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Selective Effects of Interference on Implicit and Explicit Memory for New Associations

Peter Graf and Daniel L. Schacter
Department of Psychology, University of Toronto, Toronto, Ontario, Canada

On standard memory tests, such as recall and recognition, subjects are required to recollect where, when, and under what specific circumstances a target item was acquired; on priming tests, such as word completion and word identification, no reference is made to the specific circumstances accompanying an item's acquisition. We have used the labels *explicit* and *implicit* to describe the forms of memory that are indexed by these two types of tests. Recent research has shown performance dissociations between explicit and implicit memory for newly acquired associations. To learn more about the nature of these dissociations, the present study examined the effects of an AB, AC interference manipulation on explicit and implicit memory for pairs of normatively unrelated words. Interference affected explicit memory, as indexed by performance on cued recall, pair matching, and modified modified free-recall tests, but did not affect implicit memory, as indexed by performance on a word-completion test. This pattern of results complements previous findings of performance dissociations between explicit and implicit memory for new associations.

Standard memory tests, such as free recall, cued recall, and recognition, explicitly require subjects to retrieve items that were studied in a specific learning episode. In contrast, priming tests, such as word completion, word identification, and lexical decision, do not require subjects to retrieve items from a specific episode. In view of this difference in requirements, it has been suggested that the retrieval of a recently studied item on a standard memory test, and the retrieval of the same item on a priming test, reflect distinct forms of memory. For descriptive purposes, we have labeled these *explicit* and *implicit* memory, respectively (cf. Graf & Schacter, 1985). Explicit memory is revealed by intentional recollection from a specific previous episode, whereas implicit memory is revealed when performance on a task is facilitated without deliberate recollection from a specific learning episode.

Explicit and implicit memory are affected differently by several experimental variables, such as level of processing, retention interval, and modality of study-list presentation (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981; Kirsner & Dunn, 1985; Roediger & Blaxton, in press; Tulving, Schacter, & Stark, 1982). It has also been demonstrated that patients with organic amnesia, whose performance on explicit-memory tests is severely impaired, can show entirely normal performance on implicit tests (e.g., Cohen & Squire, 1980; Graf, Squire, & Mandler, 1984; Moscovitch, 1982; Rozin, 1976; Schacter, 1985b; Squire, Shimamura, & Graf, 1985; Warrington & Weiskrantz, 1968, 1974). Until recently, such dissociations between explicit and implicit memory have been found primarily in experiments in which subjects studied familiar items that have unitized representations in long-term memory, such as single words, related paired associates, and common idioms (e.g., Graf et al., 1984; Jacoby & Dallas, 1981; Kirsner, Milech, & Standon, 1983; Scarborough, Gerard, & Cortese, 1979; Schacter, 1985b; Tulving et al., 1982). Thus, it was assumed that implicit memory is mediated by the automatic activation of these unitized representations, and explicit memory is mediated by newly acquired representations (e.g., Graf & Mandler, 1984; Graf, Mandler, & Haden, 1982; Mandler, 1980; Mortensen, 1980; Rozin, 1976; Warrington & Weiskrantz, 1982; Wickelgren, 1979).

The generality of this activation account has been questioned, however, by findings of performance dissociations between explicit and implicit tests under conditions in which both forms of memory were mediated by newly acquired information. One example is the case of new associations between pairs of normatively unrelated words that were acquired in a single study trial (e.g., Franks, Plybon, & Auble, 1982; Graf & Schacter, 1985; McKoon & Ratcliff, 1979; Moscovitch, 1984; Schacter, 1985b; Schacter & Graf, 1986, in press). Because unrelated words do not have unitized representations as pairs in long-term memory, both implicit and explicit memory for such pairs depend on new associations that were constructed during the study trial.

Recent research has revealed both similarities and differences between explicit and implicit memory for new associations. On the one hand, both forms of memory require some type of elaborative, relational processing of two words as a pair. A range of study conditions that focused processing on the individual

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Correspondence concerning this article should be addressed to Peter Graf, Department of Psychology, University of Toronto, Toronto, Ontario, Canada M5S 1A1.

words from each pair—by requiring subjects either to rate each word on a pleasantness scale (semantic processing) or to count the vowels in each word (nonsemantic processing)—produced no evidence of implicit memory for new associations (Graf & Schacter, 1985; Schacter & Graf, 1986). Associative effects on word-completion-test performance occurred only when subjects processed paired words in an associative, elaborative manner, for example, by generating a meaningful sentence for each pair. On the other hand, we have shown that implicit memory is not affected by different types of associative elaboration that have large effects on explicit memory (Schacter & Graf, 1986). In addition, it has also been shown that implicit but not explicit memory for new associations can be spared in some, though not all, patients with organic memory disorders (e.g., Graf & Schacter, 1985; Moscovitch, 1984; Schacter, 1985a, 1985b). Therefore, despite the finding of similarities between explicit and implicit memory for new associations, the results from the latter studies provide evidence for important differences between these two forms of memory.

