and backward associative strengths and the LSA values for these related visible semantic prime–target pairs were fairly close to those for the pairs from Experiment 1, .30, .14, and .39, respectively. Of a total of 128 target words, 24 were eight letters long, 40 were seven letters long, and 64 were six letters long. Target frequency (CELEX) was 42.54 and neighborhood size (*N*) was 1.12 (Coltheart et al., 1977). Frequency and *N* values were obtained using the N-Watch software (Davis, 2005). Nonword targets were again selected from the English Lexicon Project website (Balota et al., 2007), with 24 having eight letters, 40 having seven letters, and 64 having six letters. As in Experiment 1, nonwords with large neighborhood sizes were selected in order for them to be as word-like as possible ($N = 7.78$). The visible primes for the nonword targets were again selected from the semantic priming project and were unrelated to any of the word targets.

As in Experiment 1, nonword neighbor primes were constructed for word targets ($N = 1.18$) and nonword targets ($N = 0.91$) by replacing a single letter from the target. Masked neighbor prime–target pairs were then re-paired to provide non-neighbor prime–target pairs such that these unrelated primes and their targets were matched on length. An additional letter in the prime occasionally had to be replaced to avoid orthographic overlap with the target. All stimuli in the present experiment are shown in Appendix B. Counterbalancing for the sandwich prime group was the same as the counterbalancing for the masked prime group from Experiment 1, and counterbalancing for the short and long SOA visible prime groups was the same as for those groups in Experiment 1.

For each participant in the sandwich prime, short SOA, and long SOA visible prime groups, trials involving the target word *gander* were excluded from the analyses because of those trials having high error rates (>50%). Additionally, trials involving the target word *aluminum* were excluded from the short and long SOA visible prime groups because that target was inadvertently presented as a practice item.

Semantic priming effects. The visible semantic prime–target triplets were selected based on their ability to produce a semantic priming effect at a short SOA (82.00 ms) and at a long SOA (94.61 ms) according to the semantic priming project database.

Masked orthographic neighbor priming effects. Prior to examining the facilitation from nonword neighbor primes in the sandwich priming paradigm, we confirmed that the selected nonword primes would produce priming in a conventional masked priming paradigm. In a pilot study using a different set of participants ($N = 14$), using a prime duration of 50 ms, we obtained a masked neighbor priming effect of 16 ms, which was significant in both subject and item analyses, $F\text{s} > 5.31$.

Experimental procedure. The procedure used was identical to the one used in Experiment 1, however a sandwich priming paradigm was now used, rather than the conventional masked priming paradigm, and the masked nonword neighbor primes were presented for 50 ms rather than 67 ms (see footnote 2). Specifically, during each trial, the sandwich prime group first saw a mask that was 8 hashtags long (########) for 700 ms, followed by the target, presented for 33 ms, followed by the masked nonword prime, presented for 50 ms, followed by the target again (which was presented until a response was made or 2,500 ms had elapsed). The short SOA visible prime group first saw the visible semantic prime for 200 ms then the sandwich prime sequence (target for 33 ms, then masked prime for 50 ms, then the target). The long SOA visible prime group first saw the visible semantic prime for 700 ms, then the mask for 700 ms then the sandwich prime sequence (see Figure 4). Each participant received 12 practice trials followed by 256 experimental trials. The experiment took approximately 7 min for the sandwich prime group, 10 min for the short SOA visible prime group and 15 min for the long SOA visible prime group.

Results

When the sandwich prime, visible short SOA and visible long SOA groups were combined, for the word trials, 3.4% were incorrect responses and 1.4% were correct responses faster than 250 ms or slower than 1750 ms (outliers). For the nonword trials, 6.7% were incorrect responses and 2.3% were correct response outliers. As in Experiment 1, latency analyses excluded errors and outliers, whereas error rate analyses excluded outliers. Table 2 shows latencies and error rates for words for the sandwich prime group, and as a function of visible and masked orthographic prime types for the short and long SOA visible prime groups. The latencies and error rates for the nonword targets are shown in Appendix D.

Latencies and error rates were submitted to the same analyses as in Experiment 1. Quantiles were generated as in Experiment 1. Because 128 word targets were used in the present experiment, each condition had 64 trials. Again, the first four quantiles were retained, each having 15 trials. This procedure resulted in the loss of 2.7% of the data in the sandwich prime group, 2.0% of the data in the short SOA visible prime group and 1.7% of the data in the long SOA visible prime group. Figure 5 shows the quantile plot for the word targets as a function of masked prime type for the sandwich prime group. Figure 6 shows the quantile plots for the word targets as a function of masked (neighbor or non-neighbor) prime type (top panel) and visible (semantic or related) prime type (bottom panel) for the combined data for the short and long SOA groups.

Sandwich prime group.

Word latencies. Facilitation from masked nonword neighbor primes in the sandwich priming paradigm was observed as responses were 56 ms faster for word targets following neighbor (vs. non-neighbor) primes. The facilitation was significant in both the subject and item analyses $F_s(1, 28) = 167.62$, $p < .001$, $\eta^2 = .86$; $F_i(1, 125) = 100.31$, $p < .001$, $\eta^2 = .45$.

Word errors. No effects emerged in the subject or item analyses, both $F\text{s} < 1.77$, $p\text{s} > .20$.

Effects of masked orthographic neighbor priming across quantiles. The main effects of quantile and masked prime type were significant, $F_s(1.13, 31.58) = 513.02$, $p < .001$, $\eta^2 = .95$; $F_s(1, 28) = 253.40$, $p < .001$, $\eta^2 = .90$. Importantly, the masked orthographic priming effect in the sandwich priming group did not change across quantiles as seen in Figure 5, $F_s < 1$.

Analyses of the long and short SOA groups.

Word latencies. A semantic priming effect was found in both the subject and item analyses, $F_s(1, 80) = 58.47$, $p < .001$, $\eta^2 = .42$; $F_i(1, 122) = 60.18$, $p < .001$, $\eta^2 = .33$, as was a masked sandwich priming effect, $F_s(1, 80) = 97.37$, $p < .001$, $\eta^2 = .55$; $F_i(1, 122) = 141.65$, $p < .001$, $\eta^2 = .54$. The main effect of SOA was not significant in the subject analysis, $F_s < 1$, but was in the item analysis $F_i(1, 122) = 28.15$, $p < .001$, $\eta^2 = .19$, reflecting longer latencies following a short (vs. long) SOAs (see Table 2). However, SOA did not modulate the semantic priming effect, the neighbor (sandwich) priming effect, or the interaction between these two effects, all $F\text{s} < 1$. Importantly, additivity between the visible semantic and masked neighbor priming effects was once again observed. A Bayes factor analyses of the combined data, however, provided only weak evidence for the null hypothesis, $P_{sBIC} = .56$; $P_{iBIC} = .59$.

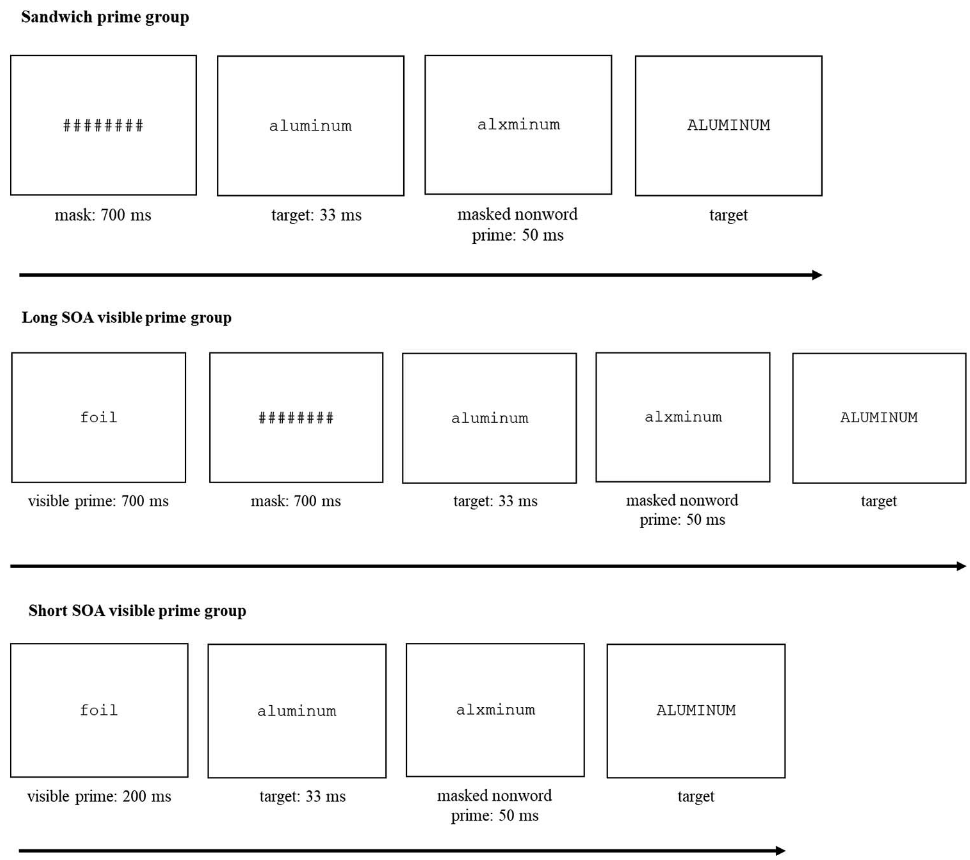

Figure 4. Trial sequence presented to the sandwich prime group (top panel), the long SOA visible prime group (middle panel), and the short SOA visible prime group (bottom panel) in Experiment 2.

Word errors. A smaller error rate following related (vs. unrelated) visible semantic primes was found in both the subject and item analyses, $F_s(1, 80) = 4.76$, $p < .05$, $\eta^2 = .06$; $F_i(1, 122) = 27.16$, $p < .001$, $\eta^2 = .18$. Similarly, a smaller error rate was found in both analyses following neighbor masked primes, $F_s(1, 80) = 7.73$, $p < .01$, $\eta^2 = .09$; $F_i(1, 122) = 6.12$, $p < .05$, $\eta^2 = .05$. The main effect of SOA, reflecting a smaller error rate following a short (vs. long) SOA (see Table 2), was marginal in the subject analysis, $F_s(1, 80) = 3.34$, $p = .07$, $\eta^2 = .04$, but was significant in the item analysis, $F_i(1, 122) = 38.24$, $p < .001$, $\eta^2 = .24$. The semantic priming effect in error rates was numerically greater in the long (vs. short) SOA group with the analyses of that difference showing that although the Visible Semantic Prime × SOA interaction was not significant in the subject analysis, $F_s(1, 80) = 2.43$, $p = .12$, $\eta^2 = .03$, it was in the item analysis $F_i(1, 122) = 16.29$, $p < .001$, $\eta^2 = .12$. The masked neighbor priming effect in error rates did not differ between the short and long SOA groups, both Fs < 1. SOA did not modulate the Visible Semantic × Masked Orthographic Neighbor prime interaction, both Fs < 1, however, the Visible Semantic × Masked Orthographic Neighbor prime interaction was marginal in both subject and item analyses, $F_s(1, 80) = 3.26$, $p = .08$, $\eta^2 = .04$; $F_i(1, 122) = 3.33$, $p = .07$, $\eta^2 = .03$ as the masked priming effect in errors was larger following an unrelated (vs. related) visible semantic prime.

Chi-square analyses of the log percent correct were done as in Experiment 1. The model assuming the Visible Semantic × Masked Orthographic Neighbor prime interaction did not differ from the model assuming just the main effects of SOA, visible semantic prime, and masked orthographic neighbor prime type, $\chi^2(1) < 1$.

Effects of masked orthographic neighbor priming across quantiles. Mean latency increased across quantiles, $F_s(1.11, 86.80) = 474.50$, $p < .001$, $\eta^2 = .86$, and the masked neighbor orthographic priming effect was significant, $F_s(1, 78) = 100.77$, $p < .001$, $\eta^2 = .56$. There was no main effect of SOA, and SOA did not interact with the masked orthographic neighbor priming effect or the Masked Orthographic Neighbor Prime × Quantile interaction, all Fs < 1. Importantly, the orthographic neighbor priming effect was constant across quantiles (see Figure 6, top panel), $F_s < 1$.

Effects of visible semantic priming across quantiles. Mean latency increased across quantiles, $F_s(1.12, 87.58) = 476.81$, $p < .001$, $\eta^2 = .86$, and the semantic priming effect was significant, $F_s(1, 78) = 112.63$, $p < .001$, $\eta^2 = .59$. There was no main effect of SOA, nor did SOA interact with visible semantic prime, quantile, or the Visible Semantic Prime × Quantile interaction, all Fs < 1. Importantly, the increase of the semantic priming effect across quantiles (Figure 6, bottom panel) was again observed as indexed by the significant semantic prime type by quantile interaction, $F_s(1.25, 97.32) = 25.07$, $p < .001$, $\eta^2 = .24$.

