Implicit Memory for New Associations: An Interactive Process Approach

Angela Micco and Michael E. J. Masson
University of Victoria
Victoria, British Columbia, Canada

The contributions of data-driven and conceptually driven processes to implicit memory for new associations were examined using a word stem completion task. Targets encoded in the context of an unrelated word were more likely to be produced on the completion task if tested in the presence of the original, rather than a different, cue word. This context effect was obtained using a semantic elaboration encoding task and a copying task that required no elaboration, but not when orthographically or semantically similar cue words were used at test. With homograph cue words the context effect depended on reinstating the appropriate interpretation of the cue word. Implicit memory for new associations is based on episodic memory for integrated data-driven and conceptually driven encoding operations that have a converging influence on the initial interpretation of a stimulus configuration.

The transfer-appropriate processing framework developed by Roediger and his colleagues (e.g., Roediger & Blaxton, 1987; Roediger, Weldon, & Challis, 1989; Srinivas & Roediger, 1990) has provided an effective characterization of the distinction between explicit and implicit tests of memory. Explicit memory tests are those that require a subject to consciously recollect a prior encoding episode, whereas implicit memory tests carry no such requirement and instead express memory for prior occurrence through facilitation in tasks such as word identification. Within the transfer-appropriate processing framework, memory for prior occurrence results from an overlap between the retrieval processes induced by a memory test and the encoding operations applied during learning. Memory tests can be classified as primarily conceptually driven, in the sense that performance relies on the recapitulation of the elaborative semantic processes that were applied during the encoding of the stimulus or primarily data driven, in which case performance depends on the match between the sensory perceptual analysis applied to the stimulus during encoding and at test. Within this framework, explicit and implicit memory test performance can rely on different retrieval processes and therefore benefit from different types of processing at study.

For experiments in which items consist of familiar words, the transfer-appropriate processing framework has been able to account for dissociations between explicit and implicit memory tests, particularly when these tests have been classified as primarily conceptually driven and data driven, respectively. For example, performance on some explicit but not implicit memory tests is strongly influenced by the degree of semantic elaboration during encoding (e.g., Graf, Mandler, & Haden, 1982; Jacoby & Dallas, 1981). In contrast, performance on some implicit memory tests is more sensitive than performance on explicit memory tests to changes in an item's surface structure between study and test (Bassili, Smith, & MacLeod, 1989; Kirsner & Dunn, 1985; Weldon & Roediger, 1987). Within this framework, however, there is no necessary relationship between the explicit and implicit nature of a memory test and the mode of processing it requires. It is possible to develop explicit memory tests that emphasize data-driven processes and implicit tests that depend on conceptually driven processes (e.g., Blaxton, 1989; Srinivas & Roediger, 1990).

The transfer-appropriate processing framework runs into some difficulty, however, in attempting to account for demonstrations of memory for new associations on implicit tests (Graf & Schacter, 1985, 1989; Schacter & Graf, 1989). In these experiments unrelated cue-target word pairs (e.g., MOTHER–WINDOW) were studied and at test the first three letters of the target were presented in the context of either the word with which it had been paired at study (e.g., MOTHER–WIN____) or with a different word (e.g., REASON–WIN____). Subjects were given one of two memory tests. For the explicit memory test, they were instructed to recall the study list word that fit the stem (letter-cued recall), and for the implicit test, they were to complete the stem with the first word that came to mind (word stem completion). Context-dependent memory was demonstrated on both tasks, in that the proportion of target items used to complete the stems was higher when the stems were presented in the context of the original cue word. The cue-target pairs were unrelated prior to the experiment, so context sensitivity was attributed to the development of a new association between the members of a pair. This result might be explained within the transfer-appropriate processing framework by proposing that the pres-
ence of a context word at study and test invoked conceptually driven processing. As we shall see, however, this is not an entirely satisfactory account of the phenomenon.

Memory for new associations as demonstrated in letter-cued recall and word stem completion appears to be contingent on processing a semantic relationship between members of a pair (Graf & Schacter, 1985; Schacter & Graf, 1986; Schacter & McGlynn, 1989). For both recall and stem completion tests, the context effect was obtained when subjects were required to encode a meaningful association between the cue-target pairs, but not when the encoding task emphasized the individual meaning of the words (e.g., pleasantness ratings), nor when a nonsemantic vowel comparison task was used (Graf & Schacter, 1985).

Recall and stem completion tests were, however, differentially affected by type of relational processing. For example, generating as opposed to reading a sentence that relates the members of a word pair produced a larger associative effect only for the letter-cued recall test (Schacter & Graf, 1986). Other ways in which explicit and implicit tests of memory for new associations have been dissociated are: (a) Proactive and retroactive interference manipulations detrimentally affected performance on explicit memory tests but not on implicit tests (Graf & Schacter, 1987); (b) explicit but not implicit tests yielded improved performance when the encoding task involved forming connections among word pairs (Graf & Schacter, 1989); and (c) some types of amnesics who showed deficits on the explicit memory test demonstrated normal associative memory on the implicit test (Cermak, Blackford, & O'Connor, 1988; Graf & Schacter, 1985).

A particularly important dissociation between explicit and implicit tests of memory for new associations is that implicit but not explicit tests yield a modality-specific effect. Schacter and Graf (1989) found context-sensitive priming on a word stem completion task when cue-target pairs were visually presented at study but not when initial exposure to the pairs was in the auditory modality. In contrast, a change in modality did not eliminate the context-sensitive effect on a letter-cued recall test. On the basis of these and earlier results, Schacter and Graf (1989) concluded that "implicit memory for new associations on a stem-completion test requires elaborative processing of semantic relations" (p. 9) and "also requires modality-specific, sensory-perceptual processing" (p. 10). It is the modality-specific nature of implicit memory for new associations that makes the transfer-appropriate processing account of the effect appear inadequate.

Schacter and Graf (1989) concluded that there is a strong connection between perceptual and semantic processing within the domain of implicit memory. Moreover, Graf and Schacter (1989) extended this notion by emphasizing the development of unitized representations. Unitization is assumed to occur when subjects are able to perceive inherent structure in a stimulus ensemble or to conceive of a structure that could be used for connecting elements of the ensemble. In the case of unrelated word pairs, they assume that elaborative processing of the meaning of the words serves as the glue or structure for a unitized representation involving sensory-perceptual as well as semantic attributes of the two words. Finally, it is assumed that modality-specific effects arise because redintegration of unitized representations (Horrowitz & Prys tulak, 1969) is the basis for implicit memory for new associations, and redintegration is driven by modality-specific test cues. In effect, modality-specific information provides an access key to unitized representations.

The emphasis on elaboration, unitization, and redintegration in the Graf and Schacter (1989; Schacter & Graf, 1989) explanation of implicit memory for new associations is consistent with views that promote the coordination of data-driven and conceptually driven pattern-analyzing operations (Kolers, 1975, 1979; Kolers & Roediger, 1984; Masson & Sala, 1978). This view is somewhat different from that of Roediger and his colleagues (e.g., Blaxton, 1989; Roediger et al., 1989), in which it is assumed that the degree of data-driven and conceptually driven processing varies across memory tasks. Rather than emphasizing the relative amount of contribution made by these two types of processing to performance on a memory test, we are most interested in the integration or coordination of the two types of processes. There is some difficulty, however, in developing a clear picture of how coordinated processing goes forward. In particular, we are concerned with the issues of how unitized representations are formed and how they are redintegrated during a test.

The formation of unitized representations that influence implicit memory for new associations appears to depend on semantic elaboration. In all of the experiments described in the line of research by Graf and Schacter, implicit memory for new associations has been obtained only when subjects engaged in some form of elaboration of the meaning of each word pair.1 We use the term elaboration to refer to the mental manipulation in working memory of a symbol's form or its meaning in relation to other knowledge (Anderson & Reder, 1979; Craik & Tulving, 1975) and differentiate it from what we call interpretive encoding, which precedes elaboration and comprises the initial identification of a symbol. We note that, in general, instructions to subjects regarding the kind of elaboration to perform on items has a powerful impact on explicit memory tests but has little or no effect on implicit memory for individual words (Graf et al., 1982; Jacoby & Dallas, 1981). Viewed from this perspective, the apparent dependence of implicit memory for new associations on the elaboration of meaning is particularly interesting. Moreover, Whittlesea and Cantwell (1987) established that unitized representations of letter strings comprising pseudowords could be created by assigning an arbitrary meaning to each pseudoword. This result is consistent with the Graf and Schacter (1989) claim that meaning is the glue for unitization.

