A CUE-COMPOUNDING MODEL OF SEMANTIC PRIMING

By

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ABSTRACT

Three projects on semantic priming are reported that converge on a variant of Ratcliff & McKoon's (1988) cue-compounding model. In Chapter 2, two experiments test the semantic matching mechanism of backward priming and nonword facilitation. Contrary to predictions derived from the semantic match, results from Experiment 1, in which stimulus onset asynchrony (SOA) is manipulated, indicate that backward priming and nonword facilitation are caused by independent mechanisms. Results from Experiment 2, which manipulates relatedness proportion and nonword ratio by including different proportions of "related" nonwords in the list, concur with the separate mechanism hypothesis. The cue-compounding model is presented in Chapter 3 to account for the data.

In chapter 4, two further experiments investigate semantic priming of degraded targets. Spreading activation accounts (e.g., Collins & Loftus, 1975) predict that priming should be greater if degradation slows identification of the target. However, it was found that at short SOA, degrading the target either by presenting it in mixed upper and lower case letters (e.g., DoCTor) or by masking it after a brief presentation (150 ms) *decreased* priming against a neutral baseline. It is asserted that this pattern of results is

inconsistent with spreading activation accounts, but can be simulated with the model presented in Chapter 3.

In Chapter 5, a critique of a recent article by McNamara (in press a) is presented. McNamara reported three experiments demonstrating three-step mediated priming (Experiment 1) and intertrial prime-target lag (Experiments 2 and 3). Although the results lead McNamara to conclude that spreading activation is the better account, this critique asserts that his results do very little to distinguish between current models because of questionable inferences and statistical procedures. The model in chapter 3 is used to simulate three-step mediated priming.

ACKNOWLEDGEMENTS

After coming to the realization some years ago that the acknowledgment section is really the only part of a Ph.D. thesis that is read with any consistency, I decided this segment needed some careful deliberation! At first, I concluded that I wanted acknowledgments that were superficially reserved and aloof, but beneath the surface, tender and heart-felt (much like a scientist's attitude toward his/her own theory). Then my decision changed; I was to write a scintillating, frisky section that had an air of satire and irony (much like a reviewer's comments on a paper submitted for publication). Finally, after considerable reflection with no solution, I decided I was spending too much time on the acknowledgments and had better get busy with other things.

I would like to express gratitude to my supervisor, Dr. Lee Brooks, whose ability to analyze and tease apart psychological problems and theories is surpassed by no one. It is his unselfish concern for his students and his numerous helpful suggestions that made this project possible. I would also like to thank the other members of my supervisory committee, Dr. Larry Jacoby and Dr. Lorraine Allan, for their useful comments and observations. Also, thanks to Dr. Bill

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Chapter 1

INTRODUCTORY COMMENTS

The experiments and discussion in this thesis are part of three projects on the semantic priming effect. The semantic priming effect occurs when the latency to identify a target word (e.g., "cat") presented shortly after an associatively related prime word (e.g., "dog"), is less than if the target word is presented after an unrelated prime word (e.g., "table") or a neutral prime word (e.g., "blank"). There are two common measures of semantic priming; latency before pronouncing the target item and latency before specifying that the target item is a "word" versus a "nonword" (pronounceable letter string that is not an English word, e.g., "tible"). The latter measure is known as lexical decision.

Each project in this thesis has been submitted independently for publication with myself as the only author. Some changes were made to the original documents in order to avoid redundancy between chapters and to improve the lucidity of the overall package. The projects are highly related since all three converge on a new model of semantic priming which is an extension of a cue-compounding model presented by Ratcliff & McKoon (1988).

The first project, which is presented in Chapters 2 & 3, addresses the mechanisms of backward semantic priming and nonword facilitation. Backward priming is a special form of semantic priming in which facilitation occurs to a target that is not an associate of the prime word. The only relationship between the prime and target is reverse in direction; the prime is an associate of the target word. Nonword facilitation occurs when response latencies to a nonword preceded by a word prime not previously presented are less than latencies to a nonword preceded by a neutral prime (e.g., the word "BLANK" presented many times throughout the experiment). Neely and colleagues have argued that both backward priming and nonword facilitation are caused by the semantic matching process (Neely & Keefe, 1989); after identifying the target word, the subject checks to see if they are related. If they are, a speeded "word" response ensues (backward priming). If they are not, a speeded "nonword" response is made relative to a neutral condition in which the semantic match is assumed to not occur (nonword facilitation). The results of the two experiments reported in Chapter 2, however, are inconsistent with predictions derived from the post-lexical semantic matching mechanism. While backward priming may indeed be caused by a speeded decision in response to the discovery of a positive semantic relationship, nonword facilitation seems to be caused by an independent "novelty of prime" effect. In short, the conditions that are compared to determine nonword facilitation (word prime not previously presented/nonword target versus neutral prime/nonword target) are not controlled with regard to prime recurrence. The results suggest that it is the difference in prime novelty between the conditions that actually causes nonword facilitation, not the availability of prime/target semantic information.

In response to the failure of the semantic matching mechanism, the extension of Ratcliff & McKoon's (1988) cue-compounding model is outlined in detail in Chapter 3. Cue-compounding models were first introduced into the literature in the late 1980's by Ratcliff & McKoon (1988) and independently by Dosher & Rosedale (1989). They represent a new, innovative method of interpreting semantic priming effects. Previous models of semantic priming have assumed the presence of a lexicon, or semantic memory system which consists of acontextual, concept nodes that are activated when a skilled reader cognitively processes words (Collins & Loftus, 1975). For example, if the word "dog" is read, the semantic "dog" node is activated. If it is activated enough (above threshold activation occurs), it is consciously identified. Activation is not unique to the "dog" node however; it can spread to highly related nodes (e.g., "cat") via links that connect them. Semantic priming is commonly attributed to that spread of activation. That is, if the word "dog" is presented as a prime, activation spreads from it to the "cat" node such that by the time "cat" is presented for identification, the "cat" representation is already partially activated. Thus it takes less time for activation from processing the word "cat" to reach threshold and for the item to be identified.

With cue-compounding models, it is assumed that a prime and target (e.g., "dog" - "cat") are combined into a compound retrieval cue which is used to access representations in memory. The accessed representations are not necessarily nodes linked together as in a lexicon, but may be episodic representations. In short, since cue-compound models are proposed in conjunction with episodic memory models (e.g., SAM, Gillund & Shiffrin, 1984) and utilize episodic memory terms such as "familiarity", they bring semantic priming into the episodic memory arena. This forces researchers to start considering semantic priming in the same context as recognition and recall and episodic memory in general. At the global level, therefore, my attempt to incorporate semantic priming effects into the compound-cue model presented in this thesis is a modest attempt toward changing the common view that semantic priming is a phenomenon that occurs because of activation spreading throughout a semantic network.

Following the presentation of the model, two additional experiments are reported in Chapter 4 which constitute Project 2. The experiments address semantic priming of visually degraded targets at short prime/target onset asynchrony. Again, these terms will be defined in the relevant chapter, but the general finding from this research is that the cue-compounding model that was presented in Chapter 3 does an excellent job of predicting the results. Conversely, spreading activation, the more commonly adopted mechanism of semantic priming effects at short prime/target onset asynchrony, does not fare so well. In fact, it predicts results opposite to those that are found.

In Chapter 5, a critique of a very recent paper by McNamara (in press a) is presented. McNamara (in press a) reported three experiments that were meant to distinguish between spreading activation and cue-compounding models of semantic priming. He concluded that spreading activation models could account for data that cue-compounding models could not. However, as Chapter 5 will outline, there were a number of inferential and statistical problems in the paper that make this conclusion inappropriate. The critique is particularly relevant to the thesis since McNamara's arguments are founded upon assumptions about cue-compounding models that are not adhered to by the model presented in Chapter 3. One of the most serious is the assumption that strengths within the model are representations of *associations in memory* (i.e., links between nodes in semantic memory). As already mentioned, this assumption is not necessarily adopted by compound cue models, and this error has disastrous consequences on the validity of the conclusions made in McNamara's paper.

Finally, some concluding comments are presented Chapter 6.

Chapter 2

BACKWARD PRIMING, NONWORD FACILITATION AND THE SEMANTIC MATCHING MECHANISM

One of the most replicated findings in cognitive psychology is the semantic priming effect. Specifically, if a word (the target) is processed in the context of an associatively related word (the prime), the target is identified as a word more quickly than if it is processed in the context of an unrelated word or a neutral prime (e.g., "XXX" or the word "BLANK" used many times throughout the experiment). The effect was first reported twenty years ago by Meyer & Schvaneveldt (1971), using simultaneous presentation of the prime and target. However, more recent studies generally have a several hundred millisecond latency between the onset of the prime and the target. In this form, semantic priming has been a topic of extensive study and numerous theories have been developed to incorporate the expanding body of empirical constraints generated by this research (see Neely, 1991 for a review).

Until recently, nearly all theoretical accounts of priming have emphasized the relationship *from* the prime *to* the target. For example, Posner & Snyder (1975) proposed that when the prime is presented, two processes occur. First, there is an automatic spread of activation (Collins & Quillian, 1969) in a semantic network from the prime node to the target node that occurs quickly and automatically. Second, the presentation of the prime allows the subject to generate a set of semantically related target candidates before the target is presented, reducing the number of potential candidates there would be if no prime were presented. This expectancy mechanism is presumed to take longer and be under the subject's strategic control. Both mechanisms operate before lexical access of the target word has occurred. It is clear, therefore, that the important relationship between prime/target pairs is forward in direction. Indeed, the notion that the reverse relationship be considered important or even relevant to semantic priming has been described as "counter-intuitive" (Neely, 1991, p. 272).

Despite its counter-intuitive status, backward priming has been demonstrated. In these experiments, primes were not associatively related to targets, but targets were highly related to primes. Examples of related prime/target pairs are down/sit or pan/bed. The backward facilitation obtained in these experiments generally was as high as forward priming. Koriat (1981, Experiment 3) was the first to establish the existence of backward priming, and it was replicated shortly after by Seidenberg, Waters, Sanders & Langer (1984, Experiment 3). More recently, Shelton & Martin (in press, Experiment 2) replicated the effect and Peterson & Simpson (1989) have demonstrated backward priming with both pronunciation and lexical decision.

Despite these demonstrations, backward priming has not been central to theorizing. This is unfortunate because this sort of priming could prove to be a powerful tool for teasing apart the different mechanisms proposed to account for priming. For example, Posner & Snyder's (1975) two process theory cannot account for backward priming without some awkward embellishments to the original version. Koriat (1981) suggested that backward priming operates via an activation feedback loop in the semantic network. That is, facilitation is assumed to occur since sub-threshold activation spreads from the target (bed) to the prime (pan) and back to the target again. However, it is unclear from this analysis exactly how activation from the prime feeds back to the target since there is no relationship in that direction. Surely if such process were possible, it would be expected to occur upon initial processing of the prime. It might be proposed that with pairs like "pan-bed", "bedpan" becomes activated (since "bed" and "pan" are simultaneously activated) and activation spreads back to "bed" thus causing facilitation (Neely & Keefe, 1989). However, this explanation does not apply to most asymmetrically associated words (e.g., "baby-stork") and only a small proportion of sub-compound words yield a compound word as a direct associate. Thus the average spread of activation in that direction should be slight. Additionally, it is uncertain how a constrained expectancy set could facilitate identification of the target since it is not an associate of the prime. Even if these obstacles could be overcome, it is particularly troublesome to try to explain how backward priming effects could be as large as forward priming effects for the same words. The "roundabout" route that the two-process theory must take in order to incorporate the effects would probably predict that they be attenuated.

Although the backward priming effect causes problems for the dual-process theory, other mechanisms of priming have been proposed that easily account for it. Generally, backward priming is assumed to occur because of post-lexical mechanisms (Neely, 1991; Neely, Keefe & Ross, 1989; Sereno, 1991; Peterson & Simpson, 1989; McNamara, in press a, b; Shelton & Martin, in press; Seidenberg et al. 1984). Ordinarily, post-lexical processes are proposed in conjunction with other forward-acting mechanisms of priming such as spreading activation. Post-lexical mechanisms assume that the facilitation in responding to a binary choice such as lexical decision can occur after the target has been identified. Somewhere between identification of the target and elicitation of the response, the subject checks the relatedness of the prime/target pair. If they are related, this speeds a "word" response. Various mechanisms of this sort have been proposed (e.g., plausibility check: Norris, 1986; coherence check: de Groot, 1984), however, this chapter will focus on one particular form of post-lexical relatedness check, the semantic-matching process (Neely et al., 1989; Neely & Keefe, 1989; Neely, 1977).

A central feature of the semantic matching mechanism is that a post-lexical check can occur on nonword as well as word target trials. During the semantic matching process, it is proposed that presentation of the target activates a representation in memory. If the target is a word, then a representation of that word is activated. If the target is a nonword, then representations of words that are visually similar to that nonword are activated. Thus if the nonword "bink" is presented as the target, then representations of the words "pink", "bank", "fink" and "link" may be activated. The word(s) activated by the target is then semantically compared to the prime. Because of the way that most priming experiments are designed, the results of the semantic match are usually predictive of the correct lexical decision; if the pair is related, then the target is always a word. If they are not, then it is more likely to be nonword. The latter statement is true because nonword targets in priming experiments are typically derived from words that are unrelated to the prime word. Thus, information obtained from a semantic match facilitates responses on related word/word trials and word prime/nonword trials relative to neutral prime/target pairs where no such information is available. The first facilitatory effect is (backward) semantic priming. The second is known as *nonword facilitation* (Neely, 1976, 1977; Schuberth & Eimas, 1977).

It is assumed that the semantic match does not operate when there is little time between the onset of prime and target. This is assumed because the prime/target semantic relationship will not have had time to be determined before a response is made via detailed lexical analysis of the target (Neely et al., 1989). Consistent with this notion is the report that nonword facilitation does not occur at short stimulus onset asynchrony (SOA) (Neely, 1977; de Groot, 1984; Favreau & Segalowitz, 1983). While SOA clearly has been shown to affect nonword facilitation, its effect on backward priming is not clear. Peterson & Simpson (1989, Experiment 2b) found that backward priming occurred with a lexical decision task at both 0 and 200 ms SOA. However, their procedure was slightly different from the conventional priming paradigm in that the prime and target were presented in different modalities (auditory and visual presentations respectively). Shelton & Martin (in press, Experiment 2), on the other hand, discovered that backward priming did not occur in a sequential lexical decision task at short SOA. Interpretation of their results, however, is complicated by the fact that forward priming with the same materials did not occur. Therefore, SOA is manipulated in Experiment 1 in an attempt to clarify its influence on backward priming. In turn, it is hoped a conclusion can be drawn regarding the relationship between backward priming and nonword facilitation and the role the semantic matching mechanism plays in modulating these effects.

Experiment 2 manipulates the structure of the priming list. Context variables such as the proportion of related word/word trials (relatedness proportion or RP) and the proportion of targets in the list not related to their prime that are nonwords (nonword ratio or NR) have been reported to significantly affect both the amount of semantic priming and the amount of nonword facilitation obtained (e.g., Tweedy, Lapinski & Schvaneveldt, 1977; de Groot, 1984; Neely, 1977). As long as the proportion of words to nonwords is held constant, the semantic matching process predicts that relatedness proportion will affect both semantic priming and nonword facilitation. To understand this prediction, consider the most extreme case where RP = 1.0. In that case, the targets from all related prime/target pairs are words while the targets from all "unrelated" pairs are nonwords. Thus, a post-lexical match is perfectly predictive of target lexicality, and so the probability that a particular subject will rely on the strategy should be maximized. However, the effect of list context on *backward priming* has not been studied. It would be informative, therefore, to examine the relationship between list context and backward priming given that backward priming is assumed to be caused by the same strategic mechanism that causes nonword facilitation.

Before delving into a report of the experiments, the predicted relationship between backward priming and nonword facilitation needs discussion. Although both effects are purportedly caused by the semantic matching mechanism, it is not entirely clear from descriptions of the mechanism whether a given subject always use *both* relatedness and unrelatedness information to guide responses. There is no reason to exclude the possibility that only one type of information is employed. For example, subjects may decide to use just relatedness information to bias a "word" response, or they may decide to rely solely on unrelatedness information to bias a "nonword" response. Although there is no logical constraint that necessitates that a person *must* utilize both information bases, Neely (1991) has implied in his description of the mechanism that both bases are employed if the mechanism is adopted,

> ... subjects can use information about the presence or absence of a semantic/associative relation between the prime and target and prime to bias their "word" vs. "nonword" responses, respectively. Specifically, if the target and prime are related, the correct response must be "word". Moreover, when the nonword ratio is high, if the

> target and prime are unrelated, the correct response is very likely to be "nonword". Presumably, subjects use this information to speed up their "word" responses in the related priming condition and to facilitate their "nonword" responses when a nonword target follows a word prime, relative to the neutral priming condition in which the semantic matching process does not operate because of its inutility (p. 313).

Therefore, the predictions derived for the following experiments are made with the assumption that, if the semantic matching strategy is operating, a particular subject will use both relatedness and unrelatedness information to bias their appropriate responses. This makes the empirical prediction that backward priming and nonword facilitation should be correlated across subjects. The possibility of utilizing only one information base will be considered in the General Discussion.

In sum, the experiments in this chapter were designed to test the viability of the semantic matching process as a mechanism of both backward priming and nonword facilitation. In Experiment 1, SOA is varied with the hypothesis that backward priming and nonword facilitation should be affected similarly by this variable. That is, if the semantic matching process is responsible for both backward priming and nonword facilitation, then a manipulation that affects one (e.g., SOA) should also affect the other. A parallel prediction is derived for Experiment 2 which examines list context effects (e.g., RP). The present experiments are the first to test both backward priming and nonword facilitation *in the same experiment, using the same subjects with exactly the same test list*. This is important since the semantic matching mechanism makes clear predictions regarding the relationship between these two variables (as noted above), but, to date, these predictions have not been tested appropriately. That is, Neely and colleagues have based their conclusions on comparisons made *between* experiments, which can be dangerous.

Experiment 1

Method

Subjects: Subjects were 48 introductory psychology students who participated for course credit.

Materials & Design: Ninety asymmetrically associated pairs were chosen from several different sources. One member from each pair served as the prime and the other the target. The primary source for the pairs was Keppel & Strand (1970). The main criterion for selection was that the pairs be moderately to highly associated in one direction (e.g., sit -> down), but not in the other (e.g., sit <- down). Additionally, pairs that formed compound words were generally avoided (e.g., bed -> pan) in an attempt to avoid an account of the data in terms of spreading activation theory (see Introduction). Pilot work with the Keppel & Strand (1970) materials indicated that residual forward associations were not responsible for the backward priming that occurred. For example, backward priming was larger for the pairs that had less residual forward association. A few additional pairs were obtained from published studies on backward priming (e.g., Seidenberg et al., 1984 and Peterson & Simpson, 1989).

Half the 90 pairs were used for word target trials and half for nonword trials. The 45 pairs for the word trials were divided into three groups of 15 pairs. In the first group, the pairs were kept intact and the members of the pair were presented as backward related prime and target (e.g., prime: down; target: sit). Members of pairs in the second group were separated such that an unrelated prime preceded each target. For example, the second member (target) of pair n was presented with the first member (prime) of pair n + 1. Members of pairs in the third group were also separated and the first members (primes) were replaced with a neutral prime ("BLANK"). The materials were rotated through these three conditions using three counterbalancing lists. The relatedness proportion was 0.5.

The other half of the 90 pairs were used for nonword trials. Nonwords were formed by changing one letter in each target word to form a pronounceable letter string that was not an English word. The nonword was made as orthographically and phonologically similar as possible to the word from which it was derived. For example, the word "farther" was made into the nonword "farthur" rather than "farthir". Thirty of these 45 "related" word/nonword pairs (e.g., down - sut) were separated and repaired in the same manner as unrelated word trials. This ensured that a nonword target was never presented with a prime that was related to the word from which the nonword target was derived. The remaining 15 pairs were also separated and the first members (primes) were replaced with a neutral prime ("BLANK"). Materials were also rotated through the nonword conditions using three counterbalancing lists. For example, for the first counterbalancing list, two subsets of 15 pairs (A and B) were presented as novel word prime/nonword trials, and the third (C) was presented as neutral prime/nonword trials. The second counterbalancing list had C and A as novel word prime/nonword trials and B as neutral prime/nonword trials while the third level had B and C as novel word prime/nonword trials and A as neutral prime/nonword trials. This procedure ensured that a given target appeared in each condition equally often. The nonword ratio was 0.67.

In addition to the 90 critical trials, 90 practice trials were also included. To form these 90 trials, 60 symmetrically associated pairs were chosen from Keppel & Strand (1970). The set of 60 was divided evenly into 30 word trials and 30 nonword trials. For the word trials, 25 pairs were kept intact and were presented as related prime/target trials. Five were repaired as before and presented as unrelated prime/target trials. Fifteen additional targets that resembled the other targets in the experiment were generated. They were preceded by the word "BLANK" and were presented as neutral prime/word target trials.

The 30 pairs used for nonword trials were repaired as before and presented as word prime/nonword target trials. 15 additional targets that resembled the other targets in the experiment were generated. They were preceded by the word "BLANK" and were presented as neutral prime/nonword target trials. No counterbalancing occurred with materials in the practice phase since response latencies were not measured.

<u>Procedure:</u> Subjects were tested individually on a IBM compatible personal computer. A response box consisting of three keys labelled "word", "nonword" and "start trial" which interfaced with the computer via the game port was used to measure reaction times. Subjects were informed that the object was to make a word/nonword response as quickly and as accurately as possible to the target. They were not informed of a possible relationship between the prime and target, but were told that it was important to read the prime on each trial.

"Press bottom key to start trial" was displayed on the monitor as the subject entered the experiment. As soon as the key labelled "start trial" was depressed, the message was cleared and a fixation stimulus (*) was presented in the center of the screen for 500 ms. The fixation stimulus was replaced by the prime which appeared in the same place in capital letters for either 200 ms (Short SOA condition) or 1000 ms (Long SOA condition). After a 50 ms inter-stimulus interval, the prime stimulus was cleared and the target was displayed one line below and remained there until the subject pressed a key. Its presentation started a millisecond clock which was stopped when a key was pressed. Subjects were instructed to press the top right key (labelled "word") if the target was a word or the top left key (labelled "nonword") if it was a nonword. As soon as one of these keys was pressed, the response latency was recorded and the message "Press bottom key to start trial" was displayed on the monitor again indicating a new trial which could be initiated at the subject's will. Subjects were requested to rest the index finger from the right hand on the "word" button, the left index finger on the "nonword" button, and to initiate each trial with their thumb. It was not considered necessary to counterbalance the arrangement of hands to response class since no comparisons were made between word and nonword responses. If the subject responded to the prime, pressed a wrong key or took longer than 1.5 seconds to respond to the target, an error message was flashed, a beep sounded and the RT for that trial was not used.

The 90 experimental trials were preceded by 90 practice trials made up of related, unrelated and neutral primes and both word and nonword target types in the proportions indicated above. Each subject saw a random order of 90 practice trials followed by a different random order of 90 experimental trials. No indication was provided that the practice phase was over and that response times to critical items were being measured. After the subject responded to all 180 trials, a thank-you message was displayed marking the completion of the experiment.