Table 2
Latencies (Milliseconds) and Error Rates (Percentages) for Both Word and Nonword Targets as a Function of Visible Semantic Prime and Masked Orthographic Prime Types for the Sandwich Prime, Long, and Short SOA Visible Prime Groups in Experiment 2

Group/Visible semantic prime type	Masked orthographic nonword prime type		
	Neighbor	Non-neighbor	Orthographic priming effect
Sandwich prime	628	684	56 [47.07, 64.93]
	2.4	3.0	0.6 [−0.29, 1.49]
Short SOA visible prime			
Related	645	683	38 [19.10, 56.90]
	1.9	2.3	0.4 [−0.78, 1.58]
Unrelated	677	725	48 [29.10, 66.90]
	1.7	3.5	1.8 [0.62, 2.98]
Semantic priming effect	32 [15.14, 48.86]	42 [25.14, 58.86]	
	−0.2 [−1.41, 1.01]	1.2 [−0.01, 2.41]	
Long SOA visible prime			
Related	667	704	37 [23.73, 50.27]
	3.0	3.1	0.1 [−1.07, 1.27]
Unrelated	692	736	44 [30.73, 57.27]
	5.6	6.6	1.0 [−0.17, 2.17]
Semantic priming effect	25 [10.30, 39.70]	32 [17.30, 46.70]	
	2.6 [−0.18, 5.38]	3.5 [0.72, 6.28]	

Note. SOA = stimulus onset asynchronies. Error rates are shown in the rows below latencies, and 95% confidence intervals are shown for orthographic and semantic priming effects in brackets.

Combined Analysis of Experiments 1 and 2

In a final attempt to statistically analyze the potential additivity between the visible semantic and masked orthographic neighbor priming effects, we combined the data from Experiments 1 and 2. Combining the data and, thus, increasing the number of participants and items used in the analysis, provides the most powerful test for a potential interaction between these two priming effects available to us. The data were submitted to a 2 (Experiment: 1 vs. 2) × 2 (SOA: short vs. long) × 2 (visible prime type: related vs. unrelated) × 2 (masked prime type: neighbor vs. non-neighbor) × 4 (group/set: 1 vs. 2 vs. 3 vs. 4) separately using subjects (F_s) and items (F_i) as random factors in split-plot ANOVAs, where *Experiment* was a between-subjects and between-item factor. Likewise, quantile data from Experiments 1 and 2 was combined and submitted to ANOVAs investigating the effects of visible semantic primes and masked orthographic neighbor primes on the latency distributions. The ANOVAs were the same as done in the analyses in the separate experiments, except Experiment (1 vs. 2) was now added as a between-subjects/item factor. Item analyses were included here because, unlike in the previously reported quantile analyses, most word targets now had responses in all four retained quantiles.

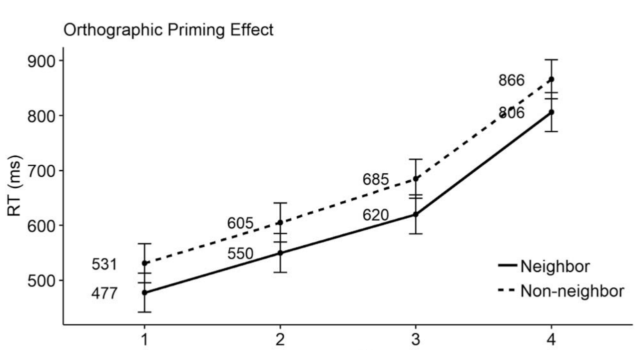

Figure 5. Effect of masked orthographic prime type on word targets across quantiles for the sandwich prime group in Experiment 2. Error bars represent 95% confidence intervals for each mean.

Word latencies. The semantic priming effect was again significant in both the subject and item analyses, $F_s(1, 192) = 96.72$, $p < .001$, $\eta^2 = .33$; $F_i(1, 182) = 80.48$, $p < .001$, $\eta^2 = .31$, as was the masked neighbor priming effect, $F_s(1, 192) = 104.72$, $p < .001$, $\eta^2 = .35$; $F_i(1, 182) = 97.27$, $p < .001$, $\eta^2 = .35$. Importantly, the lack of an interaction between these two factors was again observed, both Fs < 1.13. There was no main effect of long (vs. short) SOA, nor did that variable interact with the semantic priming effect, the orthographic neighbor priming effect, or the Semantic × Orthographic Neighbor priming interaction, in either the subject or item analyses, all Fs < 1. Longer latencies were found in Experiment 2 (vs. Experiment 1), however, the main effect of Experiment was not significant in the subject analysis, $F_s(1, 192) = 2.40$, $p = .12$, $\eta^2 = .01$, although it was in the item analysis, $F_i(1, 182) = 8.26$, $p < .01$, $\eta^2 = .04$. The semantic priming effect was similar across the two experiments, as the Experiment × Visible Semantic Prime interaction was not significant, both Fs < 1. The masked neighbor priming effect, however, was greater in Experiment 2 (vs. 1), as evidenced in the Experiment × Masked Orthographic Neighbor Prime interaction in both the subject and item analyses, $F_s(1, 192) = 16.91$, $p < .001$, $\eta^2 = .08$; $F_i(1, 182) = 16.10$, $p < .001$, $\eta^2 = .08$. Importantly, Experiment did not modulate the Null Visible Semantic × Masked Orthographic Neighbor Prime interaction, both Fs < 1.15. Bayes factor analyses again provided support for a null interaction between the semantic and neighbor priming effects in both the subject and item analyses, $P_{sBIC} = .86$; $P_{iBIC} = .81$.

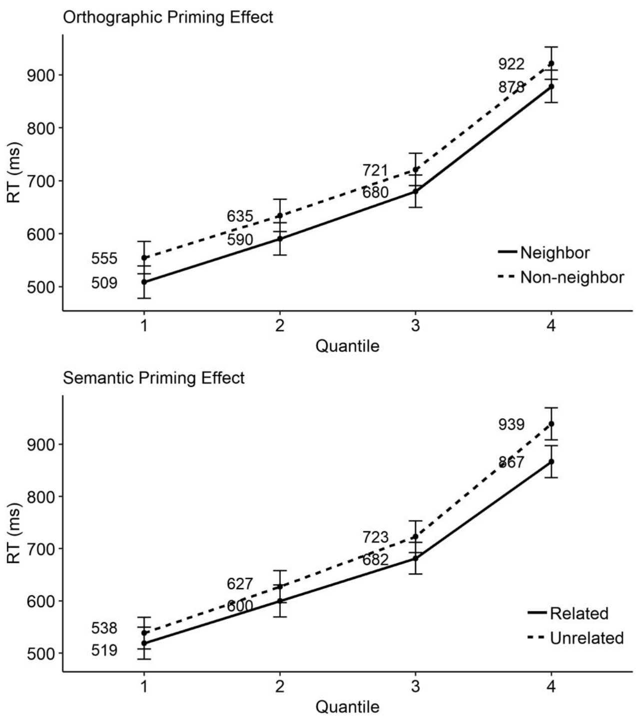

Figure 6. Effect of masked orthographic prime type (top panel) and visible semantic prime type (bottom panel) on word targets across quantiles for the short and long SOA visible prime groups in Experiment 2. Error bars represent 95% confidence intervals for each mean.

Word errors. A semantic priming effect, reflecting lower error rates following a related (vs. unrelated) visible semantic prime, was observed in both the subject and item analyses, $F_s(1, 192) = 20.81$, $p < .001$, $\eta^2 = .10$; $F_i(1, 182) = 33.50$, $p < .001$, $\eta^2 = .16$. A masked neighbor priming effect, indicating lower error rates following a neighbor prime, was marginal in both the subject and item analyses, $F_s(1, 192) = 3.24$, $p = .07$, $\eta^2 = .02$; $F_i(1, 182) = 3.38$, $p = .07$, $\eta^2 = .02$. The interaction between the semantic and neighbor priming effects was significant in the subject analyses, $F_s(1, 192) = 4.97$, $p < .05$, $\eta^2 = .03$; and marginal in the item analysis $F_i(1, 182) = 3.82$, $p = .05$, $\eta^2 = .02$. The Visible Semantic × Masked Neighbor Prime interaction reflects a greater masked neighbor priming effect following an unrelated (vs. related) visible semantic prime. The main effect of SOA was not significant in the subject or item analyses, both Fs < 1. The SOA × Visible Semantic Prime interaction was marginal in the subject analysis, $F_s(1, 192) = 3.16$, $p = .08$, $\eta^2 = .02$; and significant in the item analysis, $F_i(1, 182) = 6.84$, $p < .05$, $\eta^2 = .04$, reflecting a greater semantic priming effect in the long (vs. short) SOA groups (see Tables 1 and 2). However, SOA did not modulate the orthographic neighbor priming effect or the interaction between the semantic and neighbor priming effects, all Fs < 1.06. There was a main effect of Experiment in subject and item analyses, $F_s(1, 192) = 6.15$, $p < .05$, $\eta^2 = .03$; $F_i(1, 182) = 5.92$, $p < .05$, $\eta^2 = .03$, reflecting greater error rates in Experiment 1 (vs. 2). However, Experiment did not modulate the semantic priming effect, the orthographic neighbor priming effect, or the interaction between the semantic and neighbor priming effects, all Fs < 1.03.

Frequencies of correct responses were generated by Experiment, SOA, visible semantic prime, and masked neighbor prime. As in the chi-square analyses of data from Experiments 1 and 2, a model assuming a Visible Semantic × Masked Neighbor Prime interaction was compared with a model assuming only the main effects of each factor. Again, the model assuming the Visible Semantic × Masked Orthographic Neighbor Prime interaction did not fit the frequencies better than the model just assuming main effects, $\chi^2(1) < 1$.

Effects of masked orthographic neighbor priming across quantiles. The mean latency increased across quantiles according to both the subject and item analyses, $F_s(1.12, 211.69) = 1084.25$, $p < .001$, $\eta^2 = .85$; $F_i(2.00, 311.54) = 1808.96$, $p < .001$, $\eta^2 = .92$. The masked orthographic neighbor priming effect was again significant, $F_s(1, 189) = 103.92$, $p < .001$, $\eta^2 = .35$; $F_i(1, 156) = 156.09$, $p < .001$, $\eta^2 = .50$. Overall latencies were faster in Experiment 1 (vs. 2) in both the subject and item analyses, $F_s(1, 189) = 9.94$, $p = .002$, $\eta^2 = .05$; $F_i(1, 156) = 342.50$, $p < .001$, $\eta^2 = .69$. An interaction between Experiment and masked neighbor prime type in both subject and item analyses, $F_s(1, 189) = 18.34$, $p < .001$, $\eta^2 = .09$; $F_i(1, 156) = 342.50$, $p < .001$, $\eta^2 = .69$, reflected the greater masked orthographic neighbor priming effect in Experiment 2 (where the sandwich priming procedure was used). There was no effect of SOA in either the subject or item analyses, both Fs < 1 nor was there evidence that SOA modulated the size of the masked orthographic neighbor priming effect in either experiment, both Fs < 1.

Most importantly, there was no evidence of a Masked Orthographic Neighbor Prime × Quantile interaction as the masked priming effect was again constant across quantiles in both subject and item analyses (see Figure 7, top panel), both Fs < 1. The Null Masked Orthographic Neighbor Prime × Quantile interaction was not modulated by SOA in either the subject or item analyses, both Fs < 1, or by Experiment, both Fs < 1. The Experiment × SOA × Masked Neighbor Prime × Quantile interaction was also not significant in either the subject or item analyses, both Fs < 1.

Effects of visible semantic priming across quantiles. Mean latency increased across quantiles in subject and item analyses, $F_s(1.12, 212.47) = 1039.65$, $p < .001$, $\eta^2 = .85$; $F_i(1.89, 296.39) = 1648.25$, $p < .001$, $\eta^2 = .91$, and the semantic priming effect was significant, $F_s(1, 190) = 149.30$, $p < .001$, $\eta^2 = .44$; $F_i(1, 157) = 180.19$, $p < .001$, $\eta^2 = .53$. The semantic priming effect was not modulated by SOA or by Experiment in either the subject or item analyses, all Fs < 1. The Experiment × SOA × Visible Semantic Prime Type interaction was not significant in the subject analysis, $F_s < 1$, and was marginal in the item analyses, $F_i(1, 157) = 3.39$, $p = .067$, $\eta^2 = .02$. The SOA × Visible Semantic Prime Type interactions were investigated separately for Experiments 1 and 2 in analyses reported above.

Importantly, the semantic priming effect increased across quantiles (see Figure 7, bottom panel) as indexed by the significant Visible Semantic Prime Type × Quantile interaction, $F_s(1.31, 248.57) = 36.05$, $p < .001$, $\eta^2 = .16$; $F_i(2.27, 356.02) = 3.68$, $p = .021$, $\eta^2 = .02$. The Visible Semantic Prime Type × Quantile interaction was not modulated by Experiment or SOA in either the subject or item analyses, all Fs < 2.19, ps > .133. The Experiment × SOA × Visible Semantic Prime Type × Quantile interaction was not significant in either the subject or item analyses, both Fs < 1.07, ps > .345.

