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Repetition Priming for Newly Formed and Preexisting Associations: Perceptual and Conceptual Influences

Yonatan Goshen-Gottstein and Morris Moscovitch
University of Toronto

Three experiments demonstrate that association-specific repetition effects can be obtained for both newly formed and preexisting associations and that these effects are sensitive to modality of presentation. After studying a list of word pairs, participants were shown the original intact pairs and pairs formed by recombining the original pairs. In a lexical-decision task in which participants were asked to indicate whether both items were words, responses were faster to newly formed associations in the intact than in the recombined condition. This association-specific repetition priming effect was also observed for preexisting associations when a speeded relatedness judgment task was used. Both effects were found to be attenuated under cross-modal presentation. Finally, an explicit speeded recognition task revealed an associative effect that was not attenuated when modality was crossed for newly formed associations and was actually exaggerated for preexisting associations, suggesting that the repetition priming effects were not produced by conscious recollection. Results are discussed in terms of frameworks that are based either on perceptual representation systems or on a transfer-appropriate processing model.

Traditional memory tests such as cued recall, free recall, and recognition require participants to refer explicitly to the experienced event—a process that involves conscious recollection. These explicit tests can be contrasted with implicit tests in which memory is inferred from changes in performance that an experimentally studied episode produces on tasks that make no explicit reference to that episode. Such tasks include word fragment completion (e.g., Graf, Mandler, & Haden, 1982; Tulving, Schacter, & Stark, 1982; Warrington & Weiskrantz, 1974), stem completion (Graf & Schacter, 1985), perceptual identification (e.g., Jacoby, 1983; Jacoby & Dallas, 1981), and lexical decision (e.g., Glass & Butters, 1985; McKoon & Ratcliff, 1979; Scarborough, Cortese, & Scarborough, 1977; Scarborough, Gerard, & Cortese, 1979). Superior performance for experimentally studied materials, as compared with unstudied materials, that is typically observed in these tasks is known as the repetition priming effect and is dissociable from measures of performance on explicit tests in normal and brain-damaged people (for reviews see Moscovitch, Vriezen, & Goshen-Gottstein, 1993; Richardson-Klavehn & Bjork, 1988; Roediger & McDermott, 1993; Schacter, 1987).

A central question in research on repetition priming has been whether acquisition and retention of new information, information not preexisting in semantic memory, can be revealed on implicit tests of memory or whether memory for new material always requires explicit reference to the study episode. Two approaches have been followed in attempting to answer this question. One involves studying repetition priming for truly novel material such as newly created words (nonwords) and line drawings of nonsense forms. The other approach has been to study implicit memory for newly formed word pairs.

With respect to single, novel items, this question has been answered in the affirmative (for reviews see Moscovitch et al., 1993; Roediger & McDermott, 1993). Normal repetition priming effects have been reported for pronounceable, but meaningless, nonwords (Bowers, 1994; Dorfman, 1994; Feustel, Shiffrin, & Salasoo, 1983; Gordon, 1988; Haist, Musen, & Squire, 1991; Musen & Squire, 1991; Rueckl & Olds, 1993; Salasoo, Shiffrin, & Feustel, 1985; Smith & Oscar-Berman, 1990) and for novel, meaningless, line drawings (Musen, 1991; Musen & Squire, 1992; Musen & Triesman, 1990; Schacter, Cooper, & Delaney, 1990).

Still unresolved is the question of whether memory for new associations between pairs of items can be demonstrated on implicit tests of memory. This question has important implications for theories of memory. Recently it has been proposed that *perceptual repetition priming,* priming that is displayed on implicit tests that are data driven, is mediated by domain-specific perceptual representation systems (PRS), or perceptual input modules. These systems process and retain presemantic, structural information of stimuli as *perceptual records* (Kirsner & Dunn, 1985; Moscovitch, 1992a, 1992b; Moscovitch & Umilta, 1990, 1991; Schacter, 1990; Schacter & Tulving, 1994; Tulving & Schacter, 1990). According to this hypothesis, repetition priming effects for written words are mediated by the visual word form system (Peterson, Fox, Posner, Mintun, & Raichle, 1989; Warrington & Shallice, 1980); for objects, by

Yonatan Goshen-Gottstein and Morris Moscovitch, Department of Psychology, University of Toronto, Toronto, Ontario, Canada.

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Correspondence concerning this article should be addressed to Yonatan Goshen-Gottstein, who is now at the Department of Psychology, Tel-Aviv University, Ramat Aviv, 69978, Israel. Electronic mail may be sent via Internet to goshen@freud.tau.ac.il.

the structural representation system (Riddoch & Humphreys, 1987); and for spoken words, by the auditory word form system (Ellis & Young, 1988; Schacter & Church, 1992; Schacter, Chiu, & Ochsner, 1993). This hypothesis can account for much of the data on perceptual repetition priming for single items in normal people and in patients with memory and perceptual disorders (Moscovitch, 1992a; Moscovitch et al., 1993). It is not clear, however, whether this hypothesis can be extended to include studies on the acquisition and retention of new associations. Perceptual representation systems and input modules are designed to deal with presemantic structural features. It is an open question whether these systems can deal with associative information because, in principle, this information can be either structural (i.e., perceptual contiguity) or semantic (i.e., conceptual relatedness).

In this article, we address two questions. Can reliable association-specific repetition priming effects be obtained, and, if so, are they perceptually or conceptually based?

Can Reliable Association-Specific Repetition Priming Effects Be Obtained?

As yet, it is unresolved whether memory for new associations between pairs of items can be demonstrated on implicit tests after a single trial. To provide such a demonstration it is necessary to show that test performance is facilitated when repeated items are accompanied by the same item as at study (i.e., the *intact* study pair) relative to a baseline condition when they are accompanied by a different study item (*recombined* study pair). We refer to this facilitation as the *associative repetition effect.* Because the individual items in both the intact and the recombined condition are presented at study, better performance in the intact relative to the recombined condition can only be attributed to the retention of associative information. Typically, unstudied control pairs are also presented so that superior performance on recombined pairs as compared with control pairs can index an item-specific repetition effect against which the association-specific effect can be measured.

Memory for associations on explicit tests has been demonstrated by using recognition and cued recall (Clark & Shiffrin, 1987; Hockley, 1992; Murdock, 1974, 1982), but this has yet to be demonstrated unequivocally on implicit tests. Three different tasks have been used to investigate associative repetition priming: speeded naming of degraded stimuli, lexical decision, and stem completion. Using speeded naming of degraded stimuli as the implicit test, Moscovitch, Winocur, and McLachlan (1986) found associative repetition priming in normal and amnesic participants after a single study trial. Musen and Squire (1993), however, had difficulty replicating their results for both amnesic patients and normal subjects, unless multiple study trials were used, but did report a weak associative repetition effect on a test of perceptual identification following a single study trial. Similarly, Paller (unpublished data cited in Mayes, 1992) found associative repetition priming in normal, but not amnesic, people in perceptual identification of briefly presented stimuli.

Using the lexical-decision task, McKoon and Ratcliff (1979) found association-specific repetition effects both in accuracy and in latency. Attempts to replicate this finding have been largely unsuccessful (Carroll & Kirsner, 1982; Dagenbach, Horst, & Carr, 1990; Neely & Durgunoglu, 1985; Smith, MacLeod, Bain, & Hoppe, 1989; but see Durgunoglu & Neely, 1987, Experiment 3; McKoon & Ratcliff, 1986) despite efforts to manipulate encoding strategies to enhance memory.

One of the possible reasons for the discrepant findings is that McKoon and Ratcliff (1979) used long (650–800 ms) intervals (stimulus onset asynchronies; SOAs) between the items that formed the pairs, whereas other investigators did not. Because attentional control processes operate at long but not short SOAs (Neely, 1977, 1991), the facilitation observed by McKoon and Ratcliff (1979) may have been mediated by conscious recollective processes operating during the interval (but see Durgunoglu & Neely, 1987, Experiment 3; McKoon & Ratcliff, 1986).

Using the stem completion task in which participants were asked to complete the stem (i.e., the first three letters) of the target with the first word that came to mind, Graf and Schacter (1985, 1987, 1989; Schacter & Graf, 1986a, 1989; see also Micco & Masson, 1991) obtained associative repetition effects, with target stems of intact pairs being completed more often as study items than target stems of recombined pairs. This outcome, however, was not found in normal subjects under shallow encoding instructions (Graf & Schacter, 1985), in normal subjects who were unaware of the purpose of the task (Bowers & Schacter, 1990; but see Howard, Fry, & Brune, 1991), or in densely amnesic patients (Schacter & Graf, 1986b). These latter three results are at variance with the pattern observed for item-specific repetition effects. Although the cause of the failure to obtain the associative repetition effects in these conditions could be attributed to deficient encoding, another possible interpretation is that the associative stem completion task is contaminated by conscious recollective processes at retrieval (cf. Reingold & Goshen-Gottstein, in press). Whichever interpretation proves to be correct, the fact remains that perceptual repetition effects for newly formed pairs have reliably been reported only under elaborative encoding conditions and when stem completion was tested in normal people who were aware that pairs were repeated.

