In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 57-94). New York: Psychology Press. (2003)

This is a pre-publication version.

A Retrospective View of Masked Priming: Toward a Unified Account of Masked and Long-Term Repetition Priming

Michael E. J. Masson
University of Victoria

Glen E. Bodner
University of Calgary

We propose a general, unified account of masked and long-term priming, based on the assumption that prime events create a memory resource that can be recruited to assist with subsequent target processing. This account is contrasted with the classical account of priming, in which it is assumed that a prime proactively creates a temporary change in the cognitive system (e.g., through spreading activation or opening a lexical entry) that enables more efficient or accurate encoding of a target that is related in some way to the prime. In support of the classical, abstractionist account of priming, masked priming has been dissociated from long-term priming on three different bases: (1) lack of masked priming of nonwords, (2) additivity of masked priming and word frequency, (3) masked priming is short-lived. We closely examine these dissociations and describe recent evidence that challenges each of them. These challenges serve to support the proposition that masked and long-term priming have a common basis. Moreover, we review evidence showing that the recruitment of a prime may or may not occur, depending on factors such as need for the prime resource (as determined by target processing difficulty) and validity of the prime (as determined by prime-target relatedness proportion). These novel results are readily interpreted within a retrospective account of masked priming.

The fundamental idea we wish to develop in this article is, on first encounter, likely to appear radical--perhaps even absurd to some. Nevertheless, we hope to demonstrate that this proposition is well grounded in prior empirical and theoretical work and is strongly supported by the program of research that is described here. To build our case, we begin by contrasting two different ways of conceptualizing the process by which a prime event can influence identification of a subsequent target stimulus. In the classical approach, which is widely accepted in the field, it is assumed that a prime proactively creates change in the cognitive system (e.g., through spreading activation) that enables more efficient or accurate encoding of a target that is related in some way to the prime. The contrasting, retroactive view of priming, which we advocate as a viable alternative to the classic approach, postulates that a prime event creates a memory resource that is subsequently recruited to assist with target identification.

On a strong version of this retroactive account, both masked priming and long-term priming are driven by the establishment of a memory resource representing the prime event. The account of priming we develop here was inspired in part by Kolers' ideas about how processing operations, modified by experience, form the basis of memory (Kolers, 1975, 1976; Kolers & Roediger, 1984). In Kolers' procedural framework, the processing operations responsible for acquiring information, such as the operations involved in reading a sentence, form the mental representation of that information. Thus, after reading a sentence, one retains a form of memory for the reading operations themselves, not just the semantic content of the sentence (Kolers, 1976). Moreover, prior experience, having created skill in responding to a particular task-stimulus combination, serves as a basis for transfer of skill to other tasks that have some correspondence to the original. We propose that transfer of skill to similar tasks, relying as it does on the similarity of underlying processing operations, is the foundation for priming. It is the similarity between processing operations applied to a prime event and those applied to a target that determine the degree to which the experience with the prime will benefit target processing. We propose that this general framework governs both masked and long-term priming.

The commonality between masked and long-term priming that we exploit in this article is founded on automatic or unconscious influences of memory on task performance, as distinct from influences that are guided by conscious, or deliberate strategies. Although such strategies can powerfully modulate priming effects (e.g., Neely, 1977), they are unlikely to operate when masked primes are used because subjects typically are unaware of the presence of the primes. Therefore, our interest lies in the influences of priming that operate without intentional control.

The claim that masked and long-term priming spring from a common source runs counter to a set of dissociations between masked and long-term priming that Forster and his colleagues have established (e.g., Forster & Davis, 1984). Therefore, we present empirical evidence that closely examines the validity of those dissociations. We then go on to present demonstrations of contextual control over masked priming that are consistent with a retroactive account of priming and that challenge the classic proactive account. Finally, we consider some implications of the idea that priming can be construed as a retroactive process, particularly with respect to psycholinguistic approaches to word identification processes and their possible synergy with memory theory.

Prospective Accounts of Priming

It is a well-established fact that presentation of a prime stimulus shortly before the appearance of a related target can increase the efficiency with which that target is identified (e.g., Meyer & Schvaneveldt, 1971; Meyer, Schvaneveldt, & Ruddy, 1975). The classic account of such relatedness effects is that the prime creates some form of temporary change in the cognitive system that provides an advantage or head-start in the processing of the target, relative to the case in which the prime consists of an unrelated or neutral stimulus. For instance, in the case of semantically related prime-target pairs, the theory of automatic spreading activation assumes that the prime stimulus activates not only its own lexical entry, but also the entries of other semantically related words (e.g., Anderson, 1983; Collins & Loftus, 1975; Neely, 1977). If one of these related words then appears as the target, it will be more readily identified because its lexical entry has already been activated by the prime.

The general notion that the prime event activates knowledge sources relevant to the identification of an upcoming target word opens the way for the use of priming paradigms as tools for examining the early stages of word identification. One such application has been the investigation of how phonological processes contribute to visual word identification. Humphreys, Evett, and Taylor (1982) proposed that if identification of a visually presented target could be facilitated by a homophonic nonword (pseudohomophone) that is masked to prevent its identification, then one could conclude that visual word identification involves rapid and automatic construction of a phonological code. Using individually adjusted masked prime durations of approximately 35-40 ms, Humphreys et al. failed to obtain pseudohomophone priming evidence in a task that assessed accuracy at identifying masked target words.

More recently, however, other researchers (e.g., Brysbaert, 2001; Grainger & Ferrand, 1996; Perfetti & Bell, 1991) obtained a priming effect with pseudohomophones when the prime exposure duration was greater than 35 ms. Masked pseudohomophone priming effects have also been found in speeded identification tasks in which target words are clearly visible. In both the word naming (e.g., Grainger & Ferrand, 1996; Lukatela & Turvey, 1994) and the lexical decision task (e.g., Lukatela, Frost, & Turvey, 1998; Ferrand & Grainger, 1996; Grainger & Ferrand, 1996), masked pseudohomophone primes led to shorter target word identification latencies than orthographically related control primes. By manipulating the duration of the prime, it has been argued that one can reveal the time course of the activation of different knowledge sources or codes (e.g., phonological and orthographic) involved in the early stages of word identification (e.g., Berent & Perfetti, 1995; Lukatela & Turvey, 2000; Perfetti & Bell, 1991).

A crucial assumption underlying the interpretations of semantic, phonological, orthographic, and other forms of priming is that the prime creates a temporary state of activation that influences, usually in a beneficial way, processing of the target. Moreover, it is often assumed that although strategic factors may influence the operation of priming to some degree, it is in principle possible to construct situations in which automatic, non-strategic influences can be observed (e.g., Ferrand & Grainger, 1996; Forster, 1998; Humphreys et al., 1982; Neely, 1991; Shelton & Martin, 1992). An crucial advantage of using masked primes, then, is the fact that the combination of forward and backward masking of primes and brief exposure duration typically serve to prevent subjects from being aware of a prime's identity and often leaves subjects unaware even of the presence of the prime event.

Dissociations Between Masked Priming and Long-Term Priming

An important source of evidence for the assumption that the influence of masked primes on word identification operates through an automatic activation of lexical knowledge is the establishment of a set of dissociations between masked priming and long-term priming. This set of dissociations is important because there is considerable evidence to support the view that long-term priming of word identification is based on episodic memory representations of priming events, rather than activation of lexical knowledge.

In long-term priming tasks involving word identification, subjects typically are presented with a list of words that later appear, along with a set of new words, on an identification task. Tasks such as word naming, lexical decision, word-stem completion, word-fragment completion, and masked word identification show either enhanced speed or accuracy in identifying words that appeared on the study list relative to nonstudied items (e.g., Feustel, Shiffrin, & Salasoo, 1983; Jacoby & Dallas, 1981; MacLeod & Masson, 2000; Scarborough, Cortese, & Scarborough, 1977; Toth, Reingold, & Jacoby, 1994; Tulving, Schacter, & Stark, 1982). These enhanced identification effects are thought by many to be generated by a form of memory for the specific study episode, particularly memory for the perceptual aspects of that episode, rather by activation of a stable, lexical representation.

Episodic basis for long-term priming. Support for an episodic account of long-term priming is based on various features of long-term priming. First, priming effects can last over hours, days, or even longer (e.g., Jacoby, 1983a; Jacoby & Dallas, 1981; Kolers, 1976; Tulving et al., 1982), whereas theories that account for priming on the basis of temporary activation of existing knowledge typically assume that priming dissipates quickly. Second, long-term priming effects are sensitive to the perceptual overlap between study and test presentations of words. In particular, changes in modality or study tasks that do not involve directly perceiving a target item often produce reduced, if any, priming on a subsequent identification test (e.g., Jacoby, 1983b; Roediger & Blaxton, 1987; Weldon, 1991). Modality-specific effects are inconsistent with the view that priming is due to activation of an abstract, amodal representation and has led to modification of such accounts of priming to include modality-specific representations of word knowledge such as logogens (Clarke & Morton, 1983; Morton, 1979). Third, long-term priming effects are sensitive to contextual manipulations such as proportion of items in the test list that had been previously studied--greater proportions of old items lead to larger priming effects (e.g., Allen & Jacoby, 1990; Jacoby, 1983a). Finally, long-term priming has been demonstrated not only for identification of known lexical items, but also for nonwords, newly formed associations between items, and novel visual patterns (e.g., Graf & Schacter, 1985; Logan 1990; Micco & Masson, 1991; Musen & Squire, 1991; Musen & Treisman, 1990). Priming effects of this nature are most readily explained by appealing to the formation of new episodes during the study phase that subsequently assist performance on identification or cued generation of recently encountered, novel items.

In general, these features of priming do not conclusively rule out accounts based on abstract representations. Our primary aim in this chapter, however, is to demonstrate the value of conceptualizing priming phenomena from an episodic perspective with respect to generating new, empirically based insights into how the influences of priming arise.

Dissociative features of masked priming. The possibility that there is an episodic basis for priming of word identification is problematic from the perspective of researchers who wish to use priming techniques to examine basic word identification processes. The problem is that episodic influences are seen as a contaminant that obscures the operation of lexical processes (Forster, 1998; Forster & Davis, 1984). For this reason, the masked priming technique has been commonly employed, as described above, to examine contributions of phonological, orthographic, and other processes to the early stages of word identification. The fundamental assumption in adopting the masked priming methodology is that by masking the prime, one can avoid the possibility of episodic influences. In support of this assumption, Forster and Davis

(1984) established three important dissociations between masked and long-term repetition priming.

First, Forster and Davis (1984) found that masked priming enhanced lexical decision speed for word targets but did not affect performance on nonword targets. A number of subsequent studies have replicated this observation (e.g., Forster, 1987; Forster, Davis, Schoknecht, & Carter, 1987; Rajaram & Neely, 1992, for nonstudied nonwords). If masked priming were episodically based, one might expect that nonwords would also show a priming effect as they do in long-term priming paradigms. On the other hand, if masked priming is based on access to a lexical entry, only words have the possibility of producing priming because only those items have lexical entries.