To learn more about the nature of the processes that underlie explicit and implicit memory for new associations, the present study examined the effects of interference manipulations. Historically, interference research has focused on associative memory and has firmly established that explicit remembering is impaired by interference manipulations (e.g., Barnes & Underwood, 1959; Martin, 1971; McGovern, 1964; Postman & Stark, 1969). In view of the pervasive finding of associative interference on explicit memory tests, studies of the effects of interference on implicit memory should have significant theoretical implications. If interference manipulations affect implicit as well as explicit memory for new associations, theories that emphasize the similarity between these two forms of memory would receive strong support. However, if interference manipulations do not affect implicit memory for new associations, there would be further evidence suggestive of a fundamental distinction between implicit and explicit memory, a distinction that would have to be accommodated by any comprehensive account of memory dissociations.

The general strategy for the present experiments was for subjects to study unrelated word pairs and then receive either an explicit- or an implicit-memory test. The critical manipulation involved an AB, AC interference paradigm. Under interference conditions, we required subjects to study a list of target word pairs (e.g., shirt–window) that had the same stimuli or A words as the interference list pairs (e.g., shirt–finger). Under control conditions, the target and interference lists had no words in common. Explicit memory was assessed with a cued-recall test in Experiment 1, and with a pair-matching test in Experiment 2; implicit memory was assessed with a word-completion test in both experiments.

Experiment 1

A combined proactive and retroactive interference paradigm was used in Experiment 1. Subjects were required to learn a target list, designated as AB pairs, and an interference list, either under experimental or control conditions. In the experimental conditions, the stimulus or A words from the target list were also used as the A words for the interference list, designated as AC, whereas in the control conditions, the interference and target lists had different stimulus words, designated as AB, CD. In the proactive-interference conditions, subjects studied the AB target list *after* the interference list, and in the retroactive-interference conditions, subjects studied the AB list *before* the interference list. For one half of the subjects in each condition, explicit memory for the AB pairs was assessed with a letter-cued-recall test, whereas for the other subjects, implicit memory was assessed with a word-completion test.

The same form was used for letter-cued recall and word-completion testing. Each test item on this form consisted of an A word together with the initial three letters—the stem—of a B word from the target pairs (e.g., shirt–win___). For the recall test, subjects were required to remember the B words from the study-list pairs with the help of these letter cues; for the completion test, subjects had to complete each word stem with the first word that came to mind. On the test form, some word stems appeared together with the same A word as in the study list (i.e., shirt–win___; same-context condition), and some appeared with a different A word (i.e., bottle–win___; different-context condition). The reasoning behind this same/different context manipulation is straightforward: If recall and completion performance are based solely on memory for individual B words, type of test context should not affect performance; however, if recall and completion are based on associative memory for word pairs, performance should be higher in the same- than in the different-context condition. Consistent with previous studies, we expected an associative interference effect on the explicit-memory test. The critical question was whether we would also observe an interference effect on the implicit-memory test.

Method

Design. The design included two between- and one within-subjects factors. The between-subjects factors were type of interference (proactive or retroactive) and type of test (letter-cued recall or word completion). The within-subjects factor was study condition (experimental or control). In the experimental condition, subjects studied an interference list that had the same A words as the target list, whereas in the control condition, the interference list did not include any words from the target list.

Subjects. Subjects were 64 volunteers who participated in return for pay or for credits in an introductory psychology course. They were randomly arranged into four groups of 16 each, with one group assigned to each of the conditions defined by the factorial combination of test type and interference type.

Materials. One hundred and twenty words were required for the construction of 24 target list pairs, 60 interference list pairs, and 6 practice and filler pairs. These words were between 4 and 10 letters long (M = 6.0) and of medium frequency (M = 65.5, range: 1 to 220 occurrences per million, Kučera & Francis, 1967). The selection of the 24 words that were used as responses or B words for the target-list pairs was constrained by two additional criteria. First, the stem of each word (e.g., win for window) was unique among all words that were used in the entire experiment. Because the stems were used as cues on the recall and completion tests, this selection criterion ensured that we had a unique test cue for each B word. Second, for each B word stem, a pocket English dictionary had to list at least 10 common words with the same stem (e.g., window, winner, winter, wine), thus ensuring that each subject would easily be able to generate a completion for each stem.

