Memory Blocks in Word Fragment Completion Caused by Involuntary Retrieval of Orthographically Related Primes

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Seven experiments showed that word fragments are not solved as well following prior exposure to orthographically similar primes (e.g., ANALOGY as a prime for A_L_ _GY) relative to orthographically dissimilar primes (e.g., UNICORN). This blocking effect was influenced by the modality (auditory vs. visual) of the primes but not by the depth to which they were processed. This blocking effect occurred even when participants were informed about it and told to try to avoid remembering the primes, and it was not affected by the proportion of test fragments for which the orthographic primes were correct versus incorrect answers. The results have implications for theories concerned with unconscious mechanisms that underlie memory blocking and blocks to creative problem solving.

Memory blocks (sometimes referred to as *retrieval inhibition;* Anderson & Bjork, 1994) are phenomena in which one's knowledge or memories of events cannot be brought to mind. A temporary inability to recall a well-learned name or word is an example of a memory block. Key to the definition is having an inability to remember something even though one's potential to remember exists, as verifiable by other tests.

Researchers of memory blocking have investigated numerous phenomena observable in the laboratory, including proactive and retroactive interference effects (e.g., Postman & Underwood, 1973), part-list cuing and part-set cuing effects (e.g., Nickerson, 1984), directed forgetting (e.g., Bjork, 1972, 1989), retrieval-induced forgetting (e.g., Anderson, Bjork, & Bjork, 1994), negative priming (e.g., Neill & Valdes, 1992), and tip-of-the-tongue effects (e.g., Jones, 1989). Understanding memory blocking in episodic and semantic memory is important for both theoretical issues (e.g., Roediger & Neely, 1982) and applied clinical concerns (e.g., Bower, 1990; Erdelyi & Goldberg, 1979).

In the present experiments we demonstrated that involuntary retrieval of recent events can intrude, block, or interfere with performance on word fragment completion, an indirect test of memory. Word fragment completion has been described as revealing implicit memory, or memory without an accompanying awareness of remembering (e.g., Schacter, 1987; Tulving, Schacter, & Stark, 1982). In this task participants encounter word primes (e.g., *ALLERGY*) and

are later given a number of word fragments to complete, some of which correspond to the primes presented earlier (e.g., *A_L_ _GY*). An increase in fragment completion rates as the result of earlier experiences with the solution words is referred to as an example of *repetition priming* and has been interpreted as evidence of implicit memory (e.g., Roediger & McDermott, 1993).

Of the relatively few studies in which interference in indirect memory tests has been examined, no clear picture has emerged. Jacoby (1983), for example, did not find interference effects in a perceptual identification task, nor did Sloman, Hayman, Ohta, and Tulving (1988) or Graf and Schacter (1987) find effects of interference in word fragment completion. On the other hand, Nelson, Keelean, and Negrao (1989) found interference effects in a test that required participants to complete words from fragments made up of word endings. The present set of experiments may help in determining some of the conditions that lead to interference effects in indirect tests of memory.

In our first three pilot experiments in which the effects of negative primes (orthographically similar primes) on fragment completion were examined, we found blocking effects that were reliable, but the experiments involved only a small set of materials. In the fourth pilot experiment we tested the effects on an expanded set of effective materials.

Pilot Experiments

In four of our pilot experiments[1] we found blocking effects in fragment completion. The four test items used in the first three pilot experiments were word fragments with only two or three blank spaces taken from words ranging in

[1] Pilot Experiments 1 and 2 were reported at the Weiskrantz Symposium on Memory, April 1993, at Baylor University. Pilot Experiment 3 was reported to the Midwestern Psychological Association, April 1993, in Chicago. Pilot Experiment 4 was presented to the Psychonomic Society, November 1994, in St. Louis. We have also discovered similar results obtained by Neely and Durgunoglu (1985).

length from 6 to 10 letters: AN_TO_Y (ANATOMY), IN_RT_ _ (INERTIA), L_D_ER (LADDER), and LE_T_RE (LECTURE). The fragments were fairly easy to solve; without any priming the baseline completion rates ranged from about 40% to 85% correct. The negative primes were words with spellings similar to the spellings of correct solutions, but the negative primes could not be used to complete correctly any of the test fragments: ANCHOVY was the negative prime for the fragment AN_TO_Y, INVERTED for IN_RT_ _, LEADER for L_D_ER, and LETTER for LE_T_RE. Unrelated primes, words that were orthographically dissimilar to any target fragments, were presented along with negative primes in incidental tasks.

In Pilot Experiment 1 negative primes and unrelated words were shown on an incidental task. Participants gave affect ratings for a list of negative primes and unrelated words first, and a few minutes later they were given the fragment completion task. In Pilot Experiment 2 negative primes were simultaneously shown with test fragments (no affect rating test was given). Each test fragment was given for 10 s with a word (either a negative prime or an unrelated word) printed above it. In Pilot Experiment 3 negative primes were presented as simple fragments; that is, as fragments with only one vowel missing (e.g., LETT_R). The negative primes always immediately preceded their corresponding test fragments. Table 1 shows that consistent blocking effects were found in all three pilot experiments.

Given the consistent blocking effects in the first three pilot experiments in which just four effective negative prime–target pairs were used, we then went about identifying a larger set of materials that would show a blocking effect. Tindell (1994) systematically generated and tested a set of stimuli to produce blocking in word fragment completion. Using specific rules to determine orthographic similarity, we had taken word fragments and their corresponding primes from Kučera and Francis's (1967) word frequency norms.

Tindell's (1994) materials included 48 singular nouns with seven letters, which were formed into 24 prime–target word pairs. The two words in each of the 24 word pairs that were selected shared four or five of their letters, with the shared letters in the same order for the paired prime and target words. At least one of the shared letters was in a different position for the two words. The first letters of both the prime and target words of a pair were always the same. For all pairs meeting the above criteria, one word was designated the prime, and the other the target. Target word fragments were constructed by deleting two or three letters from the target words and by inserting blanks into the deleted spaces. The letters deleted from the target word were the letters not shared with its corresponding prime word. All test fragments had unique solutions. Positive primes were words that correctly completed test fragments, whereas negative primes were the orthographically similar words that could not be used to complete any test fragments. Unrelated primes were seven-letter words that were not orthographically similar to the solutions of any test fragments.

In Pilot Experiment 4 a list of primes, including correct fragment solutions (positive primes), negative primes, and unrelated words, was presented in the form of an incidental

Table 1

Mean Proportion of Completed Fragments as a Function of Type of Prime in Four Pilot Experiments

Pilot experiment	Type of prime		
	Unrelated	Negative prime	Blocking effect
1	.69	.53	−.16
2	.67	.50	−.17
3	.71	.58	−.13
4	.56	.50	−.06

Note. Blocking effect = mean completion with negative primes minus mean completion with unrelated primes.

learning task. A word fragment completion test was given approximately 3 min after the incidental learning task. It was found that fragments corresponding to positive primes were most easily solved (completion rate with positive primes was .87, giving a facilitation effect of .31), and those corresponding to negative primes were most poorly solved (Table 1).

Having identified a larger set of negative primes in Pilot Experiment 4, we then replicated the blocking effect with the 12 most effective items and tested it for transfer-appropriate processing patterns in Experiment 1. In Experiments 2, 3, and 4 we tested whether participants could voluntarily avoid or escape memory blocks if participants were warned about the negative primes and were asked to try to avoid remembering them while completing word fragments. In Experiments 5, 6, and 7 we examined the influence of primed filler fragments on the blocking effect.

Experiment 1

Greater repetition priming effects in fragment completion are generally observed if the perceptual characteristics of the primes (such as the sense modality) are similar to those of the test fragments (Blaxton, 1989; Weldon, 1993). Schacter and Graf (1989) and Weldon (1993), among others, have reported modality specific facilitatory priming effects in word fragment completion. Weldon has also shown that the effects of modality in fragment completion tasks are more dominant if fragments are presented briefly (i.e., 2 s or less), probably because such a brief presentation reduces the possibility that deliberate retrieval attempts can be made. Manipulation of conceptual variables at input, however, is less likely to affect fragment completion performance. For example, level of processing at input has often been found to have little or no effect on perceptual or data-driven memory tests (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981; see also Brown & Mitchell, 1994; Challis & Brodbeck, 1993).

