

Isolating Retrospective Priming Processes Using Relatedness Proportion Manipulations

by


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B.A. (Honours), University of Winnipeg, 1994


A Thesis Submitted in Partial Fulfillment of the  
Requirements for the Degree of


MASTER OF SCIENCE


in the Department of Psychology

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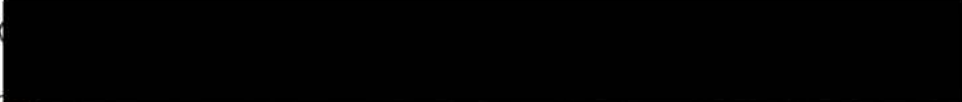
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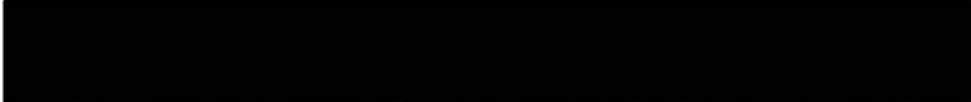
### ABSTRACT


Semantic priming is commonly thought to reflect the contributions of spreading activation and expectancy processes, both of which operate before target presentation. However, retrospective processes operating after target presentation can also contribute to priming effects. The contributions of these latter processes were assessed in the context of relatedness proportion (RP) manipulations in which the proportion of related-prime trials in the stimulus list was varied. In both lexical decision and word reading tasks, semantic priming is typically greater for subjects receiving a high-RP than for subjects receiving a low-RP, leading some researchers to claim that high-RP subjects are more likely to generate expectancies about the upcoming target. To test this claim, RP x Priming interactions were sought under conditions where their presence could be attributed to a retrospective mechanism but not to expectancy. In Experiments 1 and 2, the contributions of expectancy were controlled by a novel within-subject manipulation of RP in the lexical decision task. In Experiment 3, the effects of expectancy were limited by using a short 240-ms SOA in the word reading task. Finally, Experiment 4 examined the effect of the proportion of identity-prime trials on masked repetition priming in the lexical decision task, where masking eliminates expectancy. The results provide some support for an episodic retrieval account in which subjects retrospectively retrieve priming episodes to help guide target processing. Further experiments to help clarify these results are suggested.

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## Dedication

This work is dedicated to my mother, Cheryl Bodner.

## Introduction

Semantic priming refers to the finding that responses to a target word (e.g., music) are facilitated if the target is preceded by a meaningfully-related word prime (e.g., radio) rather than by an unrelated word prime (e.g., truck). This effect is often attributed to the operation of prospective processes such as automatic spreading activation and/or expectancy (e.g., Becker, 1980; Collins & Loftus, 1975; Neely & Keefe, 1989; Posner & Snyder, 1975). By contrast, the present experiments test the claim that a retrospective process that operates after target presentation plays at least as important a role in producing semantic priming effects (e.g., Balota & Lorch, 1986; de Groot, 1984; Norris, 1986; Ratcliff & McKoon, 1988; Whittlesea & Jacoby, 1990). To test this claim, experimental paradigms are employed in which the effectiveness of prospective processes is controlled or eliminated, leaving only a retrospective process to produce an effect that is often attributed to expectancy.

The specific effect of interest is the relatedness proportion (RP) effect, the finding that priming increases as the proportion of experimental trials with meaningfully-related prime-target pairs increases (e.g., de Groot, 1984; den Heyer, 1985; den Heyer, Briand, & Dannenbring, 1983; Seidenberg, Waters, Sanders, & Langer, 1984; Tweedy, Lapinski, & Schvaneveldt, 1977). When two groups of subjects are compared, this effect appears as a RP x Priming interaction with more priming occurring for a high-RP group than for a low-RP group. Depending on the task, this effect has been partially (Neely, Keefe, & Ross, 1989) or completely (Keefe & Neely, 1990) attributed to greater use of expectancy by subjects in the high-RP group. The current experiments test whether a retrospective process alone could also produce this interaction.

To this end, the first two experiments rely on a novel within-subjects manipulation of RP which controls the influence of expectancy on high-RP and low-RP items, leaving only a retrospective process to produce a RP x Priming interaction. In the latter two experiments, the interaction is sought where expectancy is eliminated by reducing the prime-target SOA and/or by masking the primes. If the interactions are found, then the operation of a retrospective process would be supported and the need to postulate a strategic expectancy process would be questioned. Before the logic of the experiments is elaborated, however, the traditional prospective and retrospective processes are described, and the literature on RP effects is introduced (see Neely, 1991, for an extensive review).

### Prospective Processes in Semantic Priming

Two processes have been hypothesized to operate following prime presentation and before target presentation. The first process, automatic spreading activation, relies on the notion that memory consists of a web-like array of linked nodes, each node

corresponding to a known concept or word (e.g., Collins & Loftus, 1975; Neely, 1977; Posner & Snyder, 1975). In this web, links between concepts are shorter (or stronger) for related concepts than for unrelated concepts. Presentation of a prime word automatically causes activation in the prime's node to spread to related nodes in the network, including the node for an upcoming related target. Semantic priming results because less activation and hence time is required to reach recognition threshold in preactivated/related target nodes than in unactivated/unrelated target nodes.

Despite its widespread influence, the metaphor of spreading activation cannot by itself account for many priming phenomena (Neely, 1991, p. 298-299). For example, because it occurs automatically, spreading activation should be insensitive to RP, yet RP x Priming effects are commonly observed (e.g., de Groot, 1984; den Heyer, 1985; den Heyer et al., 1983; Seidenberg et al., 1984; Tweedy et al., 1977). Additionally, spreading activation cannot explain certain priming phenomena that occur in the lexical decision task, such as backward priming (e.g., Koriat, 1981; Seidenberg et al., 1984). In backward priming, the prime is related to the target only in the backward direction (e.g., hop-bell), so that activation would not be expected to spread from the prime node to the target node. Because the focus of the present experiments is RP x Priming interactions that are not explained by this process, spreading activation will not be discussed in much detail here.

A second prospective process, expectancy, has been hypothesized either in addition to spreading activation (e.g., Posner & Snyder, 1975) or in place of it (e.g., Becker, 1980). Unlike spreading activation, this process is thought to be under subjects' strategic control. The basic idea is that if subjects notice that primes and targets are often related, they will adopt a strategy of using the prime (e.g., winter) to derive an expectancy set of potential targets (e.g., snow, cold, summer) before the target is presented. On Becker's (1980) account, for example, items in the expectancy set are matched against a visual representation of the target when it is presented. Priming occurs if the target matches an item in the expectancy set because a response can be made immediately, without having to search the visually defined set that is serially being constructed for the target. If the target is not in the expectancy set, as is the case on unrelated prime trials, then the visually-defined set is searched once it has been constructed, thus slowing responses.

Expectancy accounts for some of the data that are problematic for the spreading activation process. In particular, the RP x Priming interaction can be explained by arguing that subjects are more likely to strategically generate an expectancy set as RP increases. However, even in combination with spreading activation expectancy does not account for backward priming effects in the lexical decision task, since the expectancy set

would not likely contain the target (e.g., Koriat, 1981; Seidenberg et al., 1984). Other priming phenomena are also problematic for expectancy (see Neely, 1991, p. 304-306).

### Retrospective Processes in Semantic Priming

Empirical demonstrations such as backward priming suggest that priming is also influenced by a process that occurs after presentation of the target. In fact, many researchers have postulated a retrospective process as a partial account (e.g., Balota & Lorch, 1986; de Groot, 1984; Neely & Keefe, 1989) or complete account of semantic priming effects (e.g., Norris, 1986; Ratcliff & McKoon, 1988; Whittlesea & Jacoby, 1990). For example, Ratcliff and McKoon's (1988) compound cue model contains a unique retrospective process in which the prime and target are combined into a compound cue in short-term memory. A familiarity value for the compound cue is computed based on the number of long-term memory traces containing either or both cue members. Semantic priming occurs because related prime-target pairs receive higher familiarity ratings than unrelated prime-target pairs, and higher familiarity speeds responses. The compound cue model accounts for backward priming easily, since the order of members in the compound is assumed to be irrelevant in the computation of familiarity. On the negative side, this model was proposed for binary decision tasks such as lexical decision, and therefore does not provide an explanation for priming effects in the word reading task where responses cannot be based on familiarity alone. Moreover, Neely (1991, p. 311-312) argues that several other priming phenomena are problematic for the compound cue model, including the RP x Priming interaction, unless a strategic process that regulates the setting of familiarity criteria is added to the model. Additional retrospective processes are introduced below.

### Neely and Keefe's (1989) Three-Process Account

Perhaps a better account of semantic priming would incorporate both prospective and retrospective processes. This is the approach taken by Neely and Keefe (1989; Keefe & Neely, 1990; Neely, 1991; Neely et al., 1989) who cobbled together a three-process account of semantic priming incorporating two prospective processes, spreading activation and expectancy, and one retrospective process, semantic-matching. Like expectancy, semantic matching is a strategically deployed process. Semantic matching becomes useful to subjects if they notice that primes and targets are often related. If this occurs, subjects can learn to make accurate lexical decisions based solely on whether they detect a semantic match between the prime and target. The detection of any relationship correctly biases a word response, while the lack of a relationship will bias a nonword response which will slow responses on unrelated trials, thus producing priming. Note that because semantic matching occurs after the target is presented, it naturally explains

backward priming (e.g., Koriat, 1981; Seidenberg et al., 1984). Semantic matching thus helps account for the different patterns of priming effects found in lexical decision and word reading tasks. According to Neely and colleagues, semantic matching is not used in the word reading task because simply detecting a prime/target relationship does not help provide the subject with a naming response for the target. Therefore, these researchers argue that priming effects in the word naming task are produced solely by prospective processes. Although it cannot explain all priming phenomena (see Neely, 1991, p. 320-321), Neely argues that the three-process account is the most complete account of semantic priming. This assertion followed studies of the important priming phenomenon described next.

### Relatedness Proportion Effects

Tweedy et al. (1977) were the first to report an effect of a manipulation of RP on semantic priming in the lexical decision task. Recall that RP is computed as the proportion of word-target trials in the experiment where the prime is meaningfully-related to the target. Semantic priming effects in the Tweedy et al. study increased linearly as RP increased from .13 to .50 to .88. Tweedy and Lapinski (1981) confirmed that this effect was due to strategic factors, rather than spreading activation, since subjects' priming effects varied in accordance with whether prime/target pairs in the first block of trials were always related or never related (i.e., a RP of 1.0 or 0). There should have been no effect of RP if spreading activation alone produced priming, because activation should spread identically, independent of RP (e.g., Fischler, 1977). Several lexical decision experiments have now replicated RP x Priming interactions at SOAs longer than 500-ms (e.g., Bushell, 1996; de Groot, 1984, den Heyer, 1985; den Heyer et al., 1983; Seidenberg et al., 1984; Stolz & Neely, 1995). The lack of RP x Priming interactions at short SOAs has been taken as an indication that strategic processes such as expectancy are absent (e.g., den Heyer et al, 1983; Neely, 1991; Stolz & Neely, 1995). However, two lexical decision studies using SOAs of 240-ms have revealed RP x Priming interactions (de Groot, 1984; Henik, Friedrich, Tzelgov, & Tramer, 1994). Finally, although Seidenberg et al. (1984) failed to find the interaction in the word reading task, subsequent studies with stronger RP manipulations have revealed RP x Priming interactions at SOAs of 500-ms or greater (Burt, Mardle, & Humphreys, 1996; Keefe & Neely, 1990).

Although it is a received idea that strategic processes promote priming effects, there is less agreement as to whether RP has its effect through expectancy alone or in combination with a retrospective process such as semantic matching (e.g., Balota & Lorch, 1986; de Groot, 1984; Neely & Keefe, 1989). According to Neely and Keefe (1989), whether semantic matching contributes to the RP effect in the lexical decision

task depends on the nonword ratio -- the number of nonword target trials divided by the number of trials in which primes and targets are not related (i.e., nonword trials + unrelated trials). In stimulus lists containing equal numbers of word and nonword targets, the nonword ratio and RP are confounded: stimulus lists with higher RPs also have higher nonword ratios. Semantic matching is argued to be more likely to be strategically employed by subjects as the nonword ratio increases because the failure to detect a prime/target relation becomes a more accurate indicator that the target is a nonword.

To test this notion, Neely et al. (1989) conducted a lexical decision experiment that unconfounded RP and nonword ratio by manipulating the number of nonword target trials across stimulus lists with different RPs. Category name primes (e.g., bird) and low- and high-dominance exemplar targets (e.g., vulture vs. robin) were used, under the assumption that the expectancy sets are more likely to contain, and hence produce priming for, high-dominance rather than low-dominance targets. In contrast, according to Neely et al. the retrospective semantic matching process should produce equivalent priming for high- and low-dominance targets. As predicted, Neely et al. found dissociable effects of RP and nonword ratio, which they interpreted as follows: Increased RP increased the use of expectancy, since high-dominance targets were facilitated more than low-dominance targets, while increased nonword ratio increased the use of semantic matching, since high- and low-dominance targets were equally facilitated. Neely et al. (1989) concluded that RP x Priming interactions in the lexical decision task are produced by the operation of both expectancy and semantic matching when RP and nonword ratio are confounded.

Using the same materials, Keefe and Neely (1990) provided evidence that expectancy alone modulates the RP x Priming interaction in the word reading task. In this task, the interaction was observed only for high-dominance targets, consistent with the operation of expectancy. Semantic matching was presumed not to be operating in this task for two reasons. First, nonwords were not used and hence there was no nonword ratio, which modulates the use of semantic matching. Second, semantic matching has no utility for subjects in the word reading task, since simply detecting a semantic relation between a prime and a target cannot help facilitate naming responses. Hence, the RP x Priming interaction in the word reading task was attributed solely to expectancy.