Results & Discussion

The mean latencies and percent errors for correct responses to words and nonwords in each of the experimental conditions are shown in Table 1.

Three-way ANOVA: It was predicted that nonword facilitation would obtain in the Long SOA group (1050 ms), but not in the Short SOA group (250 ms) since the semantic matching process is assumed to not operate at short SOA (Neely et al., 1989). The first analysis conducted was a 2 ("primed" versus not "primed") X 2 (lexicality) X 2 (SOA) mixed ANOVA on the RT data. This analysis was conducted using both the neutral and unrelated conditions as the "not primed" condition for word targets. With the unrelated word condition as the baseline, the analysis revealed main-effects of lexicality (latencies were longer for nonword targets), $F(1,46) = 135.68$, $p < .001$, $MSe = 5877.45$, and of "priming", $F(1,46) = 4.92$, $p < .05$, $MSe = 1126.58$. In addition, the SOA by "priming" interaction was significant, $F(1,46) = 7.43$, $p < .01$, $MSe = 1126.58$. No other effects were significant.

<u>Table 1</u>: Mean response times (RT) and percent errors (PE) for word and nonword targets preceded by neutral, related and unrelated primes for each condition in Experiment 1.

<u>Short SOA</u>

	words:		nonwords:	
	RT:	PE:	RT:	PE:
backward related:	607	4	-	-
unrelated:	616	7	743	10
neutral:	630	6	730	9

Backward Priming: 9 (unrelated)
23 (neutral)

Nonword facilitation: -13

<u>Long SOA</u>

	words:		nonwords:	
	RT:	PE:	RT:	PE:
backward related:	587	3	-	-
unrelated:	613	4	722	8
neutral:	629	6	744	10

Backward Priming: 26 (unrelated)
42 (neutral)

Nonword facilitation: 22

This analysis, on the surface, may seem like support for the semantic matching mechanism. That is, shortening SOA significantly reduced both nonword facilitation and backward priming, and the failure to achieve a 3-way interaction is evidence that this reduction is not different for word versus nonword data, suggesting a similar underlying mechanism. However, it will become clear shortly that this conclusion may be misleading.

The second analysis used the neutral condition as the baseline for both word and nonword data. It also revealed main-effects of lexicality, $\underline{F}(1,46) = 143.03$, $\underline{p} < .001$, $\underline{MSe} = 4947.04$ and "priming", $\underline{F}(1,46) = 7.84$, $\underline{p} < .01$, $\underline{MSe} = 2034.78$ as well as an SOA by "priming" interaction, $\underline{F}(1,46) = 4.43$, $\underline{p} < .05$, $\underline{MSe} = 2034.78$. Additionally, the lexicality by "priming" interaction was significant, $\underline{F}(1,46) = 9.00$, $\underline{p} < .01$, $\underline{MSe} = 1039.26$. This latter interaction resulted from the fact that, averaged over SOA, backward priming remained intact, whereas nonword facilitation *reversed* at short SOA thus virtually eliminating any overall effect. This suggests that the same mechanism may be not be operating to produce the effects, so further analyses were conducted.

Two-way ANOVA's: In order to further explore the data, two separate ANOVA's were conducted separately for words and nonwords. Nonword facilitation was test first and then backward priming. A 2 (trial type) X 2 (SOA condition) mixed ANOVA was conducted on the nonword latency data with trial type and SOA condition varied within- and between-subjects respectively. As predicted, it yielded a significant interaction of the variables; nonword facilitation was attained in the Long SOA condition (22 ms), but not in the Short SOA condition (-13 ms), $\underline{F}(1,46) = 4.87$, $\underline{p} < .05$, $\underline{MSe} = 1521$. This replicates previous research (e.g., Neely, 1977; Favreau & Segalowitz, 1983; de Groot, 1984). Neither main-effect approached significance, $\underline{F}(1,46) < 1$. Although the error data followed a pattern analogous to the latency data, the interaction was not significant, $\underline{F}(1,46) < 1$.

Backward priming could potentially be measured against either a neutral or unrelated baseline. Therefore, two 2 (prime type) X 2 (SOA condition) ANOVA's tested the significance of the backward priming effects. Both ANOVA's yielded a main-effect of prime-type (neutral baseline: $\underline{F}(1,46) = 16.01$, $\underline{p} < .001$, $\underline{MSe} = 1554$; unrelated baseline: $\underline{F}(1,46) = 4.98$, $\underline{p} < .05$, $\underline{MSe} = 1429$) indicating reliable backward priming using either baseline. These results were supported by significantly fewer errors in the related condition (neutral baseline: $\underline{F}(1,46) = 4.14$, $\underline{p} < .05$, $MSe = .003$; unrelated baseline: $\underline{F}(1,46) = 4.08$, $\underline{p} < .05$, $\underline{MSe} = .003$). Of particular interest, however, was the effect SOA had on the size of backward priming. Table 1 shows that less backward priming is apparent in the Short SOA than in the Long SOA condition, which is predicted if semantic matching is the mechanism that produces the effect. But, unlike nonword facilitation, the backward priming effect did not significantly interact with SOA condition in either the latency data (largest $F(1,46) = 1.50$, $p > .22$) or the error data (largest $F(1,46) = 1.56$, $p > .22$). This suggests that nonword facilitation and backward priming are not as tightly linked as the means suggest. Further support for this comes from the fact that if the neutral baseline condition is used to assess both nonword facilitation and backward priming, reducing SOA reversed nonword facilitation, but 23 ms of backward priming remained.

Another aspect of the data is worth noting. Means for the unrelated word condition are substantially less than in the neutral condition. This is at odds with much of the literature (cf. Neely, 1991 for a review). Usually the opposite effect occurs - *subjects yield inhibition* on unrelated word prime trials at longer SOA, which has been considered support for an expectancy mechanism (Posner & Snyder, 1975). That is, if subjects generate an expectancy set in response to the prime, and fail to find the target in the prime (as would be expected on unrelated prime trials), their responses are inhibited relative to a neutral baseline where no such expectancy set would be generated. One possible reason for the discrepancy between these results and previous findings is that the word pairs used here are *backward* related. Thus it is reasonable to assume that subjects would generate *no* expectancies in response to the prime since there is no prime to target association. This explains why there is no inhibition but does not predict facilitation. This issue will be addressed in detail in Chapter 3. For now, however, it is worth noting that it is not known whether facilitation for unrelated word targets in backward priming experiments is the norm since this is the first such study to include related, unrelated and neutral prime trials.

Multiple Regression: Further analysis of the latency data was conducted to better determine the relationship between the nonword facilitation and backward priming. The following analyses were conducted under the assumption that if a subject demonstrated nonword facilitation, the semantic matching process was being used. If the semantic matching mechanism was being used, then backward priming should also obtain for that subject. In order to test this assumption, all possible "effects" (difference scores) for a subject were calculated. These are shown in Table 2. For words, three different possible difference scores are possible, (1) backward priming measured from a neutral prime trial (BP:N) (2) backward priming measured from a unrelated prime trial (BP) and (3) the difference comparable to nonword facilitation for words which will hereafter be referred to as *word facilitation* (WF); the difference between the neutral and unrelated word conditions. These three scores were entered into a stepwise multiple regression in an attempt to

Table 2: Response latency difference scores for words and nonwords.

Words:

Experiment 1:

BP (backward priming) = unrelated minus related targets

BP:N (backward priming using neutral word condition as a control) = neutral minus related targets

WF (word facilitation) = neutral minus unrelated targets

Nonwords:

NF (nonword facilitation) = neutral minus unrelated targets

Experiment 2:

BNI (backward nonword inhibition) = unrelated minus related targets (Experiment 2)

BNI:N (backward nonword inhibition using neutral nonword condition as a control) = neutral minus related targets (Experiment 2) predict nonword facilitation (NF). The analysis should reveal, if the semantic match process is the basis of both effects, that BP and/or BP:N is a significant positive predictor of NF. It may also reveal that WF is a significant negative predictor. This should occur because if a subject is using the semantic check and unrelatedness information is being used to bias a "nonword" response, then the unrelatedness information obtained from unrelated word targets should also bias a "nonword" response which takes time to overcome.

The stepwise multiple regression was conducted only on latency data obtained from the Long SOA condition since this is the group where the semantic check is supposedly occurring. (Analysis of the Short SOA group yielded no significant effects.) At alpha = .05, only one variable, word facilitation, was entered as a significant predictor of nonword facilitation. Since only one variable was entered, the stepwise regression can be described simply as a correlation coefficient between NF and WF. (Only after the first variable is entered does the nature of the stepwise multiple regression equation differ from simple linear regression.) This correlation was *positive* ($r(23) = .81$, $p < .001$). That is, if a subject demonstrates a large amount of facilitation on nonword targets preceded by a novel, "unrelated" word prime instead of a neutral prime, the analogous difference for words is also large. This result is exactly counter to predictions derived from the semantic match hypothesis. Word facilitation should be in a *trade-off* (negative) relationship with nonword facilitation. If unrelatedness information is derived from a semantic match on both types of trials and is used to speed a "nonword" response, then it should inhibit "word" responses relative to a neutral baseline.

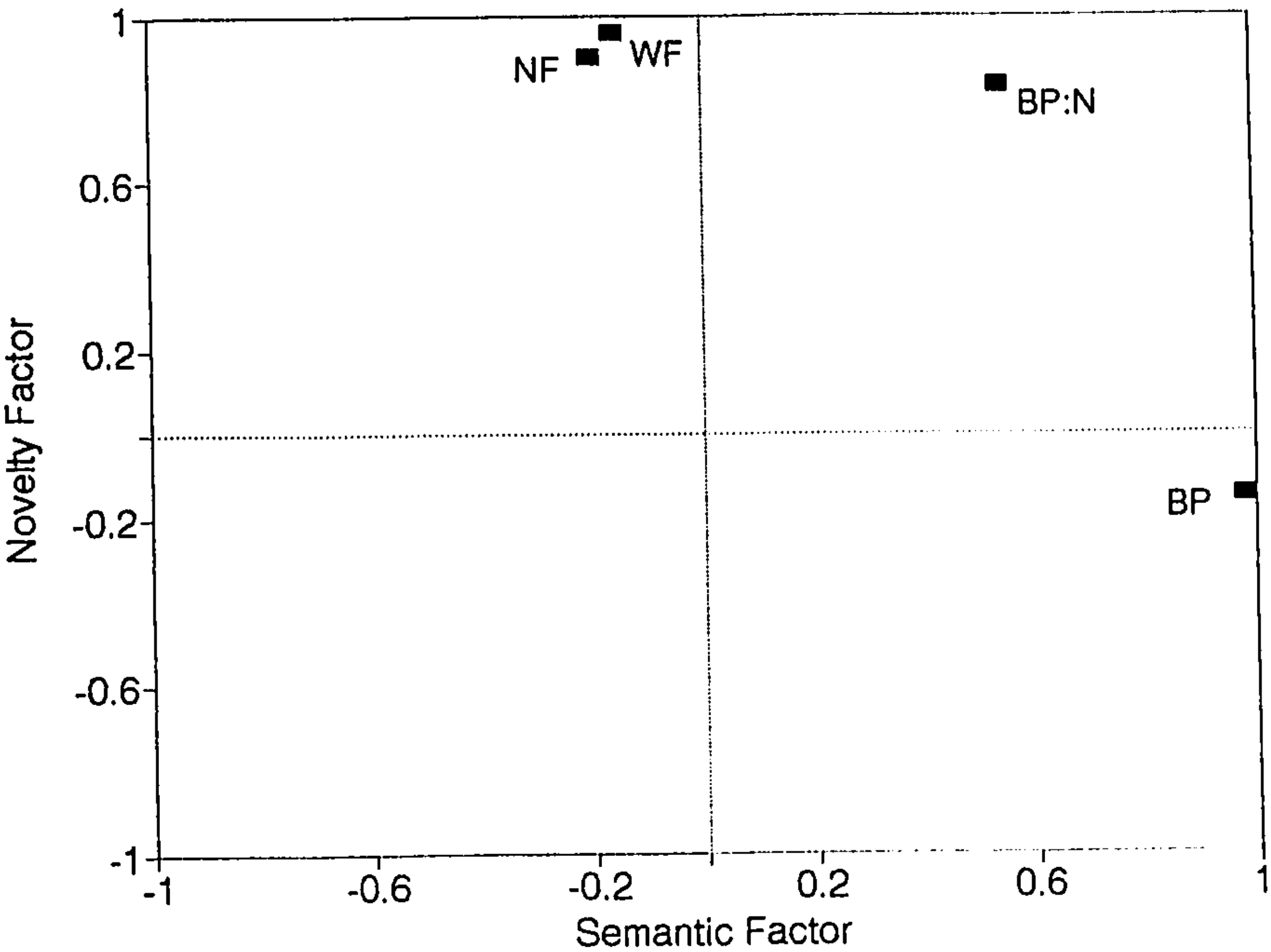
The results of the stepwise multiple regression suggest that the nonword facilitation effect is not due to presence/absence of unrelatedness information. Given that the analogous difference score for words correlates *positively* with nonword facilitation, it suggests that nonword facilitation is caused by a non-semantic aspect of the comparison. The neutral nonword and "unrelated" nonword conditions differ in two ways that may be psychologically important. The first, just explored, is whether or not a semantic match can be performed. The second is whether the prime is *novel* or not; subjects in the Long SOA condition responded more quickly to both word and nonword targets preceded by novel prime (related or unrelated) than to targets preceded by a recurring prime (e.g., the neutral word "BLANK"). The current results suggest that nonword facilitation is caused by the novelty of the prime and not facilitation from a semantic match.

If nonword facilitation is caused by an effect of prime novelty, the careful reader may be curious as to why it is affected by SOA in exactly the manner predicted by the semantic matching mechanism. One possible explanation for this is a greater effect of increased processing demands for novel prime stimuli at short SOA (Jonides & Mack, 1984). That is, if the SOA is short, the increase in processing demands for novel prime stimuli may cause a substantial increase in response latencies to the subsequent nonword target since the prime would be incompletely processed by the time the target appears for lexical decision. At longer SOA, however, the greater processing demands will have less effect since there is more time between the onset of the prime and target. The result of this is less nonword facilitation at short than at long SOA. This issue will be raised again in Chapter 4.

Factor Analysis: To test the hypothesis that novelty effects are actually responsible for nonword facilitation, a factor analysis was conducted on the data from the Long SOA group. If both nonword facilitation and backward priming are produced by the same semantic matching mechanism, then the difference scores for each subject that represent these effects should load on the same factor (i.e., BP and/or BP:N and NF should load on the same factor). Conversely, if nonword facilitation is caused by the novelty status of the prime rather than the semantic relationship between the prime and target, then it should not load on the same factor that produces "pure" backward priming effects (with the confounded novelty factor removed - BP versus BP:N). The results of the factor analysis are shown in Figure 1. Two orthogonal factors were derived from the analysis. A raw Varimax rotation converged after 2 iterations. It is apparent that nonword facilitation loaded exclusively on the first factor, while the pure backward priming loaded almost exclusively on the second. This result suggests that the two effects (NF and BP) are not caused by the same semantic matching mechanism, but rather are attributable to two processes uncorrelated in this experiment.

By examining which effects loaded on particular factors, it is possible to gain some insight into the nature of these factors. Factor 1 seems to reflect the mechanism responsible for the *novelty of prime* effect; any comparison of a novel and recurring prime condition (i.e, NF, WF, BP:N) loaded on Factor 1. Conversely, Factor 2 represents a *semantic relatedness* mechanism; it involves comparisons of related prime and target with any other condition (i.e, BP, BP:N). Clearly these results are incompatible with the notion that nonword facilitation and backward priming are caused by the same mechanism (semantic match). Instead, these results suggest that nonword facilitation is due to a difference in prime novelty between the "unrelated" nonword and neutral nonword conditions. The role of relatedness information between the prime and target seems limited to the related word condition. That is, semantic information about the

Figure 1: Loadings on the two factors from the factor analysis on the subject difference scores from Experiment 1.


1
0.6
0.2
-0.2
-0.6
-1
Novelty Factor
-1
-0.6
-0.2
0.2
0.6
1
Semantic Factor
NF
WF
BP:N
BP

prime and target does affect response times, but only if the prime and target are related. There is no evidence that unrelatedness information per se exerts any unique effects, which is necessary for the semantic matching mechanism to produce nonword facilitation.

The factor analysis is informative in another regard. One could argue that the previous regression analyses that correlated individual subject "difference scores" are problematic. For example, the high correlation between WF and NF may indeed be due to the fact that there is a large novelty component that varies positively between the two variables. However, advocates of the semantic match could argue that this novelty factor *overshadows* a smaller negatively correlated component between the variables that is attributable to the semantic match. That is, if it were possible to partial out the variance due to novelty and then correlate WF and NF, a negative correlation would be found. However, if this was occurring, then the factor analysis would yield a factor that this small, *but systematic* residual variance attributable to the semantic match could load on after the novelty effect is partialled out by novelty factor. However, this did not occur. Instead, WF and NF loaded exclusively on the novelty factor. Additionally, the factor analysis reveals that BP and NF are highly reliable measures since they load greatly (close to 1.0) on the factors that were yielded. If these measures consisted of nothing but noise (i.e., were unreliable) this would not occur. Therefore, since they are reliable, the fact that BP and NF *failed* to correlate is somewhat more meaningful. (But a null effect should be interpreted only with great caution - see Chapter 5).

The current finding that the novelty status of the prime exerts an independent effect on response times calls into question the appropriateness of the neutral priming condition as a control group. The notion that a repeated word stimulus loses signalling value has been known for some time (cf. Kraut, Smothergill, & Farkas, 1981). Jonides & Mack (1984) proposed that the neutral priming condition be excluded from experiments if possible since it can lead to a distorted picture of facilitation (e.g., nonword facilitation) and inhibition (e.g., unrelated word prime inhibition), particularly at short SOA. For example, if data from Stanovich & West's (1979) Experiment 2 are examined, evidence of inhibition measured from a neutral prime was only apparent at long SOA. Facilitation, on the other hand, was apparent at both short and long SOA. This pattern is fairly common in the priming literature (see Neely, 1991, for a review). However, Jonides & Mack (1984) pointed out that the inhibition effect was largely produced by a disproportionate *decrease* of RT's to the neutral versus the unrelated word condition (see Jonides & Mack, 1984, Figure 1). This pattern does not conform well to the notion that inhibition at long

SOA is produced by difficulty in responding to unrelated word targets (incongruent context); the large shift in baseline needs to be explained.

An analogous pattern is revealed in the data of this experiment. The neutral nonword baseline did not remain constant between the Short and Long SOA conditions. While RT's in the "unrelated" nonword condition decreased as SOA was lengthened, as the semantic matching process predicts, the neutral baseline also *increased* substantially to add to the effect. This shift is important because nonword facilitation reduces to a mere 8 ms if it measured against the Short SOA neutral condition. Clearly, the concurrent increment in RT's to the neutral condition generously supplemented the effect. Note that there is no evidence of a baseline shift in the word data thus limiting the generality of this problem.

Further discussion of the prime novelty factor and its implications for effects measured against the neutral priming will be reserved for Chapter 3. An important consideration for the moment is that Jonides & Mack (1984) and Kraut, Smothergill & Farkas, (1981) have both argued that the differential warning value of a novel versus recurring prime is probably less serious at long SOA. The current experiment has indicated that the novelty factor still exerts large independent effects even at long SOA.

It is apparent that a semantic matching mechanism that makes use of unrelatedness information does not translate easily into *either* factor derived from the factor analysis. Therefore, there is some question as to whether the semantic match occurs *at all* to produce either backward priming or nonword facilitation. If this result is true it is important. It means that our current understanding of the mechanisms causing both backward priming and nonword facilitation is notably incomplete since both effects have been attributed to a post-lexical check for a prime/target relation (Neely et al., 1989; Neely, 1991; McNamara, in press a, b; Shelton & Martin, in press). For this reason, a second experiment was conducted to further test the semantic matching mechanism.

Experiment 2

The primary source of support for the semantic matching mechanism originates from research examining *list context* effects such as relatedness proportion (Neely et al., 1989). As noted in the introduction, an increase in relatedness proportion has been reported to increase nonword facilitation. De Groot (1984) attributed this effect to prime induced expectancy. As the proportion of related prime/target pairs in the list increases, the likelihood that a subject will generate an expectancy set upon prime presentation increases. Therefore, semantic priming should increase since the likelihood that a related target will be a member of the set increases. However, de Groot (1984) proposed that *failure* to find the target in the expectancy set could also facilitate responding. That is, if the target is a nonword, or is a word unrelated to the prime, it will not be found in the expectancy set, and subjects can then use this information to bias a "nonword" response. This should produce both unrelated word prime inhibition and nonword facilitation for reasons similar to the semantic match.

Neely and colleagues (Neely & Keefe, 1990; Neely et al., 1989) have argued, however, that the seeming dependence of nonword facilitation on relatedness proportion is illusory. In fact, the relationship was actually due to a list context proportion that has previously been confounded with relatedness proportion - nonword ratio. Specifically, nonword ratio is the proportion of nonword targets in the list that are unrelated to their word prime. Presumably, if this proportion is high, then the utility of relying on unrelatedness information to bias a "nonword" response increases; unrelatedness information becomes a better predictor of correct lexicality so subjects are more likely to use the strategy to guide lexical decisions. Pure variations of relatedness proportion, on the other hand, should not affect the use of the semantic matching strategy. This is simply because in typical priming experiments, the conditional probability that a target is a word given that it is related to its prime is always unity. The *proportion* of related words in the experiment is irrelevant as long as it is greater than zero; if the prime and target are related, the target is always a word since no "related" nonwords are in the list.

To illustrate how relatedness proportion and nonword ratio were confounded in previous experiments, some potential experimental designs are shown in Table 3. Design 1 is a typical design of a priming experiment. There are 150 words and 150 nonwords. 50 words are related to their word prime while 50 are not. Additionally, 50 neutral prime trials are included. In this design, RP = 50 (related words) divided by [50 (related) plus 50 (unrelated words)] = 0.5. In addition to the word targets, 100 nonwords are included that are "unrelated" to their prime and 50 nonwords are preceded by a neutral prime. This keeps the ratio of neutral to novel prime trials for nonwords the same as words (1:2) and the overall probability of a nonword fixed at 0.5. The nonword ratio in this example = 100 ("unrelated" nonwords) divided by [100 ("unrelated" nonwords) plus 50 (unrelated words)] = .67. Design 2 shows the typical way that RP was manipulated; to change the ratio of related to unrelated words. For illustrative purposes, all related words are removed from the design such that RP = 0. However, it is evident that in the process of reducing RP, NR was also decreased from .67 to .50. Thus with this method of varying RP, NR is also manipulated.

Table 3: Possible experimental designs that affect relatedness proportion, nonword ratio and P(nonword) (see text).

