Journal of Experimental Psychology:
Learning, Memory, and Cognition
1989, Vol. 15, No. 1, 3-12

0278-7393/89/$00.75

Modality Specificity of Implicit Memory for New Associations

Daniel L. Schacter
University of Arizona

Peter Graf
University of British Columbia, Vancouver, British Columbia, Canada

In previous research we demonstrated that newly acquired associations between unrelated word pairs influence the magnitude of priming effects on word-completion tests. This phenomenon of implicit memory for new associations is observed only following semantic study elaboration. The present experiments reveal that implicit memory for new associations, though elaboration dependent, is also modality specific: Associative effects on a visual word-completion test were consistently reduced by study–test modality shifts. In contrast, explicit memory for new associations, as indexed by cued-recall performance, was uninfluenced by modality shifts. The modality effect on completion performance was eliminated when subjects were given brief visual preexposures to, or were required to construct visual images of, word pairs presented in auditory study conditions. The results pose a theoretical puzzle insofar as they indicate that within the domain of implicit memory, access to the products of elaborative processing depends on modality-specific, sensory–perceptual processing.

Memory for recent experiences can be expressed by conscious or deliberate recollection of an event, as indexed by standard tests of recall and recognition, or by facilitation of performance on tests that do not require intentional recollection, such as word completion, word identification, and lexical decision. We used the descriptive terms *explicit* and *implicit*, respectively, in reference to these two forms of memory (Graf & Schacter, 1985; Schacter & Graf, 1986a).

A variety of studies have demonstrated that explicit and implicit memory can be dissociated experimentally (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981; Roediger & Blaxton, 1987a; Tulving, Schacter, & Stark, 1982; for review and discussion, see Richardson-Klavehn & Bjork, 1988; Schacter, 1987, in press). One of the most striking kinds of evidence for an implicit–explicit dissociation comes from studies that manipulated the sensory modality (auditory–visual) in which target items were presented at study and test. Several experiments have shown that study–test modality shifts either reduce or eliminate priming effects on various implicit-memory tests, including word identification (Clarke & Morton, 1983; Jacoby & Dallas, 1981; Kirsner, Milech, & Standen, 1983; Morton, 1979), lexical decision (Kirsner et al., 1983; Kirsner & Smith, 1974; Scarborough, Gerard, & Cortese, 1979), reading transformed script (Kolers, 1975), stem completion (Graf, Shimamura, & Squire, 1985), and fragment completion (Roediger & Blaxton, 1987a, 1987b). By contrast, performance on various explicit-memory tests in these studies was generally unaffected by study–test modality shifts (for an exception, see Jacoby & Dallas, 1981, Experiment 6). These findings have led a number of investigators to argue that performance on implicit-memory tests depends heavily, though not exclusively, on modality-specific sensory and perceptual processes that are sensitive to physical features of stimulus information (e.g., Jacoby, 1983b; Kirsner et al., 1983; Roediger & Blaxton, 1987b; Squire, 1987).

In a series of recent experiments, we have uncovered a phenomenon that appears somewhat puzzling in light of the consistent finding that priming effects on implicit-memory tests are reduced by study–test modality shifts. The purpose of these experiments was to determine whether new associations acquired during a study trial affect implicit memory (cf. McKoon & Ratcliff, 1979, 1986; Schacter & McGlynn, in press). Subjects studied normatively unrelated word pairs (e.g., MOTHER–CALENDAR). Implicit memory for newly formed associations between the paired words was assessed with a stem-completion task in which some target stems appeared in the same context as in the study list (e.g., MOTHER–CAL_____) and others appeared in a different context (e.g., OFFICER–CAL_____). Subjects were instructed to write down the first word that came to mind in response to the target stem and were also told that the context word might help them to think of a completion. Across a wide variety of experimental conditions, we found significantly more priming in the same- than different-context condition (Graf & Schacter, 1985, 1987; Schacter & Graf, 1986a, 1986b), thereby indicating that newly formed associations affected stem-completion performance. However, this phenomenon, which we call *implicit memory for new associations*, occurred only when subjects had engaged in semantic elaboration at the time of study. For example, when subjects generated a sentence that linked the two members of a pair or rated the degree to which a mean-

This research was supported by a Special Research Program Grant from the Connaught Fund, University of Toronto; by Natural Sciences and Engineering Research Council of Canada Grants U0361 to Daniel L. Schacter and U0299 to Peter Graf; and by a Biomedical Research Support Grant from the University of Arizona to Daniel L. Schacter.

We thank Barry Espin, Susan McGlynn, and Kelly Nakamura for help with various aspects of the research and Jill Booker, Ken Forster, Brad Gibson, and John Kihlstrom for helpful discussion.

Correspondence concerning this article should be addressed to Daniel L. Schacter, Department of Psychology, University of Arizona, Tucson, Arizona 85721.

ingful sentence related the words (e.g., The angry MOTHER returned the CALENDAR), associative effects on the stem-completion test were observed. But when subjects did not elaborate a meaningful relation between the words, and the study task required processing nonsemantic attributes of individual words (i.e., counting vowels), judging their pleasantness, or reading them in a nonmeaningful sentence, we failed to observe any evidence of implicit memory for new associations (Graf & Schacter, 1985; Schacter & Graf, 1986a). Despite the elaboration-dependent nature of implicit memory for new associations in these experiments, however, we were able to dissociate it from explicit memory for new associations through manipulations of type of study elaboration (Schacter & Graf, 1986a), as well as proactive and retroactive interference (Graf & Schacter, 1987).