Second, Forster and Davis (1984) showed that with masked primes high- and low-frequency word targets produced similar amounts of priming, whereas low-frequency words yielded substantially more priming than high-frequency words in long-term priming. Similar findings of additive effects of frequency in masked priming (e.g., Ferrand, Grainger, & Segui, 1994; Segui & Grainger, 1990; Sereno, 1991) and larger effects for low-frequency words in long-term priming (e.g., Duchek & Neely, 1989; Norris, 1984; Scarborough et al., 1977) have been reported by others as well. Forster and Davis argued that a repetition prime serves to open the lexical entry corresponding to the prime so that when the matching target is presented, that entry is already in an open state. In the Forster and Davis account, having a word's lexical entry open at the time it is presented eliminates the need to open that item's entry, thereby saving time. Moreover, the time needed to open a lexical entry is assumed to be the same, regardless of the word's frequency, so the amount of time saved by priming is constant across word frequency values. The additivity of word frequency and priming found with masked primes, then, is consistent with the claim that masked priming operates by opening a lexical entry rather than by recruiting an episodic memory.

The third dissociation established by Forster and Davis (1984), and reinforced by Forster, Booker, Schacter, and Davis (1990), is that whereas long-term priming effects are often long-lasting, the influence of a masked prime is short-lived. Forster and Davis showed that by presenting a series of words between a masked prime and its target, priming could be reduced and, with enough intervening items to make the delay 8.5 s, priming was eliminated. The short-lived nature of masked priming is in striking contrast to the longer term effects seen when primes are presented in clearly visible form.

The set of dissociations established by Forster and Davis (1984) serve as an important foundation for the assumption that masked priming provides a means of probing early stages of word identification, free of influences from episodic or even strategic influences (Forster, 1998, 1999). Whether one wishes to argue that a masked prime opens a lexical entry (e.g., Forster & Davis, 1984; 1991) or activates some aspect of lexical knowledge prior to a target's presentation (e.g., Frost, Forster, & Deutch, 1997; Grainger & Ferrand, 1996; Lukatela & Turvey, 1994; Neely, 1991), isolating masked priming effects from episodic and strategic influences is a crucial step.

Retrospective Accounts of Priming

In establishing their case for a prospective, lexically based account of masked priming, Forster and Davis (1984) explicitly acknowledged the possible role that episodic influences have on long-term priming. But whereas Forster and Davis have emphasized factors that appear to distance masked priming from long-term priming, we have been impressed by a number of theoretical arguments and empirical findings that support an episodic, or more generally, a retrospective account of priming--even in the case of masked priming.

Theoretical Basis for a Retrospective Account

One inspiring line of theoretical argument has been Jacoby's (Jacoby & Dallas, 1981; Jacoby, 1983a) efforts to cast memory and perception within a common framework. For current purposes, we take perception to include activities such as word identification. Jacoby (1983a) proposed that memory and perception both are determined by the joint constraints provided by stimulus cues presented at the time of test and cues provided by memory for prior episodes. Importantly, the influence of memory for prior episodes need not (and perhaps is rarely) accompanied by conscious recollection (Kolers & Roediger, 1984). Moreover, Jacoby assumes that both memory and perception depend on access to a large population of memories for prior episodes (see also Kahneman & Miller, 1986; Logan, 1988). Accordingly, what is taken to be temporary activation of a stable memory representation on a prospective view of priming can, on a retrospective view, be seen as a summary statistic reflecting the number and similarity of memories for episodes recruited by the current stimulus configuration.

Another theoretical approach that encourages a retrospective view of priming is one that has been applied to semantic priming. In contrast to notions such as spreading activation, whereby a prime proactively excites related items, Ratcliff and McKoon (1988; see also Dosher & Rosedale, 1989) proposed a compound-cue retrieval theory of priming. In their account, a prime and target presented in close temporal proximity form a compound cue that is used to probe long-term memory. The existence in long-term memory of direct associations between the elements of a compound cue leads to large familiarity values, which in turn speeds response times on a target identification task. This theory successfully accounted for empirical results such as the speed of onset of priming, decay rate of priming, and the effect of an intervening word placed between the prime and target (Ratcliff & McKoon, 1988, 1994).

Priming Effects Over the Long Term

A conceptualization of semantic priming that is even more closely related to the retrospective view we wish to develop here was put forward by Becker and her colleagues (Becker, Moscovitch, Behrmann, & Joordens, 1997; Joordens & Becker, 1997). They proposed a neural network model of semantic priming in which presentation of a prime stimulus is treated as a learning event that creates a change in the connection weights among processing units that represent lexical knowledge. These weight changes, though subtle, were predicted to be long lasting, unlike the temporary change in state of activation assumed by spreading activation and related theories of semantic priming. In their experiments, Becker and colleagues found that semantic priming survived over unusually long lags (as many as eight intervening items), as predicted by the neural network model, if the word identification task required substantial semantic involvement (e.g., a semantic classification task or a lexical decision task with pseudohomophone foils). These results and the underlying neural network model provide support for a retrospective view of priming in which a prime event creates a lasting representation that can support later word identification processes, rather than a temporary change in the pattern of activation of processing units (Masson, 1995).

Demonstration of a Retrospective Influence

In addition to these demonstrations of long-lasting priming effects, a striking demonstration of how priming can work retroactively, even when the prime event occurs immediately prior to a target item, was provided by Whittlesea and Jacoby (1990). The general procedure used in their experiments is illustrated in Figure 1. Examples of two of the conditions are shown, in which the first stimulus serves as a repetition prime for the final stimulus in the sequence. There is also an interpolated stimulus that, in the examples, is related to the prime (and target). The subject's task was to view the three-item sequence, name the final item as rapidly as possible, then report the interpolated word. A crucial manipulation in their experiments was whether or not the interpolated word was degraded by presenting it in mixed case. The rationale for this manipulation was that presentation of a degraded interpolated word would lead to the related prime being used more heavily in the attempt to identify that word, which in turn would make the prime more available to assist with the task of naming the target word. The differential use of the prime in the identification of the non-degraded versus degraded interpolated word cannot be foreseen at the time the prime is presented. Therefore, if an effect of degradation is seen, it must be a retroactive response to the interpolated word's degradation,

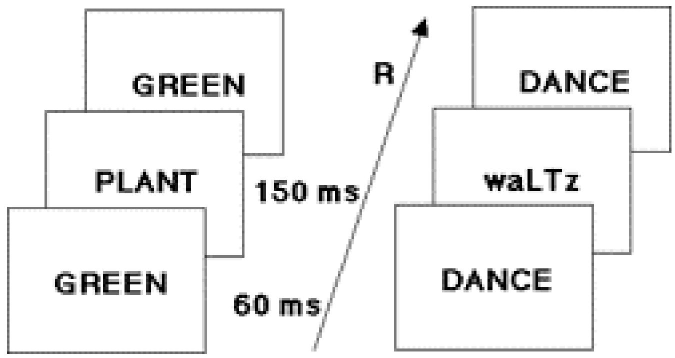

Figure 1. Examples of repetition prime trials with a nondegraded or degraded interpolated word from Whittlesea and Jacoby (1990). Degradation as achieved by using mixed case. The target item, presented as the third stimulus in the trial sequence, was in view until the subject made a naming response.

meaning that differential use of the prime is triggered by stimulus conditions that are encountered after the prime event is over. As indicated in Figure 1, the durations of the prime and interpolated words were very brief, making it unlikely that the priming effects obtained by Whittlesea and Jacoby were the result of some deliberate, strategic effect.

If the prime is more available when the interpolated word is degraded, it should provide greater assistance also in the naming of the target word. Thus, Whittlesea and Jacoby (1990), predicted that target naming would be faster when the interpolated word was related to the prime and was degraded than when it was related to the prime but not degraded. This is the result they obtained. Moreover, to rule out other possible explanations of this effect, they also demonstrated that degradation of the interpolated word did not have an effect on target naming when (1) no prime was presented (implying that a related interpolated word does not by itself produce any greater benefit when it is degraded than when it is non-degraded), or (2) when the interpolated word was unrelated to the target word, regardless of whether a repetition prime was presented or not. Thus, the specific combination of a repetition prime and a related interpolated word was necessary to produce the degradation effect. Degradation of the interpolated word made it more likely that the prime was recruited in service of identifying the interpolated item, making the prime more available to support identification of the target. A form of selectivity appears to operate, then, whereby recruitment and use of the memory resource created by the prime event is an optional outcome of the presentation of a target event. In the last major section of this chapter, we closely examine one factor that appears to influence recruitment of prime-induced memory resources.

Long-Lasting Influence of a Brief Exposure

An important feature of long-term priming is that effects can be seen even when a substantial delay occurs between the study episode and the time of test. The mere exposure effect provides evidence that even very brief exposures to stimuli can result in relatively long-lasting effects on behavior. In the procedure that generates this effect, subjects are provided very brief exposures to stimuli in a study phase. The stimuli are usually pictures of objects that do not have distinct verbal labels, such as polygons, chairs, or outdoor scenes (e.g., Kunst-Wilson & Zajonc, 1980; Mandler, Nakamura, & van Zandt, 1987; Seamon, Marsh, & Brody, 1984; Whittlesea & Price, 2001). The typical finding is that although subjects perform at or near chance on a forced-choice recognition memory test that requires discrimination between a studied and a non-studied item, subjects show above chance discrimination between such items when the task is to make an evaluative judgment about the pair such as indicating which item they prefer (e.g., subjects show greater preference for the studied item).

Whittlesea and Price (2001) obtained this pattern of results even when stimuli were presented in a rapid visual sequence with an exposure duration of 40 ms and no interstimulus interval. These presentation characteristics are similar to those of masked priming, except that a series of masked items is presented rather than a single prime. Whittlesea and Price showed that subjects favored previously exposed items not only on a preference judgement task, but also when given a memory test that did not invoke analytic processing of the test items (subjects judged which member of a pair was "similar" to a studied item). The fact that a briefly presented item can be distinguished from a new item (at least when making nonanalytically based judgments) shows that a brief, masked exposure to a stimulus has the potential to produce a lasting impact on behavior. Importantly, however, Whittlesea and Price found that just a single, brief presentation of an item usually was not adequate for subjects to discriminate between that item and a new one. But when an item was presented three or five times in the study phase, subjects were more likely than chance to select that item over a new one when making preference or similarity judgments. These results indicate that a brief, masked presentation of a stimulus can have a relatively long-lasting effect on behavior, at least if a stimulus is exposed multiple times.

Context Effects in Masked Priming

A final example of evidence that is consistent with the notion that masked priming is based on recruitment of a form of memory for a briefly presented prime event is the demonstration that masked priming is contextually sensitive. Ferrand and Grainger (1996; Grainger & Ferrand, 1994) showed that the influence of masked homophone primes in the French language (e.g., *fois-FOIE*) varied, depending on the nature of the nonword targets used in a lexical decision task. When the nonwords were pronounceable (e.g., *FIPE*), homophone primes produced facilitation of word targets relative to an unrelated prime condition. With orthographically illegal nonwords (e.g., *RNAE*), however, homophone primes failed to prime word targets. Finally, when one third of the pronounceable nonword targets were replaced by pseudohomophone nonwords, it was found that homophone primes slowed responding to word targets relative to an unrelated prime condition. Ferrand and Grainger interpreted these contextual effects as evidence for a form of strategic control over "what is done with information that is automatically computed" (p. 518). Although the spirit of this concept is somewhat different from our proposal that masked priming can be conceptualized as a retrospective process, it is consistent with the more general idea that the influence of a masked prime may be variable and dependent on processing operations that occur after the prime event has transpired.