Design 1:

Relatedness Proportion = .50
Nonword Ratio = .67
P(nonword) = .50

Words (150):

50 Related words
50 Unrelated words
50 Neutral words

Nonwords (150):

0 Related nonwords
100 Unrelated nonwords
50 Neutral nonwords

Design 2:	Design 3:	Design 4:
(confounded RP & NR)	(Modelled after Neely et al., 1989)	(Experiment 2)
RP = 0	RP = .50	RP = .50
NR = .50	NR = .50	NR = .50
P(nonword) = .50	P(nonword) = .33	P(nonword) = .50
Words (150):	Words (150):	Words (150):
0 RW	50 RW	50 RW
100 UW	50 UW	50 UW
50 NW	50 NW	50 NW
Nonwords (150):	Nonwords (75):	Nonwords (150):
0 RN	0 RN	50 RN
100 UN	50 UN	50 UN
50 NN	25 NN	50 NN

Neely et al. (1989) introduced a clever method of unconfounding RP and NR. Design 3 of Table 3 shows how this was done. If Design 3 is compared to Design 1, NR is again reduced from .67 to .5, but RP is held constant at .5. When this method was used to manipulate RP and NR, Neely et al. (1989) reported that RP no longer affected nonword facilitation. Instead, nonword facilitation was affected only by variations in NR. This was considered good evidence that the semantic match mechanism, which is presumably sensitive to NR and not RP, was the cause of nonword facilitation.

Although Neely et al. (1989) managed to successfully unconfound RP and NR in their experiments, they *introduced* a new confound in the process. If Design 3 is compared to Design 1 again, it is apparent that the overall probability of a nonword was reduced from .5 to .33. Neely et al. (1989, p.1015-1016) were aware of the problem and addressed it in some detail. They argued that a number of effects were obtained that could not be explained by nonword probability alone. However, there are also a number of comparisons (also pointed to by Neely et al., 1989) that suggest that P(nonword) was an important variable in their experiments. For example, if the RP(.33)/NR(.50) group is compared to the RP(.67)/NR(.50) group, nonword facilitation *reduces* from a significant 22 ms to a nonsignificant 6 ms. Since NR was held constant and RP was *increased*, the lowering of nonword facilitation was probably due to a decrease in P(nonword) from .40 to .25. Clearly, the results of their experiments would be less ambiguous if P(nonword) was held constant.

Design 4 in Table 3 demonstrates that it is possible to unconfound RP and NR and hold P(nonword) constant by including "related" nonword targets in the list. A "related" nonword target is a nonword that is derived from a word that is related to the prime. For example, if the prime is "lion", then a "related" nonword target would be "tager" which is derived from the related word "tiger". By splitting the 100 "unrelated" nonwords into 50 "unrelated" and 50 "related" nonwords, RP and P(nonword) remain constant at .5, but as before, NR is reduced from .67 in Design 1 to .50 in Design 4. This method of varying RP and NR will be used in Experiment 2 and allows the list context variables RP and NR to be manipulated independently without the contaminating effects of P(nonword).

Including "related" nonwords in the list could have a number of different effects. First, their inclusion may persuade subjects to no longer rely on the semantic matching process. Their presence may force subjects to realize that prime/target relatedness does not predict target lexicality very well and so the matching process is stopped. Conversely, their presence may not affect subjects' strategy. This may occur if the "related" nonword is compared to an unrelated activated word representation. For example, suppose a subject is shown the prime "baby" and the "related" nonword target "sturk". The nonword may then activate word representations "stork", "stuck", and "stark". If the prime "baby" is matched against the activated word representation "stork", it is likely that the prime and target will be discerned as related. However, if it is matched against "stuck" or "stark", the prime and target will not be perceived as related. Note that, in this example, there are more activated representations unrelated to the prime than there are related ones. This is likely to be true for the majority of cases since only one representation is related to the prime, whereas several representations are likely to be activated (see Neely et al., 1989; Neely, 1991). Therefore, it is quite possible that any attempt to have the semantic match reveal relatedness for "related" nonword targets will be futile. If this occurs then including "related" nonwords in the list should not affect the use of the semantic matching process. It should be noted, however, that residual forward association between the prime and target may mean that the "related" representation will be activated somewhat more than the other representations, thus increasing the likelihood that the "related" representation ("stork") will be used for the match.

It is important to note that once "related" nonwords are included in the experiment, relatedness proportion should begin to affect the use of the semantic matching mechanism.

Once these item are incorporated, the conditional probability that a target is word given that it is related to its prime is no longer fixed at unity. Thus, the more "related" nonwords that are included in the list, the less predictive both relatedness *and* unrelatedness information becomes of correct lexicality. Of course, this is dependent on subjects discerning a relationship between a word prime and a nonword target.

Three independent groups of subjects were tested using three different list structures. Following Neely et al., (1989), the groups were defined by the relatedness proportion and nonword ratio in each group. For example, the RP(.83)/NR(.50) group had a relatedness proportion of .83 and a nonword ratio of .50. Each group consisted of a practice and test phase. The values of RP and NR actually refer to the practice phase; these proportions were held constant in the test phase. This was done since under conditions of high RP, very few unrelated word targets can be included. Indeed at the extreme where RP = 1.0, *no* unrelated words can be included. Therefore, in order that sufficient trials could be included to obtain a measure of each priming condition, list structure was manipulated during the practice phase while equal numbers of each type of trial were presented during the test phase. This procedure will be effective to the extent that strategies developed during practice maintain during the test phase. The three conditions used in

Experiment 2 are shown in Table 4. If conditions 1 and 2 are compared, the effect of NR unconfounded from RP and P(nonword) can be determined. Conversely, if conditions 1 and 3 are compared, it is possible to estimate the effect of RP also unconfounded from NR and P(nonword).

Method

Subjects: 63 introductory psychology students participated for course credit. They were assigned to three groups with 21 subjects in each.

Design & Materials: The materials used were the same as Experiment 1. Most aspects of the design were also similar to Experiment 1. However, some important changes were made to the construction of the lists in the critical and practice phases.

The construction of the practice phase constituted the major independent variable in the experiment. Unlike, Experiment 1 where the proportions of related, unrelated and neutral word and nonword targets were fixed, in this experiment the proportions were varied. Table 4 reveals the number of each type of trial in the three experimental conditions. As in Experiment 1, unrelated targets were formed by pairing the second member of a related pair (target) with the first from another pair (prime). Neutral trials were made by replacing the first member of the pair with the word "BLANK".

Table 4: The number of word and nonword trials in the practice and test phases with each prime type in the three conditions used in Experiment 2.

Condition 1: RP(.83)/NR(.50)

	Practice	Test
Words:	25 RW	15 BRW
	5 UW	15 UW
	15 NW	15 NW
Nonwords:	25 RN	15 BRN
	5 UN	15 UN
	15 NN	15 NN

Condition 2: RP(.83)/NR(.86)

	Practice	Test
Words:	25 RW	(as above)
	5 UW	
	15 NW	
Nonwords:	0 RN	
	30 UN	
	15 NN	

Condition 3: RP(0)/NR(.50)

	Practice	Test
Words:	0 RW	(as above)
	30 UW	
	15 NW	
Nonwords:	0 RN	
	30 UN	
	15 NN	

Note: RP = relatedness proportion; NR = nonword ratio; RW = related prime/word target; BRW = backward related prime/word target; UW = unrelated prime/word target; NW = neutral prime/word target; RN = "related" prime/nonword target; BRN = backward "related" prime/nonword target; UN = "unrelated" prime/nonword target; NN = neutral prime/nonword target.

Instead of separating all the related pairs for the nonword trials in the critical phase such that the prime was never related to the word from which the nonword target was derived, 15 of the 45 pairs were kept intact. These 15 trials constituted "related" nonword trials (e.g., prime: "down"; target: "sut" where "sut" is derived from "sit"). Thus one major difference between this experiment and the last for the critical trials was the presence of "related" as well as "unrelated" and neutral nonword targets in the test phase. This resulted in the nonword target trials being directly analogous to the word target trials (see Table 4). All other aspects of the design were the same as Experiment 1.

Procedure: All aspects of the procedure were the same as Experiment 1 except that the SOA for all groups was fixed at 1050 ms (equal to the SOA in the Long SOA condition from Experiment 1).

Results and Discussion:

The mean latencies and errors for words and nonwords in each experimental condition are presented in Table 5.

Nonword Facilitation and Backward Priming: It is apparent that there is little evidence of nonword facilitation in this experiment. A 2 (unrelated/neutral nonword) X 3 (list structure) mixed ANOVA on the nonword latencies yielded no main-effects nor an interaction (all p's > .05). A similar analysis on the errors also failed to

Table 5: Mean response times (RT) and percent errors (PE) for word and nonword targets preceded by neutral, related and unrelated primes for each condition in Experiment 2. RT difference scores are shown below each condition (see Table 2).

Condition 1: RP(.83)/NR(.50)

	words:		nonwords:	
	RT:	PE:	RT:	PE:
backward related:	632	5	765	7
unrelated:	671	5	757	7
neutral:	668	6	763	8

BP = 39
BP:N = 36
WF = -3

BNI = -8
BNI:N = -2
NF = 6

Condition 2: RP(.83)/NR(.86)

	words:		nonwords:	
	RT:	PE:	RT:	PE:
backward related:	607	6	728	13
unrelated:	629	6	714	9
neutral:	657	4	719	5

BP = 22
BP:N = 50
WF = 28

BNI = -14
BNI:N = -9
NF = 5

Condition 3: RP(0)/NR(.50)

	words:		nonwords:	
	RT:	PE:	RT:	PE:
backward related:	631	6	752	8
unrelated:	645	6	732	8
neutral:	667	5	739	7

BP = 14
BP:N = 36
WF = 22

BNI = -20
BNI:N = -13
NF = 7

yield any significant effects, all p's > .05. The failure to achieve an interaction suggests that neither the manipulation of RP or NR affected the amount of nonword facilitation obtained [NF = 5, 6 or 7 ms in RP(.83)/NR(.86), RP(.83)/NR(.50) and RP(0)/NR(.50) respectively]. On the surface, these results might be interpreted as an indication that including "related" nonwords in the list made no difference. However, quite the opposite is true; nonword facilitation is actually *highly* sensitive to the presence of *any* related nonwords. Evidence for this derives from the fact that very few "related" nonword trials were necessary to virtually eliminate nonword facilitation. The only difference between the RP(.83)/NR(.86) condition in Experiment 2 and the Long SOA condition from Experiment 1, where significant nonword facilitation was obtained, was the presence of 15 "related" nonwords in the test list. The practice phases of these groups were identical. Apparently,the presence of a few "related" nonwords was enough to reduce a significant 22 ms nonword facilitation effect to a nonsignificant 5 ms effect.

Backward priming, on the other hand, does not appear to have been affected by the presence of "related" nonwords. Although a 2 (prime type) X 3 (list structure) mixed ANOVA conducted on the word error data failed to reveal any significant effects using either the neutral or unrelated baseline, all F's < 1, a significant main-effect of prime type was obtained with both baselines when the latency data was used (neutral baseline: $F(1,60) = 26.05$, $p < .001$, MSe = 2033; unrelated baseline: $F(1,60) = 13.06$, $p < .001$, MSe = 1533). Neither the main-effect of list structure or the interaction was significant (both p's > .05).

These results suggest that backward priming and nonword facilitation are caused by different mechanisms. "Related" nonwords appear to greatly affect nonword facilitation, but have no effect on backward priming. In fact, "pure" backward priming effects (where novelty status of the prime is not an issue - BP) are largest (39 ms) in the RP(.83)/NR(.50) condition where many "related" nonword targets were presented to subjects during the practice phase (see Tables 4 and 5). Clearly, this general pattern of results is quite inconsistent with the notion that both effects are caused by semantic matching.

Multiple Regression: As in Experiment 1, a stepwise multiple regression was conducted on the latency difference scores obtained for each subject. Since "related" nonwords were included in the list, two new difference scores were obtainable; backward nonword inhibition measured against an "unrelated" nonword baseline (BNI) and backward nonword inhibition measured against a neutral nonword baseline (BNI:N). Thus five difference scores could potentially enter into the stepwise multiple regression in an attempt to predict NF; BP, BP:N, WF, BNI, BNI:N (see Table 2). However, some of these difference scores are correlated since they involve similar conditions. For example, if BNI were included into the analysis to predict NF, it would be entered into the equation for very uninteresting reasons; both difference scores derived from the "unrelated" nonword condition. Therefore, only differences experimentally orthogonal to NF were included in the analysis (i.e., BP, BP:N, WF). It is predicted that if backward priming is caused by the semantic matching strategy, then BP and/or BP:N should be a significant positive predictor of NF since both are presumed to be caused by a similar cognitive mechanism. In addition to the difference scores, the nonword ratio and relatedness proportion were also added to the analysis.

In fact, none of the factors entered was a significant predictor of NF, all $\underline{p}$'s > .05. Additional analyses were conducted in a attempt to predict other difference scores. As before, only experimentally orthogonal difference scores were included. Only one variable was significant in any of the analyses. This means that the results can be described simply as a correlation coefficient; BNI:N was correlated with BP:N, $\underline{r}(62) = .264$, $\underline{p} < .05$. As in Experiment 1, however, this correlation was reverse to what the semantic matching mechanism predicts. To the extent that subjects are relying on the process, they should biased to respond "word" when relatedness information is obtained. This would results in large *positive* values of backward priming and large *negative* values of backward nonword inhibition (see Table 2). Again, it appears as though effects measured against the neutral condition are modulated by differences in prime novelty. Novelty exerts influence quite independent from semantic relationships between the prime and target. This is important since a semantic matching explanation of nonword facilitation places emphasis on the *semantic* difference between neutral and "unrelated" nonword conditions, not the difference in prime novelty.

Backward "Related" Nonword Inhibition: Responses to "related" nonword trials in all three groups were slower than to either the neutral or "unrelated" nonword trials. Although a 2 (prime type) X 3 (list structure) mixed ANOVA using the neutral condition as a baseline indicated no significant effects, all p's > .05, a similar analysis using the "unrelated" nonword condition as a baseline yielded a significant effect of prime type, $F(1,60) = 4.26$, $p < .05$, $MSe = 1445$. Additionally, error rates were generally higher in the "related" nonword condition. A 2 (prime type) X 3 (list structure) mixed ANOVA on the error data revealed a marginal effect of prime type when the "unrelated" condition was used as a baseline, $F(1,60) = 2.11$, $p < .13$, $MSe = .004$. A similar analysis using the neutral condition revealed a reliable main-effect of prime-type, $F(1,60) = 4.78$, $p < .05$, $MSe = .004$, which was qualified by a prime-type by list structure interaction, $F(1,60) = 5.64$, $p < .01$, $MSe = .004$.

The interaction with the error data was caused by a disproportionate increase in errors in the "related" nonword condition in the RP(.83)/NR(.86) group (see Table 5). Indeed, the 13% error rate for "related" nonwords in that group alone was significantly greater than the 9% rate for "unrelated" nonwords, $\underline{F}(1,20) = 4.57$, $\underline{p} < .05$, $\underline{MSe} = .005$, and the 5% rate for neutral nonwords $\underline{F}(1,20) = 12.67$, $\underline{p} < .005$, $\underline{MSe} = .005$. Possible reasons for particularly high error rates "related" nonwords in the RP(.83)/NR(.86) condition will be discussed later. For now, it is important to note that the semantic matching mechanism can explain the inhibition effect since a prime/target semantic relationship would be revealed on these trials which would bias the subject to respond "word".

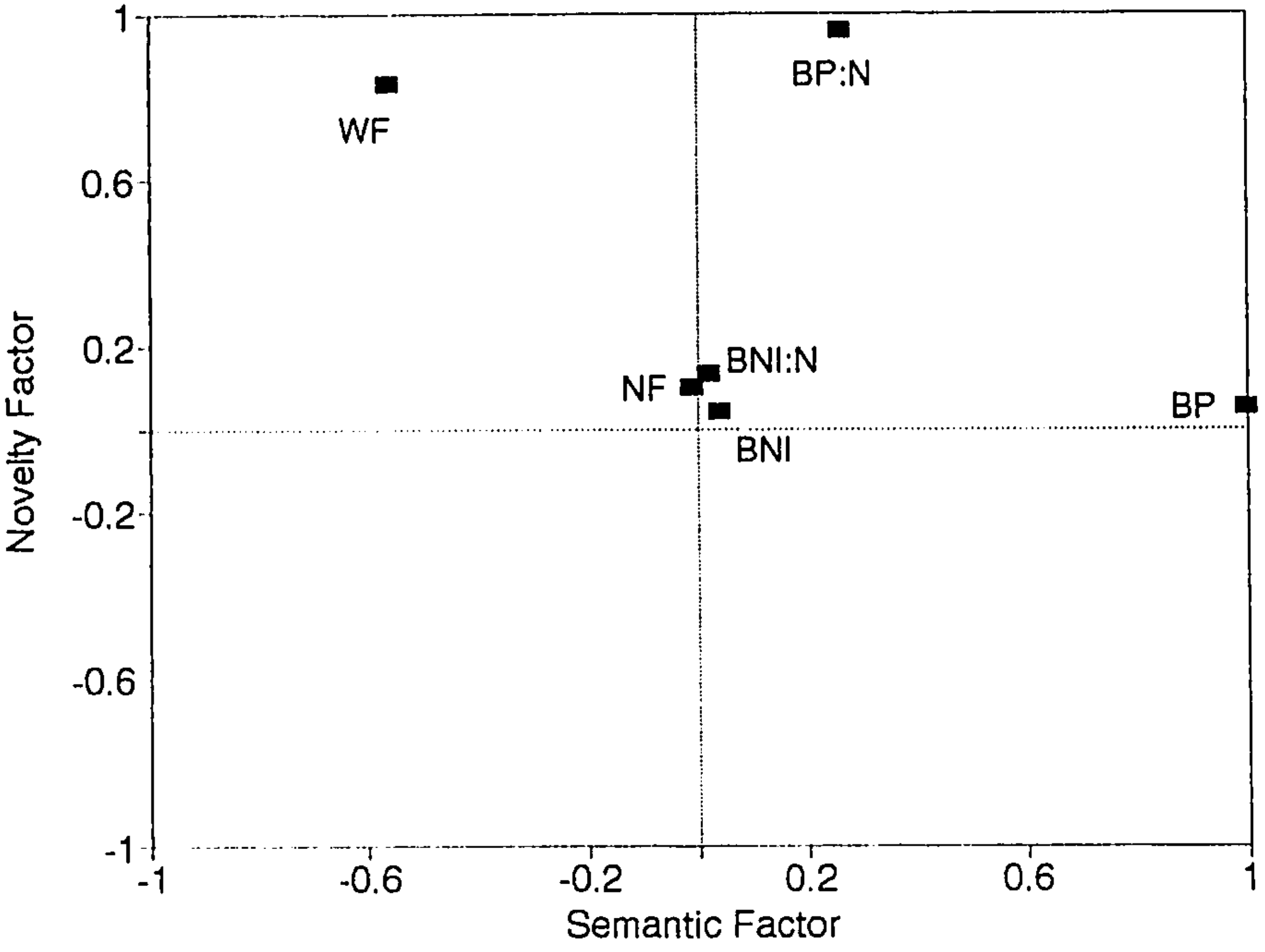
Previous research has found an inhibitory effect of for "related" nonwords (e.g., Schvaneveldt & McDonald, 1981; O'Connor & Forster, 1981). However, this experiment is the first to establish *backward* inhibition, where the "relationship" is *from* the target *to* the prime.

The presence of backward "related" nonword inhibition also validates the use of "related" nonwords as a reasonable method of manipulating nonword ratio. In the context of semantic matching, the possibility was raised that the "related" nonword target would activate several word representations and that the prime would be matched against an unrelated representation. If this occurred then the inclusion of "related" nonwords should have had no effect. However, the significance of the inhibition effect indicates either that the activation of multiple representations was not a serious problem or that the strategy was relied upon enough that the problem was overcome. However, if subjects are relying on the semantic matching process to the degree that the multiple activation problem can be overcome, then the absence of nonword facilitation is particularly troubling to the semantic matching hypothesis.

Factor Analysis: As in Experiment 1, a factor analysis was conducted on the latency difference scores obtained for each subject. Thus six variables were entered into the factor analysis; BP, BP:N, WF, BNI, BNI:N, NF (see Table 2). It is predicted that if backward priming is caused by the semantic matching strategy, BP and/or BP:N should load on the same factor as NF since both are presumed to be caused by a similar cognitive mechanism.

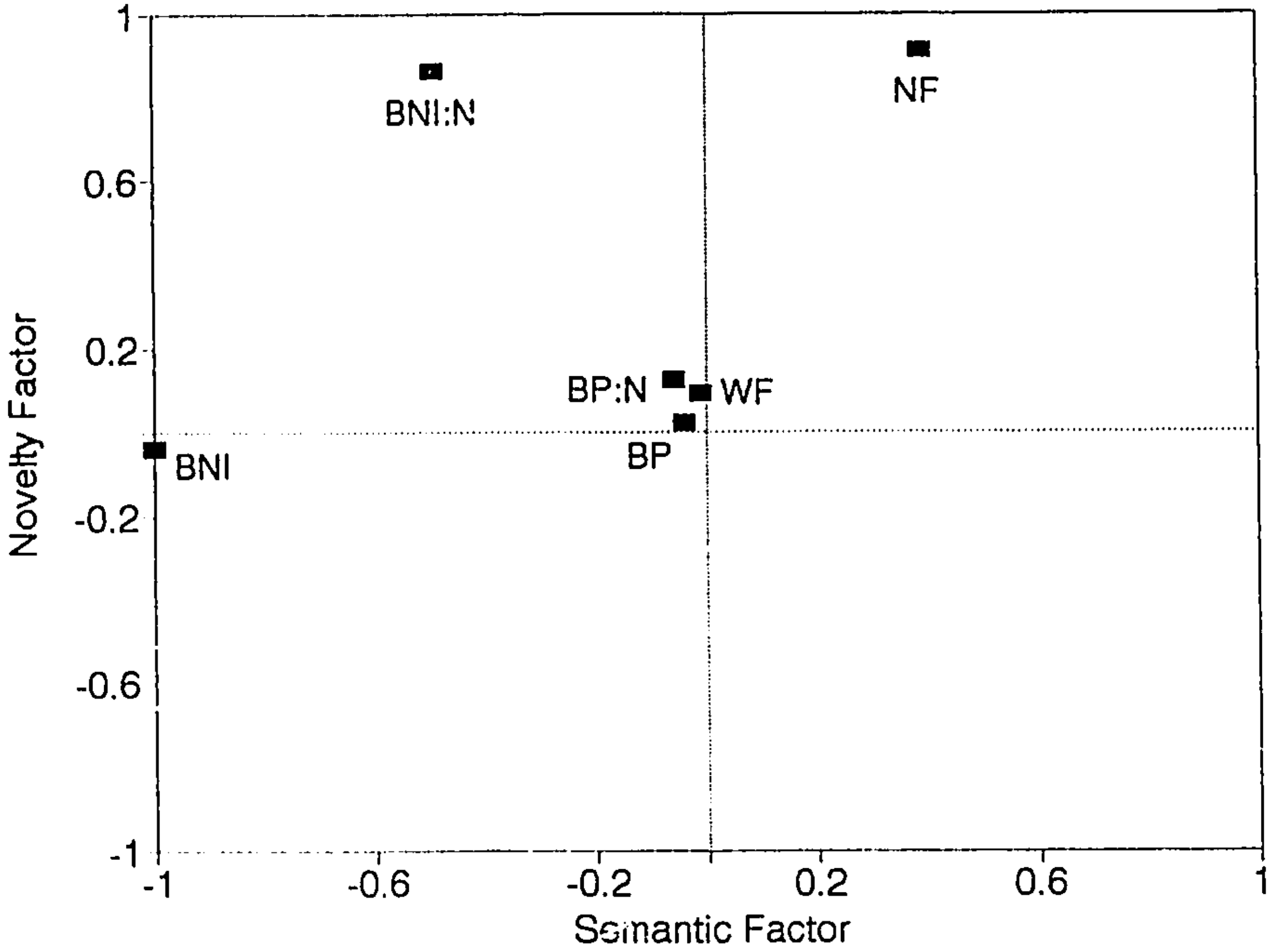
The analysis yielded four factors. The factor loadings after a raw Varimax rotation which converged after 4 iterations are shown in Figures 2a and 2b. Although the results are not as simple as Experiment 1, they are analogous. First, it appears that two factors were yielded to account for the word data and two factors for the nonword data (highest absolute cross-lexical loading = .13). The loadings, therefore, were separated into word and nonword factors in Figure 2a and 2b. The two factors for both words

Figure 2a: Loadings on the two word factors from the factor analysis on the subject difference scores from Experiment 2. The nonword factors are shown in Figure 2b.