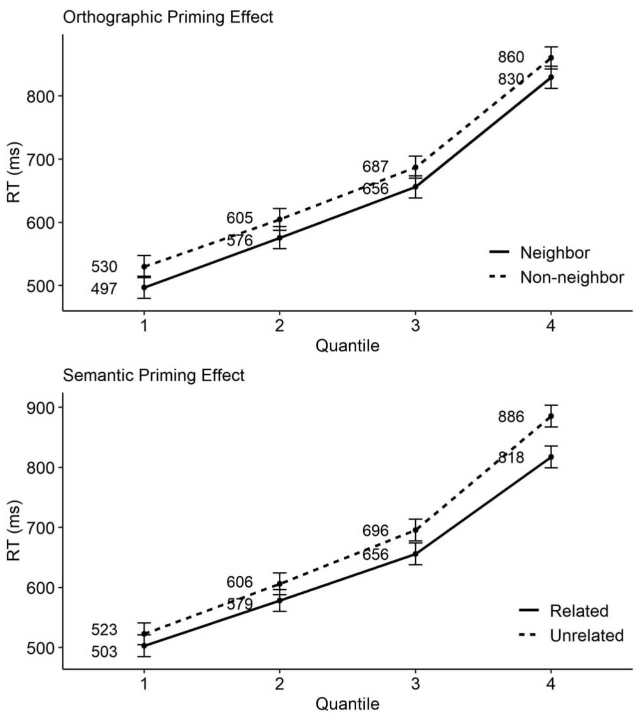

Figure 7. Effect of masked orthographic prime type (top panel) and visible semantic prime type (bottom panel) on word targets across quantiles for the short and long SOA visible prime groups in Experiments 1 and 2. Error bars represent 95% confidence intervals for each mean.

Discussion

The goal of Experiment 2 was to provide a more sensitive test for the interaction between semantic and orthographic neighbor priming by using the sandwich priming paradigm. It was expected that the sandwich priming paradigm, in comparison with the conventional masked priming paradigm, would increase the magnitude of the facilitation from the masked neighbor primes by heightening the level of activation that they would generate in the target. An interaction between the semantic and orthographic neighbor priming effects would suggest semantic primes influence the lexical activation of their targets, whereas additivity would suggest semantic primes act after the lexical selection of the target is essentially complete.

As shown in the combined analyses, a semantic priming effect comparable to the one obtained in Experiment 1 was found for the stimuli selected for Experiment 2 at both short and long SOAs. Additionally, a large masked orthographic neighbor priming effect was obtained using the sandwich priming paradigm. Importantly, the results in Experiment 2 suggest additivity between semantic and orthographic neighbor priming, consistent with the results from Experiment 1. Bayes factor analyses of the posterior probability for the null hypothesis again provided evidence in favor of additivity. Although the probabilities based on the analyses of the data from Experiment 2 constituted only weak evidence favoring the null hypothesis, the probabilities based on analyses of the combined dataset from both Experiments provided positive evidence favoring the null hypothesis.

The effects of the masked nonword neighbor primes and visible semantic primes on the latency distributions in Experiment 2 were consistent with those from Experiment 1. The orthographic neighbor priming effect in the sandwich priming paradigm was constant across quantiles, presumably reflecting a head-start attributable to the lexical activation of the targets. The semantic priming effect increased in later quantiles as it did in Experiment 1, a result supporting the idea that there is a postlexical locus of the semantic priming effect.

The statistical analyses of the latency data in Experiments 1 and 2 consistently indicated additivity and, thus, independence, between the masked neighbor and visible semantic priming effects. A reasonable conclusion, therefore, is that the semantic priming effects investigated in these two experiments are not lexical activation phenomena. Rather, they are postlexical effects. Consistent with the idea that these semantic priming effects in all the experiments arose from the same source is the fact that the semantic priming factor did not interact with either SOA or Experiment. That is, the semantic priming effect did not vary in size as a function of either of those manipulations.

Before fully endorsing this conclusion, however, a couple of caveats need to be noted. First, even though the Bayes factor analyses support this conclusion, the conclusion is based on an acceptance of the null hypothesis, a situation that is better to avoid whenever possible. Such may be especially true in the present situation because, as Sternberg (1969) has noted, there is always the possibility that two factors can influence the same stage in an additive fashion (see Balota & Paul, 1996). Indeed, Plaut and Booth (2000) have provided a clear example of how that could happen using their model of word recognition in which activation of semantic units is a sigmoidal function of input strength (determined by factors such as the frequency of the target word, perceptual ability, and whether the preceding prime was related or unrelated). Their analysis showed that an interaction or additivity could be obtained between two factors (e.g., semantic priming and word frequency) depending on the position of the target on the activation curve when responding is initiated.

Second, although there was very little evidence of a significant interaction in the latency data, even in the overall combined analysis, the semantic priming effects were not numerically identical in all situations. Specifically, the semantic priming effect was 10 ms larger for the non-neighbor pairs than the neighbor pairs in the long SOA group in Experiment 2, 9 ms larger for the non-neighbor pairs than the neighbor pairs in the long SOA group in Experiment 1, and 7 ms larger for the non-neighbor pairs than the neighbor pairs in the short SOA group in Experiment 2. Only in the short SOA group in Experiment 1 was the semantic priming effect numerically smaller (5 ms) for the non-neighbor pairs than for the neighbor pairs. Further, marginal Visible Semantic × Masked Orthographic Neighbor Prime interactions were found in the error rate data in Experiment 2 and a significant interaction was found in the combined analyses of Experiments 1 and 2. Consistent with the latency data, the semantic priming effects were greater for the non-neighbor (vs. neighbor) pairs.

When considering the implications of the error data, as Sternberg (1969) has pointed out additive factors logic does not apply in quite the same way to error data as it does to latency data. For example, although latencies from successive stages may add together to produce an ultimate latency, allowing an additive factors analysis to follow logically, such would not be the case for errors. An additional reason that additive factors logic does not apply well to error data is the fact that there is a clear floor to error rates, which can cause any effect sizes to be reduced when accuracy is high, as it was in the present experiments. In fact, in the lexical-decision task, considerable care must be taken because it is likely that some of the words used are simply not in the participants' vocabulary (i.e., a "nonword" response is the correct response for those participants). Hence, the effective floor is not 0% errors but is something higher. In particular, the data from Experiments 1 and 2 suggest that the effective floor on error rates for our participants might have been somewhere in the 3% to 4% range, the range in which the error rates following masked orthographic neighbor primes seemed to fall. Hence, it is quite possible that there was little room available to observe a semantic priming effect on error rates following masked orthographic neighbor primes.[5]

Because additive factors logic does not strictly apply to error rates, Schweickert (1985) devised a way to use additive factors logic in an error rate analysis. That procedure involved applying additive factors logic to the log percent correct. Schweickert further recommended analyzing frequencies of percent correct by using a chi-square test. Although the assumption of independence of observations is violated when the chi-square test is applied to within-subject designs (i.e., the present experiments), Schweickert noted several disadvantages of trying to use ANOVAs to analyze error rates (or logarithmically transformed error rates). Specifically, the frequencies of correct and incorrect responses differ across conditions, so the variances also likely differ across conditions. Additionally, the number of errors in a condition is constrained by the number of trials in a given condition. Both of these facts mean that the assumptions of ANOVAs are violated when analyzing error rates, even logarithmically transformed rates.

Following Schweickert's (1985) suggestions, therefore, in the present experiments, comparisons of a log-linear model which assumes a Visible Semantic × Masked Orthographic Neighbor Priming interaction with one which assumes additivity between these factors were carried out. These analyses consistently showed that the model assuming an interaction between visible semantic priming and masked orthographic neighbor priming is not a better fit than the model assuming additivity between these two factors. According to Schweickert's logic, therefore, our findings support the idea that there is additivity between the effects of visible semantic primes and masked neighbor primes in the error data, in contrast to what the ANOVA analyses seemed to show and, therefore, that the additivity found in latencies is not a product of a speed–accuracy trade-off.

Although the weight of the statistical evidence, therefore, does favor additivity, the overall data pattern raises the possibility that semantic priming effects are larger following non-neighbor primes implying that semantic and neighbor priming do affect the same process in a particular way. Specifically, the interaction is a weak one and, therefore, difficult to detect even in very powerful experimental designs. More centrally, an interaction of this sort would be what can be described as an "underadditive" one in which the impact of the two factors is less than the impact of each factor separately. That is, the interpretation would be that there is a limit to how highly activated a lexical representation can be following the presentation of related primes. As a result, the latency and the error rate in the doubly related condition is constrained, causing the semantic priming effect to be smaller when the masked prime is a neighbor than when it is not.

When considering the viability of this possibility at a general level, it is worth noting that there are very few examples of underadditive patterns in the literature (i.e., most nonadditive patterns are overadditive). For example, Pastizzo, Neely, and Tse (2008; see also Thomas, Neely, & O'Connor, 2012) compared primes which were related to their targets semantically (*swim—float*), orthographically/phonologically (*coat—float*), or semantically and orthographically/phonologically (*boat—float*) in a task where a letter search was conducted on the prime and a lexical decision was made to the target. Pastizzo et al. found the effect of semantic and orthographic/phonological primes was actually greater than the sum of the effects of semantic primes and orthographic/phonological primes (i.e., in contrast to our results they observed an overadditive interaction).

More centrally, the idea that there is a limit to how preactivated a lexical representation can become (which could then lead to an underadditive interaction) receives virtually no support from a number of lexical decision experiments in which multiple semantically related primes were used (Balota & Paul, 1996; Brodeur & Lupker, 1994; Klein, Briand, Smith, & Smith-Lamothe, 1988). For example, Brodeur and Lupker showed that semantic priming effects with a single primes (14 ms and 18 ms) were enhanced considerably (47 ms and 73 ms) when four semantically related primes preceded the target (the unrelated condition in the latter situation involved four unrelated primes). In general, the pattern across these experiments was for the additional primes to increase the size of the priming effect in a linear fashion.

Thus, there seems to be little evidence to support an account based on the idea that there is a limit to how highly activated a lexical representation can be following the presentation of more than one related prime. A point that is also worth noting because it applies to the upcoming discussion in the General Discussion concerning the differences in priming between the LDT and other tasks is that a similar increase in priming from multiple primes did not emerge in Brodeur and Lupker's (1994) naming task.

Experiment 3

Recognizing the problems inherent in additive factors logic (McClelland, 1979) as well as the fact that some aspects of the data do suggest the potential for an interaction between orthographic neighbor priming and semantic priming, Experiment 3 was an attempt to examine the idea that semantic priming is a lexical activation phenomenon in a different, but potentially more direct, fashion. Specifically, Experiment 3 was an examination of the effect of a visible semantic prime on a masked neighbor word

[5] The conjecture that the present participants may have had an effective floor of 3% errors because they simply didn't know some of the words in the experiments receives support from the error data results in two (unpublished) studies carried out by the first author using the same participant pool and target words as used in Experiment 2. These were go/no-go lexical decision tasks (i.e., respond on word trials and withhold the response on nonword trials) using the present double priming procedure. The only errors on word trials, therefore, are failure-to-respond errors (the timeout was at 1750 ms which is the latency cutoff used in the present experiments). Overall error rates in these experiments (i.e., failures to recognize that a word was indeed a word) were 3.1% in one experiment and 4.5% in the other.

prime. That is, the visible primes in Experiment 3 were semantically related (or unrelated) to the masked word prime itself rather than the target word (e.g., *light—lamp—LAMB*) and half of the masked primes were word neighbors of the target.

As discussed, in contrast to masked nonword neighbor primes, masked word neighbor primes inhibit orthographically similar targets because of the fact that they strongly activate their own lexical representations, which then compete with that of the target during lexical selection (Davis & Lupker, 2006). The result is that the facilitative priming effect produced by nonword neighbor primes disappears and the priming effect often becomes overall inhibitory. If semantic priming is a lexical activation process, visible semantic primes that are semantically related to the masked word primes should heighten the lexical activation of those primes. If the lexical representations of masked word primes are more highly activated by the prior presentation of a semantically related prime, they should then be quite effective at inhibiting an orthographically similar (i.e., neighbor) target. The result should be a larger inhibition effect than when the visible semantic prime is unrelated to the masked word prime or in the situation in which no visible semantic prime is used. Hence, there are two contrasts of relevance here. That is, a prime semantically related to the masked neighbor prime should create an inhibition effect that is larger than both (a) the inhibition effect when there is no visible prime prior to the masked neighbor prime and (b) the inhibition effect following a visible prime that is semantically unrelated to the masked neighbor prime (i.e., there should be an interaction in the visible semantic prime by masked neighbor word prime analysis).

The targets from Experiment 1 were used. For each word target, a word prime that had a greater frequency was selected as a word neighbor prime for the target. These prime–target pairs should produce an inhibition effect (or at the very least, a prime lexicality effect, Davis & Lupker, 2006). Visible semantic primes related to the masked word neighbor primes were then selected. Experiment 3 first examined the inhibition produced by the masked word neighbor primes in the *masked prime* group. The ability of visible semantic primes to make the masked word neighbor prime a more effective lexical inhibitor was then examined in the *short SOA visible prime* group and the *long SOA visible prime* group.

Method

Participants. A total of 157 undergraduate students participated in Experiment 3 for course credit. Data from five of the 37 who participated in the *masked prime* group, were excluded from the analyses because of high rates of errors and outliers on nonword trials (using the same criteria as used previously). In the *short SOA visible prime* group, data from 11 out of the 67 participants were excluded and in the *long SOA visible prime* group, data from 9 out of the 53 participants were excluded.