Deconstructing Dissociations

Having laid the groundwork for the proposal that masked priming can be explained within a retrospective account of how priming events influence word identification, we now turn to a consideration of the evidence for the dissociation between masked priming and long-term priming effects. Our goal here is to demonstrate that these two forms of priming are not as strongly dissociated as originally suggested by Forster and his colleagues (e.g., Forster & Davis, 1984). By challenging the dissociations between masked and long-term priming reviewed above, we aim to build a case for the idea that these two forms of priming may have a common basis, namely, the recruitment of an episodic representation of a prime item to assist with the identification of a target item.

The Lexical Constraint on Masked Priming

An important part of the evidence that masked priming is free of episodic influences and is instead dependent on activation of an established lexical entry is the finding that masked priming of lexical decisions is restricted to word targets (e.g., Ferrand et al., 1994; Forster & Davis, 1984). We have suggested that the lack of masked repetition priming of nonword targets may be an unintended consequence of how nonwords are classified during lexical decision tasks (Bodner & Masson, 1997; Masson & Isaak, 1999). In particular, we proposed that although encoding of nonword targets may benefit from following a masked repetition prime, the resulting processing fluency might serve as evidence that the current target is a word. This evidence, of course, would work against making the correct classification of the nonword target, thereby slowing the response (see also Balota & Chumbley, 1984; Feustel et al., 1983; Kirsner & Speelman, 1996). Thus, the fluency generated by a repetition prime in the case of a nonword target is, generally speaking, cancelled by the cost of this fluency in the decision making process.

To test this idea, we adopted two approaches. First, we sought to gain control over the fluency/decision trade-off that we postulated to be responsible for the lack of priming among nonword targets (Bodner & Masson, 1997). To do so, we attempted to induce subjects to rely more heavily on the prime in making their lexical decisions. Following Whittlesea and Jacoby (1990), we assumed that by presenting targets in case alternation, rather than in pure uppercase format, targets would be more difficult to identify and this would lead subjects to rely more heavily on the primes. If the primes can provide greater assistance to target encoding when targets are in alternating case than when they are in pure case, then a net benefit of priming should be observed even for nonword targets. That is, the relatively large processing fluency benefit generated by a masked prime should outweigh the cost associated with decision making processes. Similarly, we reasoned that if word/nonword discrimination were made more difficult by using pseudohomophones as nonword targets (e.g., *HOAP*), subjects again should come to rely rather heavily on the primes. Here, too, we expected that masked priming should produce a net benefit when responding to nonword targets. In both cases, nonword targets showed substantial priming effects with shorter response times when repetition rather than unrelated primes were presented. The results of these two studies, including data for word targets, are shown in Table 1.

The discerning reader will realize that by using alternating case for targets, roughly half of the letters in each target physically match the letters of a repetition prime (e.g., *breem-bReEm*). Therefore, a control experiment was conducted in which the letters of a repetition prime that did not physically match target letters were replaced with different letters (e.g., *bleam-bReEm*), so that the physically matching letters constituted the only overlap between prime and target items. Relative to primes that had no letters in common with the targets, these partially matching primes generated no priming effect at all, allowing us to rule out physical matching as the basis for the priming effect seen with targets presented in alternating case.

An additional method we used to gain control over the hypothesized trade-off between processing fluency and decision processes involved inducing subjects to rely heavily on an immediate sense of familiarity in making their lexical decisions. Under these conditions, we expected that the fluency created by repetition priming of a nonword would be particularly problematic for the decision making process because (1) fluency would be the primary basis for decision making and (2) fluency would incorrectly suggest a "word" response. As a result, we expected that when subjects rely mainly on familiarity as a basis for lexical decisions, masked priming would increase response latency to nonword targets. To test this idea, subjects were presented with very high-frequency words and with consonant strings as nonwords to allow for rapid and easy discrimination between the types of target. The results of this experiment are summarized in the final two rows of Table 1. As expected, although word targets showed a reliable benefit from masked repetition priming, responses to nonword targets were slower by a small but significant amount under repetition priming. Taken together, the results shown in Table 1 suggest that masked repetition priming of nonwords can be produced, but that such priming depends on a trade-off between processing fluency and decision making.

The second approach we took to testing the hypothesis that decision making processes may offset the benefits of masked priming of nonwords was to use an identification task that does not involve a binary choice response. In this study, subjects named word and nonword targets that followed repetition or unrelated masked primes (Masson & Isaak, 1999). To rule out the possibility that masked priming of naming responses could be due to different onsets in unrelated prime and target pairs (Forster & Davis, 1991), we used unrelated primes that shared onsets with their respective targets (e.g., *nalk-NUMP*). Across two experiments, we found that

Table 1

Mean Response Time, Percent Error, and Repetition Priming for Lexical Decisions to Words and Nonwords from Bodner and Masson (1997).

	Response time			Percent error		
Target	Unrelated prime	Repetition prime	Priming	Unrelated prime	Repetition prime	Priming
Alternating case						
Word	821	746	75	12.0	8.1	3.9
Nonword	1027	934	93	6.6	8.0	–1.4
Pseudohomophones						
Word	811	768	43	9.6	7.6	2.0
Nonword	909	871	38	7.6	9.9	–2.2
Consonant strings						
Word	514	491	22	2.2	1.7	0.5
Nonword	510	519	–9	2.0	2.0	0.0

target naming response latency for word and nonword targets was similarly affected by masked repetition priming: Word targets produced a masked priming effect of 24 ms and nonword targets yielded an effect of 20 ms.

The main conclusion we wish to draw from this line of work is that there are conditions under which reliable repetition priming of nonwords can be obtained. Moreover, when such priming occurs, it is comparable in magnitude to the priming obtained with word targets. This similarity does not necessarily imply that priming of the two types of target emerges through exactly the same set of processes. But we are suggesting that there is a strong common link between masked priming of words and nonwords, whereby the prime event establishes a processing resource in memory that can later be recruited to assist with target identification.

Counter-argument for a lexical account. Recently, Forster (1998) has offered alternative explanations for the various nonword priming effects observed by Bodner and Masson (1997). For the nonword priming effect observed with case-alternated targets, Forster argued that the unfamiliar format of case alternation makes explicit letter identification necessary, and that process can lead to "letter entries" being opened by masked primes. Opening of letter entries can produce priming for both word and nonword targets. If that account is correct, one should see as much nonword priming for a set of case-alternated illegal nonwords as for case-alternated legal nonwords. This prediction is yet to be tested. We have, however, obtained other evidence (reviewed in detail in the next section) pertinent to the letter-entry account. Namely, word frequency interacts with repetition priming even when targets are presented in alternating case. If masked priming of alternating case targets were dependent on priming of letter entries, this interaction would not be expected.

For pseudohomophone nonword priming, Forster suggested that if our pseudohomophone primes were one-letter different from real words (approximately half were), they would open the lexical entries of their base words (e.g., neer -> NEAR). On identity prime trials, the orthographic mismatch between the opened lexical entry and the pseudohomophone target would allow a rapid rejection of the nonword as a potential match (NEER vs. NEAR), producing repetition priming. This explanation does not appear to be adequate, however, because the orthographic mismatch between a pseudohomophone and the lexical entry it opens should be even greater on unrelated prime trials (e.g., for the prime-target pair neer-HAFF, there is a serious mismatch between HAFF, the target, and NEAR, the lexical entry presumably opened by the prime). The greater mismatch on unrelated trials would lead one to predict a negative nonword priming effect rather than the positive nonword priming effect we observed.

With respect to the negative nonword priming effect we observed when high frequency words and illegal nonwords were used as targets, Forster conceded that fluency might play a role in producing the effect with nonword targets, since there is no other activation in the lexical processor on which to base decisions. But he argued that it does not necessarily follow that fluency is also used as a source of information for making lexical decisions for word targets because there is activation in the lexical processor on which to base decisions for these items. In response, we suggest that the very rapid responding to word targets when consonant strings are used as foils and the relatively small priming seen with word targets under these conditions are consistent with our claim that word decisions, like nonword decisions, are made on a different basis than when more word-like nonwords are used. In fairness, we note that Table 1 presented here is not a valid source for comparing word response times because different sets of words were used in the different experiments whose results are shown there. But given that word frequency is presumed not to modulate masked repetition priming of words (Forster & Davis, 1984), the rather small priming effect for words tested with consonant strings as foils is clearly noteworthy.

Finally, Forster (1998) suggested that the nonword priming effects observed in the naming task occur at an articulatory level. The argument is that subjects try to pronounce the masked primes, so that on repetition prime trials the partially assembled target vocalization can be initiated sooner. As explained above, in our naming experiments the unrelated primes had onsets equivalent to their corresponding targets so that onset effects would not be part of the priming effects we observed. Nevertheless, Forster pointed out that "it is readily apparent that shared segments other than the onset could also lead to facilitation" (Forster, 1998, p. 218). Although this articulatory account may have merit, it does not seem consistent with the pattern of form priming effects with word targets found by Forster and Davis (1991) when they used the naming task. In those experiments, which also ruled out onset effects, the naming task yielded form priming (e.g., mature-NATURE) only for words in low-density neighborhoods--exactly the same constraint that was found for form priming in the lexical decision task (e.g., Forster et al., 1987). Thus, masked priming in the lexical decision and the naming tasks seem to be driven by similar processes, in contrast to Forster’s articulatory hypothesis.

Additivity of Word Frequency and Masked Repetition Priming

Forster and Davis (1984) provided evidence that, unlike long-term priming, masked priming is equally strong for low- and high-frequency target words. Our theoretical position, however, predicts that one should be able to obtain evidence for larger masked priming effects among low-frequency words, given that this is the pattern that has been seen with long-term priming (e.g., Jacoby & Dallas, 1981; Scarborough et al., 1977). Word frequency might influence the magnitude of masked and long-term priming in a number of ways. One possibility is that subjects are less skilled at processing low-frequency words and therefore the benefit of priming can have a larger impact on processing efficiency than it can for high-frequency words (Kirsner & Speelman, 1996). Another possibility is that the greater difficulty associated with processing low-frequency words means that subjects are more likely to recruit and use the prime event in their encoding of the target (Bodner & Masson, 1997; Whittlesea & Jacoby, 1990).

Our initial efforts to obtain an interaction between target word frequency and masked priming were not successful (Bodner & Masson, 1997). Even under conditions that demonstrably led subjects to be more dependent on masked primes than normal, the priming effects seen with high- and low-frequency words were quite similar. It is possible, however, that the long-term priming paradigm, which provides for a clear view and reliable encoding of a prime word, is more sensitive to differences in the impact of a study episode on words of varying frequency. If a masked prime event is seen as having less impact on the learning system that sustains the episodic basis of priming, then perhaps a stronger manipulation is needed before an

Table 2

Mean Response Time, Percent Error, and Repetition Priming for Lexical Decisions to Low- and High-Frequency Words from Bodner and Masson (2001).