WF
BP:N
BNI:N
NF
BNI
BP
Novelty Factor
1
0.6
0.2
-0.2
-0.6
-1
-1
-0.6
-0.2
0.2
0.6
1
Semantic Factor

Figure 2b: Loadings on the two nonword factors from the factor analysis on the subject difference scores from Experiment 2. The word factors are shown in Figure 2a.


BNI:N
NF
BP:N
WF
BP
BNI
Novelty Factor
1
0.6
0.2
-0.2
-0.6
-1
-1
-0.6
-0.2
0.2
0.6
1
Semantic Factor

and nonwords are similar to the two revealed in Experiment 1. Word Factor 1 and Nonword Factor 1 reflect the mechanism responsible for a *novelty of prime* effect; any comparison of a novel versus a recurring prime condition loads heavily on that factor (words: BP:N, WF; nonwords: BNI:N, NF). In addition, Word Factor 2 and Nonword Factor 2 reflect the *semantic relatedness* mechanism; comparisons involving a related condition versus anything else load on this factor (words: BP, BP:N; nonwords: BNI, BNI:N).

The loadings are not as simple to interpret as they were in Experiment 1. In support of the semantic matching mechanism, WF loads more heavily onto the semantic relatedness factor than does BP:N. Also, NF partially loads onto the semantic relatedness factor. There is evidence that WF and NF, where a semantic match would reveal unrelatedness information, are loading in the opposite direction on the semantic factor than are comparisons that would indicate a prime/target relationship (i.e., words: BP, BP:N; nonwords: BNI and BNI:N). On the other hand, contrary to the semantic matching hypothesis, the loading of NF on the semantic factor is weaker than either BNI or BNI:N and it loads much more heavily on the novelty than the semantic factor. WF also loads much more heavily on the novelty factor than the semantic factor. Nonetheless, the fact that WF and NF are showing evidence of loading on the semantic factor is actually problematic for the semantic matching account. The absence of nonword facilitation and the fact that the inclusion of "related" nonwords lowers the correlation between relatedness and correct target lexicality in this experiment both suggest that the mechanism should not be operating. Also, as in Experiment 1, difficulties are posed for the semantic matching mechanism since it is clear that NF and BP load on completely different factors.

Relatedness proportion and Nonword Ratio Effects: The manipulations of RP and NR did not appear to have much effect on the latency data. As noted in the introduction to this experiment, if conditions 1 and 2 are compared, the effect of NR independent of RP can be determined and if conditions 1 and 3 are compared, the effect of RP can be evaluated with NR controlled . Whether nonword facilitation or backward priming was tested, prime type and list structure did not interact (all p's $> .05$). In fact, the only significant result from any of these analyses was a main-effect of backward priming. The possibility was tested that the variation of list structure within the practice phase affected only the first part of the test phase (i.e., possible effects of order were examined). However, no consistent trends were discovered.

A significant prime type ("related"/neutral nonword) by list structure interaction was reported earlier when a 2 X 3 mixed ANOVA was conducted on the error data. By comparing Condition 1 specifically to Condition 2 and 3, it can be determined whether the interaction was attributable to variations in RP or NR. No evidence of an interaction was present when RP was tested by comparing Condition 1 to Condition 3, F < 1, but when Condition 1 was compared to Condition 2, both a significant effect of prime type, F(1,40) = 5.40, p < .05, MSe = .004, and an interaction, F(1,40) = 10.21, p < .005, MSe =.004, was obtained. Table 5 reveals that these effects occurred because as nonword ratio was increased from .50 in Condition 1 to .86 in Condition 2, many more errors occurred to "related" versus neutral nonwords. This could be considered support for the semantic matching mechanism. That is, as nonword ratio increases, the likelihood that subjects will rely on the mechanism increases. To the extent that this occurs, more inhibition should be apparent. It is interesting to note that backward priming measured against a neutral prime also increased from 36 to 50 ms as nonword ratio increased, which is further support. However, this 14 ms increase was accompanied by a 17 ms decrease of backward priming if it is measured against an unrelated condition (39 to 22 ms).

General Discussion:

The Status of the Semantic Matching Mechanism:

The experiments reported in this chapter eliminate the possibility that subjects generally use both positive and negative relatedness information gained from a semantic match to speed appropriate responses. If this were the case then backward priming and nonword facilitation should be tightly linked; to the extent that a subject is relying on the semantic match, both backward priming and nonword facilitation should be demonstrated. Data reported here, however, indicate that the two effects are produced by very different mechanisms. On the one hand, backward priming involves a semantic mechanism, where the presence of a positive semantic relationship between the prime and target causes faster response times to backward related pairs. Conversely, the presence/absence of a semantic relationship between the prime and target appears to be mostly irrelevant to nonword facilitation. Instead, these experiments suggest that it is the difference in prime novelty, which is confounded in a comparison of neutral and "unrelated" nonword trials, that produces nonword facilitation. The issue now is to see if any version of the semantic match can be invoked to explain these results.

The current data pose difficulties for any post-lexical mechanism in which information regarding prime/target *unrelatedness* can be used to speed nonword responses. Thus any post-lexical mechanism that is operating is different from the process proposed by Neely and colleagues. An important feature of the retrospective semantic match is that it occurs on nonword as well as word trials. Indeed, it is the notion that unrelatedness information can be used to speed nonword responses that allows Neely et al. (1989) to predict nonword facilitation and its relationship to nonword ratio. However, there is little indication here that a lack of relationship between the prime and target affects response times. In hindsight, this seems sensible. Discovering a non-relationship is surely more time-consuming than discovering that there is one. De Groot (1985) has proposed that a post-lexical coherence checking mechanism can more easily find a relation between strongly associated prime/target pairs. If this is true, it is conceivable that the amount of time it takes a subject to be confident that the prime and target are not related is as great as any post-lexical response facilitation that is based on this information. If that were the case, then the "unrelated" nonword condition should be no faster than the neutral nonword condition where these compensatory processes do not occur.

However, the current data do not rule out the possibility of a post-lexical mechanism that is sensitive to a *positive* relationship between the prime and target. This notion would be consistent with other proposed mechanisms such as the plausibility check (Norris, 1986) or coherence check (de Groot, 1984) where the post-lexical check is specific to word targets. Consider the semantic factor from Experiment 1 and 2. It captured difference scores that involved *related* pairs. A (post-lexical) mechanism that specifically speeds responses to related pairs could be represented by that factor. This mechanism could also explain the backward nonword inhibition effect that occurred in Experiment 2. On "related" nonword trials, a semantic match would reveal a relationship, and would result in a bias to respond "word". This bias would result in either an error or a slower correct response. The mechanism could also account for the apparent independence of backward priming and nonword facilitation since unrelatedness information is not used to bias responding. The mechanism does not explain the importance of the novelty status of the prime. Therefore, an alternative model will be presented in Chapter 3 to try and account for the data in these experiments.

Chapter 3

DERIVING FAMILIARITY:
AN EXTENSION OF RATCLIFF & MCKOON'S (1988) CUE-COMPOUNDING MODEL

A new approach to semantic priming has been proposed recently. This approach treats lexical decision in much the same way as other episodic memory tasks such as recognition and recall. Specifically, it is assumed that the prime and target in a priming experiment are formed into a compound retrieval cue that is subsequently used to access memory. This memory access yields a familiarity value that can be mapped into reaction times (Ratcliff, 1978; Ratcliff & McKoon, 1988; Balota & Chumbley, 1984). Generally, if the compound-cue consists of a related prime and target, familiarity will be higher than if they are unrelated. Higher familiarity values ordinarily map into faster reaction times, thus producing semantic priming. To determine the exact value of familiarity returned from memory access, cue-compounding is usually proposed in conjunction with an established memory model previously used to simulate only recognition and recall data. Ratcliff & McKoon (1988; McKoon & Ratcliff, in press) have proposed cue-compounding in conjunction with SAM (Gillund & Shiffrin, 1984) while Dosher & Rosedale (1989) used TODAM (Murdock, 1982). In general, cue-compounding is proving to be a reasonable challenger of better established models of semantic priming. For example, it can account for data that spreading activation cannot handle (cf. Whittlesea & Jacoby, 1990; Ratcliff & McKoon, 1988; McKoon & Ratcliff, in press; although see McNamara, in press a; in press b, for a different conclusion).

The cue-compounding model presented in this chapter is very similar to that presented in Ratcliff & McKoon (1988) that utilizes the SAM model of memory. For example, the method by which familiarity is calculated is borrowed from SAM; a matrix of strengths between compound elements and images in memory is constructed and familiarity is equal to the sum of the products of these strengths across all images in memory (see example below). However, a fundamental difference between this model and cue-compounding models that use SAM lies in what the strengths represent. In SAM, the strengths represent associative links between long-term memory structures (SAM is an acronym for "search of associative memory"). In the model presented here, however, the strengths represent the degree to which particular memorial representations are accessed by elements within the retrieval cue. Thus, in my model, there are no pre-computed links between items in memory. Rather, the cue established *at the time of retrieval* determines which memory representations are accessed to determine familiarity. This notion is analogous to the that established in other areas of cognitive psychology in which specific stimuli in a specific context are used to recruit particular memorial representations at retrieval (cf. Kahneman & Miller, 1986; Jacoby & Brooks, 1984; Brooks, 1987; Jacoby, 1991; Whittlesea, 1987). The focus, therefore, is on establishing which items in memory are recruited by particular retrieval cues (Dosher & Rosedale, 1989), and not on determining the nature of precomputed links in long-term memory.

The unwillingness to make a commitment to links between long-term memory structures has some important implications. For example, research on mediated priming, and particularly its hypothesized relationship to the free association task, is founded upon the notion of a pre-established network memory (see Chapter 5). Without a network assumption, it is difficult to determine what exactly mediated priming research is telling us. More will be offered on this topic in Chapter 5.

Table 6 shows how familiarity might be calculated for both backward related and unrelated pairs. For the backward related pairs, the prime is "down" and the target is "sit". They are presented on the far left column and represent elements of the compound-cue. Each element in the cue (i.e., prime and target) accesses particular representations with some strength. (1) if an element in the cue accesses a

Table 6: Calculation of familiarity for related and unrelated word targets.

Strength parameters:

Identity (sit - sit) -> 1.0
Semantic Relatedness (sit - down) -> 1.0
No Similarity (residual) (down - sit) -> .20

Backward Related Words [Prime(DOWN) <- Target(SIT)]:

		memory:			
		DOWN	SIT	LOW	CHAIR
cue:	DOWN	1.0	.20	1.0	.20
	SIT	1.0	1.0	.20	1.0
	F =	1.0 +	.20 +	.20 +	.20
	=	1.60			

Unrelated Words (DOG - SIT):

		memory:			
		DOG	SIT	CAT	CHAIR
cue:	DOG	1.0	.20	1.0	.20
	SIT	.20	1.0	.20	1.0
	F =	.20 +	.20 +	.20 +	.20
	=	.80			

representation of itself or a associate, it does so with high strength (1.0) (e.g., *sit - sit; sit - down*), (2) if the representation is not similar to the element in the cue, then there is residual strength (.20) between them (e.g., *down - sit*).

It is assumed for illustrative purposes that the elements in the cue access representations of themselves ("down" and "sit") and one other direct associate each ("low" and "chair"). These accessed representations appear in the top row. The familiarity component derived from a trace is equal to the product of all the strengths pertaining to that trace (shown in the bottom row). For example, the familiarity component derived from the trace "sit" is equal to .20 X 1.0 = .20. In the Ratcliff & McKoon (1988) model, the strengths associated with the target element are more heavily weighted (i.e. $.20^{(0.1)}$ X $1.0^{(0.9)}$ = .85). However, for the sake of simplicity in calculation, the weights were not used in this example. The resultant familiarity value for a complete round of access is the sum of the familiarity components across all items in memory. In the example below, the familiarity for the backward related pairs is higher than it is for the unrelated pairs ("dog" - "sit"). This higher familiarity value produces faster response times - backward priming.

Cue-Compounding and Nonwords: Added Assumptions The cue-compounding mechanism can also produce backward nonword inhibition. However, to do so requires adding some assumptions to the original version of Ratcliff & McKoon's (1988) model. First, *it must be assumed that nonwords can be included in the compound-cue and can access some representations with above residual strength.* In particular, representations that are visually and phonologically similar to a nonwords will be accessed. This assumption is similar to that adopted by Neely et al., (1989) for the semantic matching process and there is independent evidence that nonwords do make memorial access. For example, Rosson (1983) found that response times to "sheep" were faster if it was preceded by "famb". She argued that this occurred because the nonword "famb" activates "lamb" because it is visually similar to it. That is, the priming of "sheep" by "famb" is mediated via "lamb". Therefore, it is assumed that, in the context of the cue-compounding model, nonword access of a visually similar representations occurs with some strength slightly above residual (e.g., .50). It is not assumed to be as high as the strength associated with access by word elements since nonwords are less similar to representations in memory than are words.

Another assumption that must be added is that *more than one round of memory access must occur.* Usually this would increase the difference in familiarity between related and unrelated pairs, but it was not included in the previous calculation of familiarity for related and unrelated word trials for the sake of simplicity. The familiarity value from the second round can then be used to update the original value. In Chapter 5, it will be demonstrated that with this addition to the original model, three-step mediated priming recently reported by McNamara (in press a) can be simulated with a cue-compounding model.

Table 7 shows how backward nonword inhibition might be produced by cue-compounding with these added assumptions. Since nonwords have no meaning, they cannot access associated representations. Therefore, to keep the calculations of familiarity for word and nonword targets analogous, nonwords are assumed to access two visually similar representations. On round 1, there is no difference between the familiarity produced by backward "related" word/nonword pairs and "unrelated" pairs (.60). However, if representations that are accessed on round 1 are allowed to be incorporated into the compound-cue on the second round, higher familiarity is produced for the backward "related" pair. Note that the overall familiarity for nonword targets is lower than word targets. This is important since an increase in familiarity at *low* levels maps into a *longer* reaction time (Ratcliff & McKoon, 1988; Balota & Chumbley, 1984), an effect opposite to that which occurs at high levels (word targets). Therefore, the higher familiarity for "related" nonword targets causes backward "related" nonword inhibition.

Table 7: Calculation of familiarity for "related" and "unrelated" nonword targets.

Strength parameters:

Identity (down - down) ->	1.0
Semantic Relatedness (sit - down) ->	1.0
Visual Similarity (sut - sit) ->	.50
No Similarity (residual) (down - sit) ->	.20

Backward "Related" Nonwords [Prime(DOWN) <- Target (SUT)]:

First round of memory access:

		memory: DOWN	SIT	LOW	SET
cue:	DOWN	1.0	.20	1.0	.20
	SUT	.20	.50	.20	.50

F = .20 + .10 + .20 + .10

= .60

Second round of memory access:

		memory: DOWN	SIT	LOW	SET
cue:	DOWN	1.0	.20	1.0	.20
	SUT	.20	.50	.20	.50
	SIT	1.0	1.0	.20	1.0
	LOW	1.0	.20	1.0	.20
	SET	.20	1.0	.20	1.0

F = .04 + .02 + .008 + .02

= .088

Overall familiarity: .60 + .088 = .688

Table 7 (cont.)

"Unrelated" Nonword Targets (DOG - SUT):

First round of memory access:

		memory:			
		DOG	SIT	CAT	SET
cue:	DOG	1.0	.20	1.0	.20
	SUT	.20	.50	.20	.50

F = .20 + .10 + .20 + .10

= .60

Second round of memory access:

		memory:			
		DOG	SIT	CAT	SET
cue:	DOG	1.0	.20	1.0	.20
	SUT	.20	.50	.20	.50
	SIT	.20	1.0	.20	1.0
	CAT	1.0	.20	1.0	.20
	SET	.20	1.0	.20	1.0

F = .008 + .02 + .008 + .02

= .056

Overall familiarity: .60 + .056 = .656

It is worth noting that the predicted increment in familiarity by preceding the target by a related prime is much less for nonwords (.032) than it is for nonwords (>.80 if a second access round were included). This prediction fits the data. Overall, backward priming measured against an unrelated baseline was much greater (25 ms) than was backward "related" nonword inhibition (14 ms). The semantic matching mechanism also predicts this difference since the likelihood that a subject will discern a positive relationship on a "related" nonword trial is less than on a related word trial.

Neutral Prime Trials and Nonword Facilitation Ratcliff & McKoon (1988) argued that on neutral priming trials, the target is compounded with the target from the previous trial. However, this assumption predicts that neutral and unrelated prime trials should behave similarly since, in the vast majority of cases, the two targets will not be related. Ratcliff & McKoon (1988) have proposed that if targets on neutral prime trials are compounded with targets from the previous trial, occasionally the two items will be related by coincidence. This would mean that familiarity will be higher on neutral prime trials than unrelated prime trials. However, the probability that enough of these trials would occur in a priming experiment to differentiate the neutral and unrelated conditions is probably very low. Therefore, if it is assumed that successive targets are compounded on neutral prime trials, the neutral and unrelated conditions should not differ.

Clearly, however, the neutral and unrelated priming conditions do differ; nonword facilitation is defined as faster responding to "unrelated" versus neutral nonword trials. One possibility is that nonword facilitation occurs because the neutral prime "BLANK" is very familiar to subjects since it occurs many times throughout the experiment. As a result, the familiarity of a compound-cue containing the neutral prime is generally higher than a compound with a novel prime. This would result in longer RT's to neutral nonword trials. The problem with this explanation is that the reverse ordering should occur for words; the higher familiarity on neutral word trials should result in faster RT's compared to unrelated word trials. Although unrelated word prime inhibition occurs in many priming experiments, it did not occur in most of the groups presented here (see Table 5). Also, the presence of a strong *positive* correlation between WF and NF in Experiment 1 of Chapter 2 is as problematic for this view as it is for the semantic match.

Another possible explanation of nonword facilitation can be derived from the experiments reported in Chapter 4. In those experiments, target degradation interacted with prime novelty at short SOA; lexical decision response latencies to targets preceded by novel primes (related and unrelated) increased disproportionately compared to targets preceded by neutral, recurring primes as the target was degraded. It is argued there that this result was caused by subjects having particular difficulty compounding a degraded target with a prime that was incompletely processed. Further, it is assumed that this interference was absent on neutral prime trials because compounding *did not occur on neutral prime trials*; lexical decisions to targets preceded by neutral primes are not based on familiarity returned from a retrieval round but rather are based on more complete, analytic visual analysis of the target item. This makes the prediction that word targets preceded by a neutral prime should take longer to respond to than targets preceded by a unrelated prime. Although this pattern occurred in these data, usually it does not. An explanation of the possible discrepancy will be offered shortly.

The notion that there are two qualitatively different types of judgment - a quick, nonanalytic source and a slower analytic basis - has been proposed in several different arenas (Balota & Chumbley, 1984; Jacoby & Brooks, 1984; Brooks, 1987; Mandler, 1980; Atkinson & Juola, 1973; Jacoby, 1991; Jacoby, Toth & Yonelinas, in press; Debner & Jacoby, in press; Regehr & Brooks, in press) including priming (Balota & Chumbley, 1984). Familiarity based responses generally are faster than those with a more analytic basis (Mandler, 1980; Atkinson & Juola, 1973), thus priming trials where novel primes are presented (related and unrelated) should be faster than those with a recurring prime (neutral). Thus, although responses to unrelated word targets may sometimes be slow *relative to related prime trials* since they do not yield much familiarity, *relative to the more analytic based neutral prime trials*, they are speeded. If this assumption is made, *nonword facilitation* can be explained;

> *RT's on "unrelated" nonword trials are typically shorter than on neutral nonword trials because they are based on a faster judgment process (familiarity vs. analytic).*

Prime Novelty and Appropriate Baselines The finding in these experiments that prime novelty exerts independent influence has important implications for what comparisons are appropriate for particular conclusions in priming experiments. De Groot, Thomassen & Hudson (1982) demonstrated that the neutral prime "XXX" provided a different baseline than the prime "BLANK" thus calling into question the neutrality of neutral baselines in priming experiments. Although the latter prime may be more desirable in a priming experiment because of its lexical status (Antos, 1979), the results of these experiments suggest that prime *recurrence* within the experiment also affects how the target is processed. Kraut, Smothergill & Farkas (1981) have demonstrated that a recurring word is inferior to a novel word as a warning signal. Additionally, Jonides & Mack (1984) have argued that target processing is particularly affected by differences in prime novelty at short SOA (e.g., processing demands are greater for novel prime stimuli, so they are less likely than recurring primes to be completely processed by the time the target appears if the SOA is short). However, the experiments reported here indicated that novelty status of prime trials is also a worthy consideration at long SOA. Ultimately, these issues bear upon the validity of theoretical accounts of priming effects such as nonword facilitation and unrelated word prime inhibition which are necessarily measured against the neutral priming condition.

In defence of nonword facilitation as an effect more than a mere artifact of an inappropriate control condition, Neely (1991) has contended that,

> ... studies that have manipulated the probability that a target is a nonword given that it is unrelated to its word prime show that these nonword facilitation effects are lawfully related to other variables. The issue thus becomes whether an explanation based on the putative "nonneutrality" of the neutral primes provides a coherent account of these lawful relationships? (p. 280)

Neely (1991) has raised similar questions regarding unrelated word prime inhibition,

> ... the "nonneutrality" doomsayers must explain why this bias should (a) be different when a neutral prime is embedded in a list of category materials vs. when exactly

> the same neutral prime is embedded in a list of associatively related materials and (b) be different in just the way necessary to have produced the obtained results. (p.280)

However, an alternative argument is worth considering at this point. It is clear from the evidence presented here, and presented elsewhere (cf. Chapter 4 of this thesis; Jonides & Mack, 1984) that most comparisons against a neutral baseline involve more than the variable of theoretical interest; most comparisons are *contaminated* by prime novelty differences which have proven to be highly influential, but to date have not been controlled. To the extert that this is true, I would maintain that it is not the onus of those who have discovered this contamination to explain how the measure relates to other variables. Rather it incumbent upon the researchers who obtain such measures, and who draw theoretical implications from them, to indicate how these effects can be deciphered without concern for misinterpretation.