### An Episodic Retrieval Account

According to Neely (1991), both prospective and retrospective processes are needed to account for the collection of semantic priming phenomenon demonstrated over the last twenty years. Clearly the three-process account predicts the complicated pattern of results obtained using category materials (Keefe & Neely, 1990; Neely et al., 1989).

However, Neely et al. (1989) give few compelling reasons why they expect semantic-matching would equally facilitate responses to low- and high-dominance targets. One could instead argue that since Neely et al.'s high-dominance targets were also more frequent than their low-dominance targets, that the former would be processed faster and hence be ready earlier for semantic matching with the prime. Moreover, there may be a greater overlap in meaning between category primes and the high-dominance targets, allowing a prime-target relationship to be detected faster for these targets.

In any case, it is clear that by hypothesizing more mechanisms one can account for more data. Indeed, Neely himself notes that the three-process account "may seem overly complicated and too redundant in that many priming effects are predicted by at least two of its processes" (Neely, 1991, p. 322). Although Neely goes on to argue that such redundancy may be "biologically useful" and that the account has "good heuristic value," it seems reasonable to question whether the complexity of the three-process account is truly warranted. The rationale of the present experiments was thus to more stringently test whether three processes are necessary to explain semantic priming in the context of RP manipulations, or whether a single retrospective process might suffice.

A viable single-process model is embodied in the episodic retrieval account (Bodner & Masson, in press). On this account, priming effects can occur retrospectively through a mechanism that retrieves the episodic traces of primes in order to aid target processing (e.g., Bodner & Masson, in press; Masson & Isaak, 1997; Whittlesea & Jacoby, 1990). The basic idea is that the word recognition system may be designed to retrieve context in order to facilitate processing of the current item, just as surrounding words in a sentence can be used to help process the current word in a sentence. For example, Whittlesea and Jacoby (1990) found that priming was greater when an related interpolated word was visually unfamiliar (e.g., GREEN-pLaNt-GREEN) than when it was visually familiar (e.g., GREEN-PLANT-GREEN). They argued that the unfamiliar format made processing the interpolated word more difficult, forcing the priming episode of the first occurrence of GREEN to be "brought forward" to aid processing of the interpolated word. When the interpolated word was presented in a familiar format, less use of the priming episode for the first occurrence of GREEN was made during processing of the *interpolated word, thus reducing priming effects.*

As described in Experiment 4, an episodic retrieval process is also supported by the finding of masked repetition priming for nonwords (Bodner & Masson, in press). Under masked conditions, where strategic processes cannot operate, nonword responses can be facilitated by retrieval of the orthographically-based episode constructed for a masked repetition prime. However, the retrieval of such episodes would not produce semantic

priming, since targets usually have no more orthographic overlap with related primes than with unrelated primes. Instead, the episodic retrieval proponents must posit that the longer SOAs used in most semantic priming studies allow more semantic information to be encoded into the priming episode. When the target is presented, the priming episode is retrieved, and the semantic information contained in the trace produces priming in lexical decision and word reading tasks. For lexical decisions, priming occurs either because the shared semantic overlap between the prime and target signifies that the target is a word (as with semantic matching), or because the semantic information contained in the retrieved priming episode helps cue other relevant information about the target. The latter description provides an explanation for semantic priming effects in the word reading task. Moreover, these two different uses of retrieved priming episodes can account for the different patterns of priming effects sometimes found in these two tasks.

To examine the relative influence of retrospective processes in producing the RP x Priming interaction, paradigms must enable the contributions of a retrospective process, such as semantic matching or episodic retrieval, to be isolated from the potential effects of prospective processes, particularly expectancy. This goal was approached two ways in the current experiments. The first pair of experiments manipulated RP within subjects while controlling for the selective influence of expectancy on low- and high-RP items. The second pair of experiments isolated the effects of a retrospective process more directly using between-subject manipulations of RP in which expectancy was eliminated by using briefly-presented semantic primes (Experiment 3) or briefly-presented and masked repetition primes (Experiment 4). Thus, the present set of experiments sought to demonstrate priming effects that were sensitive to the proportion of related- or repetition-primed trials, while expectancy was controlled (Series 1) or eliminated (Series 2). Such results would provide justification for the claim that a retrospective process alone can account for an effect that is typically at least partially attributed to expectancy.

#### Series 1: Experiments Controlling Expectancy

A within-subjects manipulation wherein the RP differs depending on the target's location provides a novel way to control the effects of spreading activation and expectancy, leaving only a retrospective process to produce the RP x Priming interaction typically found in between-subjects designs. In this paradigm, all primes appear in the center of the computer screen. In Experiment 1, half the targets subsequently appear in a box just above the prime location, and the other half appear in a box just below the prime location. In Experiment 2, left and right boxes are used. Furthermore, half the targets presented at each location are words and half are nonwords. Thus, following the prime's presentation, the target is equally likely to appear in either target location, and is equally

likely to be a word or a nonword. The key manipulation in the within-subjects group is that the prime is related to the word target on 80% of the trials at one target location, but is related to the word target on only 20% of the trials at the other target location. The rest of the word targets at each target location are preceded by unrelated primes. This design thus creates a high-RP location and a low-RP location. Although other studies have varied RP within subjects across testing sessions (Bushell, 1996) or across blocks of trials (Tweedy & Lapinski, 1981), these experiments are the first to manipulate RP randomly across trials within subjects.

In addition to providing increased power, a within-subject manipulation of RP is potentially very useful for isolating the processes producing RP x Priming interactions. If larger priming effects are observed for targets in the high-RP location, any account that postulates only prospective processes runs into trouble. Activation should spread to the same extent regardless of where the upcoming target appears, so priming effects at the two target locations should not differ. More importantly, because all primes are presented in the center of the screen, and because subjects cannot know in advance where the target will appear, subjects must generate expectancies to the same extent for targets that subsequently appear at one of the two RP locations. Therefore, this paradigm prohibits expectancy from prospectively contributing to a RP x Priming interaction. In this way, the strategic effects of expectancy are controlled, leaving only a retrospective process to produce this interaction within subjects.

Neely and Keefe's (1989) semantic matching process could account for this within-subject RP x Priming interaction in the lexical decision task, if semantic matching is more likely to be engaged at the high-RP/nonword-ratio location than at the low-RP/nonword-ratio location. The episodic retrieval process could also account for this interaction, by appealing to the idea that subjects are more likely to rely on the priming episode when targets appear in the high-RP as compared to the low-RP location. Both processes produce the interaction through the greater use detection and influence on responses of an *overlap in meaning between primes and targets at the high-RP location*. To foreshadow a bit, these two processes are subsequently contrasted in Series 2, where episodic retrieval but not semantic matching predicts a RP x Priming interaction in a word reading task at a short SOA that curbs the generation of expectancies (e.g., Keefe & Neely, 1990; Neely, 1991; Neely & Keefe, 1989).

Experiments 1 and 2 thus test whether a RP x Priming interaction obtains within subjects. In doing so, they also provide a critical test of whether the differential influence of an expectancy process is necessary, or whether a retrospective process alone could produce this interaction. In the RP-within group only a retrospective mechanism can

produce a RP x Priming interaction. Importantly though, note that this interaction will only be observed if subjects are able to differentially control their episodic retrieval or semantic matching processes at the high-RP and low-RP locations.

### Experiment 1

In Experiment 1, the RP x Priming interaction obtained in a novel within-subject RP manipulation was compared to that obtained in a more typical between-subject RP manipulation. In this paradigm, all primes appeared in the center of the screen, and targets equally often appeared in a location above and a location below the prime location. In the within-subject RP design, the RP was .2 at the low-RP location, and .8 at the high-RP location, and the high-RP location (top vs. bottom) was counterbalanced across subjects. In the between-subject RP design, the low-RP group received a RP of .2 at each target location, while the high-RP group received a RP of .8 at each target location. The RP-between groups provided a check of whether the usual between-groups RP x Priming interaction obtains when more than one target location is used. Expectancy might produce a between-subjects RP x Priming interaction if subjects in the high-RP group are more likely to use the prime to generate expectancies about the upcoming target. In the RP-within group, however, subjects must strategically generate expectancies to the same extent for targets appearing in either location, so only a retrospective process could produce an interaction here. As in Stolz and Neely (1995), an 800-ms prime-target SOA was used since RP effects are more commonly observed at longer SOAs than at shorter SOAs (e.g., den Heyer et al., 1983; Stolz & Neely, 1995).

As is typical of RP experiments, this design confounded RP and nonword ratio. The high-RP location had the higher nonword ratio (.83), while the low-RP location had the lower nonword ratio (.56). By reducing the number of nonword trials in the high-RP location, the nonword ratios could have been controlled, allowing an examination of the isolated effects of RP on priming. However, a pilot experiment suggested that decreasing the number of nonwords can bias subjects toward making a word response to high-RP targets, which likely affects the observed priming effects. Moreover, since the central goal of Series 1 was to test whether a prospective expectancy process must be able to operate differentially to obtain the RP x Priming interaction, RP and nonword ratio were left confounded. Experiments 3 and 4 provide ways of contrasting the retrospective semantic matching and episodic retrieval processes.

### Method

#### Subjects

There were 10 subjects in each of the two RP-between groups and 20 subjects in the RP-within group. Except where noted, subjects were undergraduate students at the

University of Victoria who participated for extra credit in an introductory psychology course. The median age of the subjects in these experiments ranged from 18 to 22 years. No subject took part in more than one of the experiments reported here.

### Materials and design

The targets were 270 words and 270 pronounceable nonwords of 3-8 letters in length. Twenty of each target type were used as practice items. The frequency of occurrence of the word targets ranged from 1 to 2216 (mean = 91, SD = 206; Kucera & Francis, 1967). A unique semantically-related and/or associatively-related prime of 3-9 letters in length was selected for each word target. Unrelated primes for words were selected by repairing the related primes between blocks so that each word target had a dedicated unrelated prime. For nonword targets, the primes were additional words of similar mean length and frequency as the word primes. The materials are provided in the Appendix.

The critical words were divided into ten blocks of 25 items. Blocks of targets were paired with related or unrelated primes according to the RP condition so that each block of targets appeared with related primes as frequently as the RP indicated (e.g., 80% of the time for the high-RP-between group). For each subject, the critical and practice nonword/prime pairs were randomly assigned so that half the pairs appeared at each target location. Practice word targets had unique related and unrelated primes, while practice nonword targets had unique word primes. Primes for the practice word targets were paired as with the blocks of critical word targets, so that the RP of the practice trials matched the RP of the critical trials. Within the practice and critical lists the word and nonword items were randomly mixed. Finally, for the RP-within group, the high-RP location was the top location for half the subjects and the bottom location for the remaining subjects.

In the between-subject design, the high-RP group saw 16 related and 4 unrelated practice items and 100 related and 25 unrelated critical items at each target location, while the low-RP group saw the reverse proportions at each target location. The RP was thus .8 at each target location for the high-RP group, and .2 at each target location for the low-RP group. In the within-subject design, subjects were presented with 16 related and 4 unrelated practice items and 100 related and 25 unrelated critical items at the high-RP location, while the proportions were reversed at the low-RP location. Subjects in the RP-within group thus received an RP of .5 overall: .8 at one location and .2 at the other location.

### Procedure

Subjects were tested individually. Instructions and trials were presented in black 12-point courier font against a white background on a monochrome monitor attached to a

Macintosh II computer. Stimulus displays were synchronized with the raster scan cycle of the monitor to permit exact timing in increments of 15-ms. Subjects were told that they would be seeing a series of events, each event consisting of two items, and that they should pay attention to the first item, then decide whether the second item was a word or not. The prime was shown in lowercase letters in the center of the screen for 240-ms followed by an blank ISI of 560-ms, for an overall prime-target SOA of 800-ms.

Following the ISI, the target was presented in uppercase letters in a box above or a box below where the prime was presented. The approximately 4 cm x 1 cm rectangular boxes were located above and below the 1 cm space where the primes were shown. Subjects were correctly told that the second item was equally likely to appear in either location and was equally likely to be a word or a nonword. Once the target appeared, subjects were to make a lexical decision as quickly and as accurately as possible by pressing one of two labeled keys on a key pad. Subjects used their right hand to press the YES key if the target was a word and their left hand to press the NO key if the target was not a word. To encourage effortful responding, the opening instructions correctly told subjects they would be shown a summary of their performance at the end of the experiment.

A corrective feedback message appeared on the screen, and a beep sounded, on trials where the subject made an incorrect response ("INCORRECT RESPONSE" for 1 sec) or took too long to respond ("TOO SLOW" for 1 sec, for responses slower than 2 sec). The next trial began 500-ms after a correct response or corrective feedback. Following the 40 practice trials, a message came on the screen encouraging subjects to ask for clarification if they were unclear about the task. Otherwise, they pressed a key and began the critical trials. Self-paced rest breaks were provided after every 50 of the 500 critical trials. The experiment took approximately 30 minutes for each subject to complete.

### Results

In all experiments, the type I error rate was .05, and p-values are reported for all marginal effects. Also, mean reaction times (RTs) and percent error rates were computed for each subject by averaging over items. Separate analyses of variance (ANOVAs) were performed on the RTs and error rates for word and nonword targets. In this experiment, trials with RTs shorter than 300-ms or longer than 3500-ms were deleted. This trimming resulted in a loss of 22 of 20,000 trials (0.1%) across all the subjects tested, within the 0.5% ceiling recommended by Ulrich and Miller (1994). The results from the benchmark between-groups RP design are reported first, followed by the results from the novel within-subjects RP design.