	Response time			Percent error		
Frequency	Unrelated prime	Repetition prime	Priming	Unrelated prime	Repetition prime	Priming
Low	688	619	69	11.4	6.4	5.0
High	595	558	37	3.4	1.8	1.6

effect can be seen. Examination of a stronger manipulation is also warranted by the fact that in the Forster and Davis (1984) study, even long-term priming significantly interacted with word frequency in only one of the three experiments that examined that form of priming.

We note that in the Bodner and Masson (1997) experiments, the word frequency manipulation was comparable to that used by Forster and Davis (1984), namely, high-frequency words were in the range of 40-60 occurrences per million (Kucera and Francis, 1967). A stronger manipulation of word frequency was used by Forster and Davis (1991, Experiment 5) in their comparison of word naming and lexical decision tasks. High-frequency words were defined as 100 or more occurrences per million. Although repetition priming in the naming task was very similar for high- and low-frequency words, there was a stronger priming effect for low-frequency words relative to high-frequency words in the lexical decision task (54 ms vs. 72 ms). Forster and Davis did not report any tests of this interaction, but the pattern of means is suggestive.

In our series of experiments on manipulations of prime validity, reported in more detail below, we pursued the idea that a stronger manipulation of word frequency might yield evidence for an interaction between word frequency and priming like that found in long-term priming (Bodner & Masson, 2001). In those experiments, we used high-frequency words that fell within the range of 100 to 1,000 occurrences per million (median frequency was about 200 across the experiments). In four separate experiments (Experiments 2A, 2B, 3, and 6), we obtained a clear, statistically reliable interaction between word frequency and repetition priming, with a larger priming effect for low-frequency words. This result was obtained using uppercase target words, alternating-case target words, a within-subjects and a between-subjects manipulation of word frequency, and when a set of medium frequency words was included in the word list. Table 2 presents response time and percent error data averaged across these four experiments. It is clear that the low-frequency targets generated a substantially larger priming effect than did the high-frequency targets, particularly on the response time measure, although the effect is also present in the error data.

These experiments represent the first clear demonstration of a frequency-modulated masked repetition priming effect. The pattern of this interaction conforms to the pattern observed in long-term priming experiments, whereby low-frequency target words generate larger priming effects than do high-frequency words (e.g., Forster & Davis, 1984; Jacoby & Dallas, 1981). Although long-term priming may be more sensitive than masked priming to weaker manipulations of word frequency (Forster & Davis, 1984), masked repetition priming is now known to be modulated by word frequency, at least under conditions of a strong frequency manipulation.

Duration of Masked Priming

The third dissociation between masked priming and long-term priming established by Forster and Davis (1984; Forster et al., 1990) is that the influence of a masked repetition prime is relatively short-lived, whereas long-term priming effect endure over substantial delays (minutes or even days) between the prime event and presentation of a target. In their experiments, Forster and Davis found that masked repetition priming was reduced to a small 13-ms effect when delays of about 1 to 2 s were placed between the masked prime and the subsequent target and the priming was eliminated when the delay was extended to 8.5 s. Even with a delay of only 500 ms, they obtained a repetition priming effect of just 17 ms, compared with priming effects of over 40 ms when no delay intervened between prime and target. We note that these delays were filled by the presentation of additional words to which no response was required.

Thus, the results involving duration of masked repetition priming suggest that the influence of a masked prime spans a very brief interval of time. This conclusion sharply contrasts with the notion that even a masked prime event can create a form of memory representation that can be recruited at a later time to support target identification. We suspect there may be a number of reasons for the sensitivity of masked priming to delay interval. First, the masked prime event is brief and typically not consciously processed and therefore may not have sufficient impact on the memory system to produce a lasting effect. We note that in the case of long-lasting semantic priming effects and mere exposure effects reviewed above, primes were either clearly visible to subjects or, in the case of the mere exposure effect, usually required multiple presentations to be effective. Second, the presentation of other linguistic material in the delay interval that separates the prime and target displays may serve as a source of retroactive interference that weakens the memory representation of the prime event or reduces accessibility of that representation. Finally, the intervening items, as a possible source of retroactive interference, might have a particularly strong effect because they are presented as part of the larger event that defines a trial in the experimental procedure. That is, in the Forster and Davis (1984) procedure, the prime event was presented as one of a series of words that briefly appeared prior to the target item (although the prime was presented for a much shorter duration than the filler words--60 ms vs. 500 ms). By embedding the prime in a context of filler items, the potential for interference may be amplified.

We have initiated a series of experiments to examine these ideas regarding the duration of masked repetition priming and provide a preliminary report of the results here. In one approach, we created a prime-target delay by presenting the prime event and the critical target on consecutive trials. For these experiments, a "study" trial consisted of presenting a pre- and post-masked prime word in lowercase letters for 45 ms. The pre-mask was a row of Xs and the post-mask was an uppercase target letter string (word or nonword unrelated to the prime) to which the subject made a lexical decision response. In one experiment, this trial was followed by another lexical decision trial in which a pre-mask, but no prime, was presented prior to a target word. That target was either a repetition of the prime from the previous trial or was unrelated to that prime.

In the second experiment, our rationale followed the logic of transfer-appropriate processing (e.g., Morris, Bransford, & Franks, 1977) by making the processing involved when testing for the influence of the prime similar to the processing that occurred during its initial presentation. Thus, following the lexical decision trial on which the prime was briefly presented and masked, we presented a masked word identification trial. On this trial, a target word was presented for 30 ms and post-masked. The task was to identify the target, which was either a repetition of the prime on the previous trial or unrelated to that prime. The presentation conditions involved in the presentation of the prime and its reappearance as a target, then, were rather similar.

In both experiments, the only interfering item that intervened between a prime and the critical target was the target letter string that served as a postmask for the prime. The procedures in these experiments are summarized in Figure 2.

In the first of these experiments, the time interval between offset of the prime and the appearance of the critical target on the next trial was about 2 s (this varied, depending on the

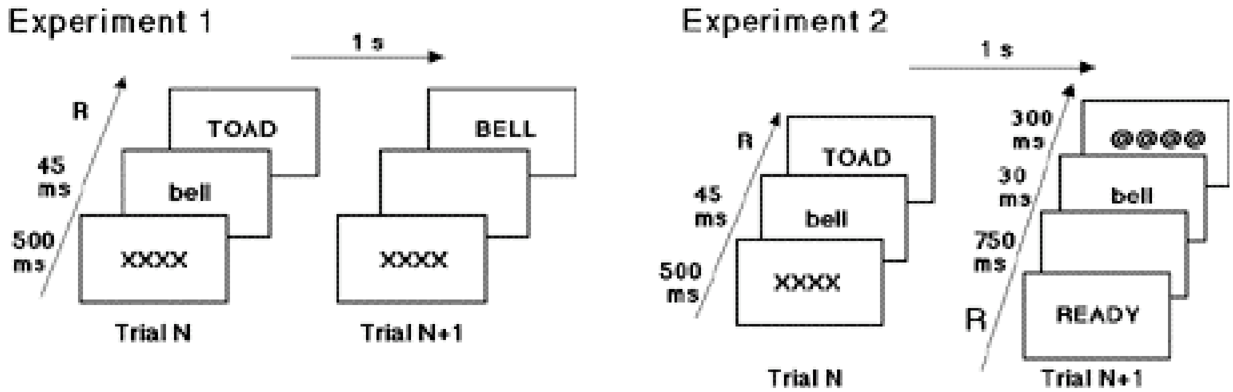

Figure 2. Examples of trial pairs from experiments that examined duration of masked priming effects. In each case, the prime was presented on the first trial of a pair and the critical target was presented on the following trial. An interval of 1 s separated the two trials in a pair. In Experiment 1, both trials required a lexical decision. In Experiment 2, the first trial required a lexical decision and the second trial required an identification response.

response time to the target that appeared after the prime). In contrast to Forster and Davis's (1984) finding that a delay of this magnitude was associated with a relative small priming effect of 13 ms, we obtained a more substantial repetition priming effect of 39 ms (590 ms vs. 629 ms). In the second experiment, the delay between prime offset and the appearance of the corresponding target on the next trial was about 2.5 s, depending on the subject's latency to respond to the target on the first trial and to respond to the ready signal on the following masked word identification trial. Accuracy on that identification trials was significantly improved if the target had appeared as a masked prime on the previous trial relative to the case where the target had not been primed (.60 vs. .49). This priming effect is at the low end of the range of effect sizes (.10 to .20) seen in studies of long-term priming of masked word identification that have used words from frequency bands (i.e., medium- and high-frequency) similar to those used here (Jacoby & Dallas, 1981; Masson & MacLeod, 1992; Weldon, 1991). In those long-term priming studies, of course, subjects were given clearly visible presentations of targets at the time of study and typically made some form of overt response to them.

It is particularly striking that these robust priming effects were obtained with a prime duration of only 45 ms. These results suggest that even a brief exposure to a masked prime creates a change in the cognitive system that survives at least for a few seconds. In these two experiments, the prime presentation was part of a circumscribed event, rather than being embedded in a long stream of irrelevant words as in Forster and Davis (1984). At this stage, it is unclear how long-lasting the influence of a masked prime might be if it appears as part of relatively brief event and is tested after some delay that is filled either with encoding of other linguistic material or with nonlinguistic events. We have begun to examine this issue by inserting a symmetry judgment task using a sequence of polygons between pairs of lexical decision trails structured as in the first experiment described here. Preliminary results indicate that a moderate priming effect is emerging with a delay of about 8 or 9 s between a word's appearance as a masked prime and its presentation as the target on the subsequent lexical decision trial. This result is a strong contrast with the Forster and Davis (1984) report of no masked priming with an 8.5-s delay interval filled with presentation of linguistic items. In future experiments, we plan to extend the delay interval and also to examine the impact of inserting linguistic encoding tasks, rather than a visual task such as symmetry judgment, between critical lexical decision trials. The objective here is to determine the factors that govern the time course of a masked prime's effectiveness. To the extent that those factors are similar to the factors that influence long-term priming effects, the case for a retrospective account of masked priming will be supported.

List-Context Effects on Masked Priming

The goal of this section is to present a new form of evidence that appears to link masked priming to long-term priming phenomena. Rather than challenging previously established dissociations between masked and long-term priming, our goal here is to demonstrate a similar influence of list context on these two classes of priming—a similarity more consistent with a retrospective account of priming.

There are many demonstrations that the influence of plainly visible primes on word identification is affected by various aspects of list context, especially the nature of the other primes and/or targets in the stimulus list (e.g., Ferrand & Grainger, 1996; Grainger & Ferrand, 1996; McKoon & Ratcliff, 1995; Smith, Besner, & Miyoshi, 1994). These findings imply that the cognitive system that processes words includes at least some mechanisms that are flexible and adaptive. The masked priming paradigm, in contrast, has been advocated as a platform for investigating those word identification mechanisms which are automatic and context-insensitive at heart. Activation-based accounts of masked priming can potentially accommodate findings showing that mixtures of different types of targets (which are plainly visible) can modulate the influence of masked primes by assuming that this list-context based modulation of priming occurs at a "post-lexical-access" decision stage, rather than modulating the action of the primes on the cognitive system prior to the presentation of the target. In contrast, activation-based accounts may have more trouble accommodating demonstrations that a manipulation of the percentages of different types of masked primes in the stimulus list can also modulate masked priming. The goal of this section is to show that masked priming is, if anything, particularly sensitive to such list-wide manipulations of prime proportion. This sensitivity to prime context bolsters our claim that priming may best be considered within a retrospective framework.