Independent Mechanism: Expectancy The cautious reader has probably already noted that the model presented so far predicts that responses to unrelated *word* trials should also be generally faster than to neutral *word* trials. This prediction does not hold. Typically, the reverse is true at longer SOA (i.e., *inhibition* occurs), although its presence depends upon whether associative or category primes are used (cf. Neely, 1991, Table 6). The apparent inconsistency can probably be understood by invoking an expectancy mechanism (Posner & Snyder, 1975; Becker, 1980). Specifically, responses to a word target item will be inhibited to the extent that the subject fails to find the target item in an expectancy set generated from the prime. The relationship between unrelated and neutral word trials is mediated, therefore, by the extent to which the expectancy mechanism is instigated. Category primes heavily induce the mechanism and so inhibition is demonstrated. Associative primes, on the other hand, induce expectancy sets to a lesser degree since the target is less likely to appear in the candidate set.

It should be noted that this analysis is quite different from Becker's (1980) which argues that the type of prime (category versus associative) affects the *size* of the expectancy set that is searched, not whether or not it is generated. Regardless, it still seems quite plausible that the type of prime the subject encounters in an experiment will have some effect on whether the strategy is adopted. It seems more plausible, for example, to start generating possible target animals that may appear as a target in response to the category prime "animal" than it does to generate associates of a prime such as "table".

To go one step further, it might be predicted that if there was no prime to target association between pairs in the list (i.e., the only related pairs are backward related), that subjects wouldn't use the expectancy mechanism at all and *facilitation* will occur because of the faster basis of responding. Consistent with this notion, when backward related pairs were used in these experiments, responses to targets preceded by unrelated primes were faster than those preceded by neutral primes. That is, in the absence of an expectancy mechanism, familiarity based responses are faster than responses based on more detailed, analytic visual analysis of both word and nonword targets. No previous studies on backward priming could have discovered this since neutral primes were not included in the design. A possible complaint directed toward this analysis is that the practice phases of both Experiments 1 & 2 had forward related pairs and that these should induce the expectancy mechanism. However, it is clear from the analyses in Chapter 2 that subjects may have been very sensitive to changes from the practice to the test list. For example, including only a few "related" nonwords in the test list reduced nonword facilitation by 17 ms. Therefore, it is plausible that very soon after backward related pairs started appearing in the test list, the expectancy mechanism ceased to be operative. However, this does not explain why word facilitation in the RP(.83)/NR(.86) condition of Experiment 2 is actually *greater* (28 ms) than in the RP(0)/NR(.50) condition (22 ms) since the higher RP in the former group should *reduce* the facilitation.

Finally, A post-lexical semantic match does not predict faster responding to unrelated word targets. To the extent that unrelatedness information is being used to bias a nonword response, it should inhibit responses to unrelated word targets, but not neutral word targets. However, the only condition in which unrelated word targets were slower than neutral word targets was in the group where the semantic match was least likely to be occurring, the RP(.83)/NR(.50) condition in which many "related" nonwords were shown to subjects.

Making the Response: The Familiarity Heuristic

It has been proposed that very high and very low levels of familiarity map into quick "word" and "nonword" responses respectively while intermediate values take longer and are more error prone (Balota & Chumbley, 1984; Ratcliff & McKoon, 1988; Ratcliff, 1978). This is produced quantitatively by translating the familiarity returned from memory access into a diffusion rate in a random walk process (Ratcliff, 1978) or submitting the returned value to a signal-detection-like model (Balota & Chumbley, 1984). Although these models have proven to be successful at predicting binary decisions in several domains including lexical decision (cf. Hayman, 1982; Kames, 1980), to be able to understand the behavior of these systems in psychological terms may be desirable.

Jacoby and colleagues (Jacoby & Kelly, 1987; Jacoby, Woloshyn & Kelly, 1989) have found considerable support for the notion that attributions of subjective experience occur readily in several different tasks. Sometimes these attributions are incorrect. For example, if solutions to anagrams were presented in a prior phase of the experiment, subjects rated them as easier to solve (for person's who had not seen the solution) than new anagrams (Jacoby & Kelly, 1987); the fluency with which the solution came to mind was misattributed to the easiness of the anagram rather than correctly attributed to oldness. In the same vein, Witherspoon & Allan (1985) have demonstrated that old words presented briefly were rated as having been displayed longer than new words. Again, this can be understood as a misattribution of processing fluency to longer display duration instead of oldness.

I would like to propose that a comparable attribution process occurs in lexical decision. It is assumed in this framework that subjects possess theories about how familiarity and "wordness" are correlated; in general, a high feeling of familiarity means that the item currently presented for lexical decision is a word while a feeling of strangeness (low familiarity) means that it is not. Items that are at intermediate levels of familiarity require longer response times because additional information is necessary to make a correct decision (i.e., further analytic evaluation occurs, Atkinson & Juola, 1973; Balota & Chumbley, 1984).

The Familiarity Heuristic and the Automatic/Strategic Distinction The differing effect SOA has on priming results is commonly attributed to a automatic/strategic distinction (Posner & Snyder, 1975; Neely, 1977, 1991; Favreau & Segalowitz, 1983; Den Heyer, 1985; McNamara, in press a; Shelton & Martin, in press). At short SOA, pre- and post-lexical strategic mechanisms are typically assumed to not operate because there is not enough time to either generate expectancies, or because the prime/target semantic relation is not yet available (although see de Groot, 1985 for a different conception). Although this distinction accounts well for a number of empirical constraints (e.g., increase in unrelated word prime inhibition and related word priming as SOA is lengthened), other data don't fit this distinction as nicely as we might like. For example, Peterson & Simpson (1989) demonstrated reliable backward priming with a short 200 ms SOA, an effect that is supposedly due to strategic mechanisms. Experiment 1 also yielded a marginal backward priming effect at short SOA. Conversely, Shelton & Martin (in press) *failed* to demonstrate short SOA *forward* priming with asymmetrically related pairs that showed reliable priming at longer SOA. According to the common distinction, automatic spreading activation should remain intact when SOA is shortened so the failure to achieve this effect is puzzling.

Perhaps the data are not straightforward because the automatic/strategic distinction is not as pure as previously thought. SOA may be affecting the compounding and/or familiarity attribution processes instead of automatic versus strategic processes. It is conceivable that under speeded, process demanding conditions, the subject is sensitive only to prime/target pairs that produce very high levels of familiarity. Symmetrically related prime/target pairs will produce more familiarity in the cue-compounding process than asymmetrically related ones. This raises the possibility that the prevalence of forward semantic priming at short SOA may actually be due to the *symmetry* of the pairs, not the *direction* of association (i.e., very few forward priming studies use asymmetrically associated pairs). With this in mind, the results of Shelton & Martin (in press) are more interpretable. The familiarity from asymmetrically related pairs, whether they are presented in a forward or backward direction, was not enough to cause facilitation under speeded conditions. Symmetrically related pairs, on the other hand, should yield enough familiarity to allow the subject to apply the familiarity heuristic. Consistent with this notion is the fact that Shelton & Martin (in press) *did* obtain short SOA facilitation in both directions with symmetric pairs.

List Structure Effects In addition to predicting backward priming, nonword facilitation and backward nonword inhibition, the cue-compounding model presented here can also handle relatedness proportion effects. Generally, if there are a lot of related items in the list, relying on the familiarity returned from memorial access with a compound-cue is beneficial (i.e., speeded RT's will result). Therefore, as the proportion of related words increases, either the likelihood that a particular prime and target will be compounded, or the likelihood that subjects will rely on the feeling of familiarity returned from memory access will increase. Additionally, nonword facilitation should also increase since the number of "unrelated" nonword trials that are subject to a quick familiarity judgment is incremented. Consistent with this analysis is the report that an increase in RP results in an increase in nonword facilitation (de Groot, 1984).

Neely et al. (1989) found that when the effects of RP were partialed out, only NR was a significant predictor of nonword facilitation. Since RP does not directly affect the utility of prime/target relatedness information whereas NR does, this result was considered support for the semantic matching mechanism. However, the main problem with the data from their experiments on nonword ratio effects is that they are contaminated with possible influences of other list structure variables. A potentially very important variable not controlled by Neely et al. (1989) was P(nonword). As they pointed out, P(nonword) and NR were highly correlated (r

= .86) in their experiments and so the apparent effects of NR may actually be attributable to P(nonword).

P(nonword) varied between groups because the method Neely et al. (1989) used to unconfound RP and NR was unsuitable. It *necessarily* introduced P(nonword) as a confounding variable. The seeming independence of RP and NR in their studies may simply reflect the fact that variations in RP affect subjects' compounding and/or familiarity attribution strategies while variations in NR (or P(nonword)) produces a response bias that affects familiarity based judgments ("unrelated" nonwords) more than analytic judgments (neutral nonwords). Until further research is conducted into the exact influence *pure* manipulations of NR have on nonword facilitation, no firm conclusions can be reached. However, the method of varying NR introduced in Chapter 2 is probably the best method established so far since NR can be manipulated independently of both RP and P(nonword). It would be informative to test the significance of NR after P(nonword) was partialed out (i.e., include P(nonword) as a variable in the multiple regression equations with RP and NR).

Other structural variables were not controlled in Neely et al. (1989). For example, the proportion of neutral to novel prime trials was allowed to vary between groups. The proportion of neutral trials in their RP(.89)/NR(.75) group was much lower (.20) than in the RP(.78)/NR(.91) group (.54).

This is important for two reasons. First, this proportion is inversely correlated with RP in their Experiment 2, one of the main independent variables, r = -.36. Also, the novelty of the prime is defined in terms of the *number of times it is presented* and this count is determined partly by the proportion of neutral trials in the experiment (i.e., if this proportion is high, it is also likely that the neutral prime is presented more often than if the proportion is low, all other things comparable). Thus it is quite possible that the cognitive treatment of a neutral prime trial in a group where the neutral prime is presented infrequently is quite different from a group where it occurs more often. For example, subjects may still compound the neutral prime with the target and base their lexical decision on familiarity on neutral prime trials if the number of neutral prime trials is low (as in the RP(.89)/NR(.75) group from Neely et al., 1989).

In the same vein, neither the total number of presentations of the neutral prime, nor the total trials in the experiment was held constant across groups. Given the subtle sensitivity of subjects to different list structure probabilities, it is desirable to control these variables as much as possible since they could produce very misleading trends. As Neely et al., (1989) themselves have noted,

> As experimenters, we need to be as sophisticated as our subjects so that we can design experiments that do not

> confound these subtle informational differences with the variable of interest (p. 1017).

In the experiments reported here, all the above mentioned variables were held constant between groups allowing for much better control and firmer conclusions.

In sum, the model presented here assumes that familiarity is the primary basis of judgment in a lexical decision task, although a more analytic basis of judgment is also operative on neutral prime trials. The familiarity of a particular trial is determined by a cue-compounding mechanism (Ratcliff & McKoon, 1988) used in conjunction with the SAM model of memory (Gillund & Shiffrin, 1984). The returned familiarity value is subsequently translated into a response via an attribution process using the familiarity heuristic. The familiarity heuristic can be simulated by a random walk process that produces fast, accurate responding at extreme levels of familiarity, but slower more error prone responses at intermediate levels.

The model is similar to that presented by Ratcliff & McKoon (1988), however, some of the assumptions were changed and the model was extended to account for nonword effects. The main alterations were (1) the basis of lexical decision on neutral prime trials is qualitatively different from lexical decisions to novel prime trials (related and unrelated). That is, no cue-compounding with either the neutral prime or any other information occurs on neutral prime trials, (2) visual and phonological similarity also plays a role in determining the strengths between elements in the cue and images (representations) in memory, (3) more than one round of memorial access can occur on a given trial and (4) strengths in the model do not represent links between long-term memory structures but rather the degree of access by a cue element of a particular representation on a given trial. In addition, an independent expectancy mechanism is assumed to operate if targets can be predicted well by the prime (e.g., category primes).

Chapter 4

INHIBITION ON NOVEL PRIME TRIALS:

THE EFFECT OF TARGET DEGRADATION ON SEMANTIC PRIMING AT SHORT STIMULUS ONSET ASYNCHRONY

Lexical decisions to a target word in the context of an associatively related word are typically faster and yield fewer errors than if the target word is presented in an unrelated context (Meyer & Schvaneveldt, 1971). For example, if "*nurse*" (target) follows the presentation of "*doctor*" (related prime), lexical decisions to "*nurse*" are faster than if it follows "*table*" (unrelated prime) or a neutral prime (e.g., "blank" or "XXX"). This effect, known as semantic priming, is usually larger if the target word is visually degraded (Massero, Jones, Lipscomb & Scholtz, 1978; Becker & Killion, 1977; Meyer, Schvaneveldt & Ruddy, 1975; Borowsky & Besner, 1991; Besner & Smith, 1992, although see den Heyer & Benson, 1988 for differing results).

The degradation by priming interaction has been explained by spreading activation within a semantic network (e.g., Collins & Loftus, 1975; Anderson, 1983). In order for spreading activation to predict increases in priming under visually degraded conditions, several assumptions must be made.

1. Identification of a word (and a subsequent lexical decision) occurs when a representation of the word in memory (a node within a semantic network) becomes activated above threshold.
2. Activation accrues at a particular node from two sources. First, processing of the word as a stimulus in the environment causes activation of its representation. Second, links that exist between semantically related nodes in memory allow for the transport of activation. For example, presentation of "*doctor*" as a prime causes the "*nurse*" node to become partially activated. Thus by the time "nurse" is available for processing as an environmental stimulus, it is closer to threshold activation level. Therefore, the amount of processing needed before conscious identification occurs is less and so lexical decision latencies are reduced - basic semantic priming.
3. Processing a visually degraded target reduces the rate at which activation accrues at its corresponding representation. That is, the amount of time it takes for activation to reach threshold levels if a word is degraded is greater than if the word is not degraded. However, the amount of activation that spreads throughout the semantic

network in response to the prime is not affected by visual degradation of the target word.

If these assumptions are met, then the degradation by priming interaction is explained in the following manner. First, an undegraded prime is presented and activation spreads from it to the target node. Since the spread of activation is unaffected by target degradation, equal amounts of activation accrue at the target node under degraded and undegraded target conditions. Once the target is presented additional activation accumulates at the target node, but it does so more slowly if the target is degraded. This difference in rate results in differential effects of the activation that has spread to the target node from the prime node. Namely, the amount of time it takes an unprimed target to "make up the difference" (i.e., to catch up to the primed target's starting activation level) will be greater in the degraded condition. This time is an index of facilitation caused by a related context. Thus semantic priming should be greater in the degraded condition.

Although spreading activation is commonly adopted as the explanation of the effect of target degradation, it is puzzling to note that target degradation research has never been conducted under conditions where spreading activation predicts the greatest effects. For example, Neely (1977; 1991) has argued that the amount of activation spreading to the target representation from the prime node peaks at approximately 250 ms. After that, it decays rapidly and other strategic priming mechanisms become active. Presumably, the previously documented interaction should be more pronounced at short SOA since the starting activation level of semantically primed targets is greater. That is, if the discrepancy in the starting activation levels of primed and unprimed targets is greater, then it will take longer for the unprimed target to catch up to the activation level of the primed target. Thus, unless strategic effects are also adding to the interaction at long SOA, degrading the target should be more effective at short SOA.

Despite these claims, the target degradation by priming interaction has not been studied at short stimulus onset asynchrony (SOA) with anything other than pronunciation latency as the dependent variable. Besner & Smith (1992) and Whittlesea & Jacoby (1990) have both obtained the interaction at short SOA, however, neither study has utilized lexical decision. Since the cue-compounding model presented in Chapter 3 is meant to simulate lexical decision, and since cue-compounding has been proposed as an alternative to spreading activation, it would seem reasonable to test for the interaction specifically with lexical decision.

The following experiments investigate the effect degrading the target has on semantic priming at short SOA (200 ms). The prediction is that the previously observed priming by degradation interaction should be obtained.

Studying the effect at short SOA better tests the spreading activation account of the priming by degradation interaction. As mentioned above, if spreading activation is the mechanism of the interaction then it should be more pronounced than in previous studies since the activation that has arrived at the target node from the prime node should be greatest at short SOA. Second, spreading activation is assumed to be the only mechanism operating at short SOA (Neely, 1977; 1991). Strategic mechanisms are thought to be inactive if there is very little time between the prime and target (Neely, 1977; den Heyer, Briand & Smith, 1985). Therefore, conducting the experiment at short SOA eliminates the possibility that strategic mechanisms are actually the cause of the interaction.

Experiment 3

Method:

Subjects: Fifty-four undergraduates participated for course credit. The 54 subjects were assigned to two independent groups of 27 each (Degraded and Undegraded conditions).

Design & Materials: Sixty associatively related word pairs were chosen from Keppel & Strand (1970). Most of these items were taken from Chapter 2, thus they were strongly associated in one direction (from prime to target), but with very little association in the other (from target to prime). One item in each pair constituted the prime and the other the target. The pairs were moderately to highly associated and varied from three to nine letters in length. The 60 pairs were divided into three critical conditions of 20 pairs each. The first 20 were assigned to the "Related" condition, the second twenty to the "Unrelated" condition and the third twenty to the "Neutral" condition. Words were counterbalanced by rotating them through the three critical conditions using a Latin square design.

The 20 pairs in the "Unrelated" condition were shuffled such that a prime from one pair was presented with a target from another pair. The twenty pairs in the neutral condition were separated and all were presented as targets with the word "BLANK" as the prime. This resulted in 40 neutral condition trials; 20 were fillers trials (i.e., the first word in pair - the item that acted as the prime in the other conditions - was presented as the target) and 20 were critical (second word in the pair was presented as target). Thus, there were 80 word trials in all; 20 in the related condition, 20 in the unrelated condition and 40 in the neutral condition (20 critical, 20 filler). The relatedness proportion was 0.5.

In addition to these 80 word target trials, there were also 80 nonword target trials. Nonwords were formed for all 120 words by changing one letter in each to construct a pronounceable letter string that was not an English word. For each nonword trial, a nonword was randomly sampled on line by the computer without replacement from this pool of 120 nonwords and was presented as the target. In addition, 40 new words that resembled the length and frequency of the other 120 words in the pool were generated and used as primes for one half of the nonword trials. On the other half of the nonword trials, a neutral prime ("BLANK") was used. Thus, in total, there were 40 word prime/nonword target trials and 40 neutral prime/nonword target trials. This design yielded a nonword ratio of 0.67. In sum, there were 160 trials in the experiment. No items, except the neutral prime "BLANK", were repeated anywhere during the experiment. The order of presentation of the trial types was randomized for each subject.

In the Degraded condition, the targets were presented in a mixture of upper and lower case letters (e.g., bUYinG; SoLDieR). Whittlesea & Jacoby (1990) found that this manipulation produced both slower overall response times and the priming by target degradation interaction using pronunciation as the dependent variable. Since degradation was a between-subject variable in this experiment, the word targets for the filler neutral trials were presented in an undegraded form so that a contrast between the different stimulus types could be cultivated within-subjects. (There was a concern that the full effect of degrading the target may not have been realized unless each subject saw both degraded and undegraded stimuli. Experiment 4 will demonstrate, however, that this concern was unnecessary.) Thus, 25% of the word targets in the Degraded condition were actually presented in an undegraded form. In order that degradation was not made predictive of the lexicality of the target, 25% of the nonword pool (40 items) in the Degraded condition was left undegraded. Thus, on average, 25% of the nonword targets in the Degraded condition were also presented in an undegraded form. These undegraded nonword targets randomly assigned to both the novel word/nonword and neutral word/nonword conditions.

<u>Procedure:</u> Subjects were tested individually on a IBM compatible personal computer. A response box consisting of three keys labelled "word", "nonword" and "start trial" interfaced with the computer via the game port to measure reaction times. Subjects were informed that their task was to make a word/nonword response as quickly and as accurately as possible to the target. They were not informed of a possible relationship between the prime and target, but were told that it was important to read the prime on each trial. The experimental trials were preceded by 32 practice trials made up of related, unrelated and neutral primes and both word and nonword target types.

At the beginning of each trial, "Press bottom key to start trial" was displayed on the computer monitor. When the subject pressed the bottom key (labelled "start trial"), the message was cleared and a fixation stimulus (*) was displayed in the center of the screen for 500 ms. The fixation stimulus was replaced by the prime which appeared in the same place in capital letters for 150 ms. After a 50 ms interstimulus interval (ISI), the target was displayed one line below and remained there until the subject pressed a key. Subjects were instructed to press the top right key (labelled "word") if the target was a word or the top left key (labelled "nonword") if it was a nonword. If the subject responded to the prime, pressed a wrong key or took longer than 1.5 seconds to respond to the target, an error message was flashed and the RT for that trial was not used.

Results and Discussion:

The mean response latencies and error rates for the Related, Unrelated and Neutral word conditions are shown in Table 8. Since priming can be determined using either the Unrelated or the Neutral word conditions as a control group, two separate analyses were conducted.

Related versus Unrelated Conditions: The response latency data for words were submitted to a 2 (Related/Unrelated) X 2 (Degraded/Undegraded) mixed ANOVA with relatedness varied within-subject and degradation varied between-subject. If the predictions of spreading activation are realized, the analysis should reveal two main-effects and an interaction. That is, priming should be apparent in both conditions, but there should be a *larger* priming effect in the Degraded condition. Additionally, the degradation of the

Table 8: Mean response latency (RT) in milliseconds and percent error (PE) for word and nonword targets preceded by a neutral, unrelated and related prime in the Degraded and Undegraded conditions of Experiment 3 and 4.

Undegraded (Experiment 3)

	words:		nonwords:	
	RT:	PE:	RT:	PE:
related:	596	3.0	-	-
unrelated:	635	4.9	724	7.0
neutral:	631	6.1	702	4.6
	UW-RW: 39		NN-UN: -22	
	NW-RW: 35			
	NW-UW: -4			

Degraded - Mixed Letters (Experiment 3)

	words:		nonwords:	
	RT:	PE:	RT:	PE:
related:	680	4.4	-	-
unrelated:	706	9.0	842	8.9
neutral:	682	8.3	833	9.3
	UW-RW: 26		NN-UN: -9	
	NW-RW: 2			
	NW-UW: -24			

Degraded - Masked (Experiment 4)

	words:		nonwords:	
	RT:	PE:	RT:	PE:
related:	639	4.5	-	-
unrelated:	665	9.0	742	28.0
neutral:	633	6.2	708	21.6
	UW-RW: 26		NN-UN: -34	
	NW-RW: -6			
	NW-UW: -32			

Note: UW = unrelated prime/word target; RW = related prime/word target; NW = neutral prime/word target; UN = "unrelated" prime/nonword target; NN = neutral prime/nonword target

target should result in longer response latencies overall in the Degraded condition. Sure enough, the analysis yielded significant main-effects of prime type, $F(1,52) = 18.58$, $p < .001$, $MSe = 1552.87$, and degradation, $F(1,52) = 10.43$, $p < .005$, $MSe = 15521.21$. But, counter to the hypothesis, the interaction between these variables did not approach significance, $F(1,52) < 1$. As Table 8 indicates, priming is evident in both the Undegraded and the Degraded groups, but the Degraded group actually shows somewhat *less* priming than the Undegraded group (26 versus 39 ms). This nonsignificant reversal of the prediction derived from spreading activation is not attributable to an ineffective manipulation of target degradation since, as predicated, response latencies were significantly greater in the Degraded condition.