The question we wish to ask is whether the activity that follows a word pair's initial identification and that is associated with elaboration of meaning is actually necessary for unitization or whether processes involved in the initial identification of a word pair might be sufficient. Although the latter possibility is acknowledged by Graf and Schacter (1989),

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1 Graf and Schacter (1989) described an unpublished experiment in which implicit memory for new associations was obtained when subjects were asked to form an interactive image of the objects represented by members of a word pair. We view this as another form of elaboration of the meaning of the words.
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it does not constitute a major component of their explanatory framework and seems to be restricted in their amount to either perceptual mechanisms or cases involving previously associated elements.

Our suggestion is that the unitized representation apparently required for implicit memory for new associations may arise from the initial, context-dependent encoding of word pairs. From this perspective, the function of the postidentification elaboration required by tasks such as sentence generation is to encourage subjects to initially encode members of a word pair in relation to one another. For instance, after identifying the first word, its meaning serves as the context within which the second member of the pair is interpreted as it is identified. Those aspects of the meaning of the second word that are most appropriate to the meaning of the first word are emphasized in the encoding. For example, given the pair HOUSE–FLOWER, the aspects of FLOWER that figure predominantly in its encoding might have to do with colorful flower beds surrounding a house rather than sweet scents or hovering bees. These encoded features might also influence the nature of the sentence that a subject would generate if given the task to produce a meaningful sentence containing the word pair.

This proposal is a rendition of the construction–integration model of comprehension developed by Kintsch (1988) in which interpretations of individual words are influenced by knowledge activated by the encoding of earlier words and propositions. We suggest that it is this initial context-dependent encoding of a perceptual pattern that yields the unitized representation underlying implicit memory for new associations. In this view, the operations applied after the words have been identified elaborate the initial encoding and contribute to performance on explicit memory tests, but they do not directly contribute to unitized encoding. We see an important distinction, then, between interpretive encoding operations that are responsible for the initial identification and interpretation of a stimulus and elaborative encoding processes that entail reflective manipulation of information (for similar views, see Graf & Ryan, 1990; Johnson, 1983; Masson & MacLeod, 1991). The contribution of elaborative task demands to implicit memory for new associations is to encourage subjects to interpret words in relation to one another as they are being identified. The emphasis on interpretive encoding rather than on elaboration is in the spirit of many demonstrations of perceptual grouping effects handed down by the tradition of Gestalt psychology. Those effects emerge directly as a result of perception, with an immediacy that precludes careful deliberation or manipulation.

An important aspect of interpretive encoding is that contributions are made by both data-driven and by conceptually driven operations that function in an integral way to converge on an interpretation of a stimulus. In this approach, dissociations between implicit and explicit memory tests are ascribed not to the data-driven or conceptually driven nature of such tests but rather to the degree to which the tests are influenced by interpretive or elaborative encoding processes. In general, implicit memory tests are influenced by interpretive encoding operations and explicit tests are most strongly affected by elaborative encoding, although interpretive encoding operations can also make a contribution to explicit memory tests by enhancing the fluency with which an item is identified or called to mind on the test (Jacoby & Hollingshead, 1990).

The interaction between conceptually driven and data-driven processes used during interpretive encoding is assumed to form an episodic representation as suggested by Kolers (1979; Kolers & Roediger, 1984). The redintegration that Graf and Schacter (1989) propose as the basis for implicit memory for new associations can be viewed as a reenactment of the interpretive encoding operations that were applied during the study phase. A critical assumption, however, is that this reenactment entails both the data-driven and the conceptually driven operations that were originally applied. As Graf and Schacter (1989; Schacter & Graf, 1989) have shown, redintegration depends on having enough of the original stimulus pattern available to generate data-driven operations similar to those that were applied during the first encoding of the word pair, yielding modality-specific effects in this paradigm. In addition, we suggest that this activity must be accompanied by an appropriate interpretation of the data. Failure to reinstate the integrated configuration of data-driven and conceptually driven processing should prevent redintegration.

In the series of experiments that we report, the objective was to pursue three implications of the framework we have described. First, if implicit memory for new associations arises from the interpretive encoding operations applied to a word pair, it should be possible to demonstrate the effect without requiring subjects to engage in an extended elaborative processing task. All that should be necessary is to encourage subjects to initially encode members of a pair in relation to one another. Second, our emphasis on the interaction between data-driven and conceptually driven processes applied during the identification of a stimulus and the episodic memory that results from this activity implies that neither type of process operating on its own would be adequate to produce implicit memory for new associations. Specifically, a cue that is only orthographically or only semantically similar to the original cue should not produce any more priming than an unrelated cue. A view that suggests visual information is an access key to a unitized representation (Graf & Schacter, 1989; Schacter & Graf, 1989) might predict, however, that a slightly altered key (an orthographically similar cue) could fit the lock. Third, our view is that the contribution of a visual cue word to the elicitation of implicit memory for an associated target lies in its ability to recruit the integrated configuration of data-driven and conceptually driven operations that were applied during its interpretation. We contrast this with the idea that the visual pattern is uninterpreted visual information that, when reinstated, provides an access route to the semantic components of a unitized representation. The first two issues were explored together in Experiments 1 and 2, and the third issue was addressed in Experiment 3.

Experiment 1

In Experiment 1 we attempted to demonstrate that an encoding task that did not involve the elaboration of word pairs but that did encourage unitization during stimulus iden-
tification could generate implicit memory for new associations. We selected word copying as a test case for two reasons. First, it does not require subjects to process the meaning of the words beyond their initial identification. Subjects need only identify the word pairs and maintain them in working memory while copying them. Second, Whittlesea and Brooks (1988) obtained evidence to indicate that the copying task encourages integral processing of unrelated items. We also included a semantic elaboration task to replicate earlier work with this paradigm. After encoding word pairs in one of these tasks, subjects were given a stem completion test in which stems were presented in the context of their original partner or in the presence of a different word.

We included a wider variety of alternative context words than Graf and Schacter used in their research. In addition to using re-paired and new cue words to establish a control condition against which context effects could be gauged, two other types of cues were used. In one condition, cue words were synonyms of the original cues and were orthographically dissimilar. In the other condition, the cue words were orthographically similar to the original cues but were semantically unrelated. If one were to argue that implicit memory for new associations is based on accessing a unitized representation either with appropriate visual information or with conceptually driven processes that emphasize word meaning, orthographically similar or conceptually similar cue words might be expected to produce some amount of priming over that generated by unrelated cue words. In contrast, by the interactive processing view that we have proposed, neither type of cue should produce an advantage over unrelated cues.

To establish that effects obtained with the stem completion test were not strongly influenced by conscious retrieval strategies, half of the subjects in Experiment 1 were given a cued-recall task that was based on the same cue-target pairs as those used in the stem completion task. Explicit recall instructions such as those associated with cued-recall tests were assumed to invoke retrieval strategies that depend on elaborative encoding operations (Craik & Tulving, 1975). Consequently, we expected to find a stronger context effect in the elaborative encoding condition than in the nonelaborative copying condition when a cued-recall test was used. In fact, it was conceivable that no context effect would emerge in cued-recall after the copying task. In contrast, we expected similar context effects to emerge for both encoding tasks on the stem completion test. If obtained, this dissociation would reflect the criticism that context effects obtained on the stem completion test resulted from deliberate retrieval strategies.

Method

Subjects. The subjects were 72 University of Victoria undergraduates who participated on a voluntary basis. Half of the subjects were randomly assigned to a word stem completion task, and the other half were assigned to a letter-cued recall task. Within each of these two groups, half of the subjects were randomly assigned an elaboration encoding task, and half were assigned a copying task.

Design and Materials. A 2 x 2 x 6 mixed factorial design was used. Retrieval task (word stem completion and letter-cued recall) and encoding instructions (elaboration and copying) were between-subjects factors, and the within-subject factor was test context (same, orthographically similar, semantically similar, re-paired, new, and baseline).

The critical test items were 60 cue-target pairs constructed according to the following criteria. The targets were medium-frequency (10–60 per million) concrete nouns selected from the Kucera and Francis (1967) norms. Each target was between 4 and 12 letters in length, and the first 3 letters (word stems) of each of the target words were represented by at least 10 common English words in a pocket dictionary. The test cues were 60 concrete nouns selected from the Whitten, Suter, and Frank (1979) synonym ratings, the Wilding and Mohindra (1983) preferred synonym norms, or Roger's Thesaurus (Mawson, 1946). The cues and targets were randomly combined to form unrelated pairs. In addition, 44 filler and practice pairs were constructed. These items consisted of medium-frequency concrete nouns, each paired with a 3-letter stem that was represented by at least 10 common English words in a pocket dictionary. Four pairs acted as practice items at the beginning of the study phase and did not appear on the test. The remaining 40 filler pairs were presented during the test phase only.