In this article, we show that reliable association-specific repetition effects can be obtained after a single study trial by using a variant of the lexical-decision task. Pairs of letter strings were presented, and participants indicated whether both members of the pair were words. Encoding of the pairs was elaborative, and the pairs were simultaneously presented both at study and at test so as to maximize the associative information available to them.

Although our review has so far focused on the formation of new associations between unrelated words, it is also of interest to know whether association-specific repetition effects can be obtained for related word pairs that have preexisting semantic representations (e.g., *cotton–wool*). Because it is presupposed that preexisting associations, in contrast to newly formed associations, are represented in semantic memory, it has been assumed that associative priming for related pairs would depend on the reactivation of these semantic representations rather than on the reactivation of perceptual records in input modules. Surprisingly little research has been conducted on this topic. To explicate the nature of perceptual associative priming for related pairs it is first necessary to establish whether these associations can exhibit repetition priming and, if so, whether this repetition priming is perceptually or conceptually based.

Several studies claimed to have found perceptual association-specific repetition priming for related pairs in normal people. In all of these studies, however, the baseline condition used to estimate the association-specific effect was inappropriate. Using the stem completion task, Graf and Schacter (1985) compared intact related pairs with related pairs consisting of studied target items and unstudied, extralist primes. Although they claimed that *associative repetition priming* was exhibited for the related pairs, in fact, all they may have found was *list-wide priming* (see Smith et al., 1989).

Using lexical decision, McKoon and Ratcliff (1979, 1986) compared intact related pairs with recombined unrelated pairs. This comparison confounded associative repetition priming with semantic priming. Finally, the recombined test pairs used by Carroll and Kirsner (1982; see also den Heyer, 1986) were not equated with the intact related test pairs with respect to the type of pair in which the individual members of the pair had been studied. Although the members of the intact related test pairs were presented at study in related pairs (e.g., study: *cotton–wool;* test: *cotton–wool*), the members of the recombined related test pairs were unrelated at study (e.g., study: *table–cotton* and *lamp–wool;* test: *cotton–wool*). The comparison of intact and recombined pairs was therefore confounded with context status at encoding.

Therefore, the question remains open as to whether perceptual association-specific repetition priming can be displayed for preexperimentally related pairs. To answer this question, we presented intact related test pairs and compared them with recombined intralist related test pairs in which the members were presented at study as part of related pairs (e.g., study: *sheep–lamb* and *mutton–wool;* test: *sheep–wool*).

Are Association-Specific Repetition Priming Effects Perceptual or Conceptual?

Evidence of modality specificity provides one of the strongest criteria that item-specific repetition effects are perceptually based. When single items are presented in one modality at study (e.g., auditory) and presented in a different modality at test (e.g., visual), the magnitude of the cross-modal repetition effect is diminished or attenuated relative to within-modality repetition priming. Attenuated cross-modal repetition priming has been demonstrated on fragment completion (Blaxton, 1989; Roediger & Blaxton, 1987), perceptual identification (Clarke & Morton, 1983; Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982; Kirsner, Milech, & Standen, 1983), and stem completion (Graf, Shimamura, & Squire, 1985). Modality effects were also found for lexical decision (Kirsner et al., 1983; Kirsner & Smith, 1974; Monsell & Banich cited in Monsell, 1985). Typically, modality is a less important factor in explicit tests of memory (Blaxton, 1989; Graf et al., 1985; Jacoby & Dallas, 1981; Kirsner et al., 1983; Roediger & Blaxton, 1987; see also Roediger & McDermott, 1993, pp. 80–81).

The only evidence that perceptual repetition priming for associations is also modality specific comes from a single stem completion study by Schacter and Graf (1989). Association-specific repetition priming, however, may have both perceptual and conceptual components. Association-specific repetition priming may depend on the perceptual gestalt that the two items form and may be further influenced by the storage and reactivation of the word pairs in semantic memory. Thus, although the individual units that make up the pairs are not conjoined in semantic memory before the experiment, the elaborative encoding that the items undergo at study may unitize them in semantic memory.

According to this suggestion, whether the perceptual or the conceptual component is emphasized may depend on the items themselves and on the tests used to assess them. For unrelated items, the new associations that are formed during study may be both perceptual and conceptual. If the repetition priming test is one that focuses on low-level perceptual or lexical features, such as lexical decision, then it is the perceptual component of the priming that will be picked up. If the test is semantic, however, then it is the conceptual component that may be emphasized.

On the basis of this framework, we predicted that repetition priming effects for new associations should be sensitive to modality in the lexical-decision task but not in a task that focuses on the semantic relations between items (e.g., a task in which participants are asked whether items are semantically related). As for related pairs that are preexperimentally associated, no new conceptual links are expected to be formed as a result of subsequent study. The repetition priming effect for related pairs, if it occurs at all, would therefore be expected to be carried primarily by the perceptual component, because seeing the related words alongside each other very likely forms a new gestalt that the participant has not experienced before.

To anticipate our findings, association-specific repetition priming effects were found only for unrelated but not for related pairs in the lexical-decision task (Experiment 1). However, in a relatedness judgment task, association-specific effects were found for both unrelated and related pairs (Experiment 2). The association-specific effect for related pairs that we found in Experiment 2 was modality specific, as was the association-specific effect for unrelated pairs when the implicit test was the lexical-decision task. Consistent with our prediction, when the implicit test was the relatedness judgment task, the conceptual component of the association-specific effect was emphasized, and the effect was not attenuated by cross-modal presentation for unrelated pairs. Finally, we showed that changing modalities between study and test produced a different effect on a speeded-recognition test than that observed on the implicit tests (Experiment 3), suggesting that performance on the implicit tasks was not mediated by conscious retrieval processes. The implications of these findings for theories of perceptual repetition priming are discussed after we present the evidence.

Experiment 1

The primary purpose of this experiment was to provide a demonstration that repetition priming can be observed for associative information. Using the stem completion task, Graf and Schacter (1985) have demonstrated that only elaborative encoding produced repetition priming for newly formed associations. Encoding instructions that did not force participants to relate the two words elaborately did not result in association-specific priming for these word pairs. Schacter and Graf (1989; see also Schacter & McGlynn, 1989) reasoned that to be primed, an association must first become unitized. To become unitized, elaborative encoding was necessary. To maximize the possibility of finding associative repetition priming, we used in this experiment elaborative encoding instructions. Elaborative encoding, however, is not sufficient to produce associative repetition priming (viz., Dagenbach et al., 1990; Smith et al., 1989).

To further enhance the probability of finding associative repetition priming, we presented prime and target items simultaneously both at study and at test (cf. Meyer & Schvaneveldt, 1971). This deviated from the standard procedure used by other researchers (Dagenbach et al., 1990; Durgunoglu & Neely, 1987; Neely & Durgunoglu, 1985; McKoon & Ratcliff, 1979, 1986; Smith et al., 1989) who presented prime–target pairs sequentially at test and asked participants to make lexical decisions regarding only target items (but see Carroll & Kirsner, 1982).

At test, participants were presented with word pairs intermixed with pairs that included pronounceable nonwords. Participants judged whether both strings formed words. In this modified paradigm, both encoding and retrieval are performed under conditions in which the prime–target pairs appear simultaneously. We reasoned that because pairs were simultaneously encoded at study, repetition priming was more likely to occur if at test they would also appear side by side. This follows from the encoding specificity principle (Tulving, 1983) that memory is enhanced the more retrieval and encoding are alike. Also, by presenting the members of the pair simultaneously both at study and at test, the associative information is emphasized.

In addition to demonstrating an associative repetition effect, we also wished to investigate how the associative information was represented and processed. To this end, we studied the effects of cross-modal manipulation on associative repetition priming. We predicted that because the lexical-decision task focuses on low-level perceptual or lexical features, the perceptual component of the priming effect will be picked up, and the effect will be sensitive to modality of presentation.

