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Abstract

Priming is the benefit that an event receives when its processing has been preceded by the processing of a related or identical event. Context effects on priming are evident when priming changes as a function of some feature of experimental trials. The most commonly explored context effect is that of relatedness proportion (RP), where it has often been shown that the magnitude of priming (semantic or repetition) is directly related to the proportion of related trials: Increasing the related trials results in greater priming. Although previously thought to depend on strategic processing, recent evidence of context effects from designs using masked primes and short stimulus onset asynchronies (SOAs; less than 250 ms) refutes this strategy view because it should not be possible to enact strategies in such brief intervals. In addition, such findings provide evidence against the dominant view that masked priming with short SOAs results from automatic spreading activation because automatic spreading activation should not be influenced by contextual factors. The current set of experiments was designed to provide converging evidence for the notion that episodic accounts may best account for priming by exploring whether differences in another context variable—list composition—would alter semantic priming in a lexical decision task (LDT) for masked, short SOA (67 ms) primes. In 3 experiments, list composition was manipulated by presenting experimental trials that contained either 3 prime types (nominally related, semantically related, or unrelated) or 2 prime types (semantically related or unrelated) in either a between-subjects design (Experiments 1 and 2) or a within-subject design (Experiment 3). List composition effects were found: Response times (RTs) to semantically related primes were associated with a response cost in the 3-Prime-Type condition but were associated with a response benefit (facilitation) in the 2-Prime-Type condition. Episodic accounts can best account for these results, whereby to best facilitate target

identification, the cognitive system is biased to detect primes containing features that are most transfer appropriate with respect to targets.

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In 1971, Meyer and Schvaneveldt published a study that clearly demonstrated that context affects word recognition. In their experiment, subjects were presented with two simultaneously occurring letter strings, one above the other, and were required to decide whether both strings were words or not: a lexical decision task (LDT). Of the half of the trials that required a yes response, half were associatively related items (e.g., *nurse-DOCTOR*) and the remaining half were unrelated (e.g., *king-BUTTER*). Results indicated that yes responses to word trials averaged 85 ms faster for semantically related compared to unrelated trials, thus strongly implicating a role for context in the facilitation of lexical decision. Their result essentially launched a new domain of research on what came to be called semantic memory (see Tulving, 1972), and has continued to attract researchers generally interested in contextual influences on word recognition.

Unlike Meyer and Schvaneveldt's (1971) methodology, where word strings were presented simultaneously, most experiments exploring context effects on word recognition since then have separated the presentation of the word strings in what is known as the single-word semantic priming paradigm (Neely, 1991). The first word string presented in a trial is called the *prime* and (usually) requires no response. The next word string that is presented is called the *target*, and it does require a response. The response required to the target has most commonly been lexical decision or pronunciation, the latter of which requires subjects to name the target as quickly as possible. The influence that context exercises over any target decision is computed by subtracting the time it takes to respond to a target preceded by an unrelated prime from the time it takes to respond to a target preceded by a related prime. Facilitation of target responses following the presentation of a semantically or associatively related prime is known as *semantic* *priming* (e.g., *doctor-NURSE)*, while facilitation of target responses following the presentation of an orthographically identical prime is known as *repetition priming* (e.g., *DOCTOR-DOCTOR)*. The single-word semantic priming paradigm is especially useful because it permits examination of how the time between the onsets of the prime and target (the SOA) impacts priming. According to the dominant view of priming—activation accounts—SOA is a key variable in determining whether controlled or automatic mechanisms primarily drive priming.

Activation accounts of priming

Word recognition, often explored through priming, is generally interpreted using activation accounts (Bodner & Masson, 2001). Essentially, such accounts propose that semantically and associatively related nodes, or memory structures, are close together or linked within an existing semantic network (Collins & Loftus, 1975; Neely, 1991). Presentation of a prime leads to the activation of the memory structure that contains its representation, and the activation spreads to nearby (related) memory structures. Activation of related memory structures reduces the time required for the activation of a related target to reach threshold for recognition or identification and, thus, responses to targets related to primes are facilitated relative to targets unrelated to primes.

According to Posner and Snyder's (1975) activation model, semantic priming occurs through two processes: A fast-acting, automatic spreading activation mechanism and a slow-acting, attentional controlled conscious mechanism (see also Shiffrin & Schneider, 1977). Briefly, the automatic spreading activation mechanism is proposed to be capacity free—that is, it operates in the absence of attention and is not under strategic control. In contrast, the consciously controlled mechanism (sometimes referred to as the limited capacity attentional mechanism) is capacity demanding, as it requires attention to operate, and is influenced by consciously derived strategies, such as may occur if upon prime presentation a person anticipates the presentation of a particular type of target.

The following illustration should clarify the contribution of the two, independent mechanisms. Upon prime presentation, memory structures (sometimes called *logogens* or *nodes*) that represent the prime are activated according to a feature match between the prime and the existing memory structures. Activation of the memory structure that contains the prime representation activates neighbouring, semantically related memory structures but does not activate distant, semantically unrelated structures; this process is called automatic spreading activation. Provided that the activation of the memory structures related to the prime have not decayed prior to the presentation of the target, targets whose representations are encoded in memory structures that are related to the primes will be activated at a level above baseline due to spreading activation, and responses to those targets will be facilitated. Processing of targets unrelated to primes will not enjoy the same processing benefit because activation only spreads to memory structures that contain representations that are related to the primes.[1]

In contrast to the automatic spreading activation mechanism, the limited capacity, attention controlled conscious mechanism requires time to initialize (at least 240 ms; Perea & Rosa, 2002), and can then increase facilitation of the target response above the level produced by spreading activation alone through the strategic deployment of attention. Essentially, attention shifts to memory structures likely to follow the prime as a result of expectancies that operate prospectively from prime presentation. For example, if a prime *dog* is presented, a subject can consciously expect to see a related target (e.g., *DOG* or *CAT*), and the expectation effectively directs attention to the relevant memory structures, leading to facilitation for expectancy-congruent targets. Critically, in contrast to automatic spreading activation, controlled processes can also direct attention to semantically incongruent memory structures and facilitate responses to semantically incongruent targets. For example, if the prime *dog* is often followed by the target *TRUCK*, then the subject can expect to see a semantically unrelated target following the prime *dog*. This expectancy, based on an episodic association, would lead the prime *dog* to activate task relevant (but semantically incongruent) memory structures if subjects direct attention according to the expectation. Responses to targets expected to follow primes enjoy facilitation because memory structures that are unexpected are inhibited to allow for the attentional shift. Thus, the controlled mechanism is hypothesized to be dependent on intention and conscious awareness because both are prerequisites for the conscious direction of attention.

A classic experiment by Neely (1977) nicely illustrates the prediction from activation theory that without sufficient time (i.e., a long enough SOA), priming is driven only by automatic spreading activation but with sufficient time, both automatic and controlled processes contribute. Unlike controlled mechanisms, automatic spreading activation should not be affected by concurrent task demands, such as demands to expect targets semantically different from those represented by primes. In Neely's experiment, subjects were required to complete a LDT for targets preceded by semantically congruent or incongruent primes. Prime words were one of three category labels: *body, building, or bird*, or were a neutral string of X's. Subjects were instructed to expect semantically related targets following the prime *bird* (Non-shift condition). However, they were told that they should shift their attention following the prime *building* to expect *BODY* related targets and to shift their attention following the prime *body* to expect *BUILDING* related targets (Shift conditions). Subjects were informed that these semantically incongruent relations would occur on most trials. In accordance with these instructions, targets in the Non-shift conditions were followed by semantically related targets on two-thirds of trials and targets in the Shift conditions were followed by the expected (but nonsemantically related) trials on two-thirds of the trials. Finally, they were told to expect *BIRD*, *BUILDING*, and *BODY* targets equally often following the presentation of the neutral primes. SOA was manipulated both within and between subjects, and ranged from 250 ms to 2000 ms, with SOAs of 400 ms and 700 ms also included.

Results of Neely's (1977) study supported Posner and Snyder's (1975) idea that the automatic component is capacity free. In the Non-shift conditions, a facilitation effect was obtained at short (and long) SOAs. However, in contrast to subjects' conscious expectations and the instruction to shift attention to a semantically different category upon prime presentation, target responses were facilitated when they were preceded by a semantically related prime for the short SOA in the shift condition. Thus, as predicted by automatic spreading activation, there was not enough time to shift attention to create the inhibition of semantically related (but unexpected) memory structures that were automatically activated by the primes. With increases in SOA, priming for expected (but semantically unrelated) targets gradually emerged: Responses in the Shift condition at the 400-ms SOA were associated with no priming and with facilitation at the 700-ms SOA. Presumably, the increase in SOA allowed attention to shift from memory structures related to the prime to memory structures expected from the prime.

Implications of activation accounts: SOA and context

Following the publication of Neely's (1977) paper, manipulating SOA to reduce or eliminate the influence that controlled, strategic processes could exert on target responding became commonplace (den Heyer, Briand, & Smith, 1985; Favreau & Segalowitz, 1983; Smith, Briand, Klein, & den Heyer, 1987). Data from these experiments converged with Neely's (1977) result in that use conscious strategies can be prevented through use of a short SOA. For instance, Smith et al. (1987) found greater facilitation following high predictive contexts (e.g., apple – FRUIT) relative to low predictive contexts (e.g., fruit – APPLE) only for SOAs of 1000 ms, but not for SOAs of 200 ms, where facilitation was the same for both high and low predictive contexts. Thus, researchers interested in exploring word recognition in the absence of strategic factors, such as the conscious deployment of attention, used short SOAs because they were thought to eliminate such influence of controlled, strategic mechanisms (Posner & Snyder, 1975).

An important implication of automatic spreading activation at short SOAs is that responses to semantically related targets will be facilitated not only regardless of conscious intentions, but also regardless of variables such as task context. When processing is automatic, other factors should not intrude. A commonly manipulated context variable is that of relatedness proportion (RP). Using that manipulation, one group of subjects completes trials that have a high proportion of semantically related trials (e.g., .80) and another group of subjects completes trials that have a low proportion of semantically related trials (e.g., .20). Spreading activation theory predicts that priming on semantically congruent trials would be equal for the two groups given a short SOA because automatic spreading activation occurs only as a function of the existing semantic network (Fischler, 1977). However, when the SOA is long enough for controlled processes to operate, greater semantic facilitation should occur in the group given the higher proportion of semantically related trials. A high proportion of related trials might lead subjects to anticipate the identity of the target, which would facilitate responses to targets that are congruent with that expectancy. A number of studies using visible primes and long SOAs have shown that the magnitude of semantic or repetition priming increases when there is a higher proportion of congruent trials (e.g., den Heyer, Briand, & Dannenbring, 1983; Keefe & Neely, 1990; Neely, Keefe, & Ross, 1989; Stolz & Neely, 1995) whereas the magnitude of semantic priming does not change as a function of RP with visible primes and short SOAs (e.g., den Heyer et al., 1983; Stolz & Neely, 1995). Of central importance to the experiments in this thesis, these results have been taken to support the notion that context does not influence priming for short SOAs and have also led researchers to use context effects as markers of conscious strategic processes.

In fact, the prediction that context should not affect priming in short SOAs is challenged by one aspect of Neely's (1977) data. Recall that, in his experiments, targets in the Non-shift condition were more likely to be related to the prime (66% chance) compared to targets in the Shift condition (33% chance). However, results revealed that priming for semantically congruent pairs in the short SOA condition for Non-shift conditions (33 ms) was more robust than for Shift conditions (20 ms). This finding is problematic for activation accounts, which would predict equal priming in the two conditions. A few other experiments have also uncovered RP effects for visible primes during short SOAs (de Groot, 1984; Henik, Friedrich, Tzelgov, and Tramer, 1994; Milliken, Lupianez, Debner, & Abello, 1999) Stronger associative semantic priming (74 vs 58 ms) was observed by de Groot (1984) when subjects completed experimental trials that contained a high (.75) relative to a low (.25) proportion of associatively related trials. A similar result was obtained by Henik et al. (1994). They found that semantic priming for associatively related pairs was higher (81 vs 5 ms) for subjects who completed experimental trials that contained a higher proportion of semantically related trials (.80 vs .20). Thus, in contrast to predictions of activation accounts, evidence is not entirely supportive of the notion that short SOAs prevent context effects. It follows that using context as a marker of controlled, strategic processes may not be warranted. The experiments in this thesis will further explore the idea that short SOAs do not prevent context effects, and other theoretical proposals—namely, episodic accounts— will be explored as an alternative mechanism of short SOA priming.