Of the 96 remaining words, a randomly selected 24 were used as stimuli or A words for the target list pairs, 60 words (5 × 12) were used as responses or C words for the interference list, and 12 words were randomly paired to produce 6 practice and filler pairs. The target-list pairs were constructed by a random pairing of the 24 A words with the 24 B words. This list of 24 AB pairs was then randomly divided into 2 sublists of 12 pairs each, designated as AB_1 and AB_2, one of which was used for study in the experimental condition, and the other in the control condition. Finally, each A word (e.g., shirt) from the target lists was randomly paired with 5 different C words (e.g., shirt–finger, shirt–energy) to produce a separate interference list (i.e., A_1C and A_2C) for AB_1 and AB_2. Overall, in constructing any word pairs we ensured that no normatively associated words appeared in the same pair. Each word pair was printed on an index card.

An additional 32 stimulus and 32 response words were required as distractors for the recall and completion tests. The stimulus distractors were selected according to the same criteria as the stimulus words for the target lists. They had an average length of 5.5 letters (range: 4 to 8) and a mean frequency of 73.4 (range: 5 to 257) occurrences per million (Kučera & Francis, 1967). Because the stems of the response distractor words were used as cues on the recall and completion tests, the response distractors were selected according to the same criteria as the target-list response words. Overall, the response distractors had an average of 5.8 letters (range: 4 to 8) and a mean frequency of 56.2 (range: 1 to 424) occurrences per million (Kučera & Francis, 1967). These stimulus and response distractors were randomly arranged to form 32 pairs of normatively unrelated words.

Tests. The same form was used for the letter-cued recall and word-completion tests. It consisted of a single page that showed a random arrangement of 56 test items. Each item consisted of a word plus a three-letter word stem (e.g., shirt–win___). The stems were from the B words of the 24 target pairs and from the response words of the 32 distractor pairs. For the latter, each test item showed a stem together with the stimulus word from a distractor pair. For the target pairs, there were two types of test items: 12 items (6 each from AB_1 and AB_2) had a B word stem together with the A word from the same target-list pair, and 12 items (the remaining 6 each from AB_1 and AB_2) had a B word stem and an A word that were not paired in the target lists (but they were from the same target list). The first 12 of these test items were used to examine recall and completion of B words tested in the *same* context (i.e., paired with the same word) as in the study list, whereas the second 12 items were used to examine recall and completion of B words tested in a *different* context (i.e., paired with a different word) than in the study list.

All test items were arranged randomly on the test form. Two versions of this form were required for each B word to be tested under both same- and different-context conditions. The distractor items were included on the form primarily to disguise its memory-testing aspects, when the form was used for word-completion testing, by merging the target items among a longer list of cues. This disguise is critical because once the memory-testing aspects of a completion test become apparent to subjects, a completion test can be transformed into a cued-recall test. Previous work has demonstrated that this transformation can be achieved by a simple change in test instructions (Graf & Mandler, 1984; Schacter & Graf, 1986).

Procedure. The general procedure consisted of instruction and practice, study, and testing. Each subject was tested individually. During instruction and practice, subjects were shown three practice word pairs and required to generate and say aloud a sentence that related the two words from each pair (e.g., shirt–window) in a meaningful manner (e.g., the angry child threw the SHIRT out of the WINDOW). Previous work has shown that this study task produces significant associative memory effects on completion and recall tests (e.g., Graf, 1982; Graf & Schacter, 1985; Schacter & Graf, 1986). In addition to generating and saying a sentence for each word pair, subjects also used a 5-point scale, labeled *easy to relate* and *difficult to relate* at its ends, to evaluate how easy or difficult it was to produce each sentence. Six seconds were allowed for generating and rating each sentence. Practice continued until each subject followed instructions.

After instruction and practice, the study list was presented, consisting of 90 word pairs: 24 target-list pairs (AB_1 and AB_2), either preceded or followed by an interference list with 60 pairs, and 6 filler pairs, 3 of which were at the beginning of the list and 3 of which were at the end. The interference list was A_1C for one half of the subjects, and A_2C for the other subjects. Because each subject studied both target lists AB_1 and AB_2, but only one interference list, only one of the target lists had the same A words as the interference list. Thus, by this procedure, the target list that shared its A words with the interference list was studied under experimental conditions, whereas the other target list was studied under control conditions.

The word pairs from the interference list were randomized and presented as a single series. The 24 target pairs were also randomized and presented as a continuous series, either immediately *after* the interference list, in the proactive condition, or immediately *before* the interference list, in the retroactive condition. Across subjects and conditions, each target list and each interference list was studied and tested equally often. The study list was presented once, at a rate of 6 s per pair, with the sentence generating instructions described above. Halfway through the study list (i.e., after 45 word pairs), there was a 1-min pause.