The cross-modal manipulation also allowed us to investigate the effect that shifting modality has on the item-specific repetition effect, as indexed by superior performance on recombined relative to control pairs. Demonstrations of the cross-modal attenuation effect have typically involved lists of words. However, changing modality should have the same effect on recombined (i.e., studied but not studied together) pairs when compared with control (i.e., unstudied) pairs as it has on single studied words compared with single unstudied words.

In previous studies, however, researchers have found that the item-specific effect as indexed by recombined relative to control performance was not equivalent to a comparison of studied versus unstudied single items. We refer to this as the *cross-modal attenuation paradox*. In particular, in all four of their experiments, Schacter and Graf (1989) observed the cross-modal attenuation paradox, with no cross-modal attenuation for recombined as compared with control pairs (for a related finding, see Bowers & Schacter, 1990, Experiments 2–3). As these results suggest, comparison of recombined to control pairs involves processes, as yet not understood, that are more complex than simple comparisons of studied-to-unstudied single items. Inclusion of the cross-modality manipulation in this experiment may provide an additional replication of the cross-modal attenuation paradox and suggest that this paradox is not an empirical anomaly but may represent more complex replicable processes.

Method

Participants

Forty University of Toronto undergraduates participated in the experiment. Participants were paid $5 or received course credit for participation.

Design and Materials

Table 1 shows the composition of a set of nine lexical-decision trials, together with illustrative examples and the number of occurrences of each type of trial in the experiment.

During the study phase, participants were presented with 66 word pairs. Thirty-three of the pairs were related, and 33 were unrelated. Of the 33 pairs from each association type, 11 pairs would later be displayed as intact and 11 as recombined pairs. The remaining 11 pairs from each association type would appear together with nonwords in foil trials.

At test, participants were presented with 66 word–word pairs and 66 pairs that included at least one nonword. Eleven related pairs were

Table 1
An Example of Study and Test Trials for Experiment 1

Type[a]	Association[b]	Example
Study phase word pairs[c]		
Intact	Related	Sheep–lamb
Recombined	Related	Mutton–wool
Intact	Unrelated	Queen–lemon
Recombined	Unrelated	Bible–honey
Nonword	Related	Cry–baby
Nonword	Unrelated	Cluster–point
Lexical-decision word pairs		
Test pair type		Example
11 occurrences		
Intact related		Sheep–lamb
Recombined related		Sheep–wool
Control related		Table–chair
Intact unrelated		Queen–lemon
Recombined unrelated		Queen–honey
Control unrelated		Cop–garden
22 occurrences		
Word nonword		Cry–bliff
Nonword word		Lutter–point
Nonword nonword		Quock–saster

Note. For half the test trials, the intact related (unrelated) pairs preceded the recombined related (unrelated) pairs. For the other half of trials, the recombined related (unrelated) pairs preceded the intact related (unrelated) pairs.
[a]The type of pair in which one or both of the studied words would appear at test. [b]The association between the words. [c]Eleven trials for each pair type.

displayed in their intact study presentation. Another 11 related pairs were rearranged to form the recombined condition. An additional 11 related pairs that had not previously been seen at study were presented at test as controls to provide an estimate of baseline performance. Thirty-three unrelated pairs were divided in the same way between intact, recombined, and control trials.

The 66 foil trials included 22 word–nonword trials, 22 nonword–word trials, and 22 nonword–nonword trials. The 44 words that were needed for these foil trials were taken from the study trials that were included for this purpose.

Thus, the experimental design consisted of two within-subject variables and one between-subjects variable. The within-subject variables were the association type (related pairs and unrelated pairs) and pair type (intact, recombined, and control). The between-subjects variable was study modality (visual and auditory).

The target materials were formed from arrays, in which each array consisted of two word pairs. We refer to these pairs as the A1–A2 pairs (e.g., *sheep–lamb*) and the A3–A4 pairs (e.g., *mutton–wool*). Intact pairs were then defined as the A1–A2 pairs (e.g., *sheep–lamb*), and the recombined pairs were the A1–A4 pairs (e.g., *sheep–wool*). These arrays were constructed to form the pool from which the pairs of preexisting associations would be drawn. Creation of the pairs from such arrays ensured that the right–left spatial order among the pair members would be preserved.

Three constraints were observed in the construction of each array (see Table 2 for an example of such arrays). First, the mean level of association, as indexed by published norms (Keppel & Strand, 1970; Palermo & Jenkins, 1964), was the same for A1–A2 and for A1–A4. Thus, overall A1–A2 pairs (e.g., *sheep–lamb*) were as related as A1–A4 pairs were (e.g., *mutton–wool*). At test, performance on the A1–A2 intact pair could be compared with performance on the A1–A4 recombined pair because the semantic association in the two pairs was equated, and the magnitude of semantic priming was therefore expected to be equivalent. The mean percentage of participants who produced the A2 word as their first response to the A1 word was 9% compared with 10% for the production of the A4 items. This difference was not significant, $t(43) = 0.18$, $p > .1$. The Pearson product–moment correlation coefficient for the percentage of production between the A2 and A4 items was .78 ($p < .05$). Because the A1 word was identical for the intact and the recombined pairs, no control was exerted over it.

Second, the mean word frequency for A2 (e.g., *lamb*) was equal to that of A4 (e.g., *wool*). The A2 items had a mean Francis and Kucera (1982) frequency of 143.6 occurrences per million, compared with 143.2 per million for the A4 items. This difference was not significant, $t(43) = 0.05$, $p > .1$. The Pearson product–moment correlation coefficient between the word frequencies of the A2 and A4 items was .95 ($p < .05$). Again, this constraint controlled for a word frequency effect for the A1–A2 pairs relative to the A1–A4 pairs.

Table 2
Example of Items That Form a Preexisting Association and a Newly Formed Association Array

Preexisting association		Newly formed association	
A1	A2	B1	B2
Sheep	Lamb	Queen	Lemon
A3	A4	B3	B4
Mutton	Wool	Bible	Honey

Note. Mean word frequency of A2 (B2) equals that of A4 (B4); mean syllable length of A2 (B2) equals that of A4 (B4); and for the preexisting association pairs, strength of A1–A2 association equals that of the A1–A4 association.

The stimuli were further constrained by ensuring that the mean number of syllables in each A2 item was equal to that of the corresponding A4 item. The mean number of syllables for the A2 items was 1.30, compared with 1.32 for the A4 items. This difference, too, was not significant, $t(43) = 0.23, p > .1$.

Only 44 arrays (i.e., 88 pairs) were found that adhered to these severe constraints. These are presented in the Appendix. These preexisting association arrays were randomly divided into four sets of 11 arrays each (i.e., 22 pairs) from which the newly formed associations would be created. For the sake of brevity, these sets are referred to as Sets 1–4. From each of the four sets, a corresponding set of 11 arrays was constructed by using the very same items as the original sets. The items in the corresponding sets were rearranged so that the new arrays would consist of newly formed associations. These words formed the pool from which the unrelated pairs would be drawn. These sets of pairs are referred to as Sets 5–8, with Set 5 corresponding to preexisting association Set 1, 6 with Set 2, and so on.

In forming the lists for the unrelated pairs, we used the identical A2 and A4 items that were used in the condition of preexisting associations, but we matched them with different A1 and A3 items. For the purpose of clarity, we distinguish between the related and unrelated pairs by referring to the unrelated pairs as B1–B2 and B3–B4 pairs. Thus, whereas the B2 and B4 items corresponded to the A2 and A4 items, the A1 items did not correspond to the B1 items, and the A3 items did not correspond to the B3 items. By maintaining the B2 and B4 items that were used for the related pairs, three constraints were imposed. First, within an array, both the B1–B2 and the B1–B4 pairs were unrelated. Second, the mean word frequency for B2 was equal to that of B4. Third, the mean syllable length of B2 was equal to that of B4. The mean word frequency and syllable length of the B2 and B4 items were identical to those in the lists of preexisting associations.

Study lists. For counterbalancing purposes, four lists were composed for presentation at study. For each list, four of the eight sets were drawn without replacement. Once a set was drawn, the set corresponding to the drawn set (i.e., that set which contained the same items in a different arrangement, for example, Sets 1 and 5) would be discarded. The choice of the particular sets in each list was determined by a Latin square design.

For each study list, 11 arrays (i.e., 22 pairs) were chosen from one of the preexisting association sets (1–4), for example, Set 1. These items would later be presented for lexical decision either intact or recombined. Another 11 arrays were chosen from the remaining unrelated sets (6–8), for example, Set 6. These words would later be presented for lexical decision either intact or recombined with other items. A further 11 A1–A2 pairs (not 11 arrays) with preexisting associations were chosen from the two sets that remained (3 and 4), for example, Set 3. These word pairs would later be presented for lexical decision as parts of pairs with nonwords. This precluded a complete confounding of the study status of an item with its lexicality (see Durgunoglu & Neely, 1987). Finally, an additional 11 newly formed B1–B2 pairs were chosen from the only remaining set (8). These words would also be presented in pairs with nonwords at test.

