Journal of Experimental Psychology:
Learning, Memory, and Cognition
1983, Vol. 9, No. 2, 196–211

0278-7393/83/0902-0196$00.75

Inhibition From Related Primes in Recognition Memory

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In three experiments, after studying a blocked-categorized word list, subjects were given a speeded yes/no recognition test in which certain critical test items were preceded by various priming manipulations. The "primes" were other test items (both targets and lures) from the same category as the critical item. When a prime immediately preceded the critical item, reaction times (RTs) were faster than when a prime was separated from the critical item by two test items from some other category, thereby demonstrating facilitation from recency of semantic priming. However, RTs were slower when six primes preceded a critical target than when two primes preceded it. This inhibition caused by increasing the number of semantically related primes occurred whether these primes were presented randomly or grouped together but did not occur when the critical item was a lure. Also, RTs were faster to both critical targets and lures when they were immediately preceded by a target rather than a lure, thereby demonstrating a facilitation from episodic priming. The critical challenge to theory posed by these data is to account for the observation that whereas recent presentation of a single semantically related prime produces facilitation, increasing the number of these related primes produces inhibition.

Recall of a word list is sometimes damaged if at test people are provided with information semantically related to the to-be-recalled words. For example, in a recall test for a categorized word list, Roediger (1973) provided subjects with (a) the names of all of the memorized categories and (b) differing numbers of randomly chosen list items that were to serve as cues for the recall of the remaining list items belonging to the same category. Roediger found that the greater the number of list-item cues, the poorer was the recall of the remaining items from the cued category (see also Rundus, 1973). This interference effect is equally great whether the cues come from within or outside the list (Watkins, 1975) but occurs only if the cues are members of the tested category (Mueller & Watkins, 1977).

An interpretation of this interference effect was provided by Rundus (1973), who argued that a cue's presentation strengthens its episodic association to its category, thereby blocking the retrieval processes involved in the generation of other items associated with that category. Reasoning from Rundus's model, Slamecka (1975) argued that if semantically related list cues affect only a recall-specific generation process (Kintsch, 1974), one should not obtain inhibitory cuing effects in recognition. To support this, Slamecka compared forced-choice recognition for words tested in the context of either zero, one, or three semantically related list-item cues and found no inhibitory cuing effect.

It is interesting that in addition to not obtaining an inhibitory cuing effect, Slamecka also failed to obtain a facilitatory cuing effect in his unpaced forced-choice recognition task. This is interesting because the presentation of semantically related information often facilitates performance in various speeded yes/no recognition tasks. For ex-

Portions of this research were reported at the annual meetings of the Psychonomic Society, St. Louis, November 1980.

The research reported here was supported by National Institute of Child Health and Human Development Grant R01 HD15054 awarded to the first and third authors. We thank Kent L. Ross for his assistance in conducting these experiments and in analyzing the data and thank Robert J. McMillen and Phillip Mueller, Jr., for their development of the extensive general-purpose software system used to conduct these experiments.

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ample, presenting a semantically related cuing item (prime) prior to a word consistently facilitates the speed of lexical (word–nonword) decisions to that word (e.g., Fischler, 1977; Neely, 1976, 1977; Schvaneveldt & Meyer, 1973). Also, in a task more like Slamecka's task, Macht and O'Brien (1980) found that an extralist semantically related prime given 2 sec prior to a target facilitated the speed with which that target was recognized as having occurred in a list memorized 15 sec earlier. (However, such a prime also inhibited the speed with which lures were correctly rejected as not having appeared in that list.) Although these studies demonstrate that the recent presentation of a single semantically related prime can facilitate various kinds of speeded recognition, to our knowledge no study has examined the effects on speeded episodic recognition of manipulating the number of semantically related primes as Slamecka did. To rectify this, we report three experiments that investigate how multiple semantically related primes affect speeded episodic recognition. (We use the term *prime* rather than *cue* because subjects were never told to use the semantically related items as cues to aid their recognition.)

In our experiments, after studying blocked-categorized word lists, subjects received a speeded yes/no episodic recognition test. Based on the results just reviewed, we thought a speeded test might be a more sensitive measure of priming than Slamecka's (1975) nonspeeded test. Also, we used a yes/no test rather than Slamecka's forced-choice test to explore further Macht and O'Brien's (1980) finding that the recency-of-priming variable had opposite effects on response speeds to targets and lures. Across the three experiments, we examined how subjects' performance on a certain critical target or lure item embedded in a test sequence varied as a function of three variables. In varying the number of primes, we manipulated whether a critical item had been preceded by tests on either two or six semantically related priming items. In varying recency of priming, we manipulated whether the most recent prime either immediately preceded the critical item or was separated from it by two unrelated test items. And in varying the type of prime, we manipulated whether the most recent related prime was a target or a lure. Because the three experiments were so similar in their methods, we present a General Method section before we provide the rationale and results for each experiment.

General Method

Subjects

Subjects were introductory psychology students who received partial fulfillment of a course requirement and graduate students who were paid $5. There were 32, 128, and 64 subjects in Experiments 1–3, respectively.

Materials

Ten high-dominance items were chosen from each of 81 categories selected from the Battig and Montague (1969), Hunt and Hodge (1971), and Shapiro and Palermo (1970) norms. These materials were used to construct one practice list and eight study lists each containing 9 (Experiment 1) or 8 (Experiments 2 and 3) five-word categories. For the practice list, a few items were added to other categories that had been deemed unacceptable for the critical lists. Thus, only data from the tests for the eight lists given after the practice list are reported. For each of these eight study lists, A and B versions were constructed so that the five target items from a particular category in the A study list were lures from that category in the test for the B study list, and vice versa.

Because the test sequences gave rise to the independent variables of interest, we will describe them in some detail. (Example test sequences are given in the Appendix.) Across the three experiments, the test sequences shared the following properties. For each of the categories in the study list, there were 10 test items (5 targets and 5 lures). Of particular interest was subjects' performance on 8 critical items in the test sequence. In the test for each study list, 4 critical items came from the A version of that study list and 4 from the B version. Because each subject studied only the A or the B version of a list, half of the critical items were targets and half lures. When both the critical item and the last related prime were targets, the critical item was the first-presented item from its category in the study list, and the prime was the second-presented item. When the critical item or the last related prime was a lure, it was taken from the comparable position in the alternate study list. The eight critical items were always tested in the order in which their respective categories appeared in the study list, and within an experiment they always occupied the same positions in every test (see Appendix). However, it is important to note that the critical items were critical only to the experimenters; to the subjects they were simply items in a long test sequence.