Episodic accounts of priming: Accounting for inconsistencies of activation explanations

Context effects during short SOAs—where priming is greater in conditions with a high proportion of semantically related trials, for instance—can be described by episodic retrieval accounts of priming (Bodner & Masson, 2001; Jacoby, 1983; Masson & Bodner, 2003; Whittlesea & Jacoby, 1990). Those accounts propose that priming occurs retrospectively: Primes form a memory representation, and the retrieval of that prime memory at the time of target presentation facilitates target identification. With respect to Neely's (1977) data, episodic accounts predict greater priming in the conditions in which primes are more likely to be semantically related (the Non-shift vs the Shift condition) even under short SOAs because prime episodes are more likely to be recruited when they are more likely to aid in the processing of an upcoming target event (Bodner & Masson, 2001; Jacoby, 1983; Masson & Bodner, 2003; Whittlesea & Jacoby, 1990) as determined through an automatic "implicit count" of the prime items (Stolz, Besner, & Carr, 2005). To illustrate, consider the following. Upon exposure, a memory for a prime is created, through either a change in existing episodic memories (by changes in connection weights) or the addition of a new episode. The episode contains a memory or an acquired skill for the processing operations that were applied to the primes. An episode for processing operations would include whatever operations were applied to identify and interpret the primes (e.g., orthographic, phonological, semantic; an idea described by Kolers procedural framework, 1975; Kolers & Roediger, 1984). *Retrospective* retrieval of a prime at the time of target presentation is more likely to occur if the identification of targets can benefit from the same processing (Morris, Bransford, & Franks, 1977). So, if a target can be processed using a strategy that focuses on orthographic features, then it will benefit from the retrieval of a prime episode that required similar processing. In contrast to predictions of activation accounts, episodic accounts maintain that transfer of processing mechanisms from primes to targets is influenced by processing context (Whittlesea, 1997).

Jacoby (1983) favoured episodic over activation accounts of priming. He argued that perception is determined through the same mechanisms as recognition memory, specifically, through the recruitment of memories of prior processing episodes. In support of the notion that priming is episodically based, Jacoby (1983) conducted a series of experiments designed to demonstrate that variables that influence recognition memory also affect performance in perceptual identification tasks. A perceptual identification task requires subjects to report the identity of a stimulus that is presented for a very short duration (e.g., 35 ms) and then masked—flanked with strings of symbols, known as *pattern masks*—to make it hard to perceive. In the first of these experiments, performance on a perceptual identification task was enhanced in a list where a greater proportion of the items (90% vs 10%) was presented first as part of an incidental reading latency task. Given that the words in the perceptual identification task were presented briefly and pattern masked, it is unlikely that subjects could perform the perceptual identification task better in the high proportion condition because they consciously recognized the items. Instead, Jacoby argued that the processing of the targets in the high proportion condition was facilitated because the same processing episodes from the earlier incidental reading task were recruited to aid identification. The "unconscious" recruitment of the incidental study-test episodes allowed for more fluent processing of those items when they appeared as targets in the perceptual identification task, because the processing operations applied to the incidental study items were applied to targets in a context that was highly similar to the previous incidental learning context. Critically, the greater the overlap in prime and target processing demands, the more likely the recruitment of prime processing episodes should benefit target processing.

Other work examining context effects on priming for short SOAs has found results that are most compatible with episodic accounts. In a set of experiments by Whittlesea and Jacoby (1990), repetition priming in a naming task varied as a function of the degradation of an associatively related, interpolated item. In their paradigm, subjects were presented with a series of three words: a prime, an interpolated word that was associatively related to the prime and target, and a third word, called the transfer target, which required a response (naming). The transfer target was identical to the prime and was used to assess whether the degradation status of the interpolated word had any effect on the processing of the prime, measured by naming latency. The experimental conditions used associatively related interpolated words (which were either degraded or not; e.g., pLAnT vs PLANT) and transfer targets (e.g., GREEN). The prime word was presented for 60 ms, followed immediately by the interpolated target that was presented for 150 ms; a transfer target was then presented until it was pronounced (e.g., GREEN – pLAnt – GREEN). Critically, episodic retrieval accounts and spreading activation accounts both predict that naming latencies will be differentially affected by the degraded and non-degraded interpolated items (e.g., pLAnt or PLANT) but make different predictions regarding the direction of the effect.

Activation accounts predict one of two outcomes on transfer target naming following the presentation of a degraded interpolated item. Target degradation might have no effect on prime processing because the spread of activation from prime to target occurs prospectively and independently from visual details of the target or other contextual factors. Alternatively, target identification might be *slowed* following the presentation of degraded interpolated items because the degradation might delay the activation of the corresponding memory structure that represents the transfer targets in the semantic network (Whittlesea & Jacoby, 1990). In contrast, episodic accounts maintain that target degradation will facilitate pronunciation of the transfer target (i.e., the repetition of the prime) because, to help clarify the identity of the interpolated word, presentation of the interpolated degraded word should lead the cognitive system to recruit or process the prime episode more heavily compared to when the interpolated word was not degraded. Thus, the representation of the transfer target, which is exactly the same as the prime, is more readily available in degraded interpolated word trials compared to non-degraded word trials, so transfer target naming in degraded trials should be facilitated more as a result. Results supported the episodic interpretation: Subjects could name targets faster when they were preceded by a degraded rather than an intact related interpolated prime.

Thus, the evidence with respect to whether priming is influenced by context when the possibility for controlled strategies is prevented (i.e., through using short SOAs or subjectively imperceptible primes) is mixed. Such mixed results have divided researchers into two theoretical camps: Those who advocate activation accounts (e.g., Forster, Mohan, & Hector, 2003; Hutchinson, Neely, & Johnson, 2001; Keefe & Neely, 1990; Neely, 1977; Neely, Keefe, & Ross, 1989) and those who advocate episodic accounts (Jacoby, 1983; Whittlesea & Jacoby, 1990; Bodner & Masson, 2003; Masson & Bodner, 2003). Context effects in such experiments support episodic accounts, which propose priming operates retrospectively from the time of target presentation. At the time of target presentation the prime memory that has been recently encoded, and that contains information about how the prime was processed, is retrieved and applied to target processing. Because the processing required to identify targets is more similar for related than for unrelated primes, responses are facilitated for related targets. In contrast, activation accounts predict no effect of context in short SOA conditions, because those accounts propose only strategic mechanisms lead to context effects, and strategic mechanisms need at least 250 ms to operate. Thus, in part to pit activation and episodic accounts against each other, the experiments contained in this thesis will assess whether priming changes as a function of context under SOAs too short to implement conscious strategies. The use of conscious strategies will be reduced further by making the primes subjectively invisible through prime masking. Prime masking will be discussed next.

Differentiating between activation and episodic accounts through prime masking

In part to differentiate between activation and episodic accounts of priming, researchers began to manipulate the conscious visibility of the primes. Proponents argued that it was unlikely that an episodic trace could be formed for a stimulus that a subject could not subjectively perceive (Forster & Davis, 1984; Forster, 1998). Thus, any priming effects obtained for primes presented below subjective threshold could not be taken to support episodic accounts. In what is known as the *masked priming paradigm* (Evett & Humphreys, 1981; Forster & Davis, 1984), the prime is blocked or "masked" from conscious influence (strategic processing from attention or conscious perception) because of the imposition of an interfering stimulus (e.g., a string of symbols or letters) in the same spatial location before, after, or surrounding its presentation. Masked prime experiments have been used extensively to explore how word recognition or priming can operate in the absence of controlled strategies. Masking primes so that they are below subjective awareness can be used with other variables, like short SOAs, to further prevent the possibility for conscious strategic processes. Because the experiments in this thesis aim to explore context effects in the absence of strategic processes, both short SOAs and prime masking will be used.

Although weaker than priming for visible primes (Bodner & Masson, 2003), beginning with the work of Marcel (1983), it has become clear that priming does occur for masked primes that are deemed consciously imperceptible at both objective and subjective threshold levels (e.g., Bodner & Masson, 2003; Brown & Besner, 2002; Dagenbach, Carr, & Wilhelmsen, 1989; Carr & Dagenbach, 1990; Dell'Acqua & Grainger, 1999; Draine & Greenwald, 1998; Frenck-

Mestre & Bueno, 1999; Greenwald, Draine, & Abrams, 1996; Greenwald, Klinger, & Liu, 1989; Hines, 1993; Naccache, Blandin, & Dehaene, 2002). A recent meta-analysis of unconscious semantic priming effects revealed moderate effects in lexical decision and naming tasks (Pitts & Klinger, 1997, unpublished manuscript as cited in Klinger, Burton, & Pitts, 2000). Masked priming has been reported for a variety of stimuli, including word-prime, word-target pairs (Bodner & Masson, 2003; Dehaene et al., 1998; Draine & Greenwald, 1998; Greenwald et al., 1996; Marcel, 1983b; Wentura & Frings, 2005), picture-prime, word-target pairs (Dell'Acqua & Grainger, 1999; Ferrand, Grainger, & Segui, 1994), and numbers (Naccache et al., 2002), and has been demonstrated to occur across visual and auditory modalities (Grainger, Diependaele, Spinelli, Ferrand, & Fernand, 2003). Exposure to masked primes has been shown to affect latency, accuracy, and preference judgments to identical or semantically related items. Subjects have even been shown to prefer geometric shapes to which they have been "unconsciously" exposed (for 1 ms) to those to which they have not been exposed, despite chance performance on a forced choice recognition test of the shapes (Kunst-Wilson & Zajonc, 1980).

Evidence that prime masking prevents the formation of a prime memory

The idea that masking a prime prevented the formation of an episodic trace was based, in particular, on three findings described by Forster and Davis (1984): the failure to find masked priming for nonwords, the lack of a frequency attenuation effect for masked primes, and the absence of masked priming in long term priming experiments. A brief discussion of those findings will now be presented for two reasons: So that it is clear how the idea that masked priming was not episodically based was developed and so that these results can be contrasted with newer work (to be presented shortly) that supports the idea that masked priming is, or at least can be, episodically based.

In contrast to unmasked priming, several experiments have failed to find masked priming effects for nonwords (Forster & Davis, 1984, Experiments 1, 2, and 5). Whereas masked primes decreased naming latency for related word targets, naming latency did not decrease for nonwords. Since there should be no memory structures that represent nonwords in the existing semantic network, the failure to find priming for nonwords supports the notion that masked priming operates by activating nodes that exist in the semantic network. In contrast, priming can occur for unmasked nonword primes since priming in that case can result from strategic processing, provided that the SOA is long enough. In contrast to predictions from masked prime paradigms, it is assumed that unmasked primes presented with a sufficient SOA can create an accessible episodic trace.

A few experiments have demonstrated that masked priming is equal for high and low frequency words in LDT tasks (but not in naming tasks; Forster & Davis, 1984). In two experiments (1 and 5), Forster and Davis (1984) found faster responses in a LDT for high frequency words compared to low frequency words but no interaction between frequency and repetition. This result contrasts with findings from unmasked priming, where repetition priming is greater for low frequency words compared to high frequency words (e.g., Duchek & Neely, 1989; Forster & Davis, 1984, Experiment 3). Episodic accounts predict that recruitment of episodes from low frequency primes might act to influence target decisions more than would recruitment of episodes from high frequency primes. Because low frequency targets are less familiar, the application of similar processing episodes to those items will increase their relative fluency more than would be the case for high frequency items that already have a high baseline level of familiarity. Or, perhaps, episodic traces of low frequency items might be stronger or easier to access than high frequency episodic traces (Forster & Davis, 1984). Regardless of the mechanism, the frequency attenuation effect appears to depend on the availability of an episodic trace, so the failure to find the effect for masked primes suggests that the episodic traces for masked primes are unavailable for retrieval.

Lastly, masked priming effects decrease as the number of intervening items and the time between the prime and target increases. Forster and Davis (1984) found that changing the SOA between the prime and target from 60 ms to between 1060 and 2060 ms and the insertion of two to four items between the repetition primes and targets decreased masked priming to 13 ms from 43 and 52 ms (Experiment 1 and 4). In another experiment (Experiment 6), no significant masked priming was obtained when 17 items and a delay of 9 s was inserted between the masked repetition prime and the target; repetition priming (17 ms) did emerge when the lag was 60 ms and only one item intervened between the prime and target. In contrast, long term priming effects can be obtained for unmasked primes (e.g., Hughes & Whittlesea, 2003, Exp. 1B; Jacoby, 1983). Again, the assumption here is that episodes can be formed for primes that are consciously perceptible. Thus, evidence that long term effects are not found with masked primes has been taken to support the notion that masking a prime prevents the formation of a prime episode.