Stimuli. As in Experiments 1 and 2, the stimuli consisted of a visible prime and a masked prime for each target. Unlike in the prior experiments, however, the masked primes were words rather than nonwords, and the visible primes were semantically related (or unrelated) to the masked primes rather than the targets. The targets were the 64 words and 64 nonwords from Experiment 1. The stimuli are shown in Appendix C.

Masked word neighbor primes were selected using the N-Watch software (Davis, 2005) for each word and nonword target. The neighbor primes differed from the target in one letter position. The neighbor primes for word targets were selected to be as high in frequency as possible to maximize the lexical inhibition (mean CELEX frequency = 322.98). Their mean neighborhood size (*N*) was 6.89 (Coltheart et al., 1977). For the nonword targets, neighbor primes were lower in frequency (CELEX = 19.32, *N* = 10.59). Non-neighbor masked primes, which did not overlap with the target in any letter positions, were obtained by re-pairing the masked neighbor prime–target pairs. To ensure that there was no orthographic overlap between the target and the non-neighbor primes, nine non-neighbor primes had to be replaced for the word targets, CELEX = 171.93, and *N* = 7.02, and 36 non-neighbor primes had to be replaced for nonword targets, CELEX = 20.50, and *N* = 7.81.

Finally, visible semantic primes that were associatively/semantically related to the masked neighbor primes were selected. These visible semantic primes had no obvious relationship with the word targets following their masked prime. For the related visible semantic primes of word targets, CELEX = 344.93, *N* = 6.08. The forward and backward associative strengths were .18, and .26, respectively and the LSA was .42. It should be noted that 22 of the 64 of the visible semantic prime–neighbor prime pairs for word targets were not contained in the University of South Florida free association norms database (Nelson et al., 1999). The forward and backward associative strengths reported here are, therefore, based on 42 of those pairs. LSA values, available for all pairs, were obtained from the Latent Semantic Analysis website (Landauer, Foltz, & Laham, 1998). For the related visible semantic primes preceding masked neighbor primes of nonword targets, CELEX = 67.67, *N* = 4.45.

Unrelated visible semantic primes were obtained by re-pairing the visible semantic prime-masked word neighbor prime pairs which was done separately for masked primes preceding word and nonword targets. As mentioned above, several masked non-neighbor primes were replaced to avoid orthographic overlap between those primes and their targets. Different visible semantic primes were thus selected in those instances. For the related visible semantic primes preceding masked non-neighbor primes of word targets, CELEX = 690.96, *N* = 6.02. The forward and backward associative strengths (Nelson et al., 1999) were available for 42 out of the 64 related visible semantic prime—masked non-neighbor prime pairs, and were .16 and .19, respectively. The LSA ratings (Landauer et al., 1998) were .40. For the related visible semantic primes preceding masked non-neighbor primes of nonword targets, CELEX = 49.80, *N* = 4.48. The counterbalancing for the masked prime, short SOA and long SOA visible semantic prime groups was the same as the counterbalancing for the corresponding groups from Experiment 1.

Semantic priming effects. Using different groups of participants, we confirmed the expected facilitation from the visible semantic primes for the masked word primes when those masked primes were the (visible) targets in a LDT, at both short (267 ms, *N* = 38) and long SOAs (1,467 ms, *N* = 46). At the 267-ms SOA, the 25-ms effect was significant in both subject and item analyses, $Fs > 8.60$. At the 1,467-ms SOA, there was a 13-ms effect that was significant in both subject and item analyses, $Fs > 5.77$.

Experimental procedure. The procedure used was identical to the one used in Experiment 1.

Results

When data from the masked prime group, the short SOA, and the long SOA groups were combined, 4.5% of the word trials were errors and 1.6% were outliers. Of the nonword trials, 7.7% were errors and 2.9% were outliers. As in Experiments 1 and 2, errors and outliers were excluded from analyses of latencies and outliers were excluded from analyses of error rates. Table 3 shows the latencies and error rates for word targets as a function of the masked prime type for the masked prime group, and as a function of visible and masked word prime types for the short and long SOA visible prime groups. The baseline inhibition effect from masked word neighbor primes was first established in the masked prime group. Whether a visible semantic prime could increase the inhibition produced by the masked word neighbor primes was then investigated in both short and long visible SOA groups.

Analyses of latencies and error rates were the same as in Experiments 1 and 2. The visible semantic prime was now a factor included in the nonword latency and error analyses, since the visible semantic primes were now related (vs. unrelated) to the masked word primes rather than the (nonword) targets. Additionally, the baseline masked word neighbor inhibition effect (in the masked prime group) was compared with the masked word neighbor inhibition effects following only the *related* visible semantic primes. For these analyses, latencies and error rates were subjected to 2 (masked prime type: neighbor vs. non-neighbor) × 2 (priming paradigm: double priming with the combination of short and long SOA groups vs. the conventional masked priming group) split-plot ANOVAs separately using subjects and items as random factors. Groups/sets were not included in these analyses because the short and long SOA groups have four counterbalance lists whereas the masked priming group has two. Quantile plots and analyses were not carried out because Experiment 3 does not examine the effect of visible semantic primes directly on their targets.

Masked prime group.

Word latencies. Neighbor (vs. non-neighbor) masked orthographic word primes slowed down responses to target words (see Table 3). The 17-ms inhibition from masked orthographic word primes was marginal in the subject analysis, $F_s(1, 30) = 3.79$, $p = .06$, $\eta^2 = .11$, but was significant in the item analysis, $F_i(1, 62) = 4.63$, $p = .04$, $\eta^2 = .07$.

Word errors. No effect of masked orthographic prime type was found, both *F*s < 1.31, *p*s > .26.

Analyses of the long and short SOA groups.

Word latencies. Target latencies were numerically, but not significantly, slower following semantically related (vs. unrelated) primes (see Table 3), both *F*s < 2.11, *p*s > .15. The lexical inhibition effect was significant in both subject in item analyses, $F_s(1, 92) = 7.50$, $p < .01$, $\eta^2 = .08$; $F_i(1, 60) = 6.97$, $p < .05$, $\eta^2 = .11$. The main effect of SOA, reflecting slower latencies in the short (vs. long) visible SOA group, was not significant in the subject analysis, $F_s(1, 92) = 1.03$, $p = .31$, $\eta^2 = .01$, but was in the item analysis, $F_i(1, 60) = 23.78$, $p < .01$, $\eta^2 = .28$. Additionally, SOA did not modulate the effect of the visible semantic prime, the masked word neighbor prime inhibition effect, or the Masked Word Neighbor Prime × Visible Semantic Prime interaction, all *F*s < 2.60, *p*s > .11. Importantly, lexical inhibition did not change depending on whether the visible semantic prime was related (vs. unrelated) to the masked neighbor prime, both *F*s < 1, *p*s > .9. Bayesian estimates further supported the null interaction between the visible semantic and masked neighbor prime factors, $P_{sBIC} = .94$; $P_{iBIC} = .93$. As shown in Table 3, the numerical (but not significant) changes in the inhibition effect as a function of the visible semantic prime are in different directions in the two SOA groups. Specifically, in the long SOA group, the inhibition effect

Table 3
Latencies (Milliseconds) and Error Rates (Percentages) for Word Targets as a Function of Visible Semantic Prime and Masked Orthographic Prime Types for the Masked Prime, Long, and Short SOA Visible Prime Groups in Experiment 3

Group/Visible semantic prime type	Masked orthographic word prime type		
	Neighbor	Non-neighbor	Orthographic inhibition effect
Masked prime	674	657	−17 [−34.68, 0.68]
	6.0	4.8	−1.2 [−3.36, 0.96]
Short SOA visible prime			
Related	713	708	−5 [−22.33, 12.33]
	4.1	4.8	0.7 [−0.81, 2.21]
Unrelated	713	697	−16 [−33.33, 1.33]
	5.0	3.7	−1.3 [−2.81, 0.21]
Effect	0 [−14.62, 14.62]	−11 [−25.62, 3.62]	
	0.9 [−0.76, 2.56]	−1.1 [−2.76, 0.56]	
Long SOA visible prime			
Related	701	679	−22 [−41.44, −2.56]
	6.3	3.1	−3.2 [−5.23, −1.17]
Unrelated	689	679	−10 [−29.44, 9.44]
	4.8	3.2	−1.6 [−3.63, 0.43]
Effect	−12 [−31.00,7.00]	0 [−19.00, 19.00]	
	−1.5 [−3.40, 0.40]	0.1 [−1.80, 2.00]	

Note. SOA = stimulus onset asynchronies. Error rates are shown in the rows below latencies, and 95% confidence intervals are shown for orthographic and semantic priming effects in brackets.

is greater following a visible semantic prime that was related (vs. unrelated) to its masked neighbor prime, whereas the opposite trend was observed in the short SOA group.

Turning to the comparison of the inhibition effect in the masked prime group with the inhibition effect in the combination of the long and short SOA groups (when the initial prime was semantically related to the masked prime), an overall (inhibitory) effect of masked neighbor prime arose in both the subject and item analyses, $F_s(1, 130) = 5.33$, $p = .02$, $\eta^2 = .04$; $F_i(1, 63) = 5.65$, $p = .02$, $\eta^2 = .08$. Latencies were longer in the combination of the long and short SOA groups (vs. the masked prime group), an effect that was marginal in the subject analyses, $F_s(1, 130) = 2.74$, $p = .10$, $\eta^2 = .02$, but was significant in the item analyses, $F_i(1, 63) = 22.89$, $p < .001$, $\eta^2 = .27$. Importantly, there was no Masked Neighbor Prime × Priming Paradigm interaction, both Fs < 1, $P_{sBIC} = .92$; $P_{iBIC} = .93$.

Word errors. Errors following visible semantic primes related (vs. unrelated) to their masked neighbor primes were similar in both the subject and item analyses, both Fs < 1. Error rates were lower following non-neighbor (vs. neighbor) masked word primes in both the subject and item analyses, similar to the inhibition effect with the latencies, $F_s(1, 92) = 9.76$, $p < .01$, $\eta^2 = .10$; $F_i(1, 60) = 8.92$, $p < .05$, $\eta^2 = .13$. There was no main effect of SOA, nor did SOA interact with the effect of a visible semantic prime, all Fs < 1. The reduction in error rates following non-neighbor (vs. neighbor) masked orthographic primes was greater in the long (vs. short) SOA group (see Table 3) with the interaction between SOA and masked neighbor prime being significant in subject and item analyses, $F_s(1, 92) = 5.71$, $p < .05$, $\eta^2 = .06$; $F_i(1, 60) = 8.18$, $p < .01$, $\eta^2 = .12$. Finally, there was no evidence of a visible semantic prime by masked word neighbor prime interaction. However, SOA did affect that potential interaction. The SOA × Visible Semantic Prime × Masked Word Neighbor Prime interaction was significant in the subject analysis, $F_s(1, 92) = 4.92$, $p < .05$, $\eta^2 = .04$, and marginal in the item analysis, $F_i(1, 60) = 2.80$, $p = .10$, $\eta^2 = .04$. Importantly, the Visible Semantic Prime × Masked Word Neighbor Prime was not significant when examined separately in the long and short SOA groups. Specifically, at the long SOA, this interaction was not significant in subject or item analyses, $F_s(1, 40) = 1.64$, $p = .21$, $\eta^2 = .04$; $F_i < 1$. At short SOA, the interaction was marginal in subject and item analyses, $F_s(1, 52) = 2.84$, $p = .10$, $\eta^2 = .05$; $F_i(1, 60) = 3.17$, $p = .08$, $\eta^2 = .05$.

Chi-square analyses of the log percent correct were done as in Experiments 1 and 2. Again, the model assuming the Visible Semantic × Masked Neighbor Prime interaction did not differ from the model assuming just the main effects of SOA, visible semantic prime, and masked neighbor prime type, $\chi^2(1) < 1$.

Turing now to the comparison of the inhibition effect in error rates in the masked prime group with the inhibition effect in the combination of the short and long SOA groups (when the initial prime was semantically related to the masked prime) yielded marginal inhibition effects in both subject and item analyses, $F_s(1, 130) = 2.79$, $p = .10$, $\eta^2 = .02$; $F_i(1, 63) = 3.68$, $p = .06$, $\eta^2 = .06$. There was no overall main effect of group, both Fs < 1.83, ps > .18. Importantly, the inhibition effect did not differ between the masked prime group and the combination of the long and short SOA groups, both Fs < 1.

Discussion

The goal of Experiment 3 was to examine the question of whether the presentation of a visible word (i.e., a prime word) increases the lexical activation of semantically related words, a process that produces a semantic priming effect in semantic priming paradigms. If the impact of semantically related primes truly is to increase the lexical activation of their related targets, evidence of increased activation should be observed in situations in which lexical activation is assumed to play a key role. In particular, any increase in the activation of a lexical representation should lead to enhanced inhibition effects if that word is then used as a masked word neighbor prime (Davis & Lupker, 2006).

To examine this issue, Experiment 3 was, again, a double prime experiment involving an initial visible prime following by a masked prime. The masked primes were all words, half being neighbors of the target, half being unrelated. The visible primes were either semantically related or unrelated to the masked word prime. Both 267-ms and 1,467-ms SOAs were used. The results provided little, if any, evidence that a word semantically related to the masked word prime enhanced the inhibition effects produced by that prime. Specifically, although, numerically, there was some evidence in the 1,467-ms SOA condition that there was more inhibition when a semantically related (vs. unrelated) prime was used, the pattern in the 267-ms SOA condition was precisely the opposite and in neither situation was there a suggestion that the effect sizes (following a visible prime semantically related to the masked prime) were larger than the inhibition effect obtained in the basic masked word neighbor prime condition, the condition in which there was no visible prime. Consistent with Experiments 1 and 2, these results imply that the influence of a visible semantic prime at both short and long SOAs is not at the lexical level.