When considered in the context of studies demonstrating that implicit memory is reduced by study–test modality shifts, it is surprising to find that associative effects on the stem-completion test occur only with study tasks that require semantic elaboration. The former results suggest that implicit memory relies on modality-specific sensory–perceptual processing, whereas the latter findings indicate that implicit memory can require semantic–elaborative processing, which is typically viewed to be modality nonspecific (e.g., Forster, 1976; Kirsner et al., 1983; Morton, 1979). However, the evidence for modality sensitivity of implicit memory derives largely from experiments in which subjects studied familiar words that have preexisting unitized representations in semantic memory. Implicit memory for familiar words typically does not require elaborative study processing; robust priming effects are observed even following various kinds of nonsemantic study tasks (e.g., Graf & Mandler, 1984; Graf, Mandler, & Haden, 1982; Jacoby & Dallas, 1981). It is thus possible that implicit memory for familiar, unitized items (i.e., words) is modality sensitive, whereas implicit memory for newly acquired associations is not modality sensitive.

The present experiments examine whether implicit memory for new associations is influenced by study–test modality shifts. In view of the elaboration-dependent nature of implicit memory for new associations, a reasonable expectation is that the magnitude of contextual or associative priming effects on a stem-completion test will be largely unaffected by study–test modality shifts. If such an outcome was observed, it would represent a significant qualification to any general statements about the modality specificity of implicit memory. In contrast, it is possible that associative effects on completion performance, though elaboration dependent, are also modality specific. Such an outcome would raise questions concerning the interpretation of modality effects on implicit-memory tests solely in terms of sensory–perceptual processing, because it would reveal a linkage between access to the products of elaborative study processing on the one hand and the modality in which target information is studied and tested on the other.

Experiment 1

To investigate the effects of study–test modality shifts on implicit memory for new associations, we adapted an experimental paradigm that we had used in previous research (Schacter & Graf, 1986a, Experiments 2 & 3). Subjects were presented with a series of meaningful sentences (i.e., The angry MOTHER returned the CALENDAR), either in the visual or auditory modality. They were later given a stem-completion test in the visual modality in which some target stems appeared in a same-context condition (i.e., MOTHER–CAL______) and others appeared in a different-context condition (i.e., SHIP–CAL______). On the basis of previous research, we expected that following visual presentation of the sentences, subjects would show implicit memory for new associations—that is, they would complete more stems with previously studied words in the same- than different-context condition. The critical question is whether there will be a smaller associative priming effect following auditory presentation. If the same–different context effect is reduced or eliminated following auditory presentation, it would indicate that implicit memory for new associations is modality specific; if the same–different effect is unaffected by auditory versus visual presentation, it would indicate that implicit memory for new associations is not modality specific.

Method

Subjects. Forty-eight University of Toronto undergraduates participated in the experiment. They either received course credit or were paid $5 for their participation.

Design and materials. A 2 × 2 × 2 mixed design was used. The between-subjects factor was type of test (word completion vs. cued recall), and the within-subject factors were study modality (auditory vs. visual) and type of test context (same vs. different).

The critical items consisted of 36 cue–target word pairs that were each composed of concrete nouns selected from the Kucera and Francis (1967) norms. All items conformed to three constraints: (a) The three-letter stems of each of the target words had to be represented by at least 10 English words in a pocket dictionary, (b) all stems had to be unique in the set of all words used for the 36 cue–target pairs, and (c) target words had to be between 5 and 10 letters in length and of medium Kucera–Francis frequency. In addition to the critical items, a set of 24 filler items was included on the completion and recall tests. These items consisted of a context word and a three-letter stem; they were produced in the same manner as the target items and were subject to the same selection constraints as were the targets. Their main purpose was to disguise the memory testing aspect of the completion task (cf. Schacter & Graf, 1986a). Finally, five study buffers that were not subsequently tested appeared on the target list, three at the beginning and two at the end.

Counterbalancing of target items across conditions was achieved by dividing the 36 critical pairs into six sets consisting of six pairs per set. For any 1 subject, two sets were studied in the visual modality and two were studied in the auditory modality; one set in each of the respective study conditions was tested in the same-context condition, the other in the different-context condition. The remaining two sets did not appear on the study list but did appear on the completion and cued-recall tests, one in the same- and one in the different-context condition. The purpose of including these items was to assess the baseline probability of completing the stems with target items. The materials were counterbalanced such that each of the six sets appeared equally often in each of the experimental conditions defined by the orthogonal combination of study modality, test context, presented versus nonpresented sets, and type of test. Two different forms of the completion and cued-recall tests were needed to achieve complete counterbalancing. Both forms consisted of a single page that contained 60 items, each with a complete word next to a three-letter stem (e.g., MOTHER–CAL______).

A distractor task was interpolated between study-list presentation and either the word-completion or cued-recall test. It required subjects to generate surnames in response to stimuli consisting of a first name and an initial letter of a second name (e.g., Jim W_____). This name-completion test consisted of two sheets of paper, each of which contained 20 typed name fragments. The purpose of this task was to induce an appropriate mental set for word-completion testing.

Procedure. All subjects were tested individually. Subjects were told that they would be studying a series of word pairs that they would later be asked to remember. They were also informed that the pairs would be presented in sentences and that to help them remember the target items, they would have to rate the degree to which each sentence meaningfully related the pair members. Subjects were further instructed that some of the sentences would be presented visually, with the target items in capital letters (e.g., the old SHACK collapsed in the STORM), and other sentences would be spoken, with the target items indicated by an emphasis in the experimenter's voice. They were instructed in the use of a 5-point rating scale, where 1 indicated that a sentence did not relate the two words very meaningfully and 5 indicated that the sentence related the two words in a highly meaningful manner.

Several practice pairs were then presented, visually and aurally, followed by presentation of the study list. Pairs were presented at a rate of 6 s per pair, with the order of presentation being determined randomly for each subject. The visual pairs were presented on 4″ × 6″ index cards. As described earlier, target items in auditory sentences were indicated by an emphasis in the experimenter's voice. Subjects had no difficulty detecting the target pairs in this manner.