In Experiment 1, input modality (visual vs. aural) and input level of processing (deep vs. shallow) were independently manipulated. The initial orienting tasks were either to rate primes for pleasantness (deep processing) or to count the number of syllables in the words (shallow processing). The transfer-appropriate processing hypothesis predicted that only modality, a perceptual manipulation, should affect

performance because word fragment completion is primarily a data-driven test. The brief presentation times for fragments should have emphasized the perceptual nature of the word fragment completion task even more. Level of processing, a conceptual manipulation, should not affect blocking according to the transfer-appropriate processing hypothesis.

Method

Participants. The participants in all experiments were volunteers from introductory psychology classes who fulfilled part of a class requirement by participating in the experiment. Participants were recruited by posting signup sheets for group sessions to be conducted at various times. Volunteers could enroll for any session of many experiments, including the present experiment. Because equal numbers of participants did not enroll for every session, there were unequal numbers of participants in the treatment groups. Sessions were conducted in small groups of approximately 5 to 15 people. There were 264 undergraduate students who participated in Experiment 1.

Materials and apparatus. Twelve negative prime–fragment pairs drawn from Pilot Experiment 4 (see Appendix A) were used in Experiments 1–6. Each of the three (counterbalanced) lists of primes consisted of 12 words that corresponded with the 12 critical fragments on the following test. The 12 primes included 4 negative primes, 4 positive primes, and 4 unrelated primes. The fragment completion test consisted of the same 16 word fragments in all conditions; the first 4 were unrelated fillers, and the remaining 12 (i.e., the critical test fragments) corresponded to the 12 primes. The 3 prime types (positive, unrelated, and negative) were counterbalanced between subjects; each of three sets of 4 word fragments was positively primed in one counterbalancing, negatively primed in a second, and primed with unrelated words in a third counterbalancing group.

Materials were presented on a videotape that was recorded from the output of an Amiga computer. Primes were presented on a television screen in black uppercase letters on a white background with an extra space between letters. Test fragments were shown in black uppercase letters on a white background with an extra space after each letter to improve legibility, and underlining was used to denote missing letters. Participants wrote answers to the word fragments on blank lines on a piece of paper. None of the letters of the fragments were printed on the response forms.

Design and procedure. Participants were given two tasks for the experimental session: first, an incidental orienting task in which the primes were presented and, second, a word fragment completion task. The incidental orienting task involved either shallow processing (participants wrote the number of vowels in each prime) or deep processing (participants wrote pleasantness ratings of primes). For the affect rating task participants saw each word, and they had 5 s to indicate on a scale of −3 to +3 how the word made them feel, with responses ranging from −3 (*feel very bad*) to +3 (*very good*).

Primes were presented on a TV screen either visually or aurally. In the visual condition, words were shown on the screen for 5 s, with 3-s intervals between trials. In the aural condition, a recorded male voice spoke the primes on the videotape. The TV screen remained blank while words were spoken every 8 s on the videotape in the aural condition. In both the visual and aural conditions, a computerized voice spoke the word *next* between primes.

After a brief interval in which forms from the first task were collected and new blank forms were distributed, participants were told that they would be given a word completion task. The instructions for the second task included explanations of example word fragments. Participants were told that the solution to each word fragment was a word that could be completed by correctly filling in the missing letters. They wrote the completed words on blank lines on the response forms; none of the letters of word fragments were shown on the response forms. In all, about 3 min intervened between the last item on the affect rating task and the first item of the word fragment completion task. No mention was made of the previous affect rating task. For the word fragment completion task, each test fragment was shown on the TV screen for 5 s; a computerized voice then said "next," and the screen was blank for 3 s before the next fragment appeared. This relatively rapid pace was used to minimize conceptual processing and explicit remembering so that observed effects would largely be due to nondeliberate retrieval.

Results

The analyses described in all of our reported experiments were collapsed across item counterbalancings because differences among the three counterbalanced sets of items were irrelevant to interpretations of the analyses. Because blocking and facilitation analyses both included the same control condition, the significance level was adjusted to $p < .025$ for all tests reported in Experiments 1–6 unless otherwise specified.

Blocking. A 2 × 2 × 2 (Mode × Level of Processing × Type of Prime) analysis of variance (ANOVA) was computed by using proportion of fragments completed as the dependent measure. Mode (visual vs. aural) and level of processing (shallow vs. deep) were between-subjects variables, and type of prime (unrelated or negative) was a within-subject variable. The effect of type of prime was significant, $F(1,260) = 20.50$, $MSE = .054$; fragments corresponding to negative primes had poorer completion rates than did fragments corresponding to unrelated primes (Table 2).

There was no main effect of mode, $F(1,260) = 1.13$, $MSE = .072$, but the Mode × Type of Prime interaction was significant, $F(1,260) = 7.61$, $MSE = .054$. Simple main effect analyses indicated that there was a significant blocking effect for visually presented primes, $F(1,139) = 28.76$, $MSE = .053$, but the effect was not significant for aurally presented primes, $F(1,123) = 1.34$, $MSE = .054$.

There was no main effect of level of processing, $F < 1$, $MSE = .072$, nor did level of processing interact with type of prime, $F(1,260) < 1$, or mode, $F(1,260) = 1.01$, $MSE = .072$.

Facilitation. A second 2 × 2 × 2 (Mode × Level of Processing × Type of Prime) ANOVA was computed by using proportion of fragments completed as the dependent measure. Type of prime, a within-subject variable, was unrelated or positive. The effect of type of prime was significant, $F(1,260) = 126.41$, $MSE = .064$; fragments corresponding to correct primes had better completion rates than did unprimed fragments (Table 2).

There were no other significant main effects or interactions in the facilitation analysis. The effect of level of processing was not significant, $F(1,260) = 2.79$, $MSE = .064$, nor was the effect of mode, $F(1,260) = 2.48$, $MSE = .064$.

Table 2

Mean Proportion of Completed Fragments as a Function of Input Modality and Input Level of Processing in Experiment 1

Type of prime	Visual				Aural			
	Shallow ($n = 70$)		Deep ($n = 70$)		Shallow ($n = 57$)		Deep ($n = 67$)	
	M	SE	M	SE	M	SE	M	SE
Positive	.789	.025	.714	.034	.737	.030	.690	.030
Unrelated	.514	.031	.496	.031	.478	.030	.470	.033
Negative	.382	.029	.332	.031	.421	.033	.455	.029
Blocking	−.132		−.164		−.057		−.015	
Facilitation	.275		.218		.259		.220	

Note. Blocking = mean completion with negative primes minus mean completion with unrelated primes; facilitation = mean completion with positive primes minus mean completion with unrelated primes.

Discussion

The results of Experiment 1 replicated the blocking effects found in the pilot experiments, showing that completion rates were poorer for fragments primed with negative primes than for those primed with orthographically unrelated words. A transfer-appropriate processing pattern was found; blocking was not affected by input level of processing, but it was affected by input modality, with visual primes (same modality as test fragments) having a greater effect than aural primes (different modality from test fragments). This pattern is the same as that typically found in facilitative repetition priming paradigms (Blaxton, 1989).

The results of Experiment 1 help explain why primes that are orthographically similar to targets do not inhibit retrieval of target words when the words are cued by their definitions (Brown, 1979; Roediger, Neely, & Blaxton, 1983). A transfer-appropriate processing pattern indicates that perceptual tests should not be affected by primes that do not contain perceptual features of the cues and that semantically cued tests should not be affected by primes that do not contain semantic features of the cues. Word fragment completion, a perceptual test of memory, was not affected by aurally presented primes in Experiment 1 because the auditory primes did not contain the perceptual features of the orthographically similar cues. In Brown's (1979) and Roediger et al.'s (1983) experiments, memory was prompted with a semantic cue; such a test would not be expected to be affected by orthographically similar primes, which share no semantic features with the definitions used as cues.

One anomalous finding of Experiment 1 was that facilitation effects were not significantly affected by modality, as is often found (e.g., Weldon, 1993). The reason for this anomaly is not readily apparent, although the very high rate of fragment completion in the positive priming conditions might represent a ceiling effect of facilitative priming, thus preventing modality effects from being observed.

Experiment 2

It could be that participants in Experiment 1 tried to intentionally recollect primes, thinking it would facilitate

fragment completion performance. If so, then the observed blocking effects could have been caused, at least in part, by an inappropriate recollective strategy, what Anderson and Bjork (1994) have termed an *executive control bias*. If the blocking effects observed in Experiment 1 were caused by intentional recollection of the primes, then a warning to avoid such recollection could conceivably eliminate or decrease the blocking effect. Furthermore, an instruction to intentionally recollect the primes would have little effect on fragment completion if most uninstructed participants were already using such a strategy or if recollection did not affect fragment completion.