General Discussion

The present research was an attempt to evaluate the locus of the semantic priming effect in the LDT by combining a visible semantic priming manipulation with a masked orthographic neighbor priming manipulation. Whereas the locus of semantic priming has been debated, masked orthographically similar primes are assumed to operate automatically and influence the lexical activation of their targets (Davis & Lupker, 2006; Forster et al., 1987; Forster & Davis, 1984; Forster, Mohan, & Hector, 2003; McClelland & Rumelhart, 1981). A masked nonword prime activates the lexical representation of orthographically similar targets without activating lexical competitors of the target to a large extent, and thus can produce an overall facilitation effect. In contrast, a masked word prime activates its own lexical representation which acts as a competitor of orthographically similar targets, typically resulting in an overall inhibition effect for those target words. The findings of Davis and Lupker (2006; Experiment 1) that for a set of targets, nonword primes produced facilitation, whereas word primes produced inhibition, provide support for these ideas.

In the present Experiments 1 and 2, visible semantic primes preceded masked nonword orthographic neighbor primes in order to examine whether visible semantic and masked neighbor priming would interact, where an interaction would indicate that visible semantic primes influence the lexical activation of their targets. Following Sternberg's (1969) additive factors logic, an interaction between the two priming effects would suggest that visible semantic primes influence the same process as masked neighbor primes (i.e., lexical activation). In contrast, additivity between the priming effects would suggest that visible semantic primes and masked neighbor primes influence different processing stages during word recognition. Specifically, semantic primes may well influence their targets postlexically, potentially via something like a semantic matching process (de Wit & Kinoshita, 2014; Neely et al., 1989).

Additivity was found in the latency data using both the conventional masked priming paradigm in Experiment 1 and the more sensitive sandwich priming paradigm in Experiment 2, supporting the idea that the basis of the semantic priming effect is a postlexical process. That is, these results support the conclusion that semantic priming in the LDT is not a lexical activation process at either a short or long SOA.

Further support for this conclusion derives from the fact that the size of the semantic priming effect in the latency data was not only essentially unaffected by the masked neighbor priming manipulation across both Experiments 1 and 2 but also by the SOA manipulation in both experiments. That is, the quite similar semantic priming effects obtained at short and long SOAs would appear to be more consistent with a single process rather than a spreading activation process in one case and an expectancy generation process in the other.

Finally, additional support for this conclusion derives from the fact that the two types of priming effects differed as a function of quantile. The masked orthographic neighbor priming effect was constant across quantiles, suggesting that that effect is a preactivation head start effect. In contrast, the visible semantic priming effect showed an increasing effect size across quantiles, consistent with the idea that semantic priming derives from a different source than orthographic neighbor priming. The increasing effect size of the semantic priming effect across quantiles has also been reported by de Wit and Kinoshita (2015a, 2015b) as well as Thomas et al. (2012). Specifically, as will be discussed in more detail below, Thomas et al. reported an increasing semantic priming effect across quantiles for both prime–target pairs that were asymmetric backward associates (*small – shrink*) and prime–target pairs that were symmetric associates (*east – west*), but not when the pairs were asymmetric forward associates (*keg – beer*).

Although the results of Experiments 1 and 2 were supportive of the conclusion that semantic priming effects are not lexical activation effects, the evidence they provide for this conclusion can be challenged. In particular, there was a trend for the semantic priming effect to be slightly larger when the masked prime was a non-neighbor nonword than a neighbor nonword. Further, a similar pattern emerged in the error data. In addition, as Sternberg (1969) noted, the finding of a null interaction must be interpreted with some caution because it is possible for two factors to affect a common stage in an additive fashion. Experiment 3 was, therefore, an attempt to evaluate the conclusion that semantic priming is not a lexical activation phenomenon in a slightly different fashion.

Experiment 3 used visible semantic primes that were related (vs. unrelated) to the masked primes (now words) rather than the targets. Specifically, Experiment 3 examined whether visible semantic primes could make the masked word primes more effective lexical inhibitors of neighbor targets by increasing those primes' lexical activation. Results indicate that the lexical inhibition effect produced by the masked word neighbor primes was not increased by the visible primes that were semantically related to the masked primes (at either the 267-ms or 1,467-ms SOA), again suggesting that visible semantic primes do not affect lexical activation of semantically related concepts. Therefore, the findings of all three experiments are most supportive of the idea that, in the LDT, the locus of the semantic priming effect is postlexical (e.g., via semantic matching).

Implications

As just noted, the results of the present research are most consistent with postlexical accounts of semantic priming, where the related prime facilitates the discrimination of words from nonwords in a LDT (Neely et al., 1989; Ratcliff & McKoon, 1988). To a large degree, this conclusion dovetails with the recent claims of de Wit and Kinoshita (2014, 2015a, 2015b) based on (a) those authors' demonstration that semantic priming can be modulated by RP in an LDT even with a short SOA, (b) those authors' claim that when the visibility of the prime is carefully controlled, as it was in their experiment, there is no evidence of a masked semantic priming effect (if spreading activation is a real process, one would expect to observe it even when the prime is masked), and (c) unlike in the semantic categorization task, the size of the priming effect in the LDT was larger for slower items (as was also observed in the present experiments).

With respect to the first of these claims, note that de Wit and Kinoshita (2014, 2015a, 2015b) consistently used a 240-ms SOA to limit the use of expectancy set generation, allowing them to focus on the existence of spreading activation rather than lexical activation in general. Assuming that no expectancy set generation was possible in de Wit and Kinoshita's (2015a) experiments is crucial in interpreting their observation of an RP effect. That is, because expectancy sets presumably cannot be formed within a 240-ms SOA, any effect they observe would have to be either a spreading activation effect or a postlexical effect. Because the spreading activation process, presumably, cannot produce an RP effect, the existence of such an effect clearly points toward the impact of a postlexical process.

One point that should be noted here, however, is that it isn't entirely clear how long expectancy generation actually takes. For example, although Hutchison et al. (2001) did not find an RP effect at an SOA of 167 ms, they did find an RP effect at an SOA of 300 ms whereas Hutchison (2007) found an effect with a 267-ms SOA. Results such as these suggest that the idea that an SOA of less than 300 ms removes the ability of participants to generate expectancies is likely a bit too strong. Further, it would seem that the ability to generate expectancies would seem to be affected by at least two other factors, the ability/motivation of the participants as well as the nature of the particular expectancies being generated. With respect to the first of these, Hutchison (2007; see also Heyman, Van Rensbergen, Storms, Hutchison, & De Deyne, 2015; Hutchison, Heap, Neely, & Thomas, 2014) has argued that individuals vary in their ability to generate associates based on his demonstration of an RP effect (in a naming task) at a 267-ms SOA that interacted with differences in a measure of participants' attentional control. This result provides support for the idea that when using SOAs in the 267-ms range, the existence or nonexistence of RP effects reflect individual differences in generating semantic associates.

With respect to the second issue, the nature of the particular expectancies being generated, it's important to begin by noting that: a) it was Neely's (1977) experiments that initially suggested that the SOA needs to be at least longer than 250 ms for expectancy generation to produce priming and b) that Neely's experiments seemed to require an rather unusual expectancy generation process. Specifically, in the two crucial conditions, category primes were used and participants were required to generate expectancies for exemplars from a different category. That is, they were expected to generate an expectancy of exemplars from the building part category (e.g., *door*), based on the category prime *body* and exemplars from the body part category (e.g., *neck*) based on the category label *building*. Generating expectancies for associates or semantically similar items (i.e., the types of related pairs typically used in most experiments in the literature) is likely to be somewhat faster than generating expectancies was in Neely's experiments, a point that has been previously been argued by Balota, Black, and Cheney (1992). Hence, it is not impossible that neither de Wit and Kinoshita's (2014, 2015a, 2015b) short SOAs nor the short SOA conditions in the present experiments have provided an uncontaminated examination of the potential impact of spreading activation (i.e., an impact uncontaminated by effects attributable to expectancy generation).

There are reasons, therefore, to challenge not only de Wit and Kinoshita's (2015a, 2015b) claim that they have provided an uncontaminated examination of the spreading activation hypothesis but also, as noted previously, their other claims as well. The present findings do, nonetheless, not only provide support for their basic claim that semantic priming effects in the LDT at short SOAs have a postlexical locus (e.g., semantic matching) rather than a lexical locus (i.e., automatic spreading activation), these findings also extend de Wit and Kinoshita's basic argument that semantic priming has a postlexical locus to the situation in which expectancy set generation is possible. Specifically, even when the SOA is long enough to allow generation of expectancy sets, a process that is assumed to heighten the activation of the lexical representations of the words in the expectancy set, the semantic priming effect still appears to be driven by a process like semantic matching. The conclusion the present data suggest, therefore, that semantic priming in a LDT is not a lexical activation process at any SOA, is, in fact, even a bit stronger than the claims made de Wit and Kinoshita.

Semantic Priming × Stimulus Quality Interaction

Although the present data and conclusions dovetail well with de Wit and Kinoshita's (2014, 2015a, 2015b) position, those data and conclusions do not seem to dovetail well with a number of other phenomena in the literature. Although a full examination of these apparent contradictions will not be provided here, it would seem to be important to discuss at least of few of what might be considered the more prominent ones. One is the seemingly well-established overadditive interaction between semantic priming and stimulus quality in the LDT (Balota et al., 2008; Becker & Killion, 1977; Borowsky & Besner, 1993; Meyer, Schvaneveldt, & Ruddy, 1975; Scaltritti, Balota, & Peressotti, 2013; Stolz & Neely, 1995; Thomas et al., 2012). Specifically, the semantic priming effect has been typically found to be larger when the targets are degraded (vs. clear). Target degradation is assumed to have its impact early in the word recognition process by slowing the rate at which visual features activate their letter-level representations. Numerous researchers (e.g., Borowsky & Masson, 1996; Scaltritti et al., 2013; Stolz & Neely, 1995; Thomas et al., 2012) have argued, therefore, that, based on additive factors logic (Sternberg, 1969), the Semantic Priming × Stimulus Quality interaction indicates that the two factors influence a common stage of word processing, presumably an early stage. The Semantic Priming × Stimulus Quality interaction would seem, therefore, to provide good evidence for accounts of semantic priming as a lexical activation phenomenon. For example, Stolz and Neely (1995; see also Borowsky & Besner, 1993) proposed that a related semantic prime will activate the lexical representation of its target, reducing the amount of visual information required for recognition (thus compensating for the slower extraction of visual information as a result of the degradation).

More recently, however, Thomas et al. (2012) have produced new evidence concerning the nature of the semantic priming by stimulus quality interaction. As noted above, Thomas et al. examined this interaction as a function of the direction of the association between the prime and target, using prime–target pairs with only strong backward associations (e.g., *small-shrink*), only strong forward associations (*keg-beer*), or symmetric associations (*east-west*). Thomas et al. found the overadditive interaction with symmetric and backward associated prime–target pairs but not with forward associated pairs. That is, the interaction only arose for pairs in which there was a backward association. That fact led Thomas et al. to argue that the existence of a backward overadditive interaction was attributable to a strategic and compensatory *retrospective* use of the semantic information from the prime while processing the degraded target. That is, similar to the logic of Balota et al. (2008), Thomas et al. suggested that degraded targets lead to greater reliance on the information from the prime than when the target is clear, although retrospective use of the prime is still occurring with clear targets, just to a lesser extent. Greater reliance on a semantically related prime leads to a reduced impairment from degradation when the prime is related (vs. unrelated) to the target in a backward direction. If Thomas et al.'s analysis is correct, the implication would be that the commonly found Semantic Priming × Stimulus Quality interaction does not reflect the actions of a preactivation process and, therefore, does not pose a strong challenge to the conclusion that semantic priming is a postlexical phenomenon.

Two other aspects of Thomas et al.'s (2012) data are also relevant to this discussion. One is that the priming effects in their symmetric and backward associated pairs increased across quantiles, paralleling the effects in the present experiment, while the priming effects in forward associated pairs did not. Second, the semantic priming effects obtained by Thomas et al. in prime–target pairs with symmetric associations were equivalent to the sum of the priming effects in prime–target pairs with forward and backward associations. Based on their entire pattern of results, Thomas et al. argued for both prospective and retrospective priming mechanisms with the forward associated pairs invoking only the former, the backward associated pairs only the latter and the symmetric pairs invoking both.

If Thomas et al.'s (2012) argument is correct, it does raise the question of what is the locus of the priming effects for forward associated pairs. As just noted, Thomas et al.'s findings that there was no interaction between semantic priming and target degradation for forward associated pairs and that those pairs did not show increasing effect size across quantiles, suggest that those primes did not produce priming via the same sort of retrospective mechanism producing priming for the other two types of pairs. Although there is no obvious answer to this question, it's worth noting that the semantic priming effects in the present Experiments 1 and 2 were based to a greater degree on forward associations than backward associations, as the visible semantically related prime–target pairs in the present Experiments 1 and 2, had greater forward than backward association strengths (.27 vs. .14 in Experiment 1 and .30 vs. .14 in Experiment 2). Thus, the present results do not provide a replication of Thomas et al.'s results using forward associated pairs. Rather, our findings of additivity between visible semantic and masked neighbor priming effects and an increasing semantic effect size over quantiles suggest that even essentially forward associated pairs produce priming via a retrospective mechanism.