Following study-list presentation, subjects were instructed that they would have to complete some filler tasks before their memory for the study-list pairs was assessed. They were then given the name-completion task and were allowed about 3 min to do it. For half the subjects, the word-completion test was subsequently introduced as a second filler task. Subjects were instructed that they should write down the first word that came to mind in response to a three-letter stem. They were also told that the context word next to the stem might help them to think of a completion but that it was unimportant whether the completion was in any way related to the context word. Subjects were further informed that they should not provide proper names as completions but that beyond this, there was no right or wrong response. Subjects were encouraged to perform the test as quickly as possible.

The other half of the subjects were given the same test form immediately after the name-completion test, but with cued-recall instructions. They were told that some of the stems represented words from the study list and that they should think back to the study list and do their best to complete the stems with study-list targets. They were informed that some of the stems appeared together with their study-list cues, others appeared with different context cues, and still others had not appeared on the study list at all. However, they were required to complete all stems, even if they felt that they were just guessing.

Results

Word completion. Baseline performance was .10 for same-context items and .14 for different-context items. Because these proportions did not differ from one another, $t(23) = 1.12$, they were averaged to yield a mean baseline completion rate of .12.

The mean proportions of stems completed with target words in the main experimental conditions appear in Table 1. Completion rate in all cases was significantly above baseline, smallest $t(23) = 2.50$ ($p < .05$ significance level for this and all subsequent statistical tests), thereby indicating that exposure to target words on the study list yielded priming effects. Following visual exposure to the critical pairs, performance in the same-context condition (.35) was higher than in the different-context condition (.20), replicating our previous results with the sentence rating task (Schacter & Graf, 1986a). By contrast, there was little difference in completion rate for same- (.24) and different-context (.21) items following auditory exposure. This impression was confirmed by a 2 × 2 within-subjects analysis of variance (ANOVA), which showed a significant main effect of test context, $F(1, 23) = 5.32$, $MS_e = 1.32$; a marginally significant effect of study modality, $F(1, 23) = 3.44$, $MS_e = .78$, $p = .07$, and, most important, a significant interaction between these two variables, $F(1, 46) = 5.13$, $MS_e = .66$. The t tests revealed that completion rate following visual study was higher for same- than different-context items, $t(23) = 3.25$, but no such same-different effect was observed following auditory study, $t(23) < 1$.

Table 1
Word Completion and Cued-Recall Performance in Experiment 1

	Test context					
	Word completion			Cued recall		
Study modality	Same	Different	*M*	Same	Different	*M*
Visual	.35	.20	.28	.56	.33	.45
Auditory	.24	.21	.23	.54	.25	.40
M	.30	.21	.26	.55	.29	.42

Cued recall. The data from subjects who received the cued-recall test also appear in Table 1. As on the stem-completion test, there is some probability that subjects will complete nonpresented target cues with study-list items. Baseline recall rate was .11 for same-context items and .10 for different-context items, approximately the same baseline rate that was found on the completion test. Similar baseline rates were observed on the cued-recall test in each of the present experiments (i.e., in the range of .09–.13), and recall performance was always significantly higher than baseline; accordingly, cued-recall baselines will not be presented individually for subsequent experiments.

Consistent with our previous results, cued-recall performance was generally higher than completion performance, and more items were recalled in same- than different-context conditions. Unlike the word-completion results, however, the magnitude of the context effect was not diminished following auditory study relative to visual study. An ANOVA performed on the cued-recall data revealed a significant main effect of test context on cued-recall performance, $F(1, 23) = 19.77$, $MS_e = 2.96$. The effect of study modality was nonsignificant, $F(1, 23) = 1.03$, $MS_e = .82$. An ANOVA that included type of test as a variable revealed a significant Type of Test × Study Modality × Test Context interaction, $F(1, 46) = 5.13$, $MS_e = .74$. The interaction reflects the fact that the context effect in word completion, but not in cued recall, was reduced by a study–test modality shift.

Discussion

The results of Experiment 1 indicate that associative effects on the stem-completion task are reduced significantly by a study–test modality shift: We found evidence of implicit memory for new associations following visual, but not auditory, presentation of target pairs. However, explicit memory for new associations was unaffected by the modality in which target pairs were studied. Thus, a study–test modality shift produces dissociative effects on implicit and explicit memory for new associations, just as it results in a dissociation between implicit and explicit memory when the target materials are familiar words (e.g., Graf et al., 1985; Jacoby & Dallas, 1981; Kirsner et al., 1983; Roediger & Blaxton, 1987a, 1987b). The latter dissociation has been used to argue that implicit memory relies heavily on sensory–perceptual processes that are sensitive to physical features of the stimuli presented at study and test. The present findings, however, in combination with our previous research that showed that implicit memory for new associations requires some semantic study processing (Graf & Schacter, 1985; Schacter & Graf, 1986a), indicate that the relation between modality effects and implicit memory is rather more complex. On the basis of results of Experiment 1, it appears that reinstating the study modality on a visual stem-completion test is necessary to provide access to the semantic elaborations that support implicit memory of new associations. No such reinstatement of study modality appears to be necessary for explicit remembering of newly acquired associations on a visual cued-recall test.

One perplexing feature of the word-completion data merits brief commentary. A study–test modality shift had no effect on priming in the different-context condition; performance was virtually identical in the visual (.20) and auditory (.21) conditions. On the basis of results of previous studies (Graf & Schacter, 1985; Schacter & Graf, 1986a), we have assumed that performance in the different-context condition reflects priming of target words, independent of the study context. Because previous research has shown that word priming effects on the stem-completion test are modality sensitive (Graf et al., 1985), this assumption should be questioned. The modality insensitivity of performance in the different-context condition is replicated repeatedly in each of the present experiments, and we will thus reserve further commentary about it until the General Discussion.