On the other hand, if our observed blocking effects were caused by involuntary retrieval of negative primes, then instructions to avoid remembering the primes would not influence blocking effects. Furthermore, an instruction to intentionally recollect primes could conceivably increase blocking because increased recollection of negative primes, added to unintentional retrieval of them, might strengthen blocking effects.

In Experiments 2, 3, and 4 we tested whether the blocking effect could be voluntarily avoided. In these three experiments we examined the effects of instructions on blocking. Would participants be able to avoid blocks if they were warned that remembering negative primes could hinder word fragment completion?

Because stimuli were shown on a television screen and participants wrote responses to word fragments on blank lines on response forms, it was possible for them to mistakenly write down incorrect answers to word fragments. In most cases the incorrect answers were the negative primes. The rates of these intrusions in which negative primes were mistakenly written as answers (intrusions that were not negative primes were not included) are reported for Experiments 2–6.

Method

Participants. The 260 participants were student volunteers from an introductory psychology class.

Materials, design, and procedure. The same materials, design, and procedure used in Experiment 1 were used in Experiment 2,

with the following exceptions. All primes were presented visually, and a deep processing orienting task (affect rating) was used in all conditions. On the fragment completion test the instructions to the control group were the same as the instructions given to participants in Experiment 1. Instructions to the remember group were the same as those to the control group, but they included a statement that participants should try to remember primes to help them complete word fragments. The forget group was told, in addition to the standard control group instructions, that some primes were similar to test fragments but that those primes would not correctly complete the fragments; therefore, forget participants were asked to do their best to avoid remembering primes during the fragment completion test (forget and remember instructions are shown in Appendix B).

Results

Blocking. To assess the blocking effects, a 3 × 2 (Instruction × Type of Prime) ANOVA was computed by using proportion of completed fragments as the dependent measure. Instruction (control, remember, or forget) was a between-subjects variable. Type of prime (negative or unrelated) was a within-subject variable. There was a significant main effect for type of prime, $F(1,257) = 89.45$, $MSE = .051$, again indicating that fragment completion rates were poorest for blocked fragments (Table 3). The main effect of instruction did not reach significance, $F(2,257) = 3.31$, $MSE = .075$. The Type of Prime × Instruction interaction was significant, $F(2,257) = 6.89$, $MSE = .051$. The pattern of means indicates that the blocking effect was greatest in the remember condition (Table 3).

To compare the relative sizes of the blocking effects in each of the three instruction conditions, we computed three simple interaction analyses. The 2 × 2 (Instruction × Type of Prime) ANOVA comparing the control and forget conditions found a significant effect only for type of prime, $F(1,174) = 33.76$, $MSE = .050$, indicating that completion rates were poorer for negatively primed fragments. The effect of instruction ($F < 1$) and the Instruction × Type of

Prime interaction, $F(1,174) = 1.84$, $MSE = .050$, were not significant, indicating that the blocking effect was not significantly different in the control and forget conditions.

The 2 × 2 (Instruction × Type of Prime) ANOVA comparing the control and remember conditions found a significant effect for type of prime, $F(1,173) = 95.23$, $MSE = .048$, again showing a blocking effect. The Instruction × Type of Prime interaction was also significant, $F(1,173) = 6.10$, $MSE = .048$, indicating that the blocking effect in the remember condition was larger than in the control condition. However, the simple main effects of type of prime for both the control group, $F(1,90) = 31.22$, $MSE = .042$, and for the remember group, $F(1,83) = 64.00$, $MSE = .054$, were significant, showing a blocking effect for both groups. The effect of instruction, $F(1,173) = 3.98$, $MSE = .073$, was not significant.

The 2 × 2 (Instruction × Type of Prime) ANOVA comparing the forget and remember conditions found a significant effect for type of prime, $F(1,167) = 58.28$, $MSE = .056$, again showing a blocking effect. The main effect of instruction was also significant, $F(1,167) = 6.19$, $MSE = .071$. This effect was mediated by a significant Instruction × Type of Prime interaction, $F(1,167) = 12.29$, $MSE = .056$, indicating that the blocking effect was greater in the remember condition than in the forget condition. The simple main effect of type of prime in the forget group was nonetheless significant, $F(1,84) = 8.28$, $MSE = .058$.

As previously mentioned, cases in which negative primes were written as answers were referred to as *intrusions.* The proportions of responses that were intrusions (incorrect answers that were not negative primes were not included) were analyzed by a 3 × 2 (Instruction × Type of Prime) ANOVA. Instruction was control, forget, or remember and type of prime was negative or unrelated.[2] There was a significant effect of type of prime, $F(1,257) = 148.55$, $MSE = .025$; far more intrusions were made with negative primes than with unrelated primes (Table 3). The effect of instruction was also significant, $F(2,257) = 22.25$, $MSE = .024$; however, this effect was mediated by a significant Instruction × Type of Prime interaction, $F(2,257) = 28.16$. Simple main effect analyses revealed that the effect of instruction was significant for the negative prime condition, $F(2,257) = 26.91$, $MSE = .046$. Pairwise comparisons showed significant differences[3] between the control and forget conditions, $t(174) = 4.848$, between the control and remember conditions, $t(173) = -2.867$, and between the forget and remember conditions, $t(167) = -7.424$. Thus, all three conditions differed from one another, with the fewest intrusions in the forget condition and the most in the remember condition. Instruction did not have a significant

Table 3
Mean Proportions of Completed Fragments and Intrusions as a Function of Instructions and Type of Prime in Experiment 2

Type of prime	Control (n = 91)		Remember (n = 84)		Forget (n = 85)	
	M	SE	M	SE	M	SE
Positive	.824	.022	.842	.021	.468	.039
Unrelated	.500	.025	.500	.030	.482	.028
Negative	.330	.027	.214	.023	.376	.029
Blocking	−.170		−.286		−.106	
Facilitation	.324		.342		−.014	
Intrusions						
Negative	.192	.023	.298	.032	.056	.006
Unrelated	.011	.001	.003	.033	.021	.002

Note. Blocking = mean completion with negative primes minus mean completion with unrelated primes; facilitation = mean completion with positive primes minus mean completion with unrelated primes; intrusions = proportion of time when a negative prime is given as a response to a fragment.

[2] Because the frequency of intrusions was so low when word fragments were positively primed, we did not include positive priming conditions in the intrusion analyses. The weighted average of the intrusion rates for positively primed word fragments, combined for Experiments 2–6, was .02.

[3] Using a Bonferroni correction with familywise error = .05, we set the significance level for each of the three pairwise comparisons at $\alpha = .0167$.

effect on intrusions for the unrelated prime condition, $F(2,257) = 2.04$, $MSE = .003$.

Facilitation. To assess facilitation effects, we computed a 3×2 (Instruction $\times$ Type of Prime) ANOVA by using proportion of completed fragments as the dependent measure. Instruction (control, remember, or forget) was a between-subjects variable. Type of prime (positive or unrelated) was a within-subject variable. There was a significant main effect for type of prime, $F(1,257) = 98.19$, $MSE = .062$; positive primes led to better completion rates than did unrelated primes (Table 3). There was a main effect of instruction, $F(2,257) = 28.87$, $MSE = .073$, indicating that completion rates were lowest in the forget condition. This effect was mediated, however, by a significant Instruction $\times$ Type of Prime interaction, $F(2,257) = 27.74$, $MSE = .062$. It appears that the control and remember conditions produced facilitation, whereas the forget condition did not. To test this interpretation, we followed up the interaction by three simple interaction analyses.

The 2×2 (Instruction $\times$ Type of Prime) ANOVA comparing the control and forget groups found significant effects for type of prime, $F(1,174) = 29.76$, $MSE = .071$, and instruction, $F(1,174) = 40.54$, $MSE = .076$. Both of these effects, however, were mediated by a significant Instruction $\times$ Type of Prime interaction, $F(1,174) = 35.69$, $MSE = .071$. A simple main effect analysis showed a significant facilitation effect for the control group, $F(1,90) = 100.53$, $MSE = .048$, but not for the forget group ($F < 1$).

The 2×2 (Instruction $\times$ Type of Prime) ANOVA comparing the control and remember conditions found a significant type-of-prime effect, $F(1,173) = 209.31$, $MSE = .046$, showing a facilitation effect. Both the effect of instruction ($F < 1$) and the Instruction $\times$ Type of Prime interaction ($F < 1$) were not significant.