A study of long-term repetition priming motivated our exploration of list-context effects in masked priming. As mentioned above, Allen and Jacoby (1990; Jacoby 1983a) found that subjects' ability to identify masked targets following a study phase was greater when the percentage of studied versus new targets presented in the masked word identification task was 90% rather than 10%. This proportion overlap effect was attributed to increased recruitment of episodes constructed during the study phase when there was a high degree of overlap between the study and test lists. The effect does not appear to have been modulated by conscious recruitment of prior episodes because it was somewhat stronger for words that had been read at study than for words generated from anagrams at study, even though the generated words were more likely to be recognized on a recognition memory test.[1]

In addition to results from long-term priming of masked word identification, Cheesman and Merikle (1986, Experiment 3) obtained some evidence that the Stroop effect produced by a color-word prime (e.g., the word *blue*) can be modulated by the proportion of congruent-prime trials. Importantly, this modulation was obtained even when the primes were masked and presented at a subjective threshold at which subjects reported being unable to identify the primes; the mean exposure duration across subjects was 45 ms. The effect of congruity between the color-word prime and a subsequently presented colored rectangle to which the subjects

---

[1]Allen and Jacoby's (1990) proportion overlap effect has been the center of some controversy (Bowers, 2000; Challis & Roediger, 1993; Tenpenny, 1995). Most recently, Bowers (2000) has challenged the conclusion that the effect was not due to conscious recollection. This challenge is based on the similarities reported by Allen and Jacoby between the recognition and masked word identification tests with respect to overlap effects. In Experiment 1 of Allen and Jacoby, there was a somewhat stronger proportion overlap effect for read than for generated items on the recognition memory test and there was a similar tendency on the identification test. In that experiment, however, the recognition test given to all subjects contained an equal proportion of old and new items, so there was no actual overlap manipulation in effect. Rather, different proportions of old words (i.e., more for the high-proportion overlap group) had been presented in the identification test. These items were likely to have been identified on that test (especially the read items) and therefore would be more likely to be nominated as old on the recognition test. In Experiment 2, the recognition test was given to a different group of subjects and in that case, there was a trend for a larger overlap effect in the generate condition. That trend contrasted with the trend in the identification test for a larger overlap effect among read items. Moreover, in both experiments, read items were more likely to be identified than generate items but less likely to be recognized. If the overlap effect in the identification test were due to conscious recollection, the effect should have been clearly greater among generate items, but it was not.

responded was greater when the prime and colored rectangle were congruent on 75%, as opposed to 25%, of the trials. This result suggests that it should be possible to obtain an effect of prime relatedness even when primes are masked so that subjects are unaware of their identity. In a sense, masked primes in the word identification literature can be thought of as being presented under conditions of subjective threshold--subjects often report being unaware of the primes, yet their responses to targets are reliably affected by the prime-target relation.

We reasoned that if masked priming and long-term priming share a common mechanism, then masked priming might also be enhanced by a high degree of contextual overlap between study and test episodes. As the overlap between study and test episodes increases, recruitment of study episodes becomes a more valid activity in service of identifying targets. In the masked priming paradigm, an analogous situation of high prime validity can be created by providing useful primes on a high percentage of trials and unrelated primes only infrequently. Would the cognitive system come to rely on priming episodes to a greater extent when prime validity is high than when it is low (i.e., when a high proportion of primes are unrelated to their targets)? Such an outcome would fit well within a context-sensitive episodic account, but would not be predicted by abstractionist accounts of repetition priming, semantic priming, or number priming. We have recently examined these three types of priming using masked priming techniques and in each case, as described below, the influence of masked primes was remarkably sensitive to prime validity.

Repetition Priming Experiments

In a series of 12 lexical decision experiments, Bodner and Masson (2001) examined whether masked repetition priming would be enhanced when 80% as opposed to only 20% of the primes in the stimulus list were repetition primes. These respective percentages were chosen for the high and low prime validity groups because they provided a strong manipulation of prime validity, while still providing enough trials of the minority prime type for computing stable estimates of mean response times. To further the latter goal, subjects were given a substantial number of trials (n = 400). The prime duration (and SOA) in these experiments was either 45 ms or 60 ms.

In eight sets of data we found evidence consistent with the claim that high prime validity enhances the effectiveness of masked primes. In these cases, the group given a high percentage of repetition prime trials showed reliably more masked priming than the group given a low percentage. This prime validity effect occurred with word targets from several frequency ranges (high, medium, low) and mixed with several types of nonword foils (pronounceable, pseudohomophone, consonant string) for which prime validity was also manipulated. The average response latencies, error rates, and priming scores to word targets in each condition, averaged across the eight data sets, appear in Table 3. That the list-wide validity of the primes, of which subjects were typically unaware, modulated masked repetition priming is a result that is difficult to reconcile with the notion that masked primes automatically activate their lexical entries (Forster, 1998; Forster & Davis, 1984). Instead, the cognitive system appears to adapt to the current processing situation, relying on masked primes to a greater or lesser extent depending on their probabilistic utility for that situation.

A further difficulty for activation-based accounts is that masked prime validity in this set of experiments produced a form of bias effect in which the high-validity group was significantly faster than the low-validity group on repetition prime trials, but the former group made significantly more errors on unrelated prime trials. The latter result, an interference effect, is particularly problematic for activation-based accounts (see also, Jacoby & Whitehouse, 1989). For example, it is difficult to see why opening a lexical entry for an unrelated word prime would increase lexical decision errors at all, let alone why it would increase errors to a greater extent when prime validity is high. In contrast, these prime validity effects and their bias-like form were both expected on the episodic account. Thus, greater reliance on priming episodes by the high-validity group facilitated responding on the 80% of trials where the priming episode was useful (i.e., the decrease in response times on repetition prime trials) and interfered with target

Table 3

Mean Response Time, Percent Error, and Repetition Priming for Lexical Decisions to Words as a Function of Prime Validity Across Eight Sets of Data from Bodner and Masson (2001).

	Response time			Percent error		
Prime validity	Unrelated prime	Repetition prime	Priming	Unrelated prime	Repetition prime	Priming
Low	629	597	32	4.8	3.1	1.6
High	636	579	57	5.7	3.5	2.1

responding on the 20% of trials where the priming episode was not useful (i.e., the increase in error rates on unrelated prime trials).

Does the presence of a high percentage of valid primes invariably increase priming? The answer, we found out, is clearly no. Bodner and Masson (2001) obtained similar masked priming effects for low- and high-validity groups in four other sets of data. When we compared those experiments that showed sensitivity of priming to prime validity to those that did not, we identified a variable that seems to predict whether prime validity modulates priming or not: The degree of trial-to-trial variation in target processing difficulty. In each experiment where prime validity had an effect on priming, targets on the majority of trials were either relatively difficult (e.g., low-frequency words and pronounceable nonwords) or relatively easy (e.g., high-frequency words and consonant-string nonwords) to process for making a lexical decision. In contrast, when prime validity did not modulate priming, targets varied considerably more from trial to trial on this dimension (e.g., high-frequency words vs. pronounceable nonwords; high- vs. low-frequency words). This "variability" explanation is consistent with reports that word naming latencies can be influenced by the type of target presented on the preceding trial or trials (Kang & Simpson, 2001; Taylor & Lupker, 2001). In the case of prime validity, our hypothesis is that when variability in classification difficulty among targets is high, subjects will make substantial use of masked primes regardless of their validity (see Bodner & Masson, 2001, for details).

If the variability explanation is correct, we reasoned that it should be possible to produce an effect of prime validity for a set of targets that did not originally show such an effect by reducing the trial-to-trial variation in target processing difficulty. This prediction was confirmed in an experiment where the likelihood of steep cross-trial transitions between high- and low-frequency words was reduced by including a set of medium-frequency words (Bodner & Masson, 2001, Experiment 6). Thus, in the process of examining the influence of one list-context variable on masked priming (prime validity), we discovered a second list-context variable (target variability) that appears to modulate the influence of the first. It is our suspicion that interactions of subtle list-context variables of this sort are a major reason why it has proven so challenging for researchers to map out the mechanisms that underlie visual word identification. The influence of primes on the processing of targets appears to reflect a dynamic and flexible process, rather than one that is static and ballistic. Our ability to benefit from a repetition prime—like our ability to recall or recognize events from our past (e.g., Smith & Vela, 2001)—can be robustly influenced by subtle contextual factors.

Semantic Priming Experiments

Having shown that list-wide prime validity can influence repetition priming, we

Table 4

Mean Response Time, Percent Error, and Semantic Priming for Lexical Decisions to Words as a Function of Prime Validity from Bodner and Masson (2002).

	Response time			Percent error		
Prime validity	Unrelated prime	Related prime	Priming	Unrelated prime	Related prime	Priming
Experiment 1						
Low	656	644	13	5.7	4.1	1.4
High	665	641	24	6.8	5.5	1.6
Experiment 2						
Low	712	701	11	7.9	6.4	1.5
High	674	639	35	5.6	4.4	1.2

considered whether a similar effect might be found with masked semantic primes. Once again, the literature was not exactly encouraging. In his review of semantic priming, Neely (1991) suggested that semantic priming should not be influenced by the percentage of semantically related prime-target pairs in the stimulus list (i.e., *relatedness proportion*) if the SOA is less than 500 ms, let alone if the SOA is 45 ms and primes are masked. However, at the time of Neely's review, no published studies had tested whether masked semantic priming increases with an increase in relatedness proportion. Perhaps this was because relatedness proportion effects with semantic primes had typically been attributed to a consciously driven expectancy process (e.g., Neely, 1991; Neely & Keefe, 1989). By this process, subjects given a high relatedness proportion and a sufficiently long prime-target SOA develop a conscious strategy of using the prime to predict what the target will be, thereby increasing their priming effect.

A conscious expectancy strategy is not likely to be used by subjects when primes are masked. This assumption was confirmed in a lexical decision experiment described in Forster (1998), where repetition primes were either complete or incomplete words (e.g., playmate or playm) and targets were either masked (with a 60 ms SOA) or not (with a 500 ms SOA). The basic idea was that subjects would use expectancy to try to complete the incomplete primes if the SOA and awareness of the primes allowed them to do so. The key result was that repetition priming was larger for incomplete primes than for complete primes when primes were not masked, but was smaller for incomplete primes than for complete primes when primes were masked. Forster interpreted this result as evidence that subjects use a conscious expectancy process when primes are incomplete and unmasked, but do not use such a process when primes are incomplete and masked. We agree with Forster's interpretation.[2] Given our prime validity effects with repetition primes, however, we were less inclined than Forster to reason that prime validity would therefore not have an influence on masked semantic priming.