Lexical Decision Versus Semantic Categorization Tasks

Although masked semantic priming effects have been found in the LDT (e.g., Marcel, 1983), as argued by de Wit and Kinoshita (2014) those effects have been unreliable (see McNamara, 2005 for a review). Unlike in the LDT, however, one inevitably finds masked semantic priming effects in a semantic categorization task (e.g., Frenck-Mestre & Bueno, 1999; Grainger & Frenck-Mestre, 1998; McRae & Boisvert, 1998). The obvious implication is that the priming in that task is attributable to something like a preactivation process. What needs to be noted, however, is that the mechanisms of semantic priming very likely differ in the lexical decision and semantic categorization tasks (de Wit & Kinoshita, 2014, 2015a, 2015b; Kusunose, Hino, & Lupker, 2016) and, therefore, the activation producing the masked priming in the semantic categorization task may very well not be activation of lexical representations. For example, de Wit and Kinoshita argue that in the semantic categorization task, evidence for the decision consists of activated semantic features that are indicative of category membership. It may well be the case that category diagnostic features are activated by a semantically related prime and are then amalgamated with those belonging to the target because of the close temporal proximity of the prime and target. The semantic features activated by a related prime, rather than a preactivated lexical representation of the target, would be, therefore, what produces a head start in accumulating evidence for an accurate decision about the target. No such process would appear to be involved when one is making a lexical decision.

Consistent with these ideas, note that de Wit and Kinoshita (2015a, Experiment 2) did observe a masked semantic priming effect when the semantic categorization task was used, in contrast to not being able to obtain a masked semantic priming effect in their LDT. Further, the masked semantic priming effects found by de Wit and Kinoshita (2015a) in their semantic categorization task did not increase across quantiles, a finding consistent with a head start because of the accumulation of semantic features from the prime as well as being one that contrasts with the pattern for semantic priming effects in the LDT both reported by de Wit and Kinoshita and observed in the present experiments.

Lexical Decision Versus Naming Tasks

The naming task has also been used to examine semantic priming effects and those effects have been attributed to spreading activation and/or expectancy generation processes. Further, as some have argued, naming (vs. the LDT) may provide a purer measure of the prelexical influences of a prime on its target (Balota & Lorch, 1986; Seidenberg, Waters, Sanders, & Langer, 1984). Unlike in the LDT, however, it has actually been harder to localize those effects for a couple of reasons. First, the effects tend to be somewhat smaller in naming than in other tasks. Therefore, unlike in the LDT or semantic categorization task, the stimulus pairs that have typically been used in those experiments were selected based on the fact that they have strong associative links. Second, as a result of mainly using strongly associated pairs, it is unclear whether the effects are based on semantic similarity or on verbal associations (e.g., Hutchison, Balota, Cortese, & Watson, 2008; Lupker, 1984). If they are based on verbal associations, the basis for the priming may very well not be the activation of the target's lexical representation, but rather the activation of the target's phonology, because the production of phonology is what the task calls for. How that phonological information is stored and retrieved is far from clear. For example, if one subscribes to some version of the dual-route model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), one can imagine that, in many circumstances, target responding is based on some sort of assembly process rather than activation of and retrieval from the target's lexical representation.

Conclusion

The present research is an attempt to examine the locus of the semantic priming effect in an LDT. Numerous accounts suggest that semantic primes facilitate responses in an LDT by preactivating the lexical representations of their targets. Specifically, at short SOAs, semantic priming effects have been explained as being attributable to target preactivation via an automatic spreading activation process (Collins & Loftus, 1975), whereas expectancy generation (Becker, 1980) has been considered to be the mechanism of preactivation at long SOAs. Additive effects of visible semantic primes and masked nonword neighbor primes (Experiments 1 and 2), as well as the finding that a visible semantic prime did not make a masked word neighbor prime a more effective lexical inhibitor of its target (Experiment 3) suggest that the impact of a semantic prime is not to heighten the activation of related targets but, rather, that the impact of a semantic prime arises postlexically. That is, as has been argued elsewhere (Balota & Chumbley, 1984; Balota, Ferraro, & Connor, 1991), an LDT response depends not only on word identification processes, but also on the process of discriminating between words and, in particular, word-like nonwords. The present results suggest that the impact of a related (vs. unrelated) semantic prime appears to be to facilitate the process of making that discrimination.

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(*Appendices follow*)

Appendix A

Stimuli in Experiment 1

Related visible semantic prime	Unrelated visible semantic prime	Neighbor masked prime	Non-neighbor masked prime	Target
		Word targets		
kilometer	believe	milz	bgsh	MILE
harvest	moonlight	crvps	plwte	CROPS
interrupt	recycle	rqde	fjst	RUDE
shrub	entrance	bgsh	cglm	BUSH
characteristic	sunrise	trjit	blgsh	TRAIT
pickles	cane	diwl	cbte	DILL
paste	claw	glun	crqb	GLUE
vote	century	elgct	spwke	ELECT
knife	rough	fbrk	mpll	FORK
winner	torch	lnser	swnat	LOSER
secretary	purpose	bwss	milz	BOSS
basket	measurement	wepve	stpck	WEAVE
china	cap	dnsh	wrol	DISH
plaza	crocodile	mpll	achb	MALL
lobster	parking	crqb	bikd	CRAB
hip	continent	bhne	knss	BONE
key	rationalize	lvck	dnsh	LOCK
seashore	when	shsll	prjce	SHELL
ozone	bean	layqr	stbck	LAYER
pile	service	stzck	frims	STACK
exercise	teller	swnat	trjit	SWEAT
cinnamon	escargot	tohst	shsll	TOAST
coral	smoky	rvef	tfrt	REEF
meat	drapes	stvak	fpnce	STEAK
mutton	corporation	lkmb	dvsk	LAMB
defrost	proprietor	thfw	glun	THAW
deal	chipmunk	cwrds	lxdge	CARDS
intoxicated	diminish	drtnk	bglly	DRUNK
french	chairperson	frims	stmff	FRIES
push	kleenex	shdve	prtss	SHOVE
daring	untrue	brsve	ddtnk	BRAVE
gate	secretive	fpnce	spvll	FENCE
fight	fugitive	fjst	lkmb	FIST
balcony	proof	lxdge	stzck	LEDGE
jock	pan	strbp	lnser	STRAP
disgusting	world	grjss	shdve	GROSS
dawn	buy	dvsk	rqde	DUSK
mammal	scotch	whkle	sphll	WHALE
dip	lean	chbp	rvef	CHIP
rigid	pudding	stmff	twsty	STIFF
lips	lonely	knss	sxng	KISS
adorable	sling	cbte	drjp	CUTE
uptight	happening	trnse	strbp	TENSE
song	sharp	sxng	bhke	SING
hiking	loss	bovts	xrsve	BOOTS
stomach	reflection	achb	chbp	ACHE
chicken	mellow	sfup	lvck	SOUP
embarrass	erect	blgsh	prnme	BLUSH
trench	reminiscence	cbat	thwn	COAT
leak	energy	drjp	hmll	DRIP
idol	swoon	bglly	crvps	BILLY
cushion	quest	coxch	gwrds	COUCH
pedal	rock	bikd	fbrk	BIKE
washcloth	all	towql	shnve	TOWEL
sheep	chemist	wrol	cbts	WOOL

(*Appendices continue*)

Appendix A (*continued*)

Related visible semantic prime	Unrelated visible semantic prime	Neighbor masked prime	Non-neighbor masked prime	Target
soothe	cry	cglm	shvw	CALM
fog	entertain	mfst	lmnd	MIST
litter	roast	cbts	sfup	CATS
borrow	starving	lmnd	mfst	LEND
tangy	plates	tfrt	mnle	TART
foam	expensive	shnve	layqr	SHAVE
delicious	reality	twsty	whkle	TASTY
pour	mafia	sphll	towqr	SPILL
dish	tame	plwte	swrry	PLATE
		Nonword targets		
	spot	rznes	plsmb	PAKE
	gloves	binws	rpddy	CATE
	maggot	selns	wvody	GATS
	monastery	cmrts	glnze	MEST
	squeak	gakrs	bjnny	DARS
	wart	seqls	fmnch	DATS
	gene	silrs	broty	LANS
	cooler	plats	lhwly	DEAT
	slay	gnre	dtgs	GARE
	further	rgle	dhts	RALE
	organize	silf	dkrs	SILE
	minutes	wxts	midv	WATS
	commander	poqt	lqre	POOT
	warmth	lgat	pcke	LEAT
	tack	caln	rinv	CALE
	lingerie	hmne	wxts	HANE
	dice	shtes	fbzzy	DAGS
	merit	cinzs	mtggy	HARS
	thesaurus	tanvs	fclly	LAVE
	none	wbtes	chznk	FANE
	hide	bxtch	mirtf	HORE
	wag	slgnk	wbtty	PAGS
	everyday	dowkd	sgrly	RANS
	jaw	ltnks	bkmpy	SARE
	castle	hwne	gnrk	HINE
	pyramid	midv	gwts	MIDE
	sleep	tanh	lgat	TANE
	deteriorate	ponb	baqt	PONE
	tree	lqre	mcst	LARE
	attract	rinv	hgrs	RINE
	saliva	bdal	rgle	BEAL
	giggle	rfme	dsat	RAME
	crook	pcke	bdel	RINES
	cry	cath	svro	BINES
	havoc	gwts	dtke	SEANS
	appearance	mcst	caln	CORTS
	hula	dkrs	silf	GAKES
	transplant	dhts	tonh	SEELS
	verse	lrns	hwre	SILES
	extravagant	dsat	lkve	PEATS
	twist	tatjs	rjmmy	TATES
	unload	crles	dgwdy	CALES
	ore	catgs	plmnk	CATES
	clean	pvlls	tjmid	PELLS
	type	tbked	blrom	TAKED
	dislike	rlves	pjtty	RIVES
	introduce	hkves	tzint	HOVES
	vacate	ralds	bcnny	RALES
	sapphire	dtgs	cbat	SATES

(*Appendices continue*)

Appendix A (*continued*)

Related visible semantic prime	Unrelated visible semantic prime	Neighbor masked prime	Non-neighbor masked prime	Target
	gang	hgrs	coth	CINES
	message	lkve	bwts	TANES
	gander	fcne	plbk	WATES
	bow	hwre	rbns	BETCH
	tuxedo	pkgs	hwne	SLANK
	aright	rbns	pomb	DOWED
	ordinary	svre	lrns	LANKS
	tight	metrs	cltck	MEARS
	steel	phkes	wjnch	PAKES
	razor	ctles	pqrky	COLES
	stairs	kvnes	bxlgy	KINES
	nylon	pkres	chgck	PARES
	wit	lknds	mxcky	LINDS
	labyrinth	rxats	mbldy	REATS
	noun	fynes	dftty	FANES

Appendix B

Stimuli From Experiment 2

Related visible semantic prime	Unrelated visible semantic prime	Neighbor masked prime	Non-neighbor masked prime	Target
		Word targets		
foil	jail	alxminum	evidengx	ALUMINUM
downstairs	pissed	upstadrs	dinojaur	UPSTAIRS
detail	physiology	specidic	umstakrs	SPECIFIC
climate	razor	wekther	edomion	WEATHER
agency	pliers	cmmpany	britzin	COMPANY
feeling	gate	edotion	tiyhteg	EMOTION
file	development	cabsnet	fightcr	CABINET
foggy	plain	unclcar	jokrney	UNCLEAR
movement	step	mohion	windvw	MOTION
caution	originate	dacger	wgnnuf	DANGER
again	opening	reneat	pimkle	REPEAT
center	summer	mxddle	reneat	MIDDLE
boxing	libel	glozes	scarmd	GLOVES
clorox	example	blpach	geojge	BLEACH
machine	left	washbr	cheeme	WASHER
swiss	art	cheeme	systxm	CHEESE
convince	claim	perguade	mujcerer	PERSUADE
agree	mailman	disdgree	subfract	DISAGREE
killer	sample	murcerer	byogcoli	MURDERER
baggage	sandpaper	lyggage	colosna	LUGGAGE
egypt	attract	pyramsd	mijifum	PYRAMID
cabinet	punctuation	kipchen	fomevar	KITCHEN
england	like	britzin	ajerica	BRITAIN
tricycle	runner	bicycxe	dajloon	BICYCLE
angel	thrift	hehven	circye	HEAVEN
unconscious	lettuce	aslmep	exhjle	ASLEEP
buck	glory	dollyr	crnfts	DOLLAR
presume	grandpa	aksume	sticgy	ASSUME
princess	production	prynce	gllwth	PRINCE
hydrogen	fire	oxygln	rrcket	OXYGEN
curious	honey	geojge	pxnder	GEORGE
congress	bike	srnate	oxygln	SENATE
careful	cyclone	cautiows	obsnacle	CAUTIOUS

(*Appendices continue*)

Appendix B (*continued*)