The 2×2 (Instruction $\times$ Type of Prime) ANOVA comparing the remember and forget groups revealed a significant effect of type of prime, $F(1,167) = 32.19$, $MSE = .070$, and instruction, $F(1,167) = 39.37$, $MSE = .083$. Both of these effects, however, were mediated by a significant Instruction $\times$ Type of Prime interaction, $F(1,167) = 38.23$, $MSE = .070$. A simple main effect analysis revealed a significant facilitation effect for the remember group, $F(1,90) = 109.30$, $MSE = .045$, but not for the forget group ($F < 1$).

Discussion

Participants in the control condition showed the same blocking effect seen in Experiment 1. The magnitude of the blocking effect in Experiment 2 did not decrease when participants were instructed to avoid thinking about primes, even though the forget instruction eliminated the positive priming effect. These results indicate that even though the forget instruction made participants avoid or reject correct primes, the instruction did not help them avoid retrieving negative primes.

The remember instruction increased blocking. This result suggests that uninstructed control group participants were not trying to recollect primes on the fragment completion test; if participants were already recollecting primes, then an instruction to recollect would not increase priming effects. This result also implies an interesting source of memory blocking: inappropriate recollective strategies. That is, participants can be even further stumped if they are misled into using inappropriate retrieval strategies, which were encouraged in the remember condition.

The results of Experiment 2 indicate that blocking in word fragment completion is involuntary (e.g., Richardson-Klavehn, Gardiner, & Java, 1994), both in the sense that it is not caused by deliberate remembering and in the sense that it cannot intentionally be avoided. Whether this involuntary retrieval of negative primes is automatic (i.e., requires no attentional resources) or implicit (i.e., occurs without the participant's awareness), however, was not tested in the present study.

Two aspects of the intrusion analyses are noteworthy. One is that there were close to zero intrusions for unprimed word fragments, indicating that it is unlikely that people mistakenly accepted negative primes as correct answers for word fragments. The second noteworthy result is that the forget instruction decreased intrusions and the remember instruction increased intrusions. This latter result indicates that the instructions appear to have affected a verification process in which participants checked the efficacy of retrieved answers to word fragments, causing them to reject inappropriate solutions in the forget condition and to accept them in the remember condition.

A curious and unexpected result of Experiment 2 was the elimination of facilitative priming effects in the forget condition. This result could indicate that the positive priming effect in the control condition was caused by deliberate attempts to retrieve primes and that this intentional strategy was prevented by the forget instruction. Such an interpretation, however, would attribute positive priming to strategic recollection and blocking to nondeliberate retrieval, and it is not clear why the two priming effects, blocking and facilitation, should be caused by different memory processes.

A second interpretation of the lack of positive priming in the forget condition could be that the forget instruction leads participants to inhibit retrieval of the set of primes (e.g., Bjork, 1989), suppressing retrieval of the primes. If this explanation were true, however, it would mean that blocking effects are not reduced when retrieval of negative primes is inhibited.

A third possible explanation for the missing positive priming effect in the forget condition is that participants misunderstood the forget instruction, taking it to mean that primes they recollected would not count as correct answers on the fragment completion test. Thus, participants in that condition might have completed positively primed fragments only when they failed to consciously recollect the corresponding primes. Experiment 3 was conducted to determine whether the anomalous finding was caused by a misunderstanding of the forget instruction.

Experiment 3

In Experiment 3 the instructions given to participants were elaborated to make the relation between the prime list

and the test fragments clearer. The instruction to forget the primes, which was given to all participants in Experiment 3, included an extra statement in which participants were told that although they should try not to think about the primes, if they thought of a word that solved a test fragment, then they should write that word on the response form, whether or not it was remembered from the prime list. This extra instruction was intended to disambiguate the forget instruction, making it clear that any correct fragment completion was acceptable, whether or not it was recollected.

Method

Participants. The 51 participants were student volunteers from an introductory psychology class.

Materials, design, and procedure. The same materials, design, and procedure used in Experiment 2 were used in Experiment 3, with two exceptions. First, all participants in Experiment 3 were given the forget instruction. Second, in addition to the forget instructions described in Experiment 2, the forget condition participants in Experiment 3 were told to write any solution that would accurately complete a fragment, regardless of whether they thought it had been a prime (see Appendix B).

Results

Blocking. A one-way (type of prime) ANOVA was computed to assess blocking by using proportion of completed fragments as the dependent measure. Type of prime, a within-subject variable, was negative or unrelated. There was a significant main effect for type of prime, $F(1,50) = 19.95$, $MSE = .049$, indicating that fragment completion rates were poorer for blocked fragments (Table 4).

Another one-way (type of prime) ANOVA was computed by using the proportion of responses that were intrusions as the dependent measure. Type of prime was negative or unrelated. The main effect for type of prime, $F(1,50) = 3.77$, $MSE = .016$, was not significant (Table 4).

Facilitation. Another one-way ANOVA was computed to assess facilitative priming by using proportion of completed fragments as the dependent measure. Type of prime, a

Table 4
Mean Proportion of Completed Fragments and Intrusions as a Function of Type of Prime in Experiment 3

Type of prime	M	SE
Positive	.667	.042
Unrelated	.509	.030
Negative	.314	.035
Blocking	−.205	
Facilitation	.158	
Intrusions		
Negative	.078	.022
Unrelated	.029	.011

Note. n = 51. Blocking = mean completion with negative primes minus mean completion with unrelated primes; facilitation = mean completion with positive primes minus mean completion with unrelated primes; intrusions = proportion of time when a negative prime is given as a response to a fragment.

within-subject variable, was negative or unrelated. There was a significant positive priming effect, $F(1,50) = 9.48$, $MSE = .066$; fragments corresponding to positive primes were solved at a higher rate than were unprimed fragments (Table 4).

Discussion

The robust blocking effect found in Experiment 3, as in Experiment 2, occurred in spite of the forget instruction. Again, this finding supports the notion that blocking in word fragment completion is caused by unintentional retrieval of negative primes and cannot voluntarily be avoided or escaped.

As in Experiment 2, the forget instruction minimized the intrusion rate, making the frequency of intrusions not significantly higher following negative primes than with unprimed word fragments. The low intrusion rate with the forget instruction, coupled with the failure to eliminate the blocking effect, supports the conclusion that the instruction affected a verification process rather than influencing involuntary retrieval of negative primes.

The clarified instructions used in Experiment 3 appeared to have affected positive priming in the predicted manner. That is, even though it had been eliminated in Experiment 2, there was a significant positive priming effect in Experiment 3, indicating that participants were able to benefit from retrieved primes.

Experiment 4

Although the blocking effects seen in Experiments 2 and 3 appear to have been involuntary, it may be that the forget instruction was too general to have been used effectively by participants. That is, the occasional retrieval of correct answers (positive primes) may have undermined the participants' ability or motivation to suppress memory of the primes, thus weakening the response set suppression. When encountering a fragment that corresponded to a negative prime, participants may have failed to suppress the response set. Therefore, in Experiment 4, each of the four critical blocked fragments was identified to participants in advance with asterisks, which were shown on the screen a few seconds before each of the four blocked fragments. It was predicted that this specific warning system would diminish the blocking effect in Experiment 4. Furthermore, if participants are able to "switch on and off" their suppression of the primes, then the positive priming effect should not be affected by the forget instruction in Experiment 4, as it was in Experiment 2. This prediction was made because there were no warnings (asterisks) before positively primed fragments.

Method

Participants. The 186 participants were student volunteers from an introductory psychology class.

Materials, design, and procedure. The same materials, design, and procedure used in Experiment 3 were used in Experiment 4, with the following exception. Besides the instructions described in

Experiment 3, forget participants in Experiment 4 were also told that if a word fragment was similar to a negative prime, it would be indicated by a beep and a row of asterisks shown on the screen for 3 s before presentation of the fragment. Forget participants were told to avoid remembering primes while trying to solve those few word fragments that were preceded by warning asterisks (see Appendix B).

Results

Blocking. A 2 × 2 (Instruction × Type of Prime) ANOVA was computed by using proportion of completed fragments as the dependent measure. Instruction, a between-subjects variable, was control or forget. Type of prime, a within-subject variable, was negative or unrelated. There was a significant main effect for type of prime, $F(1,184) = 31.08$, $MSE = .047$, again indicating that fragment completion rates were poorer for blocked word fragments (Table 5). The main effect of instruction was not significant ($F < 1$).

The Type of Prime × Instruction interaction was not reliable, $F(1,184) = 3.65$, $MSE = .047$, although the effect was marginally significant ($p = .06$). Simple main effects of blocking were found for both control, $F(1,88) = 31.91$, $MSE = .040$, and forget, $F(1,96) = 6.13$, $MSE = .054$, conditions.

