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The Effects of Semantic Priming on Lexical Processing

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Abstract

The present experiments were designed to investigate the locus of the semantic priming effect, a phenomenon that has received much research attention. Semantically related primes (e.g., cat) might activate the lexical representations of their targets (e.g., DOG) through automatic spreading activation at short stimulus onset asynchronies (SOAs) between the prime and target, or through generation of words expected to follow the prime at long SOAs. Alternately, semantically related primes might be used strategically to aid responding after target identification. The effects of masked orthographic primes (e.g., judpe-JUDGE), in contrast, are assumed to be strictly lexical and automatic. Lexical processing of targets is facilitated by orthographically similar masked nonword primes and is inhibited by orthographically similar masked word primes (Davis & Lupker, 2006). Using the lexical decision task (LDT), I found additivity between the facilitative effects of visible semantic primes at long and short SOAs and the facilitative effects of masked orthographically similar nonword primes and repetition primes. The masked nonword and repetition primes also produced a shift in the latency distribution of target responses, which is consistent with a head-start produced by pre-activating the target lexical representations. Semantic primes affected the skew of the distribution and had a greater effect on trials with longer latencies, consistent with the idea of those primes being used after target identification. Additionally, visible semantic primes at long and short SOAs did not make masked word primes more effective lexical inhibitors of their targets. Taken together, these findings suggest that the impact of a semantic prime is not to increase the lexical activation of its related target. Rather the locus of the semantic priming effect in an LDT appears to be a post-lexical process, consistent with the idea that the effect is due to the discovery of the existence of a relationship between the prime and target which biases participants to make a "word" response.

Keywords

semantic priming, masked priming, interactive activation and competition model, spreading activation, expectancy generation, semantic matching

Co-Authorship Statement

Dr. Stephen Lupker supervised and edited this dissertation and a submitted manuscript incorporating some of the experiments contained in the dissertation.

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1 Chapter 1: Introduction

In order to successfully read a word, its abstract representation in the mental lexicon must be selected based on the visual information provided. Furthermore, 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 relevant contextual and semantic information. For example, words with more semantic information associated with them are recognized faster in general (James, 1975; Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008; Pexman, Lupker, & Hino, 2002; Yap, Pexman, Wellsby, Hargreaves, & Huff, 2012). Findings that semantic information influences word recognition are consistent with the idea that the lexical system at least partially activates information about the meaning of candidate words before the actual word itself is fully identified (although the mechanisms by which semantic information influences word recognition are not agreed upon, for reviews, see Lupker (2008) and Pexman (2012)).

Reading also involves the integration of contextual information, for example, information from previously read words. The present research examines how contextual information in the form of semantic relationships with previously read words affects the word recognition process. The specific question explored in the present research is how information from a semantically related prime and lexical processing of the target word interact during reading. Semantic priming effects are assumed to provide insight into how semantic information is stored and retrieved from memory during word recognition (McNamara, 2005). The starting point for this research is the Interactive Activation and Competition (IAC) model (McClelland & Rumelhart, 1981) as it has been often used as a general framework for describing the processes involved in visual word recognition.

1.1 Interactive Activation and Competition Model

The IAC model was initially proposed to explain the word superiority effect (Reicher, 1969; Wheeler, 1970), where letters are often identified faster and more accurately when they are in a word than in a nonword or by themselves. The word superiority effect is an example of higher-level information influencing the processing of lower-level information, since the representation of the word must be at least partially activated in order for it to aid in identifying the letters contained in it. The IAC model involves three levels of representation (McClelland & Rumelhart, 1981). Visual input activates feature-level representations, the lowest level representations, which then activate the letter-level representations which then activate word-level (i.e., lexical) representations. Since the IAC is an example of a localist model, the individual features, letters, or words are represented by individual nodes at their respective levels of representation. One of the key aspects of the IAC model is that it assumes activation can flow not only from lower- to higher-level representations but also from higher- to lower-level representations (i.e., activation is interactive). A second key aspect of the IAC model is that it also assumes that activation is cascaded (vs. thresholded), meaning that the next highest level begins receiving activation as soon as processing at the next lower level begins rather than after the processing at that level is complete. The enhanced recognition of letters embedded in a word is thus due to the activation letter-level representations receive from the activated word-level representations (McClelland & Rumelhart, 1981).

In an effort to extend the IAC in order to allow it to explain the influence of semantic information on recognition of words, Balota, Ferraro, and Connor (1991) proposed a modified version of the model containing meaning-level representations above the lexical-level representations. As with feature, letter, and word representations, concepts are represented as individual nodes. Activation between the lower levels and the meaning level is also cascaded and interactive. Balota et al. argued that more activation in the meaning-level representations would benefit both word- and letter-level processing through facilitative feedback, much like activation at the word level is presumed to help letter-level processing in a way that produces the word superiority effect. The framework for the influence of semantic information on the lexical representations of words proposed by Balota et al. focuses on isolated word recognition, and thus was not intended as an account of the processing facilitation due to semantic information from a related context.

In addition to the between-level activation processes, the IAC model posits that representations at the same level produce intra-level inhibition (Davis, 2003, 2010; Davis & Lupker, 2006; McClelland & Rumelhart, 1981; Segui & Grainger, 1990). Most importantly for present purposes, an activated lexical unit will inhibit other lexical-level units including those that may also have been activated by the activated letter-level representations. Suppression of other (incorrect) candidate lexical representations is, in fact, crucial to successfully completing the lexical selection process (Davis & Lupker, 2006).

The lexical decision task (LDT) is the task used most often to examine lexical access in word recognition. In the LDT, participants indicate whether a letter string is a word or a nonword. The latencies and error rates are indicators of how quickly and accurately a word is processed. LDT responses have been assumed to be driven mainly by lexical-level activity (e.g., Grainger & Jacobs, 1996; Hino & Lupker, 1996; Pexman et al., 2002). For example, according to multiple read-out model of word recognition (Grainger and Jacobs), which is based on the IAC framework, a visually presented letter string increases the activation level of multiple lexical representations that are spelled similarly to the presented letter string. The multiple lexical representations then compete for identification. The competition between multiple representations is resolved through inhibition. In the LDT, a word response is made once the activation of one of the lexical representations (presumably, that of the word being read) reaches a certain threshold. A word response can also be made if the overall level of activity in the lexicon reaches a specific threshold. However, a nonword response is made if a temporal deadline is reached before either of the above thresholds is reached. What this model does not contain is a decision-making component, a process that would be assumed to take place after a word candidate had been selected based on the lexical selection process. The lexical decision task typically has been assumed to involve a decision-making component (e.g., Balota & Chumbley, 1984) involving verification of the lexical candidate presented by lexical selection.

In addition to contrasting mean latencies, analyses of latency distributions are also used when examining the effects of a variable, as analyzing the distribution, rather than just the mean, can provide more information about the effects of a variable (Balota & Yap, 2011). A variable of interest may affect a latency distribution in a number of different ways (Pratte, Rouder, Morey, & Feng, 2010). Specifically, a variable may cause a constant shift in the whole distribution, a skew in the distribution, or both. Of relevance to the present experiments, one way to examine the effect of a variable on the latency distribution is a quantile plot, where trials are ordered from fastest to slowest and divided into equal size quantiles. Some measure of the average latency in each quantile is then plotted against quantile number. A distributional shift would show itself as a constant effect of the variable across the quantiles, while effects on the skew of the distribution would show up as changes in the effect sizes across quantiles and there would be an interaction between quantiles and the effect.

Returning to the IAC Model, the numerous results indicating that LDT latencies are shorter for words associated with a greater amount of semantic information are consistent with the notion that facilitative semantic feedback flows from conceptual representations to lexical (i.e., word) level representations aiding processing at that level. For example, ambiguity effects in the LDT (i.e., shorter latencies for words with multiple meanings) have usually been explained as being due to semantic feedback (Pexman, 2012). Greater semantic activation exists for ambiguous (vs. unambiguous) words because of their multiple meanings, and thus those words generate a greater amount of feedback to the lexical level which assists LDT performance. Numerous results support this interpretation including, for example, Hino and Lupker (1996) showing faster LDT latencies for ambiguous (vs. unambiguous) words which were otherwise matched on multiple factors including frequency (see also Borowsky & Masson, 1996; Hino, Lupker, Sears, & Ogawa, 1998; Pexman & Lupker, 1999). A similar finding is that words for which participants list a greater number of features (words associated with a greater amount of information at the semantic level) elicit faster LDT responses than words for which participants list fewer features (Grondin, Lupker, & McRae, 2009; Pexman, 2012; Pexman et al., 2002). In general, Pexman (2012) makes the case that faster LDT responses for semantically richer words, however defined (see also, Pexman et al., 2008), result from greater activation in the semantic units which leads to greater feedback to the units at the lexical level of representation, producing shorter latencies.

To investigate the basic question of how information from semantic primes interacts with lexical processing during word recognition in the LDT, semantic and masked orthographic priming manipulations were used in the present studies, with each experimental manipulation discussed in detail below. Briefly, the semantic priming manipulation was combined with a masked orthographic priming manipulation in an effort to test whether semantic primes also influence the lexical processing of their targets. It is generally agreed that masked orthographic priming influences the lexical processing of the target word (i.e., masked orthographic priming influences lexical selection), a locus that is within the IAC framework. In contrast, the locus of the semantic priming effect is unclear. As explained in more detail below, some accounts of the phenomenon posit that semantic primes pre-activate the lexical representations of their targets. Such accounts posit that the locus of the semantic priming is lexical, and is thus within the IAC framework. Other accounts posit that the locus of semantic priming is post-lexical (i.e., occurs after lexical selection). Specifically, the effect of the semantic prime is during a decision-making component where the candidate selected during lexical processing is verified. Post-lexical accounts of semantic priming are outside the IAC framework.

To evaluate whether semantic primes influence the lexical processing of their targets, or the post-lexical verification of the selected candidate, the additive factors method (Sternberg, 1969) was applied. The additive factors method assumes the existence of a series of discrete stages between the presentation of a stimulus and the output of a response. In an experiment where multiple stages of information processing are assumed, and multiple experimental factors are used, the additive factors logic posits that when factors do not jointly influence any stages, the effects of these factors on mean latencies will be additive. In contrast, factors that jointly influence at least one stage are most likely to produce an interaction.

With respect to the present experiments, the two stages assumed to be involved in producing a response in the LDT are lexical selection, which presents a candidate word, and the post-lexical verification process. While masked orthographic priming is thought to influence only the lexical selection stage, semantic priming might influence lexical selection, or the post-lexical decision-making stage that involves verification of the candidate presented during lexical selection. Following additive factors logic (Sternberg, 1969) an interaction between the semantic and masked orthographic priming factors would suggest the two priming effects influence a common stage in word processing in the LDT, supporting the conclusion that the visible semantic prime influences the lexical processing of its target. In contrast, an additive pattern for the two priming effects would imply that the two priming effects do not influence the same stage of word recognition, and that the effects of semantic primes are not lexical. To foreshadow, additivity was obtained, suggesting that the effects of semantic primes are not lexical.

A third priming phenomenon, masked repetition priming (also explained in detail below) was examined in light of the conclusion reached in the present studies that semantic priming is not a lexical phenomenon. The semantic priming manipulation was combined with a masked repetition priming manipulation to examine whether masked repetition primes have a semantic component (Forster, 2009; 2013). That is, again, additive factors logic was used to test whether semantic and masked repetition priming effects would interact, and thus whether what conclusions one can draw about the nature of masked repetition priming effects.

1.2 Semantic Priming

The semantic priming effect (Meyer & Schvaneveldt, 1971) is the finding that responding to a target word is facilitated when it shares an associative or featural relationship with a preceding prime. This effect represents an additional way in which nonlexical information, specifically, semantic information, may affect word recognition and, as will be discussed further below, semantic priming effects do appear to be reasonably well explained within an extended IAC framework. Whereas a number of mechanisms have been proposed to explain semantic priming effects, those mechanisms tend to involve two main distinctions (Jones & Estes, 2012). The first is whether the prime pre-activates the target (i.e., semantic processing of the prime influences the lexical activation and, hence, the 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 (or processes) that produces the priming is 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 node representing the prime spreads to the target's lexical node, through either direct linkages or through connections through semantic memory. Information from the semantic prime would thus influence the lexical processing of the target. In general, spreading activation is assumed to be involved in producing semantic priming effects when the 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 pre-activates the lexical units of any expected target words 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 is modulated by relatedness proportion (RP), that is, the proportion of trials involving semantically related prime-target pairs (Hutchison, 2002; Hutchison, Neely, & Johnson, 2001). More specifically, because predicting the target is more beneficial if the RP is high, this type of process seems to be used more frequently when the RP is high. The process of generating expectancy sets is not something that is envisioned within the IAC framework as the facilitation is produced strategically, however, it is not a process that is inconsistent with that framework either. Note also that the set of expected words would likely overlap with the set of words activated through automatic spreading activation. Expectancy could, therefore, be viewed as a strategic extension of the automatic spreading activation process.

Semantic matching: Accounts of this sort posit that participants 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 Wit & Kinoshita, 2014, 2015a, 2015b; Neely, Keefe, & Ross, 1989, see also Hoedemaker &

Gordon, 2017). 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 semantically unrelated to their primes. As a result, participants are slowed a bit in correctly responding to words following unrelated primes. Like expectancy set generation, semantic matching is thought to be at least somewhat under strategic control, but unlike expectancy set generation and automatic spreading activation, semantic matching occurs essentially after the lexical selection of the target word. Semantic matching is not a process envisioned within the IAC framework because the benefit of semantic primes occurs after the target word has been identified (i.e., after lexical selection is complete), however, it is not a process that is necessarily inconsistent with the IAC framework. Specifically, semantic matching can be envisioned as a verification process operating on the candidate that has been selected during lexical processing. The idea is that the verification process can use information from the semantic prime to facilitate its processing.

Stimulus onset asynchrony (SOA- the time between the onset of the prime and the onset of the target) is often used to investigate the factors driving semantic priming and to test predictions of the above theoretical accounts. Specifically, longer SOAs (over 300 ms) are presumed to be necessary in order 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) RP when the SOA is long. In contrast, with SOAs under 300 ms, RP generally does not appear to influence the semantic priming effect (e.g., Hutchison et al., 2001; Neely et al., 1989; Neely, 1977) suggesting that the effect in that situation is not due to expectancy generation. In particular, Neely provided a demonstration that short SOAs do seem to preclude the generation of expectancy sets. Neely found that with a short SOA (240 ms), but not with a long SOA (400 ms), targets in the same category as their primes were facilitated even when participants were told that primes actually cued targets from other categories. Neely concluded that facilitation of target words was based on conscious expectancies, rather than being automatic, only when SOA was longer. In contrast, it is possible that both long and short SOA priming effects may be due to a semantic matching process (assuming that such a process does, indeed, exist) as the viability of using that process would not be affected by the prime-target SOA.

As 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 due to automatic spreading activation due to the fact that RP effects are usually not found at those SOAs. Recent findings by de Wit and Kinoshita (2014, 2015a) (see also de Groot, 1984), however, have suggested that RP effects can be seen at short 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, at least in lexical decision tasks with short SOAs (so that expectancy sets cannot be formed), are solely driven by a retrospective semantic matching mechanism. Specifically, de Wit and Kinoshita claimed that the semantic priming effect in the LDT: a) is modulated by RP, b) disappears when the prime is masked, and c) grows in magnitude in later quantiles, findings all consistent with a retrospective matching mechanism rather than automatic spreading activation. The present research was an attempt to examine these ideas concerning the nature of the semantic priming effect.

In fact, de Wit and Kinoshita (2015a) directly investigated whether RP modulates the magnitude of the semantic priming effect in the LDT at short SOA of 240 ms (precluding the formation of expectancy sets). The authors reasoned that RP should not modulate the effect of an automatic process. In contrast to findings that RP effects are not found at short SOAs (e.g., Hutchison et al., 2001; Neely, 1977; Neely et al., 1989), de Groot (1984) had reported that RP modulated the semantic priming effect in the LDT with a 240 ms SOA. Consistent with de Groot, de Wit and Kinoshita (2015a) found a small but not significant priming effect at low RP, and a robust semantic priming effect at high RP.

Next, de Wit and Kinoshita (2015b, Experiment 1) examined the impact of masking the semantic prime on the semantic priming effect in the LDT. The authors reasoned that use of retrospective semantic matching, and thus the corresponding semantic priming effect, should be eliminated when the prime is masked. Neely (1991) argues that the existence of masked semantic priming effects is evidence for automatic spreading activation as the driver of these effects at short SOA. De Wit and Kinoshita, however, noted that semantic priming effects with masked primes are not always present, and, when present, might instead result from an unsuccessfully masked (i.e., visible) prime. Thus, de Wit and Kinoshita compared the semantic priming effects when the prime was either visible (240 ms SOA), or masked (50 ms SOA). Those authors found a robust semantic priming effect when the primes were visible and no effect when those same primes were masked (see Cheesman & Merikle, 1984, for similar findings in the Stroop priming task), consistent with their claim that retrospective matching rather than automatic spreading activation drives semantic priming effects in the LDT at short SOA.

Finally, de Wit and Kinoshita (2015a,b) evaluated the semantic priming effect as a function of quantile. Balota, Yap, Cortese, and Watson (2008, Experiments 2 and 3; see also Gómez, Perea, & Ratcliff, 2013) found that the semantic priming effect increased across quantiles. Balota et al. argued that the overadditive interaction between quantile and the semantic priming effect reflects the use of a retrospective semantic matching strategy. During slower trials, more time becomes available to process the prime and thus the information from the prime will have a greater impact on the response. In contrast, priming effects driven by automatic spreading activation would be expected to produce the same size priming effects for all targets (i.e., a "distributional shift"), since a related (vs. unrelated) prime would produce a head start to the processing of the target by pre-activating its lexical representation (Balota et al.; Gómez et al.). At short SOA (240 ms) with visible primes, de Wit and Kinoshita (2015a,b) also found that the semantic priming effect was larger for slower items in the LDT. (Note that they also found that there was a constant priming effect across quantiles in their semantic categorization task, suggesting that the locus of the effect in the LDT is different than that in a semantic categorization task.)

A possible explanation for why the semantic priming effect is greater on slower trials is that the relevant semantic representation of the prime, that is, the component of its representation that is shared with the target (vs. other possible meanings of the prime) may become increasingly strongly activated throughout, and as a result of, target processing. The increasing activation of a specific semantic representation of the prime would be consistent with models of word recognition positing multiple meanings are initially activated early in the recognition process, for example, the TRACE model (McClelland & Elman, 1986). Similarly, Swinney (1979, see also Onifer & Swinnery, 1981) found that both meanings of an ambiguous semantic prime were accessed. During slower trials, as the relevant semantic representation of the visible semantic prime becomes more activated, the prime would become more useful to target processing. However, even if slower trials do allow for stronger activation of the relevant semantic representation of the prime, the greater impact of the semantic prime on the response during slower trials still reflects a post-lexical locus of the semantic prime instead of a head start to the processing of the target via activation of the lexical representation.

De Wit and Kinoshita (2014, 2015a, 2015b) concluded that the semantic priming effect in the LDT with short SOAs is driven by a retrospective matching mechanism (there is a post-lexical locus), rather than automatic spreading activation within the lexicon. Note that in their studies, the authors used a short SOA to preclude the formation of expectancy sets, which is a proposed account of semantic priming effects at long SOA (Becker, 1980; Neely, 1977). Thus, even if their conclusion about spreading activation is correct, it is thus unclear whether semantic primes could pre-activate the lexical representations of their targets via expectancy set generation when the SOA is long enough to allow for the formation of such sets. The present experiments examine the locus of semantic priming at both long and short SOA to test the expectancy generation as well as the automatic spreading activation accounts of semantic priming.

Additionally, while as de Wit and Kinoshita (2015b) note, masked semantic priming effects in the LDT are unreliable, they have been demonstrated in numerous studies (e.g., Bodner & Masson, 2003; Marcel, 1983; Perea & Gotor, 1997; Perea & Rosa, 2002). De Wit and Kinoshita do note various methodological shortcomings that can explain masked semantic priming effects in the LDT, such as, inadequately masked primes resulting in them being consciously identified, as well as using an associative but not purely semantic relationship between the prime and the target (see also Holender, 1986, for a review).

However, the presence of masked semantic priming effects, although unreliable, challenges their argument that semantic priming is entirely post-lexical. The present experiments will provide an additional way of examining the locus of semantic priming effects.

1.3 Lexical Inhibition from Masked Orthographic Primes

Unlike semantic priming effects, masked orthographic priming effects appear to be strictly a lexical phenomenon. In the masked priming paradigm, the prime is preceded by a forward mask and followed by the target, which serves as a mask for the prime. The prime is presented so briefly that it is rarely, if ever, consciously recognized by participants. Thus, any effects of the prime are also typically assumed to be automatic, rather than strategic.

Because there is an intra-level competition/inhibition process, according to the IAC, masked primes can either facilitate or inhibit the recognition of target words. Specifically, consistent with the IAC, masked word primes that are orthographically similar to their targets (“orthographic neighbors”) (*lamp – LAMB*) typically slow down recognition of the target word (e.g., Davis & Lupker, 2006; Grainger, Colé, & Segui, 1991; Segui & Grainger, 1990). In contrast, nonword primes that are orthographically similar to their targets (i.e., “nonword neighbors”, *lkmb – LAMB*) typically facilitate target word recognition (e.g., Forster & Davis, 1984; Perea & Rosa, 2000). As Davis and Lupker note, these effects are readily explainable in terms of the IAC principles. Any orthographic neighbor primes should pre-activate the target word’s lexical representation, potentially resulting in some facilitation. However, *word* neighbor primes will activate their own representations as well, which will act as strong lexical competitors of the targets 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 activating the target.

When the prime is a word neighbor, the relative prime-target frequency also moderates the effects of masked orthographic primes. Segui and Grainger (1990) observed a greater inhibition effect when the primes were higher in frequency than the targets (see also Davis & Lupker, 2006). According to the IAC model, representations of higher frequency words are activated more quickly and more strongly. Therefore, 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. 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 the reverse. Davis and Lupker also found that although word neighbor primes produced this inhibition effect, nonword primes produced a facilitation effect for the same targets. Those authors 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 models based on the IAC framework.

Although nonword neighbor primes do not activate lexical competitors to a sufficient degree to delay target processing, according to IAC principles they do 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 impact of the target activation provided by a nonword 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 first prime is identical to the target, the second is the orthographic prime of interest. The brief presentation of the identity prime should raise the activation level of the target word. Consequently, the lexical competitors of the target word that are activated by the orthographic nonword prime would have a reduced capacity to inhibit the target. In addition, the presentation of an orthographically similar prime of interest allows the target's activation to be maintained at a high level 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 priming in the sandwich priming task. Sandwich priming, in comparison to conventional masked orthographic nonword priming, should result in greater facilitation of the target word, and thus can offer a more sensitive test of whether semantic priming interacts with a strictly lexical priming manipulation in the present studies.

1.4 Components of Masked Repetition Primes

Finally, in masked repetition priming experiments, responding is facilitated when the target word is preceded by a masked prime identical to the target (e.g., judge-JUDGE) rather than an unrelated word (Bodner & Masson, 2001, 2004; Forster & Davis, 1984; Forster, 2009, 2013; Perea, Jimenez, & Gómez, 2014). Effects of masked repetition (vs. orthographic) primes are consistently stronger (e.g., Forster, 2009, 2013; see Forster, Mohan, & Hector, 2003 for review), however, there is some debate about the locus of masked repetition priming effects. Compared to orthographic primes, repetition primes have complete orthographic overlap with their targets, suggesting that masked repetition priming is simply a stronger form of masked orthographic priming. In contrast, Forster (2009, see also Forster, 2013) argues that masked repetition primes add an independent semantic component to the priming effect which masked orthographic primes do not. The framework developed in the present experiments has the potential to allow an examination of Forster's idea that masked repetition priming involves an additional semantic component that masked orthographic primes do not. In light of additivity between semantic and masked orthographic priming effects that will be reported below (findings which suggest semantic primes have a post-lexical lexical locus), masked repetition primes were examined in an effort to discover whether they might have a semantic component. Therefore, one final aim of the present experiments was to examine

Forster's ideas (described directly below) about masked repetition primes having a semantic component.