All variables were manipulated within subjects. The number of related primes tested prior to a critical item was manipulated by having either two or six prior tests of other items (half targets and half lures) from the same category as the critical item. The remaining items from the critical item's category were not tested until after the critical item had been tested. In varying recency of priming, we manipulated whether the last prime for the critical item's category occurred immediately prior to the critical test item or two items back. Finally, in varying the type of prime, we manipulated whether the last prime from the critical item's category was a target or a lure. To equate for response repetition effects in comparisons involving the immediate and two-back priming conditions, the unrelated item that immediately preceded the critical item in the two-back priming condition was always the same type of item (target vs. lure) as the related item that immediately preceded it in the immediate priming condition. Counterbalancing assured that across subjects every critical item appeared equally often in each condition. Also, for any one subject, the conditions were counterbalanced across the tests for the eight lists so that each condition occurred once in each eighth (Experiments 1 and 3) or in each fourth (Experiment 2) of the test sequence. (In Experiment 2, across subjects each condition appeared once in each eighth of the test list.) Each of the 8 conditions of Experiments 1 and 3 appeared once in every test list whereas each of the 16 conditions of Experiment 2 appeared once in every other test list. Thus, for each subject there were eight observations per condition in Experiments 1 and 3 and four observations per condition in Experiment 2.

Procedure

Subjects were usually tested in groups of two while seated before separate video monitors. Oral instructions informed subjects (a) about the mechanics of the task, (b) that the test items would equally often be old and new and that the new items were from the same categories as the old items, and (c) that it was important to respond as quickly as possible while keeping errors at a minimum. Each subject responded with the first and second fingers of his or her right hand: The first finger was the "new" response made to lures, and the second finger, the "old" response made to targets.

List presentation was controlled by a Cromemco Z-2D microcomputer equipped with a FLASHWRITER video board. At the beginning of each study list the words GET READY appeared for 2.8 sec followed by a 1.2-sec blank screen. Then the first category name appeared followed by the words in that category. The category name appeared in all uppercase letters for 1.75 sec followed by a .375-sec blank screen before the first category exemplar was presented. Each category exemplar appeared in all lowercase letters for 1.2 sec followed by a .375-sec blank screen before the next category exemplar was presented. The other category names and exemplars were presented in the same fashion. After each list, subjects saw the GET READY message again, followed by the presentation of 40 two-digit numbers (.375 sec on, .375 sec off), which subjects were to read aloud. Following the digits, another GET READY message warned them of the test. The test words appeared in all lowercase letters for 2.8 sec with a 1.2-sec interval between test words. Thus, subjects had a total of 4.0 sec to respond to each test item. Subjects were given short breaks between the test of one list and the presentation of the next. A session lasted about 1.75 (Experiment 1) or 1.5 (Experiments 2 and 3) hr.

Experiment 1

With Experiment 1, we seek to answer two questions. The most important is whether recognition of a critical item deteriorates with increasing numbers of semantically related primes, as occurs for recall. The second question is whether recognition of a critical item will be affected by the recency of the last related prime, which occurred either immediately prior to the critical item or two items back. If recognition of a target is facilitated by the recent presentation of a related prime, the results would extend the generality of the facilitation effect produced by recency of priming in the lexical decision task (e.g., Schvaneveldt & Meyer, 1973) and for target items in a short-term episodic recognition task (e.g., Macht & O'Brien, 1980). If, at the same time, the rejection of a lure is inhibited by the recency-of-priming manipulation, the results would replicate those of Macht & O'Brien.

Design

Eight conditions were produced by a 2 (number of related primes: two vs. six) × 2 (recency of a related prime: immediate vs. two items back) × 2 (type of critical item: target vs. lure) factorial design.

Test Sequence

An example study list and test sequence is presented in the Appendix. Because the priming items that preceded the critical item were blocked by category, it was necessary to have nine rather than eight categories in the study list so that the last category in each study list could provide buffer items to be tested before the first critical item. The two items immediately preceding each critical item were always, in order, a lure and a target from the same category. In the immediate priming condition these two items were from the critical item's category; in the two-back priming condition they were both from a category other than the critical item's category.

Results and Discussion

The means of subjects' median reaction times (RTs) for correct responses for each condition are given in Table 1, along with the percentage of errors for each condition. These RT data and error data were submitted to separate 2 (number of primes: two vs. six) × 2 (recency of priming: immediate vs. two-back) × 2 (type of critical item: target vs. lure) × 32 (subjects) analyses of variance,

Table 1
Means of Median Reaction Times (in msec) and Percentage of Errors for the Conditions of Experiment 1

Type of critical item	No. of primes					
	2		6		2–6	
	M	% E	*M*	% E	*M*	% E
Immediate priming condition						
Target	791	10.1	821	10.0	−30	.1
Lure	1,067	16.1	1,054	14.2	13	1.9
Two-back priming condition						
Target	956	8.0	1,027	8.9	−71	−.9
Lure	1,307	20.6	1,205	17.5	102	3.1

Note. % E = percentage of errors.

with subjects treated as a random effect and the other variables as within-subjects fixed effects. If an interaction was statistically significant, the mean square error (MS_e) for the interaction was used to compute Fisher's least significant difference for individual post hoc t tests. Unless otherwise noted, all effects referred to as significant have p values less than .05 (two-tailed for the t tests).