The test phase followed immediately after the study phase. Each subject was given first a distractor task and then a memory test, either letter-cued recall or word completion. The functions of the distractor task were to engage subjects in an unrelated activity for about 3 min before administering the critical memory tests, and more important, to induce an appropriate set for word-completion testing. For the distractor task, subjects were presented with two pages that listed 20 common first names (e.g., John ___), as well as 20 names together with the initial letter of a surname (e.g., Barbara J___). Subjects were required to read aloud each first name and then to free associate to the presented name cues by writing the first surname that came to mind.

The same form was used for recall and completion testing. For the letter-cued-recall test, subjects were instructed to remember the words from the study list with the help of the cues provided on the test form. Specifically, they were required to read aloud the word next to each word stem and use the stem as an aid for remembering a response word from the study-list pairs. The instructions emphasized that the context word would not always provide a clue for remembering because it could be either from the same or from a different study-list pair than the word stem, or it could be a new word that had not appeared in the study list. Subjects were required to proceed in order through the test items. They were allowed up to 10 s for each item. If they could not recall an appropriate study-list word in the allotted time, they were requested to write their best guess. Subjects were required to write a word for each stem.

The completion test was given with instructions that made no reference to memory for the study lists. Subjects were told that before they would receive a memory test, they had to "complete each word beginning on the [completion test] form with the first word that [came] to mind." They were informed that they could write any word except proper names, and when a proper name was given an alternative completion was requested. Because each word stem was presented in the context of another word, some of which were from the target lists, subjects were told that the context word might sometimes help them to think of a stem completion. Subjects were required to read aloud each context word and then to complete the stem next to it with the first word that came to mind, as quickly as possible.

Results

The main dependent measures were the proportions of B words remembered on the letter-cued-recall test, and the proportions of B words produced on the completion test. In scoring each test, a response was counted as a B word only if it was in its exact study list or plural form. A more lenient method of scoring, which also accepted adjectives, adverbs, gerunds, and other forms of the B words, did not change the overall pattern of results. The significance level for all statistical tests was set at .05.

To assess the completion test effects attributable to memory for the target pairs, we also required an estimate of baseline performance, that is, an estimate of how often subjects would write B words as completions without a prior presentation of the target lists. This estimate was obtained from an independent control group of 36 subjects who received the completion test with the same instructions as the experimental groups. This control group showed similar levels of performance of same- (.12) and different- (.09) context test items. These means did not differ and thus the combined mean of .10 was used as a reference point for assessing the completion-test effects produced by memory for unrelated word pairs.

Word completion. Table 1 shows the means for completion-test performance in the experimental and control conditions. Three aspects of these findings are noteworthy. First, the mean levels of performance were higher than baseline in all conditions (smallest $t[15] = 1.7$, after retroactive interference, for control condition with different-context cues); this indicates that studying the word pairs produced a general increase in completion-test performance. Second, overall performance was higher on same-context test items (.34 and .33 for pro- and retroactive conditions, respectively) than on different-context items (.20 and .19 for pro- and retroactive conditions, respectively). This finding indicates that performance was facilitated by the associative information that was afforded by the same-context test items. Third, and most important, completion performance was not affected by the interference manipulations. Following both types of interference, overall performance was comparable in the experimental conditions (.28 and .27 for pro- and retroactive, respectively) and in the control conditions (.25 and .26 for pro- and retroactive, respectively). An analysis of variance (ANOVA) supported this description of the results by showing a significant main effect for test context (same vs. different), $F(1, 30) = 27.2$, $MS_e = 250$, with no other effects approaching significance.

Cued recall. Table 1 also shows the levels of recall in each condition of the experiment. The means show that overall recall was higher on same-context test items (.56 and .48 for pro- and retroactive conditions, respectively) than on different-context items (.29 and .32 for pro- and retroactive conditions, respectively); this indicates that recall performance was also facilitated by the associative information that was afforded by the same-context test items. In contrast to completion performance, however, recall performance was impaired by the interference manipulations. Following both types of interference, overall recall was lower in the experimental conditions (.35 and .34 for pro- and retroactive, respectively) than in the control conditions (.49 and .45 for pro- and retroactive, respectively). This finding is consistent with previous reports of similar interference effects on explicit-memory tests in pro- and retroactive interference experiments. Finally, as expected, the size of the interference effects was considerably larger on same-context test items (.22 and .15 interference for pro- and retroactive conditions, respectively) than on different-context test items (.05 and .07 interference for pro- and retroactive conditions, respectively). An ANOVA supported this description of the results by showing significant main effects for study condition (experimental vs. control), $F(1, 30) = 12.9$, $MS_e = 387.7$, and for test context (same vs. different), $F(1, 30) = 52.5$, $MS_e = 413.8$, as well as a significant interaction between these two factors, $F(1, 30) = 4.4$, $MS_e = 287.0$. No other effects approached significance.