Related visible semantic prime	Unrelated visible semantic prime	Neighbor masked prime	Non-neighbor masked prime	Target
sub	curious	sandwvch	perguade	SANDWICH
senate	push	congless	mnstache	CONGRESS
reckless	picture	drixing	abapdon	DRIVING
language	brunette	enklish	mannfrs	ENGLISH
thanks	wag	wtlcome	kipphen	WELCOME
usual	hidden	uvusual	wqiting	UNUSUAL
loosen	raft	tiyhten	uvusual	TIGHTEN
dinner	dissimilar	sjpper	jaqkut	SUPPER
beautiful	kilometer	prmtty	whgper	PRETTY
lapel	goal	colfar	wziteq	COLLAR
diameter	silk	circye	ayvici	CIRCLE
suggest	no	ayvice	cvreal	ADVICE
contemporary	opportunity	modbrn	nxpdle	MODERN
contest	chart	wgnner	lahdip	WINNER
fiber	official	cvreal	dacger	CEREAL
proof	corridor	evidenge	disqgrea	EVIDENCE
pastry	develop	dohghnut	sandwvch	DOUGHNUT
shears	ambulance	scessors	cgutiows	SCISSORS
known	clown	unkcown	cabsnet	UNKNOWN
monday	patience	tudsday	cmmpani	TUESDAY
always	even	fomever	mansbik	FOREVER
liberty	detach	freedqm	bsilper	FREEDOM
tupperware	fasten	pvastic	tudjday	PLASTIC
metric	magnet	systxm	prmlty	SYSTEM
scare	polyester	frbght	colfar	FRIGHT
insecure	lick	secuqe	frbght	SECURE
fig	spring	newtrn	dollyr	NEWTON
inhale	for	exhjle	funlus	EXHALE
cowgirl	grocery	covboy	thgead	COWBOY
burst	since	bsbble	novrca	BUBBLE
dig	fall	svovel	aslmap	SHOVEL
system	sunny	comptter	busicess	COMPUTER
normal	egypt	avnormal	cememony	ABNORMAL
corporation	piece	busicess	specidic	BUSINESS
frankenstein	gloves	monsber	achkeve	MONSTER
defend	screw	progect	enlland	PROTECT
etiquette	friday	mannfrs	unclcar	MANNERS
cursive	elf	wqiting	lyggage	WRITING
delicate	salad	fragike	pmowect	FRAGILE
innocence	sale	guzlty	blpach	GUILTY
shrine	cloak	trmple	bsbbhu	TEMPLE
poet	zit	wrgter	glozas	WRITER
rung	denial	lahder	swfool	LADDER
kill	air	murfer	rqttle	MURDER
arts	shield	crnfts	offzce	CRAFTS
rake	airport	leazes	grouyd	LEAVES
development	tuxedo	grlwth	nfture	GROWTH
add	sash	subfract	avnosmal	SUBTRACT
issue	oodles	mfgazine	tehriblz	MAGAZINE
cauliflower	metric	byoccoli	dathrcom	BROCCOLI
london	sheep	enlland	glwsses	ENGLAND
quest	college	jokrney	wtlcome	JOURNEY
goal	girl	achseve	drixing	ACHIEVE
contractor	toss	bsilder	garbaye	BUILDER
warrior	toothpaste	fightcr	trailzd	FIGHTER
glass	affair	windvw	afbica	WINDOW
zit	slimy	pimkle	trnpra	PIMPLE
server	dad	wziter	leazis	WAITER
bacteria	tear	funlus	aksume	FUNGUS
needle	rent	thgead	murfer	THREAD

(*Appendices continue*)

Appendix B (*continued*)

Related visible semantic prime	Unrelated visible semantic prime	Neighbor masked prime	Non-neighbor masked prime	Target
hairspray	hold	sticgy	ljpper	STICKY
roam	temper	wcnder	helpkj	WANDER
shake	diameter	rqttle	wcnder	RATTLE
indoors	rhythm	outdtors	mfgazine	OUTDOORS
drapes	ash	curtqins	oatdtorc	CURTAINS
overcome	steel	obsnacle	dohghnut	OBSTACLE
crab	dead	lobswer	feebing	LOBSTER
emotion	meaningful	feesing	graguke	FEELING
musk	original	colosne	pvastic	COLOGNE
tractor	gym	trailzr	enklish	TRAILER
dump	advance	garbaye	lobswer	GARBAGE
hole	alto	grouyd	mohion	GROUND
launch	office	rrcket	modbrn	ROCKET
college	obligation	swhool	prynce	SCHOOL
crayola	post	craynn	tvcket	CRAYON
assistant	age	helpkr	guzlty	HELPER
natural	government	nfture	covboy	NATURE
goose	seem	gxnder	hehvan	GANDER
guardian	annihilate	pyrent	craygn	PARENT
ritual	careful	cememony	botptter	CEREMONY
beard	saltine	mnstache	curfqins	MUSTACHE
fossil	clorox	dinojaur	colgless	DINOSAUR
helium	defend	bajloon	freedqm	BALLOON
lens	delicious	glwsses	wekthor	GLASSES
maximum	jaw	mijimum	pyransd	MINIMUM
disown	provision	abapdon	bicycxe	ABANDON
usa	tube	ajerica	unkcown	AMERICA
beginner	rod	novrce	mewtrn	NOVICE
vest	winner	jaqket	cjring	JACKET
loving	dignity	cjring	vhcest	CARING
jesus	chunk	chcist	srnate	CHRIST
post	entertainment	offzce	svovel	OFFICE
fear	crab	scarmd	pyrent	SCARED
admission	lava	tvcket	sekuqe	TICKET
continent	threat	afnica	washbr	AFRICA
		Nonword targets		
	baseball	blpnging	phimtrdw	BLINGING
	mountain	flwtting	bilckadr	FLOTTING
	firefly	stdpping	counbumk	STIPPING
	charger	dendpng	kuarils	DENDING
	tornado	happihg	clowosd	HAPPING
	student	dappnng	gtiliak	DAPPING
	comment	louzded	millijg	LOUNDED
	nervous	dailisg	silmokw	DAILING
	future	magked	huttyr	MACKED
	flower	cayigg	pfgged	CAYING
	number	pqnder	rogpod	PENDER
	drawer	caggtd	yebrek	CAGGED
	around	badter	netjlc	BASTER
	better	counns	barxed	COUNDS
	nephew	pfgged	bocktr	PUGGED
	honest	yagred	gmking	YAGGED
	handle	goundirg	prrppyns	GOUNDING
	headache	bllcking	stdppamc	BLICKING
	superior	grokping	batvered	GROPPING
	trouble	sillikg	nastmnq	SILLING
	everything	nastmng	hemsimk	NASTING
	alright	gasttng	zeariyq	GASTING
	strange	rbsting	cetmubs	RASTING

(*Appendices continue*)

Appendix B (*continued*)

Related visible semantic prime	Unrelated visible semantic prime	Neighbor masked prime	Non-neighbor masked prime	Target
	mistake	pecling	daifosp	PELLING
	create	sqmble	randjr	SUMBLE
	energy	bazted	desnar	BALTED
	secret	randjr	cuxped	RANDER
	staple	heqter	loalvd	HETTER
	hating	brynch	ssarts	BRENCH
	tissue	henjer	loptad	HENDER
	direct	prxing	ratttr	PAXING
	strict	nettlr	hicves	NETTER
	valuable	ratcling	gounderl	RATCHING
	criminal	stapzing	toundbrt	STAPPING
	innocent	toundbng	blpjgidf	TOUNDING
	success	nendzng	dadkifz	NENDING
	clothes	rcating	dendpsq	REATING
	bargain	rixling	seafobp	RILLING
	soprano	mitbers	lopming	MITTERS
	patient	lillijg	papqanv	LILLING
	seller	lotger	henjak	LOTTER
	polite	ssarts	ccsing	SHARTS
	smooth	dacded	ceyigg	DACKED
	accuse	degder	prxing	DENDER
	marker	pucged	negmas	PUCKED
	finish	smacks	colted	SPACKS
	chance	colted	paylow	COOTED
	before	huttyr	pxshed	HUTTER
	electric	slorping	drundugk	SLOOPING
	tabletop	drunding	ratcltre	DOUNDING
	medicine	batvered	jounging	BATHERED
	pudding	yeating	slupner	YEARING
	alcohol	gtiling	nackjop	GAILING
	cleaner	cotnded	nendzng	COUNDED
	tent	pestilg	mitbers	PESTING
	weekend	rwnning	peclaum	RINNING
	tomato	pogled	ranbas	POILED
	coil	davwng	powisk	DAVING
	hunger	follhd	pqnder	FOLLED
	kidnap	baplow	lotger	BALLOW
	picket	ratttr	feying	RATTER
	ending	faying	bezted	FATING
	attack	sxamed	rvving	STAMED
	armadillo	paylow	kogbed	PALLOW
	security	trbpping	pevwnadl	TROPPING
	backward	prvwning	ramtered	PROWNING
	juvenile	counbing	lounring	COUNDING
	bedroom	roppikg	gyndunk	ROPPING
	wedding	ranring	dimtaum	RANNING
	tyrrany	yetbing	rwnnaum	YETTING
	meaning	ldaming	dappnak	LEAMING
	partner	slatner	fetbixg	SLATTER
	potato	ccsing	baplow	COSING
	stress	wrcked	slacas	WOCKED
	dishes	ranbed	ngmgle	RANNED
	abstract	wlcing	magked	WACING
	change	camred	pepyas	CARRED
	divide	slaced	dinixz	STACED
	report	bocktd	sxamek	BOCKED
	gamble	nugmed	rickpo	NUGGED
	inferior	jounging	stapzugl	JOUNDING
	thursday	srribing	tlorposd	STRIBING
	remember	plintrng	srribiqp	PLINTING

(*Appendices continue*)

Appendix B (*continued*)

Related visible semantic prime	Unrelated visible semantic prime	Neighbor masked prime	Non-neighbor masked prime	Target
	reptile	cetming	rcatutc	CETTING
	crackle	nackjng	pestils	NACKING
	clipper	zeariyg	happuhd	ZEARING
	science	gynding	knlktjs	GENDING
	promise	kearilg	rynkanl	KEARING
	reason	barxed	wrckap	BARTED
	found	powisg	vinger	POWING
	polish	dining	smacrs	DIRING
	turtle	rvving	cipred	RIVING
	course	pxshed	counns	PASHED
	whole	rogped	wlcing	ROPPED
	meat	happmd	ceqter	HAPPED
	prison	gmking	follhd	GAKING
	decision	glantvng	spoomimp	GLANTING
	backpack	lounring	kattercd	LOUNDING
	reaction	ramtered	flwlting	RATTERED
	preview	clowisg	gasttna	CLOWING
	excited	lipming	mdanaum	LIPPING
	grandma	knnding	rixlaum	KENDING
	attempt	hemsing	louzded	HEASING
	brother	seafing	yitbadf	SEADING
	navigate	blcker	dapptd	BUCKER
	cactus	langjd	heppma	LANGED
	appear	cipred	langjk	CIPPED
	choose	hecver	davwng	HEAVER
	female	cuxped	stawos	CUMPED
	sports	vinger	camrod	VINDER
	saucer	bzving	caggtd	BAVING
	seatpost	desner	lilgod	DESTER
	geometry	spooming	trbppubp	SPOOTING
	stillness	prrpping	glantvvp	PRIPPING
	homework	lattercd	grokping	LATTERED
	present	papqing	yeatets	PAPPING
	highway	danting	rulrodw	DANNING
	closing	dadking	roppoks	DACKING
	crunchy	fettixg	rbsgond	FETTING
	flowers	rynking	cotnded	RINKING
	record	ngmble	pucged	NUMBLE
	church	dapptd	bedter	DAPPED
	hunter	lealvd	digder	LEALED
	peanut	rickpd	bzving	RICKED
	sneeze	lepted	sqmble	LESTED
	winter	lilged	blckor	LINGED
	hammer	stawhd	brynch	STAWED
	sorrow	papyed	decdak	PAPPED

(*Appendices continue*)