Of primary interest is the effect of the number of related primes on RTs to critical items. Although there was no main effect on RTs of increasing the number of related primes ($F < 1$), there was a strong interaction between the effects of the number of related primes and the type of critical item, $F(1, 31) = 8.41$, $MS_e = 22{,}084.67$. That is, averaged across the recency-of-priming manipulation, subjects were 51 msec slower to recognize a target preceded by six rather than two related primes, $t(31) = 1.93$, whereas they were 57 msec faster to reject a lure, $t(31) = 2.17$. Although RTs were 191 msec faster in the immediate priming condition than in the two-back priming condition, $F(1, 31) = 65.29$, $MS_e = 35{,}794.75$, the effect of the recency-of-priming manipulation did not interact with the effects of either the number of primes or the type of critical item (both Fs < 1), nor did it interact with their interactive effects, $F(1, 31) = 2.38$, $MS_e = 27{,}943.38$. The only other reliable effects were that responses to targets were 259 msec faster, $F(1, 31) = 118.75$, $MS_e = 36{,}320.16$, and 8.8% more accurate, $F(1, 31) = 16.63$, $MS_e = 238.19$, than responses to lures. This effect is typical and also occurred in Experiments 2 and 3. However, because it was confounded with the effects of finger of response, it will not receive further mention. The only other effect to even approach statistical significance was the Recency of Priming × Type of Critical Item interaction for errors, $F(1, 31) = 3.44$, $MS_e = 141.49$, $p < .10$. All other Fs were less than 1.03.

The facilitation from the recency-of-priming manipulation is similar to that obtained in the lexical decision task (e.g., Schvaneveldt & Meyer, 1973). However, our recency-of-priming effects differ in part from those of Macht & O'Brien (1980). They found that a recent related prime produced facilitation for target recognition and inhibition for lure rejection, whereas we found facilitation for both targets and lures. This discrepancy between their results and ours may be due to the fact that our most recent prime was always an intralist item whereas theirs was always an extralist item. We test this in Experiment 2.

Our error data replicate Slamecka's (1975) results in that subjects did not make reliably more errors after six related primes than after two. Although RTs to targets were slower for the six-prime condition than for the two-prime condition, thereby demonstrating an inhibition from multiple related primes, the generality of this inhibition is weakened by the observation that compared with the two-prime condition, the six-prime condition facilitated lure rejection. In any case, recent research by Todres and Watkins (1981) may help explain why our six-prime condition did not produce more errors than our two-prime condition. They found that with extralist primes, forced-choice recognition accuracy was worse following related primes than following unrelated primes. However, with intralist primes, the inhibition from related primes occurred only when the list had been presented randomly rather than blocked by category. Todres and Watkins proposed that with blocked presentation of the list, the inhibitory effect of multiple related intralist primes was eliminated by a compensatory facilitation from reinstating the study context. Thus, two factors may have operated in our Experiment 1 to diminish any inhibitory effect of multiple related primes. First, we used blocked-categorized rather than randomly presented lists. Second, and more important, half of our related primes were intralist primes, and the most recent prime was always an intralist prime.

Experiment 2

To accentuate any inhibition from multiple related primes, Experiment 2 had two features designed to decrease the likelihood that the related primes would reinstate the study list context: (a) The most recent related prime was on some trials a lure rather than a target. (b) The test items were randomly ordered rather than blocked by category. However, unlike in Todres and Watkins's experiments in which the several related or unrelated primes that immediately preceded the critical recognition test were either all intralist or all extralist primes, we continued to use half targets and half lures as related primes. We did this because the consecutive presentation of only targets or only lures might produce response biases that would overcome the effects of interest. Presumably, this was not a problem in Todres & Watkins's experiments, since they did not require recognition decisions on the primes.

Experiment 2 is also an attempt to replicate Macht and O'Brien's (1980) finding that the recent presentation of a related extralist prime inhibits lure rejection. By varying both the recency and the nature of the last prime, we can determine from Experiment 2 whether the discrepancy between the lure data from our Experiment 1 and from Macht and O'Brien's experiment was due to our last related prime being an intralist item rather than the extralist item they used.

Design

Sixteen conditions were produced by a 2 (number of related primes: two vs. six) × 2 (recency of a related prime: immediate vs. two items back) × 2 (type of last related prime: target vs. lure) × 2 (type of critical item: target vs. lure) factorial design. Thus, Experiment 2 provides a conceptual replication of Experiment 1 and at the same time includes the added variable of type of last related prime.

Test Sequence

Because the primes preceding the critical items were not blocked by category, a buffer category was not needed and each study list contained only eight categories. To manipulate recency of priming, the test list construction differed slightly from that of Experiment 1. One difference was that the recency-of-priming manipulation was varied between rather than within lists. For half of the subjects, the order of test was I, 2, I, 2, 2, I, 2, I (where I = immediate and 2 = two-back), whereas for the other half the order was reversed. However, because subjects could not distinguish critical items from other test items, the fact that recency of priming was manipulated between lists should have had no effect on their strategies. A second difference was that in the two-back priming condition, the items intervening between the prime and critical item were drawn from two different categories and could be any one of four combinations of lures and targets (both lures, both targets, lure–target or target–lure). However, as in Experiment 1, response repetition between the critical item and its immediate predecessor was equated for the two recency-of-priming conditions. Within the constraints imposed by the various priming manipulations, targets and lures from the different categories were tested in a random order. These constraints were severe when the first critical item was in the six-prime condition but not thereafter. Examples of the immediate priming and two-back versions of a test sequence are given in the Appendix.

Results and Discussion

The RT data and error data were collated and analyzed as in Experiment 1, except that type of prime (target vs. lure) was added as a within-subjects fixed effect. The top two rows of Table 2 correspond to the replication of Experiment 1 embedded in the current experiment (i.e., the conditions in which the last related prime was a target). The bottom two rows represent the new conditions in which the last related prime was a lure.

There are two noteworthy aspects of the number-of-primes effect in Experiment 2. First, when the last related prime was a target as in Experiment 1, the pattern of results replicated that of Experiment 1. That is, averaged across recency of priming, compared with the two-prime condition, the six-prime condition produced 28 msec of inhibition for targets but produced 44 msec of facilitation for lures (in Experiment 1 these figures were 51 msec of inhibition and 57 msec of facilitation). Also, as in Experiment 1, there was no substantial difference in errors between the six- and two-prime conditions. The second interesting feature of the number-of-

Table 2
Means of Median Reaction Times (in msec) and Percentage of Errors for the Conditions of Experiment 2

Type of critical item	Immediate priming condition						Two-back priming condition					
	No. of primes						No. of primes					
	2		6		2–6		2		6		2–6	
	M	% E	*M*	% E	*M*	% E	*M*	% E	*M*	% E	*M*	% E
	Target as last related prime											
Target	817	11.0	835	10.0	−18	1.0	890	10.2	918	9.2	−38	1.C
Lure	1,083	20.8	1,021	19.1	62	1.7	1,153	21.2	1,127	19.5	26	1.7
	Lure as last related prime											
Target	832	7.3	858	11.4	−26	−4.1	876	8.5	945	8.9	−69	−.4
Lure	1,094	16.8	1,096	22.3	−2	−5.5	1,144	24.0	1,180	22.7	−36	1.3

Note. % E = percentage of errors.

primes effect can be seen by comparing the magnitudes of this effect in the bottom two rows of Table 2 with those in the top two rows. Such a comparison reveals that increasing the number of related primes produced more inhibition for target RTs or less facilitation for lure RTs when the last related prime was a lure rather than a target.