Table 1
Experiment 1: Mean Levels of Test Performance, With Proactive and Retroactive Manipulations, Under Experimental and Control Conditions, and on Same- Versus Different-Context Test Items

	Study condition			
	Experimental		Control	
Condition	Same	Different	Same	Different
Proactive:				
Completion				
M	.35	.21	.32	.18
SE_M	.03	.03	.04	.04
Cued recall				
M	.45	.26	.67	.31
SE_M	.04	.06	.06	.06
Retroactive:				
Completion				
M	.32	.21	.34	.17
SE_M	.04	.04	.04	.04
Cued recall				
M	.40	.28	.55	.35
SE_M	.04	.04	.04	.06

Discussion

Consistent with the results from previous research, Experiment 1 showed that on both word-completion and letter-cued-recall tests, performance was higher on same- versus different-context test items. The critical new finding is that interference manipulations had no effect on word-completion performance, even though they produced a significant impairment on the letter-cued-recall test. The higher level of completion and cued recall on same- versus different-context test items indicates that performance on both tests was affected by associative information that was newly acquired during the study trial. The impaired performance on the letter-cued-recall test, and not on the word-completion test, indicates that explicit but not implicit memory was affected by the interference manipulations. Moreover, the finding that the interference effects were considerably larger on same- than different-context test items emphasizes that the interference manipulations had a selective effect on explicit memory for new associations. In combination, therefore, these results show a dissociation between explicit and implicit memory for new associations.

The finding that the interference manipulations impaired only explicit but not implicit memory for new associations must be interpreted with caution for two reasons. First, in view of extensive previous findings of associative interference effects on explicit-memory tests, one might speculate that our interference manipulations were weak, that is, perhaps only strong enough to affect letter-cued recall but not completion-test performance. Second, the literature contains scattered reports of failures to find interference effects on explicit-recognition-memory tests (e.g., Anderson & Watts, 1971; Postman & Stark, 1969; for demonstrations of interference effects on recognition tests, see Delprato, 1971; Garskof & Sandak, 1964). It is possible that the interference manipulations from Experiment 1 would also have failed to affect performance on a recognition test, thereby questioning the generalization that interference affects explicit but not implicit memory for new associations. This generalization would be strengthened considerably by the finding that implicit memory for new associations can remain unaffected even by an interference manipulation that impairs performance on an associative recognition test. Experiment 2 addressed this possibility.

Experiment 2

Experiment 2 differed in several respects from Experiment 1. First, because Experiment 1 showed similar results under pro- and retroactive interference conditions, only one interference manipulation—retroactive—was used in Experiment 2. An advantage of the retroactive paradigm is that the original level of memory for a target list can be assessed prior to the interference manipulation and, thus, it can be held constant across experimental and control conditions. Second, to strengthen the interference manipulation, we required subjects to achieve perfect recall for each of two interference lists. By this method, we could ensure similar amounts of interference learning in the experimental and control conditions. Third, to examine interference on explicit memory, Experiment 2 used a recognition test—pair matching—that presented subjects with the A and B words from the target-list pairs and required them to match the two words that formed each pair. We expected that the pattern of findings in Experiment 2 would be similar to that observed in Experiment 1.

Method

Design. In contrast to Experiment 1, the design of Experiment 2 included study condition (experimental and control) and test type (word completion and pair matching) as between-subjects factors. In the experimental condition, each subject learned two interference lists, designated as AC and AD, that had the same A words as the target list, whereas in the control condition, subjects studied and were tested on two interference lists, designated EC and ED, that had different stimulus words than the target list. The interference lists were always studied after the target list.

Subjects. Subjects were 64 volunteers who participated for pay or in return for credits in an introductory psychology course. They were randomly assigned to four groups, defined by the factorial combination of study condition (experimental and control) and test type (pair matching and word completion).

Materials. The words selected for Experiment 1 were also used in Experiment 2. Thirty-two of these words that served as B words for the target list had a three-letter stem that was unique in the set of all words that were required for the experiment, and for each stem a pocket English dictionary listed at least 10 common words with the same stem. Of the remaining words, 32 were used as A words for the target list. The A and B words were paired randomly to produce the AB target pairs. The target pairs were then randomly divided to form two lists of 16 pairs each, designated as AB_1 and AB_2.

Of the remaining 56 words, two randomly selected sets of 16 words each were used as responses for the interference lists (i.e., C and D words), one set of 16 words was used as stimuli for the interference lists (i.e., E words), and 8 words were randomly combined to produce four practice pairs. The interference lists were produced by randomly pairing the A words with the C and D words, and by pairing the E words with the C and D words, thus generating the following interference lists: A_1C, A_1D, A_2C, A_2D, EC, and ED. Overall, in constructing any word pair, we ensured that no normatively associated words appeared in the same pair. Each word pair was printed on an index card.