Experiment 2

The modality specificity of implicit memory for new associations—an elaboration-dependent phenomenon—is unexpected and somewhat counterintuitive. Accordingly, we assessed the robustness of this finding by determining whether it can be replicated under different conditions. To this end, Experiment 2 was identical to Experiment 1 in all respects except for the study task, which required subjects to generate their own sentences rather than simply reading them. For this task, subjects were presented with pairs of unrelated words (e.g., NURSE–GARDEN) and were instructed to generate a sentence that links them meaningfully (e.g., The NURSE sat in the GARDEN with a patient). We have previously found similar levels of implicit memory for new associations following sentence generating and sentence rating tasks (Schacter & Graf, 1986a). What is important for the present purposes is that with the sentence generating task, only the target word pairs are presented in a modality-specific manner (i.e., in written or spoken form), whereas in the sentence rating task, both the target pairs and the elaborative information that links them (i.e., the sentence frame) are presented in a modality-specific fashion. Generation of a meaningful sentence in response to a word pair depends on semantic–elaborative processing that is presumably the same whether the pair is presented in written or spoken form. In view of these considerations, we expect that the sentence generating task would be even less likely than the sentence rating task to produce modality-specific implicit memory for new associations. Consequently, Experiment 2 provides a strong test of the robustness of the phenomenon observed in Experiment 1.

Method

Subjects. Forty-eight subjects participated in the experiment, either for course credit or for payment of $5.

Design, materials, and procedure. A 2 × 2 × 2 mixed design was used. The between-subjects variable was type of test (word completion vs. cued recall); the within-subjects variables were study modality (auditory vs. visual) and test context (same vs. different). The materials, counterbalancing of items across experimental conditions, and procedure were the same as in Experiment 1, except for (a) the stimuli that were presented for study and (b) the study task. In Experiment 2, the stimuli were the target word pairs from the sentences that had been used in Experiment 1, and subjects were required to think of and say aloud a meaningful sentence for each pair. Specifically, subjects were instructed to "generate a sentence that relates the two words in a meaningful manner." Subjects were told that they would later receive a memory test for the target pairs and that the sentence generating task would help them to remember the two words as a pair. After practicing the study task with a few pairs, the target pairs and buffer pairs were either read by the subject or spoken by the experimenter at a rate of about 6 s per pair, as in Experiment 1. Immediately after study, the name-completion filler task, the word-completion test, and the cued-recall test were given exactly as described for Experiment 1.

Results

Word completion. Baseline performance was .09 and .13 on same- and different-context test items, respectively. These proportions did not differ, $t(23) = 1.32$, and were averaged to yield an overall baseline rate of .11.

The mean proportions of test items that were completed with study-list targets in the main experimental condition are shown in Table 2. Performance in all conditions was significantly higher than the baseline completion rate, smallest $t(23) = 2.65$, thereby revealing consistent priming effects. For the visually presented target pairs, completion performance was considerably higher on the same-context items (.39) than on the different-context items (.19), thus replicating the results of Experiment 1 and previous studies (Schacter & Graf, 1986a). In contrast, however, for pairs presented in the auditory condition, the size of this same–different effect was

Table 2
Word Completion and Cued-Recall Performance in Experiment 2

Study modality	Test context: Word completion Same	Different	M	Cued recall Same	Different	M
Visual	.39	.19	.29	.74	.44	.59
Auditory	.29	.22	.26	.69	.42	.56
M	.34	.21	.28	.72	.43	.58

reduced considerably (.29 and .22 for same- and different-context items, respectively). An ANOVA showed a significant main effect of test context, $F(1, 23) = 6.76$, $MS_e = 2.34$; a nonsignificant main effect of study modality, $F(1, 23) = 1.39$, $MS_e = .60$; and a marginally significant interaction between these two variables, $F(1, 23) = 3.60$, $MS_e = 1.04$, $p = .06$. The t tests showed that the difference between performances on same- and different-context items was significant following visual presentation, $t(23) = 2.66$, but not following auditory presentation, $t(23) = 1.31$.

Cued recall. Table 2 also shows mean cued-recall performance. As expected, overall cued recall was higher than completion performance, and there were large associative effects for items studied in both visual and auditory modalities. There was a trend for slightly higher performance following visual than auditory study in both the same- and different-context conditions. However, in contrast to completion performance, the magnitude of the associative effect—the difference between performances in the same- and different-context conditions—was about the same in the two study conditions. An ANOVA revealed a significant main effect of test context, $F(1, 23) = 110.284$, $MS_e = 1.21$. Although the results suggest a small overall effect of study modality, the main effect of this variable did not achieve significance, $F(1, 23) = 2.84$, $MS_e = 1.62$, $p = .10$. In contrast to the ANOVA of the completion data, the interaction between test context and study modality did not approach significance, $F(1, 23) = .20$, $MS_e = 1.33$. A further analysis that included type of test as a variable revealed that the three-way interaction of Study Modality × Test Context × Type of Test approached, but did not attain, statistical significance, $F(1, 46) = 2.85$, $MS_e = 1.28$, $p = .09$.

Discussion

The results of Experiment 2 extend those of Experiment 1 by showing that even when subjects generate their own elaborators at the time of study, associative effects on stem-completion performance, but not cued-recall performance, are reduced significantly by a study–test modality shift. Because these associative effects are dependent on semantic study processing (Graf & Schacter, 1985; Schacter & Graf, 1986a), Experiment 2 provides further evidence that when implicit memory is assessed with a visual test, as in the present experiments, the semantic information that supports associative priming effects appears to be fully accessible only when target pairs are studied visually. An alternative possibility, however, is that the failure to observe significant associative effects on stem completion following auditory encoding owes to the fact that subjects do not engage in the same elaborative study activities for sentences or word pairs that are presented auditorily versus visually. For example, if study processing were not as "good" or "deep" in the auditory condition as in the visual condition, the semantic information that normally supports implicit memory of new associations may have been insufficient following auditory encoding. Two observations cast doubt on the validity of this idea. First, the cued-recall data from both Experiments 1 and 2 indicate that explicit memory for new associations was not influenced significantly by the study–test modality shift. If the auditory study condition somehow yielded "poorer" semantic elaboration, recall of pairs studied auditorily should have been lower than recall of pairs studied visually. Second, even though it may be plausible to suggest that the type of study processing differs when the elaborators are presented either visually or auditorily, as in the sentence rating task of Experiment 1, it seems implausible to argue that when subjects generate their own elaborators, as in Experiment 2, the quality of the generated elaborators depends on the modality in which a word pair is presented. In view of these considerations, we reject the idea that the observed modality effects are attributable to impoverished elaboration during auditory study. We hypothesize instead that when a visual stem-completion test is used, processing a target pair in the same modality at study and test is necessary to gain access to the semantic information that supports implicit memory for new associations. In Experiment 3, we evaluated one direct implication of this idea.