In a series of experiments, Forster (2009) examined the effects of an intervenor stimulus on the priming effects from masked repetition primes and masked nonword primes. An intervenor is an unrelated stimulus inserted between the prime and the target (see also Joordens & Besner, 1992; Forster, 2013). Forster (2009, Experiments 1 and 2) found that a visible unrelated word intervenor reduced the masked repetition priming effect to the level of the orthographic priming effect (which itself was unaffected). In his Experiments 3 and 4, when the word intervenor was masked, Forster found that the repetition priming effect was reduced as in Experiments 1 and 2, and the orthographic priming effect was eliminated. Based on this pattern of results, Forster argued that masked nonword primes consist of a lexical component, while the masked repetition primes have both lexical and semantic components. The visible intervenor disrupted the semantic component, reducing the repetition priming effect but not affecting the orthographic priming effect. The masked intervenor disrupted the lexical component, reducing the repetition priming effect and eliminating orthographic priming.

Based on this pattern of results Forster (2009) argued that semantic and conceptual information associated with the repetition prime (but not with a nonword prime) is activated and play a role in the priming process (see also Bodner and Masson (2001) for a similar claim). Forster (2013) further argues that processing of the semantic properties (but not the lexical properties) of a masked prime continues during target processing (indeed, semantic processing may require at least 150 ms as suggested by ERP experiments, e.g., Hauk, Davis, Ford, Pulvermüller, & Marslen-Wilson, 2006). Thus, unlike masked orthographic nonword primes, masked repetition primes may contribute a distinct semantic component to facilitating the processing of the target word, a component that may affect the post-lexical semantic matching process.

1.5 The Present Experiments

The framework for discussing the present experiments involves a, model, the IAC, with a localist structure (i.e., each node is a separate representation), with lexical representations, because only a localist framework can accommodate all the necessary effects examined here. Connectionist models (e.g., Cree, McRae, & McNorgan, 1999; McRae, De Sa, & Seidenberg, 1997; Plaut & Booth, 2000) can explain semantic priming effects as being due to the prime and target having similar distributed patterns of activity. Thus, a semantically related prime facilitates target processing because the network starts from the pattern of activity produced by the prime. Similarly, Masson and Isaak (1999) explain facilitation from masked orthographic and repetition primes in terms of the processing applied to the prime being similar to the processing applied to the subsequently presented target. While many priming effects can be explained in this fashion, that is, without invoking lexical representations, at present, there does not seem to be any such explanation for the orthographic inhibition effect from masked word primes outside models involving an IAC-type framework. That is, what these other types of models cannot explain is Davis and Lupker’s (2006, Experiment 1) finding of slower LDT latencies to a set of targets when the masked orthographic primes were words, while, at the same time faster latencies when the masked orthographic primes were nonwords. Explaining this facilitation/inhibition pattern appears to require a localist framework

Lexical processing of the target was manipulated by using a masked, orthographically similar (i.e., neighbor) or orthographically unrelated (i.e., non-neighbor) prime. Prior to the presentation of the 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 suggest that those factors influence a common stage of processing during word recognition in a LDT. Thus, an interaction between semantic and orthographic priming would clearly indicate that the visible semantic primes influence the lexical activation level of the target. In contrast, additive semantic and masked orthographic priming effects would suggest that semantic priming and orthographic priming influence separate stages in word recognition in an LDT. In particular, additivity would suggest a (potentially strategic) post-lexical locus of any semantic priming effect that occurs after lexical selection but prior to the response (Neely et al., 1989; de Wit & Kinoshita, 2014). That is, this type of result would support de Wit and Kinoshita’s (2014, 2015a, 2015b) somewhat novel arguments that there is no spreading activation process affecting the lexical activation of the target. Note also that those authors examined semantic priming at short SOA, so as to preclude the formation of expectancy sets. In contrast, the present experiments examined semantic primes at both long and short SOAs. The present experiments will thus extend the studies by de Wit and Kinoshita by additionally testing whether semantic primes can pre-activate lexical representations of their targets via expectancy set generation (when the SOA is long enough to permit generation of expectancy sets), in addition to automatic spreading activation at short SOA.

As noted, an additional aim of the present research was to examine Forster's (2009; 2013) proposal that there is an independent semantic component in masked repetition priming. As with the other experiments in this dissertation, targets were preceded by visible semantically related or unrelated primes. However, a masked repetition (rather than orthographic) prime followed the visible semantic prime. To foreshadow, the additive effects of semantic and masked orthographic primes in Experiments 1-3 suggested a post-lexical locus of semantic priming. Combining semantic and masked repetition primes then allowed an examination of whether masked repetition primes have a semantic component that influences the post-lexical mechanism of semantic priming. Specifically, if semantic information from the masked repetition prime is extracted and processed while also processing the target (Forster, 2013) then a post-lexical semantic matching mechanism between the target and the visible semantic prime may be facilitated. Thus, an interaction between the semantic and masked repetition priming effects would suggest that masked repetition primes have an extra semantic component that orthographic primes do not. In contrast, additivity between the effects would suggest that masked repetition primes yield greater facilitation effects because of their complete orthographic overlap with the target which provides a stronger influence on the lexical selection of the target. That is, consistent with the IAC framework, the semantic information from a masked repetition prime may well activate the semantic representation of its target, which would then provide facilitative feedback to the lexical representation of the target rather than providing information that is used by a post-lexical, semantic matching process.

In addition, the effects of visible semantic primes, masked orthographic, and masked repetition primes on the latency distributions of their targets were examined via quantile plots. Masked orthographic 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 orthographic 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 also Balota et al., 2008 for a more complete explanation of this logic) would suggest a strategic and post-lexical 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 pre-activating their lexical representations. Finally, the masked repetition priming effect would be expected to increase across quantiles if masked repetition primes have a semantic component which contributes to the retrospective matching between the visible prime and the target.

Experiment 1 examined how the facilitative effect of a masked nonword prime was influenced by visible semantic primes presented with both a long SOA (1476 ms) and a short SOA (267 ms). The long SOA should allow for the generation of expectancy sets based on the visible semantic prime (i.e., lexical activation of a set of potential targets) which would lead to heightened lexical activation and, hence, a lexically-based priming effect. A short SOA (i.e., an SOA under 300 ms) should prevent the generation of expectancy sets by not allowing enough time to do so (Hutchison et al., 2001). The selected SOA would, however, allow for automatic spreading activation from the primes to activate the lexical representations of related target words, producing a semantically-driven lexically-based priming effect. An interaction of semantic and orthographic priming effects at either SOA would suggest that the process producing semantic priming was lexically based. Regardless of the SOA, semantic priming could, of course, have a post-lexical locus. As semantic matching is a post-lexical process, it should not influence the lexical effects of the masked orthographic primes Additivity would, therefore, suggest that the semantic priming effect at either SOA was due to a post-lexical semantic matching process.

As noted, there is typically a somewhat larger orthographic facilitation effect in the sandwich priming paradigm. Therefore, use of that paradigm in Experiment 2 should allow for a more sensitive test of whether there is an interaction between the masked orthographic and visible semantic priming effects than that allowed by the conventional masked priming paradigm used in Experiment 1 if Experiment 1 shows no indication of an interaction. Experiment 2 examined the effects of semantic primes on orthographic facilitation using the sandwich priming paradigm (Lupker & Davis, 2009). As in Experiment 1, semantic primes were presented with both long and short SOAs between those primes and the first masked prime in the sequence.

Whereas Experiments 1 and 2 examined whether semantic primes influence lexical processing using additive factors logic (Sternberg, 1969), Experiment 3 provided a more direct examination of the notion of semantic priming being a lexical activation process. As noted, masked orthographically similar word primes typically inhibit target processing. The question is in Experiment 3 was whether the (inhibitory) impact of those primes can be enhanced due to lexical activation from a visible semantic prime. If visible semantic primes can be shown to increase the inhibition caused by masked word primes, would be evidence that those visible semantic primes truly are able to influence the lexical representations of the words they are related to. Therefore, rather than being related to the target word, the visible primes in Experiment 3 were related to the masked orthographic primes. Following the logic of Experiments 1 and 2, at long SOAs, the influence of the visible prime on the activation of the masked orthographic prime's lexical representation would be due to the generation of expectancy sets based on that visible prime. At a short SOA, any influence of the visible prime on the activation of the masked orthographic prime's lexical representation should be due to spreading activation created by the visible prime. If the visible semantic prime influences the activation of the masked prime's lexical representation in either circumstance (via expectancy generation at long SOA, or automatic spreading activation at short SOA), one would expect that word neighbor primes would be more effective inhibitors of target processing than when the masked word neighbor primes are not preceded by visible semantic primes.

Finally, Experiment 4 examined whether masked repetition primes have a semantic component (Forster 2009, 2013), a component that can influence a post-lexical process. Visible semantic primes were presented at long and short SOAs as in previous experiments. Masked repetition primes now preceded the targets. Following the logic of Experiments 1 and 2, an interaction between the semantic and repetition priming effects would indicate that both primes influence a common stage in word recognition. In light of findings (from the present Experiments 1-3) which suggest semantic priming has a post-lexical locus, an interaction between visible semantic primes and masked repetition primes would support Forster's argument by suggesting that the semantic component of masked repetition primes facilitates the semantic matching process between the target and the prime. Additivity between the priming effects would suggest that the effects of masked repetition primes are lexical, like the effects of masked orthographic nonword primes (cf., Forster, 2009, 2013).

2 Chapter 2: Experiments

2.1 Experiment 1

As 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 to 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 priming effect. Thus, various prime-target relationships (i.e., synonyms, antonyms…) were included, and prime-target pairs varies of forward and backward association strengths. To create the orthographic primes, orthographic nonword neighbors were then generated from the targets (e.g., *lkmb* generated from *LAMB*) and their lexical facilitation of the targets, compared to unrelated pairs (e.g., *dvsk*), was first established (this group of participants will be referred to as the *masked prime* group). In the main part of this experiment, the visible semantic prime, related or unrelated to each target, was presented preceding the masked orthographic prime (e.g., *mutton-####-lkmb-LAMB* vs *mutton-####-trmd-LAMB*), so as to observe the effects of the visible prime on the orthographic facilitation effect. The effect of visible semantic primes was examined at a long SOA in the *long SOA visible prime* group, and at a short SOA in the *short SOA visible prime group*. The particular SOAs were chosen to separately test the potential effects of expectancy generation (long SOA) and automatic spreading activation (short SOA) from the visible semantic primes. Specifically, the long SOA in the present experiments was comparable to the long SOA (1200 ms) used by Hutchison et al. (2013), and would allow enough time for the formation of expectancy sets. The short SOA in the present experiments was kept under 300 ms (Neely, 1977) so as to preclude the formation of expectancy sets, and was comparable to other studies testing potential automatic processing in semantic priming by using a short SOA (e.g., de Wit & Kinoshita, 2014, 2015a, 2015b; Hutchison et al.) The key question is whether a visible semantic prime influences the lexical activation of the target (through an expectancy generation process in the long SOA visible prime group or through automatic spreading activation in the short SOA visible prime group) producing an interaction between the semantic and the orthographic priming effects.

Additionally, the impact of visible semantic primes at long and short SOA, as well as the effects of masked nonword primes, on latency distributions was examined through quantile plots. While the masked orthographic priming effect is expected to remain constant across quantiles (reflecting the head-start targets receive from lexical activation), of interest is whether the semantic priming effect increases across quantiles (indicative of semantic matching) or also remains constant (indicative of automatic spreading activation at short SOA or expectancy generation at long SOA).

2.1.1 Method

2.1.1.1 Participants

A total of 179 undergraduate students, who self-identified as fluent English-speakers, participated in Experiment 1 for course credit. Due to their high error rates on nonword trials (> 20%), data from one participant out of 37 in the *masked prime* group, 13 participants out of 85 in the *long SOA visible prime group* and 9 participants out of 57 in the *short SOA visible prime group* were excluded from the analyses. Error rates on nonword (rather than word) trials were used as exclusion criteria so as to remove participants displaying a tendency to make *word* responses without processing the target sufficiently. Excessive nonword error rates may make it more difficult to observe a post-lexical semantic matching strategy, that is, a strategy in which a relationship between the prime and target biases participants to make a word response. If participants tend to make word responses without sufficient processing, the bias to make a word response from detecting a relationship between target and prime may be obscured and any semantic priming effect may be minimized.

2.1.1.2 Stimuli

Sixty-four visible prime-target word triplets were selected from the semantic priming project (Hutchison et al., 2013). Each triplet contained the target word (e.g., *lamb*), an associatively or featurally related prime (*mutton*), and an unrelated prime *corporation*).

The semantic priming project is an online repository (http://spp.montana.edu) which contains lexical decision data for 1661 target words based on 768 participants with priming effects being available for each target word. 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, & 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 via 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 orthographic neighbor primes were then constructed in order to form masked prime-target pairs. The orthographic neighbor primes for word targets (N = 4.84) and nonword targets (N = 7.05) were constructed by replacing a single letter in the target. To provide non-neighbor primes for the targets, the masked prime-target pairs were re-paired. 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 1.

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 long and short SOA visible prime groups. Word targets were divided into four sets, such that each set of targets was preceded by related and unrelated visible primes as well as neighbor and non-neighbor masked orthographic primes across four groups of participants. The nonword targets were split into two sets as each nonword was paired with both related and unrelated masked orthographic primes but only one visible prime.

2.1.1.2.1 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 database. However, due to the length and frequency restrictions imposed on the target words due to the plan to use them in Experiment 3, the selected triplets had a much weaker facilitation effect at the long (4.18 ms) than at the short (101.52) SOA as reported in the semantic priming project database. Therefore, in a pilot experiment (different participants were used) we tested whether the selected stimuli would provide semantic facilitation at both a long SOA (1467 ms) and a short SOA (267 ms) for members of the present participation pool. Semantic priming was confirmed as there was a 28 ms facilitation effect at a long SOA that was significant in both subject and item analyses, *Fs* > 7.66. At the short SOA, there was a 29 ms facilitation effect, again significant in both subject and item analyses, both *Fs* > 8.73.

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 repository versus those obtained in the present pilot experiment (i.e., 4.18 ms vs. 28 ms at a short SOA, and 101.52 ms vs. 29 ms at a long SOA). There were, however, a couple of procedural differences between those experiments and the present pilot experiment. For example, while the overall SOAs used in the present experiment were comparable to 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, semantic primes were shown for 150 ms in the long and short SOA conditions by Hutchison et al. and the blank interstimulus interval between prime and target was varied to create the long and short SOA conditions.

2.1.1.3 Experimental Procedure

Participants were tested individually in a quiet and well-lit room. For the masked prime group, each trial consisted of the mask (#####), presented for 700 ms, followed by the masked orthographic nonword prime, presented for 67 ms, followed by the target. The target appeared in uppercase and remained on the screen until a response was made or

2500 ms had elapsed. The long SOA visible prime group first saw the visible prime for 700 ms, then the mask for 700 ms, the 67 ms masked orthographic prime, and the target as presented to the masked prime group. The short SOA visible prime group, in contrast, saw the visible prime for 200 ms, which was immediately followed by the 67 ms masked orthographic prime, followed by the target as presented to the masked prime and long SOA visible prime groups.

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 12 min for the long SOA visible prime group, and about 8 min for the short 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).

2.1.2 Results

Combining the masked prime and the long and short SOA groups, 13.3% of the nonword target trials and 5.5% of the word target trials were incorrect responses, or correct responses faster than 250 ms or slower than 1750 ms, and those trials were excluded from the latency analyses. Table 1 shows the latencies and error rates for word targets for the masked prime group, and as a function of visible and masked prime types for the long and short SOA visible prime groups. The latencies and error rates for the nonword targets are shown in Appendix D.

Table 1. *Latencies (milliseconds) and error rates (percentages) for word targets as a function of visible prime and masked nonword prime types for the Masked Prime, Long, and Short SOA Visible Prime groups in Experiment 1.*

	Masked Nonword Prime Type		
Group/Visible Prime Type	Neighbor	Non-neighbor	Orthographic Priming Effect
Masked Prime	625 (4.9)	643 (3.9)	18 (-1.0)
Long SOA Visible Prime			
related	636 (3.5)	646 (3.4)	10 (-0.1)
unrelated	662 (5.4)	681 (6.5)	19 (1.1)
Semantic Priming Effect	26 (1.9)	35 (3.1)	
Short SOA Visible Prime			
related	653 (6.4)	677 (5.9)	24 (-0.5)
unrelated	680 (8.7)	699 (9.1)	19 (0.4)
Semantic Priming Effect	27 (2.3)	22 (3.2)	

Note. Error rates shown in parentheses.

Quantiles of word trials used in the above latency analyses were then 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 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 7 trials each and the fifth quantile would have the remaining four, 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 this analysis.

Not using the fifth quantile resulted in the loss of 9.0% of the word trials in the masked prime group. Likewise, in the long SOA visible prime group, not using the last 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. Finally, in the short SOA visible prime group, 6.6% and 6.7% of the word trials were not used when examining the effects of visible prime type and masked prime type respectively. The mean score of each quartile was then calculated. Figure 1 shows the quantile plot for the word targets as a function of masked prime type for the masked prime group. Figure 2 shows the quantile plots for the word targets as a function of masked prime type (top panel) and visible prime type (bottom panel) for the long SOA group, and Figure 3 shows these quantile plots for the short SOA group.

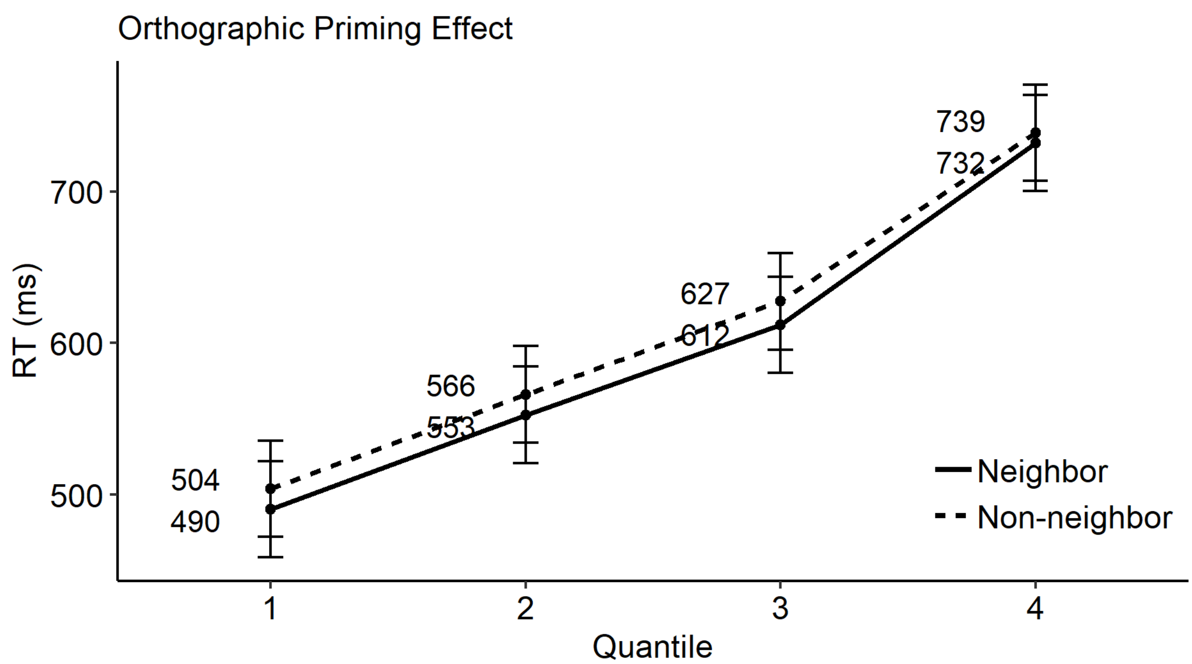

Figure 1. Effect of masked prime type on word targets across quantiles for the masked prime group in Experiment 1. Error bars represent 95% confidence intervals.

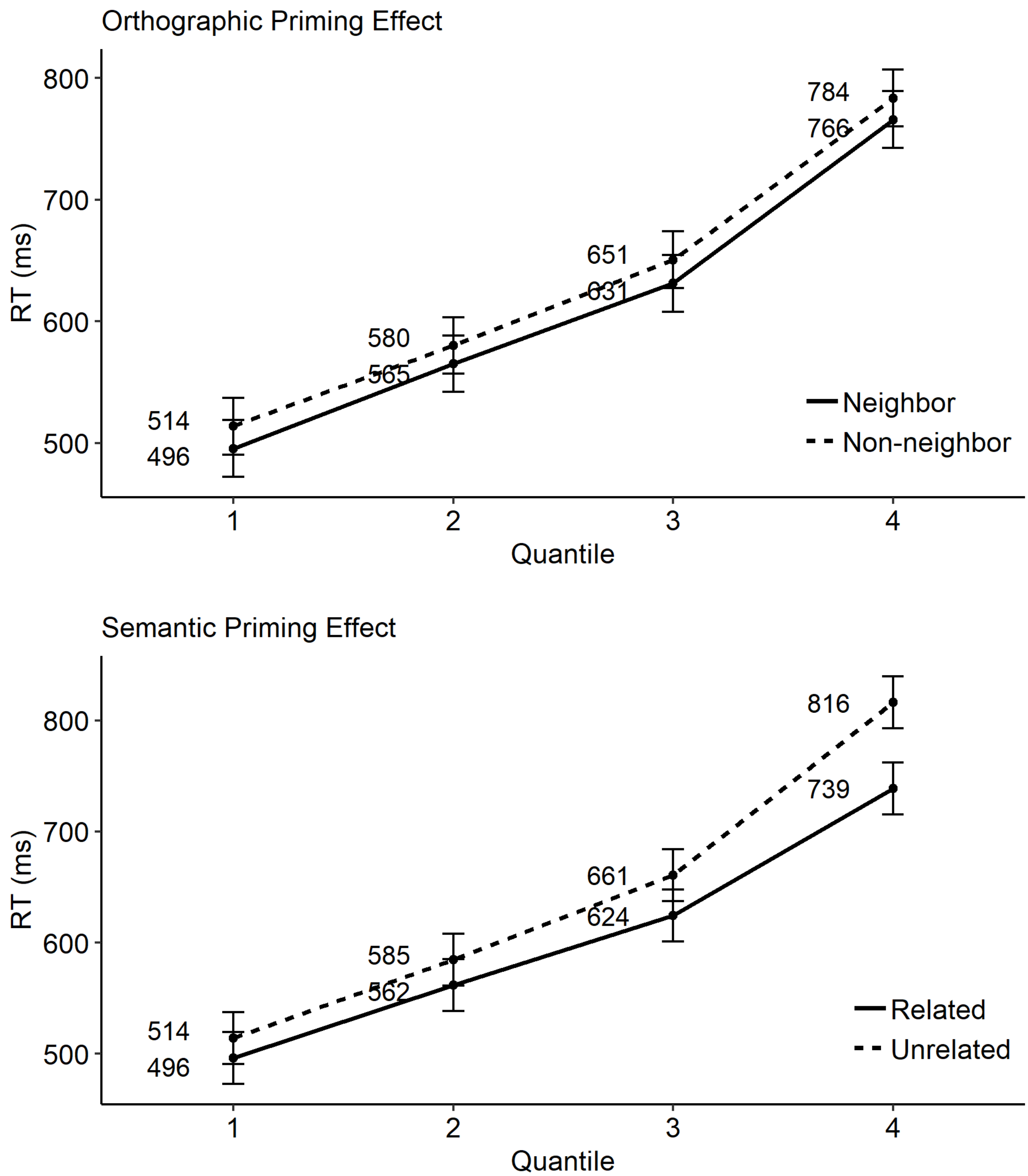

Figure 2. Effect of masked prime type (top panel) and visible prime type (bottom panel) on word targets across quantiles for the long SOA visible group in Experiment 1. Error bars represent 95% confidence intervals.