Another 2 × 2 (Type of Prime × Instruction) ANOVA was computed for the proportion of responses that were intrusions. The analysis revealed a significant effect of type of prime, $F(1,184) = 19.76$, $MSE = .021$; considerably more intrusions were found for negatively primed fragments than for unprimed ones. The effect of instruction was also significant, $F(1,184) = 51.44$, $MSE = .487$. This effect was mediated, however, by a significant Instruction × Type of Prime interaction, $F(1,184) = 51.89$, $MSE = .021$. Simple main effect analyses revealed that there were more intrusions in the control condition than in the forget condition for the negatively primed fragments, $F(1,184) = 51.44$, $MSE = .031$, and more intrusions in the forget condition than in the

Table 5
Mean Proportion of Completed Fragments and Intrusions as a Function of Instructions and Type of Prime in Experiment 4

Type of prime	Control (n = 89)		Forget (n = 97)	
	M	SE	M	SE
Positive	.775	.023	.686	.028
Unrelated	.447	.025	.412	.024
Negative	.278	.022	.330	.026
Blocking	−.169		−.082	
Facilitation	.329		.274	
Intrusions				
Negative	.197	.021	.013	.001
Unrelated	.022	.002	.054	.005

Note. Blocking = mean completion with negative primes minus mean completion with unrelated primes; facilitation = mean completion with positive primes minus mean completion with unrelated primes; intrusions = proportion of time when a negative prime is given as a response to a fragment.

control condition for the unprimed fragments, $F(1,184) = 4.60$, $MSE = .010$; see Table 5.

Facilitation. A 2 × 2 (Instruction × Type of Prime) ANOVA was computed to assess facilitative priming. Instruction, a between-subjects variable, was control or forget. Type of prime, a within-subject variable, was positive or unrelated. There was a significant main effect for type of prime, $F(1,184) = 150.28$, $MSE = .056$, indicating that fragment completion rates were better for positively primed fragments than for unprimed ones (Table 5). The main effect of instruction was also significant, $F(1,184) = 5.62$, $MSE = .064$; more fragments were completed in the control condition than in the forget condition. The Type of Prime × Instruction interaction was not significant, $F(1,184) = 1.28$, $MSE = .056$.

Discussion

In spite of heavy-handed and specific warnings in the forget condition to avoid recalling primes on the four critical word fragment trials, participants nonetheless showed a blocking effect. Although a trend suggested that blocking may have been somewhat smaller in the forget condition than in the control condition, the blocking effect for the forget group alone was significant. Therefore, it can be concluded that blocking in the forget condition was caused by involuntary retrieval of negative primes.

The forget instruction again reduced the frequency of intrusions for word fragments associated with negative primes. Thus, the forget instruction may have alerted participants to check the accuracy of their responses more carefully before writing them down. This extra verification process could have slightly mitigated the observed blocking effect in the forget condition by encouraging participants to "try again" on a fragment once the first response had been rejected.

Curiously, the forget instruction and asterisk cues, targeted specifically and solely at negatively primed fragments, decreased fragment completion levels when only positive and unrelated items were analyzed, although positive priming, per se, was not significantly reduced. This result, combined with the slight (albeit nonsignificant) reduction of both blocking and facilitation, could be a hint that retrieval inhibition may have been acting on all of the primes in the forget condition. Further research will be needed to assess this possibility.

Experiment 5

Although we tried to minimize deliberate retrieval of primes in the first four experiments, we may not have eliminated it altogether. One potential problem could be that the duration of fragment presentations, which was 5 s in the reported experiments, could have allowed some time for deliberate recollection. Weldon (1993) found that cross-modal priming in fragment completion was marginally present at 5-s fragment exposures, suggesting that 5 s may allow enough time for deliberate recollection. Therefore, in Experiment 5 fragments were shown for 1.5-s durations to

further reduce the contribution of conscious recollection to fragment completion performance.

A second problem could have been caused by the proportion overlap of the stimuli, defined as the proportion of the primes that are correct solutions (e.g., Challis & Roediger, 1993; Roediger & McDermott, 1993). Although Challis and Roediger (1993) found no evidence of proportion overlap effects, it is nonetheless conceivable that having correct fragment solutions as 25% of our prime list could have encouraged conscious recollection of primes, thereby trapping participants when they encountered fragments corresponding to negative primes. In Experiment 5 we varied the composition of fillers (fragments other than the critical items) in the lists. In the positive fillers condition, the 12 filler fragments all corresponded to correct primes; whereas in the negative fillers condition, the 12 filler fragments corresponded to negative primes. In the unrelated fillers condition, the filler fragments were orthographically dissimilar to primes. This proportion overlap manipulation served as a check to help determine whether the very brief exposure durations of word fragments in Experiment 5 truly eliminated recollection. If deliberate recollection is encouraged by positive fillers and discouraged by negative fillers, then blocking (and facilitation) should be greatest in the positive fillers condition and smallest in the negative fillers condition. If blocking is caused by involuntary retrieval, then the type of fillers used should not affect blocking.

Method

Participants. The 125 participants were student volunteers from an introductory psychology class.

Materials. The list of 24 primes consisted of 12 words corresponding to the critical fragments (the same as those used in Experiments 1–4), plus 12 filler primes that corresponded to 12 filler word fragments. In the positive fillers condition, all 12 filler primes were correct solutions to filler fragments, producing a prime list with 16 positive primes (i.e., the 12 filler primes plus 4 critical primes), 4 negative primes, and 4 unrelated primes. In the negative fillers condition, all 12 filler primes were negative primes, yielding a list with 16 negative primes, 4 positive primes, and 4 unrelated primes. In the unrelated fillers condition, all filler primes were orthographically dissimilar to fragments, leaving only 4 correct primes and 4 negative primes in the prime list.

Design and procedure. The procedure was the same as described for the control conditions in Experiments 2 and 4, except that fragments were shown on the screen for only 1.5 s, with 5 s to write each response. Type of prime (positive, unrelated, and negative) was varied within subject and counterbalanced between subjects as in Experiments 1–4. Filler type was varied between subjects and was positive, unrelated, or negative fillers.

Results

Blocking. A 3 × 2 (Filler Type × Type of Prime) ANOVA was computed by using the proportion of correct fragment completions as the dependent measure. Filler type, a between-subjects variable, was positive, negative, or unrelated fillers. Type of prime was negative or unrelated. There was a significant effect of type of prime, $F(1,195) = 93.47, MSE = .039$, showing a robust blocking effect (Table

Table 6

Mean Proportion of Completed Fragments and Intrusions as a Function of Fillers and Type of Prime in Experiment 5

Type of prime	Negative (n = 63)		Unrelated (n = 61)		Positive (n = 74)	
	M	SE	M	SE	M	SE
Positive	.770	.028	.766	.032	.811	.027
Unrelated	.373	.033	.344	.028	.351	.027
Negative	.167	.026	.152	.022	.169	.020
Blocking	−.206		−.193		−.182	
Facilitation	.397		.422		.459	
Intrusions						
Negative	.274	.034	.369	.034	.453	.031
Unrelated	.032	.011	.066	.014	.044	.011

Note. Blocking = mean completion with negative primes minus mean completion with unrelated primes; facilitation = mean completion with positive primes minus mean completion with unrelated primes; intrusions = proportion of time when a negative prime is given as a response to a fragment.

6). The effect of filler type was not significant ($F < 1$), nor was there a significant Filler Type × Type of Prime interaction ($F < 1$).

Another 3 × 2 (Filler Type × Type of Prime) ANOVA was computed by using the proportion of responses that were intrusions as the dependent measure. There was a significant effect of type of prime, $F(1,195) = 265.92, MSE = .037$; more intrusions were found for negatively primed fragments than for unprimed ones. There was also a significant effect of filler type, $F(2,195) = 7.35, MSE = .043$. This effect was mediated, however, by a significant Filler Type × Type of Prime interaction, $F(2,195) = 6.56, MSE = .037$. Simple main effect analyses revealed that the effect of filler type was significant for the negative prime condition, $F(2,195) = 7.65, MSE = .071$. Pairwise comparisons showed significant differences (see footnote 3) between the positive and negative filler conditions, $t(135) = −3.924$. The unrelated fillers condition, however, did not significantly differ from the negative fillers condition, $t(122) = −1.971$, or the positive fillers condition, $t(133) = 1.823$; see Table 6. Filler type did not affect intrusions in the unprimed condition, $F(2,195) = 1.92, MSE = .010$.