Evidence that prime masking does not prevent the formation of a memory

Recent work has uncovered new evidence that challenges the evidence provided by Forster and colleagues and used to advocate that masking a prime prevents the formation of a prime memory. Bodner and Masson (Bodner & Masson, 1997; Masson & Bodner, 2003) have collected evidence that confirms masked priming effects can occur for nonwords, that it can be influenced by frequency, and that it can survive long delays between the prime and the target. An overview of these findings will now be presented because they illustrate that masked priming effects may very well be episodically based.

Bodner and Masson (1997) proposed that the failure to find masked priming for nonwords might result from subjects experiencing a greater degree of fluency or familiarity when presented with targets that followed nonword repetition primes. That increase in fluency might bias a word response, effectively slowing responses to nonword targets and overshadowing any benefit that primes might otherwise have relayed to targets (Bodner & Masson, 2003). To test this idea, Bodner and colleagues manipulated either target degradation (bReEm) or the difficulty of the nonword decision through use of pseudohomophone targets (e.g., HOAP). Following Whittlesea and Jacoby (1990), it was hypothesized that prime episodes would more likely be recruited to aid target identification when they could substantially aid target identification. Importantly, the processing advantage that could be gained from recruiting the prime episode could potentially outweigh any cost of the decision process as a result of the perceived fluency. Indeed, in these conditions, Bodner and Masson (1997) found masked priming for nonwords that was comparable in magnitude to that obtained using word targets: Priming for nonword targets was 93 and 38 ms in the target degradation and pseudohomophone experiments compared to 75 and 43 ms for the word primes in those same experiments. Another experiment measured priming for words and nonwords through naming latency. This task does not require any decision making, so nonword priming should emerge if it requires that the increased fluency overpowers any bias in the decision making process. As expected, priming was found for nonword targets (20 ms) to a degree comparable to that obtained with word targets (24 ms).

There is also evidence that masked priming can be greater for low frequency words. However, obtaining that effect seems to require a very strong manipulation of word frequency, whereby the high frequency words fall at least at 100 occurrences per million as opposed to 40 to 60 occurrences per million, as per Kucera and Francis (1967) norms. Indeed, Forster and Davis

(1991) found greater masked priming in a LDT using high frequency words that were 100 occurrences per million. Similarly, although Bodner and Masson (2001) failed to observe any change in masked priming as a function of word frequency when the high frequency words were those with 60 occurrences per million, the effect was quite robust when the high frequency words were those that fell within 100 to 1000 occurrences per million. The result was replicated in four experiments, with an average masked repetition priming of 69 and 37 ms for low and high frequency targets, respectively.

The finding that masked priming effects seem to dissipate rapidly over increased SOAs (e.g., from 43 ms with a 60 ms delay to 13 ms with a delay of just over 1s in Forster & Davis, 1984) has been questioned as a valid source of evidence regarding the notion that masking prevents the formation of prime episodes. Masson and Bodner (2003) argued that the decrease in masked priming over short delays is expected according to episodic accounts. Because masking primes below subjective conscious awareness creates a weaker episodic representation than an unmasked prime, it should be prone to fast degradation. They also argued that aspects of the design of the Forster and Davis experiments might have increased the chance or speed of the episode degradation. Specifically, they argued that the presentation of clearly presented (500 ms) intervening items between the masked prime and target in the Forster and Davis experiments likely created retrospective interference that weakened the episodic memory or reduced its access.

To test their suspicion, Masson and Bodner (2003) examined the possibility that masked priming would be significant across a one to two second duration comparable to that used by Forster and Davis (1984; Experiment 6) but without the inclusion of clearly presented filler items. In one of these experiments, masked primes were presented for 45 ms and were immediately followed by a target that required lexical decision. Critically, in the next trial, the prime was replaced by a blank screen and the target was a repetition of the prime on the previous trial. Thus, the item that intervened between the prime and critical target (that occurred on the second trial) was actually a target on a separate trial instead of a filler item; if retroactive interference increases when intervening items are presented as filler items, then the masked priming for the critical target that was a repetition of the prime from the first trial should be greater than it was in Forster and Davis. Indeed, the repetition priming effect in this experiment was 39 ms, much larger than the 13 ms effect Forster and Davis obtained in their experiment using a 1s SOA.

In another experiment, Masson and Bodner explored masked priming for targets that appeared approximately 2.5 s after the presentation of a repetition prime. The first part of the trials in that experiment was the same as the one previously discussed: A masked prime was presented for 45 ms and was immediately followed by a target that required a lexical decision response. In the next trial, the prime was again masked and presented for a short duration (30 ms) but this time subjects were required to identify the prime through naming. The logic here followed that described by transfer appropriate processing (TAP) accounts: Masked repetition priming should be greater in conditions where the processing required for the primes and targets were similar (both required identification rather than only target identification). As predicted, masked repetition identification priming was increased relative to a condition where no prime was presented in the first trial (.60 vs .49). Thus, although it makes sense that the episodic trace associated with a briefly presented masked prime would be weaker than that associated with an unmasked prime, due to differences in conscious accessibility, masked priming effects can be retained over delays of at least one or two seconds. Spreading activation accounts predict that any activation of memory structures represented by the prime should have dissipated over such relatively long delays (Forster & Davis, 1984).

Other findings inconsistent with predictions of automatic spreading activation

The traditional view that masked priming occurs through prospective automatic spreading activation, whereby priming effects operate in a forward manner from the prime to the target, has been undermined in other ways as well. Klinger et al. (2000) obtained evidence suggesting that conscious task goals may be a prerequisite for masked priming. In their experiments, masked semantic priming effects were only obtained for masked primes that were related to targets on a dimension of meaning relevant for target task performance. For example, the prime target pair RAT-BUNNY is congruent on the animacy dimension, but incongruent on the affective dimension. Klinger et al. found congruent animacy did not expedite responding for subjects whose task was to judge the affect of the target word (Experiment 4) but did for subjects whose task was to judge animacy. Similarly, word or nonword status of prime stimuli facilitated performance in a LDT whereas congruent affective relations or associative relations did not (Experiments 2 and 3, respectively). Other work has demonstrated that attention to the temporal window of prime-target presentation is a prerequisite for masked priming. Naccache et al. (2002) failed to find masked priming effects in a number judgment task using a design where targets presented after masked primes appeared in a temporally unpredictable manner. Specifically, masked number primes that were congruent with an appropriate target response (the target number is greater or less than 5) did not facilitate target responses when the target appeared in one of three temporal positions following a (temporally consistent) masked prime. In a second experiment, Naccache et al. explicitly manipulated preparedness to respond to targets by inserting a cue (green square) that reliably predicted the temporal onset of the prime target pair within a stream of a random number of pattern masks. These onset cues appeared only on one third of trials; primes and targets appeared within the stream of pattern masks at an unpredictable onset in the remaining trials (primes and targets were always separated by a

100 ms SOA). Priming was only obtained in the cued trials. Thus, in contrast to predictions of spreading activation, masked priming in these experiments did not occur independently from conscious task goals; rather, it was contingent on the ability to consciously attend to the temporal time frame of the masked prime, target appearance sequence.

Failures to find context effects for primes at short SOAs: Not necessarily inconsistent with episodic accounts

Most published work that has assessed context effects for short duration primes has used unmasked primes (Hutchinson et al., 2001; Stolz & Neely, 1995). Those experiments assessed context effects by manipulating RP. In contrast to experiments that have found greater semantic priming for lists with high RP for SOAs over 300 ms (den Heyer, 1985; Neely & Keefe, 1989; Neely et al., 1989; Perea & Rosa, 2002; Stolz & Neely, 1995), experiments that have used SOAs shorter than 300 ms often find no measurable effect of RP on semantic priming (e.g., den Heyer et al., 1983; Perea & Rosa, 2002; Stolz et al., 2000; Stolz & Neely, 1995). It is assumed that long SOAs allow subjects enough time to intentionally generate expected targets from the primes, and that the conscious motivation to do so is high when primes are especially predictive of a semantically related target in high RP conditions. The absence of RP effects for short SOAs is interpreted as evidence that priming for short SOAs arises exclusively from automatic spreading activation that operates separately from controlled strategies such as conscious motivation to generate expected targets from perception of the prime.

Critically, the presence of context effects has been taken to indicate the use of strategic processes. However, the more recent work of Bodner and colleagues (Bodner & Masson, 2001, 2003; Bodner & Dypvik, 2005) using the masked prime paradigm is inconsistent with the notion that context effects are markers of conscious strategic processes. They obtained evidence for RP effects using very short SOAs (45 and 60 ms) in semantic, repetition, and parity judgment (is the target an odd or an even number?) tasks. Not only were these SOAs too short for controlled expectancy processes to operate, the primes were masked such that subjects could not subjectively perceive the primes. Thus, the plausibility that the RP effects in those experiments arose as a function of controlled expectancy strategies is highly unlikely. Let us turn to that research now.

Context effects in masked priming: Further evidence inconsistent with activation accounts

In a series of experiments designed to pit episodic accounts against activation accounts of priming, Bodner and colleagues (Bodner & Masson, 2001, 2003; Bodner & Dypvik, 2005) combined the use of masked primes with short SOAs (45 ms) to assess context effects on priming. Context effects were assessed by manipulating RP according to perceptual or semantic dimensions. In two experiments, Bodner and Masson (2003) manipulated the proportion of semantically related prime-target pairs by using experimental lists that contained either 80% or 20% semantically related trials, with the remainder of the trials using unrelated prime-target pairs. Results showed that LDT masked priming effects were greater for lists that contained higher proportions of prime valid trials (80% versus 20%), with effects of 24 vs 14 ms and 35 vs 11 ms in Experiment 1 and 2, respectively. This result was obtained despite the fact that subjects were not informed of the RP and despite the fact that they could not subjectively perceive the primes. These results have also been replicated using a naming task (Bodner & Masson, 2004). Stronger masked repetition priming has also been found with the use of higher proportions of repetition trials for SOAs of 60 ms (65 vs 36 ms; Bodner & Masson, 2001). Finally, Bodner and Dypvik (2005) replicated the context effect for masked word number and digit primes in several experiments. In the first two experiments, subjects could more quickly decide whether a word target (e.g., "three" - Experiment 1) or a digit target (e.g., "3" - Experiment 2) was odd or even if it was preceded by a congruent prime, and the effect was greater for conditions where there was a higher proportion of valid trials. A third experiment replicated the context effect for masked digit primes using a magnitude judgment task: Subjects could more quickly decide whether a target digit was less or more than five when the prime that preceded it was congruent, and the effect was stronger when there was a higher proportion of parity valid trials. As a result of such findings, Bodner and colleagues have advocated that through an implicit count of prime validity, our cognitive systems are able to tune into the usefulness of a prime context to determine the extent to which we will rely on that context to maximize target identification.

Bodner and his colleagues explain their context-dependent masked priming effects using an episodic memory recruitment account. By this account, primes are represented in episodic memory, and this memory can be recruited at the time of target processing. Thus, although the episodic prime trace is too weak to be accessed consciously, masking does not prevent formation of the prime episode. As previously outlined, the transfer of processing from the prime episode to the target is most beneficial in contexts of high processing overlap. Further, they hypothesize that prime episodes are more likely to be recruited when they can benefit target processing to a large extent, such as when target identification is difficult (Whittlesea & Jacoby, 1990) or when primes are especially predictive of targets (Bodner & Masson, 1997, 2001, 2003, 2004; Masson & Bodner, 2003; Masson & Isaak, 1999). This episodic memory recruitment account greatly contrasts with spreading activation accounts, the latter of which predict no influence of context on masked priming. Instead, context specific effects of primes might be a product of a cognitive system that is able to adapt to different processing conditions so that it can most efficiently recognize and interpret stimuli within that environment (Masson & Bodner, 2003).

Context as list composition

A context variable that has received little attention in masked priming research is that of *list composition*. The term list composition will be used to refer to the types of prime-target relations that are exemplified in the experimental trials. Critically, the list composition variable can be used to evaluate and extend results of other experiments that have used different context variables (i.e., relatedness proportion) in order to contrast episodic and activation accounts of priming. Let us explore what results episodic and spreading activation accounts would predict as a function of list composition when the use of conscious strategies is prevented.