A similar analysis of the error data yielded comparable results. Both a main-effect of prime type, $F(1,52) = 11.87$, $p < .005$, $MSe = .002$, and degradation, $F(1,52) = 6.83$, $p < .02$, $MSe = .003$ was obtained, but the interaction was not significant, $p > .05$. Thus priming the target decreased errors and degrading the target increased them, but these effects did not interact.

Related versus Neutral Conditions: A similar 2 X 2 mixed ANOVA was conducted on the word latencies using the Neutral condition as the second level of prime type. Spreading activation makes similar predictions for this comparison as for the previous one. Again, both main-effects of prime type, $F(1,52) = 7.66$, $p < .01$, MSe = 1218.55, and degradation, $F(1,52) = 8.48$, $p < .01$, MSe = 14270.8, were obtained. Additionally, the interaction was significant, $F(1,52) = 6.13$, $p < .02$, MSe = 1218.55. However, Table 8 reveals that this interaction is directly counter to the prediction derived from spreading activation; there is significantly *less* priming in the Degraded condition than in the Undegraded condition (2 versus 35 ms) whereas spreading activation predicts that there should be more. As before, this significant reversal is not attributable to an ineffective manipulation of target degradation since, as predicted, response latencies were significantly greater in the Degraded condition.

A similar analysis on the error data yielded somewhat analogous results. Both a significant main-effect of prime type, $F(1,52) = 10.75$, $p < .005$, MSe = .003, and of degradation, $F(1,52) = 4.13$, $p < .05$, MSe = .002 was obtained. Again, a related prime decreased errors whereas degrading the target increased them. However, unlike the analysis on the reaction times, no significant interaction was obtained. Given that response latencies capture more of the subtleties of lexical decision than do errors, this result is not surprising. Indeed, no interactions were significant in *any* of the error analyses conducted on any of the experiments reported in this chapter. For this reason, subsequent discussion will concentrate specifically on the latency data.

Nonwords: Nonword data are reported along with word data in Table 8. The first analysis conducted on nonwords was a check to ensure that no systematic biases resulted from the different methods of choosing words and nonwords for presentation. (Word presentation was highly controlled whereas nonwords were sampled from a large pool of items.) In particular, it was important to ensure that the proportions of undegraded words and nonwords presented to subjects in the Degraded condition were comparable. As described in the Method section, 20 (25%) filler word targets in the Undegraded condition were not degraded. If this proportion was not the same for the nonword targets then the degradation status of the target becomes predictive of its lexical status. Subjects could then presumably rely on a "surface scan" of the letters to guide their lexical decisions rather than attempting to semantically process the items. As expected, however, the proportions were comparable. The mean number of undegraded nonwords presented to each subject in the Degraded condition was 20.11 (25.14%) which compares well to 20 (25%) undegraded filler word targets. Approximately equal numbers of undegraded nonword targets were preceded by a neutral prime as an "unrelated" word prime.

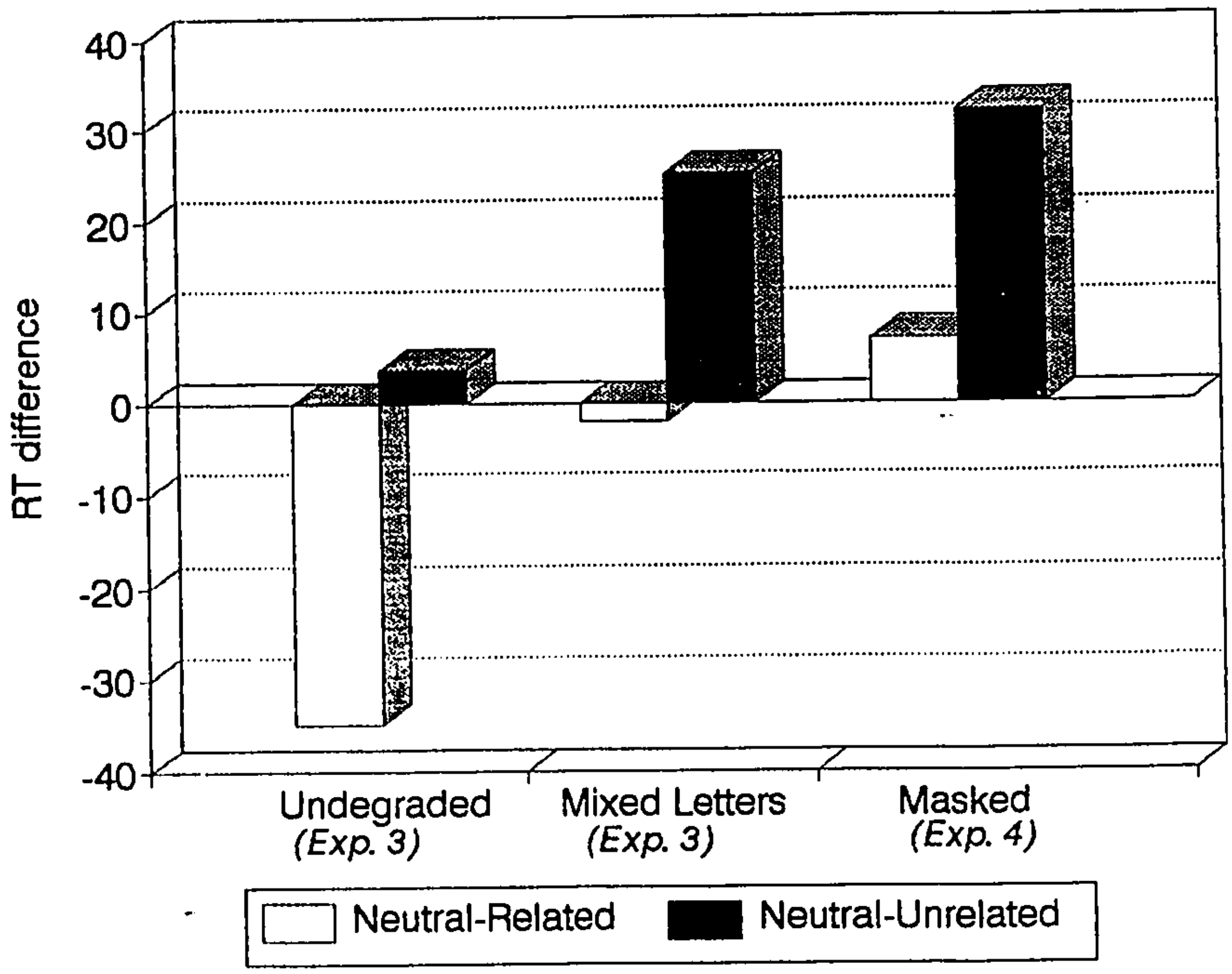
Since nonwords were not a central issue in this chapter, no statistical analyses were completed on the data. However, it is worth noting that both error rates and RT's indicate no nonword facilitation in this experiment. Of course, there is no reason to expect nonword facilitation given the short SOA, and in fact, it replicates the pattern obtained in the Short SOA group of Experiment 1 in Chapter 2 (NF = -13). However, if anything, the *reverse* trend occurred; subjects seemed to have more difficulty responding to nonwords preceded by an "unrelated", novel word prime. The possibility of the *reverse* effect occurring may prove to be informative, and will be raised again in the General Discussion of this chapter.

The analyses on words, using either the Unrelated or Neutral condition as a baseline, yielded results directly counter to the predictions derived from spreading activation. In the context of spreading activation, visually degrading the target should cause an increase in semantic priming to the extent that the degradation manipulation slows the accrual of activation at the target node. Response latencies for all the Degraded conditions (Related, Unrelated and Neutral) are much higher than the Undegraded conditions, suggesting that the rate of accumulating activation was indeed reduced. However, priming was less in the Degraded condition.

If the analyses using the two control conditions are compared, a clue is obtained as to what may be occurring in the data. A significant prime type by degradation interaction was obtained for the neutral - related comparison, F(1,52) = 6.13, p < .02, MSe = 1218.55, but was completely absent in the unrelated - related comparison, F(1,52) < 1. Table 8 reveals that this occurred because *the degradation manipulation slowed RT's more in the related (84 ms) and unrelated (71 ms) word conditions than in the neutral (50 ms) condition.* Figure 3 demonstrates that once the effect of degradation on the neutral baseline is equated in each group, residual increase to the novel prime conditions (related and unrelated) remains. Thus an interaction is apparent when the related condition is compared to the neutral condition, but not when it is compared to the unrelated condition.

It appears, therefore, that degrading the target has two effects. First, it caused an general increase in RT's to all target types. In addition, however, it interacted with (caused a disproportionate increase in RT's to) targets preceded by a *novel* prime. This unexpected pattern is clearly contrary to predictions derived from spreading activation models. Not only does spreading activation predict the opposite interaction if identification of the target is slowed, but its "inhibitionless" nature (Neely, 1977) means that it has no way of accounting for selective

Figure 3: Demorstration of disproportionate increases in response latencies for related and unrelated trials versus neutral trials as target is degraded. Each bar represents the residual differences in each condition after the corresponding baseline differences (neutral trial latencies) are removed (i.e., "0" represents the Neutral condition).


40
30
20
10
0
-10
-20
-30
-40
RT difference
Undegraded
(Exp. 3)
Mixed Letters
(Exp. 3)
Masked
(Exp. 4)
Neutral-Related
Neutral-Unrelated

inhibition of responses to novel prime/degraded target trials. Nonetheless, the unusual pattern remains to be interpreted. More will be offered on this later.

The differential increase in response times to degraded targets preceded by a novel prime is quite counter-intuitive. The purpose of Experiment 4, therefore, was to test a different method of degrading the target to ascertain whether the current pattern was due to some peculiarity of the manipulation used. This seems unlikely since Whittlesea & Jacoby (1990) used the mixed upper and lower case letters manipulation and successfully obtained the *conventional* priming by degradation interaction. Nonetheless, if the results replicated with a different type of degraded stimulus, our confidence that we are examining a real phenomenon would be greatly boosted.

In Experiment 4, the target was presented for a brief period and then masked with ampersands. This degradation manipulation was used by Durgunoglu (1988, Experiment 4) in a study examining semantic and repetition priming. She found that pronunciation latencies showed more inhibition, but not facilitation, in response to the target degradation. However, for reasons that are not entirely clear, only one of three possible neutral conditions was used to measure these effects. If the related condition is compared to the mean of all three neutral conditions pooled, there is evidence that facilitation also increased (undegraded: +19 ms; masked: +29 ms). Additionally, given that the neutral baseline responded differently to target degradation in Experiment 3 of this chapter, there is some question regarding the appropriateness of this condition to measure facilitation effects. If instead the unrelated word condition is used as a baseline, Durgunoglu's (1988) data indicate that facilitation increased from 24 to 53 ms as a result of masking the target. Thus the masking manipulation was employed in this experiment in an attempt to replicate the results of Experiment 3.

Experiment 4

Method:

Subjects: 27 additional undergraduate psychology students participated for course credit. These subjects were drawn from the same pool, and performed in the experiment at the same time as those in Experiment 3. The division into two experiments, therefore, was done for rhetorical convenience.

Design and Materials: All aspects of the experimental design and of the materials used were the same as in Experiment 3 except that, (1) the targets were degraded by presenting them for only 150 ms and then masking them with ampersands ("&&&&&&&&&&&"), (2) all targets in the Degraded condition were masked. That is, none of the filler word targets or the nonword targets were presented in an undegraded form.

Procedure: All aspects of the procedure were identical to Experiment 3.

Results & Discussion:

The mean response latencies and error rates for the Related, Unrelated and Neutral word conditions for the Masked condition are shown in Table 8. Since priming can be determined using either the Unrelated or the Neutral word conditions as a control group, two separate analyses were conducted.

Related versus Unrelated Condition: As in Experiment 3, the response latency data for words were submitted to a 2 (Related/Unrelated) X 2 (Masked/Undegraded) mixed ANOVA with relatedness varied within- and degradation varied between-subjects. The Undegraded group from Experiment 3 was used as a comparison group to determine the effect of masking the target. As in Experiment 3, a significant effect of prime type was obtained, $F(1,52) = 13.77$, $p < .001$, $MSe = 2008.41$. However, neither the main effect of degradation or the interaction was significant (both p's $> .05$).

A similar analysis of the error data revealed analogous results. A main effect of prime type was obtained, $F(1,52) = 12.53$, $p < .001$, $MSe = .002$, but neither the main-effect of degradation, or the interaction was significant (both p's $>$ .05).

The failure to achieve an interaction indicates that masking the stimulus did not affect the amount of semantic priming obtained. Nonsignificantly *less* priming was obtained in the Masked (25 ms) than in the Undegraded condition (39 ms). This result is analogous to that obtained in Experiment 3.

A crucial difference between the results of this experiment and Experiment 3 is the overall effect of degrading the target. Masking the target did not cause an overall significant slowing of reaction time (i.e., the effect of degradation was not significant in this experiment). This is contrary to Durgunoglu (1988, Experiment 4) in which a main-effect of stimulus quality was obtained for pronunciation latencies when a similar manipulation was used. The reason for the discrepancy is probably that targets in this experiment were presented for longer (150 ms presentation + 0 ms before mask) than in Durgunoglu's (1988) study (30 ms presentation + 30 ms before mask). Also, it is important to note that both the related and unrelated conditions were *directionally* slower when the target was masked in this experiment.

The failure to discover a priming by degradation interaction is, by itself, not damaging to a spreading activation account since overall longer processing time is a necessary prerequisite. Nevertheless, it will soon become apparent that other aspects of the data are problematic for this view.

Related versus Neutral Condition: As before, response latencies for words were submitted to a 2 (Related/Neutral) X 2 (Masked/Undegraded) mixed ANOVA with relatedness varied within-and degradation varied between-subjects. The analysis revealed a marginal effect of prime type, $F(1,52) = 3.73$, $p < .06$, $MSe = 1446.25$ which was qualified by a significant prime type by degradation interaction, $F(1,52) = 8.31$, $p < .01$, $MSe = 1446.25$. The main-effect of degradation was not significant, $F(1,52) < 1$.

Analysis of the error data revealed only a significant effect of prime type, $F(1,52) = 7.10$, $p < .02$, $MSe = .002$. The interaction was not significant as it was with the latency data. However, as was mentioned in Experiment 3, this is not too troubling since error data tend not to reveal subtle aspects of lexical decision. Therefore, future discussion will concentrate on the latency data.

The same interaction between prime novelty and target degradation that occurred in Experiment 3 also occurred here. When prime novelty is held constant and the Related condition is compared to the Unrelated condition, no prime type by degradation interaction occurred. But when the Related condition was compared to the Neutral condition where a recurring prime is used, a significant interaction was apparent which was *opposite* to the prediction derived from spreading activation. Examining Table 8 indicates that this pattern occurred in Experiment 4 (as well as in Experiment 3) because *the masking manipulation slowed RT's more in the related (43 ms) and unrelated (30 ms) word conditions than in the neutral (2 ms) condition.* Figure 3 again reveals that once the neutral baselines are equated, residual increase in RT's caused by degrading the target is apparent in the related and unrelated conditions (slightly more than in Experiment 3).

Thus, in both experiments, degrading the target caused a disproportionate increase in reaction times for the trials that received novel primes (Related and Unrelated conditions). It is important to immediately dismiss the notion that this pattern of data can be interpreted as a simple "psychological refractory period" (Kantowitz, 1974; Whittlesea & Jacoby, 1990). With only 200 ms separating the onset of the prime and target, processing of the prime is not likely to be complete by the time the target is presented. Additionally, it is reasonable to expect that the refractory period would be longer with novel primes than with recurring primes since they demand more processing resources. However, the refractory effect is not merely dependent on the novelty status of the prime. Response latencies were significantly *shorter* in the Undegraded - Related condition where the prime was novel than in the Undegraded - Neutral condition where it was not, $\underline{t}(26) = 3.48$, $\underline{p} = .002$, two-tailed. Instead, interference only occurs when the prime is novel AND the target is degraded. The issue now is to try to determine why this particular combination of events produces interference.

General Discussion

Any attempt to explain the pattern of data in these experiments with spreading activation will not work. These models were developed with the *opposite* interaction in mind. To the extent that the rate of activation accumulation at the target node is reduced (i.e., the target is visually more difficult to read), semantic priming should be greater. This result should be particularly apparent at short SOA where activation that has spread from the prime to the target node has not had time to decay. However, there was no evidence of an increase in priming as a result of degrading the target at the short SOA used in these experiments. Additionally, spreading activation has no way of handling the selective inhibition caused by degrading targets preceded by novel primes (i.e., related and unrelated versus neutral prime conditions). Spreading activation only predicts facilitation effects (cf. Neely, 1977) and clear evidence of interference was obtained in both experiments when the target was degraded and the prime was novel.

Cue-Compounding and Target Degradation: Given that spreading activation cannot interpret the results of the experiments presented here, it seems sensible to try to understand them in terms of a cue-compounding model. Several variants of cue-compounding have been proposed, however, I will concentrate specifically on the model outlined in Chapter 3. The reason is simply that the model presented there is able to incorporate prime novelty effects. Simply, it was proposed there that *cue-compounding does not occur on neutral prime trials* such that responses on these trials are qualitatively different from related and unrelated trials. When the prime is word that has appeared many times throughout the experiment (e.g., "BLANK"), subjects no longer base their judgments on the familiarity of the compound cue. Instead, identification is based on more complete visual analysis of the target item (e.g., Balota & Chumbley, 1984).

If the variant of Ratcliff & McKoon's (1988) cue-compounding model presented in Chapter 3 is applied here, the complicated pattern of data becomes more interpretable. However, it must be assumed that a compound-cue takes some time to form before memory access can occur. The compounding of the prime and target is not something that occurs instantaneously upon presentation of the target. Usually, this time is negligible and a quick familiarity based response follows. However, at short SOA where the prime is incompletely processed, any manipulation that makes processing of the target more difficult may also hinder formation of a compound cue. I would like to propose that the interference observed in the Degraded conditions when a novel prime is present (Related and Unrelated conditions) is due to *difficulty in compounding a degraded target with an* *incompletely processed prime*. The difficulty arises from excessive processing demands; if the target is hard to read *and* the prime is incompletely processed, interference results because of processing pressure. Since compounding does not occur on neutral prime trials, this interference is absent. As a result, there is a disproportionate increase in RT's for novel prime conditions when the target is degraded. Additionally, if the target is not degraded, then compounding it with a partially processed prime is not as difficult. Thus facilitation is observed in the Undegraded-Related condition when it is compared to the Undegraded-Neutral condition.

The fact that there was some hint of the *reverse* of nonword facilitation occurring in the conditions of this experiment and the Short SOA group of Experiment 1 of Chapter 2 is consistent with the notion of processing pressure. That is, subjects may have difficulty compounding an incompletely processed prime with a nonword target just as they find it difficult with a degraded word target. Thus the nonword facilitation that occurs at longer SOA is reduced or even reversed at short SOA. It is this aspect of the cue-compounding model that predicts the correlation between nonword facilitation and SOA.

The results of Experiment 4 indicate that interference on novel prime trials was observed even though RT's in the Masked - Neutral condition were not different from the

Undegraded - Neutral condition. This suggests that difficulty in forming a cue is not necessarily dependent on the target taking *longer* to process. Again, it is the *processing demands* that make the prime and target difficult to compound. Processing demands and duration of processing are probably correlated (as in the mixed upper and lower case manipulation from Experiment 3), but they are not synonymous. It may only take a short time to process the target, but if that processing requires effort, then compounding it with an incompletely processed prime will be time consuming and interference will obtain. Thus, masking the stimulus increases processing demands enough to make it difficult to compound it with the prime, but it does not increase the duration of target processing. The imperfect correlation between compounding difficulty and processing duration allows cue-compounding to interpret these results when spreading activation cannot. With spreading activation, any interactions between priming and target degradation are dependent on the target taking longer to process.

The Conventional Priming by Degradation Interaction: The results in these experiments are counter to the conventional priming by degradation interaction. If cue-compounding is going to remain a reasonable competitor of spreading activation, it must also be able to account for *increases* in priming resulting from degrading the target which occur for lexical decisions at longer SOA.

Whittlesea & Jacoby (1990) demonstrated that cue-compounding is indeed able to predict the conventional interaction. They developed a paradigm that consisted of the successive presentation of three words, instead of two which is more common in priming studies. For example, successive presentations may have been "GREEN - PLANT - GREEN". The dependent variable was pronunciation latency to the third word. In addition, a degradation manipulation was applied. However, rather than degrade the target (second presentation of "GREEN"), the interpolated word was degraded. For example, in the degraded condition, the sequence of items was "GREEN - pLAnT - GREEN". It was argued that the easiest prediction from spreading activation would be no difference in response times to the third word. Since the target itself is not degraded, then there is no reduced rate of activation accrual at the target node, thus there is no mechanism to produce increased priming. However, they argued that cue-compounding would result in faster response times to the third word in the degraded condition. This is predicted because when the interpolated word is degraded, the first word is compounded with it. If the current item is difficult to read, the previous word is "brought forward" to assist in its identification. Thus, when the target is subsequently presented, the first word ("GREEN") is readily available for assistance in identification of the target (repetition of "GREEN"). In a series of experiments, increased facilitation of identifying the target in the degraded condition was obtained thus supporting cue-compounding and negating spreading activation accounts.

Although Whittlesea & Jacoby (1990) were able to predict the conventional priming by degradation interaction with the three-word paradigm, some question remains as to whether or not cue-compounding can predict it in the *standard* two-word paradigm. I would like to propose that the interaction that occurs in two-word priming experiments is caused by a process very similar to that suggested by Whittlesea & Jacoby (1990) to explain the three-word interaction. Simply, if the target is difficult to read, the likelihood increases that a subject will "bring forward" the prime to aid in its identification. Thus, the visually degraded target will be compounded with the current context (prime) more often than if it is not degraded. The reason no such interaction occurred when the related and unrelated condition latencies in these experiments were compared (i.e., when novelty of prime was held constant and was no longer a factor) is again due to interference in forming the compound. That is, the priming was not larger because any increased facilitation resulting from additional tendency to compound the prime and target under degraded conditions was offset by difficulty in completing this task since the prime was incompletely processed.