Bodner and Masson (2002) tested for prime validity effects on masked semantic priming

[2] On Forster's (1998) view, however, a prime more than one letter different from a real word should not open that word's lexical entry. Therefore, Forster's incomplete repetition primes, which were three letters different from their targets, should not have produced any masked repetition priming—yet a 41-ms priming effect was found for these items. From the episodic account, the reduction in priming with incomplete primes relative to that observed with complete repetition primes (84 ms) makes sense because more impoverished orthographic or phonological information would be encoded in the processing episode formed for an incomplete prime (Bodner & Masson, 1997; Masson & Isaak, 1999).

in two lexical decision experiments. In Experiment 1, a low-validity group received semantic primes on 20% of the trials, and a high-validity group received semantic primes on 80% of the trials. The rest of the primes were unrelated to their targets. The prime-target SOA was 45 ms. The results, laid out in Table 4, were straightforward: There was reliably more masked semantic priming in the high-validity group than the low-validity group. This relatedness-proportion effect could not have been produced by expectancy because the primes were masked. Importantly, the effect also could not have been produced by automatic spreading activation (e.g., Collins & Loftus, 1975) because activation should have spread to the same extent regardless of the list-wide validity of the primes. Interpreted using a retrospective account, however, this effect makes sense: High prime validity increased recruitment of masked prime episodes. The system took advantage of the high likelihood of overlap between the processing applied to the prime and the processing required to respond to the target. Moreover, the trend within this single experiment (cf. Table 3) was for the high validity group to be somewhat faster on semantic prime trials and somewhat slower on unrelated prime trials relative to the low-validity group—suggesting the emergence of a bias effect.

In Experiment 2, the low-validity group was defined as above, but the high-validity group received repetition, semantic, and unrelated primes on 60%, 20%, and 20% of the trials, respectively. Our goal was to determine whether the cognitive system is sensitive to the specific type of relationship between primes and targets, or simply to the overall likelihood that the primes will be useful for target processing. Because repetition primes were now the most common type of prime in the high-validity group, it was possible that the system might become tuned to this relationship and if so, target processing might not benefit on semantic prime trials. Alternatively, because 80% of the primes in the high-validity group still contained valid information about their targets, the system might rely on primes extensively on all trials, in which case semantic priming would continue to be greater in the high- group than in the low-validity group. This latter possibility was supported by the data. As shown in Table 4, semantic priming in Experiment 2 was again greater in the high-validity group than in the low-validity group.[3]

In his review of semantic priming, Neely (1991) foreshadowed the significance of these results. He suggested that if relatedness proportion were shown to modulate masked semantic priming, then to preserve an expectancy account one would have to conclude that subjects use a "*veiled* expectancy strategy that is unavailable to consciousness but which can be consciously controlled" and that "the hand waving that would be required to make sense of such an appeal would be exhausting" (p. 317). Rather than attempting to preserve an expectancy account, we suggest that the sensitivity of masked semantic priming to list context is readily interpretable if a retrospective account of masked priming is considered as an alternative to an activation-based view.

Parity Priming Experiments

Thus far, our claim that the cognitive system comes to rely on priming episodes to a greater or lesser extent according to their validity in a given context has been supported only using word stimuli and only when assessed with the lexical decision task. If adaptation to list context represents a general property of the cognitive system, then it should be possible to observe prime validity effects with other types of masked stimuli in other tasks. Audny Dypvik, a graduate student at the University of Calgary, wondered whether the validity of a set of masked primes might also modulate number processing. As it turns out, the answer to her question has important implications for theories of how numbers are represented.

We discovered that some of the assumptions we had been questioning in the word-processing domain had direct analogues in the number-processing domain. For example, the

[3]A 69-ms repetition priming effect was also displayed by the high-validity group. This priming effect was reliably greater than the 45-ms SOA, a result that does not support Forster's (1999) claim that masked priming is a savings effect and hence should be no larger than the prime-target SOA (cf. Forster, Mohan, & Hector, this volume, however).

most prominent accounts of number processing are abstractionist in nature (see Dehaene & Cohen, 1995, for a review). Moreover, spreading activation has often been invoked to explain priming with numbers as follows: A number prime activates an abstract number representation, causing activation to spread along an abstract number line and to activate neighboring numbers, and as this activation spreads it decreases in strength. A strong prediction that follows from this account is that a prime closer to its target on the number line should produce more priming than a prime further from its target. Den Heyer and Briand (1986) expressed this prediction as follows:

> "It was assumed that single digit numbers are represented in semantic memory on some ordered continuum. Thus, *five* and *six* are more closely situated in semantic space than, say, *five* and *seven*. It follows that if activation in response to the presentation of the prime *five* dissipates with distance, then *six* should receive more activation than *seven*. This in turn should reflect itself in latency measures where the distance between the prime and target is varied." (p. 331)

Den Heyer and Briand found exactly this pattern in a letter/number decision task and in a lexical decision task with plainly visible primes. This “distance effect” has since been replicated with masked primes in a greater-than-five/less-than-five number magnitude decision task (Koechlin, Naccache, Block, & Dehaene, 1999) and in both number naming and odd/even parity decision tasks (Reynvoet & Brysbaert, 1999).[4] The effect has been taken as evidence that activation from a number prime spreads along an abstract number line or otherwise activates an abstract magnitude representation (e.g., Koechlin et al., 1999).

From an episodic perspective, the influence of a prime should depend upon its usefulness for doing the task at hand. In most tasks, the closer a number prime is to its target, the more processing of the number target should benefit, just as recruiting a strongly related semantic prime is more helpful than recruiting an unrelated prime in the lexical decision task. When the task is to make odd/even parity judgments, however, the episodic account makes a prediction that is "at odds" with the abstractionist view of number priming: A prime two numbers away from its target should produce more priming than a prime one number away from its target. This prediction follows because a prime two numbers away from its target will be of the same parity as its target and hence will be parity-valid (e.g., 4 and 6, 5 and 7), whereas a prime one number away from its target will be of a different parity than its target and hence will be parity-invalid (e.g., 5 and 6, 6 and 7). The episodic account further predicts that the benefit from a match between prime and target parity should be stronger when the percentage of parity-valid trials in the stimulus is high rather than low. In contrast, the abstractionist account predicts that primes closer to their targets (i.e., parity-invalid primes) will activate their targets (and hence facilitate parity judgments) to a greater extent than primes further from their targets (i.e., parity-valid primes) regardless of the list-wide validity of the primes.

To compare these accounts, Dypvik and Bodner (2001) tested whether odd/even parity judgments to number words (Experiment 1, 50-ms SOA) and Arabic digits (Experiment 2, 42-ms SOA) would be influenced by the percentage of trials in which the masked prime and its target were parity valid. Critically, the stimuli were arranged so that on parity-valid trials the prime and target were always two numbers apart, whereas on parity-invalid trials they were always only one number apart. The low-validity group received parity-valid primes on 20% of the trials, and parity-invalid primes on 80% of the trials. In the high-validity group, these percentages were reversed.[5] Table 5 summarizes the mean response times and percent error in the two experiments.

The results support the episodic account. In the low-validity group, where most of the trials were parity invalid, primes did not have much influence on parity judgments. This makes

[4]The last of these is not especially relevant to our parity priming experiments because the prime and target were always of the same parity.

[5]In the number word experiment, of the parity-valid trials in the high-validity group, 60% were repetition primes and 20% were non-identical parity-valid primes. The repetition prime trials were not included in the analyses described here. Repetition prime trials were not present in the digit experiment, and the results were very similar to those obtained in the number word experiment.

Table 5

Mean Response Time, Percent Error, and Parity Priming for Number Parity Decisions from Dypvik and Bodner (2001).

	Response time			Percent error		
Prime validity	Parity-invalid prime	Parity-valid prime	Priming	Parity-invalid prime	Parity-valid prime	Priming
Experiment 1						
Low	586	583	2	4.7	3.8	0.9
High	570	544	25	8.0	3.6	4.4
Experiment 2						
Low	544	537	7	4.3	3.0	1.3
High	542	516	26	7.2	2.7	4.6

sense from the episodic account because when most of the primes do not contain accurate parity information about the target then the system should rely on the primes to a lesser extent. In the high-validity group, parity judgments were much faster on parity-valid trials than on parity-invalid trials, even though parity-valid primes were always further from their targets on the number line. This result also fits well with the episodic account. When 80% of the primes were parity-valid, the system tuned in to the prime resource and relied on priming episodes to a greater extent. The abstractionist account's predictions that parity-invalid primes should produce more priming, and that this pattern should occur regardless of prime validity, were clearly not supported.

A critic might argue that these parity-valid priming effects arise due to response incompatibility on parity-invalid trials—the prime biases the wrong parity judgment, and hence these effects might be better viewed as interference effects. However, this argument fails to explain why list-wide prime validity influenced priming. Moreover, if forced to predict prime-validity effects, this response-incompatibility explanation would predict more interference in the low-validity group, where 80% of the trials involve parity-invalid primes. Comparisons among the mean response times and among the mean error rates in Table 5 contradict this prediction: The high-validity group shows more interference, not less interference, from parity-invalid primes. The response-incompatibility explanation would also predict that the low- and high-validity groups should perform equivalently on parity-valid trials, where no response incompatibility exists. This prediction is also contradicted by the data, where the high-validity group clearly shows more benefit from parity-valid primes. These bias effects provide strong support for the episodic account, which correctly predicts that increased reliance on the primes by the high-validity group would facilitate responses on parity-valid trials, but would interfere with responses on parity-invalid trials.

We view these results as providing a new illustration of transfer-appropriate processing (Morris et al., 1977). Here we have shown that the influence of a masked prime depends on the list-wide usefulness of the primes for doing the task at hand. In contrast, prospective abstractionist accounts must attribute list contexts effects to "post-lexical" decision processes (e.g., Forster et al., this volume), because primes are thought to activate abstract representations in a manner that is context insensitive (e.g., Forster, 1998) and that cannot be made conditional on the task at hand nor on the nature of the upcoming target (e.g., Whittlesea & Jacoby, 1990). It remains to be seen whether abstractionist accounts will be able to provide a unified account for the similarity of prime validity effects we have found in word-and number-processing domains. For now, we suggest that these data provide important converging evidence for a context-sensitive episodic view of priming.

Characteristics of Prime Validity Effects

The goal of this last subsection is simply to mention four potentially important and under-studied characteristics of the list-context effects described above. Our hope is that others may be motivated to help us to explore each of them further.

First, although on average about a quarter of the subjects in these experiments reported some minimal awareness of the masked primes (usually they reported having noticed "something flickering"), our list-context effects do not appear to have been modulated by conscious awareness of the primes. Removal of prime-aware subjects did not eliminate any of the prime-validity effects we have described here. In fact, subjects often report that their awareness of the primes was more distracting than helpful. In one case, examination of the performance of prime-aware subjects has confirmed that intuition (Bodner & Masson, 2002). Thus, masked prime validity effects appear to occur even when subjective awareness of the primes is absent.

Second, in the section on repetition priming, we suggested that a high likelihood of trial-to-trial variability in target processing can eliminate prime-validity effects. One remaining question is why this elimination occurs. Bodner and Masson (2001) provided some evidence that the presence of marked variability in target processing causes the cognitive system to increase its use of the primes independently of their validity. We found that priming effects were as large in the low-validity groups in experiments where prime-validity effects did not occur as they were in the high-validity groups in experiments where prime-validity effects did occur. The implication of this pattern of results is that the cognitive system, when faced with an uncertain processing situation, may rely on a source of information even if that source is unlikely to be valid. Although speculative, this possibility is worth following up.