Test context conditions were established by varying the study cues within subjects and keeping the test cues constant across conditions. To do this, five lists of study cues were constructed. One list consisted of the same cues as those used on the test with the original pairings intact. This list was used in the same cue condition. The second list consisted of the test cues reassigned to different target words, and this list was the re-paired-context condition. The third list consisted of an orthographically similar version of each test cue, and each item was derived by changing one of the test cue's interior letters so that the result was a legal English word that was semantically dissimilar to the test cue. The fourth list was comprised of semantically similar but orthographically dissimilar cues that were normative synonyms of the test cues. Each synonym cue was selected from the same source as the test cue. This list was used in the semantically similar condition. The fifth list of cues consisted of 60 medium-frequency words selected from the Kucera and Francis (1967) norms and randomly paired with target words. This list constituted the new context condition. In the baseline condition, the cue-target pairs were not presented during study. The first three letters of all the filler and critical words were unique. The entire list of critical targets and cues is shown in Appendix A.

For counterbalancing purposes, the 60 critical targets and their corresponding sets of cues were divided into six blocks of 10 targets each. For each subject, one of the six blocks was not presented at study and was used to assess the baseline probability of completing the stems with the target item. The remaining five blocks of targets were presented during the study phase, one block of targets appearing with each of the five possible study cues. Assignment of blocks of targets to these six conditions was made according to a Latin square counterbalancing scheme so that across subjects each block of targets was tested equally often in each context condition.

Each word pair used in the study phase was typed in uppercase on an index card. For the test phase, the 60 critical and 40 of the filler cue-target pairs were typed in uppercase and in random order on a set of four pages. In each pair, the target item appeared as a word stem with only the first three letters available, and a series of 10 underscore characters was appended to each target to indicate where the remainder of the word was to be printed (e.g., COLLAR--SNA--). The fillers were included for the benefit of subjects in the word stem completion condition to disguise the fact that the critical pairs were seen at study. The goal was to reduce the likelihood of subjects becoming aware that the word stem completion task was assessing memory for an item's prior occurrence because this knowledge may result in the adoption of an explicit retrieval orientation.
To further reduce the possibility of using deliberate retrieval strategies on the word stem completion task, a distractor task that required subjects to generate the names of cities in response to stimuli consisting of the initial letter of the city (e.g., H_____) was interpolated between study list presentation and the test. This test consisted of 20 first-letter cues typed on one sheet of paper.

**Procedure.** Subjects were tested individually. In the study phase, half of the subjects were asked to copy each pair of words side by side on a separate sheet of paper, and the other half were asked to generate and say aloud a sentence that would meaningfully relate the word pair together (e.g., MAYOR-BOULDER: The MAYOR stood on top of a BOULDER to give her speech). The letter task has been used successfully by Graf and Schacter (1987) to produce implicit memory for new associations. Subjects were not informed that their memory for the word pairs would be tested. In keeping the procedure established by Graf and Schacter (1989), the word pairs were presented for 6 s each. The four filler pairs were presented first, followed by 50 critical pairs in a random order.

After the critical pairs had been presented, all subjects were given 3 min to complete the distractor task involving city names. Half of the subjects were then given a word stem completion task, and the other half were given a letter-cued recall task. In the word stem completion task, subjects were instructed to complete each word stem with the first word that came to mind that would fit the stem. Subjects were also told that the context word next to the stem was present to serve as an aid in helping them to think of a completion but that it was not necessary that the completion be related in any way to the context word. Subjects were told not to complete the fragments with proper names and were informed that beyond this restriction there was no correct or incorrect response. Subjects were encouraged to perform this test as quickly as possible and not to leave any stems incomplete.

Subjects in the letter-cued recall task were instructed that the task was a cued-recall test and that they were to think back to the study list and complete the word stems with the study list targets. Subjects were informed that some of the stems appeared in the context of their original study partner, some appeared with a word that was paired with another context word on the study list, and some appeared in the context of words that had not appeared in the study list. In addition, some word pairs had never been presented before. Subjects were encouraged to work as quickly as possible and, as in the work by Schacter and Graf (1989; Graf & Schacter, 1987), were instructed to complete all the stems even if they felt that they had to guess.

**Results and Discussion**

In all the analyses that we report, the Type I error rate was set at .05. The dependent measure was the proportion of targets recalled on the letter-cued recall task or the proportion of target words produced as word stem completions. In scoring each test, a response was counted as correct if it matched the study list target or its plural form.

**Letter-cued recall.** The mean proportion of targets produced on the cued-recall test as a function of encoding task and context condition is displayed in the upper section of Table 1. The first analyses were conducted to demonstrate that the probability of recalling studied targets exceeded the probability of producing targets that had not been studied. Performance in each condition of the design involving previously studied targets was individually compared with performance on new targets. These comparisons were done separately for subjects in the elaboration and copying groups. All but one of these comparisons (orthographically similar context word in the copying group) exceeded or approached significance, indicating that subjects generally produced more targets that they had actually studied than nonstudied targets.

Scores in the re-paired and new context conditions were compared separately for each encoding group. Given the previous work of Graf and Schacter (1985), we did not anticipate any reliable difference between these two conditions, and none was found, $F(1, 17) = 1.84, p > .15$, for the elaboration group and $F < 1$ for the copying group. Therefore, performance in the new and re-paired context conditions was combined to form a single, more reliable estimate of performance when stems were tested in contexts unrelated to those used during the study phase. In the analyses to follow, we refer to this combined score as the *unrelated condition.*

Performance on items tested in contexts that varied in their relationship to the originally studied cue word was assessed in a single analysis of variance (ANOVA) with test context (same, orthographically similar, semantically similar, and unrelated) and encoding task (elaboration and copying) as factors. The ANOVA revealed that performance was reliably

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### Table 1

**Letter-Cued Recall and Word Stem Completion Performance as a Function of Study Task and Test Context in Experiment 1**

<table>
<thead>
<tr>
<th>Test context</th>
<th>Test and encoding task</th>
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<tbody>
<tr>
<td></td>
<td>Same</td>
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<tr>
<td>Cued-recall</td>
<td></td>
</tr>
<tr>
<td>Elaboration</td>
<td>.44</td>
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<tr>
<td>Stem completion</td>
<td></td>
</tr>
<tr>
<td>Elaboration</td>
<td>.34</td>
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<tr>
<td>Copying</td>
<td>.28</td>
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<tr>
<td>(M)</td>
<td>.29</td>
</tr>
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*Note.* The pooled estimate of the standard deviation taken across all conditions in the cued-recall task was .16, and across all conditions in the stem completion task the pooled estimate was .13.

*Orth. = orthographically similar.

*Unrelated = mean of re-paired and new conditions.
higher in the elaboration group than in the copying group (.31 vs .22), \( F(1, 34) = 6.81, MS_e = 0.041 \). There was also a reliable difference among the test context conditions, \( F(3, 102) = 4.09, MS_e = 0.022 \), indicating that the cued-recall task yielded context sensitivity. Furthermore, there was a reliable interaction between encoding task and test context, \( F(3, 102) = 3.31, MS_e = 0.022 \). The interaction and the pattern of means suggested that for the cued-recall test the advantage of using the same context word at study and test was restricted to the elaboration group.

This conclusion was supported by a set of planned comparisons for each encoding group. Performance in the unrelated condition was compared with performance in the same, orthographically similar, and semantically similar context conditions in turn. In the elaboration group, it was found that the same context condition produced reliably higher scores than the unrelated condition (.44 vs .24), \( F(1, 17) = 11.52, MS_e = 0.030 \). Neither of the other two comparisons approached significance. In the copying group, the only significant comparison indicated that scores in the orthographically similar condition were lower than scores in the unrelated condition (.18 vs .26), \( F(1, 17) = 6.15, MS_e = 0.011 \). Because the obtained difference was in an unexpected direction, we do not offer an interpretation for it.

The outcome of the planned comparisons indicated that retrieval cues reliably enhanced recall only when subjects engaged in an elaborative encoding task. The lack of enhancement found with same cues in the copying condition was quite convincing. The difference between the means for the same context and unrelated context conditions was in the wrong direction (.24 vs .26). Moreover, there was an overall advantage for the elaboration group over the copying group in recall performance. These results are consistent with our characterization of the differential contribution of elaborative processes to the sentence generation and the copying tasks.

**Word stem completion.** The mean proportions of targets produced in the word stem completion task are shown in the lower section of Table 1. These data were analyzed using the same series of analyses as were applied to the cued-recall data. First, in the comparisons of each condition against the baseline condition it was found that all but two of the comparisons (semantically similar and orthographically similar context conditions in the elaboration group) approached or exceeded significance. These results indicate that even though subjects were not instructed to produce items that had been seen earlier, they were more likely to generate those targets than targets that had not been encoded during the study phase.