Other support for the idea that the neutral priming condition behaves differently from the unrelated priming condition when the target is degraded can be found in the literature. For example, Borowsky & Besner (1991), using lexical decision and an SOA of 800 ms, found that priming was greater when compared to the unrelated priming condition (88 versus 50 ms). However, it was *less* in a different group of subjects, where the baseline was a string of asterisks (44 versus 56 ms). These results are somewhat comparable to those reported here. Although their degradation manipulation did not differentially increase RT's in the novel versus neutral prime conditions such that priming was *eliminated* as was obtained here, the direction of the effect is similar. This is understandable in terms of the cue-compounding theory. Simply, the longer SOA (800 ms) in Borowsky & Besner (1991) means that there is an increased tendency (as previously described) to form a compound-cue and *less* of a problem in completing the task since prime processing is probably complete by the time the target appears. Thus the conventional interaction is obtained when the related and unrelated conditions (where compounding occurs) are compared. However, if there is any increase in the time it takes to form a cue from having the target degraded (versus undegraded), then the interaction will be less (or reversed depending on the amount of RT increase resulting from forming the cue) if priming is measured against the neutral condition. Consistent with this, additivity (approaching underadditivity) is observed in the relevant data of Borowsky & Besner (1991).

Similar results concerning the additivity issue were obtained by den Heyer & Benson (1988). They found in two different long SOA experiments that low brightness intensity did not increase priming when measured against the neutral prime "BLANK". This occurred despite the fact that degradation produced both a main-effect increase in RT's and a significant interaction with repetition. Given previous lexical decision results at long SOA, it is quite conceivable that had den Heyer & Benson (1988) included an unrelated priming condition, they would have observed the usual priming by stimulus quality interaction. The point again, however, is that the neutral priming condition behaves qualitatively differently from the unrelated priming condition, which is predicted by the cue-compounding model presented in Chapter 3, but is not predicted by spreading activation models. Of course, other strategic mechanisms may have been operating with den Heyer & Benson's subjects since the SOA was long.

Although additivity of priming and degradation has been obtained previously when the neutral condition is used as a baseline, the results reported in this chapter are the first to demonstrate significant *underadditivity*. In addition to Whittlesea & Jacoby (1990), Besner & Smith (1992) have also obtained the conventional priming by degradation interaction at 200 ms SOA against an unrelated word prime baseline. The question remains as to why the results in this chapter yield additivity against the same baseline. The answer probably lies in the fact that, in both studies, the dependent measure was pronunciation. Since cue-compounding is assumed only to occur in binary choice paradigms, the processing pressure that is hypothesized to occur in forming a cue from a degraded target and a partially processed prime would be absent. It may very well be the fact that it was the particular combination of lexical decision (which allows for cue-compounding) and a short SOA (which coupled with target degradation creates excessive processing demands) that produced the unique results reported in this chapter.

Other possible reasons for the discrepancy are listed below. There is no particular theoretical reason to suspect any one of these. Instead they are listed for the reader's convenience.

(1) Many asymmetrically associated words were used in this experiment. It should be noted, however, that the prime/target pairs were always paired such that the direction of the association was *forward* (from prime to target). Thus, spreading activation still makes the aforementioned predictions.

(2) Stimulus quality was manipulated between- rather than within-subjects (the latter being more traditional).

(3) Although the pattern of degraded data replicated in a second experiment, the undegraded data that was used for comparison was limited to a single group. If there was anything uncharacteristic about the subjects in that condition, then the replication does not mean a great deal and the results may have been a fluke. However, this is very unlikely since the subjects for that group were drawn from the same pool and were tested at the same time as subjects in the degraded conditions.

At the very least, the results of Experiments 3 and 4 suggest that the processing in the neutral priming condition is qualitatively different from novel word prime trials. This conclusion again calls into question the appropriateness of the neutral baseline. This issue was raised previously and was discussed in detail in Chapter 4. Particularly relevant to the current issues, however, is Jonides & Mack's (1984) argument that the *processing demands* of novel primes are greater than for neutral. They contended that these differential demands can carry-over and affect responses made to the target, particularly at short SOA. As noted in Chapter 3, ultimately, these matters have implications regarding the validity of several theoretically important priming effects that are measured against the neutral priming condition such as unrelated word prime inhibition and nonword facilitation. However, the current experiments paint an even bleaker picture. They suggest that not only do we need to worry about the simple effect prime novelty has on target responding, but that it is also necessary to consider how this variable *interacts* with different aspects of target presentation. Prime novelty and a short SOA by themselves were not enough to eliminate facilitation measured against a neutral prime. But when the target was hard to read, all these factors combined to eliminate priming.

In sum, the experiments reported in this chapter seriously question the viability of spreading activation accounts of the priming by degradation interaction. Previous studies that have established the interaction with lexical decision have not used a short SOA. However, it is very important to do so since the effects of spreading activation are supposedly maximized at short onset asynchrony (Neely, 1977; 1991). The experiments reported here indicate that when this crucial test is conducted, the reverse interaction is obtained. However, since both the conventional and current interactions can be interpreted with cue-compounding models, their status as a important competitor of spreading activation is more firmly established. More research is necessary, but the general picture seems to be that cue-compounding can do everything spreading activation can and more.

Chapter 5

A CRITIQUE OF MCNAMARA (1992)

In an article that has recently appeared in *The Journal of Experimental Psychology: Learning, Memory and Cognition*, McNamara (1992a) reports three experiments that examine semantic priming using a sequential lexical decision task at short stimulus onset asynchrony (SOA). These experiments were meant to distinguish between two possible mechanisms of semantic priming; automatic spreading activation (Collins & Loftus, 1975; Anderson, 1983) and cue-compounding (Ratcliff & McKoon, 1988; Dosher & Rosedale, 1989; Chapter 3 of this thesis). Using the results from experiments addressing associative distance (Experiment 1) and intertrial prime-target lag (Experiments 2 and 3), McNamara (1992a) argues that spreading activation is the more viable account of priming. However, there are a number of inferential and statistical problems in the article that raise serious question about this general conclusion. The first part of this critique reviews these problems in detail. The latter part demonstrates how the cue-compounding model presented in Chapter 3 accounts for McNamara's three-step mediated priming effect. Throughout this critique, I will concentrate specifically on the cue-compounding model presented in Chapter 3.

Comments on Experiment 1 - Associative Distance

In Experiment 1, McNamara (1992a) demonstrates three-step mediated priming. That is, subjects are faster to respond to the target "*turtle*" if it is preceded by "*cheetah*" even though free association norms indicate that "*turtle*" is not an associate of "*cheetah*". The priming effect is assumed to occur because it is mediated via direct associations to two other words ("fast" and "slow") forming the following chain: *cheetah -> fast -> slow -> turtle*. McNamara (1992a) argues that this result is strong evidence against cue-compounding since these models cannot account for anything greater than two-step mediated priming. However, spreading activation models predict a small effect (8 or 9 ms) which is very close to the difference obtained (10 ms). McNamara (1992a) does a commendable job of eliminating the possibility that there are, in fact, weak direct or two-step associations between the items as measured by a free association task which could nullify the results.

These results and arguments are valid only if the following assumptions are true:

1. Spreading Activation: Free association norms are a perfect index of the associative strengths between nodes in memory.

2. Cue-Compounding: Free association norms are a perfect index of the strengths between elements of the compound cue and images in memory.

Whether or not the first assumption is true is debatable. As McNamara has pointed out elsewhere (McNamara, 1992b), three different sources have been used to estimate associations in a semantic network, each with some success; free associations, relatedness judgments and co-occurrence measures. Therefore, if *any* of the above measures indicate an association between two items, there should be reasonable suspicion that one exists. In order to eliminate that reasonable suspicion, it is necessary to test the prime/target pairs with all three tasks to ensure that none of them indicate an association. The simple reason is that the so-called mediated priming effect observed is *completely dependent* on establishing the absence of a weak direct association between the prime and target in memory. To rely wholly on results from free associations is weak evidence simply because it is only one of several tasks used to measure associations in memory. This may seem unreasonable, but McNamara is in the unfortunate position of trying to prove the absence of an effect. To the extent that this research strategy is going to be effective, one must be prepared to work very hard to convince skeptics that every attempt was made to obtain the effect before giving up.

Relying on one source when three are available is not convincing enough.

More serious problems arise when McNamara applies the results of free association to cue-compounding models (assumption 2). Free association norms hold no special status for the cue-compounding model in Chapter 3. The strengths within the model are a measure of the *degree to which a particular memorial representation is accessed by an element in the compound,* not an index of some association in memory. This "access index" is roughly correlated with associative strength (as measured by free association norms), but access must also be affected by other variables, as will become apparent shortly. Indeed, the cue-compounding explanation doesn't necessarily even accept the notion that items are "associated in memory" since a semantic network is not an assumption.

To understand these objections, it is necessary to outline the critical differences between my cue-compounding model and spreading activation models. Traditionally, priming has been viewed as a phenomenon that occurs in a semantic network. Both the free association task and the semantic priming paradigm were assumed to be tapping this memory system. The fact that "nurse" is a common associate of "doctor" and the fact that "doctor" primes "nurse" were both considered phenomena of activation spreading through the same semantic network. Specifically, residual activation arriving at the "nurse" node from the "doctor" node via an associative link was considered the mechanism producing an effect in both tasks. However, the cue-compounding model does not necessarily assume the presence of a semantic network or a spread of activation between nodes in the network. Instead, priming effects are produced by variability in the contents of retrieval cues used to access representations in memory. Priming is not produced by stable associations between representations (i.e., links between long-term memory structures), but instead by increased access of particular representations by particular retrieval structures. It is the similarity of the retrieval cue to representations in memory that determine the degree of access. Many different representations can be accessed directly by a particular cue to the extent that it is similar to several items in memory. Conversely, spreading activation models assume that *already existing* links between representations stored in memory determine whether an item will be retrieved. As soon as one node is activated, several others are also via the links that interconnect them. The access does not occur via direct similarity to the retrieval cue.

Since the assumptions regarding the nature of long-term memory are fundamentally altered, *the free association task loses its special status for controlling strengths in the cue-compounding model*. Without the mediating semantic network, the free association task and the priming paradigm are connected only in that they are both tasks that tap memory. As McNamara points out in his General Discussion, the free association task is analogous to a generic cued recall, while priming trials are more akin to generic recognition. All researchers of memory are well aware that very different mechanisms operate in recall and recognition, and current memory models incorporate this fact, including SAM. In the context of compound-cue models, therefore, it is not surprising that a dissociation can exist between words produced in a free association task and the priming effects for those words. In fact, current data already suggest that associative norms are only a weak correlate of priming effects. For example, Warren (1977) compared priming effects produced by moderate (34%) and strong (64%) associates at short SOA. Even though the associative strength for these groups of items differed almost by a factor of two, nonsignificantly *larger* priming was found for the moderate associates.

Ultimately, the objective is the same for advocates of either spreading activation or cue-compounding. That is, in order to avoid circularity, it is necessary to find a task that will predict parameters in the model that is *methodologically independent* of priming effects. Without this, we are stuck with *post*dicting rather than *pre*dicting the effects that we observe. However, in the process of doing this, we are bound to experiment with several tasks that are imperfect correlates of these strengths. Therefore, the fundamental error in McNamara's approach toward mediated priming is not that he hasn't found the perfect task yet to predict these strengths, but that he is using a task that we already know is imperfect in a context where perfection is needed - attempting to prove the absence of association. It is one thing to use the results of free association to choose pairs of words for a priming experiment. It is quite another to argue on the basis of these results that there is no way an association can exist between words in memory. For that conclusion, the predictor had better be exquisitely accurate.

It is conceivable that a task encompassing processes more comparable to those involved in lexical decision would predict facilitation between three-step mediated pairs. For example, a relatedness rating task is probably more akin to generic recognition than is the free association task since it is not incumbent on the subject to *generate* items. However, the relatedness rating task is not necessarily suitable either. Although it is probably closer to a recognition task, McNamara (1992b) has indicated that strategic mechanisms are more likely to be utilized in a relatedness rating task than in a lexical decision task at short SOA. Nonetheless, it is probably a better task for determining strengths than is a free association task. In sum, therefore, McNamara's demonstration that a primeable target never occurs as a direct (or semi-direct) free associate of the prime is of questionable importance.

The dissociation between the lexical decision and free association tasks is made even less relevant by the fact that the strengths in the cue-compound model (and spreading activation models) *must* be affected by variables *unable* to affect free association results. Consider experiments that have revealed the associative influence of nonwords. For example, Rosson (1983) demonstrated priming for the target "sheep" if it was preceded by the nonword prime "famb" (derived from the related word "lamb"). In addition, O'Connor & Forster (1981) have shown increased error rates, and increases in errors and RT's for "related" nonword targets was demonstrated in Chapter 2. That is, a nonword response to the target *"famb"* is slower and/or more error prone if it is preceded by *"sheep"* than if it is preceded by an "unrelated" item. Since "famb" is a nonword, it is not semantically associated with *any* items, including "sheep". In fact, it is not even represented in semantic memory. In order for any model to explain these effects, it must be assumed that memorial access is partially determined by *sensory factors*; the target "famb" accesses a representation of "lamb" because it *looks and sounds like it*, not because it is semantically associated with it in memory. Thus, the strengths in the models must be affected by sensory similarity and well as semantic similarity.

Lest there be some confusion here, allow me to point out that I am not trying to argue that the three-step priming effect McNamara observed in Experiment 1 is due to sensory similarity between the prime and target; "*cheetah*" hardly has much visual or phonemic resemblance to "*turtle*". The point is simply that the unique emphasis that McNamara places on direct associative strength between the prime and target as measured by the free association task implies that he believes the strengths in the cue compound model (and spreading activation models) derive *only* from this source. Experiments revealing the facilitatory and inhibitory effects of nonwords, however, indicate that this cannot be the case.

In sum, the conclusion that cue-compounding models fail to simulate McNamara's three-step mediated priming is not necessarily correct. In the context of cue-compounding models, the finding merely represents a dissociation between two memory tasks that were suspected a priori to involve very different mechanisms anyway. The conclusion is also called into question since the prediction derived for cue-compounding assumes that retrieval strength is equal to associative strength. However, this is not true since other types of similarity (e.g., visual) affect the likelihood of retrieval.

Nonetheless, if a cue-compounding model were produced that simulates three-step mediated priming under the constraints imposed by McNamara, the flexibility of this class of model would be demonstrated. Therefore, an amended cue-compounding model (using SAM) is presented at the end of this chapter. The model keeps direct and two-step strengths residual, but simulates three-step mediated priming.

Comments on Experiments 2 and 3 - Lag

In Experiment 2, McNamara demonstrates priming effects when one unrelated item intervenes between the prime and target in a sequential lexical decision task, but not when two unrelated items intervene. Determining the lag over which priming occurs is important because, in the context of cue-compounding models, it can be used to estimate the size of the compound-cue. Using the results of Experiment 2, he estimates that the compound-cue contains three items; the target and the two preceding items.

In Experiment 3, McNamara again tests the cue-compounding and spreading activation models. Two important predictions are derived for each model (see McNamara, 1992a, Table 8);

1. Cue-Compounding: If the two words preceding the target are related, then response times to the target will be faster than if the two preceding items are unrelated. This occurs because the familiarity of the cue containing the target and the two preceding items will be higher in the related case. For example, the familiarity of the compound cue "lion-tiger-table" is higher than "sand-tiger-table".

<u>Spreading Activation:</u> no effect of varying the relationship of the two items preceding the target.

2. <u>Cue-Compounding:</u> If the item preceding an adjacent prime and target is a nonword, then response times will be slower to the target than if the preceding item is a word, assuming that the nonword is included in the cue. This occurs because the familiarity of the cue containing prime, target and nonword will be lower than if it contains three words. For example, the familiarity of the compound-cue "sand-tiger-table" is higher than "telf-tiger-table".

   If the nonword preceding the prime and target is not included in the cue, then familiarity should be higher because of the inverse correlation between number of elements in the cue and familiarity (i.e., two versus three items). For example, the familiarity of "sand-tiger-table" is lower than "tiger-table" because of the multiplication procedure used in SAM.

   <u>Spreading Activation:</u> no effect of varying the lexical status of the item preceding an adjacent prime and target.

With regard to the first prediction, McNamara does not mention that the predicted effect for cue-compounding should be very small because of weights assigned to elements in the compound (Ratcliff & McKoon, 1988). In the cue-compounding model, the target should be assigned most of the weight while the prime and other item in the cue receive very little weight. Since the manipulation does not involve the target, any differences in familiarity should be slight.

With regard to the second prediction, if the nonword is included in the cue, McNamara contends that,

> ... if the average associative strength between nonwords and words is sufficiently small, then the familiarity of a compound cue containing a nonword might be so low that performance would be unaffected by the prime target relation; that is, semantic priming might be reduced or eliminated. (McNamara, 1992a, p.31)

Here again, however, McNamara has assumed that the strengths in the model are equivalent to "associative strength". As we have already seen, however, this notion is wrong; sensory factors must play a role in determining strength values. Indeed, even the notion of *associative* strength between words and nonwords is undefined since nonwords are not represented in memory and have no meaning.

Instead, the nonword in the cue (e.g., "famb") is likely to access some representations (e.g., "lamb") with reasonably high strength because of visual similarity (Neely & Keefe, 1989) thus yielding reasonably high familiarity. It is true that a compound cue containing a nonword will have less familiarity than one containing three words, but the effect should not be large, particularly since the weights assigned to pre-target items are low.

If the nonword is not included in the cue, then the effect will be large, but in the opposite direction. That is, familiarity will be higher if a nonword precedes the prime and target since there would only be two words in the cue instead of three. Indeed, this effect should be large, but suppose some nonwords are included in the cue and some are not. If this occurs then the large effect may be reduced since these trials would yield *lower* familiarity as already described. In sum, it is difficult to predict the size of the effect of the second prediction for cue-compounding, but it is conceivable that it should not be great. If this is so, then the general pattern of predictions for Experiment 3 should be very similar to the one produced for Experiment 1 except reversed; this time cue-compounding predicts small effects while spreading activation predicts none.

McNamara concludes that neither manipulation had an effect and argues that this conclusion is problematic for cue-compounding models. However, both the conclusion itself and whether the conclusion is informative are debatable. First, McNamara is again in the awkward position of trying to prove a null hypothesis; that the manipulation did NOT affect subjects' responses. This position is awkward because the skeptic can call foul on lack of power much more readily than if an effect is reported. Below are two independent sources that may have decreased power enough to eliminate the predicted small effect for cue-compounding.

1. Subject power: There were only 40 subjects run in Experiment 3 instead of 200 as in Experiment 1. As previously outlined, both experiments could conceivably yield a small effect (if any), so the same sample size should have been used in Experiment 3 before giving up on the notion that the effect is obtainable. Regarding the first prediction, the nonsignificant effect present after 40 subjects is already 1.7 times as great as the significant effect in Experiment 1 (17 versus 10 ms) and is apparent with errors as well (6 versus 4%). Why stop there? Would the conclusions be the same if the sample sizes were reversed for Experiments 1 and 3?
2. Item power: Why were only a few (10) critical items used in each condition to test for the effect of relatedness between pre-target words? Perhaps if more were used, then more stable scores for each subject would have been obtained and an effect demonstrated.

In general I would argue that a null effect is only informative if it is contrasted to a similar situation where the effect occurred or if every attempt is made to reassure critics that the failure to obtain a difference was not due to lack of power. To my mind, neither of these criteria are met and so the demonstrations of null effects of Experiment 3 are of dubious import.

Statistical Errors in Experiment 3

Despite these problems, there is reason to suspect that an effect *did* occur in Experiment 3, supporting the second prediction made by cue-compounding. If the item preceding the adjacent prime and target was a nonword, RT's were significantly greater than if it was a word (see Table 9a). McNamara argues, however, that the difference is actually due to a confound in the experiment. Namely, subjects in the "Nonword" condition responded "nonword-word-word" whereas subject in the "Word" condition responded "word-word-word" (see Table 10b). This additional positive "word" response in the sequence could speed execution of a "word" response to the target for reasons independent of those operating in cue-compounding. Rather than conduct another experiment that tests the models without the confound, however, McNamara attempted to estimate the size of the effect of this confounding variable. He then subtracts this estimate from the difference between the means that was obtained, presumably to remove the effect of the confounding variable to see if any residual effect of treatment remains. However, the estimate obtained as an index of the effect size of the confounding variable is completely inaccurate since it actually contains a large portion of treatment effect.

In order to understand how the estimate of the confounding variable's effect size is contaminated with treatment effect, it is necessary to examine how McNamara

Table 9a: Mean Response Latencies (ms) for Selected Conditions of McNamara's Experiment 3 (Partial reproduction of McNamara, 1992a, Table 7).

	Pre-prime letter string:		
	Word	Nonword	Lag 1
Related	536	560	542
Unrelated	562[+]	***593***[*]	556

Table 9b: Mean Latencies for Targets Preceded by 1, 2 and 3 Unrelated Words

Number of Unrelated Words Preceding Target:		
1	2	3
593[*]	567[+]	548[+]

Note.

* -> the "Nonword - Unrelated" condition is composed entirely of trials with one unrelated word preceding the target. Thus the mean latency for targets preceded by one unrelated word is equal to the mean of that condition (593 ms).

\+ -> 76% of trials in the "Word - Unrelated" condition are preceded by two unrelated words while 24% are preceded by three unrelated words. The weighted average of mean latencies for targets preceded by two or three unrelated words is equal to the mean of the "Word - Unrelated" condition, thus suggesting that all of these trial were derived from that condition.

[(.76)(567 ms) + (.24)(548 ms) = 562 ms]

Table 10a: Selected Conditions of McNamara's Experiment 3 (Partial reproduction of McNamara, 1992a, Table 6).

	Pre-prime letter string:		
	Word	Nonword	Lag 1
Related	around hammer nail	telf hammer nail	hammer oats nail
Unrelated	around wizard nail	telf wizard nail	wizard oats nail

Table 10b: Responses Made in Selected Conditions of McNamara's Experiment 3 (confounding variable)

	Pre-prime letter string:		
	Word	Nonword	Lag 1
Related	*word* *word* *word*	*nonword* *word* *word*	*word* *word* *word*
Unrelated	*word* *word* *word*	*nonword* *word* *word*	*word* *word* *word*

derived it. First, the mean latencies for trials preceded by one, two and three unrelated words were calculated. These latencies were 593, 567 and 548 ms respectively (see Table 9b). He argued that the average difference in RT's between these adjacent means is an estimate of the facilitation produced by each additional positive response. That is,

Facilitation produced by each additional positive response:

$$[(593 - 567) + (567 - 548)]/2 = 22.5 \text{ ms}$$

McNamara maintains that this estimate (22.5 ms) can be used to adjust the means in the "Word" and "Nonword" conditions "under the assumption that targets in both conditions had been preceded by exactly two words" (McNamara, 1992a, p.37). When these adjustments are made, the difference between the means is removed. He then argues that the difference between the means is wholly attributable to the confounding variable. That is, there is actually no effect of treatment, and this supports the spreading activation account.