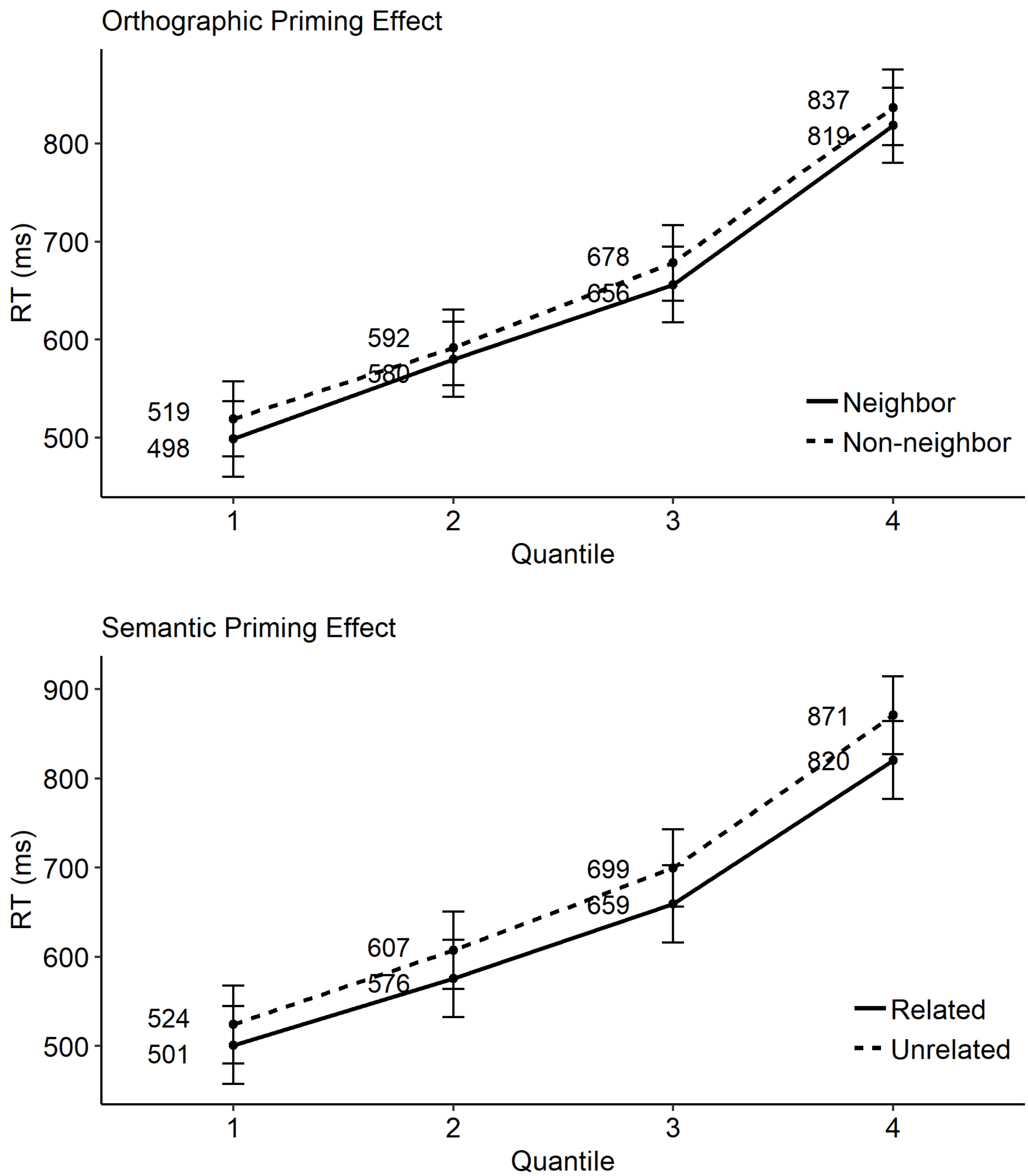

Figure 3. Effect of masked prime type (top panel) and visible prime type (bottom panel) on word targets across quantiles for the short SOA visible group in Experiment 1. Error bars represent 95% confidence intervals.

To examine facilitation from masked orthographic primes, word latencies and error rates from the masked prime group were subjected to 2 (masked prime: neighbor vs. non-neighbor) x 2 (group/set: 1 vs. 2) subject (F_s) and item (F_i) split-plot ANOVAs. *Masked prime* was a within-subject and within-item factor, whereas *group* was a between-subject factor and *set* was a between-item factor. In the *long and short SOA visible prime group*s, word latencies and error rates were subjected to 2 (visible prime: related vs. unrelated) x 2 (masked prime: neighbor vs. non-neighbor) x 4 (group/set: 1 vs. 2 vs. 3 vs. 4) subject (F_s) and item (F_i) split-plot ANOVAs where *visible prime* was also a within-subject and within-item factor. The analyses of nonword latencies and error rates for the masked prime, long, and short SOA visible prime groups are described and presented in Appendix E.

In the masked prime group, the latencies selected for quantile analyses were subjected to a 2 (masked prime: neighbor vs. non-neighbor) x 4 (quantile: 1 vs. 2 vs. 3 vs. 4) x 2 (group/set: 1 vs. 2) split-plot ANOVA to examine the effects of masked primes on the latency distribution (i.e., whether the orthographic priming effect varied across quantiles). In the long and short SOA visible prime groups, effects of visible primes and masked primes on latency distributions were analyzed with separate ANOVAs. To investigate the effect of semantic primes on the latency distribution, a 2 (visible prime: related vs. unrelated) x 4 (quantile: 1 vs. 2 vs. 3 vs. 4) x 4 (group/set: 1 vs. 2 vs. 3 vs. 4) split-plot ANOVA was used. To investigate the effect of masked orthographic primes, a 2 (masked prime: neighbor vs. non-neighbor) x 4 (quantile: 1 vs. 2 vs. 3 vs. 4) x 4 (group/set: 1 vs. 2 vs. 3 vs. 4) split-plot ANOVA was used. 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 quantile analyses. As with the mean latency and error analyses, results involving the group and set variables are not reported. When sphericity was violated, the Greenhouse-Geisser correction was applied to the degrees of freedom.

2.1.2.1 Masked prime group.

2.1.2.1.1 Word latencies.

A significant (18 ms) facilitation effect was found from nonword masked primes. Facilitation from the neighbor (vs. non-neighbor) masked primes on word targets was significant in the subject analyses $F_s(1, 34) = 5.69$, $p = .03$, $\eta^2 = .14$, and item analyses, $F_i(1, 62) = 9.90$, $p = .003$, $\eta^2 = .14$.

2.1.2.1.2 Word errors.

No effect of masked prime type was found, both $Fs < 1.64$, $p > .21$.

2.1.2.1.3 Effects of masked 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 facilitation effect from masked nonword primes was now marginal, $F_s(1, 34) = 3.84$, $p = .06$, $\eta^2 = .10$. Importantly, as suggested in Figure 1, the orthographic priming effect remained consistent throughout quantiles. There was no interaction between masked prime type and quantile, $F_s < 1$.

2.1.2.2 Long SOA visible prime group.

2.1.2.2.1 Word latencies.

A semantic priming effect was observed. The facilitation from related (vs. unrelated) visible primes was significant in the subject, $F_s(1, 68) = 39.83$, p < .001, $\eta^2 = .37$, and item analyses, $F_i(1, 60) = 40.87$, p < .001, $\eta^2 = .41$. A facilitation effect from masked nonword primes was also found in both analyses, F_s (1, 68) = 8.85, p = .004, $\eta^2 = .12$; F_i (1, 60) = 7.78, p = .007, $\eta^2 = .11$. Critically, the interaction between visible prime type and masked prime type was not found in subject or item analyses, both $Fs < 1$, indicating that the facilitation effects from long SOA visible primes and masked nonword primes are additive.

To confirm the null interaction between visible prime type and masked prime type, we evaluated the evidence for the null interaction using a Bayesian estimate, where evidence for a model assuming a null effect is compared against evidence for a model assuming an effect. The method of computing the Bayesian estimate is outlined in Masson (2011), and requires the transformation of the sum-of-squares values generated by an ANOVA. For the null interaction between visible prime type and masked prime type in the subject analyses, the posterior probability of the null hypothesis being true was P_{sBIC} = .83. For the same null interaction in item analyses, the posterior probability of the null hypothesis being true was P_{iBIC} = .82.

2.1.2.2.2 Word errors.

Semantically related (vs. unrelated) visible primes reduced errors according to both analyses, $F_s(1, 68) = 14.75$, $p < .001$, $\eta^2 = .18$; $F_i(1, 60) = 10.81$, $p = .002$, $\eta^2 = .15$. The effect of masked prime type was not significant in either analysis nor was the visible prime x masked prime interactions, all *Fs* < 1.71.

2.1.2.2.3 Effects of masked prime type across quantiles.

The mean latency increased across quantiles, $F_s(1.10, 74.93) = 365.05$, $p < .001$, $\eta^2 = .84$. The facilitation from masked nonword primes was significant, $F_s(1, 68) = 17.00$, $p < .001$, $\eta^2 = .20$. As in the masked prime group, the orthographic priming effect was consistent across quantiles as suggested in Figure 2 (top panel), $F_s < 1$.

2.1.2.2.4 Effects of visible prime type across quantiles.

Again, mean latency increased across quantiles, $F_s(1.09, 74.31) = 386.72$, $p < .001$, $\eta^2 = .85$, and the semantic priming effect was observed, $F_s(1, 68) = 63.67$, $p < .001$, $\eta^2 = .48$. Critically, the semantic priming effect increased across quantiles as seen in Figure 2 (bottom panel), $F_s(1.36, 92.65) = 23.03$, $p < .001$, $\eta^2 = .25$.

2.1.2.3 Short SOA visible prime group.

2.1.2.3.1 Word latencies.

A main effect of semantic priming was obtained in both subject and item analyses, $F_s(1, 44) = 11.19$, $p = .002$, $\eta^2 = .20$; $F_i(1, 60) = 12.28$, $p < .001$, $\eta^2 = .17$. Facilitation from masked nonword primes was also observed in both subject and item analyses, $F_s(1, 44) = 11.64$, $p = .001$, $\eta^2 = .21$; $F_i(1, 60) = 8.16$, $p = .006$, $\eta^2 = .12$. Importantly, the effects from visible and masked primes were again additive as the visible prime x masked prime interaction was not significant, both *Fs* < 1.

As in the long SOA group, Bayesian estimates were calculated to evaluate the evidence of a null visible prime x masked prime interaction. The posterior probability of the null hypothesis being true in the subject analysis was P_{sBIC} = .91, and in the item analysis it was P_{iBIC} = .93, providing further support for the null interaction.

2.1.2.3.2 Word errors.

Semantic facilitation led to a reduction in errors according to both the subject and item analyses, $F_s(1, 44) = 6.96$, $p = .01$, $\eta^2 = .14$; $F_i(1, 60) = 4.65$, $p = .04$, $\eta^2 = .07$. No effect of masked prime type was observed, nor was there an interaction between masked and visible prime types, all *Fs* < 1.

2.1.2.3.3 Effects of masked prime type across quantiles.

Main effects of quantile and masked prime type were observed, $F_s(1.13, 48.46) = 242.28$, $p < .001$, $\eta^2 = .85$; $F_s(1, 43) = 5.56$, $p = .02$, $\eta^2 = .11$. As in the long SOA visible prime group, the orthographic priming effect did not increase across quantiles (Figure 3, top panel), $F_s < 1$.

2.1.2.3.4 Effects of visible prime type across quantiles

Again the main effects of quantile and visible prime type were observed, $F_s(1.10, 48.62) = 194.90$, $p < .001$, $\eta^2 = .82$; $F_s(1, 44) = 17.06$, $p < .001$, $\eta^2 = .28$. The numerical increase of the semantic priming effect across quantiles as shown in Figure 3 bottom panel was not significant however, $F_s(1.28, 56.47) = 1.77$, , $p = .19$, $\eta^2 = .04$.

2.1.3 Discussion

Experiment 1 examined whether a visible semantic prime influences the lexical processing of its target by determining whether there was an effect of the visible semantic prime on the lexical facilitation from masked nonword primes. Furthermore, the SOA of the visible prime was varied to examine the effects of the different processes that have been proposed to drive semantic priming. Specifically, at a long SOA, the process driving semantic priming effects via lexical activation of the target word is presumed to be expectancy generation. At a short SOA, automatic spreading activation from the visible prime is assumed to influence the lexical activation of the target. Additionally, at both long and short SOAs, semantic matching could be driving the semantic priming effects. An interaction between semantic and orthographic priming effects would suggest that the effect of visible semantic primes occurs at the same stage as the effect of masked nonword orthographic primes (i.e., during lexical selection). In contrast, additive effects would suggest that the effects of visible and masked primes arise at different points in processing.

There were clear semantic priming effects in the double priming paradigm at long and short SOAs that were similar in magnitude to the effects found in pilot testing, confirming the existence of semantic facilitation for our visible prime-target pairs in that paradigm. Additionally, the orthographic priming effect found in the masked prime group was also found in both the long and short SOA double priming groups. Importantly, the semantic and orthographic priming effects were additive in both the long and short SOA visible prime groups, suggesting that the observed semantic priming is not a lexical activation phenomenon. Posterior probabilities of the null hypothesis (Masson, 2011) provided another source of evidence for a null interaction between the semantic and 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 probability. According to this convention, the posterior probabilities of the null hypothesis (i.e., null interaction between the semantic and orthographic priming effects) constitute “positive” evidence for the null hypothesis.

Experiment 1 also examined the effects of masked orthographic primes and visible semantic primes on the latency distribution using quantile plots. Influence on the lexical activation 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 word. The effect should thus remain consistent across quantiles. In contrast, a post-lexical 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 primes was similar across quantiles, consistent with the notion that effects of these primes offer a head-start to the target words (i.e., through activation of lexical representations). Importantly, the effect of visible semantic primes increased in later quantiles, although this increase was not statistically significant in the short SOA visible prime group. According to Balota et al., as more time becomes available to process the primes (i.e., during the slower trials) prime information will facilitate the LDT response to a greater extent. The effects of visible semantic primes on the latency distribution are thus consistent with a post-lexical locus of semantic priming (i.e., semantic matching).

The masked orthographic nonword priming effect in Experiment 1, while similar in magnitude to the 26 ms effect found in Davis & 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 lexical facilitation from the masked nonword prime 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 orthographic priming effects (e.g., Forster, Davis, Schoknecht, & Carter, 1987).

2.2 Experiment 2

As in Experiment 1, a set of visible semantic prime-target pairs, which yielded a semantic priming effect at both long and short SOAs in the semantic priming project (Hutchison et al., 2013) was obtained. Nonword neighbors were then generated from the target words. Experiment 2 first established the facilitation from these nonword primes in the sandwich priming paradigm (e.g., *aluminum – alxminum – ALUMINUM)* in the *sandwich prime* group. The effect of visible semantic primes on the lexical facilitation from the nonword primes in the sandwich priming paradigm was then examined *(e.g., foil – aluminum – alxminum – ALUMINUM).* As in Experiment 1, the effect of the visible primes was examined at a long SOA in the *long SOA visible prime group*, and at a short SOA in the *short SOA visible prime group*. Consistent with the logic set up in Experiment 1, an interaction between the semantic and orthographic priming effects would indicate that the semantic prime influences the lexical processing of its target (through expectancy generation at a long SOA, or automatic spreading activation at a short SOA). Additivity would imply that the effects of the semantic prime are more likely to be due to a post-lexical process (e.g., semantic matching). As in Experiment 1, the effects of both masked orthographic primes and visible semantic primes on the latency distribution was examined through quantile plots. A constant effect across quantiles would indicate an effect a lexical locus of the effect, while an increase of the effect in later quantiles would indicate a post-lexical locus.

2.2.1 Method

2.2.1.1 Participants.

A total of 147 undergraduate students participated in Experiment 2 for course credit. Due to high error rates on nonword trials (>20%), data from 11 of the 41 participants in the *sandwich prime* group, 7 of the 59 participants in the *long SOA visible prime group*, and 11 of the 47 participants in the *short SOA visible prime group* were excluded from the analyses.

2.2.1.2 Stimuli.

As in Experiment 1, primes and target words were selected from the semantic priming project repository (Hutchison et al., 2013). Out of a total of 128 target words, 24 were eight-letters, 40 were seven-letters, and 64 were six-letters. 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 orthographic 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 prime-target pairs were then re-paired to provide non-neighbor primes such that the 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 for the present experiment are shown in Appendix 2. Counterbalancing for the sandwich prime group was the same as counterbalancing for the masked prime group from Experiment 1, and counterbalancing for the long and short SOA visible prime groups was the same as for those groups in Experiment 1.

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

2.2.1.2.1 Semantic Priming Effects.

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

2.2.1.2.2 Masked Orthographic Priming Effects.

Prior to examining the orthographic facilitation from nonword primes in the sandwich priming paradigm, I examined whether the selected nonword primes would yield facilitation in a conventional masked priming paradigm. In a pilot study using a different set of participants, using a prime duration of 50 ms, I obtained a masked orthographic priming effect of 16 ms, which was significant in both item and subject analyses, $Fs > 5.31$. A prime duration of 50 ms was used because at least some letters in the longer masked primes used in the present experiment were sometimes visible when the prime duration was the same as that used in Experiment 1 (67 ms).

2.2.1.3 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 primes were presented even more briefly due to their greater length. Specifically, during each trial, the sandwich prime group first saw a mask (########) for 700 ms, followed by the target, presented for 33 ms, followed by the masked orthographic nonword prime, presented for 50 ms, followed by the target again (which was presented until a response was made or 2500 ms had elapsed). The long SOA visible prime group first saw the visible prime for 700 ms, then the mask for 700 ms, then the sandwich prime sequence (target for 33 ms, then masked prime for 50 ms, then the target). The short SOA visible prime group first saw the visible prime for 200 ms, then the sandwich prime sequence. Each participant received 12 practice trials followed by 256 experimental trials. The experiment took approximately 7 min for the sandwich prime group, 15 min for the long SOA visible prime group, and 10 min for the short SOA visible prime group.

2.2.2 Results

When the sandwich prime, visible long SOA and visible short SOA groups were combined, 5.3% of the word target trials and 9.0% of the nonword target trials were errors or correct responses faster than 250 ms, or slower than 1750 ms, and those trials were excluded from latency analyses. Table 2 shows latencies and error rates for word for the sandwich prime group, and as a function of visible and masked prime types for the long and short SOA visible prime groups. The latencies and error rates for the nonword targets are shown in Appendix D. Latencies and error rates were subjected 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. Not using the fifth quantile resulted in the loss of 2.7% of the word trials in the sandwich prime group. In the long SOA visible prime group, 1.7% of the word trials were not used in creating the quantiles for the semantic priming effect and in creating the quantiles for the masked orthographic priming effect. In the short SOA visible prime group, 2.0% of the word trials were likewise not used in making quantiles for each effect. Figure 4 shows the quantile plot for the word targets as a function of masked prime type in the masked prime group. Figures 5 and 6 show the quantile plots for the word targets as a function of masked prime type and visible prime type for the long and short SOA groups, respectively.

Table 2. *Latencies (milliseconds) and error rates (percentages) for word targets as a function of visible prime and masked prime types for the Sandwich Prime, Long and Short SOA Visible Prime groups in Experiment 2.*

	Masked Nonword Prime Type		
Group/Visible Prime Type	Neighbor	Non-neighbor	Orthographic Priming Effect
Sandwich Prime	628 (3.4)	684 (3.7)	56 (0.3)
Long SOA Visible Prime			
related	667 (4.0)	704 (4.0)	37 (0.0)
unrelated	692 (7.0)	736 (7.7)	44 (0.7)
Semantic Priming Effect	25 (3.0)	32 (3.9)	
Short SOA Visible Prime			
related	645 (3.4)	683 (3.9)	38 (0.5)
unrelated	677 (3.4)	725 (6.2)	48 (2.8)
Semantic Priming Effect	32 (0.0)	42 (2.3)	

Note. Error rates shown in parentheses.

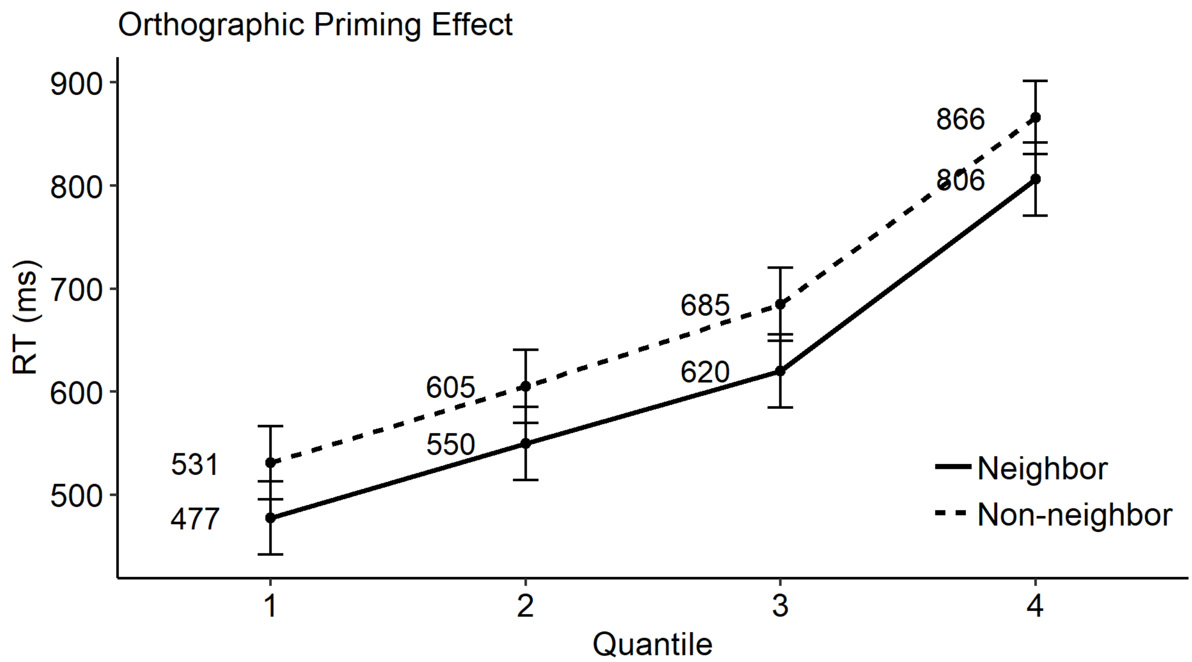

Figure 4. Effect of masked prime type on word targets across quantiles for the sandwich prime group in Experiment 2. Error bars represent 95% confidence intervals.