#### RP-between groups

The results for word and nonword targets are reported separately. For word targets, RTs and error rates were analyzed in separate ANOVAs with target location (top box vs. bottom box), priming (related vs. unrelated), and RP (low vs. high) as the factors. For nonword targets, RT and error rates were analyzed in separate ANOVAs with target location (top box vs. bottom box) and RP (low vs. high) as the factors. Target location and priming were within-subjects factors, while RP was a between-subjects factor.

Word Targets. For each RP-between group at each target location (and overall), the top half of Table 1 shows the means and standard deviations for subjects' RTs and error rates for each type of prime as well as the corresponding priming effect.

Table 1

Mean Reaction Times (RT, in ms), Error Percentages (%E), and Priming Effects for Words in Experiment 1

Condition	Related prime		Unrelated prime		Priming effect	
	RT	%E	RT	%E	RT	%E
RP-between						
Low RP						
Top Box	727 (82)	2.0 (2.8)	736 (48)	2.7 (2.3)	9 (44)	0.7 (2.2)
Bottom Box	775 (73)	2.4 (2.8)	794 (56)	4.0 (2.1)	19 (39)	1.6 (3.1)
Overall	751 (79)	2.2 (2.8)	765 (59)	3.4 (2.2)	14 (34)	1.2 (1.7)
High RP						
Top Box	590 (77)	4.5 (4.0)	627 (96)	11.2 (6.5)	37 (46)	6.7 (5.5)
Bottom Box	640 (79)	7.3 (7.0)	685 (89)	12.4 (8.9)	45 (33)	5.1 (7.0)
Overall	615 (80)	5.9 (5.7)	656 (95)	11.8 (7.6)	42 (28)	5.9 (4.5)
RP-within						
Low RP						
High RP Top	698 (71)	3.2 (4.1)	729 (80)	5.0 (2.5)	31 (39)	1.8 (2.7)
High RP Bottom	697 (67)	4.4 (4.0)	755 (67)	5.2 (3.1)	58 (25)	0.8 (3.8)
Overall	698 (67)	3.8 (4.0)	742 (73)	5.1 (2.8)	45 (35)	1.3 (3.3)
High RP						
High RP Top	632 (54)	2.4 (2.7)	661 (62)	7.2 (5.6)	29 (40)	4.8 (6.4)
High RP Bottom	757 (69)	3.3 (2.5)	797 (95)	6.4 (5.0)	40 (52)	3.1 (4.2)
Overall	695 (88)	2.9 (2.6)	729 (105)	6.8 (5.2)	34 (45)	4.0 (5.4)

Note: Standard deviations are in parentheses.

To begin, there was an unexpected main effect of target location,  $F(1, 18) = 17.66$ ,  $MSe = 3,280$ , in which targets in the top box were responded to 54-ms faster than targets in the bottom box. This advantage for the top box fortunately did not interact with RP, priming, or both, all  $F_s < 1$ . The high-RP group was 123-ms faster than the low-RP group independent of the target location or prime type, producing a main effect of RP,  $F(1, 18) = 16.30$ ,  $MSe = 18,477$ . The 28-ms advantage for related over unrelated primes produced a significant main effect of priming,  $F(1, 18) = 15.18$ ,  $MSe = 1,006$ . Critically, however, the 28-ms difference between priming effects for the low- and high-RP groups approached but did not reach significance,  $F(1, 18) = 3.72$ ,  $MSe = 1,006$ ,  $p = .07$ . This marginal RP x Priming interaction was followed up in separate two-factor repeated measures ANOVAs for the low- and high-RP groups, with priming and target location as the factors. For the low-RP group, the 14-ms priming effect was not reliable,  $F(1, 9) = 1.63$ ,  $MSe = 1,191$ ,  $p = .23$ , whereas the 42-ms priming effect for the high-RP group was reliable,  $F(1, 9) = 20.78$ ,  $MSe = 821$ ,  $p = .001$ .

The same three-factor ANOVA applied to word RTs was also applied to the error rates. The target location variable did not produce a reliable main effect or any interactions, all  $F_s < 2.23$ . There were 6.1% more errors made by the high-RP group than by the low-RP group, producing a main effect of RP that traded-off against their faster overall RTs,  $F(1, 18) = 11.42$ ,  $MSe = 64.50$ . Moreover, 3.5% more errors were made on unrelated than on related prime trials, resulting in a main effect of priming,  $F(1, 18) = 22.29$ ,  $MSe = 11.13$ . Unlike in the RT analysis, the important RP x Priming interaction was significant in the error rates,  $F(1, 18) = 10.05$ ,  $MSe = 11.13$ . Related primes reduced error rates 4.8% more for the high-RP group than for the low-RP group.

Nonword Targets. The top half of Table 2 shows the means and standard deviations for subjects' RT and error rates for targets occurring in the top and bottom boxes (and overall), when the RP for words was high or low (and overall). In the RT and error analyses, only the main effect of RP in the RT analysis was significant,  $F(1, 18) = 20.76$ ,  $MSe = 13,203$ . Responses to nonwords were an impressive 166-ms faster on the average in the high-RP group than in the low-RP group (other  $F_s < 2.30$ ).

#### RP-within group

Having shown that a semantic priming paradigm with two target locations produces the typical between-subjects RP x Priming interaction, at least in the error rate analysis, the effects of manipulating RP within-subjects are now examined. For word targets, separate three factor repeated-measures ANOVAs with high-RP location (top box vs. bottom box), priming (related vs. unrelated), and RP (low vs. high) as the factors were performed on the RT and the error rate data (Table 1, bottom). For nonword targets, RT

and error rates were analyzed in separate mixed-factor ANOVAs with high-RP location (top box vs. bottom box) manipulated between-groups and RP (low vs. high) manipulated within subjects (Table 2, bottom).

Table 2

Mean Reaction Times (RT, in ms) and Error Percentages (%E) for Nonwords in Experiment 1

Condition	Low RP		High RP		Overall	
	RT	%E	RT	%E	RT	%E
RP-between						
Top Box	868 (76)	5.1 (1.3)	712 (98)	7.5 (9.8)	790 (117)	6.3 (6.9)
Bottom Box	887 (72)	3.8 (3.4)	712 (88)	8.4 (11.7)	799 (119)	6.1 (8.7)
Overall	878 (73)	4.5 (2.6)	712 (91)	7.9 (10.5)	795 (116)	6.2 (7.7)
RP-within						
High RP Top	801 (98)	3.1 (1.7)	765 (89)	3.9 (1.0)	783 (92)	3.5 (1.4)
High RP Bottom	879 (119)	3.8 (2.9)	891 (106)	4.7 (2.9)	885 (110)	4.2 (2.9)
Overall	840 (113)	3.4 (2.3)	828 (115)	4.3 (2.1)	834 (112)	3.9 (2.0)

Note: Standard deviations are in parentheses.

Word Targets. In the RT analysis, there was a main effect of high-RP location in which RTs were 72-ms faster when the high-RP location was the top box rather than the bottom box,  $F(1, 18) = 6.24$ ,  $MSe = 16,461$ . The only other reliable effect involving high-RP location was its interaction with RP,  $F(1, 18) = 28.57$ ,  $MSe = 2,449$ . This interaction is equivalent to an effect of target location; responses were 59-ms faster in the top box than in the bottom box. Hence, the high-RP location main effect was likely due to especially fast responses in the top box when the high-RP was in this location. There was no RP main effect,  $F < 1$ , but there was a 39-ms main effect of priming,  $F(1, 18) = 32.07$ ,  $MSe = 966$ . However, the critical within-subjects RP x Priming interaction was not significant,  $F < 1$ . Following Cohen (1988), the power to detect the RP x Priming interaction in the RP-within group was estimated using the size of the RP-between interaction. In the RP-between group comparison, the low-RP priming effect was 33.3% of the high-RP priming effect. In the RP-within group, the .50 power estimate for

detecting a priming effect for the low-RP items 33.3% the size of that found for the high-RP items was not very high (Cohen's  $d = .64$ ).

In the error rate analysis, there were no effects involving the high-RP location variable,  $F_s < 1$ . The main effect of priming was reliable, with 2.6% more errors on unrelated than on related prime trials,  $F(1, 18) = 9.84$ ,  $MSe = 14.06$ . As in the RP-within RT analysis, there was no RP main effect,  $F < 1$ . Unlike the RP-within RT analysis, however, the RP x Priming interaction was reliable in the error rates,  $F(1, 18) = 5.75$ ,  $MSe = 6.11$ . Although subjects made fewer errors following related primes than following unrelated primes for both high-RP and low-RP items, there was significantly more improvement (2.6%) for high-RP items.

Nonword Targets. In the RT analysis, there was a 102-ms advantage for nonwords overall (i.e., in both locations) when the high-RP location was the top rather than the bottom box,  $F(1, 18) = 4.96$ ,  $MSe = 20,843$ . The main effect of RP did not reach significance ( $F < 2.18$ ). The high-RP location x RP interaction was significant,  $F(1, 18) = 9.82$ ,  $MSe = 604$ . This interaction represents a 24-ms advantage for responses in the top over the bottom box. In the error rate analysis, only the main effect of RP approached significance,  $F(1, 18) = 3.41$ ,  $MSe = 2.27$ ,  $p = .08$ , with more errors in the high-RP rather than the low-RP location (other  $F_s < 1$ ).

### Discussion

Manipulating RP between subjects using more than one target location replicated the usual finding of more priming in the high-RP than in the low-RP group (e.g., Bushell, 1996; de Groot, 1984, den Heyer, 1985; den Heyer et al., 1983; Henik et al., 1994; Seidenberg et al., 1984; Stolz & Neely, 1995; Tweedy et al., 1977; Tweedy & Lapinski, 1981). Unlike these studies, however, the RP x Priming interaction was reliable only in the error rates, although it was marginal in the RTs. Given this benchmark, and the fairly low power in the RP-within design, it is not surprising that there was no interaction in the RT analysis for the RP-within group. However, evidence that RP-within subjects were sensitive to the RP manipulation came from the finding of a reliable RP x Priming interaction in the error rates, where related primes reducing errors more for targets in the high-RP than the low-RP location. Because expectancy could not operate selectively to reduce errors in this paradigm, errors should have been equally reduced at each location. This interaction provides some support for the claim that a retrospective process alone, such as semantic matching or episodic retrieval, can produce the RP x Priming interaction that has been taken as proof of the operation of expectancy.

The lack of an interaction in the within-subjects RT analysis was still somewhat surprising. It is possible that favouritism for the top box may have interfered with

subjects' use of priming episodes, which may have decreased the RP x Priming interaction in the RT analysis in both the RP-within and RP-between groups. Although target location did not interact with priming, in all groups priming effects were larger in the bottom box than in the top box. In Experiment 2, a slight change in the procedure was made to try to eliminate the target location effect and therefore boost the RP x Priming interactions in the RT analyses.

Finally, the data from Experiment 1 indicate that responses to nonword targets are affected by the RP of the word targets. Responses to nonwords were faster in the high-RP group than in the low-RP group in the RP-between design. This result is consistent with a retrospective process in which subjects take advantage of the fact that as the RP/nonword ratio increases, the failure to detect a relationship between a prime and a target becomes a more accurate indicator that the target is a nonword. In contrast, by the expectancy process, responses to nonwords should not have been affected by the RP manipulation since the subject could not know in advance whether the target would be a word or a nonword.

## Experiment 2

Experiment 2 was exactly the same as Experiment 1, except targets appeared in a left or right box located just below the prime location, rather than appearing in boxes above and below the prime location. The hope was that left and right boxes would reduce the target location effects seen in Experiment 1, perhaps allowing stronger RP x Priming interactions to emerge in the RT analyses.

### Method

#### Subjects

There were 10 subjects in each of the two RP-between groups and 20 subjects in the RP-within group.

#### Materials, design, and procedure

Experiment 2 was identical to Experiment 1, except that targets now appeared in left and right boxes just below where the prime was shown. The boxes were of the same size as in Experiment 1, and were adjacent with no space in between.

### Results

The data from Experiment 2 were analyzed exactly as in Experiment 1. Deletion of trials with RTs shorter than 300-ms or longer than 3500-ms resulted in a loss of 11 of the 20,000 trials (0.06%) across the 40 subjects.

#### RP-between groups

For word targets, the top half of Table 3 shows the means and standard deviations for subjects' RTs and error rates for each type of prime as well as the corresponding priming

effect for each RP-between group, at each target location and averaged across target location. The top half of Table 4 shows the corresponding values for nonword targets, less the priming effects.

Table 3

Mean Reaction Times (RT, in ms), Error Percentages (%E), and Priming Effects for Words in Experiment 2

Condition	Related prime		Unrelated prime		Priming effect	
	RT	%E	RT	%E	RT	%E
RP-between						
Low RP						
Right Box	647 (84)	2.8 (3.3)	680 (70)	5.7 (4.2)	33 (42)	2.9 (5.6)
Left Box	688 (75)	2.4 (2.8)	691 (73)	8.1 (6.1)	3 (24)	5.7 (6.9)
Overall	667 (80)	2.6 (3.0)	685 (70)	6.9 (5.2)	18 (26)	4.3 (5.5)
High RP						
Right Box	651 (53)	2.4 (1.8)	726 (83)	10.8 (6.5)	75 (46)	8.4 (7.2)
Left Box	690 (38)	4.3 (3.5)	766 (59)	8.4 (6.4)	76 (33)	4.1 (6.7)
Overall	670 (49)	3.4 (2.9)	746 (73)	9.6 (6.4)	76 (39)	6.3 (6.7)
RP-within						
Low RP						
High RP Right	681 (73)	4.4 (4.0)	714 (69)	6.2 (4.4)	33 (29)	1.8 (5.9)
High RP Left	734 (106)	3.2 (5.9)	778 (96)	6.1 (3.2)	44 (40)	2.9 (6.5)
Overall	708 (93)	3.8 (4.9)	746 (88)	6.2 (3.7)	38 (34)	2.4 (6.1)
High RP						
High RP Right	686 (72)	3.9 (2.4)	724 (76)	5.6 (4.7)	38 (25)	1.7 (5.9)
High RP Left	675 (109)	1.8 (1.6)	725 (117)	2.4 (3.4)	50 (41)	0.6 (3.2)
Overall	680 (90)	2.9 (2.3)	724 (96)	4.0 (4.3)	44 (34)	1.2 (4.6)

Note: Standard deviations are in parentheses.