The new and re-paired context conditions were then compared separately for each encoding group, and it was found that the two conditions were not reliably different in either case (Fs < 1). Performance in these two conditions was averaged and used as the unrelated context condition in an ANOVA with test context (same, orthographically similar, semantically similar, and unrelated) and encoding task (elaboration and copying) as factors. This ANOVA produced a significant main effect of test context, \( F(3, 102) = 3.91, MS_e = 0.018 \). The main effect of encoding task and the interaction were nonsignificant (Fs < 1). The main effect of test context indicated that the stem completion task reflected a degree of context sensitivity, and the lack of an interaction suggested that the effect was similar among both encoding groups. This result contrasts with the outcome of the cued-recall test in which reliably stronger context effects were found in the elaboration group.

Given the lack of an interaction between encoding task and context, the main effect of context was explored by collapsing across encoding task to increase power. Performance in the unrelated context condition was compared with each of the other context conditions. Only the comparison between the same and unrelated conditions was significant, \( F(1, 34) = 4.76, MS_e = 0.015 \). Not only were the comparisons involving the orthographically and semantically related conditions not significant, the means for these two conditions were slightly lower than the mean for the unrelated condition.

The context effect observed in the copying condition of the stem completion task is an important result because previous research has obtained context effects only when elaborative encoding tasks have been used. We sought to confirm this result independent of any contribution from subjects in the elaboration task. Therefore, a comparison was made between the same and unrelated context conditions among subjects in the copying group. This comparison, however, was not significant, \( F(1, 17) = 2.49, p > .10 \).

An important issue in Experiment 1 was whether context-sensitive priming in stem completion could be generated by test cues that were orthographically or semantically similar to the original encoding cues. The answer suggested by the results of Experiment 1 is that neither type of cue was successful. Another issue pertains to the kind of encoding required to produce context sensitive priming. There was no interaction between encoding task and context for the stem completion results, suggesting that elaborative encoding is not necessary for the context effect. But we were unable to find evidence that the context effect held when data from only the copying group were analyzed. Given the weakness of the context effect in the copying group and the fact that both the orthographically and semantically similar context conditions failed to produce reliable context effects, it was important to attempt a replication of these key results.

One clear and convincing result from Experiment 1 was the dissociation between the cued-recall and stem completion tests. For cued recall, type of encoding task played a powerful role in determining whether context sensitivity was observed. Specifically, a benefit for repeating the original context word was found on the cued-recall test only when the elaboration task was used in the study phase. For the stem completion task, this benefit was not reliably different across the two encoding tasks. Moreover, this dissociation was supported by an ANOVA that included subjects from the two memory task conditions. Scores from the same and unrelated context conditions were analyzed as a function of encoding task and memory task, and a significant three-way interaction was found, \( F(1, 68) = 4.30, MS_e = 0.02 \). The objective in Experiment 2, therefore, was to examine context effects only in the word stem completion task. Given that we were attempting to establish context effects following a copying task and that this effect did not appear under explicit recall instructions, we concluded that context effects in stem completion
under these conditions could not be construed as a product of explicit retrieval strategies.

At this point, we wish to make only brief mention of one additional aspect of the stem completion data. Although our theoretical emphasis is on the influence of context on completion performance, it is apparent from Table 1 that the size of the effect of manipulating context (same vs. unrelated cue conditions, \( d = 0.46 \)) is only about one third of the full priming effect (same context vs. baseline, \( d = 1.31 \)). To obtain further evidence regarding the priming effect that appeared in conditions where context had been changed, we analyzed data from both encoding groups, using two scores per subject. One score was obtained by collapsing across the orthographic, semantic, and unrelated conditions, and the other score consisted of performance in the baseline condition. An ANOVA with encoding task as a between-subjects factor compared performance on studied and baseline items. A reliable effect of study condition was found, with higher performance in the studied condition (.21 vs. .12), \( F(1, 34) = 16.36, MS_e = 0.009 \). Neither the effect of encoding task nor the interaction were significant (\( F_S < 1 \)). Clearly, priming in the word stem completion task does not depend entirely on the contextually bound interpretive encoding operations that we have proposed. We return to this issue in the General Discussion section.

Experiment 2

The low level of context sensitivity on the stem completion task in Experiment 1 might be attributed to a lack of power to detect such effects or perhaps to the nature of the elaborative semantic task that we had used. To increase power in Experiment 2, the number of items and the number of subjects per condition were increased. The increase in number of items was accomplished by eliminating the new context and baseline conditions and by distributing the items among the remaining conditions. The new and re-paired conditions produced similar results in Experiment 1, so there appeared to be no need to examine them separately. The baseline condition was included in Experiment 1 only to establish that stem completion performance was influenced by prior exposure to targets, regardless of whether context-sensitive effects were obtained. Given the clear advantage of most context conditions over baseline, we thought it reasonable to dispense with this condition in Experiment 2, where the critical issue was context sensitivity.

The semantic elaboration task used in Experiment 2 required subjects to generate a single word that described how a cue–target pair were related (Graf & Schacter, 1987). It was assumed that this task might enforce the integrative elaboration of the two words more effectively than generating a sentence in which the two critical words might even be placed in different propositions. Finally, it was judged unnecessary to include the letter-cued recall task because a clear result regarding that task was established in Experiment 1. In Experiment 2, then, only a stem completion test was used after an elaboration or a copying task, and items were tested in one of four possible context conditions: same, orthographically related, semantically related, or re-paired.

Method

Subjects. The subjects were 56 students drawn from the same population as in Experiment 1, and none had taken part in that experiment. Half of the subjects were randomly assigned to the elaboration condition, and half were assigned to the copying condition.

Design. The experiment consisted of a 2 x 4 mixed factorial design. Type of encoding task (elaboration and copying) was the between-subjects factor, and test context (same, orthographically similar, semantically similar, and repaired) was manipulated within subjects. As in Experiment 1, changes in context were achieved by manipulating the study context within subjects, keeping the test context constant across subjects.

Materials and procedure. The materials used were identical to those in Experiment 1. In this experiment, only the same, orthographically similar, semantically similar, and re-paired context conditions from Experiment 1 were used. The new and the baseline context conditions were excluded. The 60 cue–target pairs from Experiment 1 were randomly assigned to four lists of 15 pairs each for purposes of counterbalancing. The arrangement of critical items meant that there were 60 old targets and 40 new targets (the filler items) on the test form. Although the proportion of old items influences performance on implicit memory tests, the influence has been demonstrated only in cases of much larger ratio differences (e.g., 90:10 or 80:20), and the influence apparently does not stem from the use of conscious retrieval strategies (Allen & Jacoby, 1990).

The procedure was identical to that of Experiment 1, with the exception of the elaboration encoding task. In the elaboration task, subjects were instructed to generate a single word that would describe how the cue and the target word could be related. As with the sentence generation task used in Experiment 1, subjects were allotted 6 s per pair to generate a response.

Results

The proportion of targets produced as word stem completions was the dependent measure, and the mean proportion of items completed with targets as a function of test context and encoding task is shown in the upper half of Table 2. These data were first analyzed by an ANOVA with encoding task (elaboration and copying) and test context (same, orthographically similar, semantically similar, and re-paired) as factors. This ANOVA revealed a significant main effect of

<table>
<thead>
<tr>
<th>Experiment and encoding task</th>
<th>Test context</th>
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<tbody>
<tr>
<td></td>
<td>Same</td>
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<tr>
<td>Experiment 2</td>
<td></td>
</tr>
<tr>
<td>Elaboration</td>
<td>.31</td>
</tr>
<tr>
<td>Copying</td>
<td>.27</td>
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<tr>
<td>M</td>
<td>.29</td>
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<tr>
<td>Experiments 1 and 2</td>
<td></td>
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<tr>
<td>Elaboration</td>
<td>.30</td>
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<tr>
<td>Copying</td>
<td>.27</td>
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<tr>
<td>M</td>
<td>.29</td>
</tr>
</tbody>
</table>

Note. The pooled estimate of the standard deviation across all conditions in Experiment 2 was .12.

\(^*\) Orth. = orthographically similar
Experiment $d = 2$, was medium in size, 0.58, and held when context sensitivity on a stem completion test, it appears that MS $= 0.015$. Two estimates were made of this test's power greater than the re-paired condition.

In the elaboration task. The power estimate under this assumption was reliably greater than that found in the re-paired condition, $F(1, 27) = 8.00, M_{S_E} = 0.010$, but neither of the other two conditions produced levels of priming that were reliably greater than the re-paired condition.