Taken together, each of the four lists contained 66 word pairs: half of which were preexperimentally associated, and half of which were not. These 66 pairs were composed of 11 preexisting and 11 newly formed association arrays (i.e., 22 preexisting and 22 newly formed association pairs) for target test conditions and an additional 11 preexisting A1–A2 and 11 newly formed B1–B2 pairs for trials containing nonwords.

Test lists. Four test lists were constructed, one corresponding to each of the study lists. Each test list contained 66 word–word pairs. The 11 preexisting association arrays (22 pairs) from the study list were used again at test. Eleven of the pairs were presented as intact A1–A2 pairs, and an additional 11 pairs were presented as recombined A1–A4 pairs. The intact pair involving a particular word preceded the corresponding recombined pair involving the same word on half of the presentations and followed it on the other half. The same procedure was followed for the 11 arrays (22 pairs) that produced the unrelated set at study. In addition, 22 A3–A4 pairs that were not presented at study (these were pairs that served as study items only in the other counterbalanced lists) were presented at test. These 22 pairs provided an estimate of baseline performance for preexisting and newly formed associates. Thus, 22 of the test pairs were intact, 22 were recombined, and 22 were control.

Each of the four test lists also contained 66 trials with nonword items. All nonword items were derived from legal English words by changing one letter and substituting it with a letter of equal bigram frequency. These trials were composed of 22 word–nonword, 22 nonword–word, and 22 nonword–nonword items. The 44 words that were needed for these conditions were taken from preexisting and newly formed pairs that were presented at study for this purpose.

Procedure

Participants were randomly divided into one of two equal-sized groups ($n = 20$) corresponding to the two between-subjects conditions. In each of these two groups, participants were further subdivided into four groups ($n = 5$) corresponding to the four study lists.

In the visual study condition, individually tested participants were told that they would be shown some word pairs on the computer screen, and after a distractor task they would then be asked to remember them. The participants were asked to generate a sentence that contained the two words. The sentence was to be meaningful and would retain the order of the words as they appeared on the screen. All participants were given 10 practice pairs to illustrate the nature of the study task. The study pairs were then presented on the screen of a MacIntosh Plus computer in random order for each participant. Each pair was presented for 5 s, after which it disappeared. Participants were required to generate a sentence, even if the pair was no longer visible. The A1 and A3 words were always presented to the left of the A2 and A4 words. Similarly, the B1 and B3 words were always presented to the left of the B2 and B4 words. After generating a sentence, participants pressed the space bar; this led to the appearance of the next pair.

After the study list was presented, participants were told that they would perform a distractor task and that after this distractor task, their memory of the original items would be tested. The distractor task was in fact the implicit lexical-decision test. Participants were told that two letter strings would appear on the computer screen. They were instructed to press one of either the *M* or the *Z* key with their dominant hand if both letter strings were legal English words and the other key if one or both letter strings were non-English words. Participants were instructed to choose as quickly and with as few errors as possible. It was explicitly mentioned to the participants that some of the letter-string pairs had appeared at study. They were told to disregard this, as it was purely due to convenience of setting up the experiment. All participants were then given 10 pairs for practice. After that, the test list that corresponded to the given study list was presented in a different random order for each participant. The delay between the end of the study and the beginning of the test was approximately 5 min.

All aspects of the procedure in the auditory study condition were identical to those of the visual study condition, except that participants were instructed to listen to the pairs of words presented on a Sony cassette player. The experimenter controlled the cassette player by turning it on and off to enable the participants to generate the sentences.

The word pairs were recorded in a soundproof room, with approximately 2 s of silence separating each pair. This period was used to enable the experimenter to turn off the cassette player, wait for the participant to generate a sentence, and turn the cassette player back on. To enable the experimenter to hear the stimuli and monitor participants' sentences, we did not use head phones. A separate recording was made for each of the four counterbalanced study lists.

Results

For each participant in each of the six within-subject conditions (3 [pair type] × 2 [association type]) we calculated means from the reaction time (RT) distributions of correct responses, in which skewness was reduced by eliminating values that were more than 2,000 ms. In all, fewer than 1% of the observations were eliminated. The means were then averaged across subjects and are presented, along with the proportion of correct responses, in Table 3.

Examination of the RTs revealed that the pair type manipulation affected related and unrelated pairs differently. In the visual study condition, lexical-decision times for unrelated pairs were faster to intact pairs than to recombined pairs, with the slowest responses to control pairs. For related pairs, responses to recombined pairs were faster than to intact pairs. In addition, the cross-modal manipulation eliminated the advantage of the intact unrelated pairs over recombined unrelated pairs, but it did not affect the item-specific effect.

The data were analyzed by using a three-way analysis of variance (ANOVA) with pair type (intact, recombined, and control) and association type (related and unrelated) as within-subject variables and study modality (visual and auditory) as a between-subjects variable. For this and subsequent experiments, the significance level was set at $\alpha = .05$, and unless otherwise stated, results are reported for two-tailed tests.

The main effect for pair type was significant, $F(2, 76) = 20.01$, $MSE = 5{,}485$, $p < .001$, and RTs were shorter for the

Table 3
Mean Reaction Times (RTs; in Milliseconds), Mean Percentage of Error Rates (ER), and Priming Effects for Lexical Decisions in Experiment 1

Association type	Intact RT	Intact ER	Recombined RT	Recombined ER	Control RT	Control ER
Visual study modality						
Related						
M	813	2	796	1	847	2
Priming	−17	−1	+51	+1		
Unrelated						
M	866	3	924	2	986	2
Priming	+58	−1	+62	0		
Auditory study modality						
Related						
M	865	1	849	2	872	1
Priming	−16	+1	+23	−1		
Unrelated						
M	907	1	916	3	1,019	1
Priming	+9	+2	+103	−2		

Note. Priming for the intact pairs (i.e., association-specific priming) was computed by subtracting the RT (ER) for the intact pairs from that for the recombined pairs. Priming for the recombined pairs (i.e., item-specific priming) was computed by subtracting the RT (ER) for the recombined pairs from that of the control pairs. Correct responses were yes for all conditions.

preexisting pairs than for the newly formed pairs, $F(1, 38) = 67.68$, $MSE = 82{,}046$, $p < .001$. Most important, the interaction between the pair type and the association type conditions was significant, $F(2, 76) = 9.32$, $MSE = 5{,}004$, $p < .001$, and this interaction did not vary between the study modality conditions, $F(2, 76) = 1.25$, $MSE = 5{,}004$, $p > .25$.

To determine whether the association-specific information could account for the Pair Type × Level of Association interaction, we conducted a three-way ANOVA using only intact and recombined pairs (Levin, Serlin, & Seaman, 1994). We found that the pair type main effect was insignificant, $F(1, 38) < 1$, as was the interaction between pair type and study modality, $F(1, 38) = 1.48$, $MSE = 3{,}665$, $p > .2$. Responses to related pairs were found to be faster than to unrelated pairs, $F(1, 38) = 37.16$, $MSE = 5{,}655$, $p < .001$. Most important, the interaction between pair type and level of association was significant, $F(1, 38) = 7.09$, $MSE = 3{,}644$, $p < .015$, and its pattern was not significantly different for the two study modality conditions, $F(1, 38) = 1.78$, $MSE = 3{,}644$, $p = .19$.

To understand better the nature of the interaction between pair type and association level, we analyzed related and unrelated pairs separately. For the related pairs, none of the effects were significant: for pair type, $F(1, 38) = 1.33$, $MSE = 4{,}193$, $p > .25$; for study modality, $F(1, 38) = 1.12$, $MSE = 49{,}726$, $p > .29$; and for the interaction, $F(1, 38) < 1$. Thus, responses to intact and recombined pairs were not significantly different and did not differ as a function of study modality.

For the unrelated pairs, the study modality main effect was not significant, $F(1, 38) < 1$. However, responses to intact unrelated pairs were significantly faster than responses to recombined unrelated pairs, $F(1, 38) = 7.46$, $MSE = 3{,}116$, $p < .01$. Most important, the magnitude of this associative repetition effect was greatly attenuated in the cross-modal condition, $F(1, 38) = 3.82$, $MSE = 3{,}116$, $p < .03$, one-tailed. Thus, unrelated pairs showed a modality-specific associative repetition effect, with faster responses to intact than to recombined pairs only in the within-modality presentation condition.