An additional 32 words (16 word pairs) were required as stimulus (16 words) and response (16 words) distractors for the word-completion test. These words were obtained by a random selection of 16 pairs from the pool of 32 pairs that had been used for the same purpose in Experiment 1.

Tests. The word-completion test form was a single page that listed 48 test items, with each item consisting of a word plus a word stem, as described in the preceding experiment. Sixteen of these items consisted of an A word together with the stem of the B word that had been in the same target-list pair (8 each from AB_1 and AB_2), and 16 test items consisted of an A word together with the stem of a B word that had been in two different target-list pairs (the remaining 8 from AB_1 and AB_2). The first 16 of these target-list items were used to assess completion of B words tested in the *same* context (i.e., paired with the same word) as in the study list, whereas the second 16 items were used to assess completion of B words tested in a *different* context (i.e., paired with a different word) than in the study list. In addition, the completion test included 16 distractor items that were constructed in the same manner. The 32 target and 16 distractor items were arranged randomly on the completion test form. Two alternative test forms were required for counterbalancing B words across same- and different-test-context conditions.

The pair-matching test consisted of a single page with two columns of 16 words, on the left side of the form the A words and on the right side of the form the B words. The words were arranged randomly in each column. There were two forms for this test, one each for list AB_1 and AB_2.

Procedure. The general procedure consisted of four parts: instruction and practice, one study–test trial on the target list, a series of study–test trials on each of two interference lists, and final testing. Each subject was tested individually. During instruction and practice, subjects were presented with four practice pairs and required to generate and say aloud a single word for each word pair "that relates the two words in a meaningful manner" (e.g., student for the pair essay–floor). Subjects were told that they would be presented with a series of word pairs at a rate of 5 s per pair, and that they had to generate and say a meaningful connector word for each pair. This study task was used instead of the sentence-generating task from Experiment 1 because the word task produces lower levels of explicit memory (see Schacter & Graf, 1986), thus decreasing the likelihood of ceiling effects on the pair-matching test. Subjects were told that immediately after the presentation of the last pair, they would be given a distractor task for 20 s, and then a memory test in which the first word from each pair would be provided as a cue.

Following instruction and practice, one of the target lists, either AB_1 or AB_2, was presented at a rate of 5 s per pair. Immediately after the last pair, subjects were engaged in a backward-counting distractor task for 20 s before a paired-associate recall test was given. The test form that was used for this purpose listed the stimulus words from the studied pairs and subjects were required to remember the response words with the help of these cues. Subjects were encouraged to recall as many words as possible, and the test continued until a subject had not written anything for about 1 min. The phrase "paired-associate recall test" is used for this test to distinguish it from the letter-cued-recall test that was given in Experiment 1.

After this single study–test trial on the target list, the first interference list was studied and tested under conditions in which it was possible to calibrate immediate associative-recall performance at 100%. For this purpose, the study pace was increased to 2 s per pair. Subjects were allowed to rely on their own methods of study and were not required to generate and say aloud a connector word for each pair. Study–test trials were repeated until each subject recalled the list perfectly. A study trial and a test trial were always separated by a 20-s distractor task. The first and second interference list were studied and tested in the same manner. For the subjects in the experimental condition, the two interference lists had the same A words as the target list (i.e., A_1C and A_1D for target list AB_1, or A_2C and A_2D for target list AB_2). For the subjects in the control condition, the two interference lists were always EC and ED and thus not related to the target lists.

Following the last study–test trial on the second interference list, all subjects received the name-completion distractor task used in Experiment 1, and then two groups received the pair-matching test and two groups received the word-completion test. These tests are described in the Materials section. Prior to the name-completion test, subjects were informed that they would soon receive a memory test, but that they first had to complete some other tasks. The name-completion test was given with the instructions described in Experiment 1; subjects read aloud each first name on the test form and then wrote the first surname that came to mind. Immediately after name completion, memory for the target-list pairs was assessed either with a word-completion or pair-matching test. For subjects who received the word-completion test, the instructions emphasized that the test was similar to the name-completion test; the instructions made no reference to memory for the target pairs, and subjects simply read aloud the context word for each test item and then wrote the first stem completion that came to mind. Subjects who received the pair-matching test were informed that the test form listed all stimulus and response words from the first study list in a random order, and they were required to match (i.e., draw a line between) the words that had been paired in the study list.