Given that three of the results of Experiments 1 and 2 (the lack of an interaction between encoding task and context and the lack of context-sensitive priming with orthographically similar and semantically related context words) were null effects, it was important to obtain as powerful a test of each effect as possible and to estimate the power of the tests. This was accomplished by combining the stem completion data from Experiments 1 and 2. The means for the combined data are shown in the lower half of Table 2. The combined data were used to compare each of the context conditions in turn with the re-paired condition, with encoding task as an additional factor.

In the ANOVA comparing the same and re-paired conditions, only the effect of context was reliable, $F(1, 90) = 21.94, M_{S_E} = 0.015$. Two estimates were made of this test's power to detect an interaction between encoding task and context. In the first, it was assumed that the true context effect in the copying task was half the size of the observed effect in the elaboration task. The power estimate under this assumption was .29. In the second estimate, it was assumed that there was no true context effect in the copying task. In this case, the power estimate was .80. No effects were significant in the ANOVAs comparing the orthographically similar and semantically similar context conditions to the re-paired condition. The test of the context effect produced $F < 1$ in both cases. The estimated power to detect a true effect equal to half of the effect observed in the same condition was .83 and .77 for the orthographically and semantically similar conditions, respectively.

Discussion

Although we are not aware of any previous report of instances in which a nonelaborative encoding task has yielded context sensitivity on a stem completion test, it appears that the effect is genuine. The effect was statistically significant in Experiment 2, was medium in size, $d = 0.58$, and held when data from Experiments 1 and 2 were combined. Moreover, the argument that context sensitivity in the copying condition was the result of subjects' adopting an explicit retrieval orientation during the word stem completion task seems untenable. In Experiment 1, we demonstrated that for cued-recall the advantage of using the same cue at study and test was apparent after the elaborative task but not after the copying task. If subjects were deliberately trying to retrieve target items while performing the stem completion task, there should have been no context effect in the copying condition but, of course, there was.

The demonstration of implicit memory for new associations following a nonelaborative copying task calls into question the suggestion that this phenomenon relies on semantic elaboration (Schacter & Graf, 1986; Schacter & McGlynn, 1989). We conclude that the unitized representation emphasized by Graf and Schacter (1989) can be formed without requiring subjects to engage in elaboration of the relation between two items. Integral encoding of a word pair can be encouraged in a number of ways, including the copying and elaboration tasks we used in Experiments 1 and 2 (see also Whittlesea & Brooks, 1988). We suggest that a further example of integral encoding without elaboration can be found in a result reported by Jacoby, Woloshyn, and Kelley (1989). Fictitious names read in the first part of their experiments were later more likely to be judged as famous than completely unfamiliar names. The encoding task involved merely reading aloud a list of names, and we conjecture that this effect would be reduced if first and last names were rearranged as in the re-paired condition of the new associations paradigm.

Although our statistical tests were not sufficiently powerful to allow us to conclude that copying and elaboration tasks produce equally strong context effects, it is clear that the copying task was adequate to produce a reliable effect of nontrivial size. We suspect that the additional processing entailed in elaborative encoding tasks serves to encourage subjects to integrally encode word pairs when they are initially identified, even before elaborative processing begins. The added incentive to engage in integral encoding during identification may be responsible for the larger size of the context effect found in the elaborative encoding condition. Elaboration processes themselves, however, may have a direct impact only on explicit memory test performance. The finding by Graf and Schacter (1989)—that varying the nature of elaborative tasks influences recall but not stem completion—is consistent with this idea.

An additional important aspect of the results of Experiment 2 is that orthographically similar and semantically similar cues did not produce context-sensitive priming. If implicit memory for new associations depends on visual information providing access to a unitized representation as suggested by Graf and Schacter (1989), one might have expected the orthographically similar cues to have an effect. Alternatively, if one were to view the paradigm as a reflection of conceptually driven processing brought on by testing stems in the presence of context words, in keeping with the theme developed by Roediger et al. (1989), it might be expected that conceptually related cues (i.e., synonyms) would enhance the priming
effect. The absence of a context effect for these two types of
cues is, however, consistent with predictions derived from a
framework that emphasizes integration of data-driven and
conceptually driven processing operations during the initial
encoding of stimuli.

Experiment 3

The suggestion made by Schacter and Graf (1989; Graf &
Schacter, 1989), that visual information provides access to a
unitized encoding of stimuli. An important aspect of the proposal
we have developed is that the modality-specific nature of the
context effect is not tied exclusively to visual processing
operations but reflects the integration of data-driven and
contextually driven operations involved in interpretive en-
coding. By this view, modality-specific effects arise because
an important component of the original, integrated set of
encoding operations is not reinstated by the format of the
retrieval cue. Furthermore, a complementary result should
occur if data-driven operations are reinstated without the
original conceptually driven processes. That is, it should be
possible to reduce the context effect by altering not modality
but the interpretation applied to a visually presented context
word. The critical notion is that to be effective, a contextual
cue must reinstate, at least partially, the original perceptual
pattern that was presented during the study phase, and the
subject must interpret it in the same manner. If the subject
can be led to construct an altered interpretation of the cue,
we predict that implicit memory for new associations will be
impaired.

This prediction was tested in Experiment 3. Implicit mem-
ory for new associations was assessed as in Experiments 1 and
2, except that homographs (e.g., PUPIL) were used as cue
words to allow for changes in their interpretation between
study and test. During the study phase, subjects were pre-

tained as a completion because the same degree of perceptual
overlap between study and test was present for either inter-
pretation of each homograph (e.g., CHAIR, CHAIN). For each pair of targets, one arbitrarily chosen
homograph cue word was selected from various sources (Gorfein,
Viviani, & Leddo, 1982; Holley-Wilcox & Blank, 1980; Nelson,
McEvoy, Walling, & Wheeler, 1980; Schvaneveldt, Meyer, & Becker,
1976; Wollen, Cox, Cochran, Shea, & Kirby, 1980; Yates, 1978), with
the restriction that both the dominant and the subordinate interpre-
tation of each homograph was a concrete noun (e.g., cave BAT,
baseball BAT).

A set of four sentences was constructed for each target–homograph
triad. Each sentence was written so that the homograph, with one of
its meanings biased by the sentence context, appeared in the first part
of the sentence and one of the target words appeared at or near the
end. Across the four sentences, each target was paired with each
interpretation of the homograph. An example of one set of sentences
is as follows:

1. The electric FAN was purchased at the hardware STORE.
2. The electric FAN was placed on a large desert STONE.
3. The starry eyed FAN waited for hours in the record STORE.
4. The starry eyed FAN threw a STONE at the singer.

Each sentence was typed on a separate index card with the homo-


graph and target in uppercase letters. For counterbalancing purposes,
the four sentences in a set were broken into two pairs. Within each
pair, different interpretations of the homograph and different targets
were represented. In the example above, Example 1 would be paired
with Example 4 and Example 2 would be paired with Example 3.
One pair of sentences from each set was assigned to one study list,
and the other pair was assigned to a second study list. Half of the
subjects were exposed to one study list, and the remainder were
exposed to the other list. During the study phase, 24 of the 36 pairs
of sentences on the study list were shown to subjects, along with 12
filler sentences, for a total of 60 sentences. The remaining 12 pairs of
critical sentences were not shown, so that their target words could be
treated as nonstudied items in the test phase. The set of 12 nonstudied
sentences was counterbalanced across subjects.

For the word stem completion test, two forms were prepared using
the same format as the earlier experiments. On these forms, however,
each capitalized cue-stem pair appeared with a context word printed
in lowercase. The context word served to bias either the dominant or
the subordinate meaning of the homograph cue (e.g., cooling FAN-STO.). These context words had not been used in any of the sentences presented in the study phase and appeared only on the test form. Each of the two test forms consisted of a different random arrangement of the 36 homograph cues and their associated stems and was administered to half of the subjects. On one test form, half of the items appeared with a context word that biased the dominant meaning of the homograph, and the other half appeared with a context word that biased the subordinate meaning. On the other test form, context words were used that reversed the interpretation of each homograph (e.g., sports FAN-STO.). In addition to the 36 critical items on each test form, there were 12 filler items consisting of a context word, a homograph cue, and a three-letter stem. The filler items were not included in the scoring. None of the filler words were the same as any of the critical items. The three-letter filler stems and the first three letters of all critical targets, homograph cues, and biasing words were unique. Thus, half of the items on each test form had stems with possible completions that had appeared during the study phase, and half of the items had stems whose possible completions had not been shown previously. A list of the critical sentences and test items is shown in Appendix B.

The same context and different context conditions were determined by which target had been presented during study in the context of the homograph interpretation that was implied by the test context. For example, if a subject had seen Examples 1 and 4 above during the study phase and was tested with cooling FAN-STO., the target word STORE belonged to the same context condition, and STONE belonged to the different context condition. On the other hand, if a subject had seen Examples 2 and 3 during the study phase that test item would assign STONE to the same context condition and STORE to the different context condition. This distinction was applied to nonstudied targets as well and was based on the sentences that would have been presented had they not been assigned to the nonstudied condition. When the test forms were scored, the proportions of critical studied and nonstudied stems completed with same and with different targets were computed, yielding a set of four scores per subject.