Because the Pair Type × Study Modality interaction is critical for our claim of an attenuated cross-modal effect, we also analyzed the data using the Mann–Whitney U test, which assumes little about the population distributions. We compared the difference score between intact and recombined pairs in the crossed and uncrossed modality condition. The difference was found to be significant at $p = .015$, $U = 110$; $\chi^2 (1, N = 40) = 5.93$.

Next, we analyzed the unrelated pairs within individual participants. In the visual study modality condition, 16 of the 20 participants showed slower RTs for recombined than for the intact pairs (binomial probability = .012). In the auditory study modality condition, only 11 participants showed this pattern ($p = .824$). Thus, we demonstrated that participants responded differentially to intact and recombined pairs, but they did so only when study and test were within the same modality.

Examination of the item-specific repetition effect revealed faster responses to recombined pairs than to control pairs. Of more interest, crossing modality between study and test seemed to have enhanced, rather than attenuated, the magnitude of the item-specific repetition effect for unrelated pairs. Using only recombined and control pairs (Levin et al., 1994), we analyzed the data by using a three-way ANOVA. The pair type and association type manipulations produced significant results: for pair type, $F(1, 38) = 19.40$, $MSE = 7{,}285$, $p < .001$; and for association type, $F(1, 38) = 64.99$, $MSE = 8{,}976$, $p < .001$. More important, the faster processing of recombined over control pairs was larger for unrelated than for related pairs, $F(1, 38) = 5.19$, $MSE = 4{,}029$, $p < .03$. That this pattern did not vary across modalities of study indicates that the reversed modality effect was not significant, $F(1, 38) = 2.86$, $MSE = 4{,}029$, $p = .099$. Indeed, the two-way interactions of pair type and modality for the unrelated pairs, as well as for the related pairs, did not achieve significance: for unrelated, $F(1, 38) = 1.02$, $MSE = 7{,}521$, $p > .3$; and for related, $F(1, 38) = 1.09$, $MSE = 3{,}797$, $p > .3$.

Discussion

Association-Specific Effects for Unrelated Pairs

The most important point to emerge from our results is the demonstration that the simultaneous lexical-decision task is a sensitive indicator of memory for new associations. We found that mean RTs to intact unrelated study pairs were 58 ms faster than to recombined unrelated study pairs. This effect has been difficult to obtain by using the standard lexical-decision task in which the pair items appeared sequentially, and lexical decisions were only made to the second member of the pair.

We have recently replicated the associative repetition effect for unrelated word pairs (Goshen-Gottstein & Moscovitch, 1995; see also Rueckl & Marsolek, 1993) by using a different group of participants and longer lists consisting of newly formed pairs that were not used in the present study. The replication results were robust and consistent across subjects. We conclude, therefore, that implicit memory responses to intact and recombined pairs are indeed different. In the General Discussion section, we consider why we think our paradigm yielded association-specific priming where other paradigms failed.

Determination of whether the association-specific priming is perceptually based is more problematic. On the one hand, the difference between intact and recombined pairs was eliminated when modality was crossed, suggesting that the association-specific repetition effect is perceptually based. This finding replicates that of Schacter and Graf (1989), who showed cross-modal attenuation with the stem completion task, and is consistent with similar findings reported for item-specific repetition effects.

On the other hand, as compared with the control condition, the intact pairs yielded equivalent priming in the unimodal (120 ms) and cross-modal (112 ms) conditions. Therefore, the attenuated cross-modal association-specific priming effect for unrelated pairs may have occurred because of a reversed item-specific modality effect; namely, that unrelated recombined pairs produced a 41-ms larger item-specific effect (relative to unrelated control pairs) in the cross-modal condition than in the unimodal condition.

We argue, however, that the reversed item-specific modality effect also supports the case for attenuated association-specific priming when modalities were crossed. The supposed absence of an attenuation effect when intact pairs are compared with control pairs in the cross-modal and unimodal conditions must be viewed in light of the benefit that accrues individual members of intact pairs in the cross-modal condition relative to the unimodal condition. Given the paradoxically greater priming (albeit insignificant) of item-specific information in the cross-modal condition, greater priming when comparing the intact to the control condition would also be expected. That the magnitude was unchanged, and indeed was no larger than that observed for the recombined pairs, indicates that crossing the modalities did attenuate the association-specific effect.

Perceptual factors seem, therefore, to mediate association-specific repetition effects for unrelated words. Perceptual contiguity rather than semantic relatedness seems, therefore, to underlie the associative repetition priming effect, at least when displayed on the lexical-decision task.

Item-Specific Effects for Unrelated Pairs

Although cross-modal attenuation has been observed when comparing old and new single items when using the lexical-decision paradigm (Kirsner et al., 1983; Kirsner & Smith, 1974; Monsell & Banich cited in Monsell, 1985; for reviews see Donnelly, 1988; Kirsner & Dunn, 1985), we found no attenuation of the item-specific effect when comparing recombined and control pairs. The absence of cross-modal attenuation for item-specific information replicates the cross-modal attenuation paradox reported in the four stem completion experiments of Graf and Schacter (1989). Indeed, not only was attenuation not observed in our data, we actually found a (nonsignificant) enhancement of the item-specific effect when modalities were crossed. We have no explanation for the reverse effect observed in our data. In any case, our findings demonstrate that the cross-modal attenuation paradox is robust across both the stem completion task and the lexical-decision task.[1]

Association-Specific Effects for Related Pairs

An unexpected result to emerge from the experiment was the absence of repetition priming for preexisting associations. Previous studies did find association-specific priming for related word pairs but, as noted in the introduction, these studies provided evidence only for list-wide priming (Graf & Schacter, 1985) or confounded intact and recombined pairs with encoding context (Carroll & Kirsner, 1982) or with semantic priming (McKoon & Ratcliff, 1979, 1986). Indeed, if we compare intact related pairs to recombined unrelated pairs, as did McKoon and Ratcliff (1979, 1986), we too find a significant effect, both in the unimodal condition (111 ms) and in the cross-modal condition (51 ms). To demonstrate true association-specific priming for related pairs, researchers must compare intact related pairs with a baseline of recombined pairs in which both members had been studied in a related combination. Using this correct baseline condition, we did not obtain an effect.

The absence of an associative repetition effect for related pairs, against the backdrop of facilitated performance for newly formed associations, was unexpected. It was assumed that preexisting associations would benefit from repetition that was due to the reactivation of their preexisting representations, as others had proposed for single items (e.g., Diamond & Rozin, 1984). In Experiment 2, we show that the absence of associative repetition effects is particular to the lexical-decision task, but it can be demonstrated on another implicit task involving judgments of semantic relatedness.

Item-Specific Effects for Related Pairs

Crossing modalities attenuated (albeit not significantly) the advantage of recombined related pairs over control related pairs. This finding is the standard result for data-driven implicit tests of memory, in which item-specific information is modality specific (for reviews see Donnelly, 1988; Kirsner & Dunn, 1985). The cross-modal attenuation paradox observed for unrelated pairs, however, remains an empirical enigma in that crossing modalities attenuated item-specific priming only for related pairs.

Semantic Priming

The main effect of level of association observed across our data resulted from slower RTs to unrelated pairs (936 ms) than to the related pairs (840 ms). This is an example of the semantic priming effect (Meyer & Schvaneveldt, 1971) in which lexical-decision RTs to related pairs (*sheep–lamb*) are faster than RTs to unrelated pairs (*cheese–gun*). Because semantic priming is mediated by semantic, rather than perceptual, factors the magnitude of semantic priming effect for control pairs was unaltered when modality of presentation was crossed.

The demonstration of semantic priming in our study does not replicate Neely and Durgunoglu's (1985, 1987) failure to obtain semantic priming in all of their experiments when other paired associates were presented for study. Indeed, Carroll and Kirsner (1982), as well as McKoon and Ratcliff (1979, 1986), also found semantic priming under similar conditions. It is noteworthy that only the studies that included identical related pairs at study and at test (i.e., intact related pairs) obtained the semantic priming effect. Further research may determine whether this factor is responsible for the discrepant findings.