Episodic accounts propose that the cognitive system can adapt to processing contexts to better facilitate target identification (Bodner & Masson, 2001, 2003; Bodner & Dypvik, 2005; Masson & Bodner, 2003). In keeping with the transfer appropriate processing framework, episodic accounts maintain that primes will provide the most benefit to target identification in conditions where processing or feature overlap of primes and targets are most similar. To optimally facilitate target processing, the cognitive system develops biases to process targets in the way that is most transfer appropriate with previous prime processing. Thus, patterns of priming might differ as a function of list composition. In this thesis, the list composition variable will be represented by a 2-Prime-Type or a 3-Prime-Type condition, with the 2-Prime-Type condition containing trials where primes and targets are semantically related (e.g., *nurse-DOCTOR*) and unrelated (e.g., *king-BUTTER*) and the 3-Prime-Type condition containing trials where primes and targets are semantically related, unrelated, and nominally identical (e.g., *cat-CAT*). Episodic accounts predict that semantic priming will be greater in a list composition condition where no trials contain primes that share more than a semantic overlap with targets (2-Prime-Type condition) compared to when they do (3-Prime-Type condition) because there is transfer appropriate processing bias in the 3-Prime-Type condition to process primes in terms of perfect semantic overlap (and perhaps some orthographic overlap). The transfer appropriate processing bias in the 2-Prime-Type condition should be biased to detect partial semantic feature overlap, so semantically related primes should facilitate target responding more in the 2-Prime-Type condition than in the 3-Prime-Type condition. In contrast to this effect of list composition predicted by episodic accounts, spreading activation accounts propose that priming operates only as a function of the existing semantic network when the use of conscious strategies is prevented through the use of short prime target SOAs, and as such, priming should not change as a function of list composition context.

The majority of experiments that have assessed semantic priming using LDT in unmasked prime paradigms have used only semantically related and unrelated pairs (sometimes also including neutral trials, where blank screens or strings of X's are presented in place of primes). The usual finding here is that responses to targets preceded by semantically related primes are facilitated, relative to targets preceded by either neutral primes or different category primes. Evidence that masked priming changes as a function of list composition would be inconsistent with activation accounts of priming. However, episodic accounts of priming stipulate that the nature of a masked prime's influence (i.e., the degree to which it does or does not facilitate responding to targets) depends on how useful it is for completing the target identification task (Masson & Bodner, 2003). The most benefit for target processing should occur for primes whose processing most exemplifies that which can most effectively aid in the identification of targets. If that is the case, performance in a LDT—which seems to demand a perceptual processing strategy—should benefit more from nominally related primes (e.g., *cat-CAT*) when they are included in a list with semantic primes because, due to their perfect semantic overlap, nominally related primes have a higher degree of feature overlap than semantically related items (e.g., *cat-dog*) and can benefit from more of the same processing.

Before outlining the experiments of this thesis that will test the idea that list composition will alter the pattern of masked priming effects, a brief review of the experiments that imply that list composition might alter masked priming will be presented.

Snow and Neely (1987) found larger semantic priming effects in a LDT task when there was a greater proportion of semantically related trials relative to orthographically identical (50 vs 20%) rather than the reverse. In their experiments, unmasked primes were presented for 80 ms and the targets were presented immediately following prime offset, making the SOA 80 ms. Subjects were assigned to one of two groups: Semantically related (REL) and nominally identical (NI). The semantically related group was exposed to priming trials that contained 50% semantically related trials with the remaining 50% containing equal proportions (17% each) of unrelated, nominally identical (*gorilla–GORILLA*), and neutral (*xxxx–GORILLA*) trials. The nominally identical group was exposed to priming trials that contained 50% nominally identical trials with the remaining trials containing equal proportions (17% each) of semantically related, unrelated, and neutral pairs. Subjects in the semantically related group were told to expect a high proportion of semantically related trials but those in the nominally identical group were told nothing of the relative proportions of nominally identical items to other items. Results indicated greater semantic priming (computed by subtracting RTs to semantic primes from RTs of neutral primes) for the semantic group (36 ms) compared to the nominally identical group (18 ms). If semantic priming was computed by subtracting the RTs for semantic primes from RTs of unrelated primes, semantic priming in the semantically related group was 10 ms larger than semantic priming in the nominally identical group (29 vs 19 ms), although no analyses tested the significance of this difference. Nonetheless, the statistical or numerical trend of greater semantic priming in the semantically related group contradicts predictions from activation theories, which predict no effect of context (be it list composition or RP) with short SOA.

The authors interpreted this finding as evidence that subjects in the semantically related group processed primes at a deep (semantic) level whereas the nominally identical group adopted a more shallow (non-semantic) processing strategy: That is, both groups employed processing strategies that would benefit processing the most for the majority of the trials. However, overall RTs for the semantically related and nominally related conditions were the same (669 ms and 664 ms, respectively), a result that perhaps counters the idea that the semantically related group processed primes at a deeper level, if it is assumed that semantic processing is more time consuming than orthographic processing. Indeed, non-masked priming experiments that have induced semantic or non-semantic processing strategies by manipulating the types of nonwords used in experimental trials—nonwords that are highly similar to words for inducing semantic strategies and letter strings for inducing shallow, non-semantic processing—have shown that overall RTs are shorter in trials where a non-semantic strategy can drive performance in a LDT (Smith, Theodor, & Franklin, 1983).

Other work has provided evidence suggesting that subjects cannot implement consciously deployed strategies under conditions of short SOA (Dark & Benson, 1991; Neely, 1977). Thus, it is possible that the greater semantic priming in the semantically related compared to the nominally identical group in the Snow and Neely (1987) study occurred because of differences in RP and list composition. To illustrate, consider the following. Primes will most often benefit target identification when the processing used to identify primes overlaps with the processing that will be most useful for identifying targets. Consider first the semantically related group. Even if subjects were not informed of RP (50% semantically related trials), evidence from masked priming experiments that have manipulated RP in the absence of instructed awareness of the RP suggests that subjects can implicitly detect such relations (Bodner & Masson, 2001, 2003). In such a situation, the cognitive system might be biased to retrieve prime episodes that share semantic processing or feature overlap with targets because that would benefit performance on the majority of the trials. In contrast, in the nominally identical group (50% nominally related trials), the cognitive system should be biased to retrieve prime episodes that share orthographic, phonological, and/or semantic overlap with targets. In that case, recruitment of the prime episode where targets were only related semantically (and did not exhibit a perfect overlap in semantic features) might slow responding to those targets relative to targets that were nominally related, since the system is set to detect a match in not only semantic, but also phonological and orthographic codes.

Such differences in bias for semantically related and nominally identical groups could explain the increase in semantic priming for the semantically related relative to the nominally identical groups. However, to more directly examine whether the inclusion of nominally related trials attenuates semantic priming effects, a condition where semantically related trials are included without nominally related trials is really needed. If semantic priming effects are larger in a condition where only semantically related trials are included relative to a condition where both nominally and semantically identical trials are included, then this would support the idea that the lower semantic priming effect in the nominally identical group in Snow and Neely (1987) was due in part to different biases to detect features in primes that are most transfer appropriate with targets. Since there should be no bias to detect orthographic or phonological features of primes when targets do not share those features, semantic priming should be greater in a condition where no nominally identical trials are included compared to when they are. In addition, because the context effects in Snow and Neely (1987) could also be due to the relatedness proportion differences, further experiments exploring the list composition variable would have to keep relatedness proportion equivalent across list composition conditions.

In what might be a function of the types of trials included in the experimental design, a few experiments have demonstrated that responding to semantically related trials is associated with slower responding in LDT compared to responding to unrelated (semantically different) trials. In these experiments, subjects were required to perform a semantic classification task on masked primes prior to completing the experimental trials. This task was intended to encourage a semantic processing strategy that would then carry over to influence performance on experimental trials. Following the semantic classification of masked primes, Dagenbach et al. (1989) found slower responding to targets preceded by semantically related primes relative to unrelated primes (23 ms interference) in the experimental LDT. Kahan (2000) replicated this result, showing that subjects demonstrated 26 ms of interference for targets preceded by semantically related versus unrelated primes. Finally, Carr and Dagenbach (1990) found numerically slower responding to targets preceded by same category primes compared to different category primes after subjects engaged in a semantic classification task with masked primes (-6 ms interference).

Response interference associated with semantic trials in the above experiments can be readily interpreted using an episodic account. Kahan (2000) proposed that if recruitment of a prime episode reveals phonological, orthographic, and semantic overlap with a target, then the recruitment of that prime episode would benefit processing of targets that share the same codes. However, a bias to detect three overlapping codes would slow responding to targets that match according to only one code. Specifically, the detection of one overlapping feature but not the other expected overlapping features might mediate a second retrospective check to confirm the absence of the other two codes (Bodner, 2007, personal communication). The retrospective check might also be expected to clarify semantic similarities in a system biased to detect identical semantic overlap. If a prime does not match any expected codes, subjects can quickly respond to targets because no clarification is needed through a prime-target comparison. A similar proposal—temporal discrimination theory, put forth by Milliken, Joordens, Merikle, and Seiffert (1998) to account for negative priming effects—maintains that when a target is very similar or very dissimilar to a previous stimulus occurrence (i.e., a prime), then it can be accepted or rejected quickly. If a target is only somewhat similar to a previous stimulus occurrence, however, its acceptance or rejection is slowed, an idea that goes back at least as far as Atkinson and Juola (1974) and Smith, Shoben, and Rips (1974). Importantly, although the biases in the studies by Dagenbach et al. (1989), Carr and Dagenbach (1990), and Kahan (2000) were hypothesized to occur as a result of the conscious expectancies formed from the prime detection task, episodic accounts predict that such biases can form implicitly through an implicit count of prime items (Stolz et al., 2005), and evidence of RP effects for masked primes in designs where subjects are not informed of potential prime-target relations supports such a notion (Bodner & Masson, 2003; Masson & Bodner, 2003). In the absence of conscious expectancies, then, can different prime retrieval biases change the pattern of priming as a function of list composition alone?

Despite the possibility that the results of the experiments by Carr and Dagenbach (1990), Dagenbach et al. (1989), and Kahan (2000) might have been mediated in part by list composition, how much of the response cost effect was related to task instructions, relatedness proportion differences, or the long SOA is not clear. The same can be said for Snow and Neely's (1987) experiments, where task instructions about the nature and RP of primes might have been a driving factor in the different pattern of priming observed for the different list composition conditions. If it can be demonstrated that masked priming does change as a function of list composition—in the absence of differences in test instructions, differences in RP, and subjective perception of masked primes—then this would further question the general utility of activation accounts of masked priming. The experiments contained in this thesis set out to explore this possibility.

List composition effects with masked primes at short SOAs: Context effects do not signify the operation of strategic processing

Regardless of the exact mechanism of list composition effects, an important implication of results that show context effects using *masked, subjectively invisible* primes—especially those using short SOAs—is that the presence of such context effects need not imply the operation of controlled, expectancy driven processes. Consider first the short SOA. Researchers interested in examining cognitive processes that occur in the absence of controlled processes have largely assumed, based on Neely's (1977) work and similar work that followed, that use of a short SOA prevents operation of strategic controlled processes (Balota, 1983; Carr & Dagenbach, 1990; Dagenbach et al., 1989; Fishler & Goodman, 1978; Forster & Davis, 1984; Forster, 1998; Hutchison, 2007; Hutchinson et al., 2001; Perea & Rosa, 2002). Proponents of activation accounts contend that context will only affect priming when the SOA is no less than 250 ms (although other estimates have been as high as 500 ms; see Neely, 1991) because this allows enough time to fully generate possible targets via strategic, controlled processes that operate prospectively from prime presentation. Now consider the addition of masked primes. It is difficult to argue that subjects can generate expectancies for stimuli that they cannot consciously detect, and there is research to support this notion (Cheesman & Merikle, 1986; Merikle & Joordens, 1997). Even if one were to argue that conscious expectancies can influence masked priming, but that the SOA has to be long enough to allow the activation from the (weaker than unmasked) trace to spread, such an explanation still could not account for differences in performance as a function of context for short SOAs. Automatic spreading activation is not thought to be influenced by variables like task context because it operates based on configuration of the existing semantic network (Fischler, 1977) and awareness is a prerequisite for the application of the controlled target generation strategy that operates prospectively from prime presentation (e.g., Forster & Davis, 1984; Forster, 1998; Kiefer, 2002; Marcel, 1983). Thus, results indicating that masked priming for short SOAs is influenced by context undermines the value of using context effects to assess the presence of strategic processes (e.g., Neely, 1991; Hutchinson, 2007). In contrast to that idea, context effects may instead be driven by a cognitive system that can implicitly detect, and operate as a function of, the transfer appropriateness of primes and targets.