Word Targets. The change to left and right boxes reduced but did not eliminate the main effect of target location,  $F(1, 18) = 15.17$ ,  $MSe = 1,401$ . Responses were 33-ms faster to targets in the right box, perhaps because the primes were centered between the left and right box, and people naturally read English words from left to right. The main effect of target location did not interact with RP,  $F < 1$ , but did interact marginally with priming,  $F(1, 18) = 3.31$ ,  $MSe = 349$ ,  $p = .09$ , and with RP and priming,  $F(1, 18) = 3.35$ ,

$MSe = 349$ ,  $p = .09$ . The latter interactions reflect the fact that there was more priming in the right box than the left box, especially for the low-RP group (see Table 3). There was no main effect of RP,  $F < 1.28$ , but there was a main effect of priming,  $F(1, 18) = 39.93$ ,  $MSe = 1,097$ , representing a 47-ms advantage for related over unrelated prime trials. The between-subject RP x Priming interaction was much larger than that obtained in Experiment 1,  $F(1, 18) = 15.18$ ,  $MSe = 1,097$ . The advantage for the high-RP group over the low-RP group was primarily the result of a much stronger priming effect for the high-RP group here relative to Experiment 1.

There were two reliable effects in the error rates (other  $F_s < 1.84$ ). First, there was a main effect of priming,  $F(1, 18) = 14.80$ ,  $MSe = 37.60$ , with 5.3% more errors on unrelated than on related prime trials. Second, there was a reliable three-way RP x Priming x Target Location interaction,  $F(1, 18) = 10.67$ ,  $MSe = 5.91$ , due to a particularly large reduction in errors on related primes trials compared to unrelated prime trials for the high-RP group for targets in the right box.

Table 4

Mean Reaction Times (RT, in ms) and Error Percentages (%E) for Nonwords in Experiment 2

Condition	Low RP		High RP		Overall	
	RT	%E	RT	%E	RT	%E
RP-between						
Right Box	789 (93)	7.0 (4.2)	771 (71)	3.9 (3.6)	780 (81)	5.4 (4.1)
Left Box	786 (99)	7.5 (3.8)	781 (72)	2.9 (2.3)	784 (84)	5.2 (3.9)
Overall	788 (93)	7.2 (3.9)	776 (70)	3.4 (3.0)	782 (81)	5.3 (3.8)
RP-within						
High RP Right	851 (124)	4.7 (3.1)	814 (123)	6.1 (3.3)	832 (122)	5.4 (3.2)
High RP Left	782 (84)	5.0 (2.8)	795 (96)	5.9 (4.9)	788 (88)	5.5 (3.9)
Overall	817 (109)	4.9 (2.9)	804 (108)	6.0 (4.1)	811 (107)	5.4 (3.3)

Note: Standard deviations are in parentheses.

Nonword Targets. There were 3.8% more errors to nonwords in the low-RP group compared to the high-RP group, a main effect of RP,  $F(1, 18) = 6.40$ ,  $MSe = 22.91$ . No other effects approached significance ( $F_s < 2.85$ ).

### RP-within group

For the RP-within group, the relevant means and standard deviations are shown in the bottom half of Table 3 for word targets, and in the bottom half of Table 4 for nonword targets (see Experiment 1 for details).

Word Targets. In the RT analysis there was no main effect of high-RP location,  $F < 1$ , unlike in Experiment 1. However, once again one box led to faster responses than the other. The high-RP position x RP interaction,  $F(1, 18) = 27.97$ ,  $MSe = 708$  represented a 32-ms overall RT advantage for targets in the right box. Unlike Experiment 1, the 24-ms advantage for the high-RP items over the low-RP items produced a main effect of RP,  $F(1, 18) = 16.84$ ,  $MSe = 708$ . The 41-ms main effect of priming was significant,  $F(1, 18) = 54.95$ ,  $MSe = 619$ , and close to the 39-ms effect in Experiment 1. The RP x Priming x high-RP location interaction was not significant,  $F < 1$ , and most critically, as in Experiment 1, there was no RP x Priming interaction,  $F < 1$ . The power to detect a RP x Priming interaction in the RP-within group was estimated using the size of the RP-between interaction in Experiment 2. In the RP-between groups, the low-RP priming effect was 23.1% of the high-RP priming effect. The .88 power estimate for detecting a priming effect within subjects for the low-RP items 23.1% the size of that observed for high-RP items was reasonably high (Cohen's  $d = 1.03$ ).

In the error analysis the main effect of RP was significant,  $F(1, 18) = 4.60$ ,  $MSe = 10.51$ , as in the RT analysis. Subjects made 1.6% fewer errors to high-RP items than to low-RP items. The main effect of priming was marginal, with 1.8% more errors on unrelated than on related prime trials,  $F(1, 18) = 3.52$ ,  $MSe = 17.53$ ,  $p = .08$ . The remaining effects, including the RP x Priming interaction, did not approach significance,  $F_s < 2.70$ .

Nonword Targets. In the RT analysis, there was no main effect of high-RP location,  $F < 1$ . The main effect of RP approached significance,  $F(1, 18) = 3.88$ ,  $MSe = 377$ ,  $p = .06$ , with responses being 13-ms faster for high-RP than for the low-RP nonwords. There was a reliable interaction of RP with high-RP location,  $F(1, 18) = 17.38$ ,  $MSe = 377$ ., revealing that responses to nonwords were 25-ms faster in the right than in the left box. In the error rate analysis, only the main effect of RP approached significance,  $F(1, 18) = 4.25$ ,  $MSe = 2.95$ ,  $p = .054$ , with 1.1% more errors for high-RP than for low-RP nonwords, trading off against the main effect of RP in the RTs (other  $F_s < 1$ ).

### Discussion

Changing the location of the target boxes allowed a much stronger replication of the typical RP x Priming interaction to emerge between subjects in the RT analysis (e.g., de Groot, 1984, den Heyer et al., 1983; Stolz & Neely, 1995). In the RP-within design, the

sole influence of a retrospective process was not enough to produce a RP x Priming interaction in the RTs or error rates. These null effects do not allow one to safely conclude that differential operation of expectancy is needed for the interaction to emerge. Instead, one could conclude that the subjects in the RP-within group could not selectively use retrospective processes at the two target locations.

The power of Experiment 2 to detect the within-subject RP x Priming interaction was reasonably high, but as an assurance, the RT data from Experiment 1 and 2 were combined in a single repeated-measures ANOVA with RP and priming as the factors. Again there was no RP x Priming interaction,  $F < 1$ , in part because the direction of the interaction was reversed in the two experiments. More importantly, the power of this analysis to detect an RP-within interaction, based on the interaction observed in the RP-between groups in Experiment 2, was estimated at .97 (Cohen's  $d = .88$ ).

Although the critical RP-within interactions were not significant, the RP main effect was reliable in both the RT and error analyses for words. Responses to targets at the high-RP and low-RP locations were differentially affected by the RP manipulation, but in an unexpected way. Collapsed across prime type, the overall speed and accuracy of responses to word targets was improved more at the high-RP location than at the low-RP location. Since the effect was caused by the RP manipulation, a retrospective locus is indicated. Perhaps subjects adopt a lower criterion for outputting target responses to targets in the high-RP location. This bias effectively reduced priming at the high-RP location making it more difficult to obtain a RP x Priming interaction. Main effects of RP are not always reported, and are seldom reliable (cf. Burt et al., 1996). However, they are useful in the present context because they are hard, if not impossible, to reconcile with an account of the RP x Priming interaction that appeals only to expectancy.

Taken together, the findings of Experiment 1 and 2 suggest that within-subject manipulations of RP using more than one target location make it difficult to reveal robust RP x Priming interactions, although this interaction was observed in the error rates in Experiment 1. Pilot data from experiments not reported here suggest that this interaction is also unlikely to appear when RP is manipulated within subjects by presenting targets of one RP in lowercase letters and targets of another RP in uppercase letters, or when boldfaced versus nonboldfaced fonts were used to signify different RPs. The null RP-within interactions of Experiment 2 make it unclear whether expectancy produces RP x Priming interactions, but must be allowed to operate selectively, or whether a retrospective process alone could produce this interaction, but was unable to be applied selectively across trials at different spatially-located RP locations. The next two experiments attempted to resolve this question using different paradigms.

### Series 2: Experiments Eliminating Expectancy

A simpler way to test whether expectancy is necessary to obtain a RP x Priming interaction is to test for this interaction at a short 240-ms SOA where the generation of expectancies has not had enough time to occur (e.g., den Heyer et al., 1983; Neely, 1991; Stolz & Neely, 1995). This approach has at least one distinct advantage over the RP-within design of Experiment 1 and 2, in that it completely eliminates expectancy, rather than simply controlling its influence so that it cannot produce differential priming effects at the two RP-keyed locations. That is, subjects could have generated expectancies in the within-subjects design with an 800-ms SOA, but could not have differentially generated expectancies for targets at the two locations since all primes were shown in the center of the screen. In Series 2, the relatedness or identity proportion is manipulated between subjects and the prime-target SOA is kept brief enough to prevent the generation of expectancies (Neely, 1991). Since expectancy is ruled out, and since spreading activation is insensitive to manipulations of stimulus list characteristics, only a retrospective process could produce the desired interactions. Whether this process is semantic matching or episodic retrieval is addressed differently in the two experiments.

In Experiment 3, low-RP and high-RP groups are compared in the word reading task, where semantic matching does not operate (e.g., Neely & Keefe, 1989). In accordance with Neely (1991) a prime duration of 240-ms was used to prevent expectancy from operating. If a RP x Priming interaction is obtained in this experiment, only the episodic retrieval account would be supported. On this account, subjects in the high-RP group are more likely than subjects in the low-RP group to use the priming episodes to help cue other information about targets that is stored in other memory traces.

In Experiment 4, Forster and Davis' (1984) masked lexical decision task was used to assess the effects of IP, the proportion of identity-primed trials in the stimulus list, on repetition priming for words and nonwords. Here, expectancy is eliminated by masking the primes and presenting them for only 60-ms, making them both difficult to identify and too briefly presented to use to generate expectancies. An IP x Priming interaction in this experiment could not be explained by expectancy or semantic matching processes because both are hypothesized to be under strategic control, yet subjects do not even know that primes are being presented (Neely, 1991, p. 317). However, episodic retrieval accounts for such an interaction, if subjects in the high-RP group are more likely than subjects in the low-RP group to retrieve episodes for masked primes and use the information they contain to guide their lexical decisions. Finally, as described below, an examination of IP effects has important consequences for the lexical entry-opening account of masked priming posited by Forster and Davis (1984).

### Experiment 3

The RP x Priming interaction has been demonstrated in two previous lexical decision experiments using 240-ms SOAs (de Groot, 1984; Henik et al., 1994). Moreover, the two lexical decision studies that did not find interactions either used a very short 75-ms SOA (den Heyer et al., 1983) or a relatively weak RP manipulation (.25 vs. .50) at a 200-ms SOA (Stolz & Neely, 1995). Since RP x Priming interactions have been obtained at a 240-ms SOA where according to Neely (1991) a strategic expectancy process does not have enough time to operate, the contribution of a retrospective process is indicated. However, because both episodic retrieval and semantic matching are more likely to operate when the nonword ratio is high than when it is low, the lexical decision task cannot be used to choose between these processes.

For this reason, Experiment 3 employed the word reading task. Semantic matching is not hypothesized to occur in the word reading task because detecting a relationship between a prime and its target does not help provide the subject with a naming response, and also because there are no nonwords and hence nonword ratio to modulate the use of this process (e.g., Neely, 1991; Neely & Keefe, 1989; Keefe & Neely, 1990). Thus, only the episodic retrieval account explains why a RP x Priming interaction might obtain in the word reading task at a short SOA. On this account, the information in the retrieved priming episode cues relevant information about the target from other memory traces, facilitating naming responses on related trials more than on unrelated trials. Previous RP x Priming interactions in the word reading task occurred at SOAs of 500-ms (Keefe & Neely, 1990) or 1000-ms (Burt et al., 1996) and were attributed to expectancy alone. Experiment 3 represents the first attempt to produce this interaction in the word reading task at a short SOA where expectancies have not had enough time to be generated.

#### Method

##### Subjects

There were 20 subjects in the low-RP group and 20 subjects in the high-RP group. Three subjects were members of another psychology department research lab who volunteered to take part in the experiment.

##### Materials and design

Except for the following details, the materials and design of Experiment 3 were the same as in Experiments 1 and 2. The targets were 200 critical and 20 practice words chosen from the set used in the earlier experiments (see Appendix). Unrelated primes were selected by the same repairing procedure. The critical words were divided into ten blocks of 20 items, and were randomized as described in Experiment 1. Here the RP of the practice items was slightly more extreme than that of the critical items, to try to make

the RPs more obvious to subjects, but otherwise the practice items were treated as before. The high-RP group received 18 related prime and 2 unrelated prime practice trials, while the low-RP group saw the reverse proportions, creating RPs of .9 and .1 respectively. For the critical items, the high-RP group saw 160 related and 40 unrelated trials, while the low-RP group saw the reverse proportions, creating RPs of .8 and .2 respectively.