Although inclusion of semantically related pairs at study did not obscure the associative repetition priming effect in our study, Durgunoglu and Neely (1987, Experiment 4) found that the inclusion of semantically related primes at study greatly reduced or eliminated associative repetition priming. A pos-

[1] A possible explanation for the cross-modal attenuation paradox is that conceptual information may mediate the item-specific repetition effect that is observed when modalities are crossed. Conceivably, because the comparison of recombined pairs to control pairs involved two studied items and two nonstudied items, the conceptual information that may be present in the item-specific effect to only a small degree (Weldon, 1991) may become exaggerated. This conceptual information, which is not sensitive to modality of presentation, may mediate the anomalous item-specific effect observed when modalities are crossed.

sible resolution of this discrepancy is that in our experiment test presentation was simultaneous, whereas Durgunoglu and Neely (1987) presented test pairs sequentially (for an alternate explanation, see Dosher & Rosedale, 1991). We propose that perceptual contiguity may be an essential component for recovering associative information implicitly. It follows that sequential test presentation may not enable the recovery of the perceptual information as encoded at study (see Goshen-Gottstein & Moscovitch, 1995) unless a circumscribed set of conditions, noted by Durgunoglu and Neely (1987), are met. Once again, empirical investigation is needed to establish the validity of this proposal.

Experiment 2

In Experiment 1, associative repetition priming was not observed for related pairs. However, a main effect of semantic priming was found, with related pairs showing overall faster RTs than unrelated pairs. Evidence of semantic priming for related pairs indicates that one member of the pair facilitated the processing of the other. This reduction in processing time that was due to the semantic affiliation of related pairs might have been so large as to eclipse any further reduction because of repetition. The residual effect of repetition may have been too small in the context of the semantic facilitation to be detected by the lexical-decision task (see Monsell, 1985). Another task, however, might prove more sensitive to repetition effects for related items. In this experiment, we show that perceptual repetition priming can be demonstrated for the related pairs if speeded judgment of semantic relatedness, rather than lexical decision, is the implicit task.

The demands imposed by the lexical-decision task and a relatedness judgment task are inherently different. Whereas lexical decision demands that each of the two words be processed, the task does not require that the association between the words be considered. Although ultimately participants respond positively only when both items are words, the lexicality of every item can be examined independently of the other. In contrast, for participants to perform the relatedness judgment task correctly, they must appreciate the relationship between the two words. An analysis of the individual words alone cannot lead to a correct decision. Also, the relatedness judgment task effectively depends on the same information that drives semantic priming rather than use information that is orthogonal to it, as the lexical decision does. For this reason, the relatedness judgment task may be more effective than the lexical-decision task at differentiating between related pairs that have been encountered at study and those that have not. We thus presented to participants the same pairs as in Experiment 1 but instructed them to decide whether the items were related.

Although relatedness judgments to intact related pairs should be positive ("yes, they are related"), responses to intact unrelated pairs are not as clearly defined. These stimuli were chosen to be unrelated, and so participants should respond that the items are unrelated. On the other hand, preexposure to these pairs at study, with the requirement to associate one item with the other, effectively related the previously unrelated items with each other. Therefore, the newly acquired episodic information (whether unrelated items were studied together) may intrude on semantic relatedness judgments (whether items are related). Indeed, when studying such intrusion effects, Dosher and Rosedale (1991) found a (nonsignificant) inhibitory effect, with slower responses to intact unrelated pairs than to recombined unrelated pairs and a higher false-alarm rate to intact unrelated pairs than to recombined unrelated pairs. Semantic relatedness judgments to unrelated pairs in this experiment replicate Dosher and Rosedale's conditions and provide an opportunity to confirm their results.

As in Experiment 1, we also wished to investigate how the associative information was represented and processed. For related pairs that were preexperimentally associated, no new conceptual links were expected to be formed as a result of subsequent study. The repetition priming effect for related pairs, if it occurred at all, was therefore expected to be primarily carried by the perceptual component because seeing the related words alongside each other probably formed a new gestalt that the participant had not experienced before. Therefore, we expected that the association-specific effect would be modality specific.

In contrast to related pairs, we expected new conceptual links to be established for unrelated pairs. Because relatedness judgments are primarily semantic, it is the conceptual component of the associative information that should be emphasized, and the repetition priming effect was, therefore, not expected to be sensitive to modality of presentation.

Method

Participants

Forty University of Toronto undergraduates participated in the experiment. Participants either received course credit for participation or were paid $5.

Design and Materials

The experimental design consisted of two within-subject variables and one between-subjects variable. The within-subject variables were pair type (intact, recombined, and control) and association level (related and unrelated). The between-subjects variable was study modality (visual and auditory).

We made one change in the test list for this experiment. Because items were submitted to a relatedness judgment task, all pairs had to be word–word pairs. Word–word pairs, half related and half unrelated, were substituted for the pairs containing nonwords used in Experiment 1. Because these items did not serve in any of the experimental conditions, no control was exerted over them other than maintaining a mean of 1.3 syllables over all of the items.

Procedure

The procedure was identical to that of Experiment 1, with the exception of the instructions at test. As before, participants were told that they would perform a distractor task and that after this distractor task, their memory of the original items would be tested. The distractor task was the speeded relatedness judgment test. Participants were told that two letter strings would appear on the computer screen. They were instructed to press one of either the *M* or the *Z* key with their dominant hand if the two letter strings were semantically related. They were not explicitly told to respond "unrelated" when previously studied semantically unrelated words were presented. Participants were instructed to choose as quickly and with as few errors as possible. A practice session of 10 pairs was given, in which participants were able to acquire the subjective criteria used for defining related and unrelated pairs.

Results

The mean RTs for each experimental condition were calculated as in Experiment 1, and the results are presented in Table 4. Examination of the RTs revealed that the pair type manipulation affected related and unrelated pairs differently. In the within-modality condition, relatedness judgment times for related pairs were faster to intact pairs than to recombined pairs. For the unrelated pairs, the effect was in the opposite direction. In addition, the cross-modal manipulation eliminated the advantage of the intact over recombined related pairs, but it did not eliminate the advantage of recombined pairs over intact unrelated pairs.

The data were analyzed by using a three-way ANOVA with pair type (intact, recombined, and control) and association type (related and unrelated) as within-subject variables and study modality (visual and auditory) as a between-subjects variable. The main effect for pair type was significant, $F(2, 76) = 3.92$, $MSE = 10{,}785$, $p < .025$, and RTs were shorter for the preexisting pairs than for the newly formed pairs, $F(1, 38) = 1{,}200.84$, $MSE = 723$, $p < .001$. Most important, the interaction between the pair type and the association-type conditions was significant, $F(2, 76) = 23.79$, $MSE = 751$, $p < .001$, and this interaction was significantly different for the two study modality conditions, $F(2, 76) = 4.93$, $MSE = 751$, $p < .01$.

To determine whether the association-specific information could account for the Pair Type × Level of Association interaction, we conducted a three-way ANOVA using only intact and recombined pairs (Levin et al., 1994). Responses to related pairs were faster than to unrelated pairs, $F(1, 38) = 930.27$, $MSE = 676$, $p < .001$. However, the pair type main effect was insignificant, $F(1, 38) < 1$, as was the interaction between pair type and study modality, $F(1, 38) = 1.86$, $MSE = 7{,}750$, $p > .15$. Most important, the interaction between pair type and level of association was significant, $F(1, 38) = 40.26$, $MSE = 812$, $p < .001$, and the pattern of this interaction was not significantly different for the two study modality conditions, $F(1, 38) < 1$.

To better understand the nature of the Pair Type × Association Type interaction, we analyzed related and unrelated pairs separately. For the unrelated pairs, a one-tailed test for pair type was found to be significant, with slower responses to intact than to recombined pairs, $F(1, 38) = 3.06$, $MSE = 5{,}558$, $p < .04$. However, the study modality main effect and the Pair Type × Study Modality interaction were not significant: for study modality, $F(1, 38) = 2.69$, $MSE = 41{,}301$, $p > .1$; and for interaction, $F(1, 38) < 1$. Thus, unrelated pairs showed an inhibitory effect, with faster responses to recombined than to intact pairs. This inhibition was not altered when modality was shifted across study and test.

Examination of the data for the individual participants also suggested an inhibition effect that did not vary with modality. In the visual and auditory study conditions, respectively, 13 and 12 of the 20 participants showed the inhibition effect ($p = .077$, one-tailed by a sign test, for the combined data).

For the related pairs, the study modality main effect was not significant, $F(1, 38) < 1$. However, responses to intact related pairs were significantly faster than responses to recombined related pairs, $F(1, 38) = 5.23$, $MSE = 3{,}004$, $p < .03$. Most important, the magnitude of this associative repetition effect was attenuated in the cross-modal condition, $F(1, 38) = 3.17$, $MSE = 3{,}004$, $p < .045$, one-tailed. Thus, related pairs showed a modality-specific associative repetition effect, with faster responses to intact than to recombined pairs only in the within-modality presentation condition.