The present experiments

The experiments presented in this thesis were designed to assess whether task context, specifically in terms of list composition, could alter the pattern of semantic priming. The experiments used masked primes presented for a short duration (33 ms) coupled with short SOAs (67 ms) to limit the chance that priming effects could be contaminated by consciously applied strategies (Neely, 1991). Although subjects were aware that masked primes were present, they were not told how they were related to the targets and were not instructed to attempt to process primes in a particular way. Thus, any effect of list composition could not be directly attributed to the transfer of a consciously derived prime processing strategy, as may have been the case in previous experiments (Carr & Dagenbach, 1990; Dagenbach et al., 1989; Kahan, 2000; Snow & Neely, 1987). An effect of list composition under these conditions would lend support to episodic accounts, because such accounts predict that the cognitive system can adapt to different processing contexts in order to better facilitate target processing. Alternatively, if no effects of list composition are obtained, activation accounts would receive support, because such accounts propose semantic priming should operate only as a function of the existing semantic network when strategic processes are not possible.

The dependent variable in each of the three experiments was mean RT for lexical decision for targets preceded by nominally related, semantically related, or unrelated primes. The manipulation of prime type always occurred within subject. The manipulation of list composition was whether experimental trials contained three prime types (nominally identical, semantically related, or unrelated primes) or two prime types (semantically related and unrelated primes). List composition was manipulated between subjects (Experiment 1), where subjects either received a 3-Prime-Type list (3-Prime-Type condition) or a 2-Prime-Type list (2-Prime-Type condition). Experiment 2 replicated the 2-Prime-Type condition of Experiment 1 with the exception of a minor change, and Experiment 3 was a combination of Experiment 1 and 2, where list composition (3-Prime-Type and 2-Prime-Type) was manipulated within subject in a blocked design. All experiments included nonword trials that were equal in number to the word trials to avoid biasing a word or nonword response.

Activation accounts predict both facilitatory semantic and orthographic priming in both the 2-Prime-Type and 3-Prime-Type list composition conditions. Spreading activation is hypothesized to occur only as a function of the existing semantic network, and thus should not be influenced by controlled strategies—thought to underlie context effects—when SOAs are too short or when primes are masked and thus subjectively invisible (Neely, 1991). A context effect for short SOAs and masked primes is, however, not inconsistent with episodic accounts of masked priming. Episodic accounts maintain that primes can be more beneficial for target identification in conditions in which primes are highly transfer appropriate with targets in terms of similar processing and features. To optimally facilitate target processing, the cognitive system might develop biases to process targets in a manner most transfer appropriate with the processing used to identify primes. Thus, according to episodic accounts, patterns of priming might differ as a function of list composition if experimental lists contain primes and targets that differ in the degree that they benefit from similar processing mechanisms.

Consider first a 3-Prime-Type list composition experiment. Here, primes are most transfer appropriate with targets in instances where primes are identical phonologically, semantically and partially orthographically (as is the case with nominally related pairs, e.g., *cat–CAT*). Thus, the cognitive system might be biased to detect orthographic, phonological, and semantic overlap between masked primes and targets to facilitate target identification. However, in instances where primes share only semantic overlap with the targets, a bias to detect features that are identical with respect to three features (semantic, orthographic, and phonological) might slow processing of targets that only overlap according to one feature (Kahan, 2000; Milliken et al., 1998), perhaps because the cognitive system has to perform a second retrospective check to verify the presence of only one overlapping code due to a violation of expectancy. In the case of unrelated pairs, it is possible that in a system set to detect orthographic, semantic, and phonological overlap, decisions to targets that share none of these features with the primes might be faster than decisions to targets that share only one of these features with the primes because no retrospective check is required (Kahan, 2000; Milliken et al., 1998).

Now consider a 2-Prime-Type list composition condition. Here, the processing that would be most transfer appropriate would be of a semantic nature. That is, because there are no trials where detection of phonological or orthographic features can benefit both primes and targets, the cognitive system would focus on detecting similarities in primes and targets through detection of semantic codes. Thus, despite the fact that, consciously, LDT can be completed best through focusing on orthographic properties of targets, the cognitive system might adapt to focus on features of stimuli that better facilitate target processing, which in this case would be semantic features. Thus, the pattern of priming for semantically similar pairs might differ as a function of list composition (3-Prime-Type vs 2-Prime-Type): Priming for semantically similar pairs should be greater in a 2-Prime-Type list condition compared to a 3-Prime-Type condition because semantic features are more transfer appropriate with targets in the 2-Prime-Type condition. This is the expectation of the present set of experiments.

Experiment 1

In Experiment 1, list composition (3-Prime-Type and 2-Prime-Type) is manipulated between subjects. Given that these experiments use short SOAs and masked primes, activation accounts predict that semantic priming should not be affected by context manipulations because priming effects arise prospectively from the primes and solely as a function of the existing semantic network. Thus, activation accounts predict that semantic priming should be the same in the 3-Prime-Type and 2-Prime-Type list composition conditions. In contrast, episodic accounts predict that context should alter priming effects because they predict that priming occurs retrospectively, and the retrospective application of prime processing will aid target processing differently depending on the transfer appropriateness of the prime target processing. Because the 2-Prime-type condition does not include nominally identical trials, semantic primes exemplify the most transfer appropriate relationship with targets. This contrasts with the 3-Prime-type condition, where nominally identical trials exemplify the most transfer appropriate relationship with targets. Thus, semantic priming should be greater in the 2-Prime-type condition than in the 3-Prime-type condition because in the 2-Prime-type condition the cognitive system is biased to detect semantic instead of orthographic relations.

Method

Subjects. Fifty-two undergraduate students from Wilfrid Laurier University participated in Experiment 1. Course credit or payment of $11 was provided in exchange for participation. Twenty-seven subjects were assigned to the 3-Prime-Type list composition condition and 25 subjects were assigned to the 2-Prime-Type list composition condition.

Design. The design was a 2 X 2 mixed factorial. List composition (3-Prime-Type – nominally identical, semantically related, and unrelated; 2-Prime-Type – semantically related and unrelated) was manipulated between subjects. Prime-Type (same category, different category) was manipulated within subjects. It is important to note that the third Prime-Type (nominally identical) in the 3-Prime-Type list composition factor will not be included in the assessment of any Prime-Type X list composition effects, in that it functions as a context manipulation here. Following quite standard practice, semantic priming will be computed by subtracting RTs in semantic trials from RTs in unrelated trials. [2]

Materials. Word stimuli were selected from four sources: Hines, Czerwinski, Sawyer, and Dwyer (1986); Moss, Ostrin, Tyler, and Marslen-Wilson (1995); Nelson, Bennett, Gee, Schreiber, and McKinney (1993); and Nelson, McEvoy, and Schreiber (2004). Nonword trials were the same in both the 3-Prime-Type and 2-Prime-Type conditions, so they will be described first. The 226 pronounceable nonwords were taken from Smith et al. (1994). Nonwords served as primes for 72 nonword targets and 72 word targets, and as targets for 72 nonword primes. Critical word trials in the 3-Prime-Type condition were comprised as follows. The 226 nouns were divided into 72 semantically and associatively related prime-target pairs (e.g., doctor – NURSE), 72 nominally identical prime target pairs (doctor – DOCTOR), and 72 prime-target pairs that were not semantically or associatively related (doctor – PISTOL). Critical word trials in the 2-Prime-Type condition did not contain nominally identical trials. Instead, nominally identical trials were omitted and were replaced by equal numbers of semantically similar and unrelated trials. Thus, both the 3-Prime-Type and 2-Prime-Type conditions consisted of 6 blocks of 72 trials for a total of 432 trials, 216 of which were word target trials. However, in each of the 6 blocks, there were 12 semantically related and 12 unrelated word target trials in the 3-Prime-Type condition (with an additional 12 nominally identical word target trials) and 18 semantically related and 18 unrelated word target trials in the 2-Prime-Type condition. Within each block, the same trial type could not occur more than twice in succession.

Each prime and target was presented three times, once in each of the prime category conditions. Presentation of targets in different prime conditions is not a new practice in the realm of masked priming for words (Balota, 1983; Dell'Acqua & Grainger, 1999) and especially not in the realm of masked priming for numbers (e.g., Bodner & Dypvik, 2005; Naccache et al., 2002; Naccache & Dehaene, 2001). It should also be noted that priming effects mediated by the first presentation of the primes and targets should have long dissipated by the time successive presentations of these stimuli occur. Semantic (and repetition) priming effects for briefly presented masked primes are very short lived (e.g., less than 2 seconds, Hughes & Whittlesea, 2003). Research has indicated that the effects last no longer than 3000 ms following prime presentation (e.g., Versace & Nevers, 2003). Other research has shown that when 4 intervening items are presented after a prime (over the course of 20 seconds), RTs to an identical target no longer differ from baseline (Forster, Booker, Schacter, & Davis, 1990). Additionally, it has been demonstrated that conscious perception of masked stimuli does not increase with repeated instances of the primes (Marcel, 1983).

All stimuli were presented in black on a white background. Primes were presented in lower case and targets were presented in upper case. All experiments were programmed and tested using direct RT software.

Procedure. Subjects were informed that their task was to judge whether targets were words or nonwords as quickly as possible by pressing the appropriately labeled key. Subjects were told to keep their fingers placed on each of the labeled keys because lifting their fingers off the keys would delay responding. Subjects were told that masked primes were present, and were shown an example of how each trial would proceed with masked prime presentation significantly slowed so that its presence was clearly perceptible. Prime and target stimuli used in the example were the non-concrete words *work* and HARD, respectively, and thus, they did not exemplify concrete words or relations used in the experimental trials. Demonstrating the presence of the prime was designed to encourage subjects to pay attention to the appearance of all stimuli as they appeared on the screen. It was not expected that this would increase the perceptibility of the masked primes. However, given that other work has indicated that attention to the temporal window of prime target presentation is a prerequisite for masked priming (Naccache et al., 2002), and given that prior work in my lab has demonstrated that masked priming might depend on awareness that masked primes were present, such a procedure was adopted to maximize the possibility of obtaining masked priming effects.

The 432 priming trials proceeded as follows: (a) a fixation cross in the center of the screen for 400 ms, (b) a randomly chosen forward mask composed of a string of 12 letters and symbols for 400 ms, (c) a prime word for 33 ms, (d) a backward mask (exactly like the previously presented forward mask) for 33 ms (for a total SOA of 67 ms), and (e) the target word until a response. Subjects completed 6 blocks of 72 trials following instructions and six practice trials.

Following the completion of the experimental trials, subjects were asked about subjective awareness of primes (i.e., could you ever see any of the words or nonwords between the symbols?). In addition, to assess conscious perception of masked primes beyond subjective report, subjects attempted to perform a lexical decision on the masked primes in a single block of 72 trials presented exactly like the experimental trials.[3] However, in contrast to the experimental trials, lexical decisions were required for the primes, not the targets, but targets were still presented after the masked primes. Subjects were instructed to focus on the masked prime that appeared before the target and to decide whether it was a word or a nonword. Subjects were informed that this task would be very difficult, and that they would likely be forced to guess the lexicality of the primes on most, if not all, of the trials. No time constraint was imposed.

Results & Discussion

All reported effects were reliable at $p < .05$ unless otherwise noted. Response times shorter than 300 ms and longer than 1500 ms (fewer than 0.5%) were removed (Bodner & Masson, 2003; Ulrich & Miller, 1994) as well as data for three subjects who had (surprisingly) high conscious perception scores as measured by the conscious perception trials (all above 80% correct identification of masked primes). Two of those subjects were participants in the 3-Prime-Type condition; the other was from the 2-Prime-Type condition. Note that inclusion of their data did not change the pattern of the results. Mean RTs for lexical decisions for each of the Prime-Type trials are presented in Table 1. Mean proportions of lexical decision errors for targets are presented in Table 3 for all experiments. As the principle dependent variable in these experiments is RT, and as the error data were not inconsistent with the interpretations and conclusions based on RTs, the error data will not be discussed further.

With the exception of the three subjects whose data were removed, subjects claimed that they could not detect the identities of any masked primes. Mean proportion of correct lexical decisions for masked primes was .59 in the 3-Prime-Type group and .55 in the 2-Prime-Type group. Of the three subjects who had high conscious perceptibility scores, none reported with high confidence the ability to identify primes, but all claimed that they "thought" they saw one or two specific words on one occasion. It is thus possible that the high correct prime classification scores from these subjects resulted from an actual better ability to detect such primes. Indeed, subjects have been found to vary substantially in their ability to detect masked primes (e.g., Dagenbach et al., 1989; Forster, Mohan, & Hector, 2003), and even when subjects claim that they cannot see masked primes, they often score above chance on objective perceptibility tests (Bodner & Dypvik, 2005). The insertion of a pattern mask between the prime and the target might have increased the visibility of the primes more often than would have been expected had the primes only been pre-masked (Forster et al., 2003). Regardless, since this experiment was designed to investigate conscious influence on subjectively imperceptible primes, it would not have been desirable to include subjects who claimed that they could or did perceive the primes. Moreover, it is common practice to remove subjects who exhibit high conscious perception scores in experiments of masked priming (Bodner & Dypvik, 2004; Bodner & Masson, 2003, 2004; Naccache & Dehaene, 2001).