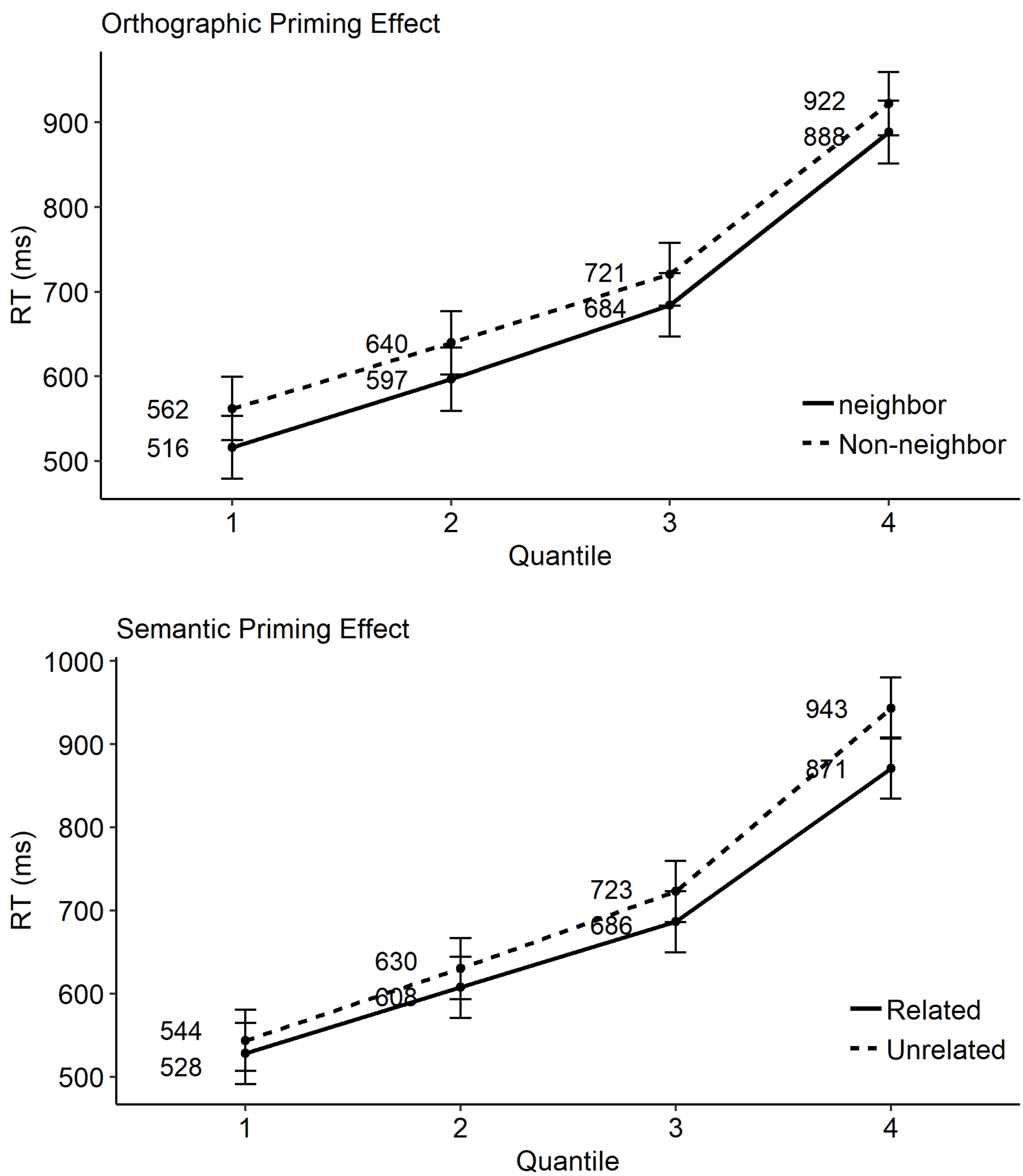

Figure 5. Effect of masked prime type (top panel) and visible prime type (bottom panel) on word targets across quantiles for the long SOA visible group in Experiment 2. Error bars represent 95% confidence intervals.

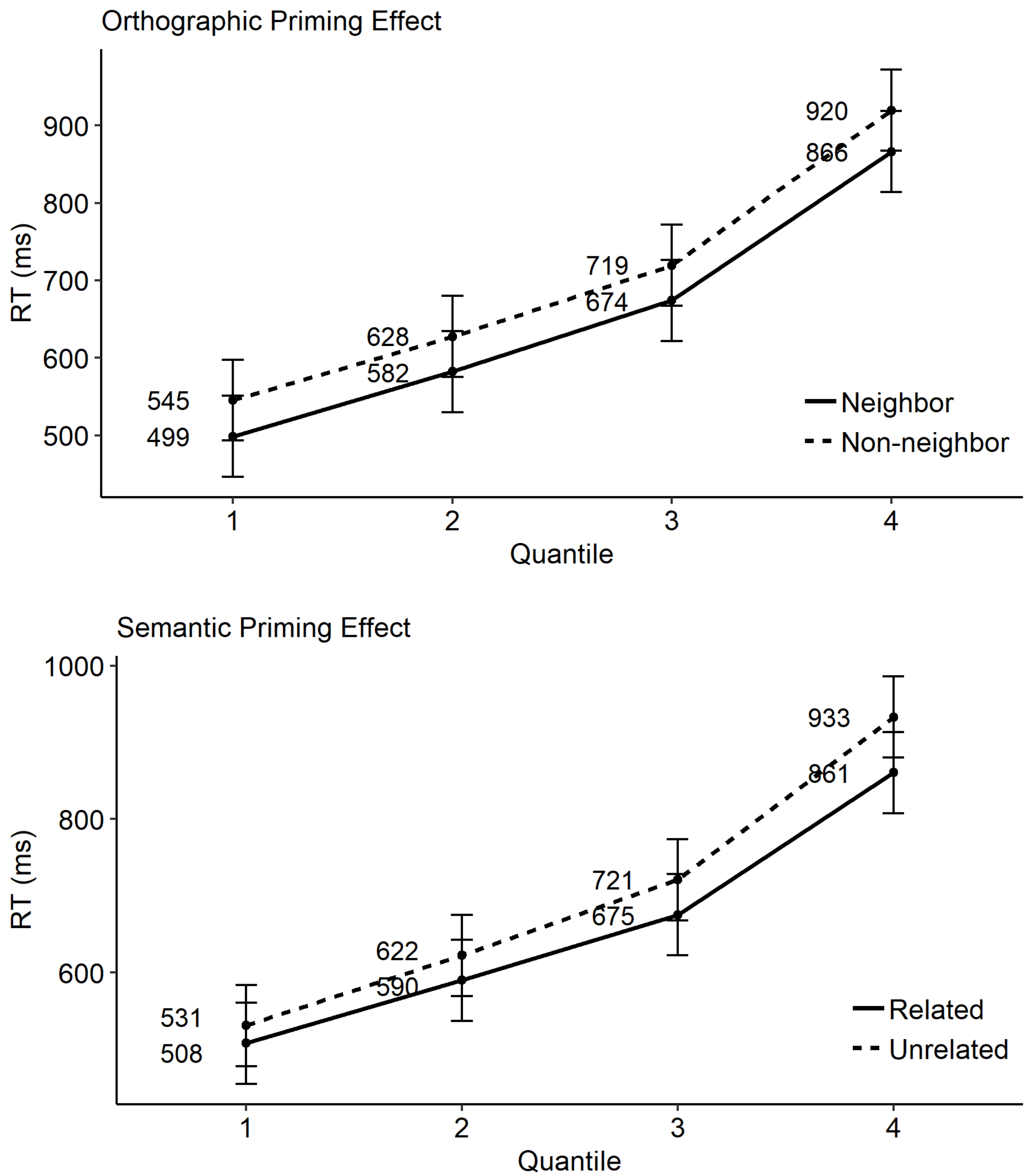

Figure 6. Effect of masked prime type (top panel) and visible prime type (bottom panel) on word targets across quantiles for the short SOA visible group in Experiment 2. Error bars represent 95% confidence intervals.

2.2.2.1 Sandwich prime group.

2.2.2.1.1 Word latencies.

Facilitation from masked nonword orthographic 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 subject and item analyses $F_s(1, 28) = 167.62$, $p < .001$, $\eta^2 = .86$; $F_i(1, 125) = 100.31$, $p < .001$, $\eta^2 = .45$.

2.2.2.1.2 Word errors.

No effects emerged in the subject or item analyses, both *Fs* < 1.

2.2.2.1.3 Effects of masked prime type across quantiles.

The main effects of quantile and masked prime type were confirmed, $F_s(1.13, 31.58) = 513.02$, $p < .001$, $\eta^2 = .95$; $F_s(1, 28) = 253.40$, $p < .001$, $\eta^2 = .90$. Importantly, the masked orthographic priming effect in the sandwich priming paradigm did not change across quantiles as seen in Figure 4, $F_s < 1$.

2.2.2.2 Long SOA visible prime group.

2.2.2.2.1 Word latencies.

A semantic priming effect was found in subject and item analyses $F_s(1, 48) = 23.80$, $p < .001$, $\eta^2 = .33$; $F_i(1, 122) = 34.64$, $p < .001$, $\eta^2 = .22$. An orthographic facilitation effect was also found in the subject and item analyses $F_s(1, 48) = 64.11$, $p < .001$, $\eta^2 = .57$; $F_i(1, 123) = 66.85$, $p < .001$, $\eta^2 = .35$. Importantly, the interaction between the semantic and orthographic priming effects was absent in the subject and item analyses, both *F*s < 1. Bayesian estimates of the posterior probabilities for the null hypotheses again confirmed a null interaction between the semantic and orthographic priming effects in the subject analysis, $P_{sBIC} = .81$ and the item analysis, $P_{iBIC} = .82$.

2.2.2.2.2 Word errors.

An advantage for targets following related (vs. unrelated) visible primes was observed in the subject and item analyses $F_s(1, 48) = 6.42$, $p < .01$, $\eta^2 = .12$; $F_i(1, 122) = 42.73$, $p < .001$, $\eta^2 = .26$. No facilitation from orthographic primes was observed, both $Fs < 1$, nor was there a visible (semantic) prime x masked (orthographic) prime interaction, both $Fs < 1$.

2.2.2.2.3 Effects of masked prime type across quantiles.

There were main effects of quantile and masked prime type, $F_s(1.10, 50.81) = 352.86$, $p < .001$, $\eta^2 = .88$; $F_s(1, 46) = 48.26$, $p < .001$, $\eta^2 = .51$. As with the masked prime group, the facilitation from masked nonword primes in the sandwich priming paradigm did not change across quantiles (Figure 5, top panel), $F_s < 1$.

2.2.2.2.4 Effects of visible prime type across quantiles.

Main effects of quantile and visible prime type were observed, $F_s(1.12, 51.47) = 373.60$, $p < .001$, $\eta^2 = .89$; $F_s(1, 46) = 71.47$, $p < .001$, $\eta^2 = .61$. Importantly, as shown in Figure 5, bottom panel, the semantic priming increased in later quantiles, $F_s(1.25, 57.28) = 17.86$, $p < .001$, $\eta^2 = .28$.

2.2.2.3 Short SOA visible prime group.

2.2.2.3.1 Word latencies.

A semantic priming effect was again found in the subject and item analyses $F_s(1, 32) = 41.45$, $p < .001$, $\eta^2 = .56$; $F_i(1, 122) = 34.02$, $p < .001$, $\eta^2 = .22$, as was a masked orthographic priming effect $F_s(1, 32) = 36.68$, $p < .001$, $\eta^2 = .53$; $F_i(1, 122) = 70.64$, $p < .001$, $\eta^2 = .37$. No interaction was found in the subject or item analyses, Fs < 1. Bayesian estimates again supported a null interaction in both the subject and item analyses $P_{sBIC} = .72$; $P_{iBIC} = .81$.

2.2.2.3.2 Word errors.

A marginal reduction in errors following a related (vs. unrelated) visible primes was found in the subject analyses, and a significant reduction was found in item analyses F_s(1,

32) = 3.53, p = .07, η^2 = .10; F_i(1, 122) = 4.11, p = .04, η^2 = .03. Similarly, the reduction of errors following neighbor (vs. non-neighbor) masked primes was significant in the subject and item analyses, F_s(1, 32) = 10.11, p = .003, η^2 = .24; F_i(1, 122) = 5.49, p = .02, η^2 = .04. In the subject analysis, the interaction was not significant, F_s(1, 32) = 2.69, p = .11, η^2 = .08, but in the item analysis the interaction was significant, F_i(1, 122) = 4.05, p = .05, η^2 = .03. The facilitation effect of orthographic primes (i.e., error reduction) was greater following unrelated (vs. related) visible primes.

2.2.2.3.3 Effects of masked prime type across quantiles.

There were main effects of quantile and masked prime type, F_s(1.11, 35.65) = 159.24, $p < .001$, η^2 = .83; F_s(1, 32) = 53.76, $p < .001$, η^2 = .63. Again, the facilitation from masked nonword primes in the sandwich priming paradigm did not change across quantiles (Figure 6, top panel), $F_s < 1$.

2.2.2.3.4 Effects of visible prime type across quantiles.

Main effects of quantile and visible prime type were confirmed, F_s(1.12, 35.87) = 153.24, $p < .001$, η^2 = .83; F_s(1, 32) = 43.69, $p < .001$, η^2 = .58. As seen in Figure 6, bottom panel, the semantic priming effect increased in later quantiles, F_s(1.21, 39.01) = 8.89, p = .003, η^2 = .22.

2.2.3 Discussion

The goal of Experiment 2 was to provide a more sensitive test for the interaction between semantic and orthographic priming effects by using the sandwich priming paradigm. It was expected that the sandwich priming paradigm, as opposed to the conventional masked priming paradigm, would increase the magnitude of the facilitation from the masked orthographic primes. Following the logic of Experiment 1, semantic primes could influence the lexical processing of the target via expectancy generation at a long SOA (1483 ms) or via automatic spreading activation at a short SOA (283 ms). Additionally, semantic primes could be producing semantic priming post-lexically through the semantic matching mechanism. While an interaction between the semantic and orthographic priming effects would suggest semantic primes influence the lexical activation of their targets, additivity would suggest semantic primes act after the lexical selection of the target is essentially complete.

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 priming effect was obtained using the sandwich priming paradigm. Importantly, the results in Experiment 2 suggest additivity between the semantic and orthographic priming effects, consistent with the results from Experiment 1. Bayesian estimates of the posterior probability for the null hypothesis again provided evidence in favor of additivity. Consistent with Experiment 1, the posterior probabilities constituted positive evidence for the null hypothesis (with the exception of the subject analysis in the short SOA group, which constituted only weak evidence for the null hypothesis).

The effects of the masked nonword primes and visible semantic primes on the latency distribution were consistent with those from Experiment 1. The orthographic priming effect in the sandwich priming paradigm was consistent across quantiles reflecting a head-start due to the lexical activation of the targets. The semantic priming effect, at long and short SOA, increased in later quantiles as it did in Experiment 1, consistent with a post-lexical locus of the semantic priming effect.

Although Experiments 1 and 2 consistently suggest statistical additivity and, thus, independence, between the masked orthographic and visible semantic priming effects, the priming effects were not numerically identical. Specifically, the semantic priming effect was 10 ms larger for the orthographically unrelated pairs than the orthographically related pairs in the long SOA group in Experiment 2, 9 ms larger for the orthographically unrelated pairs than the orthographically related pairs in the long SOA group in Experiment 1 and 7 ms larger for the orthographically unrelated pairs than the orthographically related 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 orthographically unrelated pairs than for the orthographically related pairs. Further, as Sternberg (1969) has noted, there is always the possibility that two factors can influence the same stage in the word recognition process in an additive fashion. For example, Plaut and Booth (2000) proposed a distributed model of word recognition where 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). The authors further ran simulations showing that an interaction or additivity could be obtained between two factors (semantic priming and word frequency) could be obtained depending on the position of the target on the sigmoidal activation curve. Thus, even a numerically null interaction is not conclusive proof that two factors are affecting separate processes. Experiment 3 was designed, therefore, to provide a slightly different, but potentially more direct, test of the independence of visible semantic and masked orthographic priming effects. Specifically, Experiment 3 examined the effect of a visible semantic prime on a masked orthographic *word* prime, that is, the semantic prime was related (or unrelated) to the masked prime itself.

2.3 Experiment 3

The goal of Experiment 3 was to examine whether a visible semantic prime can make a masked word prime a more effective lexical inhibitor. In contrast to masked nonword primes, masked word primes inhibit the target by activating their own lexical representations, which then compete with that of the target during lexical selection (Davis & Lupker, 2006). In Experiment 3, the visible prime was thus related (or unrelated) to the masked word prime rather than the target which had been the case in Experiments 1 and 2, (e.g., *light – lamp – LAMB)*. Furthermore, because the masked word prime is neither beneficial to responding nor consciously recognized, any effect it might have on target processing would be automatic rather than strategic. The effects of the visible prime would only result from its impact on lexical processing of the target by making the masked word prime a more effective lexical inhibitor of the target. Consistent with the logic in Experiments 1 and 2, at a long SOA, the visible prime could influence the lexical representation of the masked word prime via expectancy generation. At a short SOA, the visible prime could influence the lexical representation of the masked word prime via automatic spreading activation. If visible semantic primes can influence lexical representations of their targets, then the lexical representations of masked word primes should be more highly activated, making them more effective at inhibiting their targets. For example, *lamp* would be a more effective lexical inhibitor of *LAMB* when preceded by a related visible prime (*light*) instead of an unrelated one (*brick*). The result should be an interaction between the semantic and the inhibitory orthographic priming effects. In contrast, additivity between the semantic and orthographic priming effects would indicate that the inhibition from the masked word prime is not modulated by the preceding visible semantic prime.

The targets from Experiment 1 were used. For each word target, a word prime that had a greater frequency than the target was selected as an orthographically similar word prime which should allow that prime to inhibit that target (Davis & Lupker, 2006). Visible primes semantically related to the masked word primes were then selected. Experiment 3 first established the inhibition of the target words from the masked word primes in the *masked prime* group. The ability of visible primes to make the masked word prime a more effective lexical inhibitor was then examined in the *long SOA visible prime* group and the *short SOA visible prime* group.

2.3.1 Method

2.3.1.1 Participants.

A total of 157 undergraduate students participated in Experiment 3 for course credit. Data from 5 out of the 37 who participated in the *masked prime* group, were excluded from the analyses due to high error rates on nonword trials using the same criterion as used previously. In the *long SOA visible prime* group, data from 9 out of the 53 participants were excluded, and in the *short SOA visible prime* group, data from 11 out of the 67 participants were excluded for that same reason.

2.3.1.2 Stimuli.

As in Experiments 1 and 2, the stimuli consisted of a visible semantic prime and a masked orthographic prime for each target. Unlike in the prior experiments, the masked primes were words rather than nonwords, and the visible semantic primes were 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 3.

Masked word orthographic neighbor primes were selected using the N-Watch software (Davis, 2005) for each word and nonword target. The neighbor primes differed from the target, word or nonword, in one letter position. For word targets, the neighbor primes were selected to be as high in frequency as possible in order 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 masked primes were also selected (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 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 primes that were associatively/semantically related to the masked primes were selected. These visible primes had no obvious relationship with the word targets following their masked prime. For related visible primes preceding neighbor masked primes of word targets, CELEX = 344.93, N = 6.08. For related visible primes preceding neighbor masked primes of nonword targets, CELEX = 67.67, N = 4.45. Unrelated visible primes were obtained by re-pairing the visible prime-masked 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 primes were thus selected in these instances. For related visible primes preceding non-neighbor masked primes of word targets, CELEX = 690.96, N = 6.02, and of nonword targets, CELEX = 49.80, N = 4.48. Counterbalancing for the masked prime, long SOA and short SOA visible prime groups was the same as the counterbalancing for the corresponding groups from Experiment 1.

2.3.1.2.1 Semantic Priming Effects.

Using different groups of participants, I first sought to confirm facilitation from the visible primes for the masked orthographic word primes when those primes were the targets in a LDT, at both long (1467 ms) and short SOAs (267 ms). At the long SOA, I found a 13 ms effect that was significant in both subject and item analyses, *F*s > 5.77. At the short SOA, the 25 ms effect was significant in both subject and item analyses, *F*s > 8.60.

2.3.1.3 Experimental Procedure.

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

2.3.2 Results

When data from the masked prime group, the long SOA, and the short SOA groups were combined, 6.1% of the word target trials and 11.0% of the nonword target trials were errors, or correct responses faster than 250 ms, or slower than 1750 ms, and those trials were excluded from the latency analyses. Table 3 shows the latencies and error rates for word targets as a function of the masked word prime type for the masked prime group, and as a function of visible and masked word prime types for the long and short SOA visible prime groups. The baseline inhibition effect from masked word primes was first established in the masked prime group. Whether a visible semantic prime could increase the inhibition produced by the masked word primes was then investigated in both long and short visible SOA groups. Analyses on latencies and error rates were the same as in Experiments 1 and 2, except the visible 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 targets.

Table 3. *Latencies (milliseconds) and error rates (percentages) for word targets as a function of visible prime and masked prime types for the Masked Prime, Long and Short SOA Visible Prime groups in Experiment 3.*

	Masked Word Prime Type		
Group/Visible Prime Type	Neighbor	Non-neighbor	Orthographic Inhibition Effect
Masked Prime	674 (6.9)	657 (6.7)	-17 (-0.2)
Long SOA Visible Prime			
related	701 (7.7)	679 (4.8)	-22 (-2.9)
unrelated	689 (5.8)	679 (4.3)	-10 (-1.5)
effect	-12 (-1.9)	0 (-0.5)	
Short SOA Visible Prime			
related	713 (6.4)	708 (5.9)	-5 (-0.5)
unrelated	713 (6.3)	697 (5.5)	-16 (-0.8)
effect	0 (-0.1)	-11 (-0.4)	

Note. Error rates shown in parentheses.

Separate quantile plots were generated to investigate the effect of masked prime type on the latency distribution following related and unrelated visible primes. Thirty-two word targets were preceded by visible primes that were related (or unrelated) to the masked prime. Thus, each masked prime type condition had only 16 trials. As a result, all trials were retained in making the quantile plots. Figure 7 shows the quantile plot of the masked orthographic inhibition effect as a function of masked prime type in the masked prime group. Figure 8 shows the quantile plots of the masked inhibition effect following a visible prime related to the masked prime (top panel) and unrelated to the masked prime (bottom panel) for the long SOA visible prime group. Figure 9 similarly shows the quantile plots of the masked inhibition effect following related and unrelated visible primes for the short SOA visible prime group.

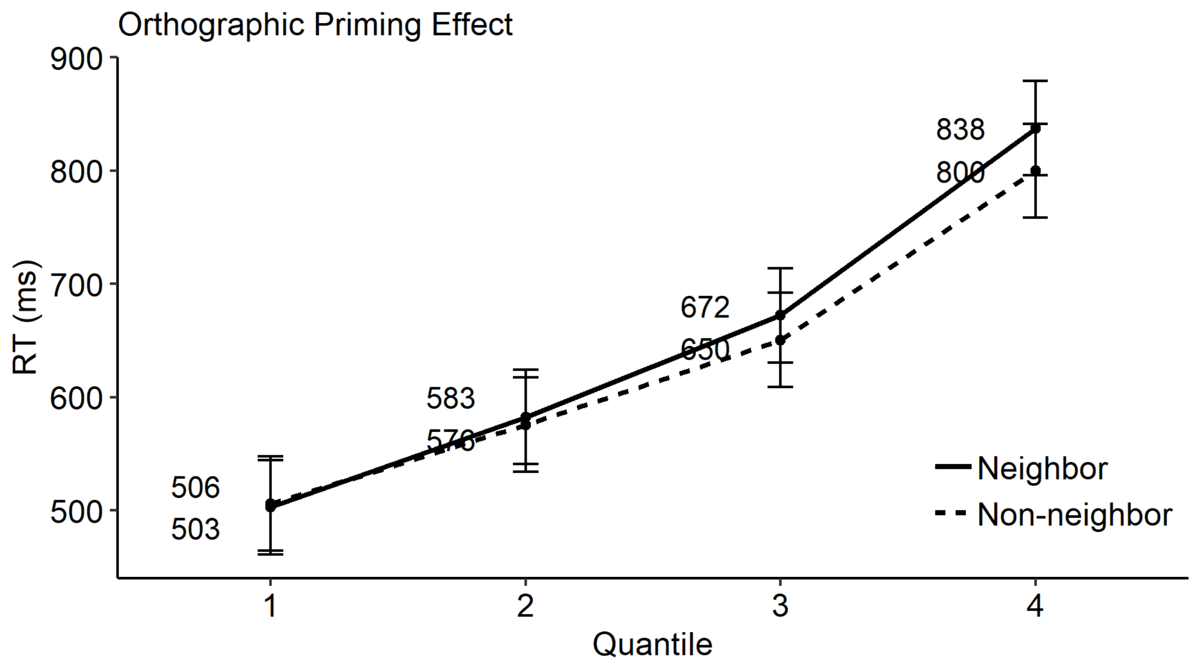

Figure 7. Effect of masked prime type on word targets across quantiles for the masked prime group in Experiment 3. Error bars represent 95% confidence intervals.