### Procedure

The testing procedure was similar to Experiments 1 and 2. A microphone wired into the computer's mouse detected vocal responses by simulating a mouse-click that stopped the clock measuring the subject's RT. Subjects were told that they would be seeing a series of events, each event consisting of two words. They were asked to pay attention to the first word, then say the second word out loud. The prime was shown in lowercase letters in the center of the screen for 240-ms, then erased and followed immediately by the target in uppercase letters located just below where the prime was shown. No boxes were used. Once the target appeared, subjects said it out loud as quickly and accurately as possible. The target remained on the screen until the microphone picked up a word reading response, at which point the target was erased. The experimenter scored the response as correct, or as incorrect or spoiled. The error rates were thus a combination of genuine word reading errors and accidental triggerings of the microphone. If the subject took longer than 1 sec to respond, then after the trial was scored a beep sounded and the phrase "TOO SLOW" appeared on the screen for 1 sec. The next trial began 500-ms after the correct response or corrective feedback. Self-paced rest breaks were provided after every 40 of the 200 critical trials. At the end of the experiment, subjects were asked to estimate the percentage of trials in which the prime and target were related in meaning, and whether or not their responses were faster when the prime was related than when it was unrelated to the target. The experiment took approximately 20 minutes for each subject to complete.

### Results

In Experiment 3, trials with RTs shorter than 300-ms or longer than 2000-ms were deleted, resulting in a loss of 66 of 8,000 trials (0.8%), only slightly above the 0.5% limit recommended by Ulrich and Miller (1994). The mean estimate of the RP given by low-RP subjects was 44% (SD = 19), and 65% thought they were faster when the prime was related to the target. In contrast, the mean RP estimate of high-RP subjects was 70% (SD = 14), and 85% felt that related primes quickened their responses. Thus, despite the short SOA, subjects were fairly accurate at estimating the RP to which they were exposed, and the high-RP group was more likely to report that related primes were helpful.

Table 5

Mean Reaction Times (RT, in ms), Error Percentages (%E), and Priming Effects in Experiment 3

Condition	Related prime		Unrelated prime		Priming effect	
	RT	%E	RT	%E	RT	%E
Low RP	541 (74)	1.1 (1.5)	556 (78)	2.1 (1.9)	15 (22)	0.9 (2.2)
High RP	494 (54)	1.1 (0.9)	515 (63)	2.9 (2.5)	21 (17)	1.9 (2.5)

Note: Standard deviations are in parentheses.

For each RP group, Table 5 shows the means and standard deviations for subjects' RTs and error rates for targets following related and unrelated primes, as well as the corresponding priming effect. For each dependent variable, a mixed-factor ANOVA was performed with RP (low vs. high) as the between-subjects factor and priming (related vs. unrelated) as the within-subjects factor. In the RT ANOVA, related primes led to faster responses than unrelated primes, producing a reliable 19-ms main effect of priming,  $F(1, 38) = 33.09$ ,  $MSe = 193$ . Although it was in the expected direction, with 15-ms of priming for the low-RP group and 21-ms for the high-RP group, the critical RP x Priming interaction did not approach significance,  $F < 1$ . This result contrasts with the reliable interactions obtained at SOAs greater than 500-ms in the word reading task (Burt et al., 1996; Keefe & Neely, 1990; but see Seidenberg et al., 1984). The power of Experiment 3 to reveal a RP x Priming interaction was estimated using the amount of priming in the low-RP group relative to the high-RP group in the RP-between analysis of Experiment 2 (see Experiment 2). The power estimate was a reasonably high .71 (Cohen's  $d = .82$ ). Although the interaction of RP and priming was not reliable, the main effect of RP was reliable,  $F(1, 38) = 4.23$ ,  $MSe = 9080$ . High-RP subjects were 44-ms faster than low-RP subjects independent of the type of prime shown on a trial. In the error rate ANOVA, only the main effect of priming was reliable,  $F(1, 38) = 13.96$ ,  $MSe = 2.80$ , with 1.4% more errors on unrelated than on related prime trials.

#### Discussion

Despite reasonably high power, Experiment 3 did not reveal a RP x Priming interaction in the word reading task at a 240-ms SOA where expectancies do not have time to develop (Neely, 1991). This lack of interaction replicates the lexical decision

experiments of den Heyer et al. (1983) and Stolz and Neely (1995) at 75- and 200-ms SOAs, but does not replicate interactions observed at 240-ms SOAs in the lexical decision experiments of de Groot (1984) and Henik et al. (1994). If only the RP x Priming interactions are considered, then this pattern of results is consistent with the idea that semantic matching can produce this interaction at SOAs of 240-ms or greater, while expectancy can produce it in the word reading task at SOAs of 500-ms or greater (Burt et al., 1996; Keefe & Neely, 1990). Interpreted in this way, the lack of interaction in Experiment 3 supports Neely and Keefe's (1989) three-process account since expectancy could not operate at the 240-ms SOA, semantic matching did not operate because the word reading task was used, and spreading activation produces priming effects that are insensitive to RP.

However, by the three-process account the RP manipulation used in Experiment 3 should not have had any effect, yet a main effect of RP was observed. The high-RP group was faster than the low-RP group overall, collapsing across related and unrelated prime types, suggesting that the RP manipulation did have an effect, albeit not the predicted one. Recall that a main effect of RP was also obtained in the within-subject RT and error analyses in Experiment 2. The three-process account cannot explain the RP main effect in the word reading task at a 240-ms SOA, since neither expectancy nor semantic matching should be operating. One speculation for the RP main effect is that high-RP subjects may be more sensitized to the fluency they experience during target processing, since very often this processing is made easier by a preceding related prime. Greater sensitivity to fluency might make high-RP subjects more likely to respond based on minimal target processing on both related and unrelated prime trials, thus creating a main effect of RP. In other words, high-RP subjects might adopt a lower criterion for outputting not only binary lexical decisions, as was the case in Experiment 2, but for outputting word reading responses as well. Because this fluency is linked to the RP manipulation, it must arise during target processing, making it compatible with the episodic retrieval account, in which the role of fluency has already been described (see Bodner & Masson, in press). Given that the low-RP and high-RP groups were fairly accurate at estimating the RP of the items they saw, perhaps differences in experienced fluency reduced priming in the high-RP group, thus creating a main effect of RP instead of the anticipated RP x Priming interaction.

#### Experiment 4

Identity or repetition priming refers to the finding that responses to a stimulus are facilitated if that stimulus has been recently encountered (e.g., Scarborough, Cortese, & Scarborough, 1977). Since Bodner and Masson's (in press) episodic retrieval account

was postulated as an explanation for identity priming in the masked lexical decision task, Experiment 4 used this task to look for an interaction of identity-prime proportion (or IP) with priming. Repetition priming was studied because masked semantic priming effects tend to be rather small (e.g., 24-ms in Carr & Dagenbach, 1990), making it unlikely that an IP x Priming interaction would obtain in a between-group comparison.

Two published studies have specifically manipulated IP. Bushell (1996) did so within subjects across testing sessions in a lexical decision task using a 1000-ms prime-target SOA. She did not find an IP x Priming interaction in a group of normal subjects, but did find a large interaction in a group of Broca's aphasics. However, the null interaction in normals could reflect a lack of power, since only eight normals were tested, and their repetition priming effects were quite small (13-ms in the .2 IP group, and 20-ms in the .8 IP group). Burt et al. (1996, Experiment 3) found a robust IP x Priming interaction in a between-subjects manipulation in the word reading task at a 1000-ms prime-target SOA. Subjects in the .5 IP group showed 57-ms of priming, in contrast to the 16-ms effect in the .17 IP group. Burt et al. attributed this interaction to greater use of expectancy in the high-IP group, but they conceded that they could not rule out a retrospective process. Experiment 4 tests whether an IP x Priming interaction appears in a paradigm where both expectancy and semantic matching are ruled out.

In the masked priming paradigm adopted from Forster and Davis (1984), a brief 60-ms lowercase prime follows a 500-ms premask (e.g., a row of Xs) and is followed by an uppercase target. Subjects are usually unaware of the existence of the primes, or are at least unable to identify them, yet responses to targets are faster following repetition primes than following unrelated primes (e.g., Bodner & Masson, in press; Forster & Davis, 1984). Forster and Davis claim that masking eliminates any episodic influences, leaving only lexical influences to produce priming. More specifically, on their lexical account a masked word prime temporarily opens the lexical entry corresponding to the prime word. If the target on a repetition trial closely follows in time, the same lexical entry does not have to be re-opened, thus speeding responses relative to unrelated trials.

Support for Forster and Davis' (1984) lexical account has come primarily from two findings. First, on the lexical account, episodic influences produce the word frequency x priming interaction shown with unmasked primes, where low frequency words show more priming than high frequency words (e.g., Forster & Davis, 1984; Jacoby & Dallas, 1981; Rajaram & Neely, 1992; Scarborough et al., 1977). Forster and Davis (1984) found that masking eliminated this interaction but preserved priming effects. Second, on the lexical account, episodic influences produce nonword priming effects seen at long and unmasked SOAs (e.g., Besner & Swan, 1982; McKone, 1995; Scarborough et al., 1977).

Under masked conditions, Forster and Davis (1984) found that nonwords did not show repetition priming. Since there are no entries to be opened by nonword primes, the lack of priming for nonwords supported the lexical account. For both these effects, these researchers argued that masking stripped away the episodic component to reveal the effects of a more basic lexical component.

Recently, however, a retrospective episodic retrieval account of masked priming has been forwarded by Bodner and Masson (in press). These researchers claim that episodes for masked primes are still formed, and can still be retrieved to help guide target processing. By their account, word frequency does not interact with priming under masked conditions because the retrieved priming episodes contain primarily orthographic-level information that is insensitive to word frequency. Moreover, by this account masked nonword priming typically does not occur because word and nonword targets are easily discriminated (i.e., can be processed relatively easy), reducing subjects' reliance on the fluency provided by the masked primes. In support of the latter claim, masked nonword priming effects were revealed when the usefulness of priming episodes was increased by decreasing target discriminability. Experiments 2 and 3 in Bodner and Masson (in press) revealed strong masked nonword priming effects for nonword targets presented in case-alternation (e.g., wOrD) and for pseudohomophone nonwords (e.g., BRANE). These masked nonword priming effects supported the episodic retrieval account but not the lexical account.

The episodic retrieval account would be further bolstered if IP x Priming interactions could be obtained in the masked priming paradigm. For word targets, to the extent that Neely and Keefe's (1989) three-process account applies to repetition priming, this interaction should not be observed. This follows because expectancy and semantic matching, the two processes in the three-process account that can produce this interaction, are strategic processes that cannot operate when briefly-presented masked primes are used (Neely, 1991). On the lexical account, priming should be uninfluenced by a manipulation of IP, since lexical entries are opened by primes in an automatic way. In contrast to these accounts, episodic retrieval predicts that an interaction could obtain since the usefulness of the priming episodes should be greater for subjects in the high-IP group than for subjects in the low-IP group. For nonword targets, the three-process account makes no claims, and the lexical account predicts that neither IP group should show any repetition priming. On the episodic retrieval account, an IP x Priming interaction with nonword targets is possible, but would be more likely if the word/nonword discriminability was decreased (e.g., Bodner & Masson, in press). To test these claims, a low-IP group received an IP of .2 for both words and nonwords, while a

high-IP group received an IP of .8 for both words and nonwords. Subjects performed the masked lexical decision task, and the effect of interest was whether IP x Priming interactions would obtain for word and/or nonword targets.

### Method

#### Subjects

There were 20 subjects in the low-IP group and 20 subjects in the high-IP group. Six high-IP and five low-IP subjects were graduate students or members of other psychology department research labs who volunteered to take part in the experiment.

#### Materials and design

The materials were the same as in earlier experiments, with the following exceptions. The targets were 200 critical and 20 practice words and 200 critical and 20 practice nonwords primarily chosen from the set used in the earlier experiments (see Appendix). Unrelated word and nonword primes were unique, rather than repeated, to ensure that each unrelated prime and target pair: 1) had no more than two letters in common, 2) had no letters in common in the same position, and 3) had the same number of letters.

The design was the same as Experiment 3, except that nonwords were included in the counterbalancing and randomizing as in Experiments 1 and 2. The critical words and nonwords were divided into ten blocks of 20 items. The IP of the practice items matched that of the critical items, and the practice items were treated as before. The high-IP group saw 16 repetition and 4 unrelated practice trials, and 160 repetition and 40 unrelated critical trials both for words and for nonwords, and these numbers were reversed for the low-IP group. Thus, the IP was .8 for both words and nonwords in the high-IP group, and was .2 for both words and nonwords in the low-IP group.

#### Procedure

The set-up of Experiment 4 differed from that of earlier experiments in the following ways. Subjects were told that several briefly-displayed items would be shown on each trial and that they should focus on responding to the uppercase target which would remain on the screen until they made their lexical decision. Each trial began with a 500-ms mask consisting of a row of uppercase Xs matched for length with the prime and target. The mask was then erased and followed immediately by a 60-ms lowercase prime. The prime was then erased and followed immediately by the uppercase target that was shown until the subject responded. All items were shown in the center of the screen. Subjects made lexical decisions and received feedback as in Experiment 1, except here the "TOO SLOW" message appeared following responses slower than 1500-ms. Following the experiment, the subjects were asked what they saw on each trial, just

before the target appeared, as well as follow-up questions, to assess their awareness of the primes. The experiment took approximately 30 minutes for each subject to complete.

### Results

In Experiment 4, two trials with RTs outside a 300ms to 3000-ms boundary were deleted (0.01%). Eleven out of the 40 subjects reported being aware that something other than a row of X's was shown before each target. However, upon further questioning, most of these subjects were not aware of the specific nature of the masked primes (e.g., they did not identify the two types of primes, they did not know that the primes were in lowercase letters). Thus, the masking procedure produced the typical level of prime awareness (see Forster & Davis, 1984). The RT and error rate data for word and nonword targets were analyzed in four separate mixed-factor ANOVAs with IP (low vs. high) as the between-subjects factor, and priming (repetition vs. unrelated) as the repeated-measures factor. The means from these ANOVAs, as well as the corresponding priming effects and standard deviations, appear in Table 6.