Procedure. Each subject was tested individually. In the study phase, the 48 critical and the 12 filler sentences were presented in a uniquely determined random order. Subjects were instructed to read each sentence and to generate a word that would relate the two capitalized words in the sentence. Subjects were allowed 8 s per sentence for this task. Presenting the ambiguous context word and target in a sentence provided a means of biasing a particular interpretation of the context word. The additional requirement of generating a word that related the context and target was intended to encourage integrative encoding of those two items. The rest of the procedure was identical to that of Experiments 1 and 2.

Results and Discussion

The mean proportions of studied and nonstudied items that were completed with targets in the same and different context conditions are shown in Table 3. Test context was a dummy variable for the nonstudied items. An ANOVA with test context and prior presentation as factors was applied to the data. The main effect of prior presentation was reliable, as studied targets were more likely to be produced on the stem completion test than nonstudied targets, $F(1, 15) = 26.11$, $MSE = 0.007$. The main effect of test context was not reliable, but the interaction between prior presentation and test context was significant, $F(1, 15) = 6.48$, $MSE = 0.005$. The interaction indicates that for studied targets only, those targets encoded with the same interpretation of the homograph as that implied by the biasing word at test were more likely to be given as completions than targets encoded with the alternative meaning of the homograph. A planned comparison involving studied targets confirmed this, finding a reliable difference between the probabilities of generating targets associated with same versus different context, $F(1, 15) = 6.80, MSE = 0.006$. Given that less priming was observed in the different context condition, we also compared performance on studied versus nonstudied items in the different context condition to determine whether changing context permitted any priming to occur. This comparison revealed a significant priming effect, $F(1, 15) = 6.48, MSE = 0.005$.

The results of Experiment 3 were not consistent with the view that context-sensitive priming reflects purely data-driven access to a unitized representation. If this view were correct, the two targets would have been provided as completions equally often because the context on the stem completion test comprised perceptual patterns that did not favor one target over the other. The context consisted of two words, a homograph and a word that biased its interpretation. The biasing word was never presented at study, nor was there a tendency for subjects to generate the biasing word during study. The argument that differential priming effects for targets in the same and different conditions were due to the change in the visual pattern between study and test is not tenable because the visual pattern was not differentially altered in favor of the same context target. We conclude, therefore, that context-sensitive priming is mediated by the conceptual interpretation that was recruited from the visual pattern at study.

These results also provide a different perspective on the finding in Experiments 1 and 2 that completion performance did not differ between the orthographically similar and the re-paired context conditions. The cue in the orthographically similar condition differed from the study cue by one letter, therefore it could be argued that changing a letter disrupted data-driven access to the unitized representation, thus eliminating the context effect. In Experiment 3, however, we found that priming was dependent on reinstatement of the interpretation of the cue word. A reasonable explanation of the lack of effectiveness of orthographically similar cues in Experiments 1 and 2, then, is that by changing the orthographic

<table>
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<th>Test context</th>
<th>Same</th>
<th>Different</th>
<th>$M$</th>
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</thead>
<tbody>
<tr>
<td>Studied</td>
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<td>$\frac{18}{11}$</td>
<td>$\frac{22}{12}$</td>
<td></td>
</tr>
<tr>
<td>Nonstudied</td>
<td>$\frac{11}{12}$</td>
<td>$\frac{12}{15}$</td>
<td>$\frac{11}{15}$</td>
<td></td>
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<tr>
<td>$M$</td>
<td>$\frac{18}{15}$</td>
<td>$\frac{15}{15}$</td>
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</tbody>
</table>

Note. The pooled estimate of the standard deviation across all conditions was .09.
structure, the interpretation of the visual pattern was also changed. Consequently, the interpretation recruited from the visual pattern at study could not be recreated at test, and the context effect was eliminated. Further support for the argument that the conceptual interpretation is important in priming effects was provided by Murrell and Morton (1974). They found that prior presentation of a word primed morphologically related items where the visual pattern and the meaning of the studied item were reprocessed at test (e.g., card primed cards), but did not prime orthographically related items where only the studied item's visual pattern was reprocessed at test (e.g., card did not prime cars).

The use of conscious retrieval strategies during the stem completion test in Experiment 3 may be an issue because we did not include a manipulation that dissociated implicit and explicit memory tests. For the following reasons, however, we are prompted to argue that the subjects did not use explicit retrieval strategies. First, the procedures we used closely followed those used in the previous work (e.g., Graf & Schacter, 1987; Experiment 1 in the present study) in which word stem completion was dissociated from letter-cued recall, so there is little reason to suspect that our subjects treated the completion task differently from the subjects in previous studies. Second, unlike the work conducted by Schacter and his associates (Graf & Schacter, 1989; Schacter & Graf, 1986, 1989; Schacter & McGlynn, 1989), subjects in our study were not informed at the beginning of the experiment that their memory for the study items would be tested. If a memory test were not expected, then the probability of approaching the test with an explicit retrieval orientation should be lower than in the previous work. Third, postexperimental interviews indicated that the subjects were following the test instructions to complete the fragment with the first word that came to mind. Some subjects reported that they did not realize that there was a relationship between the test and study items, and others indicated that they recognized the cue-target pairs as being from the study list only after they had completed the stem.

General Discussion

The experiments that we have reported produced three major results: (a) In contrast to past indications that implicit memory for new associations is contingent on elaborative semantic processing (Schacter & Graf, 1986; Schacter & McGlynn, 1989), a context effect was observed following a nonelaborative copying task; (b) when stems were tested in the presence of cues that were orthographically or semantically similar to the cues with which targets were initially encoded, priming was not significantly different from priming obtained with unrelated cues; and (c) completion performance was optimally facilitated when the conceptual interpretation of the cue word was reinstated at test. These results suggest refinements to the view of implicit memory for new associations that has been advanced recently by Graf and Schacter (1989, Schacter & Graf, 1989) and to the transfer-appropriate processing view that data-driven and conceptually driven processes contribute independently to priming (Roediger et al., 1989).

Graf and Schacter (1989) have promoted unitized representations to account for implicit memory for new associations. Although they suggested that various attributes other than the meaning of words may contribute to unitization, all of the previous results in this paradigm have depended on the use of tasks that demand semantic elaboration of word pairs. Our goal in demonstrating implicit memory for new associations following a nonelaborative task was to shift the emphasis regarding operations that produce unitized representations. Rather than viewing semantic elaboration as a direct influence on the creation of unitized representations, we emphasize operations that provide the initial interpretation of words during encoding. The function of semantic elaboration tasks may be to encourage subjects to interpret word pairs in relation to one another when they are first identified. Subsequent elaboration of the meaning of the words might have a direct impact on performance of intentional retrieval tasks, as indicated by the finding that variations in the requirements of the elaborative encoding task affect cued recall but not stem completion (Graf & Schacter, 1989; Schacter & Graf, 1986).

We have also tried to specify how redintegration of a unitized representation is accomplished. Graf and Schacter (1989, p. 939) proposed that redintegration occurs because modality-specific information provides an access key to unitized representations. The results of Experiment 3 have ruled out a strictly data-driven interpretation of this proposal. Although using the same modality for encoding and test is important for generating reliable context effects in the new associations paradigm, we have shown that the conceptual interpretation of the context is important as well.

The collaborative contribution of data-driven and conceptually driven processing to implicit memory for new associations is a phenomenon that is not anticipated by the transfer-appropriate processing view developed by Roediger and his colleagues (Blaxton, 1989; Roediger & Blaxton, 1987; Roediger et al., 1989), in which the contributions of these two types of operation apparently are seen as independently varying. From the transfer-appropriate processing account, one could argue that implicit tests such as stem completion are primarily data driven when stems are tested in isolation, but a strong conceptually driven component may be assumed when context words are present. This line of reasoning is not completely satisfactory, however, because it does not provide a means of explaining the modality-specific nature of context-sensitive priming. In fact, if one were to break this priming effect into context-dependent and context-independent components, the two components line up with conceptually driven and data-driven processes in a manner opposite to that suggested by the transfer-appropriate processing view. Schacter and Graf (1989) demonstrated in three separate experiments that (a) context effects in stem completion are modality specific (they should be based on conceptually driven processes and therefore be modality-independent by the transfer-appropriate processing view), and (b) priming among stems
tested with changed context words is equally strong for both visual and auditory study modalities. (This part of the priming effect should be data driven and therefore strongly dependent on modality.)