Facilitation. A 3 × 2 (Filler Type × Type of Prime) ANOVA was computed to assess facilitation priming. Filler type, a between-subjects variable, was positive, negative, or unrelated fillers. Type of prime was positive or unrelated. There was a significant positive priming effect, $F(1,195) = 345.48, MSE = .042$. Both the main effect of filler type ($F < 1$) and the Filler Type × Type of Prime interaction ($F < 1$) were not significant. The facilitation effects for the three conditions are shown in Table 6.

Discussion

The finding of robust blocking regardless of filler type suggests once again that the blocking effect is caused by involuntary retrieval of negative primes. The use of positively primed filler items was expected to encourage deliberate recollection of the critical primes, and the use of

negatively primed fillers was expected to discourage such recollection. If such was the case in Experiment 5, then it is clear that the observed blocking effects found were not due to deliberate recollection of primes because there were no differences in blocking for the three treatments.

The analyses of intrusions in Experiment 5 echo similar results found in Experiments 2, 3, and 4. Having numerous negatively primed filler fragments on their test should teach and encourage participants to reject unintentionally retrieved negative primes, just as the forget instruction did in Experiments 2, 3, and 4. Likewise, both the forget instruction in Experiments 2, 3, and 4 and the blocked filler fragments in Experiment 5 reduced levels of intrusions, even though the same manipulations did not mitigate the negative effects of negative primes on correct fragment completion rates. The finding that rejection of involuntarily retrieved negative primes did not improve fragment completion rates shows that the blocking effect persisted over the relatively brief times given in Experiments 1–5. Whether this blocking effect persists for longer times was tested in Experiment 6.

Experiment 6

The fragment exposure durations used in Experiments 1–5 were somewhat faster than the typical case, in which word fragments may appear for 10 s or more (Weldon, 1993). To generalize our results to paradigms that use longer fragment exposure durations, we used a 10-s exposure time for fragments in Experiment 6.

Method

Participants. The 154 participants were student volunteers from an introductory psychology class.

Materials. The same materials used in Experiment 5 were used in Experiment 6.

Design and procedure. The design and procedure for Experiment 6 were the same as for Experiment 5, except that test fragments were presented for 10 s each with a 5-s pause between fragments, and the unrelated fillers condition was omitted.

Results

Blocking. A 2 × 2 (Filler Type × Type of Prime) ANOVA was computed by using the proportion of correct fragment completions as the dependent measure. Filler type (positive vs. negative fillers) was a between-subjects variable. Type of prime (negative or unrelated) was a within-subject variable.

There was a significant effect of type of prime, $F(1,152) = 32.48$, $MSE = .050$, again showing a robust blocking effect (Table 7). The effect of filler type was not significant, $F(1,152) = 1.46$, $MSE = .089$, nor was there a significant Filler Type × Type of Prime interaction ($F < 1$).

A 2 × 2 (Filler Type × Type of Prime) ANOVA was computed by using the proportion of responses that were intrusions as the dependent measure. Intrusions were significantly more frequent for negatively primed fragments than for unprimed ones, $F(1,152) = 48.84$, $MSE = .014$. The effect of filler type was also significant, $F(1,152) = 40.17$,

Table 7
Mean Proportion of Completed Fragments and Intrusions as a Function of Fillers and Type of Prime in Experiment 6

Type of prime	Negative (n = 73)		Positive (n = 81)	
	M	SE	M	SE
Positive	.805	.025	.836	.024
Unrelated	.514	.035	.488	.025
Negative	.384	.029	.327	.031
Blocking	−.130		−.161	
Facilitation	.291		.348	
Intrusions				
Negative	.041	.014	.179	.020
Unrelated	.003	.003	.025	.008

Note. Blocking = mean completion with negative primes minus mean completion with unrelated primes; facilitation = mean completion with positive primes minus mean completion with unrelated primes; intrusions = proportion of time when a negative prime is given as a response to a fragment.

$MSE = .012$; more intrusions were found with positive fillers than with negative fillers (Table 7). The Filler Type × Type of Prime interaction was also significant, $F(1,152) = 18.03$, $MSE = .014$, indicating that filler type had a bigger effect on intrusions for the negatively primed fragments than for the unprimed ones. However, simple main effect analyses revealed that filler type had a significant effect on intrusions for both the negatively primed items, $F(1,152) = 31.44$, $MSE = .023$, and the unprimed ones, $F(1,152) = 5.15$, $MSE = .003$, with more intrusions in the positive filler condition than in the negative filler condition.

Facilitation. A 2 × 2 (Filler Type × Type of Prime) ANOVA was computed to assess facilitation priming. Filler type (positive vs. negative fillers) was a between-subjects variable. Type of prime (positive or unrelated) was a within-subject variable.

There was a significant facilitation effect, $F(1,152) = 168.14$, $MSE = .047$. The main effect of filler type was not significant ($F < 1$). The Filler Type × Type of Prime interaction was not significant, $F(1,152) = 1.37$, $MSE = .047$. The facilitation effects are shown in Table 7.

Discussion

Once again, robust blocking effects were found, and, again, the composition of fillers (positive vs. negative) had no effect on blocking. This replicates the lack of a proportion overlap effect found in Experiment 5. The intrusion analysis showed further that even if unintentionally retrieved negative primes are rejected, the blocking effect still cannot be evaded for 10 s.

The findings of Experiment 6 extend the blocking effect to more typical word fragment completion paradigms that give 10 s or more for each fragment. One implication of this result could be that typical fragment completion studies should be careful to avoid using primes that are orthographically similar to any critical test fragments because blocking from such primes could diminish estimates of facilitative priming effects.

Experiment 7

Semantic memory blocking effects were reported by Brown (1979), who found that participants were slower at answering general knowledge questions when semantically related primes had been seen before the definition. The conclusion that automatic spreading inhibition had occurred, however, was challenged by Roediger et al. (1983), who pointed out that Brown's priming procedure always involved presenting at least some correct primes before the definitions used to cue semantic memory. Roediger et al. stated that Brown's inclusion of correct primes could have induced participants to consider the appropriateness of primes when definitions were presented, thereby delaying retrieval of the correct targets when negative primes were used. If so, then Brown's observed semantic memory blocking effects could not be attributed to inhibition but rather to deliberate processes. In Experiments 1–6 the inclusion of even a small number of correct primes might have likewise encouraged deliberate retrieval of primes, in spite of the abundance of incorrect primes (Experiments 5 and 6) and explicit warnings to avoid retrieving them. Therefore, in Experiment 7 no correct primes were given in the priming task.

In Experiments 1–6, the proportion of word fragments related to primes (either positively or negatively) was relatively high. This high proportion overlap (Challis & Roediger, 1993) could have served to reinstate the priming context, thereby enhancing or encouraging retrieval of negative primes. In Experiment 7 the proportion overlap was manipulated in the blocking conditions. In the high-overlap blocking condition, two thirds of the filler word fragments corresponded to negative primes; in the low-overlap blocking condition, no filler fragments corresponded to primes. Furthermore, only four critical items (10% of the test items) were presented, thus minimizing the overlap between the primes and the test fragments.

Although intrusions in the unprimed conditions of the previous experiments were virtually nonexistent, it may have been possible that participants sometimes thought that negative primes were correct answers for test word fragments. Therefore, a procedural change in Experiment 7 involved presenting test word fragments on participants' paper test forms rather than on a television screen. In Experiment 7 participants merely filled in the blanks of test fragments to complete the words rather than writing whole words on their blank forms, thereby eliminating the possibility that they would mistakenly accept negative primes as correct completions for test word fragments.

Method

Participants. One hundred and sixty-five student volunteers from introductory psychology classes served as participants in Experiment 7.

Materials. The same 40 word fragments were tested in all three conditions used in Experiment 7. All fragments were seven letters in length and contained two or three blank spaces. Four critical test fragments were drawn from the list shown in Appendix A. None of the remaining 36 filler fragments began with the same letters as the

four critical items. The 40 word fragments were printed in black uppercase letters on white paper with extra spaces between letters and underlining was used to denote missing letters. The fragments were arranged vertically in columns on two pages with one column of 20 items per page and with several spaces vertically separating each fragment.