Table 6

#### Mean Reaction Times (RT, in ms), Error Percentages (%E), and Priming Effects for Words and Nonwords in Experiment 4

Condition	Repetition prime		Unrelated prime		Priming effect	
	RT	%E	RT	%E	RT	%E
<b>Word Targets</b>						
Low IP	582 (55)	2.1 (2.7)	628 (44)	3.4 (2.8)	46 (34)	1.3 (2.5)
High IP	574 (62)	2.6 (3.0)	636 (62)	6.5 (5.0)	62 (22)	3.9 (4.2)
<b>Nonword Targets</b>						
Low IP	711 (69)	4.6 (3.3)	720 (68)	4.1 (3.2)	9 (28)	-0.6 (3.0)
High IP	660 (77)	3.5 (4.2)	679 (77)	3.9 (5.0)	20 (34)	0.4 (3.1)

Note: Standard deviations are in parentheses.

#### Word targets

In the RT analysis, the 54-ms advantage for repetition over unrelated prime trials produced a significant main effect of priming,  $F(1, 38) = 140.83$ ,  $MSe = 413$ . There was no main effect of IP,  $F < 1$ . Most importantly, the advantage for the high-IP over the

low-IP group produced a marginal IP x Priming interaction,  $F(1, 38) = 3.10$ ,  $MSe = 413$ ,  $p = .09$ . Because there are no other data on masked IP effects it is worth mentioning that this interaction was reliable in a more powerful item analysis with the same factors,  $F(1, 199) = 4.84$ ,  $MSe = 4,108$ ,  $p = .03$ . The 2.6% advantage for repetition over unrelated primes also produced a main effect of priming in the error rate analysis,  $F(1, 38) = 22.28$ ,  $MSe = 6.00$ . There was a marginally significant main effect of IP, which showed a 1.8% advantage for the low-IP group,  $F(1, 38) = 3.40$ ,  $MSe = 18.86$ ,  $p = .07$ . Though marginal in the RT analysis, the IP x Priming interaction was significant in the error rates,  $F(1, 38) = 5.90$ ,  $MSe = 6.00$ , revealing a larger decrease in errors on related trials for high-IP subjects than for low-IP subjects.

#### Nonword targets

In the RT analysis, the small 14-ms nonword priming effect was nonetheless reliable,  $F(1, 38) = 8.35$ ,  $MSe = 485$ . Interestingly, the 46-ms main effect of IP was also reliable,  $F(1, 38) = 4.16$ ,  $MSe = 10,153$ . In contrast, the IP x Priming interaction did not achieve significance,  $F < 1.20$ . However, post-hoc tests showed that while the 9-ms low-IP priming effect was not reliable,  $F < 2.04$ , the 20-ms high-IP priming effect was,  $F(1, 19) = 6.57$ ,  $MSe = 585$ . The power to detect an IP x Priming interaction for nonwords was estimated using the proportion of low-IP priming relative to high-IP priming for the word targets in Experiment 4 (which was .74). The power estimate was very low, .08 (Cohen's  $d = .16$ ), suggesting that there was little chance of finding this interaction with the nonwords. The lack of power is not surprising given the small magnitude of the nonword priming effects and the between-groups design. There were no reliable effects in the nonword error rates,  $F_s < 1.03$ .

#### Discussion

The pattern of results in Experiment 4 provide strong support for the episodic retrieval account of masked repetition priming (Bodner & Masson, in press). For word targets, the IP x Priming effect was marginal in the RT analysis and reliable in the error analysis, representing the first such interaction to be reported in the masked priming paradigm. These results were predicted by episodic retrieval, which claims that priming episodes are more likely to be used by high-IP subjects than by low-IP subjects. In contrast, Forster and Davis' (1984) lexical account and an extension of Neely and Keefe's (1989) three-process account to repetition priming would predict that priming should have been uninfluenced by the IP manipulation. For nonword targets, there was an overall nonword priming effect that was reliable only for the high-IP group. The occurrence of nonword priming effects in masked lexical decision (Experiment 4; Bodner & Masson, in press; Forster, 1985; Sereno, 1991) and word reading tasks (Masson &

Isaak, 1997) is highly problematic for the lexical account, and is not addressed by the three-process account. By the lexical account, neither RP group should have produced nonword priming, since nonwords have no entries for primes to preactivate. On the episodic retrieval account, the same mechanism produces masked priming effects for nonwords and for words, providing a useful alternative to the lexical account. Although the nonword IP x Priming interaction was not significant, the power to detect this interaction was very low.

As in Experiments 1-3, a main effect of the proportion manipulation was observed. Here, high-IP subjects' responses to nonword targets were faster than low-IP subjects' responses overall, compromising the high-IP priming effect and hence the IP x Priming interaction for nonwords. This main effect suggests that high-RP subjects may have been more in-tune to the fluency masked primes provided, speeding correct responses to word targets, and allowing them to set a lower criterion for making nonword decisions independent of the type of nonword prime.

As indicated above, these results suggest that Neely and Keefe's (1989) three-process account of semantic priming does not extend well as an account of repetition priming. Since expectancy and semantic matching are strategic processes requiring awareness of the primes, and since spreading activation is insensitive to IP, there should have been no effect of the IP manipulation. In contrast, the extension of the episodic retrieval account of repetition priming to semantic priming in Experiments 1-3 fared better. Although repetition and semantic priming sometimes produce dissociable effects (Bushell, 1996; Neely & VerWys, 1996), it does not follow that episodic retrieval cannot account for both types of effects. As described below, episodic retrieval has more potential than any other single process to provide a unitary account of semantic and repetition priming effects.

#### General Discussion

One of the most revealing semantic priming findings is that priming effects are larger when the relatedness proportion is high than when it is low (e.g., de Groot, 1984; den Heyer et al., 1983; Neely & Keefe, 1989; Stolz & Neely, 1995; Tweedy et al., 1977). A common explanation for these RP x Priming interactions is that as RP increases, subjects become more likely to strategically use primes to generate expectancies about what the target might be. In addition, Neely and Keefe (1989) have suggested that a strategic retrospective semantic matching process also contributes to RP x Priming interactions in the lexical decision task when RP and nonword ratio are confounded. However, the primacy of expectancy was bolstered when this interaction was also found in the word reading task where semantic matching does not occur (Burt et al., 1996; Keefe & Neely, 1990). In their three-process account, Neely and Keefe (Keefe & Neely, 1990; Neely,

1991; Neely & Keefe, 1989; Neely et al., 1989) amalgamated expectancy, semantic matching, and spreading activation, allowing them to explain the majority of extant semantic priming phenomena later summarized by Neely (1991). The four experiments reported here questioned whether expectancy must operate in order for RP x Priming interactions to be revealed. To answer this question, the interaction was sought where it could be produced by a retrospective process, but not by expectancy.

In Experiments 1 and 2, a unique within-subjects RP manipulation was used in which expectancy could not produce a RP x Priming interaction. All primes were shown in the center of the screen, and word and nonword targets subsequently appeared equally often at two locations, one with a high-RP and one with a low-RP. Top and bottom boxes were used in Experiment 1, while left and right boxes were used in Experiment 2. Since subjects could not know the target's location in advance, they were forced to generate the same expectancies for all targets, leaving only a retrospective mechanism to produce a RP x Priming interaction. Although a main effect of RP obtained within subjects in the RTs and error rates of Experiment 2, the within-subjects interaction obtained only in the error rates in Experiment 1. This was not due to the insensitivity of the two-location paradigm, however, since the typical RP x Priming interaction was found between subjects in the error rates in Experiment 1 and also in the RT analysis in Experiment 2 (e.g., de Groot, 1984; den Heyer et al., 1983; Neely & Keefe, 1989; Stolz & Neely, 1995; Tweedy et al., 1977).

Instead of preventing the differential employment of expectancies across two target locations within subjects, Experiments 3 and 4 sought the RP x Priming interaction in between-subjects paradigms where expectancies would not have time to develop because of the brevity of the prime-target SOA (Neely, 1991). In Experiment 3, a 240-ms prime-target SOA was used in a word reading task. Expectancy is not thought to operate at this short of a SOA, and semantic matching does not operate in the word reading task, leaving only episodic retrieval to produce a RP x Priming interaction. However, while this experiment revealed a main effect of RP in the RTs, no RP x Priming interaction was found.

In Experiment 4, the masked priming paradigm was used in a lexical decision task in which the proportion of identity-primed words and nonwords was manipulated (termed IP). With masked 60-ms SOA primes, expectancy and semantic matching cannot operate, because both are strategic processes requiring conscious awareness of the primes. The critical IP x Priming interaction was marginal in the RTs but reliable in the error rates. Reliable masked nonword priming and a main effect of IP on nonword latencies were also observed.

### Processes Underlying Semantic and Repetition Priming Effects

The implications for this rather complicated pattern of results for claims about the mechanisms producing semantic and repetition priming effects are considered in detail below. Experiments that could provide more definitive conclusions are also suggested.

Semantic Priming Processes. With respect to the experiments in Series 1, if the non-significant RP x Priming interactions of the RT analyses in the RP-within conditions of Experiments 1 and 2 are taken at face value, then one might conclude that expectancy must be able to operate selectively to produce this interaction. These results would further justify the inclusion of expectancy as a key process in Neely and Keefe's three-process account of semantic priming (e.g., Neely & Keefe, 1989). However, a stronger test of the importance of expectancy would involve testing an RP-within group where the primes are made predictive of the target location. By having the prime appear in the location where the target will appear, it would be possible for subjects to generate more expectancies from primes at the high-RP location than at the low-RP location. If the RP x Priming interaction obtained, the need to postulate an expectancy process to account for RP x Priming interactions would be better supported. If the interaction is not observed, however, then the utility of the two-location within-subject design for isolating retrospective processes would be compromised. The safest conclusion would be that subjects cannot be selectively influenced by different RPs at different locations within a randomly mixed series of trials. Such a finding would place an important limit on claims that semantic effects are strongly affected by subtle manipulations of test list construction (e.g., Snow & Neely, 1987; Stolz and Besner, 1996).

In fact, there are reasons to suspect that the within-subject RP manipulations were not very obvious to subjects. When informally asked, subjects in the RP-within groups were unsure whether there were more related trials in one target location than in the other. In retrospect, this is not entirely surprising since the difference in the percentage of related prime-target trials relative to the total number of trials shown in each target location was not very great (10% in the low-RP location vs. 40% in the high-RP location). To make the RP manipulation more obvious to subjects without changing the RP, the number of nonwords in the high-RP location would have to be reduced. However, in a pilot experiment, this manipulation had the unfortunate drawback of biasing subjects towards making word responses, since it increased the overall proportion of word targets in the high-RP location relative to the low-RP location. A better solution might be to use the word reading task since there are no nonwords to "water down" the salience of the RP manipulation.

Another way to make the RP manipulation stronger involves using Tweedy and Lapinski's (1981) "training" procedure and a short 240-ms SOA. One group of subjects could be given a RP of 0 in a first block of trials, and another group could be given a RP of 1 in this block. If a between-subjects RP x Priming interaction obtains on a second block of trials with an intermediate RP, this interaction could be attributed solely to a retrospective process. Moreover, if it also appears in the word reading task or using masked primes, where use of semantic matching is precluded, then only episodic retrieval would be supported.

In evaluating the results of these experiments, one should avoid taking the null within-subject interactions of Experiments 1 and 2 and the null between-subject interaction of Experiment 3 as strong evidence for the role of expectancy. This is especially true since the pattern of reliable results across the four experiments are more consistent with the episodic retrieval account than with expectancy and the three-process account. In Experiment 1, the within subjects RP x Priming effect in the error rates was predicted only by a retrospective process, since expectancy could not operate selectively. A retrospective process can also account for the main effect of RP on RTs to nonwords that occurred between subjects. Greater use of semantic matching or episodic retrieval by high-RP subjects would bias them toward making nonword responses when a match between the prime and target could not be found. Because subjects cannot know whether the target will be a nonword in advance, expectancy could not produce this effect.

Taken together, the main effects of RP found for words within subjects in the lexical decision task (Experiment 2), between subjects in the word reading task (Experiment 3), and for nonwords in the masked lexical decision task (Experiment 4), are consistent only with episodic retrieval. These main effects were not predicted by expectancy, and semantic matching is thought not to occur in the latter two tasks. This bias-like effect is consistent with the idea that when RP is higher, subjects respond sooner, even though they may be basing their responses on the same amount of fluency experienced by subjects for targets presented in lower RP conditions. Subjects receiving more related primes may become more tuned to the feeling of fluency experienced during processing of targets, that is, they become accustomed to making responses based on less target processing, even on unrelated trials. This improvement of target responses on both related and unrelated trials reduces high-RP priming and therefore the chance of revealing RP x Priming interactions. The fact that a RP main effect occurred in the word reading task, and not just in the binary-response lexical decision task is an interesting result that warrants further investigation. For now, these effects are consistent enough that they should be explained by any comprehensive account of semantic priming. Indeed, the

standard "RP effect" term was not used in these experiments in order to clearly distinguish RP x Priming interactions from main effects of RP. For now, the importance of the fluency experienced during target processing has been described only in the context of the episodic retrieval account (Bodner & Masson, in press).

While these semantic priming experiments provided some support for the operation of episodic retrieval, additional support was gained from the masked repetition priming results of Experiment 4. The interactions of IP and priming for word targets where expectancy and semantic matching are ruled out were predicted only by episodic retrieval. A replication of this result in a masked semantic priming paradigm would prevent this interaction from being attributed to the operation of a process unique to repetition priming (e.g., since repetition primes have orthographic and phonological overlap with targets). The fact that recent studies have shown dissociable effects of semantic and repetition priming in normals (Neely & VerWys, 1996) and in Broca's aphasics (Bushell, 1996) does not rule out a single process account of both types of priming.