To assess whether RTs differed as a function of Prime-Type, paired samples *t* tests were conducted for each of the list composition groups separately. In the 3-Prime-Type list composition group, RTs were 11 ms faster for targets preceded by nominally identical targets compared to unrelated targets, $t(24) = 2.07$, $SEM = 4.89$. Response times to targets preceded by semantically similar primes were slower than responses to targets preceded by nominally identical primes by about 25 ms, $t(24) = -6.16$, $SEM = 4.01$. However, RTs to targets preceded by semantically similar primes were also slower than RTs to targets preceded by unrelated primes by about 15 ms, $t(24) = -2.48$, $SEM = 5.89$. In the 2- Prime-Type list composition group, RTs to targets preceded by semantically related primes were about 12 ms faster than they were for targets preceded by unrelated primes, $t(23) = -2.65$, $SEM = 4.40$. It appeared that although the usual facilitatory semantic priming effect was obtained in the 2-Prime-Type condition, the semantic priming effect in the 3-Prime-Type condition was associated not with a response benefit but with a response cost.

Mean RTs for targets preceded by semantically similar and unrelated primes (Prime-Type) were assessed using list composition (3-Prime-Type vs 2-Prime-Type) as a between subject factor in a repeated measures analysis. The Prime-Type X list composition interaction was highly significant, $F(1, 47) = 12.59$, $MSE = 334.78$. The main effect of list composition was also significant, $F(1, 47) = 5.12$, $MSE = 11760.11$, but the main effect of Prime-Type was not, $F < 1$. A one way ANOVA revealed that mean RTs to targets preceded by unrelated primes differed as a function of list composition, with unrelated trials about 62 ms faster in the 3-Prime-Type condition than in the 2-Prime-Type condition, $F(1, 47) = 8.44$, $MSE = 48165.91$. Although numerically RTs in the semantic condition were 37 ms faster in the 3-Prime-Type condition than in the 2-Prime-Type condition, this trend did not reach conventional significance, $F(1, 47) = 2.55$, $MSE = 16296.93$, $p = .12$.

Thus, in contrast to predictions of activation accounts, semantic priming was found to differ as a function of context. When semantic primes were presented in a list that contained nominally identical pairs, responses to targets preceded by semantic primes were associated with a response cost compared to responses to targets preceded by unrelated primes. However, when semantic primes were presented in a list where the only related pairs overlapped semantically, responding to targets in semantically related trials was facilitatory. Such a result is consistent with episodic accounts of priming, where context can affect masked priming under short SOAs. An episodic account of priming could account for the list composition effects by maintaining that the cognitive system is biased to detect processing similarities or features of primes that can most benefit target identification and thereby process targets using the same processing mechanisms applied to identify primes. In a context where nominally identical and semantically related prime target pairs are represented in equal proportions, a bias to detect and process semantic, orthographic, and phonological features might emerge because complete overlap in those features is most transfer appropriate and can provide the most benefit for target identification. Then, the bias to detect prime episodes that share three features with targets—perhaps through the application of processing that will allow for the detection of perceptual and semantic overlap—slows responding to targets that match according to only one code. Because no clarification of the mismatched codes is necessary, decisions to targets that share no code overlap with primes would still be expected to be faster than decisions to targets that overlap according to only one code.

Such an explanation is consistent with the results in the 3-Prime-Type condition, and is consistent with temporal discrimination theory (Milliken et al., 1998) and episodic retrieval accounts (Kahan, 2000) of priming. In the 3-Prime-Type condition, the bias to detect and process orthographic properties in primes and targets slowed responses to targets preceded by primes that were only semantically related, perhaps because the cognitive system had to verify the presence of a semantic relation (Bodner, 2007, personal communication). This explanation can also explain why the pattern of semantic priming was facilitatory in the 2-Prime-Type condition. In a context where the only similarities between primes and targets are semantic, a bias to detect semantic overlap will provide the most benefit for target identification. Thus, the cognitive system will be biased to detect primes that overlap with respect to semantic codes, and responses to targets preceded by semantically related primes will be facilitated: No retrospective check of a semantic relation is required when that is the relation that is most transfer appropriate and expected.

Regardless of the exact mechanism driving the list composition context effects, it is certain that those effects are not consistent with predictions of activation theories. The findings also imply that using the presence of context effects as a marker of strategic processes can be unwarranted, at least in conditions where primes are masked to subjective unawareness and when short SOAs are used.

Experiment 2

Experiment 2 was a replication of the 2-Prime-Type list composition condition of Experiment 1. In Experiment 1, the number of semantic and unrelated trials in each block was greater in the 2-Prime-Type block than in the 3-Prime-Type block. This was because nominally related trials in the 3-Prime-Type block were removed and replaced with an equal number of semantic and unrelated trials. In Experiment 2, instead of replacing the omitted nominally related trials in the 2-Prime-Type condition, an equal number of nonword trials was removed. Thus, to control for the possibility that the facilitatory semantic priming in the 2-Prime-Type condition of Experiment 1 was a result of the greater number of semantically similar prime target trials included—108 compared to 72, where 18 semantically related trials instead of 12 occurred per block— instead of replacing nominally related trials with an equal number of semantically related and unrelated trials, an equal number of nonword trials were deleted.

A facilitatory semantic priming effect under these conditions would favour the hypothesis that the response cost in the 3-Prime-Type condition of Experiment 1 was associated with the inclusion of nominally related trials together with semantically related trials. It was expected that Experiment 2 would replicate the 2-Prime-Type condition in Experiment 1 under the argument that the inclusion of nominally related trials in Experiment 1 was a necessary component for the semantic response cost effects in the 3-Prime-Type condition.

Method

Participants. Twenty-four undergraduate students from Wilfrid Laurier University participated in exchange for course credit. None had participated in Experiment 1.

Materials. With the following exceptions, the materials were the same as in Experiment 1. The 72 nominally related prime-target pairs and 72 nonword target trials were removed from the 3-Prime-Type condition. Thus, the same numbers of semantically similar and semantically different trials were present in each of the 6 blocks of trials as the 3-Prime-Type condition of Experiment 1. There were now 6 blocks of 48 trials.

Procedure. The procedure was identical to that of Experiment 1. All subjects were generally informed of prime presence. That is, subjects were told that masked word or nonword primes were present but were not told of the semantic nature of those primes nor of the possible semantic relation between primes and targets.

Results

Response times shorter than 300 ms or longer than 1500 ms (fewer than 0.5%) were removed (Bodner & Masson, 2003; Ulrich & Miller, 1994). No subjects had high conscious perception scores as measured by the conscious perception trials (above 80% correct lexical decision of masked primes), and no subjects claimed that they could perceive the primes. Therefore, the data from all subjects were included. Mean proportion correct lexical decision scores for the LDT for the primes was .59. Mean RTs in the LDT for the word targets are presented in the lower portion of Table 1.

As expected, results replicated the 2-Prime-Type condition of Experiment 1. Semantic priming was significant and facilitatory: RTs in semantic trials were about 15 ms faster than RTs in unrelated trials, $t(23) = 2.93$, $SEM = 5.15$. Next the results of the 2-Prime-Type condition here were compared to those of the 3-Prime-Type condition of Experiment 1 to explore whether the Prime-Type X list composition interaction from Experiment 1 replicated. A repeated measures ANOVA examined the effect of Prime-Type as a function of list composition. There was a reliable Prime-Type X list composition interaction, $F(1, 47) = 14.30$, $MSE = 377.00$.

Thus, it seems that the presence of semantic interference effects in the 3-Prime-Type condition of Experiment 1 and the facilitatory semantic effects in the 2-Prime-Type condition of Experiment 1 are attributable to the inclusion or exclusion of nominally identical trials and not to differences in the number of semantically related trials. The fact that there were fewer semantically related and unrelated trials in the 2-Prime-Type condition in Experiment 2 did not alter the pattern of results. Considering the results from the planned paired samples *t*-test, then, it seems that the inclusion of nominally identical trials changes the pattern of semantic priming from benefit (facilitation) to cost. The finding that RTs in unrelated trials were faster in the 3-Prime-Type condition compared to the 2-Prime-Type condition also supports the idea that there are different biases in these conditions. Specifically, perhaps the lexical decision for trials that are unrelated is faster in a system searching for three overlapping codes compared to one. Or, perhaps, in the 3-Prime-Type condition, the system is only biased to detect orthographic and/or phonological overlap, in which case the rejection of unrelated trials might be faster because neither of those codes—that share almost perfect feature and processing overlap with the congruent trials—is exemplified by the unrelated trials. However, how the latter interpretation can explain the finding of a response cost in semantically related trials in the 3-Prime-Type condition is unclear, unless one assumes that the detection of a semantically related prime in a system biased to detect perfect semantic overlap (and perhaps partial orthographic feature overlap and perfect phonological overlap) slows responding through some sort of retrospective check.

The most critical result of this experiment is the finding that the pattern of priming changes in a consistent way as a function of list composition. Such a finding directly conflicts with predictions of activation accounts but is consistent with episodic accounts.

Experiment 3

To further verify the finding that different list compositions can create different patterns of semantic priming, Experiment 3 manipulated list composition within subjects. Each subject completed two blocks of trials. One block contained three prime types (nominally related, semantically related, and unrelated; 3-Prime-Type Block) and the other block contained two prime types (semantically related and unrelated; 2-Prime-Type Block). Order of blocks was counterbalanced, such that each subject completed all trials in either the 3-Prime-Type Block or the 2-Prime-Type Block first. It was expected that the results from Experiment 1 would replicate, in that semantic priming would differ as a function of list composition: Priming for semantically related trials should be associated with a response cost (relative to unrelated prime trials) in the 3-Prime-Type block and with a response benefit (facilitation) in the 2-Prime-Type Block. Such a result would also indicate incredible flexibility of the cognitive system, whereby processing biases can adapt quickly to changes in processing context.

Method

Participants. Thirty-six subjects were recruited from Wilfrid Laurier University and participated in exchange for course credit.

Materials. Materials were a combination of those employed in Experiments 1 and 2, along with an additional 36 pronounceable nonwords selected from Smith et al. (1994).

This experiment contained 2 blocks of trials. Both blocks of trials contained half word and half nonword target trials. However, of the word trials, only one block (3-Prime-Type) contained 33% nominally related trials (e.g., *cat-CAT*). The remaining 66% of trials in that block contained equal proportions of semantically related and unrelated trials. In the other block (2-Prime-Type), the word trials did not contain nominally related trials, and were comprised of 50% semantically related trials and 50% unrelated trials. Thus, both block types had an equal number of trials, but the 3-Prime-Type block had 36 each of nominally related, semantically related, and unrelated prime target types whereas the 2-Prime-Type block had 54 each of semantically related and unrelated trials. Order of the two list composition blocks was counterbalanced, with 19 subjects completing the 3-Prime-Type block first and 17 completing the 2-Prime-Type block first.

Procedure. Subjects were assigned to one of two block type orders. All other procedures replicate those used in Experiment 1 and 2.

Results & Discussion

Response times shorter than 300 ms and longer than 1500 ms (fewer than 0.5%) were again removed (Bodner & Masson, 2003; Ulrich & Miller, 1994) as well as data for 1 subject who had a high conscious perception score as measured by the conscious perception trials (above 80% correct lexical decision of masked primes). That subject claimed to be able to see some of the masked primes. Note that the inclusion of that subject's data did not change the pattern of the results. Mean lexical decision performance for the primes was .58. Mean RTs for lexical decisions for each of the experimental Prime-Type trials are presented in Table 2.

First, a one way ANOVA was performed to explore whether RTs to the semantic and unrelated trials in each of the list composition conditions differed as a function of block order. It did appear that RTs were faster in each of the list composition conditions in the second block of trials, a result expected because subjects would be more practiced after completing the first block (that contained 216 trials). However, none of the differences were significant: RTs in the 3-Prime-Type block were the same for semantic and unrelated trials regardless of block order, both Fs < 1, and RTs in the 2-Prime-Type block were the same for the semantic and unrelated trials regardless of block order, $F(1, 34) = 2.91$, $MSE = 4033.40$ and $F(1, 34) = 1.72$, $MSE = 4301.68$, respectively.