A set of 71 seven-letter words was used for the lists of primes. The list used for the control group contained 40 words, none of which began with the same first letters as the 4 critical test fragments. The list used for the low-overlap blocking group was the same as the control group's list except that four unrelated primes, in which the sequential positions were distributed within the middle three fourths of the prime list, were replaced with negative primes corresponding to the 4 critical test fragments. The prime list for the high-overlap blocking group was the same as the low-overlap group's list except that 27 of the 36 unrelated fillers were replaced with negative primes corresponding to 36 of the filler word fragments. In the high-overlap condition the 9 fragments corresponding to the remaining unrelated fillers were placed sequentially after the last critical fragment; thus, all word fragments seen before the fourth critical fragment were negatively primed.

The primes were printed in black uppercase letters on white paper and were arranged vertically in columns on two pages, with a rating scale (−3 to +3) printed next to each prime and with several spaces vertically separating items. A double-thickness piece of white paper was used as a mask to uncover primes and fragments. The four pages (two for primes and two for word fragments) were stapled together in a booklet, which was covered by the mask when participants were given their materials.

Design. The three experimental treatments were manipulated between subjects. The primes seen by the control group were all orthographically dissimilar to the word fragments. The low-overlap blocking group saw 36 of the same dissimilar primes plus 4 negative primes that corresponded to the four critical word fragments. The high-overlap blocking group saw the 4 critical negative primes, 27 negative primes that corresponded to filler word fragments, and 9 unrelated primes. Participants were randomly assigned to the three treatment conditions by covering up the booklets for all three conditions with masks, randomizing the order of the booklets, and passing out booklets for all conditions to the groups of participants.

Procedure. After participants were seated and given test booklets, they were given the word rating task described in Experiment 1. Beginning with the mask covering all of the primes, they uncovered words successively from the top of the page downward. Every 10 s the experimenter gave a verbal signal to rate the next word.

After they completed the priming task, participants were given instructions for the fragment completion test. All participants were told that words from the previous task might look similar to solutions to the word fragments but that none of those words could correctly complete any fragments. They were also informed that our previous experiments had shown that thinking of the primes impaired fragment completion performance, and, therefore, they should avoid thinking of the primes (see Appendix B).

Beginning with the mask covering all of the word fragments, participants uncovered test items successively from the top of the page downward. Every 10 s the experimenter gave a verbal signal to move on to the next word fragment. Both pages of word fragments were tested in this manner.

Results

A one-way ANOVA with three between-subjects levels (control, low-overlap blocking, and high-overlap blocking)

was computed by using the proportion of the four critical word fragments completed as the dependent measure. There was a significant effect of the experimental treatments, $F(2,160) = 7.24$, $MSE = .238$. Pairwise comparisons showed that the control group completed significantly (see footnote 3) more word fragments than did the high-overlap blocking group, $t(105) = 3.880$, and that the low- and high-overlap blocking groups did not significantly differ from each other, $t(108) = 1.738$. Although the control group completed 10% more of the critical word fragments than did the low-overlap blocking group, the t test comparing these conditions was only marginally significant, $t(107) = 2.068$. The means for the three groups are shown in Table 8.

Another one-way ANOVA compared the three treatment groups by using solutions on only the first critical word fragment of the test as the dependent measure. This analysis was undertaken because before the first critical word fragment, neither the control group nor the low-overlap blocking group had seen any fragments related to the primes. There was a significant effect of the treatments, $F(2,160) = 7.51$, $MSE = .230$. Pairwise comparisons showed that the first critical word fragment was completed significantly more often by the control group than by the low-overlap blocking group, $t(107) = 2.818$, or the high-overlap blocking group, $t(105) = 3.851$. The low- and high-overlap blocking groups did not significantly differ from each other, $t(108) = 0.970$; see Table 8.

Discussion

No positive primes were presented in Experiment 7, and the proportion of the test fragments related to the primes in the low-overlap blocking condition was low (10%). Nonetheless, a significant blocking effect in word fragment completion was again found, as in the previous experiments. This result shows that the presence of positive primes on the word fragment completion test is not a precondition for blocking effects.

Furthermore, the presence of negative primes before critical test fragments was also not a necessary precondition for blocking. A significant blocking effect was found comparing the control and low-overlap blocking groups on the first critical word fragment that appeared on the test. The possibility that negatively primed fragments seen before critical test fragments might have reinstated the prime list context, thereby causing the blocking effect, was not supported.

Table 8
Mean Proportion of Critical Fragments Completed as a Function of Condition in Experiment 7

Item	Control (n = 53)		Low overlap (n = 56)		High overlap (n = 54)	
	M	SE	M	SE	M	SE
All items	.703	.032	.607	.033	.528	.031
First item	.755	.060	.500	.067	.407	.067

In the first six experiments, test fragments were shown on a television screen, and participants wrote responses on blank lines of their test forms. This procedure allowed participants to write down intrusions that did not correctly complete test fragments. In Experiment 7, however, test fragments were printed on the test forms, and participants had only to fill in the blank spaces with letters, a procedure that eliminated the chances of mistakenly writing negative primes as answers for test word fragments. Therefore, the blocking effects found in Experiment 7 do not appear to have been caused by a procedure that might have caused inadequate monitoring of word fragment answers.

General Discussion

In the present article we report seven experiments, all of which found blocking or interference effects in word fragment completion, a primarily data-driven test often used to assess implicit memory. Blocking was achieved by priming with words that were orthographically similar to word fragment solutions. The same procedures that produced blocking also produced a repetition priming effect, a typical demonstration of perceptually based memory. It can be inferred that the blocking effect was caused by involuntary retrieval of negative primes.

In Experiment 1 the memory blocks followed a transfer-appropriate processing pattern, as do word fragment completion tests that measure facilitative repetition priming effects. Word fragment completion is a largely data-driven task, particularly when a relatively brief time is given to solve each fragment (e.g., Weldon, 1993), as in the present experiments. Performance on a word fragment completion test is affected primarily by perceptual input manipulations rather than by conceptual ones. Experiment 1 showed that blocking was affected by the perceptual manipulation of sense modality at input (visual vs. aural) but not by the manipulation of level of processing at input (shallow vs. deep). These results represent a transfer-appropriate processing pattern.

The present results are also consistent with Ratcliff and McKoon's (e.g., Ratcliff & McKoon, 1995a, 1995b) *bias* principle. This principle states that processing of an item is biased to be consistent with prior processing of that item. Bias, defined in this way, explains not only the typical facilitative priming effects seen in numerous studies but also predicts interference effects such as those reported in the present set of experiments. The tendency to retrieve recently presented negative primes when participants see orthographically similar word fragments is an example of the cost of bias. This cost is the typical result when a similar (but different) stimulus requires a response different from the one previously encountered (Ratcliff & McKoon, 1995a). The results of the present set of experiments extend the generality of Ratcliff and McKoon's (1995a) findings of bias in stem and fragment completion paradigms.

The memory blocks we have induced could not be avoided by participants who had been warned about them. Four different experiments showed that participants who had been instructed not to think of the primes nonetheless

showed blocking effects. Blocking occurred even when critical fragments that corresponded to negative primes were singled out and identified in advance for participants. The specific warnings given to *forget* groups for the critical fragments in Experiment 4 clearly reduced incorrect intrusions, and slightly mitigated the blocking effect, but did not eliminate blocking.

A similar pattern could be seen in Experiments 5 and 6 when participants learned for themselves that deliberate retrieval of primes was counterproductive. Those who saw many negatively primed filler fragments in Experiments 5 and 6 were better able to reject intrusions, but they were nonetheless unable to evade blocking effects in fragment completion. This pattern of results is consistent with the idea that without special warnings participants accepted involuntarily retrieved negative primes as correct solutions, but participants who had been warned through instructions or who had seen many negative filler fragments were more likely to reject the intruded memories and make an extra attempt to retrieve the correct solution. Even if warnings helped participants reject incorrect solutions to fragments, they did not help participants resolve the blocks.

Another interesting possibility raised by the present results is that the forget instruction (Experiments 2, 3, and 4) could have induced suppression or inhibition of the prime list. The elimination of positive priming in Experiment 2 could have been caused by retrieval inhibition. The return of the facilitative priming effect with clarified instructions in Experiment 3, however, shows that at least part of the disappearance of positive priming in Experiment 2 could have also been due to an "overzealous" verification-falsification process; that is, participants may have rejected any fragment solutions that were recognized as primes, whether the solutions were correct or not. Participants in Experiment 4, however, had no reason to reject positive primes because the warnings were specific; asterisks appeared as warnings only for negatively primed fragments. The facilitation analysis in Experiment 4 nonetheless found a reduction in completion rates for the forget condition. Thus, the forget instruction could have caused inhibition of the set of primes. If the forget instruction did induce retrieval inhibition, it is nonetheless clear that such inhibition did not prevent the involuntary retrieval of negative primes when participants saw corresponding word fragments. This interpretation is consistent with studies that have found that directed forgetting of a list of words can block explicit memory of the list without disrupting implicit memory (e.g., Basden, Basden, & Gargano, 1993; Bjork & Bjork, 1990; Paller, 1990).