Third, subjects rapidly adapt to prime validity. Bodner and Masson (2001) found that the size of the repetition priming advantage for the high-validity group was consistent across the four quarters of the test list. We have also found no evidence of growth in prime validity effects across blocks in our studies of masked semantic priming and masked parity priming. Although Bodner and Masson (2001) suggest that the rapid and stable emergence of the effect could be due to either local or global validity, more recent studies suggest that use of a prime on trial N might be locally influenced, perhaps primarily by the nature of the prime-target relationship on trial N-1 (e.g., Kang and Simpson, 2001; Ratcliff, Van Zandt, & McKoon, 1999; Strayer & Kramer, 1994; Taylor & Lupker, 2001).

Fourth, prime validity appears to produce a form of bias effect (e.g., Allen & Jacoby, 1990; Ratcliff & McKoon, 1997; Ratcliff, McKoon, & Verwoerd, 1989). Response latencies are shorter on valid-prime trials (a benefit), whereas response latencies and/or error rates are higher on invalid-prime trials (a cost), for the high-validity group relative to the low-validity group (see Tables 3-5). This bias pattern may have decisive implications for the viability of different accounts of masked priming. The finding that high prime validity produces a cost may prove especially problematic for activation-based accounts of priming. Even if these accounts can be modified to account for our finding that priming increases with an increase in prime validity, it is unclear how lexical entry opening, increased spreading activation, or increased feedback in a multi-level activation model (e.g., see Stolz & Neely, 1995) could produce a deficit in target processing on invalid-prime trials. An advantage of the episodic account is that it provides a simple explanation for the bias effects we have observed: When primes tend to be valid, reliance on primes increases. This increased reliance helps subjects on the 80% of the trials where the prime turns out to be valid, but hurts task performance on the 20% of the trials where the prime turns out to be invalid.

Our results suggest that the cognitive system is designed to capitalize on the probabilistic nature of the current processing environment in an effort to maximize its performance in a given task. Although such a claim does not seem bold or radical to us, it is anathema to the claim that a series of immutable stages and processes governs the identification of word and number stimuli.

Conclusion

We have reviewed two contrasting frameworks for understanding how masked priming influences word identification processes. The classic, prospective view of priming is well represented in most of the chapters in this book. But we have been struck by the empirical and theoretical clues that point to the potential benefits of adopting a retrospective framework in accounting for the influences of masked priming. First, there are theoretical accounts of both semantic priming (Becker et al., 1997; Ratcliff & McKoon, 1988) and repetition priming (Whittlesea & Jacoby, 1990) that emphasize retrospective processes. Second, the viability of a retrospective account of masked priming is enhanced by findings from the mere exposure paradigm in which brief, masked exposures of stimuli can create a lasting influence on behavior (e.g., Whittlesea & Price, 2001) and by demonstrations that masked homophone priming in a lexical decision task is sensitive to contextual manipulations involving the nature of the nonword targets (Ferrand & Grainger, 1996; Grainger & Ferrand, 1994). These effects are consistent with effects that have been obtained in long-term priming paradigms.

Discovery of similarities between masked priming and long-term priming phenomena is important because the latter are often attributed to the operation of some form of episodic memory (i.e., a retrospective process). Moreover, one of the primary sources of support for a proactive account of masked priming is the set of dissociations between masked priming and long-term priming developed by Forster and Davis (1984). We have presented what we consider to be substantial empirical challenges to those dissociations.

First, there are circumstances under which nonword targets produce clear and reliable masked repetition priming effects and these effects can be modulated in predictable ways (Bodner & Masson, 1997; Masson & Isaak, 1999). These effects support an account of nonword priming that includes consideration of a trade-off between prime-induced encoding fluency and decision processes. Second, we have shown that with a sufficiently strong manipulation of word frequency, masked repetition priming—like long-term priming—is larger for low-frequency than for high-frequency word targets (Bodner & Masson, 2001). This outcome contrasts with the additivity of word frequency and masked priming obtained by Forster and Davis (1984) and by us in some of our earlier work (Bodner & Masson, 1997), all of which used a weaker frequency manipulation. Finally, we have begun to gather evidence that masked prime events can have a longer lasting influence of word identification than originally believed. In particular, reducing the linguistic sources of retroactive interference over the prime-target delay interval appears to allow masked repetition priming to survive over delay intervals that Forster and Davis (1984) showed to be sufficiently long to extinguish masked priming. In their experiments, however, these delay intervals were filled with presentation of other words that we believe serves as potential sources of retroactive interference.

In addition to these challenges to dissociations between masked priming and long-term priming, we also presented evidence for powerful contextual effects on masked repetition priming (Bodner & Masson, 2001), semantic priming (Bodner & Masson, 2002), and parity priming of numbers (Dypvik & Bodner, 2001). All three types of priming were shown to be sensitive to the validity of masked primes. These context effects challenge the idea that masked priming is a necessary consequence of the presentation of a prime event. Rather, such effects are consistent with a retrospective view of masked priming in which it is assumed that recruitment of memory for a masked prime event is under contextual control. Although it is not yet clear how this contextual control is exerted, our conjecture is that it may operate in a relatively local sphere of influence, with recruitment of a prime event on the current trial being affected by prime validity experienced on the immediately preceding one or two trials.

Our objective in building a case for a retrospective account of masked priming has not been to show that this approach is, in some sense, the right one or that an account based on lexical activation or entry opening is necessarily incorrect. After all, it is quite likely that lexical accounts could be modified to provide suitable explanations of many of the phenomena we have reviewed here. For example, Bowers (this volume) has provided an account of masked and long-term priming based on abstract representational codes in which long-term priming transpires through a form of learning (see also Bowers, Damian, & Havelka, 2002). We view this approach as a constructive step in the direction of formulating accounts of priming that acknowledge the sensitivity of knowledge representations to ongoing episodic events.

We see three major advantages to emphasizing the utility of developing a unified, retrospective account of both masked priming and long-term priming of word identification. First, the retrospective framework provides the impetus to examine a number of influences on masked priming more closely than has been done in the past (as in the case of priming of nonwords and the relation between word frequency and masked priming). Second, that framework provides the insight and encouragement necessary to begin an examination of the influence of prime validity on masked priming. We have been able to extend this exploration to three different domains (repetition, semantic, and parity priming) and plan additional extensions as well. Finally, the retrospective framework brings the theoretical and empirical issues that drive word identification research into closer association with a rich body of memory research. We believe that the cultivation of interaction between these domains will enrich both fields and has the potential for fundamentally reshaping how researchers in each area conceptualize and empirically address problems that are of central importance.

Acknowledgement

Preparation of this chapter was supported by research grants from the Natural Sciences and Engineering Research Council of Canada to Michael Masson and to Glen Bodner. We deeply appreciate the lively and enlightening discussions we have had with Ken Forster over the past few years regarding the issues discussed here. We also thank Jeffrey Bowers, Ken Forster, and Sachiko Kinoshita for helpful comments an earlier version of this chapter.

References

Allen, S. W., & Jacoby, L. L. (1990). Reinstating study context produces unconscious influences of memory. Memory & Cognition, 18, 270-278.

Anderson, J. R. (1983). The architecture of cognition. Cambridge, MA: Harvard University Press.

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. Journal of Experimental Psychology: Human Perception and Performance, 10, 340-357.

Becker, S., Moscovitch, M., Behrmann, M., & Joordens, S. (1997). Long-term semantic priming: A computational account and empirical evidence. Journal of Experimental Psychology: Learning, Memory, and Cognition, 23, 1059-1082.

Berent, I., & Perfetti, C. A. (1995). A rose is a REEZ: The two-cycles model of phonology assembly in reading English. Psychological Review, 102, 146-184.

Bodner, G. E., & Masson, M. E. J. (1997). Masked repetition priming of words and nonwords: Evidence for a nonlexical basis for priming. Journal of Memory and Language, 37, 268-293.

Bodner, G. E., & Masson, M. E. J. (2001). Prime validity affects masked repetition priming: Evidence for an episodic resource account of priming. Journal of Memory and Language, 45, 616-647.

Bodner, G. E., & Masson, M. E. J. (2002). Beyond spreading activation: An influence of relatedness proportion on masked semantic priming. Manuscript submitted for publication.

Bowers, J. S. (2000). In defense of abstractionist theories of repetition priming and word identification. Psychonomic Bulletin & Review, 7, 83-99.

Bowers, J. S., Damian, M. F., & Havelka, J. (2002). Can distributed orthographic knowledge support word-specific long-term priming? Apparently so. Journal of Memory and Language, 46, 24-38.

Brysbaert, M. (2001). Prelexical phonological coding of visual words in Dutch: Automatic after all. Memory & Cognition, 29, 765-773.

Challis, B. H. & Roediger, H. L., III. (1993). The effect of proportion overlap and repeated testing on primed word fragment completion. Canadian Journal of Experimental Psychology, 47, 113-123.

Cheesman, J., & Merikle, P. M. (1986). Distinguishing conscious from unconscious perceptual processes.

Canadian Journal of Psychology, 40, 343-367.

Clarke, R., & Morton, J. (1983). Cross-modality facilitation in tachistoscopic word recognition. Quarterly Journal of Experimental Psychology, 35A, 79-96.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. Psychological Review, 82, 407-428.

Dehaene, S., & Cohen, L. (1995). Towards an anatomical and functional model of number processing. Mathematical Cognition, 1, 83-120.

den Heyer, K., & Briand, K. (1986). Priming single digit numbers: Automatic spreading activation dissipates as a function of semantic distance. American Journal of Psychology, 99, 315-340.

Dosher, B. A., & Rosedale, G. (1989). Integrated retrieval cues as a mechanism for priming in retrieval from memory. Journal of Experimental Psychology: General, 118, 191-211.

Duchek, J. T., & Neely, J. H. (1989). A dissociative word-frequency X levels-of-processing interaction in episodic recognition and lexical decision tasks. Memory & Cognition, 17, 148-162.

Dypvik, A. T., & Bodner, G. E. (2001). A Kink in the Number Line: Episodic Contributions to Masked Priming. Paper presented at the 3rd annual Northwest Cognition and Memory Conference, Vancouver, BC, Canada.

Ferrand, L., & Grainger, J. (1996). List context effects on masked phonological priming in the lexical decision task. Psychonomic Bulletin & Review, 3, 515-519.

Ferrand, L., Grainger, J., & Segui, J. (1994). A study of masked form priming in picture and word naming. Memory & Cognition, 22, 431-441.

Feustel, T. C., Shiffrin, R. M., & Salasoo, A. (1983). Episodic and lexical contributions to the repetition effect in word identification. Journal of Experimental Psychology: General, 112, 309-346.

Forster, K. I. (1987). Form priming with masked primes: The best match hypothesis. In M. Coltheart (Ed.), Attention and performance XII (pp. 127-146). Hillsdale, NJ: Erlbaum.

Forster, K. I. (1998). The pros and cons of masked priming. Journal of Psycholinguistic Research, 27, 203-233.