Let us examine more closely where the latencies for trials preceded by one, two or three unrelated word were obtained. First, examination of Table 10a indicated none of these trials are available from the "Related-Word" or "Related-Nonword" conditions since the item preceding the target is always related to it. Therefore, trials are only available from the "Unrelated-Word", Unrelated-Nonword" and both "Lag 1" conditions. However, it is impossible to sample the trials equally from the "Unrelated-Word" and "Unrelated-

Nonword" conditions, which is necessary to gain an unbiased estimate of the confounding variable. For example, some (or all) trials preceded by one unrelated word can be sampled from the "Unrelated-Nonword" condition, but none can be from the "Unrelated-Word" condition. The reason none can be sampled from the latter condition is simply that more than one unrelated word precedes the target in that condition. Therefore, no such trials *exist* in the "Unrelated-Word" condition (see design in Table 10a or McNamara, 1992a, Table 5). Similarly, some (or all) trials preceded by either two or three unrelated words can be sampled from the "Unrelated-Word" condition, but none are obtainable from the "Unrelated-Nonword" condition. It is clear from this analysis that the latencies from which the confound estimate is derived, are not sampled equally from the different levels of the independent variable. That is, the estimate of the effect size of the confounding variable (number of preceding positive responses) actually is an estimate of that variable PLUS treatment effect. Potentially, a large portion of the estimate may be actual true treatment effect. It is to be expected, therefore, that the significant effect of treatment would be rendered nonsignificant when a large portion of it is removed.

Analysis of data McNamara presents adds support to the hypothesis that the estimate is contaminated. The mean latencies for targets preceded by one, two and three unrelated words are 593, 567, and 548 respectively. Analysis of Tables 9a and 9b suggests that all latencies for targets preceded by one unrelated word were derived from the "Unrelated-Nonword" condition. That is, the estimate for one unrelated word preceding the target is equal to the mean of "Unrelated - Nonword" condition. Also, all latencies for targets preceded by two or three unrelated words appear to be derived from the "Unrelated - Word" condition. If the estimates for two and three unrelated words preceding the target are weighted according to the number of times each type of trial occurred in the "Word" condition, then the mean is equal to that of the "Unrelated - Word" condition. Thus it is apparent that the estimate used to adjust the means was too large since some portion of it is actually the effect of treatment.

Exactly why no trials where targets were preceded by one unrelated word were derived from the "Related - Lag 1" condition is not clear since that condition conforms to the "target preceded by one unrelated word" definition. If it were used then the estimate of the confound would be drastically reduced since its mean (542 ms) would have to be averaged in with the estimate that was used (593 ms). Probably it was avoided since the relatedness of the word two items back would cause the estimate to be lower than the others since they cannot be derived from any of the "Related" conditions. However, this would be no worse than contaminating the confounded estimate with the "Word/Nonword" manipulation which was actually done.

It is possible to sample some trials that are preceded by two and three unrelated words from the "Unrelated-Lag 1" condition (see Table 10a or McNamara, 1992a, Table 6). However, analysis of Tables 9a and 9b seems to indicate that *all* trials preceded by two and three unrelated words were derived from the "Unrelated-Word" condition (i.e., the numbers match perfectly). Nonetheless, even if some trials were derived from the "Unrelated-Lag 1" condition, the contamination would be reduced but not eliminated (e.g., it is still the case that some trials where targets are preceded by two and three unrelated words come from the "Unrelated-Word" condition, but none come from the "Unrelated - Nonword" condition).

It should be noted that if only the difference between the mean latencies for targets preceded by two or three unrelated words is used to estimate the confound, there is no longer a contamination with treatment effect. Analysis of Tables 9a and 9b suggests that these trials were derived solely from the "Unrelated - Word" condition, with none sampled from another level of the independent variable. This two versus three difference (19 ms) is very close to the contaminated estimate that was used (22.5 ms), and so it could be argued that the contamination of the former estimate really made no difference. However, another potential problem should be raised here. By estimating the effect of the confound from only selected conditions within the experiment, an assumption is being made that the effect of sequence bias is completely independent of the effect of familiarity. McNamara presents no evidence, however, in support of this assumption. It is quite conceivable that the sequence bias effect interacts with the familiarity of the compound rendering any estimate derived only from selected conditions inappropriate.

In sum, this discussion has highlighted the fact that there is insufficient evidence to make the conclusion that the confounding variable is wholly responsible for the obtained effect. Removing the effect of confounding variables *after* the experiment is complete is generally inappropriate as is clear from this analysis. An analogous experiment needs to be conducted that does not include this response sequence bias before any conclusions can be made.

Three-step Mediated Priming and the Cue-Compounding Model from Chapter 3:

The cue-compounding model presented in Chapter 3 easily simulates three-step mediated priming. As before, it would have to be assumed that representations accessed on the first round of memory access could be incorporated into the compound-cue and a second access occur. Thus memory access by compound-cues is an iterative process that allows original familiarity values to be updated. Table 11 demonstrates how

Table 11: Calculation of familiarity for three-step mediated and unrelated words.

Three-Step Mediated Words

[Prime(CHEETAH) <-> FAST <-> SLOW <-> Target(TURTLE)]:

First round of memory access:

		memory:			
		CHEETAH	TURTLE	FAST	SLOW
cue:	CHEETAH	1.0	.20	1.0	.20
	TURTLE	.20	1.0	.20	1.0
	F =	.20 +	.20 +	.20 +	.20
	=	**.80**			

Second round of memory access:

		memory:			
		CHEETAH	TURTLE	FAST	SLOW
cue:	CHEETAH	1.0	.20	1.0	.20
	TURTLE	.20	1.0	.20	1.0
	FAST	1.0	.20	1.0	1.0
	SLOW	.20	1.0	1.0	1.0
	F =	.04 +	.04 +	.20 +	.20
	=	**.48**			

Overall Familiarity = .80 + .48 = 1.28

Table 11 (cont.)

Unrelated Words: {Prime(TABLE) - Target(TURTLE)}

First round of memory access:

		memory:			
		TABLE	TURTLE	CHAIR	SLOW
cue:	TABLE	1.0	.20	1.0	.20
	TURTLE	.20	1.0	.20	1.0
	F =	.20 +	.20 +	.20 +	.20
	=	.80			

Second round of memory access:

		TABLE	TURTLE	CHAIR	SLOW
cue:	TABLE	1.0	.20	1.0	.20
	TURTLE	.20	1.0	.20	1.0
	CHAIR	1.0	.20	1.0	.20
	SLOW	.20	1.0	.20	1.0
	F =	.04 +	.04 +	.04 +	.04
	=	.16			

Overall Familiarity = .80 + .16 = .96

familiarity is calculated for the different pair types. As in the example in Chapter 3, the weights were not applied to the compound elements for simplicity. For three-step mediated pairs, the prime is "cheetah" and the target is "turtle". They are presented on the far left column and represent elements of the compound-cue used on the first round of memory access. Each element in the cue (i.e., prime and target) access particular representations with some strength. (1) if an element in the cue accesses a representation of itself or a direct associate (as measured by free association), it does so with high strength (1.0) (e.g., *cheetah* - *cheetah*; *cheetah* - *fast*), (2) if there is no similarity between an element in the cue and a representation in memory, then there is residual strength (.20) between them (e.g., *cheetah* - *turtle*). These values derive from Ratcliff & McKoon (1988).

It is assumed for illustrative purposes that the elements in the cue access representations of themselves ("cheetah" and "turtle") and one other direct associate each ("fast" and "slow"). These accessed representations appear in the top row. The familiarity component derived from a trace is equal to the product of all the strengths pertaining to that trace (shown in the bottom row). For example, the familiarity component derived from the trace "cheetah" is equal to 1.0 X .20 = .20 on the first round of access for three-step mediated pairs. The resultant familiarity value for a complete round of access is the sum of the familiarity components across all items in memory. In the example below, the familiarity for both mediated and unrelated prime/target pairs is the same (.80).

A second round of access must be included in which items that were accessed on round 1 are added to the cue. For example, "fast" and "slow" would be added in the three-step mediated example, whereas "chair" and "slow" would be added in the unrelated case. The process occurs again and a new familiarity value is derived. It is apparent that higher familiarity is derived for mediated trials (.48) than unrelated trials (.16) on round two. The familiarity for round two can be used to update the *overall familiarity* for a particular trial. In the simplest case, the two values are added together yielding a familiarity value of 1.24 for the mediated pairs and .88 for unrelated pairs. The higher value of familiarity for the mediated pairs will result in faster reaction times and produce three-step mediated priming.

Advocates of spreading activation should not object to this amendment to the model; allowing accessed memory traces to subsequently activate other memory representations is exactly what occurs during spreading activation. However, again the difference is that the access with cue-compounding occurs is determined by the similarity of the retrieval cue to representations in memory. It does not occur via preexisting links between long-term memory structures.

Summary & Conclusions

In sum, the results of the three experiments on distance and lag effects reported in McNamara (1992a) have little bearing on either the current status of cue-compounding models used with SAM or spreading activation theories.

Distance: In Experiment 1, only the free association task was used to control for direct associations between items. However, several measures of association in memory are available (cf. McNamara, 1992b) which were not used as converging assessments. Until all these measures are used to test for direct associations, there remains some question of whether three-step mediated priming was actually obtained. Additionally, McNamara's misunderstanding of how free association results relate to the strengths in cue-compounding models led to some erroneous conclusions in Experiment 1. Specifically, failure to find that word "A" does not elicit word "B" during a free association task does not necessarily mean that the strength between word "A" and "B" must be residual. Therefore, the conclusion that priming between word "A" and "B" presents a problem for these models is incorrect. (The flexibility of cue-compounding models was demonstrated, however, when an amended cue-compounding model was presented that keeps the strengths low and still produces three-step mediated priming)

Lag: The results from the lag experiments that test the spreading activation and cue-compounding models are inconclusive. Attempts McNamara made to prove the null hypothesis are questioned by limitations in experimental power. In addition, the procedure used to eliminate statistically the one important effect that did occur was inappropriate. Closer analysis revealed that the value McNamara derived to estimate the effect of a confounding variable actually contained a large portion of treatment effect. Thus, the fact that there was no residual after using it to adjust the size of the treatment effect is meaningless.

Chapter 6

CONCLUDING COMMENTS

The traditional view of science is one in which scientists conduct experiments which are interpreted objectively. In this manner, it is possible to distinguish between competing theories about the way the world works. Thus, as long as the personal beliefs of the scientist are not allowed to intrude into the scientific process, science represents a linear progression toward truth. Thomas Kuhn (1970) challenged this traditional view. He proposed that science operates within interpretive frameworks or paradigms which consist of numerous assumptions, many of which are implicit. Data obtained from experiments can only be interpreted within this theoretical framework that exists in the scientist's mind. Thus, rather than characterizing the scientist as an passive interpreter who is forced to certain conclusions because of the data, Kuhn suggested that the scientist is a much more active participant who must decide which experiments should be run and is guided every step of the way by a particular view of the world. Indeed, Kuhn went so far as to propose that science cannot operate without the active participation of the scientist's world outlook.

Kuhn also argued that as more data is collected within a particular paradigm, further constraints are imposed on the system such that it becomes increasingly difficult to make predictions which allow the process to continue. At this time, the field is ready for a scientific revolution or a paradigm shift. Usually, such revolutions occurs when a new, exciting approach to the issues within the field is offered by an innovative scientist. If the time is ripe, the new approach is adopted by many within the field, and the older, more cumbersome framework is forgotten. The important point is that the older paradigm is dropped not because it's truthfulness is rejected on the basis of rigorous, objective scientific testing. Instead, it had simply become too cumbersome to work with anymore, and the new approach offers an inspiring solution to this awkward state of affairs.

Ubiquitous acceptance of cue-compounding models like the one outlined in this thesis would constitute, to my mind, a paradigm shift within the field of cognitive psychology. For the first time in over two decades, some of the fundamental assumptions about the processes underlying semantic priming would be questioned. For example, cue-compounding models allow semantic priming to be interpreted for the first time without a semantic network. In addition, some symptoms of a paradigm shift are becoming apparent. An example of this can be seen in Chapter 5. Whereas free association and the notion of "associative distance" are highly relevant to a theoretical framework that incorporates a network memory, their relevance to the model presented in Chapter 3 is not clear. As previously outlined, even the assumption that words are "associated in memory" is not necessarily accepted.

At the same time, it is important to note that I do not believe that a paradigm shift has already occurred or will occur in the very near future. First, it will be necessary for cue-compounding models to present themselves as serious competitors to older, better established views by managing to explain some portion of the vast array of priming data that has been accumulated over the years and to do so with as few assumptions as reasonably possible. This thesis, therefore, should be viewed as a modest push in that direction.

Cue-compounding models, in general, are proving to be a reasonable competitor for better established accounts of priming. Even if McNamara's (1992a) assumptions regarding the relationship between free association norms and strengths within the model are adopted, three-step mediated priming can be simulated (see Chapter 5). Additionally, Chapters 2 and 4 have demonstrated that other priming phenomena such backward priming, nonword facilitation and the effect of target degradation can also be simulated quite well with cue-compounding models. The full potential of these models to predict the vast array of priming results is not yet known. However, it is important that they not be dismissed prematurely before this potential is realized.

Bibliography

Anderson, J.R. (1983). A spreading activation theory of memory. Journal of Verbal Learning and Verbal Behavior, 22, 261-295.

Antos, S.J. (1979). Processing facilitation in a lexical decision task. Journal of Experimental Psychology: Human Perception and Performance, 5, 527-545.

Atkinson, R.C., & Juola, J.F. (1974). Search and decision processes in recognition memory. In D.H. Krantz, R.C. Atkinson, R.D. Luce, & P. Suppes (Eds.), Contemporary developments in mathematical psychology, Vol. 1, Learning, memory and thinking, (pp. 243-293). San Francisco, C.A.: Freeman.

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

Becker, C.A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. Memory & Cognition, 8, 493-512.

Becker, C.A., & Killion, T.H. (1977). Interaction of visual and cognitive effects in word recognition. Journal of Experimental Psychology: Human Perception and Performance, 3, 389-401.

Besner, D., & Smith, M.C. (1992). Models of visual word recognition: When obscuring the stimulus yields a clearer view. Journal of Experimental Psychology: Learning, Memory & Cognition, 18, 468-482.

Borowsky, R., & Besner, D. (1991). Visual word recognition across orthographies: On the interaction between context and degradation. Journal of Experimental Psychology: Learning, Memory & Cognition, 17, 272-276.

Brooks, L.R. (1987). Decentralized control of categorization: The role of prior processing episodes. In U. Neisser (Ed.), Concepts and conceptual development. New York: Cambridge University Press.

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

Collins, A.M., & Quillian, M.R. (1969). Retrieval time from semantic memory. Journal of Verbal Learning and Verbal Behavior, 8, 240-247.

Debner, J.A., & Jacoby L.L. (in press). Unconscious perception: Attention, awareness, and control. Journal of Experimental Psychology: General.

De Groot, A.M.B. (1984). Primed lexical decision: Combined effects of the proportion of related prime-target pairs and the stimulus onset asychrony of prime and target. Quarterly Journal of Experimental Psychology, 36A, 253-280.

De Groot, A.M.B. (1985). Word-context effects in word naming and lexical decision. Quarterly Journal of Experimental Psychology, 37A, 281-297.

De Groot, A.M.B., Thomassen, A.J.W.M., & Hudson, P.T.W. (1982). Associative facilitation of word recognition as measured from a neutral prime. Memory & Cognition, 10, 358-370.

Den Heyer, K. (1985). On the nature of the proportion effect in semantic priming. Acta Psychologica, 60, 25-38.

Den Heyer, K., & Smith, K. (1988). Constraints on the additive relationship between semantic priming and word repetition and on the interactive relationship between semantic priming and stimulus clarity. Canadian Journal of Psychology, 42, 399-413

Den Heyer, K., Briand, K., & Smith, L. (1985). Automatic and strategic factors in semantic priming: An examination of Becker's model. Memory & Cognition, 13, 228-232.

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

Durgunoglu, A.Y. (1988). Repetition, semantic priming, and stimulus quality: Implications for the interactive-compensatory reading model. Journal of Experimental Psychology: Learning, Memory & Cognition, 14, 590-603.

Favreau, M., & Segalowitz, N.S. (1983). Automatic and controlled processes in the first- and second-language reading of fluent bilinguals. Memory & Cognition, 11, 565-574.

Fischler, I. & Goodman, G.O. (1978). Latency of associative activation in memory. Journal of Experimental Psychology: Human Perception and Performance, 4, 455-470.

Gillund, G., & Shiffrin, R.M. (1984). A retrieval model for both recognition and recall. Psychological Review, 91, 1-67.

Hayman, G. (1982). A task analysis of lexical decisions. Unpublished doctoral dissertation, McMaster University, Hamilton, Ontario.

Jacoby, L.L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. Journal of Memory and Language, 30, 513-541.

Jacoby, L.L., & Brooks, L.R. (1984). Nonanalytic cognition: Memory, perception and concept formation. In G.H. Bower (Ed.), The psychology of learning and motivation (Vol. 18). New York: Academic Press.

Jacoby, L.L, & Kelly, C.M. (1987). Unconscious influences of memory of a prior event. Personality and Social Psychology Bulletin, 13, 314-336.

Jacoby, L.L., Toth J.P., & Yonelinas, A.P. (in press). Unconscious influences of memory: Attention, awareness, and control. Journal of Experimental Psychology: General.

Jacoby, L.L., Woloshyn, V., & Kelly, C.M. (1989). Becoming famous without being recognized: Unconscious influences of memory produced by dividing attention. Journal of Experimental Psychology: General, 118, 115-125.

Jonides, J., & Mack, R. (1984). On the cost and benefit of cost and benefit. Psychological Bulletin, 96, 29-44.

Kahneman, D., & Miller, D.T. (1986). Norm theory: Comparing reality to its alternatives. Psychological Review, 96, 29-44.

Kames, A.J. (1980). Same-different comparison processes for words and nonwords: A random walk model. Unpublished doctoral dissertation, New York University, New York, N.Y..

Kantowitz, B.H. (1974). Double stimulation. In B.H. Kantowitz (Ed.), Human information processing - Tutorials in performance and cognition (pp. 83-132). Hillsdale, NJ: Lawrence Erlbaum Associates.

Keppel, G., & Strand, B.Z. (1970). Free-association responses to the primary responses and other responses selected from the Palermo-Jenkins norms. In L. Postman & G. Keppel (Eds.), Norms of word association. New York: Academic Press.

Koriat, A. (1981). Semantic facilitation in lexical decision as a function of prime-target association. Memory & Cognition, 9, 587-598.

Kraut, A.G., Smothergill, D.W., & Farkas, M.S. (1981). Stimulus repetition effects on attention to words and colors. *Journal of Experimental Psychology: Human Perception and Performance*, *7*, 1303-1311.

Kuhn, T.S. (1970). *The structure of scientific revolutions* (2nd Ed.). Chicago: The University of Chicago Press.

Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological Review*, *87*, 252-271.

Massaro, D.W., Jones, R.D., Lipscomb, D., & Scholtz, R. (1978). Role of prior knowledge on naming and lexical decisions with good and poor stimulus information. *Journal of Experimental Psychology: Human Learning and Memory*, *4*, 498-512.

McKoon, G., & Ratcliff, R. (1979). Priming in episodic and semantic memory. *Journal of Verbal Learning and Verbal Behavior*, *18*, 463-480.

McKoon, G., & Ratcliff, R. (in press). Spreading activation versus compound cue accounts of priming: Mediated priming revisited. *Journal of Experimental Psychology: Learning, Memory & Cognition*.

McNamara, T.P. (in press a). Theories of priming: Associative distance and lag. *Journal of Experimental Psychology: Learning, Memory & Cognition*.

McNamara, T.P. (in press b). Priming and constraints it places on theories of memory and retrieval. *Psychological Review*.

Meyer, D.E., & Schvaneveldt, R.W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. Journal of Experimental Psychology, 90, 227-234.

Meyer, D.E., Schvaneveldt, R.W., & Ruddy, M.G. (1975). Loci of contextual effects on visual word recognition. In P.M.A. Rabbitt & S. Dornic (Eds.), Attention and performance V, New York: Academic Press.

Murdock, B.B. (1982). A theory for the storage and retrieval of item and associative information. Psychological Review, 89, 609-626.

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

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

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

Neely, J.H., Keefe, D.E., & Ross, K. (1989). Semantic priming in the lexical decision task: Roles of prospective prime-generated expectancies and retrospective semantic matching. _Journal of Experimental Psychology: Learning, Memory and Cognition_, _15_, 1003-1019.

Norris, D. (1986). Word recognition: Context effects without priming. _Cognition_, _22_, 93-136.

O'Connor, R.E., & Forster, K.I. (1981). Criterion bias and search sequence bias in word recognition. _Memory & Cognition_, _9_, 78-92.

Peterson, R.R. & Simpson, G.B. (1989). The effect of backward priming on word recognition in single-word and sentence contexts. _Journal of Experimental Psychology: Learning, Memory and Cognition_, _15_, 1020-1032.

Posner, M.I., & Snyder, C. (1975). Attention and cognitive control. In R.L. Solso (Ed.), _Information processing and cognition: The Loyola symposium_ (pp. 55-85). Hillsdale, N.J.: Erlbaum.

Ratcliff, R. (1978). A theory of memory retrieval. _Psychological Review_, _85_, 59-108.

Ratcliff, R., & McKoon, G. (1988). A retrieval theory of priming in memory. _Psychological Review_, _95_, 385-408.

Regehr, G. & Brooks, L.R. (in press). Perceptual manifestations of an analytic structure: The priority of Holistic individuation. _Journal of Experimental Psychology: General_.

Rosson, M.B. (1983). From SOFA to LOUCH: Lexical contributions to pseudoword pronunciation. Memory & Cognition, 11, 152-160.

Schuberth, R.E. & Eimas, P. (1977). Effects of context on the classification of words and nonwords. Journal of Experimental Psychology: Human Perception and Performance, 3, 27-36.

Schvaneveldt, R.W., & McDonald, J.E. (1981). Semantic context and the encoding of words: Evidence for two modes of stimulus analysis. Journal of Experimental Psychology: Human Perception and Performance, 7, 673-687.

Seidenberg, M.S., Waters, G., Sanders, M., & Langer, P. (1984). Pre- and post-lexical loci of contextual effects on word recognition. Memory & Cognition, 12, 315-328.

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

Shelton, J.R. & Martin, R.C. (in press). How automatic is automatic semantic priming? Journal of Experimental Psychology: Learning, Memory and Cognition

Stanovich, K., & West, R. (1979). Mechanisms of sentence context effects in reading: Automatic activation and conscious attention. Memory & Cognition, 7, 77-85.

Tweedy, J.R., Lapinski, R.H., & Schvaneveldt, R.W. (1977). Semantic-context effects on word recognition: Influence of varying the proportion of items presented in an appropriate context. _Memory & Cognition_, _5_, 84-99.

Warren, R.E. (1977). Time and the spread of activation in memory. _Journal of Experimental Psychology: Human Learning and Memory_, _3_, 458-466.

Whittlesea, B.W.A. (1987). Preservation of specific experiences in the representation of general knowledge. _Journal of Experimental Psychology: Learning, Memory and Cognition_, _13_, 3-17.

Whittlesea, B.W.A., & Jacoby, L.L. (1990). Interaction of prime repetition with visual degradation: Is priming a retrieval phenomenon? _Journal of Memory and Language_, _29_, 546-565.

Witherspoon, D., & Allan, L.G. (1985). The effects of prior presentation on temporal judgments in a perceptual identification task. _Memory and Cognition_, _13_, 101-111.