The above conclusions were supported by the statistical analyses. Although the effect of number of primes was not statistically significant for either RTs or errors (both *F*s < 1.14), it participated in statistically significant interactions with the effects of the type of critical item, $F(1,\ 127) = 7.36$, $MS_e = 39{,}299.38$ for RTs but not for errors ($F < 1$), and the type of last prime, $F(1,\ 127) = 5.69$, $MS_e = 43{,}321.58$ for RTs and $F(1,\ 127) = 4.99$, $MS_e = 317.71$ for errors. The post hoc *t* tests revealed that averaged across recency of priming and type of prime, the 38-msec inhibition caused by increasing the number of related primes was reliable for targets, $t(127) = 2.83$, whereas the 12-msec facilitation for lures was not reliable ($t < 1$). Furthermore, when a target served as the last prime (see top half of Table 2), averaged across recency of priming and type of critical item, neither the 8-msec facilitation in RTs nor the 1.3% facilitation in errors produced by increasing the number of related primes was significant (both *t*s < 1). However, when a lure served as the last prime (see bottom half of Table 2), the 33-msec inhibition in RTs caused by increasing the number of related primes was reliable, $t(127) = 2.56$, and the 2.1% inhibition in errors was marginally reliable, $t(127) = 1.96$, $p < .06$, two-tailed.

These results are congruent with Todres and Watkins's (1981) report that following the study of a blocked-categorized list, multiple related extralist primes inhibit recognition accuracy whereas related intralist primes do not. If the percentage of hits minus the percentage of false alarms is taken as a measure of recognition accuracy, we obtained a 3.7% facilitation in accuracy of six versus two related primes when the last related prime was a target, whereas we obtained a sizeable 9.6% inhibition when the last related prime was a lure. The present results also extend the generality of Todres and Watkins's results in two ways. First, the present results show that an inhibition of target recognition caused by increasing the number of related primes can occur whether the related primes are randomly presented (Experiment 2) or blocked (Experiment 1; Todres & Watkins, 1981) during the test. Second, and more important, because we used half targets and half lures as the related primes whereas Todres and Watkins used all extralist or all intralist primes, our results may help to explain why Todres and Watkins obtained inhibition from related primes in their extralist but not their intralist priming condition. The inhibition in their extralist priming condition may have been more due to the last prime being an extralist item than to the fact that all of the primes were extralist items. Additional research is needed to answer this conclusively.

As in Experiment 1, subjects were faster, $F(1, 127) = 75.70$, $MS_e = 37{,}715.51$, but were no more accurate ($F < 1$) when the last related prime occurred immediately preceding the critical item rather than two items back. Although this recency-of-priming effect was smaller in the current experiment (74 msec) with random tests than in Experiment 1 (191 msec), in which test items were blocked by category, it was again equally as great for lures as for targets. Thus, contrary to results reported by Macht and O'Brien (1980), there was in Experiment 2 no indication of inhibition in lure rejection from recency of priming when the last related prime was a lure. In fact, averaged across number of primes, recency of priming produced 67 msec of facilitation when the last related prime and the critical item were both lures.

One procedural difference that could account for why recency of priming facilitated lure rejection in our experiments but inhibited lure rejection in Macht and O'Brien's (1980) experiments is that our retention intervals averaged about 150 sec whereas Macht and O'Brien's were 15 sec. Because making a lure more familiar slows its rejection when recognition is based on familiarity (e.g., Atkinson, Herrmann, & Wescourt, 1974), under the assumption that a related prime increases a lure's "familiarity," semantic priming should slow lure rejection at short retention intervals when recognition is likely to be based on familiarity (cf. Mandler, 1980). Indeed, that is how Macht and O'Brien accounted for the inhibitory effect that semantic priming had on lure rejection in their experiments. However, with the longer retention intervals we used, recognition would likely be based on memory search rather than familiarity, with a resulting facilitation on lure rejection from related primes.

When the most recent related prime and the critical item are both targets, there could be two interpretations as to why RTs are faster in the immediate than in the two-back priming condition. The semantic priming interpretation is that the more recent presentation of a semantically related prime facilitates the processing of the target. On the other hand, according to the episodic priming interpretation (cf. McKoon & Ratcliff, 1979), the recent presentation at test of a target prime that occurred adjacent to the critical target at study facilitates the processing of that critical target at test via the episodic association formed between it and the prime during study. However, because a recency-of-priming effect was also obtained when the last prime and the critical item had not occurred together in the study list, it must have been largely mediated by semantic priming rather than episodic priming.

Of course, the foregoing establishes only that semantic priming occurred and not that episodic priming did not occur. Indeed, because RTs were 23 msec faster when the last prime was a target rather than a lure, $F(1, 127) = 6.43$, $MS_e = 39{,}760.26$, episodic priming did occur in the current experiment. (However, the effect of type of last prime did not approach significance for errors, $F < 1$.) This episodic priming effect cannot be attributed solely to some sort of response repetition between a critical target and the immediately preceding target prime. In fact, the episodic priming effect was somewhat larger for lures (32 msec), for which the "old" response to the immediately preceding target prime was not repeated, than for targets (11 msec), for which it was repeated. However, the Type of Prime $\times$ Type of Critical Item interaction was not statistically significant for either RTs, $F(1, 127) = 1.19$, $MS_e = 42{,}262.01$, or errors, $F(1, 127) = 2.37$, $MS_e = 313.90$. In addition, the Type of Prime $\times$ Recency of Priming interaction was significant for neither RTs nor errors (both Fs < 1). This equivalence in the episodic priming effects obtained for the lure and the target critical items and for the immediate and two-back priming conditions suggests that the episodic priming effect was more than just a reinstatement on adjacent tests of a specific association formed between adjacent items in the study list. Rather, it seems that a target prime reinstates the global study list context, thereby facilitating episodic decisions about both targets and lures. This interpretation is, of course, consonant with Todres and Watkins's (1981) explanation of why multiple related intralist primes do not interfere with recognition whereas extralist primes do.