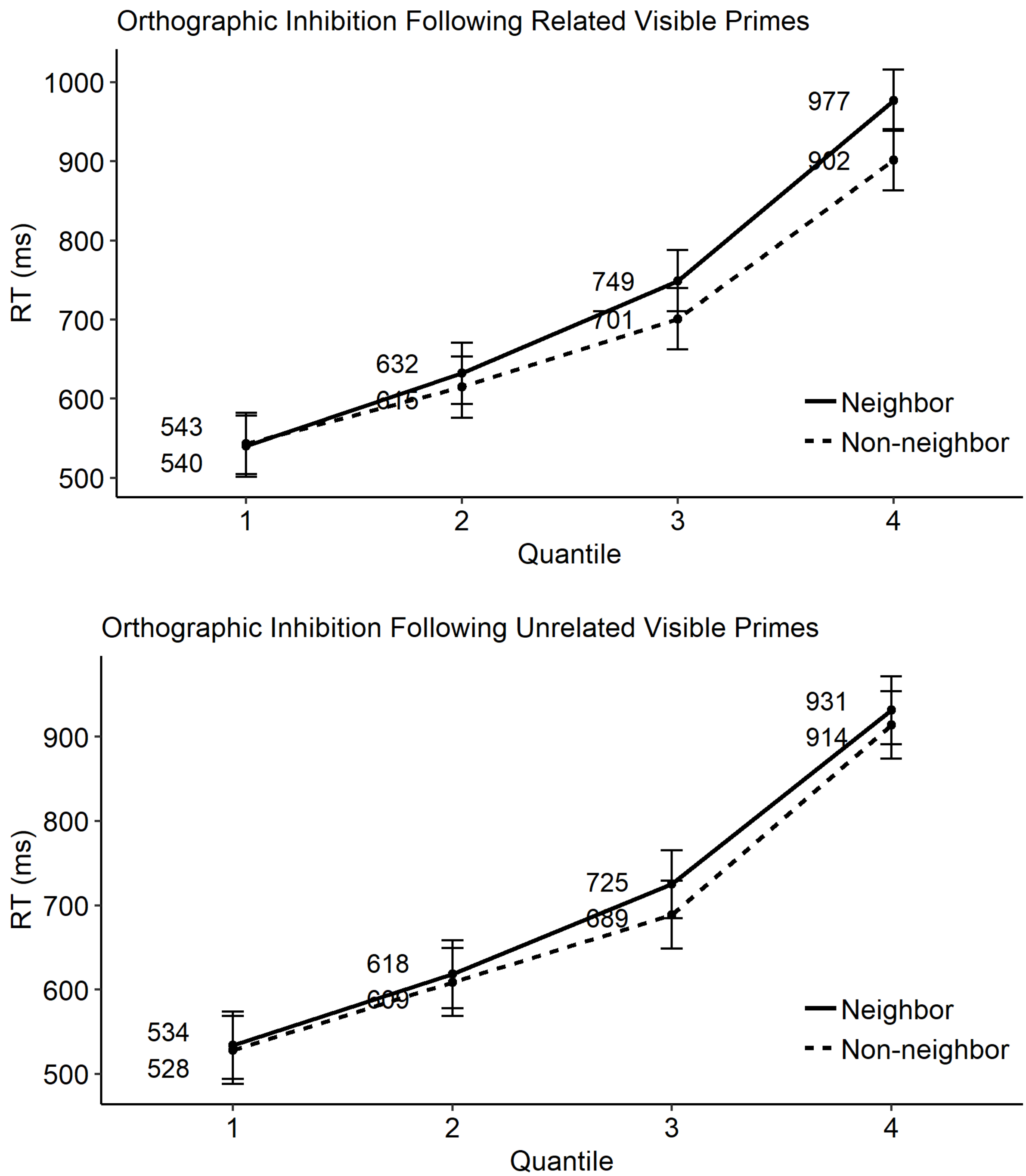

Figure 8. Effect of masked prime type following visible primes that were related to their masked primes (top panel) and unrelated to their masked primes (bottom panel) across quantiles for the long SOA visible group in Experiment 3. Error bars represent 95% confidence intervals.

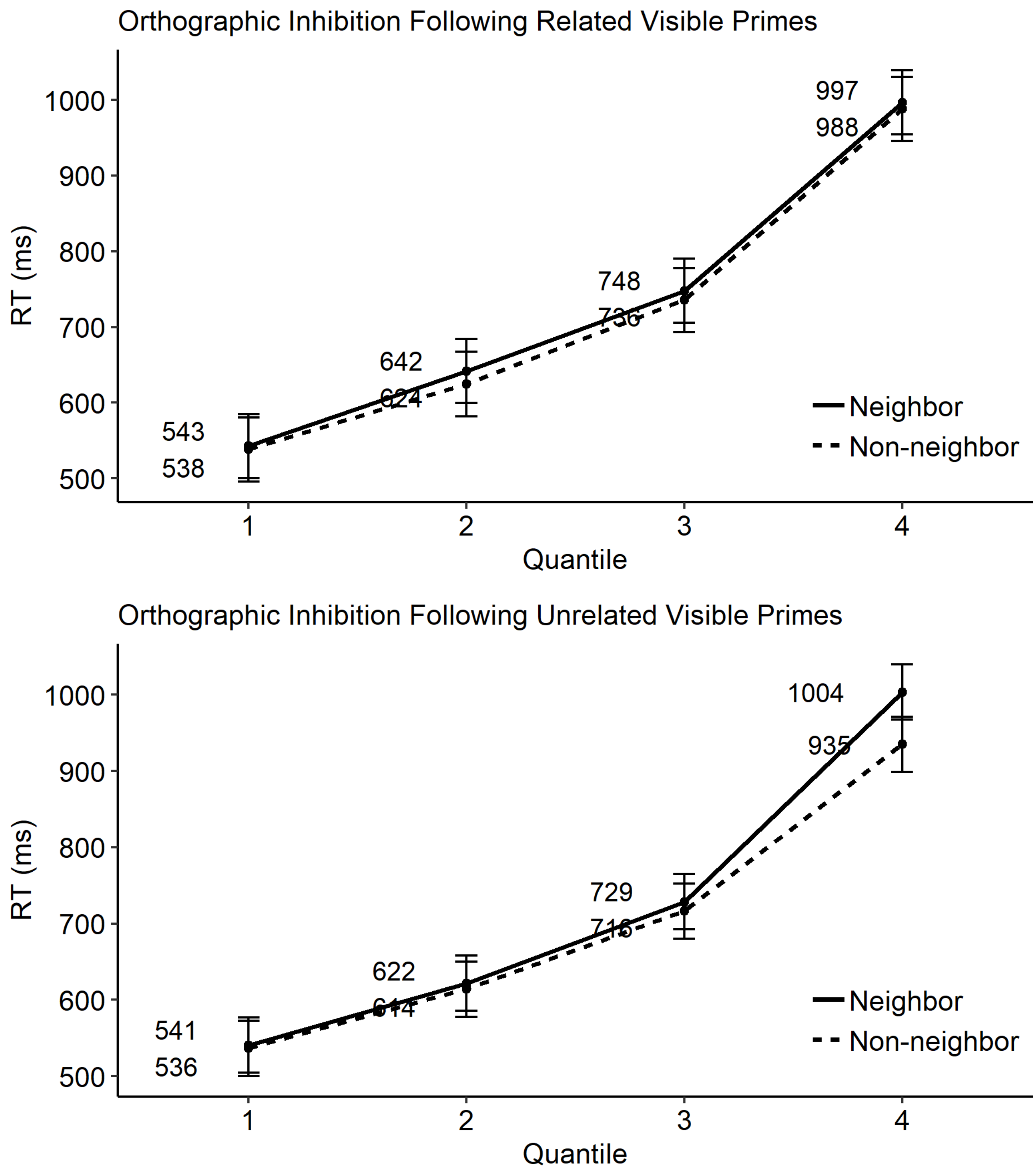

Figure 9. Effect of masked prime type following visible primes that were related to their masked primes (top panel) and unrelated to their masked primes (bottom panel) across quantiles for the short SOA visible group in Experiment 3. Error bars represent 95% confidence intervals.

For the masked prime group, the analysis examining the effect of the masked orthographic inhibition effect was the same as in Experiments 1 and 2. For the long and short SOA visible prime groups, separate 2 (masked prime: neighbor vs. non-neighbor) x 4 (quantile: 1 vs. 2 vs. 3 vs. 4) x 2 (group/set: 1 vs. 2) split-plot ANOVAs were conducted based on whether the visible primes were related or unrelated to the masked primes following them. Since not all participants had responses in the final quantile, data from some participants was excluded from the quantile analyses. In the long SOA group, data from 2 participants were excluded from the analysis following related visible primes, and data from 1 participant were excluded from the analysis following unrelated visible primes. In the short SOA group, data from 3 participants were excluded in the analysis following related visible primes, and data from 2 participants were excluded from analyses following unrelated visible primes.

2.3.2.1 Masked prime group.

2.3.2.1.1 Word latencies.

Neighbor (vs. non-neighbor) masked word primes slowed down responses to target words (Table 3). The inhibition from masked 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, $F_i(1, 62) = 4.63$, $p = .04$, $\eta^2 = .07$.

2.3.2.1.2 Word errors.

No effect of masked prime type was found, both *Fs* < 1.

2.3.2.1.3 Effects of masked prime type across quantiles.

An increase in latencies across quantiles was observed, $F_s(1.10, 32.97) = 172.58$, $p < .001$, $\eta^2 = .85$, however, the orthographic inhibition effect was marginal, $F_s(1, 30) = 2.88$, $p = .10$, $\eta^2 = .09$. Although the orthographic inhibition effect numerically increased in later quantiles as seen in Figure 7, the interaction between quantile and masked prime type was not significant, $F_s(1.17, 34.99) = 2.29$, $p = .14$, $\eta^2 = .07$.

2.3.2.2 Long SOA visible prime group.

2.3.2.2.1 Word latencies

There was no effect of the visible primes on the targets in either the subject or item analyses, both *Fs* < 1, demonstrating that the visible prime manipulation did not influence the targets themselves. The inhibition from masked neighbor word primes was significant in the subject and item analyses, $F_s(1, 40) = 5.28$, $p = .03$, $\eta^2 = .12$; $F_i(1, 60) = 7.20$, $p = .01$, $\eta^2 = .11$. Importantly, there was no increase in the inhibition effect when the visible prime was semantically related to the masked word prime. The interaction between visible prime and masked prime was not significant in the subject or item analyses, both *Fs* < 1.86, *ps* > .18. In the subject analysis, a Bayesian estimate confirmed the lack of increase in the inhibition effect when the visible prime was related (vs. unrelated) to the masked word prime $P_{sBIC} = .78$. In contrast, in the item analysis, the Bayesian estimate showed some support for the interaction between visible and masked priming effects, $P_{iBIC} = .42$.

2.3.2.2.2 Word errors.

As in the latency data, visible primes did not influence error rates of targets according to either the subject or item analyses, both *Fs* < 2.40, *ps* > .13. However, error rates were greater when word targets were preceded by neighbor (vs. non-neighbor) masked word primes in both subject and item analyses, mirroring the inhibition effect with the latencies, $F_s(1, 40) = 6.56$, $p = .01$, $\eta^2 = .14$; $F_i(1, 60) = 8.00$, $p = .006$, $\eta^2 = .12$. The visible prime type did not modulate the effect of the masked word prime however, both *Fs* < 1.

2.3.2.2.3 Effects of masked prime type across quantiles.

Following visible primes that were semantically related to their masked primes, the were main effects of quantile and masked prime type, $F_s(1.44, 43.48) = 231.58$, $p < .001$, $\eta^2 = .86$; $F_s(1, 38) = 9.51$, $p = .004$, $\eta^2 = .20$. As shown in Figure 8, top panel, the magnitude of the orthographic inhibition increased in later quantiles, $F_s(1.22, 46.55) = 5.52$, $p = .02$, $\eta^2 = .13$. When examined following visible primes unrelated to their masked primes (bottom panel), there was a main effect of quantile, $F_s(1.18, 45.94) = 223.60$, $p < .001$, η^2

= .85, however the masked inhibition effect was not significant, $F_s(1, 39) = 2.06$, $p = .16$, $\eta^2 = .05$. The masked inhibition effect also did not change across quantiles, $F_s < 1$.

2.3.2.3 Short SOA visible prime group.

2.3.2.3.1 Word latencies.

Whether visible primes were semantically related (or unrelated) to the masked word prime did not influence the latencies of target responses, consistent with the long SOA visible prime group data, both *Fs* < 1.40, *ps* > .24. The lexical inhibition effect, while numerically present, was not significant in either subject or item analyses, both *Fs* < 2.56, *ps* > .12. Importantly, lexical inhibition again did not increase when the masked word prime was preceded by a related visible prime, both *Fs* < 1.06, *ps* > .31. Bayesian estimates again support a null interaction between visible and masked primes in subject and item analyses, $P_{sBIC} = .81$; $P_{iBIC} = .72$.

2.3.2.3.2 Word errors.

No effects or interactions were found, all *Fs* < 1.

2.3.2.3.3 Effects of masked prime type across quantiles.

Following visible primes related to their masked primes, there was an effect of quantile, $F_s(1.16, 56.90) = 302.48$, $p < .001$, $\eta^2 = .86$. The orthographic inhibition effect was not significant, nor did it change across quantiles (Figure 9, top panel), both *Fs* < 1. Following visible primes unrelated to their masked primes, there were main effects of quantile and masked prime type, $F_s(1.09, 54.69) = 317.44$, $p < .001$, $\eta^2 = .86$; $F_s(1, 50) = 5.67$, $p = .02$, $\eta^2 = .10$. Specifically, the orthographic inhibition effect increased in later quantiles as shown in Figure 9, bottom panel, $F_s(1.21, 60.57) = 4.65$, $p = .03$, $\eta^2 = .09$.

2.3.3 Discussion

The goal of Experiment 3 was to more directly examine whether visible semantic primes at long and short SOAs could influence lexical processing. Unlike Experiments 1 and 2, the visible prime was now related (vs. unrelated) to the masked prime (which was a word) rather than to the target. In contrast to masked nonword primes, masked word primes slow down recognition of the target, especially when higher in frequency than the target (Davis & Lupker, 2006). In Experiment 3, therefore, I attempted to use the visible prime to increase the lexical activation of and, hence, lexical inhibition from, the masked word prime. Importantly, since the masked prime is not consciously identified, any modulation of the lexical inhibition effect would have resulted from the visible prime influencing the lexical representation of the masked word prime (through expectancy generation at long SOA and automatic spreading activation at short SOA).

The lexical inhibition effect from masked word primes was established in the masked prime group, and was also found in the long SOA visible prime group. This inhibition effect was numerically present (11 ms) in the short SOA visible prime group, however, it was not significant. Importantly, the magnitude of the lexical inhibition effect from masked word primes was not increased by the prior presentation of a semantically related visible prime. Additionally, the Bayesian estimates of the posterior probabilities showed positive evidence (Raftery, 1995) for the null hypothesis, with the exception of the posterior probability in the item analysis in the long SOA group, which showed weak evidence for the alternative hypothesis. Consistent with Experiments 1 and 2, these results imply that the influence of visible semantic primes at both long and short SOAs is not due to increasing the lexical activation of related words.

2.4 Experiment 4

Experiments 1 and 2 have found additivity between the facilitation from masked nonword primes and the facilitation from visible semantic primes (at long and short SOAs). Experiment 3 showed that visible primes do not make masked word primes more effective lexical inhibitors of their targets. These findings suggest that the effect of masked orthographic primes and visible semantic primes contribute to the LDT at separate stages, where masked orthographic primes influence the lexical activation of the target, visible semantic primes contribute to the decision component that follows lexical selection, which involves participants engaging in a semantic matching process between the target and the visible prime following the lexical identification of the target. Experiment 4 examines an implication of this conclusion for the work of Forster (2009; 2013) on the question of whether masked repetition primes have an extra semantic component that can facilitate the semantic matching process between the target and the visible prime.

Forster (2009, 2013) suggested that the semantic information that is extracted from the repetition prime could result in a semantically-based component of the priming effect. Within the interactive activation framework, this semantic information from the masked repetition primes, if present, could facilitate target processing in one of two ways. First, the activation of the target's semantic representation could provide direct feedback for the lexical representation of the target, speeding up its lexical selection. Second, the semantic activation from the masked repetition prime could facilitate the semantic matching process between the target and the visible prime. In his studies, Forster (2009, 2013) did not use a visible semantic priming manipulation, so it is unclear how the semantic information from the masked repetition primes, if present, would interact with the repetition priming effect. Experiment 4 provides an evaluation of these ideas by combining masked repetition priming with visible semantic priming (e.g., *mutton – lamb – LAMB*).

Following the logic of Experiments 1 and 2, Experiment 4 tested for the presence of an interaction between visible semantic primes and masked repetition primes. If masked repetition primes facilitate the semantic matching process between the targets and the visible primes, an interaction between the semantic and repetition priming effects should be observed. In contrast, if masked repetition primes do not facilitate the semantic matching process, but rather increases the target's lexical activation, additivity between the effects should be observed. That is, in Experiment 4, the potential interaction is not one that would be taking place at the lexical level as was the case in the previous experiments, but one that would be taking place at the post-lexical, decision-based level.

A masked repetition effect was initially demonstrated in the *masked prime* group. As in Experiments 1 and 2, the effect of the visible primes was examined at long SOA in the *long SOA visible prime* group, and at short SOA in the *short SOA visible prime* group. Of note, the control masked primes for the repetition primes were the non-neighbor nonwords rather than unrelated words (as is typically done in masked repetition priming experiments). The rationale for using nonwords as control primes was to make the findings of Experiment 4 more directly comparable to those of Experiments 1 and 2, which examined the orthographic facilitation from nonword primes and used nonword control primes.

2.4.1 Method

2.4.1.1 Participants.

A total of 162 undergraduate students participated in Experiment 4 for course credit. Due to high error rates on nonword trials (>20%), data from 7 out of the 35 who participated in the *masked prime* group, were excluded from the analyses. In the *long SOA visible prime* group, data from 9 out of the 37 participants were excluded, and in the *short SOA visible prime* group, data from 18 out of the 90 participants were excluded.

2.4.1.2 Stimuli.

The stimuli from Experiment 2 were used, except nonword orthographic neighbor primes were replaced by repetition primes (i.e., the targets). Nonword orthographic non-neighbor primes from Experiment 2 were used as control primes (e.g., *evidengx* was the control prime for ALUMINUM in Experiment 2 and in Experiment 4 as well). For participants in the masked prime, long and short SOA visible prime groups, trials involving the target word *gander* were excluded from the analyses for having high error rates (> 50%), and trials involving the target word *aluminum* were excluded because that target was inadvertently presented as a practice item.

2.4.1.3 Experimental Procedure.

A conventional masked priming paradigm was used, otherwise, the procedure was identical to the one used in Experiment 2. Specifically, only one masked prime preceded the target (repetition prime on related trials or nonword non-neighbor prime on unrelated trials) for 50 ms, rather than using the sandwich prime sequence used in Experiment 2 (target for 33 ms, then masked prime for 50 ms).

2.4.2 Results

In the combined data from the masked prime group, the long, and short SOA visible prime groups, 4.4% of the word trials and 7.9% of the nonword trials were errors, or correct responses faster than 250 ms, or slower than 1750 ms, and excluded from latency analyses. Table 4 shows the latencies and error rates for word and nonword targets as a function of masked prime type for the masked prime group, and as a function of visible and masked prime types for the long and short SOA visible prime groups. Latencies and error rates were subjected to the same analyses as in Experiments 1 and 2, except the masked prime factor now compared repetition and non-neighbor primes.

Table 4. *Latencies (milliseconds) and error rates (percentages) for word targets as a function of visible prime and masked nonword prime types for the Masked Prime, Long, and Short SOA Visible Prime groups in Experiment 4.*

	Masked Repetition Prime Type		
Group/Visible Prime Type	Repetition	Non-neighbor	Repetition Priming Effect
Masked Prime	634 (3.9)	681 (3.9)	47 (0.0)
Long SOA Visible Prime			
related	614 (2.6)	669 (2.8)	55 (0.2)
unrelated	655 (2.6)	707 (4.3)	52 (1.7)
Semantic Priming Effect	41 (0.0)	38 (1.5)	
Short SOA Visible Prime			
related	640 (3.7)	664 (3.2)	24 (-0.5)
unrelated	661 (3.6)	696 (5.5)	35 (1.9)
Semantic Priming Effect	21 (-0.1)	32 (2.3)	

Note. Error rates shown in parentheses.

Quantiles were generated and analyzed as in Experiment 2, and the first four quantiles (15 trials each) were retained. Not using the fifth quantile resulted in the loss of 2.1% of the word trials in the masked prime group. In the long SOA visible prime group, 2.3% of the trials were not used when creating quantiles for the masked repetition priming effect, and quantiles for the semantic priming effect. In the short SOA visible prime group, 2.1% of the trials were not used in creating the quantiles for the semantic priming effect and 1.9% when creating quantiles for the masked repetition priming effect. Figure 10 shows the quantile plot for the word targets as a function of the masked prime type in the masked prime group. Figures 11 and 12 show the quantile plots for word targets as a function of masked prime type (top panels) and visible prime type (bottom panels) for the long and short SOA groups, respectively. In the short SOA group, data from one participant was excluded from the analysis due to the absence of responses in the fourth quantile.

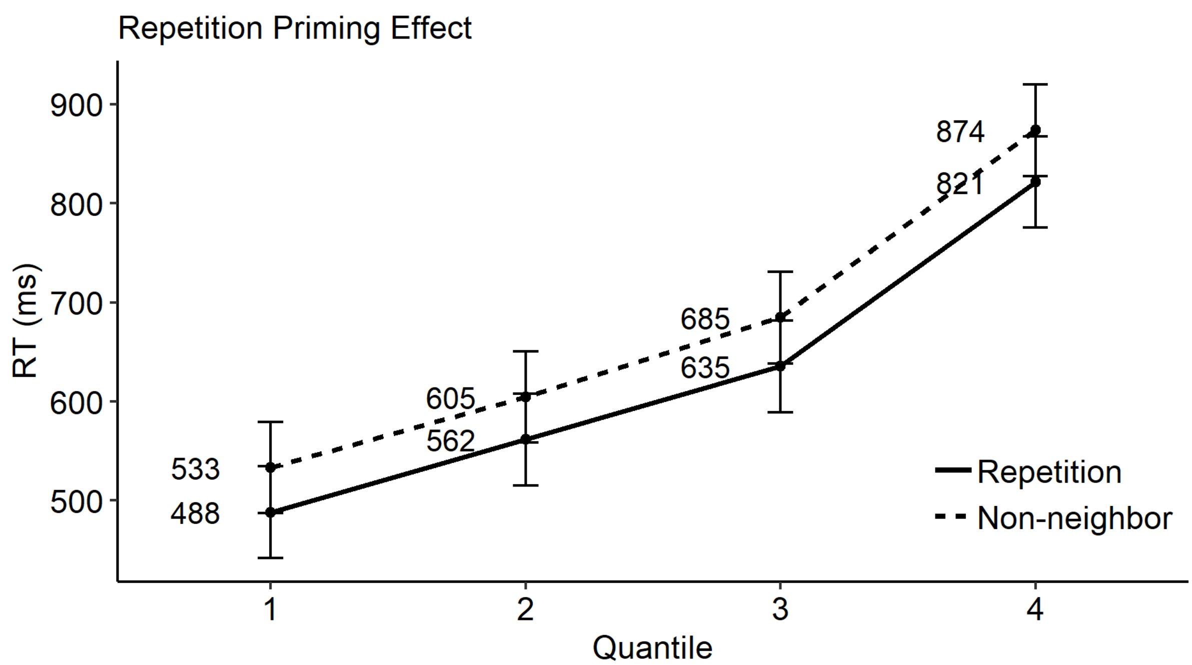

Figure 10. Effect of masked prime type on word targets across quantiles for the masked prime group in Experiment 4. Error bars represent 95% confidence intervals.