The framework that we favor is one that makes a distinction between the encoding operations that enable one to identify a stimulus, interpretive encoding operations, and subsequent reflective operations that elaborate some attributes of the stimulus. Interpretive encoding operations rely on both the perceptual analysis of a stimulus and on the context in which the stimulus occurs to produce an interpretation of it. Both data-driven and conceptually driven operations make contributions to this process. Elaborative encoding operations may emphasize either class of attributes and are assumed to be more easily controlled by task demands and the intentions of the subject. These two types of encoding produce different memory representations, as suggested by the contrast between unitization and grouping made by Graf and Schacter (1989).

We suggest that interpretive and elaborative encoding differentially contribute to performances on implicit and explicit tests of memory. In particular, reenactment of interpretive encoding operations are responsible for priming on implicit memory tests, whereas explicit memory tests are most strongly influenced by memory for elaborative encoding processes. Fluent reprocessing or generation of repeated items engendered by the reappearance of interpretive encoding operations may also contribute to explicit memory test decisions (Jacoby & Hollingshead, 1990). Dissociations between explicit and implicit memory tests arise from differences between interpretive and elaborative encoding operations and between the memory representations that they create. We concur with the core idea of the transfer-appropriate processing view, however, in assuming that within each of these types of encoding there can be contributions from both data-driven and conceptually driven processes and that conceptually driven operations typically dominate elaborative encodings.

Given the emphasis in this article on implicit memory for new associations, we are especially concerned with the interpretive encoding operations from which we claim that this effect is derived. We have advanced the general notions that conceptually driven and data-driven operations work in an integral fashion to produce an interpretation of stimuli (Kolers, 1975, 1979; Masson & Sala, 1978) and that episodic memory for this integral processing underlies implicit memory for new associations (see also Levy & Kirsner, 1989). To elaborate this general notion, we offer a framework conceptualized in terms of a connectionist architecture. Although this may eventually turn out not to be the best possible metaphor, we believe that for now it can be used to provide an account of known results and to generate propositions that have yet to be tested adequately. We will sketch the framework in terms of the architecture proposed by Seidenberg and McClelland (1989) because they incorporated both perceptual and contextual influences during identification (although only the former has been implemented in the current version of the model).

A critical aspect of the Seidenberg and McClelland model is the assumption that knowledge about the meaning of a symbol or object is distributed as a pattern of activation across an entire collection of processing units. Variations in the pattern of activation provide different nuances of a word's meaning. In the Seidenberg and McClelland model, the processing units that correspond to stimulus meaning are encapsulated in a meaning module. The pattern of activation within this module is influenced by three other similarly structured modules: (a) a context module that represents the context in which a stimulus is presented, (b) an orthography module that captures the orthographic pattern of a visually presented word, and (c) a phonology module that represents the phonological pattern of an auditorially presented word.

In the case of visual word identification, input from the orthographic module initially influences activation in the meaning module toward a pattern that is consistent with a number of candidate interpretations. For example, the visual pattern HOUSE might initially invoke a pattern of activation consistent not only with the meaning of house but also with candidates that have similar orthographic patterns (e.g., horse). The pattern of activation in the meaning module changes over time, as analysis of the input continues and eventually a relatively stable pattern emerges that represents a correct interpretation of the input.

The extent to which the pattern of activation in the meaning module is dominated by orthographic input depends on the availability of contextual information. Relevant activity in the context module may serve to direct the meaning module toward the appropriate interpretation of the orthographic input sooner than would be the case in the absence of relevant context. This process is the basis for semantic priming effects. But it also reveals how conceptually driven and data-driven processes may interact during interpretive encoding. Input from the context and orthography modules mutually influence the pattern of activation in the meaning module. A similar process is assumed to occur in the identification of spoken words, except that the source of perceptual input is the phonology module. The critical implication is that a somewhat different series of activation patterns will be instantiated in the meaning module by visual and auditory presentations of a word as the module moves toward a stable pattern of activation. For example, consider hearing versus seeing the word heart. In a visual presentation, the initial pattern of activation in the meaning module might be consistent with the meaning of other orthographically similar words such as heard, whereas in an auditory presentation the pattern of activation might tend toward alternatives like harp, but not vice versa. Not only do variations in modality imply different starting points for the pattern of activation in the meaning module, but changes in the pattern as an appropriate interpretation is constructed would follow different trajectories through the space of possible patterns of activation.

We assume that the changes in the pattern of activation in the meaning module, and other modules as well, that reflect the interpretive encoding of a stimulus leave a lasting impression that serves as a basis for implicit memory. In a connectionist model, this impression would consist of changes in the connection weights on the links between processing units. These changes would apply to links between units within a module as well as to links between modules. One possibility is that a form of Hebbian learning rule (Hopfield, 1982;
Hopfield & Tank, 1986) is applied as the pattern of activation in the meaning module moves closer to stability. A pair of processing units that undergo similar amounts and direction (increase or decrease) of change in activation might have their connection weight increased, whereas a pair of units that experience different trajectories would have their connection weight reduced. These changes in the connection weights serve as the episodic record of the encoding (see also McClelland & Rumelhart, 1985). The advantage of such a scheme, as revealed through implicit memory tests, is that when a stimulus is later repeated in a similar physical form and context, the system will move more efficiently from the initially invoked pattern of activation to a stable interpretation.

On an implicit test of memory for new associations, presentation of the appropriate cue and a word stem can produce redintegration because the pattern of activation instantiated by this partial cue is (a) similar to the pattern that was initially established during the original encoding episode and (b) the weight changes produced in the earlier encoding tend to influence this pattern of activation to move toward the same stable pattern of activation as before.

The pattern of activation in the meaning module and the series of changes through which it passes during interpretive encoding are strongly influenced by input from other modules. We suggest that the nature of this input is the source of modality-specific (Schacter & Graf, 1989) and interpretation-specific (Experiment 3) effects on implicit memory tests. By changing from auditory to visual presentation, for example, a different initial pattern of activation in the meaning module will be invoked on the two presentations. Given a change in the starting pattern of activation, the altered connection weights would have a weaker influence in moving activation toward the stable pattern that was reached on the original encoding. At the same time, however, the degree of modality specificity should be ameliorated by stronger contributions from the contextual module. In this view, changes in modality in the implicit memory for new associations paradigm should reduce but not necessarily eliminate memory for new associations. In line with our proposal, although the context effect for word pairs studied in the auditory modality was nonsignificant in each of three relevant experiments reported by Schacter and Graf (1989), there was a consistent mean difference favoring items tested in the same context condition. Averaged across the three experiments, this effect was over one third the size of the context effect observed when word pairs were studied in the visual modality. Insufficient power may have prevented the effect in the auditory study condition from reaching significance.

The framework we have proposed for context effects in implicit memory is consistent not only with effects of modality but also with the high degree of cue specificity obtained in Experiments 1 and 2. In those experiments, orthographically and semantically similar cue words failed to produce reliable priming effects beyond those obtained with unrelated cues. The process of stimulus identification is viewed here as one in which an interpretation is developed in distinction to other competing interpretations. This distinctive processing is believed to alter connection weights among processing units so that when the pattern of activation that was transformed into the final interpretation is later invoked by a stimulus configuration, the pattern will more efficiently evolve into a highly similar interpretation. In this sense, under appropriate stimulus conditions, competing interpretations are inhibited in favor of the target interpretation. Besner, Smith, and MacLeod (1990) and Carr and Dagenbach (1990) have made similar proposals. The important extension that we suggest is that these processes leave an episodic record of their activity that influences later stimulus identification.

An important aspect of our data that this framework was not intended to address is the fact that even when context was changed, a reliable priming effect was observed in comparison with nonstudied items (Experiments 1 and 3). Schacter and Graf (1989) demonstrated that this context-independent priming effect is also modality independent inasmuch as visual and auditory study conditions produced virtually the same priming effect sizes. It appears, then, that our description of integral data-driven and conceptually driven processes is not an entirely adequate amount of priming effects in the implicit memory for new associations paradigm. But we suggest that certain aspects of this general priming effect provide important clues regarding how our framework would have to be expanded to include it.

It may be that the general priming effect stems from elaborative encoding operations applied to a symbol after a conceptual interpretation has been constructed and data-driven operations completed. One fact that runs counter to this proposal is that in Experiment 1 we found no evidence that the general priming effect depends on elaborative encoding processes. As a related alternative, it is possible that simply maintaining an identified symbol in working memory contributes to priming, independent of the nature of the manipulations applied to that symbol. A third possibility is that the general priming effect is a product of interpretive encoding operations. In terms of the connectionist metaphor outlined above, one effect of each episode in which a word is identified is to sharpen the connection weights between processing units within the meaning module in a manner favorable to the meaning of that word. These connection weight changes could produce a priming effect even when context and modality are not reinstated at test because the meaning module continues to be centrally important.