Experiment 3

If implicit memory for new associations depends on modality-specific processing, then providing subjects with a brief visual exposure to a target pair prior to auditory study ought to reduce or eliminate the modality effect on visual stem-completion performance. To examine this possibility, we gave subjects a 1-s visual exposure to each target pair immediately before they performed the sentence rating task from Experiment 1 on sentences presented in either the auditory or visual modality. For comparative purposes, we gave a second group of subjects a 1-s auditory exposure to a target pair immediately prior to the sentence rating task. According to the notion suggested previously, subjects given a visual preexposure should show comparable associative effects following both visual and auditory sentence rating, because visual information about the pair would be available in both conditions. By contrast, subjects given an auditory preexposure should show reduced associative effects following auditory sentence rating, because visual information about a target pair would not be available in this condition.

Method

Subjects. Ninety-six University of Toronto undergraduates participated in the experiment, either for course credits or for a payment of $5.

Design and materials. A 2 × 2 × 2 × 2 mixed design was used. The between-subjects factors were type of preexposure of target pairs (visual vs. auditory) and type of test (completion vs. cued recall). The within-subjects factors were study modality of the sentences (visual vs. auditory) and test context (same vs. different). The materials and counterbalancing of items across conditions were as described in previous experiments, with the same counterbalancing scheme used for both the visual and auditory preexposure groups.

Procedure. The instructions and procedure were the same as in Experiment 1, with one exception. Subjects were told that they would be seeing and hearing critical word pairs in sentences and that to ensure that they knew the critical pair they would be given a brief preexposure to it. In the visual preexposure group, this consisted of a 1-s exposure to an index card on which the word pair was printed in capital letters, immediately followed by either visual or auditory presentation of the target sentence in the manner described for Experiment 1. In the auditory preexposure group, the word pair was read aloud by the experimenter, followed immediately by either visual or auditory presentation of the target sentence. All other aspects of study, completion testing, and cued-recall testing were exactly as described for Experiment 1.

Results

Word completion. Baseline completion rate was identical in the same- and different-context conditions (.12).

Table 3 indicates that performance was significantly above baseline in all experimental conditions, smallest $t(23) = 2.66$. More important, these data indicate that in the visual preexposure group, completion performance was largely unaffected by the study–test modality shift: There were robust context effects for both visual and auditory sentences. In the auditory preexposure group, a typical context effect was observed for visual sentences, but there was a much smaller context effect following auditory sentences; the magnitude of the context effect in this latter condition was roughly half of that observed in the other three conditions. Thus, when subjects did not receive a visual preexposure to the target pair, a modality effect similar to that documented in Experiments 1 and 2 was observed.

Statistical analysis revealed significant main effects of test context, $F(1, 46) = 22.55$, $MS_e = 1.23$; and preexposure condition, $F(1, 46) = 5.53$, $MS_e = 2.45$. The latter effect confirms that completion performance was higher following visual than auditory preexposure. Neither the main effect of modality nor any interactions were significant. However, t tests revealed that performance was significantly higher in the same- than different-context condition following both visual and auditory sentences in the visual preexposure condition, and following visual sentences in the auditory preexposure condition, smallest $t(23) = 3.19$. In contrast, there was a nonsignificant context effect following auditory sentences in the auditory preexposure condition, $t(23) = 1.55$. Thus, the data indicate that significant context effects were observed only when some sort of visual exposure to a pair was provided, either by a preexposure or sentence presentation.

Cued recall. Table 3 also contains the cued-recall data. As in previous experiments, cued-recall performance was higher than completion performance, there were large context effects in all conditions, and no consistent effect of study modality was observed. There was also no consistent influence of preexposure condition. These statements were confirmed by an ANOVA that revealed a main effect of text context, $F(1, 46) = 141.45$, $MS_e = 1.21$, and no other significant main effects or interactions. The only effect that approached significance was the three-way interaction of Preexposure × Study Modality × Test Context, $F(1, 46) = 3.28$, $p = .07$, which indicates that there was a larger context effect following auditory than visual study in the visual preexposure condition, and similar context effects following auditory and visual study in the auditory preexposure condition. We have no explanation for this interaction and assume that it is spurious.

Table 3
Word Completion and Cued-Recall Performance in Experiment 3

	Test context					
	Word completion			Cued recall		
Study modality	Same	Different	*M*	Same	Different	*M*
Visual preexposure						
Visual	.40	.23	.32	.56	.34	.45
Auditory	.39	.26	.33	.66	.26	.46
M	.40	.25	.33	.61	.30	.46
Auditory preexposure						
Visual	.33	.20	.27	.58	.26	.42
Auditory	.24	.17	.21	.57	.25	.41
M	.29	.19	.24	.58	.25	.41

Discussion

The results of Experiment 3 are consistent with the idea that when a visual stem-completion test is used, access to the semantic elaborations that are necessary for implicit memory of new associations depends on modality-specific, sensory–perceptual processing at study and test. A 1-s visual preexposure to the critical pairs eliminated the modality effect observed in Experiments 1 and 2: There were robust associative effects following both visual and auditory sentence rating. By contrast, following an auditory preexposure, the pattern of performance documented in the previous experiments was again observed. There were small, nonsignificant associative effects on completion performance for auditory sentences together with larger, significant associative effects following visually presented sentences.