Appendix C

Stimuli From Experiment 3

Neighbor word primes			Non-neighbor word primes			
Related visible semantic prime	Unrelated visible semantic prime	Masked prime	Related visible semantic prime	Unrelated visible semantic prime	Masked prime	Target
Word targets						
cow	james	milk	idle	chair	busy	MILE
bridge	sugar	cross	time	tv	place	CROPS
horse	team	ride	items	trim	list	RUDE
idle	green	busy	phone	tight	call	BUSH
car	higher	train	toilet	disease	flush	TRAIT
boring	have	dull	disease	hit	cure	DILL
sky	elephant	blue	take	market	grab	GLUE
monument	least	erect	wheel	bridge	spoke	ELECT
play	idle	work	female	sugar	male	FORK
higher	water	lower	sugar	ivory	sweet	LOSER
gain	read	loss	cow	deny	milk	BOSS
go	chair	leave	market	dig	stock	WEAVE
water	ivory	fish	tree	idle	wood	DISH
female	pop	male	land	toilet	acre	MALL
take	phone	grab	teeth	higher	bite	CRAB
james	gain	bond	hit	rapid	miss	BONE
have	moving	lack	water	have	fish	LOCK
scent	attempts	smell	fee	moving	price	SHELL
now	land	later	rapid	horse	quick	LAYER
market	trim	stock	attempts	things	tries	STACK
sugar	play	sweet	car	apologize	train	SWEAT
beach	poker	coast	scent	fall	smell	TOAST
fishing	market	reel	tight	juice	taut	REEF
listen	hay	speak	therefore	time	hence	STEAK
light	go	lamp	chair	boat	desk	LAMB
this	pay	that	sky	bench	blue	THAW
poker	things	yards	trim	wheel	hedge	CARDS
elephant	fishing	trunk	goofy	poker	silly	DRUNK
attempts	car	tries	things	pop	stuff	FRIES
sea	teeth	shore	bench	mean	press	SHOVE
dead	goofy	grave	juice	land	drink	BRAVE
therefore	this	hence	moving	car	still	FENCE
items	mean	list	light	minister	lamp	FIST
trim	items	hedge	beef	bruises	jerky	LEDGE
hay	female	straw	higher	therefore	lower	STRAP
green	disease	grass	sea	goofy	shore	GROSS
chair	body	desk	horse	items	ride	DUSK
during	bridge	while	deny	follow	admit	WHALE
boat	toilet	ship	fishing	tree	reel	CHIP
things	during	stuff	mean	and	nasty	STIFF
hit	time	miss	pop	dead	song	KISS
disease	tight	cure	fall	play	trip	CUTE
common	monument	sense	hay	sea	straw	TENSE
pop	bruises	song	james	beef	bond	SING
read	take	books	dead	hay	grave	BOOTS
land	light	acre	boat	scent	ship	ACHE
body	horse	soul	have	master	lack	SOUP
toilet	boat	flush	minister	take	prime	BLUSH
pay	beach	cost	and	water	then	COAT
fall	cow	trip	mast	fee	hull	DRIP
goofy	therefore	silly	bridge	sky	cross	BILLY
team	now	coach	poker	fishing	yards	COUCH
teeth	sea	bite	play	teeth	work	BIKE
ivory	fall	tower	master	cow	slave	TOWEL

(*Appendices continue*)

Appendix C (*continued*)

Neighbor word primes			Non-neighbor word primes			
Related visible semantic prime	Unrelated visible semantic prime	Masked prime	Related visible semantic prime	Unrelated visible semantic prime	Masked prime	Target
tree	listen	wood	bruises	during	cuts	WOOL
phone	tree	call	tv	body	show	CALM
least	follow	most	follow	mast	lead	MIST
bruises	boring	cuts	body	least	soul	CATS
follow	dead	lead	least	james	most	LEND
tight	master	taut	dig	phone	mole	TART
master	scent	slave	now	female	later	SHAVE
mean	common	nasty	during	light	while	TASTY
moving	hit	still	ivory	now	tower	SPILL
time	sky	place	apologize	attempts	sorry	PLATE
Nonword targets						
coal	necklace	mines	bob	road	plumb	RINES
cedars	quote	pines	cheeks	cheese	ruddy	BINES
geese	wolf	swans	allen	necklace	woody	SEANS
castles	fur	forts	donut	film	glaze	CORTS
glares	rats	gazes	easter	riches	bunny	GAKES
tapes	queen	reels	sparrow	clyde	finch	SEELS
grain	coal	silos	plunder	easter	booty	SILES
fur	chocolate	pelts	meek	swelling	lowly	PEATS
dress	left	garb	shovel	rats	digs	GARE
vale	passage	dale	polka	trees	dots	RALE
left	leaves	side	smack	thread	dabs	SILE
volt	bald	watt	helper	flower	aide	WATS
foot	ring	boot	thread	king	bare	POOT
rhythm	prong	beat	skin	warm	pale	LEAT
chocolate	tapes	bale	pork	meek	rind	CALE
rake	glory	hake	volt	sparrow	watt	HANE
lives	under	saves	warm	earl	fuzzy	SATES
waffle	cedars	cones	humid	camera	muggy	CINES
waxes	foot	wanes	wisdom	champagne	folly	TANES
electricity	king	watts	hunk	plunder	chunk	WATES
haircut	rake	butch	joy	clever	mirth	BETCH
lazy	stick	slack	clever	skin	witty	SLANK
cathedral	lazy	domed	rude	chicken	surly	DOWED
meadows	smack	larks	road	cheeks	bumpy	LANKS
film	spears	cine	dress	bathroom	garb	HINE
helper	skin	aide	blood	drab	guts	MIDE
prong	electricity	tine	rhythm	quote	beat	TANE
ring	riches	tone	foot	key	boot	PONE
thread	pork	bare	ice	volt	melt	LARE
pork	grain	rind	easy	chocolate	hard	RINE
necklace	waffle	bead	vale	tune	dale	BEAL
run	drum	race	rats	wagon	drat	RAME
skin	run	pale	necklace	pork	bead	PAKE
quote	vale	cite	king	humid	sire	CATE
blood	helper	guts	earl	donut	duke	GATS
ice	far	melt	chocolate	dirty	bale	MEST
smack	camera	dabs	left	vale	side	DARS
polka	geese	dots	prong	shoe	tine	DATS
camera	lives	lens	key	allen	hole	LANS
rats	blood	drat	shoe	rude	lace	DEAT
bald	book	pates	gin	helper	rummy	TATES
stick	glares	canes	drab	package	dowdy	CALES
motel	shoe	bates	champagne	blood	plonk	CATES
lemon	thread	peels	swelling	pay	tumid	PELLS
money	key	taxed	flower	gin	bloom	TAKED
passage	rhythm	rites	bathroom	easy	potty	RIVES

(*Appendices continue*)

Appendix C (*continued*)

Neighbor word primes			Non-neighbor word primes			
Related visible semantic prime	Unrelated visible semantic prime	Masked prime	Related visible semantic prime	Unrelated visible semantic prime	Masked prime	Target
peace	easy	doves	love	left	taint	HOVES
leaves	money	rakes	clyde	ring	bonny	RALES
shovel	dress	digs	pay	bob	cost	DAGS
easy	film	hard	quote	hoist	cite	HARS
shoe	haircut	lace	bacon	smack	bits	LAVE
wolf	peace	bane	pretty	rhythm	pink	FANE
key	cathedral	hole	riches	polka	rags	HORE
book	motel	page	film	pretty	cine	PAGS
riches	castles	rags	ring	wisdom	tone	RANS
king	foals	sire	camera	prong	lens	SARE
far	lemon	nears	chicken	shovel	cluck	MEARS
spears	meadows	pikes	hoist	foot	winch	PAKES
foals	volt	colts	trees	joy	parky	COLES
queen	waxes	kings	package	bacon	bulgy	KINES
courage	shovel	dares	wagon	love	chuck	PARES
under	polka	lings	dirty	ice	mucky	LINDS
drum	ice	beats	cheese	hunk	moldy	REATS
glory	courage	fades	tune	dress	ditty	FANES

Appendix D

Mean Latencies and Error Rates for Nonword Targets From Experiments 1–3

Latencies (Milliseconds) and Error Rates (Percentages) for Nonword Targets as a Function of Masked Orthographic Nonword Prime Type for the Masked Prime, Long, and Short SOA Visible Prime Groups in Experiment 1

	Masked orthographic nonword prime type		
Group	Neighbor	Non-neighbor	Orthographic priming effect
Masked prime	771 (13.8)	781 (12.4)	10 (−1.4)
Short SOA visible prime	804 (13.7)	814 (14.0)	10 (0.3)
Long SOA visible prime	781 (9.1)	773 (9.5)	8 (0.4)

Note. Error rates shown in parentheses.

(*Appendices continue*)

Latencies (Milliseconds) and Error Rates (Percentages) for Nonword Targets as a Function of Masked Orthographic Nonword Prime Type for the Sandwich Prime, Long, and Short SOA Visible Prime Groups in Experiment 2

Group	Masked orthographic nonword prime type: Neighbor	Non-neighbor	Orthographic priming effect
Sandwich prime	782 (7.7)	797 (7.6)	15 (−0.1)
Short SOA visible prime	799 (6.3)	820 (6.5)	21 (0.2)
Long SOA visible prime	797 (6.3)	812 (7.2)	15 (0.9)

Note. Error rates shown in parentheses.

Latencies (Milliseconds) and Error Rates (Percentages) for Nonword Targets as a Function of Visible Semantic and Masked Orthographic Nonword Prime Types for the Masked Prime, Long, and Short SOA Visible Prime Groups in Experiment 3

Group/Visible semantic prime type	Masked orthographic word prime type: Neighbor	Non-neighbor	Orthographic inhibition effect
Masked prime	798 (13.1)	792 (13.8)	−6 (0.7)
Short SOA visible prime			
Related	846 (5.7)	823 (6.1)	−23 (0.4)
Unrelated	828 (5.6)	818 (6.5)	−10 (0.9)
Effect of visible prime	−18 (−0.1)	−5 (0.4)	
Long SOA visible prime			
Related	821 (8.0)	802 (5.6)	−19 (−2.4)
Unrelated	804 (6.0)	816 (6.2)	12 (0.3)
Effect of visible prime	−17 (−2.0)	14 (0.6)	

Note. Error rates shown in parentheses.

(*Appendices continue*)

Appendix E

Analyses of Latencies and Error Rates for Nonword Targets From Experiments 1–3

Experiment 1

Masked prime group.

Nonword latencies. No effect of masked orthographic prime type was found, both *F*s < 2.47, *p*s $> .12$.

Nonword errors. No effect of masked orthographic prime type was found in the subject or item analyses, both *F*s < 1.

Short SOA visible prime group.

Nonword latencies. No effect of masked orthographic prime type was observed on nonword targets, both *F*s < 1.63, *p*s $> .21$.

Nonword errors. Likewise, no effect of masked orthographic prime type was observed, both *F*s < 1.

Long SOA visible prime group.

Nonword latencies. No effect of masked orthographic prime type was observed, both *F*s < 1.54, *p*s $> .22$.

Nonword errors. No effect of masked orthographic prime type was observed, both *F*s < 1.

Experiment 2

Sandwich prime group.

Nonword latencies. Responses to nonword targets were faster following neighbor (vs. non-neighbor) primes in subject and item analyses $F_s(1, 28) = 5.09$, $p = .03$, $\eta^2 = .15$; $F_i(1, 126) = 5.13$, $p = .03$, $\eta^2 = .04$.

Nonword errors. No effects emerged in either analysis, both *F*s < 1.

Short SOA visible prime group.

Nonword latencies. Again, latencies for nonword targets were faster when following neighbor (vs. non-neighbor) masked orthographic primes in the subject and item analyses $F_s(1, 32) = 6.83$, $p = .01$, $\eta^2 = .18$; $F_i(1, 126) = 10.49$, $p = .002$, $\eta^2 = .08$.

Nonword errors. No effect of masked orthographic primes was detected for nonword targets, both *F*s < 1.

Long SOA visible prime group.

Nonword latencies. Consistent with the sandwich prime group, the latencies for target nonwords were faster when following neighbor (vs. non-neighbor) masked orthographic primes in the subject and item analyses $F_s(1, 48) = 7.33$, $p = .009$, $\eta^2 = .13$; $F_i(1, 126) = 7.35$, $p = .008$, $\eta^2 = .06$.

Nonword errors. The facilitation from masked orthographic neighbor (vs. non-neighbor) primes was marginal in subject analyses and not significant in item analyses $F_s(1, 48) = 2.98$, $p = .09$, $\eta^2 = .05$; $F_i(1, 126) = 2.57$, $p = .11$, $\eta^2 = .04$.

Experiment 3

Masked prime group.

Nonword latencies. No effect of masked orthographic prime type was found, both *F*s < 1.

Nonword errors. No effect of masked orthographic prime type was found, both *F*s < 1.

Short SOA visible prime group.

Nonword latencies. Responses to nonword targets were numerically slower when the visible primes were related (vs. unrelated) to the masked orthographic word primes. This effect was not significant in the subject analysis $F_s < 1.93$, *p*s $> .17$, and was only marginal in the item analysis $F_i(1, 60) = 2.94$, $p = .09$, $\eta^2 = .05$. Responses to nonword targets were slower when preceded by a neighbor (vs. non-neighbor) masked orthographic word primes in the subject analysis, $F_s(1, 52) = 4.62$, $p = .04$, $\eta^2 = .08$, and marginally slower in the item analysis, $F_i(1, 60) = 3.45$, $p = .07$, $\eta^2 = .05$. No visible prime by masked orthographic prime interaction was found, both *F*s < 1.

Nonword errors. No effects or interactions were found, all *F*s < 1.

Long SOA visible prime group.

Nonword latencies. No main effects of visible prime or masked orthographic prime were found in subject or item analyses, all *F*s < 1. However, marginal interactions were found between visible and masked orthographic primes in the subject and item analyses, $F_s(1, 40) = 3.16$, $p = .08$, $\eta^2 = .07$; $F_i(1, 60) = 3.71$, $p = .06$, $\eta^2 = .06$.

Nonword errors. There were no main effects of visible prime or masked orthographic prime, all *F*s < 1.42, *p*s $> .24$. No interaction between visible and masked orthographic primes was detected in the subject analyses, $F_s(1, 40) = 2.57$, $p = .12$, $\eta^2 = .06$, however a marginal interaction was detected in the item analyses, $F_i(1, 60) = 3.09$, $p = .08$, $\eta^2 = .05$.

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