Experiment 3

Experiment 3 was intended to replicate and to clarify findings from the first two experiments. The two focal points were (a) the conditions under which inhibition is produced from increasing the number of related primes and (b) the episodic priming effect. In Experiment 3 we always placed the last related prime immediately prior to the critical item because the data from Experiment 2 (see Table 2) gave some hint that the immediate priming condition accentuated episodic priming and the inhibition in errors caused by increasing the number of related primes when the last related prime is a lure.

Design

Eight conditions were produced by a 2 (number of related primes: two vs. six) × 2 (type of last related prime: target vs. lure) × 2 (type of critical item: target vs. lure) factorial design.

Test Sequence

The tests were identical to those in Experiment 2 except that the last related prime always immediately preceded the critical test item (see Appendix).

Results and Discussion

The data from Experiment 3, displayed in Table 3, were analyzed as in Experiments 1 and 2. As can be seen in Table 3, the results of Experiment 3 nicely replicate those from Experiments 1 and 2.

In agreement with the results from Experiments 1 and 2, the main effect of number of primes on RTs was not reliable, $F(1, 63) = 1.31$, $MS_e = 19{,}869.67$, whereas the Number of Primes × Type of Critical Item interaction was, $F(1, 63) = 6.78$, $MS_e = 26{,}493.08$. Compared with the two-prime condition, the six-prime condition produced 52 msec of inhibition for targets, $t(63) = 2.54$, and a nonsignificant 23 msec of facilitation for lures, $t(63) = 1.14$. (The facilitation in lure RTs from increasing the number of related primes can also be discounted because of a speed/accuracy trade-off). Unlike the outcomes of Experiments 1 and 2, there was now a marginally reliable effect of number of primes on errors, $F(1, 63) = 3.52$, $MS_e = 145.06$, $p < .10$; 17% errors were made in the six-prime condition, and 15% errors were made in the two-prime condition.

As in Experiment 2, the inhibition from increasing the number of related primes was slightly greater for RTs when the last related prime was a lure rather than a target. That is, increasing the number of related primes produced more inhibition for targets or less facilitation for lures when the last related prime was a lure rather than a target (in Table 3, compare the bottom two rows with the top two rows under the 2–6 columns). Although the Number of Related Primes × Type of Last Related Prime interaction was not statistically significant for either RTs or errors (both Fs < 1.22), the pattern of data resembles that of Todres and Watkins's (1981) experiments as well as that of Experiment 2. For example, if the percentage of hits minus the percentage of false alarms is the measure of recognition accuracy, the inhibition from six related primes relative to two related primes was only 1.6% when the last related prime was a target whereas the inhibition was 6.4% when the last related prime was a lure. Thus, it seems safe to conclude that the inhibition from multiple related primes in episodic recognition is somewhat greater when

Table 3
Means of Median Reaction Times (in msec) and Percentage of Errors for the Conditions of Experiment 3

Type of critical item	No. of primes: 2 *M*	2 % E	6 *M*	6 % E	2–6 *M*	2–6 % E
Target as last related prime						
Target	798	10.3	846	10.4	−48	−.1
Lure	1,107	18.7	1,068	20.2	39	−1.5
Lure as last related prime						
Target	828	9.5	884	14.0	−56	−4.5
Lure	1,154	21.4	1,147	23.3	7	−1.9

Note. % E = percentage of errors.

the last related prime is an extralist item rather than an intralist item.

As in Experiment 2, RTs were faster when the most recent related prime was a target rather than a lure, $F(1, 63) = 17.26$, $MS_e = 17{,}360.03$. This 48-msec episodic priming effect was slightly larger than the 31-msec effect obtained in the comparable immediate priming condition in Experiment 2. Also, in Experiment 3, there were 2.5% fewer errors when the last related prime was a target rather than a lure, $F(1, 63) = 3.28$, $MS_e = 183.84$, $p < .10$. As in Experiment 2, episodic priming did not interact with the effects of type of critical item (for RTs and errors, both Fs < 1.49).

General Discussion

This section contains two main parts. First, we summarize our three primary findings: (a) worse performance in the six-prime condition than in the two-prime condition, (b) faster RTs in the immediate priming condition than in the two-back priming condition (recency of semantic priming), and (c) faster RTs when the last prime was a target rather than a lure (episodic priming). In this summary, we relate our findings to previous findings and in so doing note some limitations of these research efforts. Second, we discuss the theoretical implications of these findings.

Inhibition From Increasing the Number of Related Primes

Our three experiments show that speeded episodic recognition of targets is inhibited the more prior recognition tests have been given on items from the same semantic category as these targets; the experiments also show that this inhibition is greater when the immediately preceding test involves a lure rather than a target. These results, along with those of Todres and Watkins (1981), suggest that Slamecka (1975) did not obtain an inhibition from semantically related cues because he used targets, rather than lures, as cues. Apparently, then, the recent presentation of a semantically related target prime produces facilitation from episodic priming (see below) that offsets the inhibition produced by increasing the number of related primes (cf. Todres & Watkins, 1981).[1] Because the facilitation in lure-rejection RTs from increasing the number of related primes was inconsistent and possibly due to a speed/accuracy trade-off, we will not make much of it.

It is noteworthy that unlike researchers who have examined the more general issue of how prior recognition tests interfere with recognition (e.g., Schulman, 1974), we held constant both the retention interval and the total number of prior recognition tests between study and a critical test and manipulated instead how many of these prior tests involved items semantically related to the critical test item. Thus, our interference effects were produced by category-specific interference rather than by differences in retention interval and/or the total number of prior tests. However, the present experiments do not permit one to determine in the six-prime condition (a) the degree to which the recognition tests on the four additional priming items from the critical item's category retroactively or proactively interfered with recognition of the critical item (cf. Izawa, 1980) or (b) the relative contributions that the target and lure primes made to these interference effects.