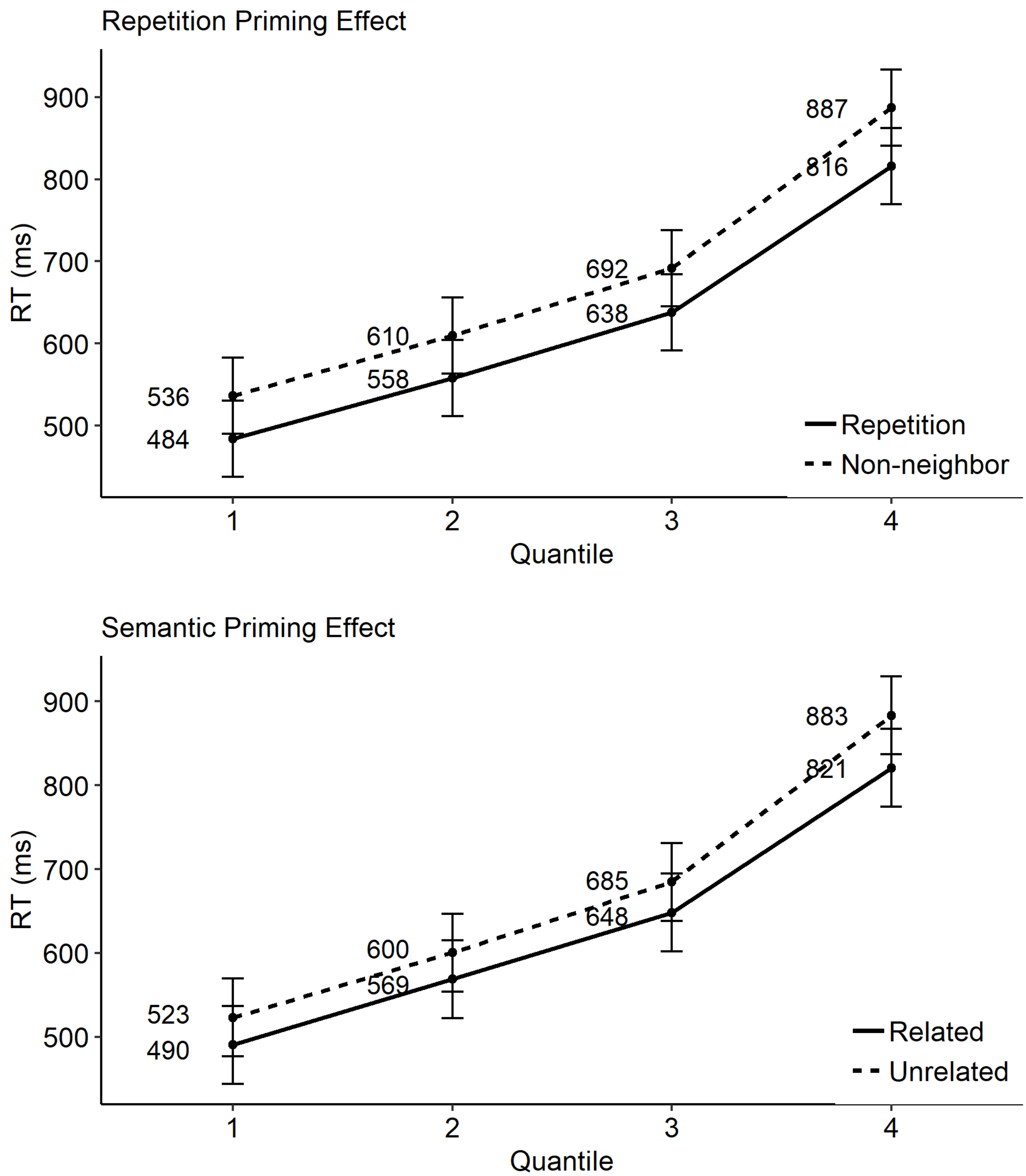

Figure 11. Effect of masked prime type (top panel) and visible prime type (bottom panel) on word targets across quantiles for the long SOA visible group in Experiment 4. Error bars represent 95% confidence intervals.

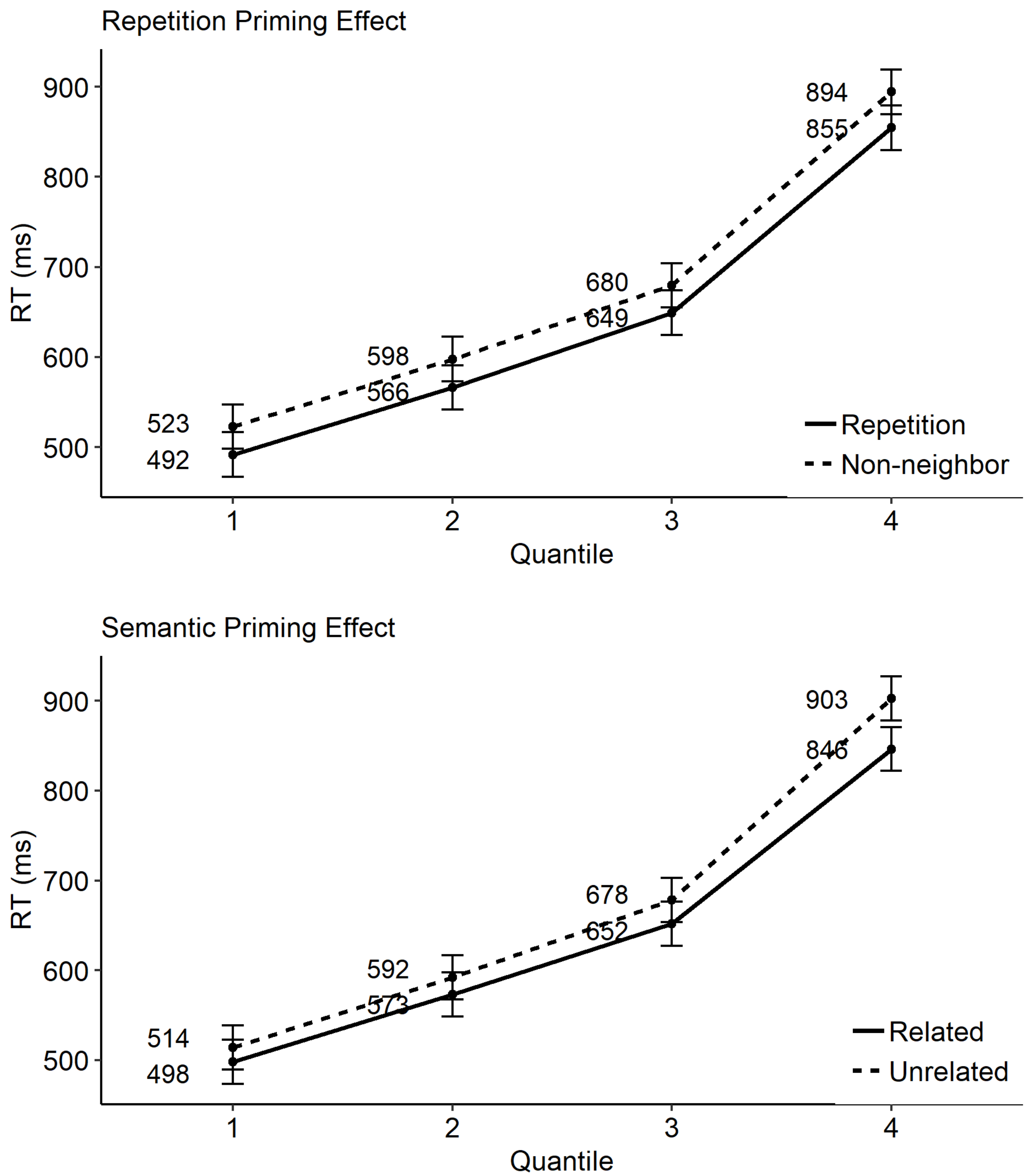

Figure 12. Effect of masked prime type (top panel) and visible prime type (bottom panel) on word targets across quantiles for the short SOA visible group in Experiment 4. Error bars represent 95% confidence intervals.

2.4.2.1 Masked prime group.

2.4.2.1.1 Word latencies.

A masked repetition priming effect was established as repetition (vs. non-neighbor) primes facilitated responses to target words (see Table 4). The facilitation was significant in subject and item analyses, $F_s(1, 26) = 35.90$, $p < .001$, $\eta^2 = .58$; $F_i(1, 124) = 52.84$, $p < .001$, $\eta^2 = .30$.

2.4.2.1.2 Word errors.

No effect of masked prime type was found, both *Fs* < 1.

2.4.2.1.3 Effects of masked prime type across quantiles.

The main effects of quantile and masked prime type were observed, $F_s(1.11, 28.75) = 209.47$, $p < .001$, $\eta^2 = .89$; $F_s(1, 26) = 84.44$, $p < .001$, $\eta^2 = .76$. Importantly, the masked repetition priming effect remained consistent across quantiles as shown in Figure 10, $F_s < 1$.

2.4.2.2 Long SOA visible prime group.

2.4.2.2.1 Word latencies.

The robust semantic priming effect found at a long SOA in Experiment 2 was observed in the subject and item analyses, $F_s(1, 24) = 25.41$, $p < .001$, $\eta^2 = .51$; $F_i(1, 122) = 44.59$, $p < .001$, $\eta^2 = .27$. The facilitation from masked repetition primes was also found in the subject and item analyses, $F_s(1, 24) = 65.21$, $p < .001$, $\eta^2 = .73$; $F_i(1, 122) = 83.75$, $p < .001$, $\eta^2 = .41$. Importantly, the interaction between semantic priming and masked repetition priming effects was absent in the subject and item analyses, both *Fs* < 1, suggesting that masked repetition primes do not facilitate semantic matching between a target and a visible prime. Additionally, Bayesian estimates provided further support for a null interaction in both subject and item analyses, $P_{sBIC} = .89$; $P_{iBIC} = .94$.

2.4.2.2.2 Word errors.

No semantic priming was found in error rates, both *Fs* < 2.02, *ps* > .15. No effect of masked prime type was found in the subject analysis, $F_s(1, 24) = 2.37$, $p = .14$, $\eta^2 = .09$, however error rates were marginally lower following repetition (vs. non-neighbor) masked primes in the item analysis, $F_i(1, 122) = 2.94$, $p = .09$, $\eta^2 = .02$. No interaction was found in subject or item analyses, both *Fs* < 2.00, *ps* > .17.

2.4.2.2.3 Effects of masked prime type across quantiles.

The main effects of quantile and masked prime type were again observed, $F_s(1.05, 25.12) = 156.90$, $p < .001$, $\eta^2 = .87$; $F_s(1, 24) = 53.70$, $p < .001$, $\eta^2 = .69$. The masked repetition prime effect (Figure 11, top panel) did not change across quantiles, $F_s < 1$.

2.4.2.2.4 Effects of visible prime type across quantiles.

The main effects of quantile and visible prime type were again observed, $F_s(1.06, 25.55) = 172.57$, $p < .001$, $\eta^2 = .88$; $F_s(1, 24) = 20.82$, $p < .001$, $\eta^2 = .46$. The numerical increase of the semantic priming effect across quantiles (Figure 11, bottom panel) failed to reach significance, $F_s(1.09, 26.13) = 1.97$, $p = .17$, $\eta^2 = .08$.

2.4.2.3 Short SOA visible prime group.

2.4.2.3.1 Word latencies.

The semantic priming effect at a short SOA from Experiment 2 was observed in subject and item analyses, $F_s(1, 68) = 64.19$, $p < .001$, $\eta^2 = .49$; $F_i(1, 122) = 47.66$, $p < .001$, $\eta^2 = .28$. The masked repetition priming effect was again found in subject and item analyses, $F_s(1, 68) = 58.53$, $p < .001$, $\eta^2 = .46$; $F_i(1, 122) = 65.28$, $p < .001$, $\eta^2 = .35$. Again, no interaction was detected in the subject or item analyses, both *Fs* < 2.20, *ps* > .14. In contrast, Bayesian analyses provided some evidence for an interaction between visible and repetition priming effects in both subject and item analyses, $P_{sBIC} = .32$; $P_{iBIC} = .48$.

2.4.2.3.2 Word errors.

Error rates were lower for word targets following related (vs. unrelated) semantic primes in the subject and item analyses, $F_s(1, 68) = 6.63$, $p = .01$, $\eta^2 = .09$; $F_i(1, 122) = 7.26$, $p =$

.008, $\eta^2 = .06$. Error rates were also marginally lower following repetition (vs. non-neighbor) primes in the subject and item analyses, $F_s(1, 68) = 3.96$, $p = .05$, $\eta^2 = .06$; $F_i(1, 122) = 3.43$, $p = .07$, $\eta^2 = .03$. An interaction was found in subject and item analyses, $F_s(1, 68) = 13.24$, $p < .001$, $\eta^2 = .16$; $F_i(1, 122) = 9.47$, $p = .003$, $\eta^2 = .07$, reflecting greater error reduction from repetition primes following unrelated (vs. related) visible primes, a pattern similar to the one found in the short SOA visible prime group in Experiment 2.

2.4.2.3.3 Effects of masked prime type across quantiles.

There were main effects of quantile and masked prime type, $F_s(1.07, 71.63) = 566.52$, $p < .001$, $\eta^2 = .89$; $F_s(1, 67) = 66.64$, $p < .001$, $\eta^2 = .50$. Again, the masked repetition priming effect did not change across quantiles (Figure 12, top panel), $F_s < 1$.

2.4.2.3.4 Effects of visible prime type across quantiles.

Main effects of quantile and visible prime type were observed, $F_s(1.06, 71.27) = 571.65$, $p < .001$, $\eta^2 = .90$; $F_s(1, 67) = 59.90$, $p < .001$, $\eta^2 = .47$. The increase of the semantic priming effect across in later quantiles in this experiment (Figure 12, bottom panel) was significant, $F_s(1.19, 79.77) = 12.25$, $p < .001$, $\eta^2 = .15$.

2.4.3 Discussion

The goal of Experiment 4 was to examine Forster's (2009, 2013) notion that the priming provided by masked repetition primes has a semantic component that is independent from the orthographic component. Specifically, Forster (2009) found that while a visible unrelated word intervenor reduced the masked repetition priming effect to the level of the orthographic nonword priming effect (which was unaffected), a masked unrelated word intervenor eliminated the orthographic nonword priming effect (and also reduced the masked repetition priming effect). Forster argued that this dissociation indicates that masked repetition primes have an additional, independent semantic component which is affected by a visible intervenor, but not a masked intervenor. The claimed independence of these components would seem to imply that the semantic component would be one that would contribute to a process other than the lexical activation process, that is, other than the process that is assumed to be affected by orthographically similar primes. Potentially, that process would be the semantic matching process.

Although Forster (2013) has not made strong claims about the nature of the semantic component, he notes that the semantic information activated by a masked repetition prime is available at the same time that the target is being processed and that it would make sense that that information may facilitate an LDT response. As noted above, the semantic component of a masked repetition prime, if it exists, could influence the LDT response by further activating the lexical representation of the target through feedback from the semantic level (consistent with IAC principles). Alternately, the semantic component could facilitate an independent process, in particular, the retrospective semantic matching process between the target and the visible prime. Forster's (2009) data seem to support the latter (independent processes) possibility, that the masked repetition prime facilitates the semantic matching process. If so, an interaction between the masked repetition and visible semantic priming effects would be expected. If the masked repetition prime only facilitates the lexical activation process, additivity between the two effects would be expected.

A semantic priming effect, comparable to the effect in Experiments 1 and 2, was observed in Experiment 4. Further, a masked repetition priming effect was demonstrated in the masked prime group, and persisted in the presence of visible semantic primes in the long and short SOA groups (although the magnitude of the masked repetition priming effect was reduced in the short SOA group). Importantly, there was additivity between the semantic priming effect and the masked repetition priming effect in both the long and short SOA groups (see also Heyer, Goring, & Dannenbring, 1985). In the long SOA group, Bayesian estimates again provided positive evidence for the additivity between the semantic and masked repetition priming effects. In the short SOA group, while Bayesian estimates provided weak evidence for an interaction between the semantic and masked repetition priming effects, it should be noted that the interaction reflects smaller semantic priming when the masked prime is identical to the target (vs. a control prime). The numerical (but not significant) interaction thus does not provide support for a semantic component of masked repetition primes. If a semantic component were to influence a process outside of the interactive activation model (i.e., semantic matching), it would facilitate this process thus resulting in an interaction where the semantic priming effect would be greater when the masked prime was identical to the target. Furthermore, the quantile plots and analyses of the masked and visible semantic priming effects in the present experiment were consistent with the quantile plots and analyses from Experiments 1 and 2. Specifically, masked repetition priming effects remained consistent across quantiles, representative of a head-start mechanism such as lexical facilitation. Visible semantic priming effects increased in later quantiles (although this increase was only significant in the short SOA visible prime group), consistent with a retrospective mechanism such as semantic matching, where information from the prime influences the response to a greater extent during longer trials. The findings of the present experiment suggest, therefore, that masked repetition primes did not influence the retrospective semantic matching between the targets and their visible primes.

It should be made clear that the results of the present experiment do not argue against a semantic component from masked repetition primes in general. Consistent with IAC principles, the semantic information retrieved from a masked repetition prime should provide feedback to the lexical representation of the target, speeding up its lexical selection. In the present experiment, however, such semantic feedback to the lexical level of the target would still produce additivity between the masked repetition and visible semantic priming effects as the full impact of masked repetition primes would arise prior to there being an impact of the visible semantic primes.

3 Chapter 3: 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 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, Davis, Schoknecht, & Carter, 1987; Forster & Davis, 1984; Forster, Mohan, & Hector, 2003; McClelland & Rumelhart, 1981). Combining the visible semantic priming and masked orthographic priming manipulations thus provides a means of assessing the locus of semantic priming effects using the known locus of masked orthographic priming effects. A masked nonword prime is presumed to activate the lexical representation of the target without activating the lexical competitors of the target to a large extent, and thus can produce an overall facilitation for recognition of target words. In contrast, a masked word prime activates its own lexical representation which acts as a competitor of the target, typically resulting in an overall inhibition effect for 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, support these ideas and are consistent with the IAC framework. Therefore, the present manipulations of lexical processing by means of the masked priming paradigm would appear to provide a good way of examining the impact of visible semantic primes on the lexical activation process.

An additional aim was to provide a test that masked repetition primes have an independent semantic component, in addition to the lexical/orthographic component that masked orthographic nonword primes also have. Forster (2009) found that a visible unrelated word intervenor reduced the masked repetition priming effect to the level of the orthographic nonword priming effect (what was unaffected). A masked unrelated word intervenor still reduced the masked repetition priming effect, but now also eliminated the orthographic nonword priming effect. Forster argued that this pattern of results indicates that masked repetition primes have an additional, independent semantic component which is affected by a visible intervenor, but not a masked intervenor.

In the present Experiments 1 and 2, visible semantic primes preceded masked orthographic nonword primes in order to examine whether the visible and masked priming effects would interact, where an interaction would indicate that visible semantic primes influence the lexical processing of their targets. In these experiments, the visible semantic primes were related (vs. unrelated) to their target words. Following the additive factors logic of Sternberg (1969), an interaction between the two priming effects would suggest that visible semantic primes influence the same stage as the masked orthographic primes (i.e., lexical processing). At a short SOA, visible semantic primes would influence their targets' lexical representations via automatic spreading activation (Collins & Loftus, 1975), while at a long SOA, the influence of the semantic prime on the target's lexical representation would come from expectancy generation (Becker, 1980). In contrast, additivity between the priming effects would suggest that visible semantic primes and masked orthographic primes influence different stages during word recognition. Specifically, semantic primes may well influence their targets post-lexically, potentially via semantic matching (de Wit & Kinoshita, 2014; Neely et al., 1989). Additivity was found using both the conventional masked priming paradigm in Experiment 1 and the more sensitive sandwich priming paradigm in Experiment 2. Bayesian estimates of posterior probabilities of the null hypothesis (i.e., no interaction between the semantic and masked priming effects) generally confirmed the additivity between the two priming effects.

Experiment 3 was an attempt to evaluate the possibility that visible semantic and masked orthographic primes influenced a common stage in word recognition in Experiments 1 and 2, but did so in an additive manner. Experiment 3 used visible primes that were related (vs. unrelated) to the masked primes (now words) rather than the targets. Specifically, Experiment 3 examined whether visible primes could make the masked word primes more effective lexical inhibitors by increasing their lexical activation (via expectancy generation at a long SOA or automatic spreading activation at a short SOA). Results indicate that the lexical inhibition effect of the masked word primes was not increased by the visible primes that were semantically related to those masked word primes (at either the long or short SOA), again suggesting that visible primes do not affect lexical activation of semantically related concepts. Bayesian estimates, overall, provided some evidence that visible semantic primes do not modulate the inhibition from masked orthographic word primes. Therefore, the findings of all three experiments suggest that in the LDT, the locus of the semantic priming effect is post-lexical (e.g., via semantic matching).

Finally, Experiment 4 examined whether masked repetition primes can contribute to the semantic matching process between the targets and their visible semantic primes. Having provided evidence for a post-lexical locus of the semantic priming effect in the present double priming paradigm in the LDT, the follow up question was whether the masked repetition priming effect would interact with the semantic priming effect. Similar to the additive factors logic in Experiments 1 and 2, an interaction between the masked repetition and semantic priming effects would suggest that the two influence a common stage in word recognition (i.e., in this case, semantic matching). In contrast, additivity between the masked repetition and semantic priming effects would suggest that masked repetition primes do not contribute to the semantic matching process. Consistent with the second possibility, additivity was found between the two effects, confirmed by Bayesian analyses. However, it should be noted that these results do not imply that masked semantic primes do not have a semantic component. The semantic information from masked repetition primes could simply facilitate the lexical activation of the target word, producing additivity between the masked repetition and visible semantic priming effects. Specifically, in accordance with IAC principles, masked repetition primes might contribute to the semantic activation of their targets, which would facilitate the lexical selection process through feedback from the semantic to the lexical level. The impact of masked repetition primes would appear then to be fully explained within IAC principles, without incorporating a post-lexical process such as semantic matching.

The impacts of masked and visible primes on the latency distribution were examined through quantile plots and analyses. Examination of the entire distribution, rather than just the means, does provide additional information concerning priming (or any other) effects. Specifically, the prime may cause a shift in the whole distribution, which is consistent with a head-start mechanism such as facilitating the lexical selection process. Alternately, the prime may influence the skew of the distribution, which is more consistent with a post-lexical effect, such as semantic matching, since the prime has a greater effect on the response as more time passes during the trial (Balota et al., 2008).