As in Experiment 1, we also analyzed the attenuated cross-modality effect by using the Mann–Whitney U test. We compared the difference score between intact and recombined pairs in the crossed and uncrossed modality condition. The difference was significant at $p = .03$, $U = 280$; $\chi^2(1, N = 40) = 4.68$.

Examination of the item-specific repetition effect revealed faster responses to recombined pairs than to control pairs. Furthermore, crossing modality between study and test attenuated the magnitude of the item-specific repetition effect, but only for related pairs. Analyzing the data with a three-way ANOVA (Levin et al., 1994) when using only recombined and control pairs, we found the pair type and association type manipulations to be significant: for pair type, $F(1, 38) = 4.60$, $MSE = 13{,}962$, $p < .05$; and for association type, $F(1, 38) = 378.23$, $MSE = 1{,}132$, $p < .001$. The Pair Type × Association Type interaction, however, was not significant, $F(1, 38) = 1.79$, $MSE = 1{,}004$, $p > .15$. Most important, the three-way

Table 4
Mean Reaction Times (RTs; in Milliseconds), Mean Percentage of Error Rates (ER), and Priming Effects for Relatedness Judgments in Experiment 2

Association type	Intact RT	Intact ER	Recombined RT	Recombined ER	Control RT	Control ER
Visual study modality						
Related						
M	951	3	1,000	2	1,057	2
Priming	+49	−1	+57	0		
Unrelated						
M	1,124	11	1,111	4	1,161	2
Priming	−13	−7	+50	−2		
Auditory study modality						
Related						
M	931	2	938	3	948	3
Priming	+7	+1	+10	0		
Unrelated						
M	1,066	11	1,020	3	1,064	4
Priming	−47[a]	−8	+44	+1		

Note. Priming for the intact pairs (i.e., association-specific priming) was computed by subtracting the RT (ER) for the intact pairs from that for the recombined pairs. Priming for the recombined pairs (i.e., item-specific priming) was computed by subtracting the RT (ER) for the recombined pairs from that of the control pairs. Correct responses were yes for all related pairs and no for all unrelated pairs.
[a]Because the repetition effect in the visual modality was inhibitory, the −47-ms priming effect observed under cross-modal presentation describes a (nonsignificant) enhanced inhibitory effect rather than attenuation of the original effect.

interaction between pair type, association type, and study modality was significant, $F(1, 38) = 4.16$, $MSE = 1{,}004$, $p < .05$. Thus, although crossing modality attenuated the item-specific repetition effect for related pairs, no attenuation was produced for unrelated pairs.

Finally, we analyzed the accuracy data. Because too few errors were made for related pairs, we analyzed only the percentage of correct responses for the unrelated pairs. Examination of the data revealed that participants made more false alarms in responding to intact than to recombined pairs under both unimodal and cross-modal study conditions. A two-way ANOVA found that the pair type manipulation had a significant effect, $F(2, 76) = 188.61$, $MSE = 0.001$, $p < .001$, but that pair type did not significantly interact with study modality, $F(2, 76) = 1.65$, $MSE = 0.001$, $p > .15$. Post hoc examination of the data (Levin et al., 1994) found only a significant association-specific pair type effect, $F(1, 38) = 203.71$, $MSE = 0.001$, $p < .001$. The item-specific pair type effect, $F(1, 38) = 2.45$, $MSE = 0.001$, $p > .1$, as well as all interactions (Fs < 1), did not achieve significance. Thus, participants made more false alarms in responding to intact unrelated pairs than to recombined unrelated pairs, and this effect was not attenuated when modality was crossed between study and test. Moreover, the data for individual participants strongly supported this finding, with 19 of 20 participants ($p < .001$) showing more false alarms to intact pairs in the unimodal condition, and all 20 participants showing more false alarms in the intact condition in the cross-modal condition.

Discussion

Association-Specific Effects for Related Pairs

The most interesting result to emerge from this experiment was that when relatedness judgment was the implicit memory test, a strong associative repetition priming effect for related associations was achieved. As speculated, relatedness judgment probably enabled the benefit that was due to repetition to reveal itself in performance rather than be eclipsed by semantic priming effects, as occurred when lexical decision (Experiment 1) was the implicit task.

Crossing modalities between study and test attenuated the associative repetition effect for related associations in the unimodal condition from a significant 49 ms to a nonsignificant 7 ms. These results suggest that the effect was primarily carried by a perceptual component of the associative information. Because new conceptual links were probably not formed for the related pairs, the repetition priming effect for these pairs was produced by the perceptual gestalt created by seeing the related words alongside each other.

Thus, the locus of the association-specific priming effect was at a perceptual stage of processing, despite the fact that the task, relatedness judgment, is a conceptual one. The benefit of repetition, accrued at the perceptual stage, was maintained at later, conceptual processing stages.

Item-Specific Effects for Related Pairs

An item-specific effect for related pairs, similar to the association-specific effect, was also observed in this experiment. This effect was attenuated when modalities were crossed. Like the attenuation observed for the association-specific effect, the item-specific effect also suggests that despite the conceptual nature of the task, the effect is at a perceptual level of processing. We discuss this interpretation further in the General Discussion section.

Association-Specific Effects for Unrelated Pairs

For the unrelated pairs, we found intrusion of the studied information on the relatedness judgment task in both latency and in accuracy measures, demonstrating an association-specific repetition effect. Responses to recombined pairs, which had not previously been studied as a unit, were significantly faster and more accurate than responses to the intact pairs. Presumably, unrelated words that had been studied together (i.e., intact pairs) were processed as a unit, thereby interfering with the decisions that they were unrelated. This interference can account for the increase in decision latencies and error rate. Dosher and Rosedale (1991) obtained similar results for accuracy, but their latency effect did not achieve significance.

Dosher and Rosedale's (1991) findings were further extended by showing that crossing modality between study and test did not significantly alter the magnitude of the interference effect for studied items. Indeed, the direction of the effect of crossing modality, albeit not significant, was to enhance the inhibitory effect (by 34 ms).

Because crossing modalities had no influence on the interference effect for unrelated pairs, it suggests that conceptual, rather than perceptual components of the associative information, contributed to priming. Conceptual processes, however, probably contributed little to associative priming for related pairs because their preexperimental semantic associations were already strong.

Item-Specific Effects for Unrelated Pairs

With regard to the item-specific repetition effect, the faster responses made to recombined unrelated pairs than to control unrelated pairs were not eliminated when modality was shifted between study and test. In contrast, item-specific attenuation was observed for related pairs on this task. The similarity between these results and those for association specific effects suggests that a common interpretation applies.

Semantic Priming

As in Experiment 1, a semantic priming effect was observed, with faster processing of related pairs than of unrelated pairs. Although the semantic priming effect was confounded with response type (yes to related pairs and no to unrelated pairs), the magnitude of the effect, similar to that found in Experiment 1, suggests that the effect was one of semantic priming. Because semantic priming is mediated by semantic, rather than perceptual, factors the magnitude of the effect was unaltered for unstudied, control pairs when modality was crossed between study and test.

Experiment 3

The purpose of this experiment was to determine whether conscious recollective processes contribute to associative repetition priming effects. The dependence of repetition priming effects on the reinstatement of perceptual features of the target, as opposed to the conceptual ones, suggests that the effect is not closely linked to intentional explicit retrieval. For example, crossing modalities between study and test is known to have little effect on intentional recognition (see Roediger & McDermott, 1993, pp. 80–81) but results in reduced priming on implicit tests, though not always as severe as that observed in our own study (Blaxton, 1989; Clarke & Morton, 1983; Graf et al., 1985; Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982; Kirsner et al., 1983; Kirsner & Smith, 1974; Monsell & Banich, in Monsell, 1985; Roediger & Blaxton, 1987; but see Brown, Neblett, Jones, & Mitchell, 1991).

To address the possibility that conscious recollection contributed to performance on the simultaneous lexical-decision task and on the relatedness judgment task, we gave participants an explicit recognition test modeled after these tasks. To date, only Schacter and Graf's (1989) stem completion study has shown that modality effects do not affect explicit associative memory. If crossing modality has similar effects on performance on the explicit as on the two implicit tasks that we devised, then it could be argued that similar conscious recollective processes are involved in both types of tests. If, however, a dissociation is found between implicit and explicit tests when modality is crossed, then it would be difficult to argue that the implicit test is contaminated by conscious recollection. Instead, such results would support our conclusion and Schacter and Graf's (1989) that associative repetition priming is perceptually based and can occur without conscious recollection.