Although our data do not resolve the latter two issues, our finding that target recognition is inhibited by increasing the number of semantically related primes has methodological implications nonetheless. Consider, for example, tests for semantic-organization effects in which recognition for lists of unrelated words is compared with recognition for lists of related words. As Neely and Balota (1981) have noted, if one uses semantically related lures in a yes/no recognition test, with

[1] There is one exception to the conclusion that multiple related intralist primes do not produce inhibition in recognition. Park (1980, Experiments 3 and 4) had subjects study blocked-categorized word lists under either interactive imagery or separate imagery instructions. In forced-choice recognition, increasing the number of semantically related intralist primes hurt recognition for subjects given separate imagery instructions but helped recognition for subjects given interactive imagery instructions. (See Roediger & Neely, 1982, for a discussion of these data.)

the same ratio of lures to targets for both kinds of lists, the test for the list of related words will necessarily contain more related "primes" than the test for the list of unrelated words. Thus, the failure to find superior recognition on lists of related words over lists of unrelated words (see Kintsch, 1974, chap. 4) may be due to a detrimental effect on recognition produced by the greater number of semantically related primes in the test for the list of related words. As Todres and Watkins (1981) stated, we "regard the concept of a pure measure of recognition, uncontaminated by the testing procedure, as nothing more than a convenient fiction" (p. 98).

There is, of course, one caveat concerning our inhibition in target recognition caused by increasing the number of semantically related primes. We cannot be sure that the six related primes are not merely producing less facilitation than the two related primes. To establish that the six-prime condition is actually producing a "true inhibition" effect, one needs a "neutral" priming condition as a baseline for assessing facilitation and inhibition. In experiments on lexical decision and letter-matching tasks in which subjects were not required to make overt responses to the primes, Neely (1976, 1977) and Posner and Snyder (1975b) have used "semantically neutral" plus signs or strings of Xs as such a baseline condition. When responses to the primes are required, as in the present experiments, it is somewhat unclear what the appropriate neutral control condition should be. (This raises the interesting question of whether one would replicate the present results if subjects were merely exposed to the primes but were not required to make recognition decisions to them.) But even if the additional primes are merely reducing facilitation, the operation of some sort of inhibitory mechanism is still implicated. Hence, to make our nomenclature coincide with that used in the pertinent literature, we will continue to attribute the poor performance in the six-prime condition to an inhibition effect.

Recency of Semantic Priming

In Experiments 1 and 2, RTs were faster when a semantically related prime appeared immediately prior to the critical test item rather than two items back. This was so regardless of whether or not the last related prime and/or the critical item had appeared in the study list. Thus, this recency-of-priming effect is analogous to what has been called semantic priming in the literature on semantic and lexical retrieval processes (e.g., Collins & Loftus, 1975; Neely, 1977). However, the absence of a neutral priming condition precludes a determination of whether this effect of recency of semantic priming should be interpreted as facilitation from the last related prime or inhibition from the unrelated prime that immediately preceded the critical item in the two-back priming condition. Nevertheless, following conventional terminology, we refer to our recency-of-semantic-priming effect as facilitation. But because a neutral priming condition was not used, it is not clear whether this facilitation from semantic priming was due to (a) subjects' using the prime to anticipate consciously that the next item would be from the same semantic category (although in the random test of Experiment 2 this seems unlikely) or (b) spreading activation (cf. Neely, 1977; Posner & Snyder, 1975a).

Although semantic priming typically produces facilitation in semantic memory tasks (e.g., Collins & Loftus, 1975; but see also Roediger & Neely, 1982), its effects on episodic recognition are more variable. When the episodic recognition test is preceded by paired-associate learning, semantic priming produces inhibition. However, when it is preceded by the learning of categorized lists, facilitation is produced. For example, when a critical target and its semantically related prime had been previously studied in the same paired associate, McKoon and Ratcliff (1979) observed a facilitation caused by priming, compared with when an unrelated prime and target had been previously studied in the same paired associate (see also Carroll & Kirsner, 1982, Experiment 2; Herrmann & McLaughlin, 1973, Experiment 1). However, as McKoon and Ratcliff noted, this facilitation could have been due to the semantically related paired associates yielding stronger episodic associations than the unrelated paired associates. Indeed, compared with an unrelated extralist prime, a semantically related extralist prime produced no effect on RTs to targets but did produce a rather substantial inhibition effect for errors. This inhibitory semantic priming effect in errors also occurs in episodic recognition when a semantically related intralist prime has been previously paired with a word other than the semantically related critical item (e.g., Carroll and Kirsner, 1982; Durgunoglu & Neely, Note 1).

With categorized lists, on the other hand, Herrmann and his associates (Herrmann & Harwood, 1980; Herrmann & McLaughlin, 1973, Experiment 2; McLaughlin & Herrmann, 1972; Schooler & Herrmann, Note 2) have shown that semantic priming facilitation occurs when the prime and target are both targets or both lures from a studied category but not when both are lures from a nonstudied category or when one is a target and one is a lure from a studied category. On the basis of these findings, Herrmann and Harwood (1980) concluded that semantic priming does not occur in this paradigm unless the two items in the display are, to use their terminology, "episodically related" (i.e., are both targets or are both lures from a studied category). Of course, the recency-of-semantic-priming effect that we obtained when the last related prime and the critical item were of different types (i.e., one a target and one a lure) is contrary to the failure of Herrmann and his associates to find semantic priming with such items. Although it is unclear what produced this discrepancy between their results and ours, the important point is that facilitatory semantic priming effects such as ours are not always obtained in episodic recognition.

Finally, our data are not analytic regarding whether semantic priming was affecting the episodic recognition judgment or other processes. But the fact that recency of semantic priming did not affect error rates is indirect evidence that it might be affecting a process other than the episodic recognition judgment, for example, an encoding process occurring prior to the episodic recognition judgment (cf. Meyer, Schvaneveldt, & Ruddy, 1975; but see also Becker & Killion, 1977; McClelland, 1979; Schvaneveldt & McDonald, 1981; Stanovich & West, 1979).