Results and Discussion

The main dependent measures were the proportions of target pairs that were correctly identified on the pair-matching test and the proportions of B words produced on the word-completion test. In addition, to assess the completion effects attributable to memory for the target-list pairs, we also required an estimate of baseline performance on this test. This estimate was obtained within subjects: Because each subject studied only one of the target lists (AB_1 or AB_2) and the completion form included test items corresponding to both lists, the probability of producing words from the nonstudied list provided an index of baseline performance. Across subject groups, baseline completion performance averaged .09 (.09 and .09 on same- and different-context test items, respectively).

Word completion. The top two rows of Table 2 show the means for completion test performance in the experimental and control conditions. These means indicate that studying the word pairs raised completion performance above baseline in all conditions (smallest $t[15] = 2.6$, for experimental condition on different context cues). Of primary interest were the proportions of B words that were written as completions for same- versus different-context test items, in the experimental and control conditions. The table shows that overall performance was higher on same-context items (.38) than on different-context items (.22), and performance was similar in the experimental (.28) and control (.32) conditions. An ANOVA supported these observations by showing a significant main effect for test context, $F(1, 30) = 17.9$, $MS_e = 218.4$, with no other effects approaching significance. Thus, as in Experiment 1, the interference manipulation did not affect implicit memory for new associations.

Table 2
Experiment 2: Mean Levels of Test Performance Under Experimental and Control Conditions and on Same- Versus Different-Context Test Items

	Study condition			
	Experimental		Control	
Condition	Same	Different	Same	Different
Completion test				
M	.36	.20	.39	.24
SE_M	.04	.04	.05	.05
	Experimental		Control	
Pair-matching test				
Mean hits	.36		.54	
SE_M	.05		.06	
Mean false alarms	.07		.07	

Pair matching. The bottom three rows of Table 2 show the mean levels of performance on the pair-matching test. Subjects identified significantly more pairs in the control condition (.54) than in the experimental condition (.36), $t(30) = 2.42$, $p < .02$. In addition, the proportions of pairs that were incorrectly identified—false alarms—were similar in the control (.07) and experimental (.07) conditions, thus indicating that the difference in hit rate between these two conditions is not attributable to a response bias.

Experiment 2 included two additional measures that help to interpret the foregoing findings. First, the results from the paired-associate recall test that was given immediately after presentation of the target lists showed that initial learning of target pairs was comparable across conditions: .39 and .38 in experimental and control, respectively, for subjects who later received the completion test, and .47 and .45 in experimental and control, respectively, for subjects who received the pair-matching test. These findings indicate that the different levels of performance in the experimental and control condition of the pair-matching test are attributable to the interference manipulation, rather than to a difference in initial memory for the target-list pairs. A second measure showed that the average delay between study of the target list and final testing was comparable across conditions: 34 min and 33 min in experimental and control, respectively, for subjects who received the word-completion test, and 38 min and 37 min in experimental and control, respectively, for subjects who received the pair-matching test. These findings indicate that the different levels of performance on the completion and pair-matching test are not attributable to different study–test delays across conditions.

General Discussion

Two main findings emerged from the present study. First, we observed a higher level of performance on both word-completion and letter-cued recall tests for words that were tested in same than in different contexts. Second, and more important, no evidence was obtained for an interference effect on the word-completion test despite the finding that both letter-cued recall and pair-matching performance were significantly impaired by the interference manipulations. The overall higher levels of performance on the same-versus different-context items of the letter-cued-recall and word-completion tests reveal that both tests were sensitive to memory for newly acquired associations. The interaction between interference and test types indicates that interference affects the explicit but not the implicit expression of memory for new associations.

The results from both letter-cued-recall and pair-matching tests are consistent with previous findings of associative interference effects on tests of explicit memory (see Barnes & Underwood, 1959; McGovern, 1964; Postman & Underwood, 1973). The generality of these results is also shown by the finding of interference effects in both within- and between-subjects designs, across different study tasks, and across different interference manipulations. Nevertheless, to establish further the generality of these findings, we also examined whether the manipulations used in the present study were sufficient to produce interference on a traditional Modified Modified Free Recall (MMFR) test (see Barnes & Underwood, 1959; McGovern, 1964). An MMFR test presents the A word from each target-list pair, and subjects are required to recall, in any order, all words that had been paired with each A word, in the entire study list. We assessed MMFR performance in two independent groups of 16 subjects each, using the general procedure from Experiment 1. One group was tested under proactive-interference conditions and the other under retroactive conditions. Subjects' MMFR performance was significantly impaired by both interference manipulations: Following proactive interference, performance was .29 and .44 in the experimental and control conditions, respectively, and following retroactive interference, performance was .09 and .29 in the experimental and control conditions, respectively. Together with the letter-cued-recall and pair-matching test results, these findings indicate that the interference manipulations used in our study had significant effects across a variety of explicit-memory tests.