The general pattern of results observed in each of the first three experiments indicates that some kind of modality-specific, sensory–perceptual processing at both study and test is necessary to observe implicit memory for new associations on a visual word-completion task. It is possible that this kind of processing is primarily data driven—initiated and guided entirely by the visual stimuli that are presented at study and test (e.g., Jacoby, 1983b; Roediger & Blaxton, 1987b). An alternative possibility, however, is suggested by findings from previous experiments in which subjects were required to form a visual image for each auditorily presented study-list word. Performance on various implicit memory tests showed almost as much priming for these previously imaged words as for words that were visually presented for study (e.g., Jacoby &

Witherspoon, 1982; Roediger & Blaxton, 1987b). This finding suggests that the sensory–perceptual study processing that mediates priming need not be initiated and guided by visually presented words. To determine whether imaging spoken word pairs is sufficient to reduce or eliminate the modality effects observed in the previous three experiments, we used a preexposure condition in which subjects imagined, rather than saw, target pairs prior to visual or auditory study. In addition to providing further information about the kind of study processing needed to observe implicit memory for new associations, examination of the role played by visual imagery may also help to understand why we have observed small, albeit nonsignificant, associative effects following auditory encoding in each experiment. It is possible that subjects occasionally formed visual images of the target pairs that were presented auditorily, thereby engaging in some task-relevant sensory–perceptual processing and making available visual information about target pairs. If this notion is correct, requiring subjects to image prior to auditory study should produce reliable associative effects.

Experiment 4

Method

Subjects. Twenty-four volunteers participated in the experiment, either for pay of $5 or for course credits.

Design, materials, and procedure. To examine the effect of visual imagery on implicit memory for new associations, subjects were given a visual rating task that required them to imagine the target word pairs immediately prior to their appearance in either written or spoken sentences. For the visual rating task, target pairs were read aloud by the experimenter, and subjects were instructed to rate the words in terms of visual similarity on a scale from 1 (*not very similar visually*) to 5 (*very similar visually*). Specifically, subjects were told to "imagine the two words in lower case letters and then rate how similar they look." Making these ratings required about 4 s per pair and was followed immediately by either the visual or auditory presentation of a sentence containing the target pair. As in Experiments 1 and 3, subjects were required to provide a meaningfulness rating for each target sentence, and they did so in the manner described previously.

Immediately following study, subjects were given the name-completion and word-completion tests. The instructions, materials, and procedure for these tests were the same as in Experiments 1–3. Following the completion test, all subjects were given the cued-recall test in the manner described in previous experiments. We did not use a separate recall group in this experiment because the absence of a modality effect on cued-recall performance has been well-established by Experiments 1–3. Moreover, we have found in previous research (Schacter & Graf, 1986a) that patterns of cued-recall performance in the present paradigm are generally similar whether or not recall is preceded by a completion test.

Results and Discussion

Word completion. Baseline performance was .14 and .11 on same- and different-context items, respectively. These proportions did not differ, $t(23) < 1$, and were averaged for an overall baseline rate of .13.

The mean proportions of test items completed with studied target words in the main experimental conditions are displayed in Table 4. As expected for the sentences presented visually, completion performance was higher in the same-context condition (.31) than in the different-context condition (.22), although the magnitude of the associative effect was somewhat smaller than that observed for visually studied items in previous experiments. More important, however, there was a large context effect for sentences presented auditorily: Performance was considerably higher for same- (.36) than different-context (.20) test items. An ANOVA confirmed these observations by showing a significant main effect for test context, $F(1, 23) = 8.50$, $MS_e = 1.50$, with no other effects approaching significance. This pattern of results indicates that imaging the target pairs prior to receiving them in spoken sentences affects implicit memory for new associations in a manner similar to seeing them prior to auditory presentation: The modality effect demonstrated in Experiments 1 and 2 is no longer observed. These findings are consistent with previous results from experiments using familiar words (Jacoby & Witherspoon, 1982; Roediger & Blaxton, 1987b); they indicate that the kind of sensory–perceptual processing and consequent modality-specific information that supports implicit memory for new associations does not require actual visual presentation of word pairs. However, in view of the considerable evidence that visual imagery and visual perception are driven by common mechanisms (e.g., Farah, 1985), the results are entirely consistent with the notion that modality-specific visual processing at the time of study is necessary to observe implicit memory for new associations when a visual completion test is used.

Recall. Table 4 also presents the mean cued-recall results. As expected, overall cued recall was higher than completion performance, and there were large context effects in both the visual and auditory study conditions. An ANOVA revealed a significant effect of test context, $F(1, 23) = 66.40$, $MS_e = .84$. No other effects approached significance. Because the recall test was always administered after the completion test in this experiment, a separate analysis was also conducted on items that were not produced on the completion test. The results of this analysis were the same as in the full recall analysis.

General Discussion

In previous research, we demonstrated that implicit memory for new associations on a stem-completion test requires elaborative processing of semantic relations at the time of

Table 4
Word Completion and Cued Recall Performance in Experiment 4

	Test context					
	Word completion			Cued recall		
Study modality	Same	Different	*m*	Same	Different	*M*
Visual	.31	.22	.27	.56	.30	.43
Auditory	.36	.20	.28	.57	.32	.45
M	.34	.21	.28	.56	.31	.44

study (Graf & Schacter, 1985; Schacter & Graf, 1986a). The results of the present experiments indicate that implicit memory for new associations also requires modality-specific, sensory–perceptual processing: Associative effects on a visual stem-completion test were robust following visual presentation of target pairs but were weak and nonsignificant following auditory presentation of pairs. This modality effect was observed when target pairs were presented in the context of meaningful sentences (Experiments 1 & 3) and when subjects generated their own sentence elaborators (Experiment 2). A 1-s visual preexposure to a target pair immediately prior to auditory study eliminated the modality effect on completion performance (Experiment 3), as did a preexposure task that required subjects to form visual images of target pairs (Experiment 4). In contrast to the modality specificity of implicit memory for new associations, explicit memory for new associations was unaffected by study–test modality shifts.