The facilitative effects of masked nonword primes in the conventional masked priming paradigm (Experiment 1) and the sandwich priming paradigm (Experiment 2) did not change across quantiles. The shift in the distribution produced by nonword masked primes is consistent with these effects being a lexical activation phenomenon. Specifically, masked nonword primes produce a shift in the entire distribution by pre-activating the lexical representations of their targets and facilitating the lexical selection process. In contrast, the semantic priming effects observed in Experiments 1, 2, and 4, at long and short SOA, increased in later quantiles (although this increase was not always significant). The increase of the semantic priming effect in the LDT is consistent with numerous studies (de Wit & Kinoshita, 2015a, 2015b; Balota et al., 2008; Gómez et al., 2013) and supports the idea that semantic relatedness has its influence during a different process than the one in which orthographic similarity has its influence. That is, the increase of the semantic priming effect in later quantiles is also consistent with the additivity we found between the semantic priming effect and the masked orthographic nonword priming effect in Experiments 1 and 2.

Potentially of some interest was the finding that the orthographic inhibition effect from masked nonword primes increased in later quantiles, although this increase was only significant following related visible primes in the long SOA group, and following unrelated visible primes in the short SOA group. The increase in the orthographic inhibition effect in later quantiles, in contrast to the constancy of the orthographic facilitation effect, may be due to the fact that masked word primes primarily activate their own lexical representations, while masked nonword primes primarily activate the lexical representations of many potential targets. On trials where the lexical selection of the word is slow, the lexical activation of the masked word prime may persist for longer and thus have a greater inhibition effect on the target. If the increase in inhibition at later quantiles turns out to be a real effect, this idea would, of course, be only one of the possible accounts of such a phenomenon.

Finally, the masked repetition priming effect in Experiment 4, also did not change across quantiles, similar to the masked nonword priming effects in Experiments 1 and 2. The finding of a constant masked repetition priming effect across quantiles and its additivity with the semantic priming effect suggest that the semantic component from repetition primes, if present, does not influence a retrospective process such as semantic matching.

It should be noted that the numerical presence of a semantic priming effect in the first quantile could be interpreted as evidence of pre-activation of the target by the semantic prime (i.e., automatic spreading activation or expectancy generation). The increase of the semantic priming effect is evidence of the post-lexical retrospective use of the prime. However, the quantile plots by themselves do not provide evidence for the absence of semantic primes activating the lexical representations of their targets, since semantic primes may influence the lexical selection process and be used retrospectively after lexical selection is complete. Additional evidence from the present experiments does support the absence of semantic primes influencing lexical processing of their targets. The consistent additivity between masked orthographic priming and semantic priming in Experiments 1 and 2, and the additivity between masked repetition priming and semantic priming in Experiment 4, suggests that masked primes and visible semantic primes do not influence any common stages in word recognition (Sternberg, 1969). Specifically, the additivity between the two priming effects suggests that masked orthographic and repetition primes influences the lexical selection process that occurs in the IAC framework. Visible semantic primes, in contrast, influence the decision-making process that is outside of the IAC framework, where the candidate offered by lexical selection is verified.

3.1 Lexical Decision Task vs. Semantic Categorization

It should be noted that the present research examined the locus of the semantic priming effect only in the LDT and, therefore, it would not be possible to extend the present conclusions directly to semantic priming effects in other tasks, for example, to the semantic categorization task. Indeed, the mechanisms of semantic priming very likely differ between tasks (de Wit & Kinoshita 2014, 2015a, 2015b; Kusunose et al., 2016). As one example of what the differences between tasks may be, 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. Category diagnostic features that are accumulated from a prime are amalgamated with those belonging to the target because of the close temporal proximity between the prime and target. The semantic features accumulated from a related prime thus represent a head start in accumulating evidence for an accurate decision about the target. No such process appears to be involved when one is making a lexical decision, meaning that one would not expect that the source of semantic priming effects would be the same in the two tasks.

Consistent with this idea, note that de Wit and Kinoshita (2015b Experiment 2) observed 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, consistent with de Wit and Kinoshita's (2015b) results, masked semantic priming effects are virtually always found in semantic categorization tasks (e.g., Frenck-Mestre & Bueno, 1999; Grainger & Frenck-Mestre, 1998; McRae & Boisvert, 1998), while masked semantic priming effects in the LDT are unreliable (for review, see McNamara, 2005). In fact, as noted, de Wit and Kinoshita (2015b) suggested that studies finding a masked semantic priming effect in an LDT had methodological problems, in particular, they often failed to prevent conscious recognition of the prime by not using a forward mask and/or a backward mask. Finally, as also noted previously, the masked semantic priming effects found by de Wit and Kinoshita (2015b) in their semantic categorization task did not increase across quantiles, a finding more consistent with a "head start" due to the accumulation of semantic features from the prime, in contrast to the pattern of an increasing size of the semantic priming effects across quantiles that is typically found in an LDT (e.g., Balota et al., 2008). There are, of course, likely to be other possible explanations for the differences between tasks that may also turn out to be consistent with de Wit and Kinoshita's data.

3.2 Implications for Accounts of Semantic Priming

The results of the present research are consistent with post-lexical accounts of semantic priming, where the related prime facilitates the discrimination of words from nonwords in a LDT (de Wit and Kinoshita, 2014, 2015a, 2015b; Lupker & Pexman, 2010; Neely et al., 1989; Ratcliff & McKoon, 1988). Especially relevant to this issue are the findings of de Wit and Kinoshita, which provide a strong challenge to the automatic spreading activation account of semantic priming. In a series of studies, de Wit and Kinoshita argued that the semantic priming effect in the LDT at short SOAs is driven by semantic matching rather than automatic spreading activation. As noted, de Wit and Kinoshita argued that, at short SOAs, the semantic priming effect should not be modulated by RP if it is driven by automatic spreading activation. Although this null interaction has often been reported (see Hutchison, 2002; Hutchison et al., 2001; Neely, 1977), de Wit and Kinoshita (2015a) did find that RP modulated the semantic priming effect in their experiment (see also de Groot, 1984). De Wit and Kinoshita (2015b) also argued that masked semantic priming, an effect that would be most likely to be due to spreading activation, does not arise when prime visibility is well controlled. In their Experiment 1, indeed, no masked semantic priming was observed. Finally, the semantic priming effects found by de Wit and Kinoshita (2015a, 2015b Experiment 1) increased across quantiles, consistent with the results of Balota et al. (2008; see also Gómez et al., 2013)[1]. The magnitude of the effect increasing across quantiles indicates that with more time, the prime has a greater influence on the decision (Balota et al., 2008), a result that is more consistent with semantic matching than spreading activation. That is, priming due to lexical activation of the target by the prime would be more consistent with a shift of the whole RT distribution and thus a consistent effect across the quantiles.

Of note is the fact that de Wit and Kinoshita (2014; 2015a; 2015b) consistently used a short (240 ms) SOA which should preclude the use of expectancy generation, allowing those researchers to directly address the issue of the existence of spreading activation. 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. However, as those authors note, the assumption that expectancy sets take time to form is based, in part, on the lack of reliable RP effects when the SOA is short (Hutchison, 2007; Hutchison et al., 2001), an effect that they themselves then produced. However, Neely's (1977) data do provide independent evidence supporting the claim that short SOAs prevent participants from generating expectancy sets as he showed that expectancies, even those trained over many trials, cannot be generated if the SOA is too short.

The present findings, therefore, provide support for the claims of de Wit and Kinoshita (2015a, 2015b) that semantic priming effects in the LDT at short SOAs have a post-lexical locus (i.e., semantic matching) rather than a lexical locus (i.e., automatic spreading activation). Additionally, the present findings extend those of de Wit and Kinoshita by suggesting that semantic priming has a post-lexical locus even when 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 semantic matching. The conclusion offered here, 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.

Additionally, the present findings suggest that semantic priming effects (i.e., context effects) are not actually explained by the IAC framework, in contrast to the effects of semantic information associated with the target word itself. As noted, LDT latencies are shorter for words that are associated with a greater amount of semantic information (e.g., Pexman et al., 2008; Yap et al., 2012). Such findings have typically been interpreted as feedback from the semantic level to the lexical level, which is consistent with the IAC framework as explained by Balota et al. (1991). Specifically, according to Balota et al., meaning-level representations are above lexical-level representations, and are also represented as individual nodes. More activation in the meaning-level representations would thus facilitate lexical selection due to greater feedback from the meaning-level representations. According to the present findings, information from a semantic prime does not provide feedback to the lexical-level representation of the target word, but rather facilitates the LDT after the lexical representation of the target word has been selected.

3.3 Implications for Normal Reading

The recognition of individual words involved in reading relies on selecting the correct lexical representation from a set of candidate lexical representations. As noted, this lexical selection process is affected by semantic information associated with the word itself (e.g., Pexman et al., 2008; Yap et al., 2012). Crucially, reading also involves the integration of previously read contextual and semantic information. The present research sheds some light on whether contextual information from previously read words affects the lexical selection process in that it examines how semantic primes affect lexical processing. The findings of the present experiments, which are consistent with post-lexical accounts of semantic priming suggest that contextual and semantic information does not influence lexical selection during word recognition. In terms of general reading, the present findings would then suggest that previously read contextual information is incorporated after the lexical selection of the word being read. Of relevance are the findings of Hoedemaker and Gordon (2017; see also Hoedemaker & Gordon, 2014), who found evidence consistent with retrospective models of semantic priming using a measure of word recognition more consistent with natural reading and a task that does not require a word-nonword discrimination.

The ocular response (Brysbaert, 1995) is a response used in word recognition research which is more consistent with natural reading processes than LDT might be. In the ocular response paradigm, participants are presented with multiple sequential letter strings and are instructed to move their eyes from the current letter string to the next if the current letter string is a word. If the ocular response is used in conjunction with an LDT, participants are instructed to press a button if the current letter string is a nonword. The display is gaze-contingent, preventing parafoveal preview or the re-reading of previously presented words, and durations of first-pass reading are used as measures of lexical encoding (e.g., Rayner, 1998). To investigate semantic priming, consecutive words are either related or not.

Using the ocular response Hoedemaker and Gordon (2014, 2017) found evidence consistent with retrospective models of semantic priming. Consistent with the present findings suggesting a post-lexical locus to semantic priming (see also de Wit & Kinoshita, 2015a, 2015b; Thomas et al., 2012), Hoedemaker and Gordon (2017, Experiment 1) found greater priming effects with increasing response times in the LDT. In Experiment 2 of their study, Hoedemaker and Gordon (2017) tested whether the semantic priming effects found in their Experiment 1 depended on the specific demands of the LDT. In that experiment, the authors used an episodic-recognition task. Participants read each of the sequentially presented words, moving onto the next word by shifting their gaze. After each sequence of words, participants pressed a key, and a probe word was presented and participants were asked to decide whether the probe word was present in the previously presented sequence. Again, consecutive words were related or unrelated. Similar to the results from their Experiment 1, Hoedemaker and Gordon found a semantic priming effect that increased in slower trials.

Those authors argue that while the episodic-recognition task differs from natural reading, since participants have to encode each of the presented words for an upcoming memory task, the episodic-recognition task still does not require explicit word-nonword discrimination that the LDT does, meaning that it would not be affected by the task specific processes unique to the LDT. Given that the two tasks, both of which do invoke reading processes, produced similar results Hoedemaker and Gordon conclude that semantic priming effects appear to have a post-lexical locus in word recognition.

3.4 Semantic Facilitation from Masked Primes

The additivity between the effects of the masked nonword and repetition primes with the effects of visible semantic primes, and the constant effects of masked nonword and repetition primes across quantiles, suggest that the effects of these primes on the target words are at the lexical level. Within the IAC framework, the effects of masked nonword primes have been framed as bottom-up activation of the lexical representations of their targets. In contrast, masked repetition primes, which possibly have a semantic component (Forster, 2009, 2013), may additionally facilitate the lexical representations of their targets through downward feedback from the semantic to the lexical level. One question that might arise is whether masked nonword primes also activate the semantic representations of their targets and thus provide facilitative semantic feedback.

Numerous studies have demonstrated semantic activation of the orthographic neighbors (which are not actually presented on the trial) of masked primes. These findings suggest that masked primes that are orthographic neighbors of their targets do activate semantic representations, not just lexical representations, of their targets. Support for semantic activation of these orthographic neighbors comes from demonstrations of semantic priming effects when one of the orthographic neighbors of the masked prime (but not the prime itself) is semantically related to the target. The semantic representation of the orthographic neighbor must be active if it can facilitate a semantically related target. For example, Bourassa & Besner (1998; see also Bell, Forster, & Drake, 2015; Perea & Lupker, 2003) found that a masked nonword prime that had an orthographic neighbor that was semantically related (vs. unrelated) to the target produced significant facilitation in an LDT (e.g., the nonword prime *deg* facilitated *CAT* because of its neighbor *dog*).

Of relevance to the present research, Kusunose et al. (2016) examined the locus of the semantic priming effect from the neighbor of a masked prime and investigated the possibility that a masked nonword prime might be confused for its word neighbor (e.g., *deg* is confused for *dog*). Kusonose et al. showed participants masked word and nonword primes that had only one orthographic word neighbor, which was semantically related (or unrelated) to the target. The masked primes themselves were not related to the targets. Furthermore, those authors manipulated RP to examine the locus of the observed semantic priming effect (see also de Wit & Kinoshita, 2014) by adding filler masked prime-target pairs that were semantically related to each other. If the semantic priming from the orthographic neighbor is due to automatic spreading activation, the effect should not be modulated by RP. In contrast, if the semantic priming effect is due to a retrospective relatedness checking strategy like semantic matching, as proposed by Bodner and Masson (2001, 2003), then the size of the effect could be modulated by RP.

Kusonose et al. (2016) found facilitation when the orthographic neighbor of the masked prime was semantically related (vs. unrelated) to the target word. Importantly, this facilitation was similar whether the masked primes were words or nonwords, suggesting that masked nonword primes were not simply confused for their orthographic word neighbors. Additionally, while the semantic priming effect from the neighbors of the masked primes was present with a high RP (between the actual primes and targets), the effect disappeared when the RP was 0. Those authors concluded that, consistent with the interactive activation framework, the orthographic information from the masked prime led to the activation of lexical and semantic representations of its orthographic neighbors. The semantic facilitation of the target from the orthographic neighbor of the prime, however, was likely due to a retrospective relatedness checking strategy similar to semantic matching. Specifically, when a relationship between the orthographic neighbor and the target was detected, a bias to make the word response was formed, and the bias to make a nonword response needed to be overcome when the orthographic neighbor and the target were not related. Kusunose et al. argued such a process was engaged when RP was high and the retrospective checking strategy would be beneficial, even when the prime itself was masked.

Consistent with Kusonose et al. (2016), the masked nonword primes in the present Experiments 1 and 2 could have activated the lexical and then the semantic representations of their targets (unlike in Kusunose et al., the orthographic neighbors of the nonword primes in the present experiment were the targets themselves). However, the direct semantic activation of targets from the masked nonword primes would have been limited and likely undetectable since the nonword primes had multiple orthographic neighbors, only one of which was the target. In contrast, the masked word and nonword primes used by Kusunose et al. (2016) had only one word neighbor and, hence, only had the potential to activate semantic information relevant to the target.

3.5 Semantic Priming x Stimulus Quality Interaction

The consistent additivity between semantic priming and masked orthographic priming in the present experiments certainly contrasts with the 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, Neely, & O’Connor, 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 & Besner; Scaltritti et al.; Stolz & Neely; Thomas et al.) have argued, therefore, that, based on additive factors logic (Sternberg, 1969), the semantic priming x stimulus quality interaction indicates that both variables influence a common stage of word processing, presumably an early stage. The semantic priming x stimulus quality interaction would seem, therefore, to provide good evidence for accounts of semantic priming such as automatic spreading activation and/or expectancy generation. For example, Stolz and Neely (1995; see also Borowsky & Besner, 1993) propose 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 due to degradation). Such a conclusion is, of course, completely the opposite of the conclusion offered here.

More recently, however, Thomas et al. (2012) produced evidence suggesting that the semantic priming x stimulus quality interaction may be due to a retrospective mechanism such as semantic matching. Thomas et al. examined the semantic priming x stimulus quality interaction as a function of the direction of the association between the (visible) prime and target. Specifically, those authors used 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 an overadditive interaction with only symmetric and backward associated prime-target pairs but not forward associated pairs. Those authors argued that the overadditive interaction is brought about by a strategic and compensatory use of the semantic information from the prime to help recognize the degraded target. 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 the semantic prime leads to a reduced impairment from degradation when the preceding semantic prime is related (vs. unrelated). If Thomas et al.'s analysis is correct, the implication would be that the commonly found semantic priming x stimulus quality interaction does not pose a strong challenge to our conclusion that semantic priming in an LDT is late stage effect.

3.6 Limitations

The task used to measure lexical access (manual LDT) and the additive factors logic guiding the interpretation of the data obtained in the present experiments have important limitations for the investigation of the impact of contextual information on the lexical selection process. As noted, the LDT is the task used most often to examine lexical access in word recognition, however the task is not a pure indication of lexical access. It has been hypothesized that the word-nonword discrimination is based on consulting lexical memory and finding (or not) the representation corresponding to the presented letter string (Rubenstein, Garfield, & Milllikan, 1970). Although LDT responses had been initially assumed to be based on lexical-level activity (e.g., Grainger & Jacobs, 1996; Hino & Lupker, 1996; Pexman et al., 2002), task-specific (i.e., performing word-nonword discrimination) decision making components occurring after lexical selection clearly contribute to the response process (e.g., Balota & Chumbley, 1984). Decision making components in the LDT limit the inferences that may be drawn about word identification in typical reading.

In addition to the influence of decision making components in the LDT, lexical processing itself may be influenced by task context. For example, the nature of the nonwords used can influence the word responses (Lupker & Pexman, 2010; Yap, Sibley, Balota, Ratcliff, & Rueckl, 2015). Lupker and Pexman found increasing the difficulty of word-nonword discrimination by making the nonwords more word-like resulted in longer word latencies (see also Stone and Van Orden, 1993). To increase how word-like the nonwords were, pseudohomophones (e.g., *brane*) were used in their Experiment 1, and nonwords created by transposing two letters of a word (e.g., the nonword *jugde* was constructed from *judge*) were used in their Experiment 2. The multiple read-out model (Grainger & Jacobs, 1996), which is based on the IAC framework, explains the longer word responses from more word-like nonwords as increasing the threshold associated with the overall activation of the lexicon needed to make a word response (since word-like nonwords themselves generate some activation in the lexicon). Word responses are, therefore, mostly based on activation of the specific lexical representation, resulting in generally longer latencies (Lupker & Pexman, 2010). Task context in the LDT can thus influence lexical selection, again making generalizing to typical reading harder. An additional finding from Lupker and Pexman that is relevant to the present experiments is that manipulations of nonword word-likeness did not interact with a semantic priming manipulation. The findings of Lupker and Pexman are consistent with the present findings, where semantic priming does not interact with a manipulation of lexical processing.

Finally, a high latency floor associated with the manual LDT response is another potential limitation of using the task to evaluate word recognition including in the present research. Hoedemaker and Gordon (2014) argued that eye movement is a practiced response to word recognition in typical reading, whereas manual responses to word recognition are less practiced and have less connection to typical reading. Manual response latencies (vs. gaze durations) are typically twice as long (e.g., Balota & Chumbley, 1984; McNamara, 2005; Rayner, 1998). As previously mentioned, Hoedemaker and Gordon (2017) examined semantic priming in using the LDT and an episodic-recognition task using the ocular response. Hoedemaker and Gordon (2017) found that the earliest semantic priming effect was evident at approximately 260 ms in both tasks. Those authors point out that most studies of semantic priming that use the manual LDT have latencies well beyond 260 ms and argue that effects may be obscured by the high floor of latencies from the manual LDT. In fact, the authors argue that a distributional shift, where the semantic priming effect is constant in slow and fast trials, may be an artefact of the high response floor.

Additive factors logic (Sternberg, 1969) used in interpreting the present findings likewise has limitations. Specifically, Sternberg noted the possibility that two factors could influence a common stage but in an additive manner. The additivity between the visible semantic priming effects, and the masked nonword priming effects in the present Experiments 1 and 2 or the masked repetition priming effect in Experiment 4, thus does not conclusively indicate that visible semantic primes and masked nonword and repetition primes act at separate stages of the word recognition process (see Plaut & Booth, 2000, for a simulation). Experiment 3 addressed this limitation by providing a more direct test of whether semantic primes can influence lexical processing (visible semantic primes were now related or unrelated to the masked word primes rather than the targets). However, it is possible that the observed inhibition effects from the masked word primes were already at their maximum level. Thus, a related visible prime could have increased the activation of the following masked word prime without increasing its ability to inhibit the target.

Furthermore, the durations of multiple stages might be additive but not independent of each other. For example, Sternberg (1969) notes that participants may prepare for an upcoming stimulus they expect to appear. Such preparation could influence multiple stages of the subsequent recognition process. In terms of the present Experiments, a related or unrelated visible semantic prime might interfere with the processing of both the subsequent masked prime and the target (although a related visible semantic prime still facilitates the target relative to an unrelated one). A visible semantic prime could thus influence the lexical processing of the target by interfering with the processing of the masked prime. However, the idea that the visible prime interfered with the processing of the subsequently presented masked prime and target is unlikely in the present studies, since the masked priming effects established when no visible prime is present (in the masked prime group in Experiments 1, 3, and 4, and in the sandwich prime group in Experiment 2) were similar to the masked priming effects found when a visible prime was present (in the long and short SOA visible prime groups).

Another limitation of the present experiments is that evidence for a post-lexical locus of semantic priming (i.e., additivity between visible semantic priming and masked orthographic priming) comes from the null hypothesis for the interaction between the two effects. It is possible that an interaction between the visible semantic and masked orthographic priming effects exists but was not detected in the present experiments due to power issues. However, the distributions and quantile analyses of both priming effects provide an additional source of evidence of the independence of these two effects. Specifically, the masked nonword and identity priming effects stayed consistent across quantiles, suggesting these primes gave their targets a head start in processing, which is consistent with lexical activation. In contrast, the visible semantic priming effects increased in later quantiles, which is consistent with a post-lexical mechanism. It should also be noted that the increase of the semantic priming effect in longer trials was established by finding an interaction (i.e., the quantile x semantic priming effect interaction) and is thus not based on a null hypothesis.

3.7 Further Research

Event-related potentials (ERPs) have often been used to investigate word recognition processes. Specifically, ERPs have been used to measure masked orthographic and repetition priming (e.g., Holcomb & Grainger, 2006, 2007; Kiyonaga, Grainger, Midgley, and Holcomb, 2007; Massol, Grainger, Dufau, & Holcomb, 2010) as well as semantic priming (e.g., Bentin, McCarthy, & Wood, 1985; Holcomb, 1988; Holcomb & Grainger, 2007; Kiefer, 2002, van Vliet, Manyakov, Storms, Fias, Wiersema, & Van Hulle, 2014). ERPs are quite useful measures of visual word recognition. Unlike behavioral measures, where inferences must be made from a single datapoint (i.e., the endpoint, when a response is made), ERPs allow for the examination of continuous processing with high temporal resolution, allowing the intermediate stages in the entire time course to be examined. Specifically, various components of an ERP waveform have been shown to reflect cognitive processes involved in word recognition (see Grainger & Holcomb, 2009 for a review). Additionally, ERPs allow for the observation of processes of interest without requiring participants to give an overt response, thus potentially allowing a purer observation of these processes without the added processes required by the task itself. In fact, van Vliet et al. (2014) found that an ERP component generated by the motor response can overlap with the N400, a component of interest when examining semantic priming, potentially obscuring the nature of the semantic priming effect.