Episodic Priming

In Experiments 2 and 3, RTs were reliably faster when the most recent related prime was a target rather than a lure. This effect may be referred to as episodic priming (cf. McKoon & Ratcliff, 1979), because presentation of the prime in the study list had an effect beyond its being semantically related to the critical item. Because episodic priming occurred for both lures and targets and in both the two-back and the immediate priming conditions, it apparently was not mediated solely by the reinstatement of a specific association formed between adjacent items during study but rather was produced in part by the target prime's reinstatement of the global list context used in episodic recognition judgments.

There is, however, an alternative explanation for our episodic priming effect. Because tests on targets are easier than tests on lures (as shown by both errors and RTs), it could be that performance on the critical item is worse when it is tested immediately following a difficult lure test rather than an easy target test (cf. Kiger & Glass, 1981). Nevertheless, we favor the episodic priming interpretation because it encompasses both the present results and those of Todres and Watkins (1981). The alternative hypothesis cannot easily account for Todres and Watkins's results because subjects in their experiments did not make episodic recognition judgments about the primes.

Theoretical Implications

Both our semantic priming and episodic priming effects can be accounted for by spreading activation theories (e.g., Anderson, 1976; Collins & Loftus, 1975). Consider first our recency-of-semantic-priming effect. According to spreading activation theories, activation of the last related prime's concept would have spread to semantically related concepts, making them more accessible. However, this heightened accessibility would have decayed with time, thus explaining why RTs in the two-back priming condition were longer than those in the immediate priming condition. Furthermore, because it is a semantic relationship that mediates the spread of activation, facilitation should occur whether the priming item or the critical item is a target or a lure, as was revealed by our results.

As for episodic priming, following the lead of Anderson (1972, 1976) and Anderson and Bower (1972, 1973, 1974), one could make two assumptions. (a) When people memorize a word list, they tag the nodes corresponding to the to-be-remembered words and the pathways connecting these nodes with contextual elements associated to a list-marker node. (b) In making an episodic recognition decision, they "count" the number of intersections of activation spreading from the list-marker node and the node of the test word. Thus, a target prime would produce faster RTs to critical items than would a lure prime because the recent presentation of the target prime makes the list-specific contextual elements used in the episodic recognition decision more accessible when the critical item is tested.

Although spreading activation theories provide a reasonable account of our semantic and episodic priming effects, they founder in explaining inhibition in target recognition caused by increasing the number of related primes. The problem is that activation spreading from the nodes of multiple primes episodically and/or semantically related to a critical target should summate to produce faster RTs in the six-prime than in the two-prime condition—not the slower RTs we observed. However, there are at least two general approaches spreading activation theorists could take to accommodate inhibition in target recognition caused by increasing the number of related primes.

The first approach would invoke mechanisms similar to those already used by Anderson (1976, chap. 8) and King and Anderson (1976) to account for "fan" effects—the observation that the more other words associated to a word there are (i.e., the greater the fan of associations from that word), the longer it takes to verify the presence or absence of any particular association to that word. According to Anderson (1976), to verify that X and Y are associated via relation Z, people determine whether the activation spreading from the X and Y nodes intersects along a path labeled with relation Z. The fan effect occurs because the more labeled paths there are emanating from the X and Y nodes, the slower is the spread of activation down any one of them and the longer it takes for the activation from the X and Y nodes to intersect.

With two additional assumptions the foregoing analysis can account for inhibition in target recognition caused by increasing the number of related primes. (a) The search for intersections of activation spreading from the list-marker node and the node of the test word is mostly confined to pathways connecting list-marker elements to nodes of words from the same semantic category (or subnode) as the test word (cf. McCloskey & Bigler, 1980; Reder & Anderson, 1980). (b) Presentation of a test item produces additional associations between its node and the contextual list-marker elements associated with the nodes of words from the same category as the test item. Thus, as more tests are made on words from a particular category, there is an increase in the fan of associations connecting contextual list-marker elements to the nodes of words from this category. This increased fan slows the spread of activation from the list-marker elements and thereby slows RTs to a test word from that category by delaying the intersection of activation spreading between the list-marker elements and node of the test word (this is analogous to what Watkins, 1979, has called cue overload). Of course, additional assumptions would be needed to account for why inhibition caused by increasing the number of related primes is greater when the last related prime is a lure rather than a target and does not occur for lure rejection. Furthermore, a different set of assumptions would be needed to account for why increasing the number of related primes also produces inhibition in semantic memory tasks in which list-marker elements need not be searched (e.g., Brown, 1981; see also Roediger & Neely, 1982).

A second, perhaps simpler approach for accommodating inhibition from multiple semantically related primes would postulate lateral inhibition in the semantic network. This general approach has been taken by Brown (1979; but see Roediger, Neely, & Blaxton, in press), Martindale (1981, chap.

8 and 9), and Walley and Weiden (1973). In this approach, semantically related nodes would be connected both by excitatory and inhibitory connections, with the inhibitory connections exerting a greater influence when several related nodes all located within a small region of the memory network have recently been activated.

Although we have focused our attention on spreading activation theories, other theories could also be used to interpret our results. The most promising are those that were developed to account for inhibition caused by increasing the number of related primes in episodic recall tasks, for example, Rundus's (1973) sampling-with-replacement model, Raaijmakers and Shiffrin's (1980, 1981) SAM model, and Watkins's (1979) cue-overload theory. Perhaps extensions of these models to episodic recognition and semantic memory tasks will be less cumbersome than the modified version of Anderson's spreading activation theory given above. Indeed, Todres and Watkins (1981) have already provided a rather simple extension of cue-overload theory to account for inhibition in episodic recognition caused by multiple semantically related primes.

Conclusion

It is now clearly established that semantically related primes can both facilitate and inhibit performance in both episodic and semantic memory tasks (see Roediger & Neely, 1982). This poses an important challenge to theory. The challenge is to specify (a) how offsetting facilitatory and inhibitory mechanisms combine to modulate performance and (b) the conditions under which the operation of the facilitatory mechanisms will dominate the inhibitory mechanisms, and vice versa. Without such specifications, any theory postulating opposing processes will have the necessary flexibility to account for any result after the fact, yet it will be unable to designate in advance whether the net result in a particular experimental condition will be one of facilitation or inhibition. Of course, with only the currently available data as a guide, it may be premature to begin such a theoretical specification. Nonetheless, we believe a crucible for theory construction is the observation that the recent presentation of a single semantically related prime typically produces facilitation, while increasing the number of related primes produces inhibition.