Because there were consistently small context effects on the completion task following auditory study, we cannot claim that implicit memory for new associations is entirely eliminated by a modality shift. However, consistent with the results of Experiment 4, it is possible that some or all of these effects may be attributable to the formation of visual images during auditory study. Whatever the validity of this suggestion, we can and do claim that implicit but not explicit memory for new associations is consistently reduced by a study–test modality shift.

Our data have implications for theoretical views of modality effects on implicit-memory tests. Morton (1979) argued that such effects are produced by the activation of modality-specific logogens. By this view, presentation of a word on a study list activates a preexisting, modality-specific representation of it; the activation persists for a relatively brief time and facilitates subsequent performance on such implicit-memory tests as lexical decision, word identification, or stem completion (see Squire, 1987, for a similar notion). This view has serious difficulties accommodating the present evidence, because the associative effects that we have shown to be modality specific are both elaboration dependent and long lasting; we have found significant associative effects after a 24-hr retention interval (Schacter & Graf, 1986a). We have therefore argued that these associative effects are mediated by components of newly formed episodic representations (Graf & Schacter, 1987; Schacter & Graf, 1986a) and, hence, involve more than just activation of preexisting representations or logogens.

At a rather general level, then, it seems clear that an adequate account of our data will be one that allows for new information acquired during a specific study episode to influence performance on implicit-memory tasks (e.g., Graf & Schacter, 1987; Jacoby, 1983a, 1983b; Masson, 1984; Moscovitch, Winocur, & McLachlan, 1986; Roediger & Blaxton, 1987a, 1987b; Schacter, 1985). One such account that has been applied to observations of modality specificity involves the distinction between data-driven and conceptually driven processing (Jacoby, 1983b; Roediger & Blaxton, 1987b). As noted earlier, data-driven processes are initiated and guided directly by information in study and test materials, whereas conceptually driven processes reflect subject-initiated activities such as elaborating, organizing, and reconstructing. Roediger and Blaxton (1987b) argued that standard implicit tests, such as word identification and stem completion, are largely data driven, whereas standard explicit tests, such as recall and recognition, are largely conceptually driven. Because the sensory modality in which target materials are studied and tested should affect data-driven processes but not conceptually driven processes, it follows that study–test modality shifts should impair performance on implicit tests more than on explicit tests. This sort of account can comfortably accommodate most of the modality effects from experiments in which subjects studied familiar words and implicit memory was assessed with word-identification (Jacoby & Dallas, 1981; Kirsner et al., 1983), word-completion (Graf et al., 1985; Roediger & Blaxton, 1987a), or lexical-decision (Kirsner & Smith, 1974) tasks. One reason for this is that there is some independent basis for classifying the foregoing tasks as data driven; performance on them is affected by within-modality changes of various kinds of surface information (Jacoby & Hayman, 1987; Roediger & Blaxton, 1987a) and is largely unaffected by semantic versus nonsemantic processing at the time of study (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981).

The elaboration-dependent nature of implicit memory for new associations, however, makes it difficult to account for the present results with the data- versus conceptually driven distinction. The fact that associative effects documented here and elsewhere (Graf & Schacter, 1985; Schacter & Graf, 1986a) require semantic study elaboration implies that the stem-completion task we have used draws on conceptually driven processing; indeed, Roediger and Blaxton (1987a) noted that completing a word fragment in the presence of another word may elicit conceptually driven processing that does not occur when the fragment is presented alone. By their account, tests that involve conceptually driven processing should be largely insensitive to study–test modality shifts. Accordingly, associative effects on stem completion should not be modality specific; hence the difficulty in accommodating our results.

Perhaps the most interesting implication of our data, and the main reason why they are not readily accommodated by existing accounts of modality-specific priming on implicit-memory tests, is that they suggest a tight link between modality-specific, sensory–perceptual processing on the one hand, and semantic–elaborative processing on the other, at least within the domain of implicit memory. One of the few theorists to recognize such a link was Kolers (1975). On the basis of experiments in which subjects read and re-read spatially transformed script, a task that appears to tap implicit memory (e.g., Cohen & Squire, 1980; Masson, 1984), Kolers concluded that memory for the semantic aspects of what was read is influenced by, and intertwined with, memory for graphemic and other kinds of sensory–perceptual information. However, Kolers's view is consistent only with our data on implicit memory for new associations. The tight interlinkage between semantic and sensory processing that Kolers discussed is evident, at least in the present experiments, only in an implicit-memory test: Our results showed that explicit memory for new associations was not affected by study–test modality shifts in any of the four experiments.

The fact that modality effects were observed for implicit but not explicit memory for new associations has implications for any account of our data that focuses on information acquired about particular study episodes. Because explicit memory for new associations is presumably based on such information, yet is not influenced by study–test modality shifts, it follows that explicit and implicit memory for new associations are based on different kinds of episodic information. A speculative hypothesis is that implicit memory for new associations depends critically on certain visual components of an episodic representation that are by-products of sensory–perceptual processing and that differ from the representational components that support explicit memory. By this hypothesis, establishment of these visual components at the time of study may be necessary in order to provide access to semantic components of the representation on a subsequent visual completion test. In view of these suggestions, it is important to determine whether modality specificity of implicit memory for new associations is observed only with visual implicit tests, or whether the phenomenon is also observed when implicit memory is tested through other sensory modalities. It is possible that reinstatement of study modality (visual, auditory, or otherwise) at the time of an implicit test is necessary to observe implicit memory for new associations. Alternatively, modality-specific effects on implicit memory for new associations may be observed only for visually studied items.