Additional support for the episodic retrieval account may be gained in the future by using target degradation to boost priming effects, which will provide a more powerful opportunity to reveal RP x Priming interactions (e.g., Becker & Killion, 1977; Bodner & Masson, in press; Borowsky & Besner, 1993). For example, Bodner and Masson argued that the influence of retrieved priming episodes increases when target processing is made more difficult. For now though, effects such as backward priming (e.g., Koriat, 1981; Seidenberg et al., 1984) provide more evidence for the necessity of a retrospective process than the null RP x Priming interactions reported here provide evidence for the need to postulate expectancy. Moreover, unlike the three-process account, episodic retrieval can explain the occurrence of RP x Priming interactions in both the lexical decision and word reading tasks without needing to invoke two processes.

Finally, a caveat concerning the within-subject RP manipulation of Experiments 1 and 2 must be mentioned. It should be clarified that expectancy could in fact produce RP x Priming interactions in the RP-within design. By design, subjects would generate prospective expectancies to the same extent for targets at each RP location, but they might be more likely to retrospectively use their generated expectancies for targets that appear at the high-RP location. However, this retrospectively-used concept of expectancy is different from the prospective, strategic version given by Neely and colleagues (e.g., Neely & Keefe, 1989), and is similar to Norris' (1986) retrospective post-lexical coherence checking mechanism. However, neither the post-lexical coherence check, expectancy, nor semantic matching mechanisms predict RP x Priming interactions

when primes are masked and/or presented at a short SOA. Such interactions, like the ones shown in Experiment 4 with masked repetition primes, could provide even stronger support for an episodic retrieval account.

Repetition Priming Processes. Although it was not the focus of these experiments, validation of Bodner and Masson's (in press) episodic retrieval account over Forster and Davis's (1984) lexical entry-opening account of masked priming was garnered in Experiment 4. As described there, the lexical account cannot accommodate the IP x Priming interaction for words, or the nonword priming effects observed in this masked priming paradigm. Proponents of the lexical account must address these effects, as well as other nonword priming effects shown in lexical decision (Bodner & Masson, in press; Forster, 1985; Sereno, 1991) and word reading tasks (Masson & Isaak, 1997). Finally, the use of degraded targets in this paradigm may boost priming effects enough to observe IP x Priming interactions for both words and nonwords. Such results would be very problematic for the lexical account, but are readily explained by the episodic retrieval account.

### Conclusions

If the retrospective process operating in semantic priming experiments is the same as that operating in repetition priming experiments, then episodic retrieval may well be a better candidate process than semantic matching, because the former accounts for masked repetition priming effects in the both the lexical decision (Bodner & Masson, in press) and word reading tasks (Masson & Isaak, 1997). Although the role of an expectancy process in producing RP x Priming interactions could not be ruled out in the present experiments, an episodic retrieval account was consistent with more of the observed results than was Neely and Keefe's (1989) three-process account. Several additional experiments were suggested that could better pit these accounts against one another. For now, the search for simplicity has made things more complicated, but fortunately the paradigms developed here provide new windows for revealing the processes responsible for producing the semantic and repetition priming effects that have intrigued cognitive researchers for so many years.

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## Appendix

## Materials Used in Experiments 1-4

## Experiment 1 and 2: Word Targets and their Related (R) and Unrelated (U) Primes

## Practice Words

<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>	<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>
almond	walnut	helmet	invade	attack	escort
beige	tan	spy	itch	scratch	junk
binge	starve	retire	satin	silk	drawer
blouse	skirt	twin	aisle	row	radish
coyote	wolf	pearl	album	record	illegal
groan	moan	locker	bang	crash	polite
ketchup	mustard	spiral	bizarre	strange	mint
applaud	clap	dock	telegram	message	rocket
boring	dull	quack	tune	song	exit
cute	pretty	lotion	flush	toilet	spear

## Critical Words

<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>	<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>
octopus	squid	turn	thumb	finger	walk
chess	checkers	flesh	virus	germs	circus
hatchet	axe	dinner	swim	pool	honest
spin	turn	leaf	boots	shoes	float
bulb	lamp	creek	sink	float	thaw
apple	fruit	lamp	false	true	finger
owe	debt	axe	hunting	fishing	hidden
pepper	salt	birth	sister	brother	mitten
stove	fridge	squid	brush	comb	note
polish	shine	fruit	crowd	people	shoes
flower	blossom	checkers	nose	eyes	expose
asleep	awake	sight	danger	safe	fishing
guilt	shame	debt	secret	hidden	pool
supper	dinner	shine	film	movie	peach
dirt	mud	twice	truth	honest	people
stream	creek	just	story	novel	eyes
tree	leaf	crate	run	walk	lost
box	crate	blossom	show	expose	brother
fair	just	mud	found	lost	true
hell	heaven	awake	tornado	hurricane	anger
blood	flesh	sit	elm	oak	hard
stand	sit	salt	stale	fresh	gold
sound	sight	fridge	tame	wild	oak
death	birth	shame	depart	leave	brain
once	twice	heaven	salad	lettuce	weather
plum	peach	novel	bee	honey	wild
clown	circus	safe	bull	cow	speak
melt	thaw	wasp	thread	needle	guide
sting	wasp	germs	quarrel	fight	leave
chord	note	comb	cancer	disease	hurricane
glove	mitten	movie	silver	gold	cow

<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>	<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>
sentence	paragraph	honey	draw	sketch	spice
mad	anger	fresh	shop	mall	spouse
cup	saucer	baby	wine	beer	sketch
loose	tight	lettuce	learn	teach	carry
soft	hard	needle	stress	nerves	eagle
rain	weather	paragraph	army	soldier	fame
drink	water	report	hold	carry	soldier
news	report	saucer	woman	man	nerves
lead	guide	tight	power	force	beer
talk	speak	water	might	maybe	musical
child	baby	house	chew	bite	country
mind	brain	disease	saturn	uranus	field
home	house	fight	velvet	plush	obey
waltz	dance	daring	noisy	quiet	rip
grape	raisin	tease	nickel	dime	plush
taunt	tease	young	button	sew	over
jam	toast	touch	tear	rip	body
fuzzy	hairy	covering	leap	jump	imagine
topic	issue	right	taxi	cab	crack
ghost	haunt	issue	prairie	field	sew
divide	multiply	steak	ritual	custom	king
candy	snack	lips	bird	robin	bite
bold	daring	dizzy	sad	happy	shallow
faint	dizzy	multiply	queen	king	uranus
blanket	covering	reject	soul	body	happy
smell	taste	pencil	wage	salary	drill
stick	glue	snack	dream	imagine	salary
meat	steak	hairy	rule	obey	dime
forget	remember	shrink	break	crack	empty
grow	shrink	wish	deep	shallow	custom
accept	reject	haunt	nation	country	quiet
bank	money	dance	low	high	robin
mouth	lips	glue	full	empty	jump
wrong	right	taste	saw	drill	high
paper	pencil	remember	under	over	cab
feel	touch	money	measles	mumps	short
want	wish	raisin	sour	lemon	bed
old	young	toast	weave	basket	bread
zebra	stripes	grain	rat	mouse	lock
quart	pint	force	plank	board	command
toad	frog	sidewalk	elbow	knee	loss
meter	metric	teach	climb	ascend	mouse
herb	spice	metric	pie	crust	fancy
wheat	grain	church	flame	fiery	knee
pavement	sidewalk	smart	stupid	poppy	pint
hawk	eagle	maybe	butter	bread	trash
priest	church	man	horn	honk	fiery
mate	spouse	master	waste	trash	good
fortune	fame	weight	seed	poppy	basket
slave	master	stripes	plain	fancy	ascend
height	weight	president	afraid	scared	mumps
senator	president	mall	sleep	bed	scared
opera	musical	frog	gain	loss	crust

<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>	<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>
key	lock	option	aunt	uncle	vegetable
choice	option	east	pound	ounce	flag
bad	good	honk	weak	strong	spray
late	early	lemon	foam	spray	yarn
west	east	board	journal	magazine	fire
order	command	early	holy	saint	kill
long	short	stupid	remove	evict	street
spinach	corn	gamble	animal	vegetable	nephew
wager	gamble	atom	murder	kill	saint
bump	hill	win	kitchen	cook	ounce
sofa	couch	regret	middle	center	think
trumpet	piano	bake	below	above	evict
grief	sorrow	big	road	street	beg
cake	bake	sorrow	study	think	uncle
stare	glare	corn	end	final	clock
nurse	doctor	fairy	time	clock	above
tale	fairy	doctor	bruise	injure	hog
dawn	dusk	glare	dryer	washer	loud
trail	path	couch	shovel	dig	copper
bomb	atom	become	beast	beauty	war
smoke	tobacco	hill	pig	hog	look
sorry	regret	tobacco	lunar	solar	swift
lose	win	fashion	insane	crazy	dig
forest	woods	clerk	razor	blade	frown
store	clerk	dusk	brass	copper	tails
clothes	fashion	piano	plate	dish	coffee
doubt	believe	allow	tea	coffee	exam
square	circle	path	blow	whistle	elect
ground	earth	woods	noise	loud	beauty
change	become	circle	throw	catch	less
let	allow	earth	listen	look	may
little	big	believe	smile	frown	blade
subtract	add	center	quick	swift	dish
bug	insect	strong	vote	elect	spring
plead	beg	purse	june	may	whistle
wallet	purse	rabbit	test	exam	apart
niece	nephew	magazine	fall	spring	solar
knit	yarn	cook	peace	war	catch
fox	rabbit	final	together	apart	injure
burn	fire	insect	heads	tails	crazy
pole	flag	add	more	less	washer

### Experiment 1 and 2: Nonword Targets and their Primes

#### Practice Nonwords

<u>Target</u>	<u>Prime</u>	<u>Target</u>	<u>Prime</u>	<u>Target</u>	<u>Prime</u>	<u>Target</u>	<u>Prime</u>
wrabe	bald	vrkel	maze	hiffer	lobster	jendo	mask
tahane	beverage	lopmet	bucket	cambit	badge	raithe	furnace
peams	chat	drenk	scam	skarger	bean	mund	mister
honad	crib	suddap	purple	fep	ferry	yarber	wicked
fodorst	adapt	quib	brochure	vincer	scout	soid	grudge

## Critical Nonwords

<u>Target</u>	<u>Prime</u>	<u>Target</u>	<u>Prime</u>	<u>Target</u>	<u>Prime</u>	<u>Target</u>	<u>Prime</u>
ecsat	pamper	rit	emerald	ully	trout	grabe	robe
srip	cloak	hetruare	syrup	eweraid	nail	ockan	tiger
strerm	howl	seripes	eternity	saft	insult	roist	fake
glound	steal	sind	fold	vadku	bacon	nox	whisper
grop	castle	darp	toe	mannow	reef	plark	revolver
gesolver	cheese	slory	drum	wooth	heater	branken	hunger
sifebalk	poison	boods	decay	srund	soup	werdine	stiff
anster	rug	smire	trick	rure	painter	cherk	cloud
clewn	sweep	meap	tent	pell	pond	errot	maid
plency	sober	shog	devil	stomath	stabl	soger	yard
ent	orange	tomic	stem	ope	roll	rainter	sell
belb	barn	mipor	sing	har	funny	ritial	poem
zorsa	blame	blass	mystery	sriff	ring	talt	leg
soje	cotton	plave	february	seng	hat	erbom	chair
seg	iron	lim	slight	starb	wind	splenn	leader
lote	raise	elt	library	poom	die	trin	pain
mufe	moon	jeb	sweet	queck	bottom	jummer	poor
gaid	clean	gos	train	thume	none	anife	moral
frint	judge	deet	supply	ret	summer	haim	father
mry	sea	tig	piece	walty	cold	vong	job
nove	wide	tage	police	tensy	wife	sporn	room
smalf	answer	frief	effect	fice	least	wump	world
crimb	plan	frop	want	lerst	never	pelom	spleen
toin	past	peath	take	together	hump	pon	braces
soba	part	heigot	wiggle	tane	shiny	swerp	groom
clorn	prank	drisk	necklace	henazel	verb	walleg	spoon
dount	dew	prairit	thirst	hontine	poker	pammer	mansion
wint	mule	prain	linen	woste	oven	zea	hail
infane	swamp	shobel	garbage	helt	doll	droom	deer
bruist	cough	hobe	turkey	sall	violin	orber	upset
stean	pants	saitor	infant	nobe	lend	forrid	whiskey
veresable	wool	chilt	gum	vellet	awful	jall	ugly
shom	arrow	foog	damp	decret	screw	stabile	pot
pretitent	tense	tob	desert	weam	fist	lind	beef
turker	lean	theckers	fog	tilk	ceiling	floger	error
accelt	tie	srrell	fence	poje	tape	sodry	hate
freevol	modest	sep	worst	wibe	rare	ince	suit
mird	ocean	fint	proof	bothel	cry	vand	minor
sry	temple	gilver	author	brust	wheel	asleet	thick
ruk	snake	uneer	plenty	hodd	cell	gife	dog
deg	grass	scref	rifle	liss	valley	nepper	pass
meb	slow	fisten	sharp	dirn	enemy	kem	plane
sote	foot	mostery	regular	bape	ball	barm	hour
kearn	watch	pandy	health	tharrel	try	spinath	red
vower	gas	gloup	student	smaft	hope	thirk	south
dorp	freedom	errom	picture	pacture	close	bofe	group
yalt	start	smone	girl	dit	white	hetter	first
nabric	town	wrone	light	woot	being	gouth	amaze
prum	help	throm	year	tert	skillet	stant	coy
danner	small	grost	banjo	opeda	tick	axame	sailor
flace	valor	sheebs	salmon	fre	weigh	feg	web