Reference Notes

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(*Appendix follows on next page*)

Appendix

Table A1
Example Study Lists and Test Sequence for Experiment 1

Category	Study list A exemplars	Study list B exemplars
FISH	trout shark catfish salmon cod	bass herring perch tuna swordfish
CLOTHING	shirt blouse coat hat jacket	pants skirt dress sweater slacks
FLOWERS	rose carnation violet lily daffodil	tulip daisy orchid pansy dandelion
ALCOHOLIC BEVERAGES	beer gin vodka scotch brandy	whiskey wine bourbon rum champagne
RELATIVES	aunt father brother nephew son	uncle mother sister niece daughter
PRECIOUS STONES	diamond emerald pearl jade amethyst	ruby sapphire opal topaz turquoise
FRUIT	apple pear peach cherry lemon	orange banana grape plum lime
KINDS OF CLOTH	cotton silk nylon linen orlon	wool rayon dacron satin velvet
DRUGS	marijuana aspirin morphine cocaine methedrine	codeine opium heroin penicillin benzedrine

Test sequence

1. bass	19. cocaine	37. aunt	55. champagne	73. swordfish
2. catfish	20. penicillin	38. niece	56. scotch	74. nephew
3. salmon	21. violet	39. mother	57. plum	75. son
4. herring	22. daisy	40. brother	58. grape	76. daughter
5. perch	23. orchid	41. sister	59. peach	77. jacket
6. shark	24. lily	42. father	60. apple	78. lemon
7. codeine	25. tulip	43. benzedrine	61. banana	79. cherry
8. marijuana	26. carnation	44. methedrine	62. pear	80. lime
[a] 9. trout	[a] 27. rose	[a] 45. uncle	[a] 63. orange	81. dandelion
10. opium	28. dress	46. bourbon	64. pearl	82. rayon
11. aspirin	29. shirt	47. beer	65. sapphire	83. dacron
12. morphine	30. coat	48. vodka	66. jade	84. nylon
13. heroin	31. sweater	49. rum	67. amethyst	85. linen
14. skirt	32. hat	50. ruby	68. opal	86. brandy
15. blouse	33. slacks	51. emerald	69. topaz	87. velvet
16. tuna	34. wine	52. pansy	70. wool	88. satin
17. cod	35. gin	53. daffodil	71. silk	89. orlon
[a] 18. pants	[a] 36. whiskey	[a] 54. diamond	[a] 72. cotton	90. turquoise

[a] Critical trials (*Trial 9:* six primes, two-back, A target; *Trial 18:* two primes, two-back, A lure; *Trial 27:* six primes, immediate, A target; *Trial 36:* two primes, immediate, A lure; *Trial 45:* six primes, two-back, A lure; *Trial 54:* two primes, two-back, A target; *Trial 63:* six primes, immediate, A lure; *Trial 72:* two primes, immediate, A target).

Table A2
Test Sequences for Experiment 2

Immediate priming		Two-back priming	
1. shark	41. bourbon	1. shark	41. mother
2. diamond	42. jacket	2. diamond	42. jacket
3. bass	43. mother	3. bass	43. bourbon
4. violet	[a] 44. aunt	4. violet	[a] 44. aunt
5. perch	45. dandelion	5. perch	45. dandelion
6. cotton	46. gin	6. cotton	46. gin
7. catfish	47. orange	7. catfish	47. orange
8. skirt	48. uncle	8. salmon	48. uncle
9. salmon	49. slacks	9. herring	49. sapphire
10. tulip	50. vodka	10. tulip	50. vodka
11. herring	51. sapphire	11. skirt	51. slacks
[a] 12. trout	[a] 52. ruby	[a] 12. trout	[a] 52. ruby
13. emerald	53. rum	13. emerald	53. rum
14. tuna	54. brother	14. tuna	54. brother
15. lily	55. jade	15. lily	55. jade
16. rayon	56. scotch	16. rayon	56. satin
17. cod	57. satin	17. blouse	57. pear
18. daisy	58. sister	18. daisy	58. sister
19. blouse	59. pear	19. cod	59. scotch
[a] 20. pants	[a] 60. apple	[a] 20. pants	[a] 60. apple
21. swordfish	61. turquoise	21. swordfish	61. turquoise
22. opal	62. champagne	22. opal	62. champagne
23. orchid	63. nephew	23. orchid	63. nephew
24. shirt	64. amethyst	24. shirt	64. banana
25. beer	65. banana	25. carnation	65. silk
26. dress	66. niece	26. dress	66. niece
27. carnation	67. silk	27. beer	67. amethyst
[a] 28. rose	[a] 68. wool	[a] 28. rose	[a] 68. wool
29. pansy	69. peach	29. pansy	69. peach
30. coat	70. velvet	30. coat	70. velvet
31. topaz	71. son	31. topaz	71. son
32. father	72. brandy	32. father	72. brandy
33. hat	73. linen	33. wine	73. linen
34. dacron	74. grape	34. hat	74. grape
35. wine	75. cherry	35. dacron	75. cherry
[a] 36. whiskey	76. orlon	[a] 36. whiskey	76. orlon
37. daffodil	77. plum	37. daffodil	77. plum
38. sweater	78. daughter	38. sweater	78. daughter
39. pearl	79. lemon	39. pearl	79. lemon
40. nylon	80. lime	40. nylon	80. lime

Note. The study lists were identical to those given in Table A1, except that the ninth category, DRUGS, was not included.
[a] Critical trials (*Trial 12:* six-prime, A-lure prime, A target; *Trial 20:* two-prime, A-target prime, A lure; *Trial 28:* six-prime, A-target prime, A target; *Trial 36:* two-prime, A-lure prime, A lure; *Trial 44:* two-prime, A-lure prime, A target; *Trial 52:* six-prime, A-lure prime, A lure; *Trial 60:* two-prime, A-target prime, A target; *Trial 68:* six-prime, A-target prime, A lure).

Received March 1, 1982
Revision received September 3, 1982 ■