The absence of an interference effect on the word-completion test contrasts with the results from the explicit memory tests, and with previous work on associative interference. However, the literature does contain a few studies in which explicit memory was not impaired by interference manipulations (e.g., Anderson & Watts, 1971; Postman & Stark, 1969). For example, Postman and Stark found no interference on an associative recognition test under conditions in which such a test was also given after each study trial during acquisition. This finding indicates that some study conditions can prevent the detrimental effects of interference on tests of explicit memory. However, although this finding reveals that not all interference manipulations impair performance on explicit memory tests, the results from the present study emphasize that implicit memory is not affected by interference manipulations that *do* impair explicit memory.

Why does interference affect explicit but not implicit memory for new associations? We do not yet have a conclusive answer to this question. However, some clues are provided by an analysis of the different performance requirements of explicit and implicit tests. Explicit tests require subjects to retrieve items from a specific, previously studied list. Under these conditions, a to-be-remembered item is defined as part of a long list of studied items and, thus, memory performance depends on the relative distinctiveness of each item within the entire list. Consequently, what is important for explicit remembering of a study-list pair are those components of its memory representation that distinguish it from other word pairs in the study list and relate it to a specific experimental situation. We assume that the distinctiveness of these representational components of two paired words, relative to other study-list pairs, is lower under interference conditions in which each stimulus word is paired with several different responses than under control conditions in which each stimulus occurs with a single response. The importance of distinctiveness for explicit remembering has been acknowledged by many investigators (e.g., Jacoby, 1974; Moscovitch & Craik, 1976; Watkins & Watkins, 1975).

Implicit tests require subjects to respond with the first words that come to mind for each cue, without reference to a particular study list. Under these conditions, the components of the pair representation that distinguish it from other study-list pairs and relate it to a specific experimental situation are not critical for test performance. Instead, implicit memory for new associations may depend primarily on those components of a representation that relate the two words in a pair to each other, independent of other pairs in the study list. If, as we suggest, interference effects on explicit memory tests are attributable to a relative decrease in the distinctiveness of the representational components that distinguish one study-list pair from others, then it is not surprising that implicit memory for new associations, which does not depend upon these components, is not affected by interference manipulations.

Our previously reported findings concerning the effects of associative elaboration on explicit and implicit memory for new associations (Schacter & Graf, 1986) are consistent with this view. We found that encoding of meaningful relations between two words at the time of study was necessary to observe implicit memory for new associations; when subjects focused on the semantic properties of each word in a pair, without encoding a meaningful relation between them, there was no evidence of an associative influence on word-completion test performance. These findings support the view that components of a memory representation that relate two words directly to each other are critical for implicit memory of new associations. However, we also found that variations in type of associative elaboration, such as generating versus reading a sentence that relates two words, had large effects on explicit but not implicit memory for new associations. It appears that the latter manipulations had a selective effect on explicit memory because they affected primarily those components of a pair's representation that distinguish it from other study-list pairs.

Although the finding of dissociations in memory for new associations is used here to suggest that different components of a memory representation underlie implicit and explicit memory, it is also possible that dissociations arise solely as a result of the different retrieval processes that are required for implicit and explicit tests. It is not clear, however, why the retrieval processes that are required for explicit-memory tests should be sensitive to interference manipulations, whereas the retrieval processes that are required for implicit-memory tests should not be sensitive to interference unless, as suggested earlier, some difference between the representational components that support the two types of retrieval processes is also acknowledged. We believe that a comprehensive understanding of explicit and implicit memory for new associations requires consideration of both representational issues and retrieval processes.

Converging evidence that is consistent with the view that different components of a memory representation underlie implicit and explicit memory for new associations comes from recent studies of patients with organic amnesia. These patients sometimes show source amnesia (Evans & Thorn, 1966; Schacter, Harbluk, & McLachlan, 1984), that is, they can retrieve a recently learned association but fail to recollect how, where and when it was acquired. Schacter et al. (1984) provided an experimental demonstration of this phenemenon. In their study one of two experimenters first presented subjects with fictional information about well-known and unknown people and, after delays of a few seconds or minutes, memory was assessed for both the fictional information and the source. The results showed that amnesics failed to recollect the source on nearly .40 of the trials on which they succeeded in retrieving the target information. These data are consistent with a distinction between components of a representation that form the internal structure of an item and components that link an item to a specific experimental situation. Similarly, recent research by Glisky, Schacter, and Tulving (1986a, 1986b) has shown that amnesic patients can learn computer commands (e.g., write, save, edit, execute), and apply them in writing simple programs. The acquisition of these new associations occurred despite some patients' lack of explicit memory for having studied the materials and for having participated in the computer training task. These results, together with the findings from the present study, point to a fundamental difference between representational components that mediate implicit and explicit expressions of memory.

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