<u>Target</u>	<u>Prime</u>	<u>Target</u>	<u>Prime</u>	<u>Target</u>	<u>Prime</u>	<u>Target</u>	<u>Prime</u>
tapi	pardon	mape	dry	pid	bucket	salgon	pull
jeel	lease	lound	nice	borts	slum	clord	drop
stams	hut	dight	thin	benlo	mob	cound	seek
duzzy	fabric	bamp	chief	wem	map	jurge	knife
crond	print	theel	letter	tifle	shower	toadeer	worth
paber	bother	tarls	near	chait	essay	swarp	window
stome	sand	shart	keep	bence	soap	bolb	food
squr	wedding	blof	night	tider	wound	birl	play
jufe	innocent	soad	some	bealth	bone	trive	car
beld	smooth	whime	cheat	faucer	stomach	ardy	general
fot	choose	raib	forbid	jeef	coat	slurent	her
bocket	sky	sint	skip				

### Experiment 3: Word Targets and their Related (R) and Unrelated (U) Primes

#### Practice Items

<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>	<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>
almond	walnut	helmet	invade	attack	escort
beige	tan	spy	itch	scratch	junk
binge	starve	retire	satin	silk	drawer
blouse	skirt	twin	aisle	row	radish
coyote	wolf	pearl	album	record	illegal
groan	moan	locker	bang	crash	polite
ketchup	mustard	spiral	bizarre	strange	mint
applaud	clap	dock	telegram	message	rocket
boring	dull	quack	tune	song	exit
cute	pretty	lotion	flush	toilet	spear

#### Critical Items

<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>	<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>
trumpet	piano	beauty	stare	glare	basket
tear	rip	beer	taxi	cab	bread
end	final	blade	tree	leaf	dinner
gain	loss	birth	choice	option	crack
army	soldier	dizzy	break	crack	cab
razor	blade	elect	journal	magazine	earth
faint	dizzy	final	boots	shoes	glare
smell	taste	hill	polish	shine	injure
truth	honest	insect	meat	steak	leaf
paper	pencil	honest	bruise	injure	lost
topic	issue	loss	button	sew	magazine
death	birth	issue	sleep	bed	may
wine	beer	mud	supper	dinner	mumps
vote	elect	pencil	crowd	people	option
bug	insect	piano	measles	mumps	sew
grape	raisin	rip	butter	bread	people
dirt	mud	raisin	found	lost	steak
beast	beauty	soldier	june	may	shoes
talk	speak	speak	ground	earth	shine
bump	hill	taste	pole	flag	church
weave	basket	bed	tornado	hurricane	circus

<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>	<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>
test	exam	couch	fair	just	saint
grief	sorrow	creek	key	lock	spice
bird	robin	dusk	rain	weather	toast
horn	honk	eagle	dream	imagine	washer
dawn	dusk	exam	jam	toast	weather
stream	creek	flag	road	street	carry
run	walk	float	virus	germs	center
priest	church	honk	forest	woods	coffee
hawk	eagle	hurricane	shovel	dig	command
velvet	plush	kill	quick	swift	dig
film	movie	plush	order	command	disease
height	weight	movie	tea	coffee	germs
sofa	couch	robin	sting	wasp	jump
clown	circus	sorrow	sentence	paragraph	lettuce
murder	kill	spray	cancer	disease	master
sink	float	walk	leap	jump	maybe
old	young	weight	niece	nephew	paragraph
foam	spray	young	might	maybe	nephew
doubt	believe	add	drink	water	right
plain	fancy	bake	hold	carry	short
noise	loud	believe	slave	master	street
subtract	add	brother	long	short	swift
guilt	shame	catch	wrong	right	wasp
pie	crust	checkers	middle	center	water
saturn	uranus	crust	salad	lettuce	woods
fox	rabbit	fancy	fuzzy	hairy	baby
chess	checkers	finger	silver	gold	beg
throw	catch	glue	heads	tails	clerk
candy	snack	less	waltz	dance	cook
senator	president	rabbit	rule	obey	dance
sister	brother	president	tale	fairy	dime
tame	wild	purse	wage	salary	fairy
wallet	purse	loud	store	clerk	fame
want	wish	shame	false	true	gold
stick	glue	snack	child	baby	multiply
cake	bake	uranus	glove	mitten	mall
thumb	finger	wish	kitchen	cook	metric
more	less	wild	nickel	dime	mitten
heaven	hell	above	plead	beg	hairy
bomb	atom	fishing	news	report	obey
box	crate	board	shop	mall	report
show	expose	crate	divide	multiply	salary
plank	board	expose	meter	metric	tails
bank	money	atom	melt	thaw	true
stress	nerves	haunt	fortune	fame	thaw
below	above	hell	time	clock	axe
home	house	just	sour	lemon	awake
hunting	fishing	imagine	little	big	clock
swim	pool	house	learn	teach	big
ghost	haunt	lock	chord	note	crazy
holy	saint	money	knit	yarn	daring
dryer	washer	nerves	insane	crazy	drill
herb	spice	pool	hatchet	axe	high

<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>	<u>Target</u>	<u>R. Prime</u>	<u>U. Prime</u>
bold	daring	lemon	draw	sketch	touch
lose	win	king	stove	fridge	squid
sound	sight	fiery	remove	evict	uncle
once	twice	note	brass	copper	trash
saw	drill	spouse	octopus	squid	war
flame	fiery	sit	aunt	uncle	whistle
mate	spouse	sight	pepper	salt	apart
low	high	strong	plate	dish	ascend
stand	sit	teach	deep	shallow	corn
asleep	awake	twice	story	novel	cow
weak	strong	win	danger	safe	custom
queen	king	yarn	pound	ounce	dish
west	east	copper	opera	musical	fire
under	over	east	spinach	corn	hog
peace	war	early	mouth	lips	frog
blow	whistle	covering	together	apart	honey
waste	trash	evict	burn	fire	musical
bad	good	empty	ritual	custom	lips
empty	full	hard	pig	hog	novel
late	early	good	climb	ascend	ounce
elbow	knee	fridge	afraid	scared	safe
feel	touch	knee	smart	stupid	salt
soft	hard	man	toad	frog	scared
woman	man	over	spring	fall	shallow
pavement	sidewalk	sketch	bull	cow	stupid
blanket	covering	sidewalk	bee	honey	fall

#### Experiment 4: Word and Nonword Targets and their Unrelated (U) Primes

##### Practice Words

<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>
aisle	spear	mate	crib	ritual	center	taxi	flag
trumpet	imagine	bizarre	weather	bang	exit	soft	bean
tale	good	grief	float	insane	finger	coyote	spiral
stand	fiery	guilt	robin	opera	honey	late	scam
blouse	locker	bee	win	journal	believe	sink	hell

##### Critical Words

<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>
time	frog	button	radish	plate	touch	wallet	people
dawn	loud	flame	drill	stress	basket	pie	sew
more	wasp	under	teach	plead	dance	show	baby
cake	gold	truth	final	salad	right	gain	hill
bold	lips	height	injure	pepper	salary	home	thaw
story	uncle	climb	novel	blow	chat	almond	helmet
hold	king	west	bald	velvet	raisin	learn	clock
tornado	brother	hatchet	disease	silver	rabbit	hawk	atom
sting	toast	want	lock	chord	awake	crowd	glare
saturn	pencil	shovel	weight	toad	past	mouth	adapt
bank	obey	wine	loss	shop	knee	peace	sight
feel	mask	bull	moon	bomb	cook	groan	blade

<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>
bruise	rocket	butter	polite	priest	dinner	deep	iron
pig	man	glove	fairy	clown	shine	long	east
dream	board	subtract	checkers	talk	dusk	tear	mint
waltz	short	break	taste	topic	earth	bad	cow
quick	house	sleep	eagle	paper	elect	stare	creek
forest	church	smell	crack	meter	clerk	news	corn
leap	note	cancer	uranus	afraid	coffee	horn	wish
beige	quack	knit	safe	saw	axe	once	fall
little	washer	foam	jump	kitchen	command	boring	escort
choice	escort	box	add	fox	mud	fortune	shallow
ghost	snack	film	just	weave	couch	together	brochure
middle	sorrow	senator	musical	telegram	magazine	sofa	wild
melt	dish	spinach	freedom	sour	fire	pavement	multiply
noise	plush	fuzzy	maybe	bug	rip	wage	over
sound	hairly	measles	fishing	virus	crate	satin	dizzy
order	haunt	june	kill	below	fancy	road	yarn
sister	option	plank	money	elbow	squid	swim	dime
holy	fame	death	speak	slave	germs	flush	piano
dryer	shame	cute	twin	beast	mumps	murder	insect
boots	speak	false	woods	burn	wide	queen	crazy
rule	hard	test	bake	chess	young	meat	walk
faint	bread	thumb	catch	polish	drawer	octopus	furnace
grape	shoes	run	bed	vote	leaf	jam	beg
pound	apart	spring	master	razor	issue	rain	true
nickel	expose	bird	glue	invade	lotion	pole	less
found	steak	lose	salt	army	beer	ground	honest
heaven	circus	album	birth	itch	junk	woman	evict
divide	nerves	hunting	whistle	applaud	soldier	empty	twice
weak	maze	remove	street	dirt	exam	draw	howl
tea	big	plain	spray	blanket	lettuce	herb	mall
key	dig	tune	dock	sentence	covering	tree	honk
end	spy	danger	report	smart	ounce	old	cab
ketchup	illegal	asleep	metric	tame	pool	brass	empty
wrong	swift	fair	high	might	spice	drink	carry
stick	above	store	tails	candy	purse	stove	trash

## Practice Nonwords

<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>
fep	lom	vand	mirt	salgon	yometh	clorn	werge
ecsat	spood	raithe	teshly	pendo	imirt	jufe	deng
ockan	hooly	hetruare	scaffita	pammer	nerple	fodorst	nabinks
nepper	yastid	prain	magda	chait	neesh	crond	thack
honad	jacey	slurent	fermice	shom	jost	deet	loma

## Critical Nonwords

<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>
vong	dage	benlo	maige	eweraid	slindle	ent	daf
darp	woge	liss	verp	squr	rilt	plave	ruton
smone	hetch	flace	kinon	ruk	hax	cound	maber
gloup	pewty	nobe	glit	sodry	wheck	hetter	washau
forrid	dugley	hobe	plok	gouth	birka	orber	smoof

<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>	<u>Target</u>	<u>U. Prime</u>
scref	ghobe	henazel	dosheck	yalt	onom	grop	wolt
hontine	pickalm	poje	karn	ully	bife	cambit	gither
seg	yut	tahane	dreefy	soje	gawm	dronk	fuper
ardy	mife	pelom	egrat	quib	skut	frint	aquid
wibe	bost	bruist	guylod	plark	qesh	mape	losh
slory	minga	rure	dest	rit	pob	weam	hist
frop	vate	smaft	lirse	errom	astit	toadeer	rucksot
peams	clorm	anife	yoral	boods	disty	fint	nafe
soad	narm	heigot	gorfas	trive	ashop	bothel	mixrap
tert	wome	stabile	mested	seripes	nomagon	thecker	zimphad
branken	thermat	helt	corb	jall	awix	borts	thosh
gife	vort	sep	tro	vincer	whalmy	bape	stom
tob	yus	ipe	hup	wooth	emedede	srip	tarf
meb	afe	sriff	rancy	theel	gorte	jeel	sart
feg	hos	turker	ellest	peath	thimp	soba	terl
smalf	derms	fre	cag	yarber	vingus	erbom	snerk
sint	parf	anster	tealth	wem	yon	sind	lerp
saft	buxa	gaid	idon	kem	lup	lind	poil
talt	dimp	tifle	fabot	starb	frenk	sudrap	moomer
pacture	beshalt	soger	vitty	nox	kir	haim	tish
raib	demp	dorp	plue	meap	frut	bealth	chomat
axame	rewer	wrone	valga	elt	ork	lim	gat
mipor	corza	trin	peng	nove	jald	fot	vek
woot	ferk	barm	ribe	zorsa	vashy	roist	nazer
swerp	recks	sall	mige	belb	horf	skarger	pishit
swarp	prent	queck	knoma	jummer	eshote	lerst	bosal
splenn	morkle	strerm	rentop	jurge	vaimy	srund	plame
throm	poose	lopmet	trisim	floger	beshar	soid	klop
uneer	amace	tharrel	cosheda	errot	ladby	gos	fak
shobel	wretip	pandy	strub	chilt	flasp	bofe	gast
sheebs	canpod	vower	sarny	toin	dist	freevol	vergise
glound	bentam	werdine	hockart	mund	bris	blof	fipe
mannow	inwerp	drisk	uttle	wump	farn	fice	bult
wrabe	theck	stean	habor	mufe	palk	thume	ilker
pon	dir	deg	swa	tane	foab	danner	ibselt
shog	jire	clewn	eagot	vadku	gresh	prum	clat
sote	famp	tilk	phap	paber	joply	beld	swoy
tider	bohon	walleg	porsir	dirn	ecks	stams	quigg
stant	plerk	frief	wasla	mry	wib	dight	treld
urkel	hollip	grost	thirp	faucer	wergle	seng	chut
mird	pepo	blass	drint	foog	whex	wint	poob
clord	hanen	srell	bouck	accelt	mindon	tage	hirk
ret	jum	bence	slarf	lote	praw	tarls	miffo
opeda	daipy	dit	pab	gesolver	salapant	zodd	faip
wiste	traik	kearn	broup	hiffer	bandow	bamp	phet



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Title of Thesis:

Isolating Retrospective Priming Processes Using Relatedness Proportion Manipulations

Author



Glen Edward Bodner

September 24, 1997