The memory blocking effects in the present study resemble phenomena in which memory of experimental events is tested, including proactive and retroactive interference (e.g., Postman & Underwood, 1973), part-list cuing effects (e.g., Nickerson, 1984), directed forgetting (e.g., Bjork, 1972), posthypnotic forgetting (e.g., Kihlstrom, 1983), and retrieval-induced forgetting (e.g., Anderson et al., 1994), as well as phenomena in which preexperimental knowledge is tested, as in tip-of-the-tongue states (e.g., Jones, 1989), negative priming (e.g., Stadler & Hogan, 1996), and inhibi-

tory orthographic priming (e.g., Grainger, 1990). In each of these cases information in memory, whether episodic or semantic in nature, is at least temporarily blocked from consciousness by an experimental manipulation. To this growing list of memory blocking phenomena, the present word fragment completion results add findings that a data-driven memory test, often used as evidence of implicit memory, can also be used to explore retrieval blocks.

A theoretical account of the present results is at present somewhat speculative; whether our blocking effects were caused by associative bias (i.e., a tendency to retrieve inappropriate associates), cue bias (i.e., a tendency to encode a cue inappropriately), or target bias (i.e., inhibition of the intended target; Anderson & Bjork, 1994), cannot clearly be determined by the present results. However, the evidence we present bears on at least one mechanism, namely, executive control processes (Anderson & Bjork, 1994). An executive control bias, according to Anderson and Bjork's taxonomy, refers to decisions made by people concerning how to search memory. An executive control bias probably caused an increase in the blocking effect in Experiment 2, in which an instruction to use retrieved primes caused an increase in blocking. Assuming that executive control was likewise affected by instructions to avoid recalling primes and by experience with numerous negative fillers (and no positive primes, as in Experiment 7), it can tentatively be concluded that decisions to deliberately retrieve primes were not necessary for the observation of blocking effects. It should be acknowledged, however, that our manipulations of executive control processes were by no means perfect; the possibility remains that some degree of deliberate retrieval could have occurred in spite of our experimental manipulations.

The blocking effects we have reported appear to be different from the negative priming results reported by many others (e.g., Neill, 1977; Neill & Valdes, 1992; Tipper, 1985). An important difference between typical negative priming effects and the present blocking effects in word fragment completion is that the methods used in the present experiments did not involve having participants ignore or reject target words at any time before the critical test, as is the case in negative priming studies. Furthermore, under most conditions that have been reported, negative priming decays after a few seconds (e.g., Neill & Valdes, 1992). In the present experiments, several minutes intervened between the presentation of a prime and the corresponding fragment. It seems unlikely that an effect that typically fades in seconds would persist for minutes. On the other hand, DeSchepper and Treisman (1996) reported a case in which negative priming effects could be detected even after a month, although that study tested only novel shapes, rather than words, as in the present study.

The blocking effects in the present study may appear to be at odds with studies that have not found inhibitory effects of orthographically similar cues (e.g., Blaxton, 1989; Brown, 1979; Roediger et al., 1983). Blaxton (1989) found that recall of target words from a studied list is facilitated when graphemically similar words are used as retrieval cues. The present results, showing that orthographically similar primes

can impede access to words, might appear to be a contradictory finding. There are important procedural differences between Blaxton's experiments and the present ones, however, including the fact that the memory targets in Blaxton's study were episodic memories, whereas in the present experiments the targets were semantic memories. It may be that graphemic cues may be useful for cuing episodic memories (as in Blaxton's study) but not for distinguishing among lexical memories (as in the present study).

Other results that may appear contradictory to the present ones are Brown's (1979) and Roediger et al.'s (1983) findings that orthographic primes did not inhibit recall of words from their definitions. A key difference between those experiments and the present ones, however, is that Brown and Roediger et al. used semantic cues (definitions), whereas in our experiments we used orthographic cues (word fragments). It seems likely that semantically cued memories are not affected by orthographically similar primes because such primes do not contain semantic features of the cues.

The present research addresses some issues that may involve unconscious blocks. One such question concerns fixation in problem solving, an impediment to solutions caused by the use of inappropriate representations and wrong approaches to problems (e.g., Dominowski, 1995). Smith (1994, 1995) proposed that fixation can occur when memory of recent events provides an inappropriate representation or approach to a problem. It is possible that inappropriate solutions are involuntarily retrieved because of prior experience and, further, that such blocks cannot deliberately be avoided, as was the case in our fragment completion experiments. The present results could also have implications for certain clinical disorders that involve memory, such as repression (e.g., Bower, 1990; Erdelyi & Goldberg, 1979) and obsessive–compulsive disorder (*Diagnostic and Statistical Manual of Mental Disorders*, 4th ed.; American Psychiatric Association, 1994). Linking the present results with such clinical phenomena, however, is highly speculative and would require a great deal of additional research before such a link could be claimed with any confidence. The relatively small number of items used in the present study, and the vast differences between our laboratory task and ecologically valid situations, are but two of the more obvious reasons to be cautious in generalizing the present results.

The results of the present experiments demonstrate a clear and consistent memory blocking effect in a word fragment completion paradigm. The effect was caused by exposure to negative primes that were orthographically similar to target word fragments. Blocking was unavoidable, even when participants were explicitly warned to avoid thinking about prime words. These results indicate that retrieval of negative primes and the resulting memory blocks can occur involuntarily.

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Appendix A

Targets, Negative Primes, and Word Fragments

Target	Negative prime	Fragment
ALLERGY	ANALOGY	A_L__GY
BAGGAGE	BRIGADE	B_G_A_E
CATALOG	COTTAGE	C_TA__G
CHARITY	CHARTER	CHAR_T_
COUNTRY	CLUSTER	C_U_TR_
CULPRIT	CRUMPET	CU_P__T
DIGNITY	DENSITY	D__NITY
FAILURE	FIXTURE	F_I_URE
HISTORY	HOLSTER	H_ST_R_
TANGENT	TONIGHT	T_NG__T
TRAGEDY	TRILOGY	TR_G__Y
VOLTAGE	VOYAGER	VO__AGE

Appendix B

Instructions to Forget and Remember Groups

Experiment 2: Remember Group Instructions

Some of the words that were on the earlier word rating test, but not all of them, are the correct solutions to the word fragments that you are about to see. It will help you to complete these fragments if you try to remember the words from the word rating task.

Experiment 2: Forget Group Instructions

Some of the words that were on the earlier word rating test, but not all of them, are similar to the word fragments that you are about to see, but they are incorrect answers. Our experiments have shown that thinking of those similar words blocks people from thinking of the correct answers. We want to see if you can avoid these blocks by trying not to think of the words from the word rating task. On the test, try your best to avoid thinking of the words from the word rating task.

Experiment 4: Forget Group Instructions

The solutions to a few of the word puzzles are very similar to words that you saw on the word rating task, but those words will NOT correctly solve the puzzles. Our experiments have shown that thinking of those similar words blocks people from thinking of the correct answers to the puzzles. We want to see if you can avoid those blocks by trying NOT to think of the words from the word rating task. Therefore, on those few items, you will hear a warning beep, and you will see some asterisks on the screen. That warning indicates that there is a word from the word rating task that is very similar to the puzzle solution. In those cases, the similar word will NOT solve the puzzle. Therefore, when you get the warning signal,

it is important to try not to think of the words from the word rating task when solving the puzzle.

Experiment 3: Instructions to All Participants

Some of the words that were on the earlier word rating test are similar to the word fragments that you are about to see, but they are all incorrect answers. Our experiments have shown that thinking of those similar words blocks people from thinking of the correct answers. We want to see if you can avoid these blocks by trying not to think of the words from the word rating task. On the test, try your best to avoid thinking of the words from the word rating task.

Experiment 7: Instructions to All Participants

Each word fragment that you are about to see has only one correct solution. Some of the words that were on the earlier word rating test, but not all of them, are similar to the word fragments that you are about to see, but they are incorrect answers. Our experiments have shown that thinking of those similar words blocks people from thinking of the correct answers. We want to see if you can avoid these blocks by trying not to think of the words from the word rating task. On the test, try your best to avoid thinking of the words from the word rating task. However, if you think of a word that solves a fragment, write it down no matter how you thought of the solution, because, again, each fragment has only one solution.