Forster, K. I. (1999). The microgenesis of priming effects in lexical access. Brain and language, 68, 5-15.

Forster, K. I., Booker, J., Schacter, D. L., & Davis, C. (1990). Masked repetition priming: Lexical activation or novel memory trace? Bulletin of the Psychonomic Society, 28, 341-345.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. Journal of Experimental Psychology: Learning, Memory, and Cognition, 10, 680-698.

Forster, K. I., & Davis, C. (1991). The density constraint on form-priming in the naming task: Interference effects from a masked prime. Journal of Memory and Language, 30, 1-25.

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation? Quarterly Journal of Experimental Psychology, 39, 211-251.

Frost, R., Forster, K. I., & Deutsch, A. (1997). What can we learn from the morphology of Hebrew? A masked priming investigation of morphological representation. Journal of Experimental Psychology: Learning, Memory, and Cognition, 23, 829-856.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. Journal of Experimental Psychology: Learning, Memory, and Cognition, 11, 501-518.

Grainger, J., & Ferrand, L. (1994). Phonology and orthography in visual word recognition: Effects of masked homophone primes. Journal of Memory and Language, 33, 218-233.

Grainger, J., & Ferrand, L. (1996). Masked orthographic and phonological priming in visual word recognition and naming: Cross-task comparisons. Journal of Memory and Language, 35, 623-647.

Humphreys, G. W., Evett, L. J., & Taylor, D. E. (1982). Automatic phonological priming in visual word recognition. Memory & Cognition, 10, 576-590.

Jacoby, L. L. (1983a). Perceptual enhancement: Persistent effecs of an experience. Journal of Experimental Psychology: Learning, Memory, and Cognition, 9, 21-38.

Jacoby, L. L. (1983b). Remembering the data: Analyzing interactive processes in reading. Journal of Verbal Learning and Verbal Behavior, 22, 485-508.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. Journal of Experimental Psychology: General, 110, 306-340.

Jacoby, L. L., & Whitehouse, K. (1989). An illusion of memory: False recognition influenced by unconscious perception. Journal of Experimental Psychology: General, 118, 126-135.

Joordens, S., & Becker, S. (1997). The long and short of semantic priming effects in lexical decision. Journal of Experimental Psychology: Learning, Memory, and Cognition, 23, 1083-1105.

Kahneman, D., & Miller, D. T. (1986). Norm theory: Comparing reality to its alternatives. Psychological Review,

93, 136-153.
Kang, H., & Simpson, G. B. (2001). Local strategic control of information in visual word recognition. Memory & Cognition, 29, 648-655.
Kirsner, K., & Speelman, C. (1996). Skill acquisition and repetition priming: One principle, many processes? Journal of Experimental Psychology: Human Learning and Memory, 22, 563-575.
Koechlin, E., Naccache, L., Block, E., & Dehaene, S. (1999). Primed numbers: Exploring the modularity of numerical representations with masked and unmasked semantic priming. Journal of Experimental Psychology: Human Perception and Performance, 25, 1882-1905.
Kolers, P. A. (1975). Memorial consequences of automatized encoding. Journal of Experimental Psychology: Human Learning and Memory, 1, 689-701.
Kolers, P. A. (1976). Reading a year later. Journal of Experimental Psychology: Human Learning and Memory, 2, 554-565.
Kolers, P. A., & Roediger, H. L., III. (1984). Procedures of mind. Journal of Verbal Learning and Verbal Behavior, 23, 425-449.
Kucera, J., & Francis, W. N. (1967). Computational analysis of present day American English. Providence, RI: Brown University Press.
Kunst-Wilson, W. R., & Zajonc, R. B. (1980). Affective discrimination of stimuli that cannot be recognized. Science, 207, 557-558.
Logan, G. D. (1988). Toward an instance theory of automatization. Psychological Review, 95, 492-527.
Logan, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? Cognitive Psychology, 22, 1-35.
Lukatela, G., Frost, S. J., & Turvey, M. T. (1998). Phonological priming by masked nonword primes in the lexical decision task. Journal of Memory and Language, 39, 666-683.
Lukatela, G., & Turvey, M. T. (1994). Visual lexical access is initially phonological. 2. Evidence from phonological priming by homophones and pseudohomophones. Journal of Experimental Psychology: General, 123, 331-353.
Lukatela, G., & Turvey, M. T. (2000). An evaluation of the two-cycles model of phonology assembly. Journal of Memory and Language, 42, 183-207.
MacLeod, C. M., & Masson, M. E. J. (2000). Repetition priming in speeded word reading: Contributions of perceptual and conceptual processing episodes. Journal of Memory and Language, 42, 208-228.
Mandler, G., Nakamura, Y., & van Zandt, B. J. (1987). Nonspecific effects of exposure to stimuli that cannot be recognized. Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, 646-648.
Masson, M. E. J. (1995). A distributed memory model of semantic priming. Journal of Experimental Psychology: Learning, Memory, and Cognition, 21, 3-23.
Masson, M. E. J., & Isaak, M. I. (1999). Masked priming of words and nonwords in a naming task: Further evidence for a nonlexical basis for priming. Memory & Cognition, 27, 399-412.
Masson, M. E. J., & MacLeod, C. M. (1992). Reenacting the route to interpretation: Enhanced perceptual identification without prior perception. Journal of Experimental Psychology: General, 121, 145-176.
McKoon, G., & Ratcliff, R. (1995). Conceptual combinations and relational contexts in free association and in priming in lexical decision and naming. Psychonomic Bulletin & Review, 2, 527-533.
Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. Journal of Experimental Psychology, 90, 227-234.
Meyer, D. E., Schvaneveldt, R. W., & Ruddy, M. G. (1975). Loci of contextual effects on visual word-recognition. In P. M. A. Rabbitt & S. Dornic (Eds.), Attention and performance V (pp. 98-118). New York: Academic Press.
Micco, A., & Masson, M. E. J. (1991). Implicit memory for new associations: An interactive process approach. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 1105-1123.
Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer-appropriate processing. Journal of Verbal Learning and Verbal Behavior, 16, 519-533.
Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen model. In P. A. Kolers, M. E. Wrolstad, & H. Bouma (Eds.), Processing of visible language (Vol. 1, pp. 259-268). New York: Plenum.
Musen, G., & Squire, L. R. (1991). Normal acquisition of novel verbal information in amnesia. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 1095-1104.
Musen, G., & Treisman, A. (1990). Implicit and explicit memory for visual patterns. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 127-137.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. Journal of Experimental Psychology: General 106, 226-254.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), Basic processes in reading: Visual word recognition (pp. 264-336). Hillsdale, NJ: Erlbaum.

Neely, J. H., & Keefe, D. E. (1989). Semantic context effects on visual word processing: A hybrid prospective/retrospective processing theory. In G. H. Bower (Ed.), The psychology of learning and motivation: Advances in research and theory (Vol. 24, pp. 207-248). New York: Academic Press.

Norris, D. (1984). The effects of frequency, repetition, and stimulus quality in visual word recognition. Quarterly Journal of Experimental Psychology, 36A, 507-518.

Perfetti, C. A., & Bell, L. C. (1991). Phonemic activation during the first 40 ms of word identification: Evidence from backward masking and priming. Journal of Memory and Language, 30, 473-485.

Rajaram, S., & Neely, J. H. (1992). Dissociative masked repetition priming and word frequency effects in lexical decision and episodic recognition tasks. Journal of Memory and Language, 31, 152-182.

Ratcliff, R., & McKoon, G. (1988). A retrieval theory of priming in memory. Psychological Review, 95, 385-408.

Ratcliff, R., & McKoon, G. (1994). Retrieving information from memory: Spreading-activation theories versus compound-cue theories. Psychological Review, 101, 177-184.

Ratcliff, R., & McKoon, G. (1997). A counter model for implicit priming in perceptual word identification. Psychological Review, 104, 319-343.

Ratcliff, R., McKoon, G., & Verweord, M. (1989). A bias interpretation of facilitation in perceptual identification. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 378-387.

Ratcliff, R., Van Zandt, T., & McKoon, G. (1999). Connectionist and diffusion models of reaction time. Psychological Review, 106, 261-300.

Reynvoet, B., & Brysbaert, M. (1999). Single-digit and two-digit Arabic numerals address the same semantic number line. Cognition, 72, 191-201.

Roediger, H. L., III, & Blaxton, T. A. (1987). Effects of varying modality, surface features, and retention interval on priming in word fragment completion. Memory & Cognition, 15, 379-388.

Scarborough, D. L., Cortese, C., & Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. Journal of Experimental Psychology: Human Perception and Performance, 3, 1-17.

Seamon, J. G., Marsh, R. L., & Brody, N. (1984). Critical importance of exposure duration for affective discrimination of stimuli that are not recognized. Journal of Experimental Psychology: Learning, Memory, and Cognition, 10, 465-469.

Segui, J., & Grainger, J. (1990). Priming word recognition with orthographic neighbors: Effects of relative prime-target frequency. Journal of Experimental Psychology: Human Perception and Performance, 16, 65-76.

Sereno, J. A. (1991). Graphemic, associative, and syntactic priming effects at a brief stimulus onset asynchrony in lexical decision and naming. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 459-477.

Shelton, J. R., & Martin, R. C. (1992). How semantic is automatic semantic priming? Journal of Experimental Psychology: Learning, Memory, and Cognition, 18, 1191-1210.

Smith, M. C., Besner, D., & Miyoshi, H. (1994). New limits to automaticity: Context modulates semantic priming. Journal of Experimental Psychology: Learning, Memory, and Cognition, 20, 104-115.

Smith, S. M., & Vela, E. (2001). Environmental context-dependent memory: A review and meta-analysis. Psychonomic Bulletin & Review, 8, 203-220.

Stolz, J. A., & Neely, J. H. (1995). When target degradation does and does not enhance semantic context effects in word recognition. Journal of Experimental Psychology: Learning, Memory, and Cognition, 21, 596-611.

Strayer, D. L., & Kramer, A. F. (1994). Strategies and automaticity: II. Dynamic aspects of strategy adjustment. Journal of Experimental Psychology: Learning, Memory, and Cognition, 20, 342-365.

Taylor, T. E., & Lupker, S. J. (2001). Sequential effects in naming: A time-criterion account. Journal of Experimental Psychology: Learning, Memory, & Cognition, 27, 117-138.

Tenpenny, P. L. (1995). Abstractionist versus episodic theories of repetition priming and word identification. Psychonomic Bulletin & Review, 2, 339-363.

Toth, J. P., Reingold, E. M., & Jacoby, L. L. (1994). Toward a redefinition of implicit memory: Process dissociation following elaborative processing and self-generation. Journal of Experimental Psychology: Learning, Memory, and Cognition, 20, 290-303.

Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 8, 336-342.

Weldon, M. S. (1991). Mechanisms underlying priming on perceptual tests. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 526-541.

Whittlesea, B. W. A., & Jacoby, L. L. (1990). Interaction of prime repetition with visual degradation: Is priming a retrieval phenomenon? Journal of Memory and Language, 29, 546-565.

Whittlesea, B. W. A., & Price, J. R. (2001). Implicit/explicit memory versus analytic/nonanalytic processing: Rethinking the mere exposure effect. Memory & Cognition, 29, 234-246.