In summary, although we have no empirical support to offer for our speculations regarding priming effects under conditions of changed context, the experiments reported here do provide evidence concerning our view of context-dependent effects in implicit memory. We propose that implicit memory for new associations can be characterized in terms of an interactive process framework in which an episodic record is formed of the influence of conceptually driven and data-driven processes during stimulus identification. These processes operate in an integral manner as indicated by the modality-specific (Schacter & Graf, 1989) and interpretation-specific (Experiment 3) nature of context effects that have been demonstrated. Furthermore, these interpretable encoding operations are responsible for developing a context-dependent
interpretation of a stimulus that evokes in contrast to other potential interpretations. Interpretive encoding can be distinguished from elaborative encoding, which involves reflective processing of an interpreted stimulus with respect to prior knowledge and which plays a central role in explicit tests of memory. We suggest that interpretive encoding operations leave an episodic record of their activity, perhaps in the form of weight changes in a distributed memory representation, and this record enhances the efficiency with which those interpretive operations may later be applied to a repeated stimulus configuration.

References


Appendix A

Critical Target and Cue Words in Experiments 1 and 2

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(Appendix continues on next page)
Appendix A (continued)

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Appendix B

Critical Materials Used in Experiment 3

For each ambiguous cue word there were two different targets and a set of four sentences. One sentence was constructed for each combination of cue word interpretation and target word. In addition, each cue-stem pair was embedded in two different contexts, one for each interpretation of the cue word.

The screeching BAT flew behind the FURNITURE.
The baseball BAT was used to destroy the FURNITURE.
The baseball BAT was placed behind the FURNACE.
vampire BAT FUR_____ homerun BAT FUR_____

The rubber BALL bounced higher after being exposed to STEAM.
A rubber BALL would have tasted better than the STEAK.
The charity BALL was disrupted by STEAM rising from the ground.
The charity BALL was followed by a STEAK dinner.
soccer BALL STE_____. dance BALL STE_____

The manager of the BANK wore a DRESS.
The manager of the BANK helped make her DREAM a reality.
The fisherman on the BANK wore a DRESS.
The fisherman on the BANK had a bad DREAM.
loan BANK DRE_____. river BANK DRE_____

He took his CLUB and attacked the horse in the BARN.
He took his CLUB and hit the BARK off a tree.
The social CLUB met in the BARN.
The social CLUB ate the BARK off a tree.
mallet CLUB BAR_____. group CLUB BAR_____.
The wooden CANE hit the man in the CHEST.
The wooden CANE hit the man on the CHEEK.
A ton of molasses CANE crushed the man's CHEST.
A piece of molasses CANE hit his CHEEK.

The beverage GIN is extracted from a flowering PLANT.
The beverage GIN was not served on the PLANE trip.

The ace was a SPADE and won the gambler a pound of BUTTER.
The ace was a SPADE and won the gambler a gold BUTTON.

The game of GIN lasted so long I missed my PLANE.

Lotion was placed on the PALM of the DRUM player.

EAT the fruit and NUT before we take the PHOTO.
EAT the fruit and NUT before you answer the PHONE.

A tune from the ORGAN made her dance across the FLOOR.
The person suffering from a bleeding ORGAN received a FLOWER.

The water from the CAPE was used to give the CHILD a bath.
The wool CAPE covered the CHILD.

The elementary school PUPIL learned to use a DRILL.
The elementary school PUPIL hated the school bus DRIVER.

The Olympic swimming COACH drank WHISKEY.
The Olympic swimming COACH talked in a low WHISPER.

The big league PITCHER signed his name with a check or CROSS.
The big league PITCHER waved to the adoring CROWD.

(Appendix continues on next page)
The receipt FILE contains the cost of the MUSIC tape.
The receipt FILE indicates he went to a spa to fix his MUSCLE tone.
Use a nail FILE to smooth the corner of the MUSIC stand.
Use a nail FILE to puncture his MUSCLE.
folder FILE MUS folder FILE MUS

The rush hour car JAM was noted as a BLANK on the accident report.
The rush hour car JAM was intensified by a man holding a BLADE.
The label on can of fruit JAM was BLANK.
He spread the fruit JAM with a BLADE.
traffic JAM BLA traffic JAM BLA

Use a metric RULER to measure how much CREAM is on the cake.
Use a metric RULER to measure the scar on his CHEEK.
The tyrannical RULER refused to drink coffee without CREAM.
The tyrannical RULER blocked the bridge over the CREEK.
inches RULER CRE inches RULER CRE

A recipe for cooking SQUASH is in the BOOK.
Delicious SQUASH was planted by a man wearing one BOOT.
The game of SQUASH was the topic of my BOOK.
The game of SQUASH is not played wearing one BOOT.
pumpkin SQUASH BOO racquetball SQUASH BOO

He threw the boat ROW at a CLOUD in the sky.
The boat ROW was used to smash the CLOCK.
The lady sitting in the third ROW looked up at the CLOUD.
The lady sitting in the third ROW kept looking at the CLOCK.

oar ROW CLO oar ROW CLO

Herbs like MINT were placed on a CHAIR.
Herbs like MINT were strung into a CHAIN.
Dimes made at the MINT were placed on a CHAIR.
Dimes made at the MINT were strung into a CHAIN.
candy MINT CHA money MINT CHA

In SPRING you can find an oyster SHELL on the beach.
In SPRING I will put the winter gear on the SHELF.
The upholstery SPRING was shaped like a SHELL.
The upholstery SPRING was found on a SHELF.
summer SPRING SHE summer SPRING SHE

A hollow willow LOG was examined in forestry CLASS.
The hollow willow LOG was filled with CLAY.
Numbers written in the LOG indicated I had missed the CLASS.
Numbers written in the LOG indicated the vase was made of CLAY.
tree LOG CLA tree LOG CLA

Behind the barrier or SCREEN you will find the LEASH.
The barrier or SCREEN dividing the building was not in the LEASE.
The movie SCREEN was rented or out on LEASE.
The movie SCREEN was blocked by a dog on a LEASH.
divider SCREEN LEA divider SCREEN LEA

The first-class LETTER was placed on the COUCH.
The first-class LETTER said the baby had a COUGH.
The spelling error included a LETTER in the word COUCH.
The spelling error included a LETTER in the word COUGH.
mail LETTER COU alphabet LETTER COU

The military TANK rolled through the BEAN field.
Metal from a military TANK was used to make a BEAD.
Jack used the water reservoir TANK to hide the magic BEAN.
The water reservoir TANK was a hiding place for a gold BEAD necklace.
army TANK BEA container TANK BEA

The suburban YARD was gardened using a FORK.
The suburban YARD once was the site of a FORT.
A metre or YARD of steel is needed to make a spoon and FORK.
A metre or YARD of steel was used to build the FORT.
lawn YARD FOR length YARD FOR
This breed of CALF is as small as a MOUSE.
This breed of CALF likes to graze on a MOUND.
Limb specialists say CALF injuries can occur in a MOUSE.
Limb specialists say CALF injuries occur when you jump off a MOUND.

The astronaut circling the EARTH carried a WEAPON.
The astronaut circling the EARTH launched a WEATHER balloon.
The gardener plowed with EARTH with a WEAPON.
The gardener plowed the EARTH when the WEATHER was nice.

The celestial STAR was shaped like a KNOT in a rope.
A celestial STAR was shaped like a KNOB.
The movie STAR tied his scarf in a KNOT.
The movie STAR hung his coat on the door KNOB.

The financial DEED stated he owned the gold SPIDER.
The financial DEED disclosure made his SPINE shiver.
The dastardly DEED was to injure the man’s SPINE.
The dastardly DEED was to steal the gold SPIDER.

A jail CELL is not an appropriate place for a PRINCE to live.
One night in a jail CELL was the PRIZE awarded in the lottery.
The essay on the human CELL was written by the PRINCE.
The essay on the human CELL was awarded first PRIZE.

Place the pop bottle STRAW on his GRAVE.
A pop bottle STRAW was used to pick up GRAIN.
Farm-grown STRAW was placed on the man’s GRAVE.
Farm-grown STRAW and GRAIN were sold at the market.

The duck’s QUACK was heard from the mountain PEAK.
The duck’s QUACK was heard from the PEAR tree.
The medical QUACK prescribed that she eat a PEAR.
The medical QUACK prescribed the crippled man to climb a PEAK.

The cholesterol-blocked VESSEL looked like a SNAIL on the X-ray.
The cholesterol-blocked VESSEL resulted from a fatty SNACK.
The Atlantic cargo VESSEL was slow as a SNAIL.
The Atlantic cargo VESSEL was used to carry the king’s SNACK.

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