Paired samples *t* tests were conducted to explore whether the general pattern of semantic priming replicated Experiment 1, where, relative to unrelated trials, responding to semantically related trials was associated with response cost in the 3-Prime-Type block and response facilitation in the 2-Prime-Type block. The semantic response cost did replicate in the 3-Prime-Type block: Responses to semantic trials were slowed relative to responses to unrelated trials by about 16 ms, $t(35) = 2.89$, $SEM = 5.38$. The other results of the 3-Prime-Type condition also replicated, where responses to trials with nominally related primes were faster than responses to unrelated trials by about 19 ms, $t(35) = -3.78$, $SEM = 5.07$, and to semantic trials by about 35 ms, $t(35) = 6.16$, $SEM = 5.12$. However, for the 2-Prime-Type block, RTs in semantic prime trials were no different than RTs in unrelated trials, $t(35) = 0.90$, $SEM = 4.08$. Thus, in the 2-Prime-Type condition, although RTs for semantic primes were approximately 4 ms faster than they were for unrelated trials, the numerical facilitatory effect did not approach significance. However, the fact that the pattern of priming in the 2-Prime-Type condition did not resemble the pattern in the 3-Prime-Type block still converges with results from Experiments 1 and 2 and constitutes evidence against activation accounts because activation accounts would predict equal priming effects in the two blocks.

It was possible that the failure to find a facilitatory semantic priming effect in the 2-Prime-Type condition was a function of block order. If presenting the 3-Prime-Type block first biased the cognitive system to detect orthographic and phonological features, then perhaps it could not adjust rapidly enough to switch to the use of a more context efficient strategy that focused on semantic features alone. Thus, RTs in each of the Prime-Type conditions were analyzed separately as a function of block order. Note that for this analysis, only half of the number of subjects was included in each comparison. Results replicated those found when analyses were conducted collapsed across block order: Responding to semantic prime trials was not significant whether the 2-Prime-Type condition was presented first, $t(16) = .07$, $SEM = 4.19$, or second, $t(18) = -1.06$, $SEM = 6.79$. However, as noted previously, compared to the other two 2-Prime-Type conditions (in Experiment 1 and 2), the 2-Prime-Type condition here had half the number of trials. The low number of trials may have prevented the emergence of a significant facilitatory semantic priming effect in the 2-Prime-Type block. To explore this possibility, an analysis of the 2-Prime-Type condition in Experiment 1 was conducted to assess priming for the first half of the trials and the second half of the trials separately (equivalent to the first and second block in this experiment). That analysis revealed that the facilitatory semantic priming effect in the 2-Prime-Type condition of Experiment 1 only reached significance when all trials were included; analysis of the first block $t(23) = -1.54$, $SEM = 7.13$, $p = .14$ and second block $t(23) = -1.85$, $SEM = 5.98$, $p = .08$ of trials separately failed to yield a significant facilitatory semantic priming effect. Thus, it is very possible that the failure to find significant facilitatory effects in the 2-Prime block was a result of an insufficient number of trials. [4]

Because the overall pattern of results was not contingent on the order of the 2-Prime-Type and 3-Prime-Type blocks, a 2 X 2 repeated measures ANOVA was conducted using list composition and Prime-Type as within-subject variables. This analysis revealed a Prime-Type X list composition interaction, $F(1, 35) = 6.49$, $MSE = 353.57$, a main effect of list composition, $F(1,35) = 6.35$, $MSE = 2048.79$, but no main effect of Prime-Type, $F(1,35) = 1.44$, $MSE = 467.71$. Pairwise comparisons revealed that the effect of list composition was driven by the 19 ms faster RTs in the 3-Prime-Type condition compared to the 2-Prime-Type condition. A paired samples *t* test was computed to compare RTs in the 3-Prime-Type and 2-Prime-Type groups for the unrelated and semantically related Prime-Type conditions. That analysis revealed that compared to RTs in the unrelated condition for the 2-Prime-Type condition, RTs in the 3-Prime-Type condition were 29 ms faster, $t(35) = -3.35$, $SEM = 8.06$. No difference was detected for responding to the semantically related trials as a function of list composition, $t(35) = -1.33$, *SEM* = 8.27.

A paired samples *t* test was conducted to assess whether the pattern of semantic priming differed as a function of list composition. Semantic priming was computed by subtracting the mean RTs for targets preceded by semantically related primes from those preceded by unrelated primes. That comparison showed that the pattern of semantic priming was indeed different, $t(35) = -2.55$, *SEM* = 6.27. As the paired samples *t* tests revealed, compared to unrelated primes, semantic primes slowed RTs in the LDT for the 3-Prime-Type group, but did not significantly alter RTs in the 2-Prime-Type group (although the numerical difference was facilitatory).

Thus, Experiment 3 replicated the most important findings of Experiments 1 and 2 using a within subject design: Differences in list composition changed the pattern of influence that masked primes exerted in LDT for short SOAs. In a 3-Prime-Type condition, targets preceded by semantic primes are associated with slower RTs relative to targets preceded by unrelated primes. This difference is consistent in both between-subjects and within-subject designs. This response cost for semantically related trials was never found in the 2-Prime-Type condition, where targets preceded by semantic primes were associated with faster RTs relative to targets preceded by unrelated primes (Experiment 1 and 2) or numerically faster RTs (Experiment 3).

The consistently observed dissociation in the effect of semantic primes as a function of list composition is inconsistent with activation accounts, which postulate that the effect of semantic primes should always be facilitatory when primes are masked and separated from targets with an SOA too short for the operation of strategic controlled processing. The results are, however, consistent with an episodic explanation wherein the cognitive system can adapt to different processing environments to help facilitate target processing. Perhaps most striking of all, these changes in priming all occurred in the context of a masked priming procedure where subjects were not even aware of the nature of the prime.

General Discussion

The hypothesis that task context, specifically in terms of list composition, could alter the pattern of masked semantic priming for short SOAs was examined. In direct opposition to predictions from activation accounts, semantic priming did vary systematically as a function of list composition. When experimental trials contained nominally related masked primes in addition to semantically related and unrelated masked primes, lexical decision RTs for semantic trials were associated with a response cost relative to RTs for unrelated trials (Experiments 1 and 3). In contrast, when experimental trials only contained semantically related and unrelated masked primes, RTs for semantic trials were associated with response facilitation relative to RTs for unrelated trials (Experiment 1 and 2) or numerical response facilitation (Experiment 3).

These results do not support an activation model based solely on the automatic activation of existing relations within a semantic network when consciously controlled strategic mechanisms are minimized: If that were the case, semantic priming would be facilitatory regardless of list composition. This work extends findings from Bodner and colleagues (Bodner & Masson, 2001, 2003; Bodner & Dypvik, 2005) showing that other context variables (RP) can alter masked, short SOA priming. Further, because the primes were not subjectively identifiable, the results undermine the prevalent idea that the presence of context effects signifies the operation of controlled, expectancy driven processes (Balota, 1983; Carr & Dagenbach, 1990; Dagenbach et al., 1989; Fischler & Goodman, 1978; Forster, 1998; Forster & Davis, 1984; Hutchinson, 2007; Hutchinson et al., 2001; Perea & Rosa, 2002).

Episodic accounts: Better accounts of masked priming?

But what does cause context effects—more specifically *list composition effects*—when the role for controlled processes is minimized through masking and short SOAs? Bodner and colleagues have put forth an episodic retrieval account of their data illustrating that priming changes as a function of the context variable relatedness proportion. They maintain that even in the absence of strategic processing, the cognitive system can adapt to processing contexts to better facilitate target identification (Bodner & Masson, 2001, 2003; Bodner & Dypvik, 2005; Masson & Bodner, 2003). A key difference between activation and episodic accounts is that episodic accounts propose that primes influence targets retrospectively, after target presentation, as opposed to through prospective spreading activation, before target identification. In a context where target identification is more likely to benefit from the same processing that benefits prime identification, prime episodes are more likely to be recruited to aid in target identification. Thus, since target identification is more likely to benefit from recruitment of prime episodes in contexts where there is a higher probability that the primes benefit from the same processing as the targets (either semantic or orthographic, Bodner & Masson, 2003, 2001, respectively), prime episodes are recruited more often and greater priming results.

The finding of list composition effects here consequently can be better described by an episodic account than by an activation account because episodic accounts by their very nature recognize that priming can change as a function of prime context. Primes will benefit target identification in conditions where processing or feature overlap of primes and targets are most similar, in keeping with the classic ideas stemming from a proceduralist account of processing (Kolers, 1975; Kolers & Roediger, 1984). The cognitive system develops a bias to detect primes that are most transfer appropriate with targets. If that is the case, then in a context where primes are present that exemplify complete feature overlap with targets, which is the case for nominally related primes that share orthographic, phonological and semantic overlap with their targets, then the cognitive system should also be biased to detect primes that share complete feature overlap with targets. If the search for primes that share complete feature overlap with targets identifies a prime that shares only partial feature overlap, such as a semantically related prime, the processing of targets semantically related to primes would be expected to be slowed (Kahan, 2000; Milliken et al., 1998) if, for instance, the cognitive system has to perform a second retrospective check to verify the presence of only one overlapping code (Bodner, 2007, personal communication). When the search for primes that share complete feature overlap with targets yields no match, no retrospective check has to be performed, and thus responding is faster than it is when partial matches are detected. Response times for targets that share complete feature overlap with primes will still be facilitated relative to unrelated trials because the transfer of processing in terms of the number of overlapping features yields the expected outcome.

Such an explanation can account for the results in the 3-Prime type condition, where RTs to targets preceded by semantically related primes were slowed relative to RTs preceded by nominally related trials and unrelated trials. The cognitive system will develop a different bias in a 2-Prime type list composition condition, where only two states exist: Primes are either related semantically or they are unrelated to targets. In that case, target processing that would be most transfer appropriate with prime processing would be of a semantic nature. Thus, to facilitate target processing, the cognitive system would become biased to detect mainly semantic feature overlap during the recruitment of primes and process primes semantically. Such a bias would facilitate responding to targets preceded by primes that share a semantic overlap relative to unrelated trials, where responding would be slowed because of the failure to detect the semantic overlap.

These results add to others that refute the idea that masked priming operates passively as a function of the automatic activation of existing relations within a semantic network. Masked priming has been found to be contingent on the target task demands, such that primes do not influence target responding when the prime-target relations are not exemplified by the target task. For example, Klinger et al. (2000) failed to find priming for affective relations (rat – BUNNY is incongruent; puppy – CANDY is congruent) when the target classification task involved animacy classification, but did find priming for affective relations when the target classification task involved affective classification. Other results have demonstrated that attention to the temporal window of prime-target presentation predisposes the emergence of masked priming, as demonstrated by the failure to find masked priming when targets were temporally unpredictable (Naccache et al., 2002). Taken together, these results and results from the current set of experiments are inconsistent with automatic spreading activation accounts of masked priming because they suggest that processing in the cognitive system is influenced by variables such as expectancies, attention, context, and task demands that are ordinarily thought only to change processing that is under strategic control.

Including three masked prime types does not always produce interference in semantic trials

In contrast to the 3-Prime type condition in the experiments reported here, other studies have reported facilitatory semantic priming effects using 3 types of primes. The second experiment in Bodner and Masson (2003) manipulated the proportion of semantically related and repetition trials in a between subject design. In that experiment, there were five blocks of trials, and each block contained an equal number of nonword trials along with one type of prime trial – either semantically related, repetition, or unrelated. In the high RP group, three blocks contained repetition trials while the remaining 2 contained semantically related trials and unrelated trials, respectively, such that RP was 60% repetition, 20% semantically related, and

20% unrelated. This high RP condition is the critical condition to assess for present purposes, since it was the only condition that contained three prime types comparable to those used in the 3-Prime-Type conditions here.[5] Results indicated that semantic priming was facilitatory (compared to the unrelated trials) in the high RP condition (35 ms). However, it is possible that the facilitatory semantic priming in their experiment was related to the separation of the semantic and repetition trials into independent blocks. Indeed, Experiment 3 in the current set of experiments showed that semantic primes were only associated with a response cost when semantic trials were mixed within blocks with nominally identical trials.