The N250 and N400 components are of relevance to the phenomena being investigated in the present studies. The N250 is a negative component which peaks at 250 ms after word onset (Grainger & Holcomb, 2009). This component is sensitive to the degree of orthographic overlap between prime and target, and is thought to reflect the mapping of orthographic representations onto lexical representations (Massol et al., 2010). Targets following masked neighbor orthographic or masked repetition primes have an attenuated N250 component compared to when the prime is a control. The most commonly examined ERP effect pertaining to semantic priming is the N400 component, which is a negative component occurring about 400 ms after stimulus onset. The N400 is sensitive to the lexical and semantic properties of the stimulus as well as its context, such that it is attenuated when the stimulus is congruent with the previously established context. For example, using a sentence verification task, Kutas and Hillyard (1980) found an attenuated N400 when the target word was congruent (vs. incongruent) with the sentence. Similarly, in semantic priming studies, the N400 is attenuated for targets following related (vs. unrelated) primes (e.g., Bentin et al., 1985). The N400 component is thought to reflect the mapping of lexical representations onto semantic representations (Massol et al.).

Massol et al. (2010) investigated the effects of masked orthographic word neighbor primes (e.g., *lamp*), nonword neighbor primes (*lkmb*), and repetition primes (*lamb*) on the N250 and N400 components of target words (*LAMB*). The authors interpreted the amplitudes of the ERP components as indicators of ease of target processing as a function of the preceding masked prime. Greater (negative) amplitude indicates greater processing difficulty. While the target words of interest did not require an overt response (van Vliet et al., 2014), participants did press a button when they detected an occasional probe word. Consistent with previous studies (e.g., Davis & Lupker, 2006) neighbor nonword primes resulted in faster response latencies while word primes result in slower response latencies (behavioral results for repetition primes are not reported). Importantly, in the electrophysiological data, the authors found that masked neighbor word and nonword, and repetition primes attenuated the magnitude of the N250 component, relative to the control primes. In contrast, while neighbor nonword primes and repetition primes attenuated the N400 component, neighbor word primes had no effect. Massol et al. argued that all three types of masked primes facilitated target recognition through orthographic overlap (as seen in the attenuation of the N250 component). However, the neighbor word primes also caused competition between various activated lexical representations, which resulted in no attenuation of the N400 component (in contrast to the neighbor nonword and repetition primes).

ERPs thus offer numerous ways to extend the present research in examining whether contextual information influences lexical processing. It would be informative to measure the effects of visible semantic primes, and masked orthographic and repetition primes on ERPs using a double priming paradigm similar to the one used in the present experiments. For example, a semantic prime, related or unrelated to the target, would be followed by a masked prime that is either a neighbor word, nonword, or repetition prime, followed by the target (e.g., *mutton – lamp/lkmb/lamb – LAMB*). Extending the findings of Massol et al. (2010), I would examine whether a related semantic prime activate the lexical representation of the target word and eliminate the lexical competition initiated by the following masked neighbor word prime. If this was the case, the N400 component following the neighbor word prime would be attenuated (as it should be following nonword and repetition primes) when the visible semantic prime is related to the target.

3.8 Conclusion

The present research examined the locus of the semantic priming effect in an LDT. Numerous accounts argue that semantic primes facilitate responses in an LDT by activating the lexical representations of their targets. Specifically, at short SOAs, semantic priming effects have been explained by automatic spreading activation (Collins & Loftus, 1975), whereas expectancy generation (Becker, 1980) has been used to explain effects at long SOAs. Additive effects between visible semantic primes and masked orthographic nonword primes (Experiments 1 and 2), as well as the finding that a visible semantic prime cannot make a masked orthographic word prime a more effective lexical inhibitor of its target (Experiment 3) suggest that the locus of the semantic priming effect is post-lexical. Specifically, semantic primes influence the retrospective verification of the candidate offered up by the lexical selection process. That is, as has been argued elsewhere (Balota & Chumbley, 1984; Balota et al., 1991), an LDT response depends not only on word identification, but also on the discrimination between words and nonwords. The impact of a related (vs. unrelated) semantic prime appears to be to facilitate that process of discriminating words from nonwords.

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Appendices

Appendix 1: Stimuli from Experiment 1

Related Visible Prime	Unrelated Visible 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
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
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 2: Stimuli from Experiment 2

Related Visible Prime	Unrelated Visible 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
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
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
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
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

Appendix 3: Stimuli from Experiment 3

Neighbor Word Primes			Non-neighbor Word Primes			
Related Visible Prime	Unrelated Visible Prime	Masked Prime	Related Visible Prime	Unrelated Visible 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
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
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 4: Latencies and error rates for nonword stimuli from Experiments 1-4.

Experiment 1

Latencies (milliseconds) and error rates (percentages) for nonword targets as a function of masked nonword prime type for the Masked Prime, Long, and Short SOA Visible Prime groups in Experiment 1.

	Masked Nonword Prime Type		
Group	Neighbor	Non-neighbor	Orthographic Priming Effect
Masked Prime	771 (15.8)	781 (13.4)	10 (-2.4)
Long SOA Visible Prime	781 (11.2)	773 (11.4)	8 (-0.2)
Short SOA Visible Prime	804 (15.2)	814 (15.9)	10 (0.7)

Note. Error rates shown in parentheses.

Experiment 2

Latencies (milliseconds) and error rates (percentages) for nonword targets as a function of masked nonword prime type for the Sandwich Prime, Long, and Short SOA Visible Prime groups in Experiment 2.

	Masked Nonword Prime Type		
Group	Neighbor	Non-neighbor	Orthographic Priming Effect
Sandwich Prime	782 (9.5)	797 (9.4)	15 (-0.1)
Long SOA Visible Prime	797 (8.1)	812 (9.2)	15 (1.1)
Short SOA Visible Prime	799 (9.2)	820 (9.3)	21 (0.1)

Note. Error rates shown in parentheses.

Experiment 3

Latencies (milliseconds) and error rates (percentages) for nonword targets as a function of visible semantic and masked nonword prime types for the Masked Prime, Long, and Short SOA Visible Prime groups in Experiment 3.

	Word Prime Type		
Group/Visible Prime Type	Neighbor	Non-neighbor	Orthographic Inhibition Effect
Masked Prime	798 (15.5)	792 (16.9)	-6 (1.4)
Long SOA Visible Prime			
related	821 (10.1)	802 (8.1)	-19 (-2.0)
unrelated	804 (8.1)	816 (9.7)	12 (1.6)
Effect of Visible Prime	-17 (-2.0)	14 (1.6)	
Short SOA Visible Prime			
related	846 (7.8)	823 (8.6)	-23 (0.8)
unrelated	828 (8.6)	818 (9.3)	-10 (0.7)
Effect of Visible Prime	-18 (0.8)	-5 (0.7)	

Note. Error rates shown in parentheses.

Experiment 4

Latencies (milliseconds) and error rates (percentages) for nonword targets as a function of masked nonword prime type for the Masked Prime, Long, and Short SOA Visible Prime groups in Experiment 4.

	Masked Repetition Prime Type		
Group	Repetition	Non-neighbor	Repetition Priming Effect
Sandwich Prime	796 (9.2)	806 (7.8)	10 (-1.4)
Long SOA Visible Prime	758 (6.6)	772 (6.3)	14 (-0.3)
Short SOA Visible Prime	780 (8.6)	785 (8.1)	5 (-0.5)

Note. Error rates shown in parentheses.

Appendix 5: Analyses of latencies and error rates for nonword stimuli from Experiments 1-4.

Experiment 1

Masked prime group.

Nonword latencies. No effect of masked prime type was found, both *Fs* < 2.47, *ps* > .12.

Nonword errors. No effect of masked prime type was found in the subject analysis, $F_s(1, 34) = 2.65$, $p = .11$, $\eta^2 = .07$, however in the item analysis, nonwords following neighbor (vs. non-neighbor) masked primes had marginally more errors, $F_i(1, 62) = 2.91$, $p = .09$, $\eta^2 = .04$.

Long SOA visible prime group.

Nonword latencies. No effect of masked prime type was observed, both *Fs* < 1.54, *ps* > .22.

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

Short SOA visible prime group.

Nonword latencies. No effect of masked prime type was observed on nonword targets, both *Fs* < 1.63, *ps* > .21.

Nonword Errors. Likewise, no effect of masked prime type was observed, both *Fs* < 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 *Fs* < 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 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 neighbor (vs. non-neighbor) primes was marginal in both the subject and item analyses $F_s(1, 48) = 2.90$, $p = .09$, $\eta^2 = .06$; $F_i(1, 126) = 3.11$, $p = .08$, $\eta^2 = .02$.

Short SOA visible prime group.

Nonword latencies. Again, latencies for nonword targets were faster when following neighbor (vs. non-neighbor) masked 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 *Fs* < 1.

Experiment 3

Masked prime group.

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

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

Long SOA visible prime group.

Nonword latencies. No main effects of visible prime or masked prime were found in subject or item analyses, all *Fs* < 1. However, marginal interactions were found between visible and masked 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 prime, all *Fs* < 1. An interaction was detected in the subject and item analyses however, $F_s(1, 40) = 6.16$, $p = .02$, $\eta^2 = .13$; $F_i(1, 60) = 5.16$, $p = .03$, $\eta^2 = .08$. The interaction reflected greater error rates for nonword targets following neighbor (vs. non-neighbor) masked primes when preceded by a related visible prime.

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 word primes. This effect was not significant in the subject analysis $F_s < 1.93$, *ps* > .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 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 prime interaction was found, both *Fs* < 1.

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

Experiment 4

Masked prime group.

Nonword latencies. No effect of masked prime type was found in the subject analysis, $F_s < 2.31$, $ps > .14$, however a marginal facilitation for nonword targets following repetition (vs. non-neighbor) primes was found in the item analysis, $F_i(1, 126) = 2.95$, $p = .09$, $\eta^2 = .02$.

Nonword errors. No effect of masked prime type was found in the subject analysis, $F_s < 2.77$, $ps > .11$, however error rates were marginally greater for nonword targets following repetition (vs. non-neighbor) primes was found in the item analysis, $F_i(1, 126) = 3.60$, $p = .09$, $\eta^2 = .03$.

Long SOA visible prime group.

Nonword latencies. Responses to nonword targets were faster following a repetition (vs. non-neighbor) prime in both the subject and item analyses, $F_s(1, 24) = 7.14$, $p = .01$, $\eta^2 = .23$; $F_i(1, 126) = 4.39$, $p = .04$, $\eta^2 = .03$.

Nonword errors. No effect of masked prime type was found in the subject and item analyses, both *Fs* < 1.

Short SOA visible prime group.

Nonword latencies. No effects of masked prime type were found, both *Fs* < 1.01, *ps* > .32.

Nonword errors. No effects of masked prime type were found, both *Fs* < 1.

Appendix 6: Ethics applications for data collection

Western Research

Research Ethics

Western University Non-Medical Research Ethics Board
NMREB Delegated Initial Approval Notice

Principal Investigator: Prof. Stephen Lupker
Department & Institution: Social Science\Psychology,Western University

NMREB File Number: 109670
Study Title: Lexical processing in word recognition

NMREB Initial Approval Date: September 05, 2017
NMREB Expiry Date: September 05, 2018

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Western University Protocol	Receive August 9, 2017	
Recruitment Items	SONA Description	2017/08/09
Letter of Information & Consent		2017/08/09
Other	Debriefing Form	2017/08/09

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the above named study, as of the NMREB Initial Approval Date noted above.

NMREB approval for this study remains valid until the NMREB Expiry Date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

[redacted]

[redacted]

Western Research

Date: 9 March 2018

To: Prof. Stephen Lupker

Project ID: 104255

Study Title: A Study of Orthographic Coding and Lexical Processing

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

Meeting Date: April 6, 2018

Date Approval Issued: 09/Mar/2018

REB Approval Expiry Date: 08/Apr/2019

Dear Prof. Stephen Lupker,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Please do not hesitate to contact us if you have any questions.

Sincerely,

[redacted]

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Curriculum Vitae

Alexander Taikh

Education:

PhD Cognitive Psychology, University of Western Ontario August 2018 (expected)

MSc Cognitive Psychology, University of Calgary November 2014

MSc Thesis: *Effects of Levels-of-processing and Test-list Context on Recognition and Pupil Dilation.*

BSc Psychology Honors, University of Calgary June 2011

BSs Honours Thesis: *Reassessing the basis of the production effect in memory*.

BSc Biological Sciences, University of Calgary June 2011

Peer-reviewed publications:

- Jouravlev, O., Taikh, A., & Jared, D. (in press). Effects of lexical ambiguity on perception: A test of the label feedback hypothesis using a visual oddball paradigm. *Journal of Experimental Psychology: Human Perception and Performance.*
- Taikh, A., & Bodner, G. E. (2016). Evaluating the basis of the between-group production effect in recognition. *Canadian Journal of Experimental Psychology, 70,* 186-194.
- Bodner, G. E., Lambert, A. M., & Taikh, A. (2016). The Production effect in long-list recall: In no particular order? *Canadian Journal of Experimental Psychology, 70,* 165-176.
- Taikh, A., Hargreaves, I. S., Yap, M. J., & Pexman, P. M. (2015). Semantic classification of pictures and words. *Quarterly Journal of Experimental Psychology, 68,* 1502-1518.
- Bodner, G. E., Taikh, A., Fawcett, J. M. (2014). Assessing the costs and benefits of production in recognition. *Psychonomic Bulletin & Review, 21,* 149-154.
- Bodner, G. E., & Taikh, A. (2012). Reassessing the basis of the production effect in memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 38,* 1711-1719.

Awards:

Graduate Student Teaching Assistant Award (Nomination Only) Sept 2017- April 2017

Ontario Graduate Scholarship ($15 000)

- Provincial research scholarship offered on April 28, 2017

Graduate Student Scholarship ($3 000)

- Provincial academic scholarship offered on March 13, 2014

University of Alberta Doctoral Recruitment Scholarship ($5 000)

- Institutional research scholarship offered on March 11, 2014

Research Interests: Psycholinguistics, Memory

Research Experience:

PhD in Experimental Psychology (Sept 2014- Present)

- Language and Concepts Research Group, University of Western Ontario, Dr. Stephen Lupker
- Examines the locus of the semantic priming effect, specifically whether semantic information influences lexical processing.

Comps Research Project (Sept 2016- April 2018)

- Language and Concepts Research Group, University of Western Ontario, Dr. Debra Jared.
- Examines effect of a shared verbal label on perceptual similarity of two objects.

MSc in Experimental Psychology (Sept 2012- Aug 2014)

- Memory and Cognition Lab, University of Calgary, Dr. Glen Bodner
- Examined the effects of test context on experiences of recollection and familiarity in recognition using pupil dilation measures.

Graduate Research Course (Sept 2013- Jan 2014)

- Language Processing Lab, University of Calgary, Dr. Penny Pexman
- Studied the effects of meaning information associated with words and images on performance in categorization tasks.

Undergraduate Honour's Thesis: (Sept 2010 to April 2011)

- Memory and Cognition Lab, University of Calgary, Dr. Glen Bodner
- Designed and conducting experiments designed to elucidate how enriching the encoding of a stimulus improves memory.

Research Assistant Positions

- **Memory and Cognition Lab, Dr. Glen Bodner** (June 2011- Sept 2012)**:** Experience using SuperLab software to program experiments and test participants.
- **Cognitive Sciences Lab, Dr. Christopher Sears** (Oct 2011- Sept 2012)**:** Programming experiments using Experiment Builder software, and subsequently using the Eye Tracker 1000.
- **Department of Sociology, Dr. Erin Gibbs Van Brunschot** (Dec 2011- Sept 2012)**:** Extracting and coding relevant information on offenders from legal documentation.

Experimental Design and Data Analysis Skills:

- Programmed experiments in SuperLab, E-Prime, Experiment Builder, DMDX
- Analyzed data using SPSS, R, Data Viewer, Matlab EEGLab
- R Workshop on Bayesian Statistics at University of Regina June 2, 2017
    - Introduction to concepts and implementation of Bayesian statistics using R
- EEG/ERP Summer Workshop at BMI by Western University. May 16-18, 2016.
- Johns Hopkins University on Coursera Certificates: The Data Scientist's Toolbox, R Programming, Getting and Cleaning Data, Exploratory Data Analysis, Reproducible Research, Statistical Inference.

Teaching Experience:

Instructor

Psychological Statistics Using Computers (Brescia University College, Oct 2017- Jan 2018)

- Presented theoretical rationale of numerous statistical analyses (including multiple regression, t-tests, ANOVAs, factor analysis), how to conduct these analyses in IBM SPSS, as well interpret and report them in APA format.
- Composed lecture material, assignments, quizzes, and the final exam. Assessed student performance and provided feedback.

Teaching Assistant

Experimental Design and Quantitative Methods for Psychology
(University of Calgary, Sept 2012- Dec 2012)

- As lab instructor, taught statistical concepts and experimental design, as well as how to run statistical analyses (t-tests and ANOVAs) using SPSS.
- Taught how to interpret and communicate the results through writing using APA.

Cognitive Psychology (University of Calgary, Jan 2013-April 2013)

- Graded student writing assignments on research in cognitive psychology, provided feedback which allowed students to develop their ideas.

Design and Analysis in Psychological Research (University of Calgary, May 2013-June 2013)

- Lab instructor.
- Presented more advanced statistical concepts (including multiple regression, MANOVA, ANCOVA, and Chi-Square), running analyses in SPSS as well as interpreting and writing the results.

Memory (University of Calgary, Sept 2013 – Dec 2013)

- Advised students in planning and executing individual research projects.
- Assisted students with analyzing their data using SPSS, interpreting, and communicating their results.

Cognitive Development (University of Calgary, Jan 2014- April 2014)

- Lab instructor.
- Advised groups of students in planning and executing research projects. Assisted students in interpreting findings to answer research questions motivating their study.

Research Methods and Statistical Analysis in Psychology
(University of Western Ontario, Sept 2014- April 2015 and Sept 2015-April 2016)

- Lab instructor.
- Presented statistical concepts as well as data analysis in SPSS.
- Taught scientific writing in APA.
- Advised students in planning and executing research projects, as well as interpreting and communicating their findings.

Research Methods in Psychology (University of Western Ontario, Sept 2016- April 2017)

- Lab instructor.
- Taught experimental design and scientific writing in APA.
- Advised students in planning and executing research projects, as well as interpreting and communicating their findings.

Research in the Psychology of Language (University of Western Ontario, Jan – April 2018)

- Programmed experiments in E-Prime for student research projects.
- Prepared data for analysis by students.
- Demonstrated use of BioSemi system to collect ERP data.

Service:

Ad-hoc Reviewer: Canadian Journal of Experimental Psychology; Behavior Research Methods

Psychology Colloquium Series 2016/17

- Involved in organizing and arranging the travel details and accommodations for guest speaker.

Conference Presentations:

- **Taikh, A.,** Jouravlev, O., & Jared, D. (2017, November). *Testing the limit of the Label-feedback hypothesis: The effect of shared verbal labels on perceptual warping.* Poster presented at the 58th annual meeting of the Psychonomic Society, Vancouver, BC.
- **Taikh, A.,** & Lupker, S. (2017, June). *Semantic priming effects and lexical processing.* Paper presented at the 27th annual meeting of the Canadian Society of Brain, Behaviour and Cognitive Sciences, Regina, SK.
- **Taikh, A.,** & Lupker, S. (2016, November). *The effects of semantic priming on lexical activation/inhibition.* Poster presented at the 57th annual meeting of the Psychonomic Society, Boston, MA.
- McPhedran, M., **Taikh, A.,** Spinelli, G., & Lupker, S. (2016, November). *The impact of visible intervenors on form and identity priming.* Poster presented at the 57th annual meeting of the Psychonomic Society, Boston, MA.
- **Taikh, A.,** & Lupker, S. (2016, June). *Effects of semantic priming on lexical processing.* Poster presented at the 26th annual meeting of the Canadian Society of Brain, Behaviour and Cognition Science, Ottawa, ON.
- Pexman, P. M., **Taikh, A.,** Hargreaves, I., & Yap, M. (2015, June). *Semantic richness effects in word and picture classification.* Paper presented at the 25th annual meeting of the Canadian Society for Brain, Behaviour and Cognitive Sciences, Ottawa, ON.
- Bodner, G. E., & **Taikh, A.** (2014, July). *What produces the production effect? Tests of a distinctiveness-based strategy.* Paper presented at the 24th annual meeting of the Canadian Society for Brain, Behaviour and Cognitive Science, Toronto, ON.
- **Taikh, A.,** & Bodner, G. E. (2014, May). *Effects of level-of-processing and test context on pupil dilation and recollect/familiar judgments.* Paper presented at the 16th annual Northwest Memory and Cognition Conference, Victoria, BC.
- Lambert, A. M., **Taikh, A.,** Shumlich, E. J., Weinsheimer, C. C., & Bodner, G. E. (2014, May). *Evaluating the basis of the production effect in recall.* Paper presented at the 16th annual Northwest Memory and Cognition Conference, Victoria, BC.
- **Taikh, A.,** & Bodner, G. E. (2014, May). *Effects of levels-of-processing and test context on pupil dilation and recollect/familiar judgments.* Poster presented at the 33rd annual Banff Annual Seminar in Cognitive Science, Banff, AB.
- Lambert, A. M., **Taikh, A.,** & Shumlich, E. J., Weinsheimer, C. C., & Bodner, G. E. (2014, May). *Evaluating the basis of the production effect in recall.* Poster presented at the 33rd annual Banff Annual Seminar in Cognitive Science, Banff, AB.
- **Taikh**, **A.**, & Bodner, G. E. (2013, June). *Evaluating the basis of the between-subjects production effect.* Paper presented at the 23rd annual meeting of the Canadian Society for Brain, Behaviour and Cognitive Science, Calgary, AB.

- **Taikh, A.,** & Bodner, G. E. (2013, May). *Evaluating the basis of the between-subjects production effect.* Paper presented at the 15th annual Northwest Memory and Cognition Conference, Surrey, BC.
- **Taikh, A.,** & Bodner, G. E. (2013, May). *Evaluating the basis of the between-subjects production effect.* Poster presented at the 32nd annual Banff Annual Seminar in Cognitive Science, Banff, AB.
- Bodner, G. E., **Taikh**, **A.**, & Fawcett, J. M. (2012, June). *The costs and benefits of production in recognition*. Paper presented at the 22nd annual meeting of the Canadian Society for Brain, Behaviour and Cognitive Science, Kingston, ON.
- **Taikh, A.,** & Bodner, G. E. (2012, May). *The production effect in recognition: increased distinctiveness vs. lazy reading.* Poster presented at the 14th annual Northwest Memory and Cognition Conference, Vancouver, BC.
- **Taikh, A.,** & Bodner, G. E. (2012, May). *The production effect in recognition: increased distinctiveness vs. lazy reading.* Poster presented at the 31st annual Banff Annual Seminar in Cognitive Science, Banff, AB.
- Bodner, G. E., & **Taikh, A.** (2011, November). *An attributional account of the production effect in a list-discrimination task.* Paper presented at the 52nd annual meeting of the Psychonomic Society, Seattle, WA.
- Bodner, G. E., & **Taikh, A.** (2011, June). *Reading words aloud makes them more… or less memorable.* Paper presented at the 21st annual meeting of the Canadian Society for Brain, Behaviour and Cognitive Science, Winnipeg, MB.
- **Taikh, A.,** & Bodner, G. E. (2011 May). *Reading words aloud makes them more… or less memorable.* Paper presented at the 13th annual Northwest Memory and Cognition Conference, Vancouver, BC.
- **Taikh, A.,** & Bodner, G. E. (2011, May). *Saying words aloud makes them more… or less memorable.* Poster presented at the 30th annual Banff Annual Seminal in Cognitive Science, Banff, AB.