In the discussion of Experiment 1, we noted a puzzling feature of the data: Priming of different-context test items was entirely unaffected by the study–test modality shift. This result was consequently replicated in Experiments 2 and 3. As noted earlier, the reason why the result was puzzling is that we had previously assumed that priming in the different-context condition is equivalent to the priming observed when individual words are studied and three-letter stems are used to assess implicit memory. Yet word priming effects under these conditions are modality specific. Therefore, if priming in the different-context condition were equivalent to word priming, it, too, should have been modality specific. We are presently unable to offer any satisfying solution to this puzzle. It is important to note, however, that in other experiments that have used stem- and fragment-completion tests, some modality-specific priming has been observed together with some cross-modal priming (e.g., Graf et al., 1985; Roediger & Blaxton, 1987a). These observations, together with the present results, indicate that an important challenge for future implicit-memory research will be to elucidate the relation between modality-specific and modality-nonspecific components of implicit memory.

References

Clarke, R. G. B., & Morton, J. (1983). Cross modality facilitation in tachistoscopic word recognition. *Quarterly Journal of Experimental Psychology, 35A*, 79–96.

Cohen, N. J., & Squire, L. R. (1980). Preserved learning and retention of pattern-analyzing skill in amnesia: Dissociation of "knowing how" and "knowing that." *Science, 210*, 207–209.

Farah, M. J. (1985). Psychophysical evidence for a shared representational medium for mental images and percepts. *Journal of Experimental Psychology: General, 114*, 92–103.

Forster, K. I. (1976). Accessing the mental lexicon. In R. J. Wales & E. Walker (Eds), *New approaches to language mechanisms* (pp. 257–287) Amsterdam: North Holland.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior, 23*, 553–568.

Graf, P., Mandler, G., & Haden, P. (1982). Simulating amnesic symptoms in normal subjects. *Science, 218*, 1243–1244.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 501–518.

Graf, P., & Schacter, D. L. (1987). Selective effects of interference on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*, 45–53.

Graf, P., Shimamura, A. P., & Squire, L. R. (1985). Priming across modalities and priming across category levels: Extending the domain of preserved function in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 385–395.

Jacoby, L. L. (1983a). Perceptual enhancement: Persistent effects of an experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*, 21–38.

Jacoby, L. L. (1983b). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning and Verbal Behavior, 22*, 485–508.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110*, 306–340.

Jacoby, L. L., & Hayman, C. A. G. (1987). Specificity of visual transfer in word identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*, 456–463.

Jacoby, L. L., & Witherspoon, D. (1982). Remembering without awareness. *Canadian Journal of Psychology, 36*, 300–324.

Kirsner, K., Milech, D., & Standen, P. (1983). Common and modality-specific processes in the mental lexicon. *Memory & Cognition, 11*, 621–630.

Kirsner, K., & Smith, M. C. (1974). Modality effects in word identification. *Memory & Cognition, 2*, 637–640.

Kolers, P. A. (1975). Specificity of operations in sentence recognition. *Cognitive Psychology, 7*, 289–306.

Kucera, M., & Francis, W. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.

Masson, M. E. J. (1984). Memory for the surface structure of sentences: Remembering with and without awareness. *Journal of Verbal Learning and Verbal Behavior, 23*, 579–592.

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

McKoon, G., & Ratcliff, R. (1986). Automatic activation of episodic information in a semantic memory task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*, 108–115.

Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen model. In P. A. Kolers, M. E. Wrolstad, & H. Bouma (Eds.), *Processing of visible language* (Vol. 1, pp. 256–268). New York: Plenum.

Moscovitch, M., Winocur, G., & McLachlan, D. (1986). Memory as assessed by recognition and reading time in normal and memory-impaired people with Alzheimer's disease and other neurological disorders. *Journal of Experimental Psychology: General, 115*, 331–347.

Richardson-Klavehn, A., & Bjork, R. A. (1988). Measures of memory. *Annual Review of Psychology, 39*, 475–543.

Roediger, H. L. III, & Blaxton, T. A. (1987a). Effects of varying modality, surface features, and retention interval on priming in word-fragment completion. *Memory & Cognition, 15*, 379–388.

Roediger, H. L. III, & Blaxton, T. A. (1987b). Retrieval modes produce dissociations in memory for surface information. In D. S. Gorfein & R. R. Hoffman (Eds.), *Memory and cognitive processes: The Ebbinghaus centennial conference* (pp. 349–379). Hillsdale, NJ: Erlbaum.

Scarborough, D. L., Gerard, L., & Cortese, C. (1979). Accessing lexical memory: The transfer of word repetition effects across task and modality. *Memory & Cognition, 7*, 3–12.

Schacter, D. L. (1985) Priming of old and new knowledge in amnesic patients and normal subjects. *Annals of the New York Academy of Sciences, 444*, 41–53.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*, 501–518.

Schacter, D. L. (in press). On the relation between memory and consciousness: Dissociable interactions and conscious experience. In H. L. Roediger III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving*. Hillsdale, NJ: Erlbaum.

Schacter, D. L., & Graf, P. (1986a). Effects of elaborative processing on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*, 432–444.

Schacter, D. L., & Graf, P. (1986b). Preserved learning in amnesic patients: Perspectives from research on direct priming. *Journal of Clinical and Experimental Neuropsychology, 8*, 727–743.

Schacter, D. L., & McGlynn, S. M. (in press). Implicit memory: Effects of elaboration depend on unitization. *American Journal of Psychology*.

Squire, L. R. (1987). *Memory and brain*. New York: Oxford University Press.

Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8*, 336–342.

Received November 23, 1987
Revision received March 8, 1988
Accepted April 15, 1988 ■