Snow and Neely (1987) also obtained facilitatory semantic priming when semantic trials occurred within blocks with nominally related (and unrelated) trials. In their experiment, however, primes were visible, and thus any implicit attempt by the cognitive system to retrieve prime episodes may have disrupted the attempted use of a conscious expectancy generation strategy (Bodner & Masson, 2003; Fischler & Goodman, 1978). In fact, it has been proposed that the failure to find context effects for short SOAs in previous experiments was related to the use of non-masked, short duration primes. Brief but perceptible primes have been classified as distracting rather than helpful by some subjects; some researchers have claimed such distraction might interfere with the automatic retrieval of a prime episode, a distraction that might overshadow any contribution that context might otherwise have exerted on target processing (Bodner & Masson, 2003; Hines, 1993; Stolz et al., 2005). There is evidence that conscious perception of briefly presented primes interferes with target processing (Fischler & Goodman, 1978; Klinger & Greenwald, 1995). For instance, Fischler and Goodman (1978) only obtained lexical decision priming for associatively related primes presented for 90 ms on trials where subjects failed to consciously identify the primes; on trials where prime identification was successful, lexical decision priming was not found. In addition, subjects in the Snow and Neely study were also informed of the prime target relations (i.e., expect to see a high number of semantically related trials). Given evidence that conscious goals can affect even masked priming (Klinger et al., 2000), it is certainly possible that conscious goals in their unmasked experiment altered the pattern of priming that would have occurred without such goals.

Kahan (2000) found that priming in a LDT could be associated with response facilitation or response cost depending on the type of prime judgment task completed before critical priming trials. Kahan's experiment contained 2 phases: A prime detection task (phase 1) and a LDT, where primes were masked but separated from targets with a long SOA of 2000 ms (phase 2). In phase 1 of the *repetition condition*, subjects first completed a prime detection task where they judged which of two words was the same as the masked prime that was presented in that trial. Following phase 1, subjects completed the LDT for targets. Priming for repetition trials was associated with 50 ms of interference compared to unrelated trials, and priming for semantically related trials was associated with 25 ms of interference. However, the other conditions included in his experiment, as defined by the type of prime detection task in phase 1, revealed different patterns of priming. If phase 1 involved classification of masked primes in terms of semantics, semantic priming was associated with interference (26 ms) compared to unrelated trials but repetition priming was facilitatory (11 ms). Masked priming was facilitatory for both semantic (49 ms) and repetition trials (31 ms) when phase 1 required subjects to detect whether masked primes were present or not (they were for half of the trials). Thus, setting subjects to employ certain processing strategies to facilitate prime detection can modify masked priming effects.

Future directions

This thesis has helped to highlight that masked priming can change as a function of context, although much remains to be learned about how this actually happens. The proposal here is that when primes are recruited to assist target identification, the cognitive system will attempt to detect and process the most transfer appropriate features that have been available and detected on previous trials. Evidence from Experiment 3 even suggests that the cognitive system can adapt quickly to contextual change, given that semantic primes were associated with two very different patterns of priming in a within-subject design where list composition (3-Prime Type and 2-Prime Type) was manipulated between blocks. This provides evidence for Masson and Bodner's (2003) idea that contextual control over the recruitment of prime episodes can adapt quickly to change in a context through detecting changes in the prime environment over the course of a few trials. The thesis also makes a strong case for list composition as an understudied and potentially quite informative tool for investigating strategic control in semantic priming, whether for masked or unmasked primes.

Experiments that further test the ability of the cognitive system to adapt according to contextual features will be able to assess the generality of episodic accounts of masked priming begun in this thesis. If it is the case that semantic priming in the 3-Prime type condition was associated with a response cost because the presence of nominally related pairs biased the system to detect primes that were the most transfer appropriate in terms of processing and features (i.e., nominally related), thereby slowing responses to targets whose primes only shared partial overlap (semantically related), then it would make sense that this finding would be more pronounced when nominally related pairs are presented in a higher proportion compared to semantically related pairs. Not only do episodic accounts predict that priming will be most pronounced in conditions where primes and targets are most transfer appropriate, they also predict that the recruitment of prime episodes will increase as the probability of prime-target processing overlap increases. Experiments that intentionally included misleading (i.e., unrelated) primes might also be informative, the intriguing possibility being that subjects would discount all primes, including those with a semantic relation to the target, if many of the primes were misleading. The episodic account makes this domain rich for exploration.

In summary, the results of the three experiments in this thesis provide evidence for list composition context effects in masked, short SOA priming. That there are context effects at all in masked priming is surprising, and these results generalize this to a new manipulation beyond relatedness proportion. At the theoretical level, these findings contradict activation accounts that predict no context effects in the absence of strategic control, which should not be possible in the present setting of masked primes and short SOAs. Instead, these data are consistent with episodic accounts, supporting the idea that, even when strategic control is not possible, our cognitive systems can adapt to help our conscious selves process our environment more efficiently.

Footnotes

[1] A key difference among different activation theories is that some propose that the automatic component is of limited capacity (e.g., Anderson, 1983) while others assume it is unlimited, operating separately from the limited capacity central processor (Posner & Snyder, 1975b). The variants of activation theories make the same predictions with respect to the variable of interest in this thesis. Thus, the discussion of activation theory will focus around Posner and Snyder's original activation model.

[2]Response times to semantically unrelated primes will form the baseline from which semantic facilitation is measured. This is the typical procedure used in both conscious and unconscious semantic priming studies (e.g., Bodner & Dypvik, 2005; Bodner & Masson, 2003; Carr & Dagenbach, 1990; Dagenbach et al., 1989; Dell'Acqua & Grainger, 1999; Fischler & Goodman, 1978; Forster, Mohan, & Hector, 2003; Frenck-Mestre & Bueno, 1999; Hines, 1993; Klinger et al., 2000; Perea & Gotor, 1997). Use of this procedure does, however, prevent knowing the extent to which related primes create facilitation or unrelated primes create interference (McNamara, 2005). To determine the extent of facilitation and interference effects in semantic priming, one would need to include a prime condition that is neutral in the sense that it is neither related nor unrelated to the target stimuli. However, there is no agreement on the most appropriate neutral baseline for use in these studies. For instance, strings of X's will not engage the linguistic system to the same extent as do real words. Neutral primes such as the words "blank, neutral, or ready" will avoid this possibility, but presenting the same neutral primes repeatedly reduces the processing time needed to encode the neutral primes due to repetition priming and may lead to an underestimation of facilitation in semantically related prime-target trials and an overestimation of interference. The use of pronounceable nonwords can circumvent the

problems of repetition effects, but the use of such pronounceable nonword neutral primes can lead to an overestimation of facilitation and an underestimation of interference because unfamiliar items (nonwords) may take longer to encode than words. Due to the problems associated with choosing an appropriate neutral baseline, some have suggested that researchers simply focus on differences in RTs that occur for responding to targets preceded by semantically related compared to unrelated primes as a function of other relevant variables (Jonides & Mack, 1984, as cited in McNamara, 2005). Because of the problems associated with the use of neutral primes, and because the goal of the present experiments is to explore how differences in list composition can modify the RT difference in responding to targets that are preceded by semantically related vs unrelated primes, the choice not to use a neutral baseline is not viewed as problematic.

[3] The debate concerning whether masked priming effects should be interpreted as unconscious if responding on a prime classification task is above chance is not resolved and is not a focus of this thesis. The experiments presented here were designed to assess masked priming effects for primes that subjects subjectively deny perceiving because the main question of interest is whether context effects can be obtained under conditions in which strategic processes are impossible. A measure of conscious detection of primes was included because this type of task is commonly used in masked priming studies (e.g., Bodner & Masson, 2003; Naccache et al., 2002) and can be used to provide data regarding conscious perception beyond subjective report. Priming at self reported subjective levels have been found to elicit the different patterns of priming as those measured at suprathreshold (visible) levels, illustrating that stimuli presented at subjective threshold preclude the use of conscious strategies (Cheesman & Merikle, 1986; Merikle & Joordens, 1997), which is the issue of central interest in this thesis. Given the

extremely short prime duration, it was expected that the majority of subjects would be objectively unaware of primes. However, above chance performance was expected because performance on prime classification tasks (at least under subjective responding) is thought to inevitably be influenced by uncontrollable priming influences (Bodner et al., 2003; Cheesman & Merikle, 1986; Merikle & Joordens, 1997; Merikle, Joordens, & Stolz, 1995), and, because attention is focused directly on primes rather than on targets (Bodner & Masson, 2003), some above chance performance is expected. In addition, it is my experience that subjects vary immensely in their ability to detect masked primes, an experience echoed by others (Dagenbach et al., 1989; Forster et al., 2003; Jarick, 2008, personal communication). Thus, objective perceptibility tests can be used to detect those who have an ability to detect primes that most others cannot see at all.

[4] Analysis of RTs in each of the Prime-Type conditions for the 3-Prime-Type block as a function of block order mostly replicated those found when that condition was collapsed across block order. When the 3-Prime-Type condition was presented in the first block, RTs to semantic trials were about 16 ms slower than RTs for unrelated trials, $t(18) = 2.10$, $SEM = 7.58$, and about 35 ms slower than RTs for nominally related trials, $t(18) = 4.16$, $SEM = 8.38$; RTs to nominally related trials were about 19 ms faster than RTs on unrelated trials, $t(18) = -3.07$, $SEM = 6.19$. When the 3-Prime-Type condition was presented in the second block of trials (i.e., after the 2-Prime-Type block), RTs to semantic trials were 8 ms slower than RTs to unrelated trials, a difference that did not reach significance, $t(16) = 1.07$, $SEM = 7.74$, $p = .30$. The other results replicated those obtained when the 3-Prime-Type condition was collapsed across block order: RTs to semantic trials were slower than RTs to nominally related trials by 19 ms, $t(16) = -2.30$, $SEM = 8.42$, and RTs to nominally related trials were faster than RTs to unrelated trials by 27 ms, $t(16) = 4.96$,

SEM = 5.58. The failure to replicate the result of significantly slower RTs for semantic trials compared to unrelated trials in the 3-Prime-Type condition when the 3-Prime-Type block was presented second is likely a result of lower power to detect a difference because of fewer subjects.

[5]The low RP condition in the Bodner and Masson (2003) study is more comparable to the 2-Prime-Type condition in the present experiments, where semantic priming would not be expected to be associated with a response cost. Specifically, one block contained semantically related trials whereas the remaining four blocks contained unrelated trials. RP was lower than it was in the present experiment RP: 20% of the trials were semantically related in Bodner and Masson's study compared to 50% in the experiments in this thesis.

Table 1.

Experiments 1 and 2: Mean RTs (ms) for lexical decision to targets as a function of prime type and list composition. Standard errors are shown in parentheses.

List composition	Prime-Type & semantic priming (mean RT unrelated – mean RT semantic)			
	Nominally identical	Semantically related	Unrelated	Semantic priming
3-Prime-Type	599 (16.60)	624 (17.82)	609 (15.46)	-15 (5.49)
2-Prime-Type (Exp 1)	---	660 (14.10)	672 (15.04)	12 (5.28)
2-Prime-Type (Exp 2)	---	634 (15.07)	649 (15.01)	15 (5.61)

Table 2.

Experiment 3: Mean RTs (ms) for lexical decision to targets as a function of prime type and list composition, with RTs for list composition split according to counterbalancing order. Overall list composition reflects mean RTs collapsed across counterbalancing condition. Standard errors are shown in parentheses.

	Prime-Type & semantic priming (mean RT unrelated – mean RT semantic)			
List composition	Nominally identical	Semantically related	Unrelated	Semantic priming
3-Prime-Type				
first	584 (11.65)	619 (12.01)	603 (11.37)	-16 (7.58)
second	579 (17.42)	607 (18.72)	599 (16.33)	-8 (7.74)
Overall	582 (10.12)	613 (10.79)	601 (9.63)	-12 (5.38)
2-Prime-Type				
first	---	643 (15.87)	643 (17.66)	0 (4.19)
second	---	607 (14.07)	614 (13.48)	7 (6.78)
Overall	---	624 (10.87)	628 (11.04)	4 (4.08)

Table 3.

Experiments 1, 2, and 3: Mean proportion errors for lexical decision to targets as a function of prime time and list composition. Standard errors are shown in parentheses.

	Prime-Type		
List composition	Nominally identical	Semantically related	Unrelated
3-Prime-type			
Exp 1	.055 (.007)	.092 (.011)	.076 (.007)
Exp 2	---	---	---
Exp 3	.022 (.003)	.024 (.003)	.033 (.003)
2-Prime-type			
Exp 1	---	.062 (.008)	.064 (.009)
Exp 2	---	.071 (.005)	.055 (.005)
Exp 3	---	.027 (.003)	.030 (.003)

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