In the explicit task, participants were referred to the study episode and were asked to indicate as quickly as possible whether pairs were formed of previously presented words. Participants were to respond "old" to both intact and recombined pairs. A "new" response was to be made only to pairs in which one or both of the items had not previously been seen. This speeded-recognition task simulates the explicit processing that participants would perform if they rely on consciously recollected information to support their lexical decision and relatedness judgment performance. The modality-specific associative repetition priming displayed for unrelated pairs in the lexical-decision task could then be compared with the speeded recognition of unrelated pairs. The modality-specific associative repetition priming displayed for related pairs in the relatedness judgment task could then be compared with speeded recognition of related pairs.

Because nonwords were included as foils in the lexical-decision test list, but not in the speeded-recognition test list, a partial confound between study status and lexicality may have biased the data in the lexical-decision task. However, this partial confound is only problematic to the extent that it would make the lexical-decision data look like the explicit recognition data (Neely, 1989, pp. 239–242), which, to anticipate our findings, it did not. Therefore, we argue that the procedural differences regarding the inclusion and exclusion of nonwords at test were inconsequential with regard to inferring that conscious processes did not mediate implicit test performance.

We predicted that in the speeded-recognition task, the advantage of intact over recombined pairs would not diminish under cross-modal presentation relative to unimodal presentation. This would suggest that conscious recollective processes do not mediate the lexical decision and the semantic relatedness task. This prediction was confirmed.

Method

Participants

Forty University of Toronto undergraduates participated in this experiment. Participants either received course credit for participation or were paid $5.

Design and Materials

The design of this experiment consisted of two within-subject variables and one between-subjects variable. The within-subject variables were the association type (related and unrelated) and pair type (intact and recombined). The between-subjects variable was study modality (visual and auditory).

With a few exceptions, the design was identical to that of Experiments 1 and 2, in which testing was implicit. Because a different yes–no split in the test materials should not affect the pattern of results when comparing unimodal and cross-modal conditions, a 44:66 yes–no split (probability of yes = 40%) was used in this design, although the yes–no split in Experiments 1 and 2 was 50:50 (probability of yes = 50%). We used the different split to satisfy two constraints. First, we wished to maintain the identical experimental materials across all three experiments (i.e., intact, recombined, and control pairs). However, because participants would be responding to control items differently (i.e., new) from their responses to experimental pairs (i.e., old), the 22 word–word pairs that had previously served as controls served in Experiment 3 as foils. Second, because decisions regarding control pairs would not demand processing of both items (because both members were unstudied words), we wished to include word pairs in which one member was a studied word and the other a nonstudied word, equal in number to the number of experimental trials. We therefore created 44 new trials by replacing the nonwords from Experiments 1 with previously unstudied words in those pairs that consisted of words combined with nonwords. All trials that included two nonwords were discarded. Thus, altogether there were 44 experimental pairs (22 intact and 22 recombined) and 66 foils (22 new–word and new–word control pairs, 22 new–word and old–word pairs, and 22 old–word and new–word pairs).

Procedure

The procedure in this experiment was identical to that used in Experiment 1, except for the instructions at test. At test, participants were told that their memory for studied items would be tested. They were told that pairs of words would be displayed on the computer screen. They were instructed to press one of either the *M* or the *Z* key with their dominant hand if both members of the pairs had previously been presented either together or in separate pairs.

After presenting the instructions, we showed participants 10 pairs for practice. These pairs included intact and recombined pairs, as well as pairs with one or two new members. The experimenter provided feedback. Afterward, the test phase began, as in Experiments 1 and 2.

Results and Discussion

The mean RTs for each experimental condition were calculated as in Experiment 1, and the results are presented in Table 5. Examination of the accuracy and latency data revealed that in both the visual and the auditory study conditions, participants were more accurate and faster in their responses to intact pairs than in responses to recombined pairs. This was true for both related and unrelated pairs. The

Table 5
Mean Reaction Times (RTs; in Milliseconds), Mean Percentage of Error Rates (ER), and Priming Effects for Episodic Recognition in Experiment 3

Association type	Intact RT	Intact ER	Recombined RT	Recombined ER	New RT	New ER
Visual study modality						
Related						
M	1,144	5	1,420	34	1,557	9
Priming	+276	+29	+137	−25		
Unrelated						
M	1,293	6	1,662	21	1,701	15
Priming	+369	+15	+39	−6		
Auditory study modality						
Related						
M	1,077	3	1,397	31	1,653	12
Priming	+320	+28	+256	−19		
Unrelated						
M	1,330	9	1,509	25	1,686	11
Priming	+179	+16	+177	−14		

Note. In this experiment, "priming" was used to describe episodic item and associative effects. Priming for the intact condition (i.e., association-specific priming) was computed by subtracting the RT (ER) for the intact pairs from that for the recombined pairs. Priming for the recombined pairs (i.e., item-specific priming) was computed by subtracting the RT (ER) for the recombined pairs from that of the control pairs. Correct responses were yes for all intact and recombined pairs and no for all new pairs. Item-specific effects were therefore not analyzed statistically.

data were analyzed by using a three-way ANOVA, with pair type (intact and recombined) and association type (related and unrelated) as within-subject variables and study modality (visual and auditory) as a between-subjects variable.

Accuracy

Unlike lexical-decision performance, which was virtually error free, errors in recognition were plentiful and merited analysis. Of the main effects, only pair type achieved significance, $F(1, 38) = 193.00$, $MSE = 0.010$, $p < .001$; for study modality, $F(1, 38) < 1$; and for association type, $F(1, 38) = 2.85$, $MSE = 0.014$, $p > .12$. The two-way interaction between pair type (intact and recombined) and study modality (visual and auditory) did not achieve significance, $F(1, 38) = 0.01$, $MSE = 0.010$, $p > .9$. Thus, in contrast to implicit tests, the association-specific effect was unaltered as a function of study modality.

The interaction between pair type (intact and recombined) and association type (related and unrelated) was found to be significant, $F(1, 38) = 18.54$, $MSE = 0.01$, $p < .001$. A comparison of intact related and unrelated pairs did not achieve significance, $t(39) = 1.70$, $p = .97$. Recombined related and unrelated pairs, however, were found to be significantly different, $t(39) = 3.32$, $p < .005$. Participants were, therefore, as accurate in recognizing words in intact related pairs as recognizing words in intact unrelated pairs. However, recombined pairs of items in related pairs were recognized worse than those in unrelated pairs.

Most important, the three-way interaction between pair type (intact and recombined), association type, and modality did not achieve significance, $F(1, 38) = 0.22$, $MSE = 0.009$, $p > .6$. Thus, for both related and unrelated studied pairs, the two-way interactions of Pair Type × Study Modality were not significant: for related, $F(1, 38) = 0.11$, $MSE = 0.012$, $p > .7$; and for unrelated, $F(1, 38) = 0.09$, $MSE = 0.007$, $p > .7$.

Analysis of the accuracy data revealed that participants responded more accurately to intact than to recombined pairs and that modality of presentation was inconsequential to performance. Unlike performance on the lexical-decision task, therefore, in the speeded-recognition task participants' accuracy performance was not sensitive to modality of presentation.

Latency

Generally, similar effects were found in the analysis of the latency data. To determine the association-specific effects, we analyzed the data by using a three-way ANOVA. Intact pairs (1,211 ms) were recognized faster than recombined pairs (1,497 ms), $F(1, 38) = 46.00$, $MSE = 70{,}731$, $p < .001$, and related pairs (1,259 ms) were processed faster than unrelated pairs (1,448 ms), $F(1, 38) = 25$, $MSE = 57{,}219$, $p < .001$. Furthermore, the two-way interaction between pair type and study modality was not significant, $F(1, 38) = 0.76$, $MSE = 70{,}731$, $p > .35$, indicating that collapsed across all other factors, the advantage of intact over recombined pairs did not change as a function of modality of presentation during study.

Unlike the analysis of the accuracy data, the two-way interactions between pair type (intact and recombined) and association type (preexisting and newly formed) were not found to be significant, $F(1, 38) = 0.33$, $MSE = 17{,}426$, $p > .55$. Indeed, RTs to intact and recombined related pairs were faster than RTs to intact and recombined unrelated pairs, respectively: for intact, $t(39) = 5.17$, $p < .001$; and for recombined, $t(39) = 3.68$, $p < .001$. Therefore, the more accurate responses found for recombined unrelated pairs relative to the recombined related pairs may have been a consequence of a speed–accuracy trade-off.

Most important, we found a significant three-way interaction between pair type (intact and recombined), association type, and modality, $F(1, 38) = 7.98$, $MSE = 17{,}427$, $p < .01$. To understand the nature of the three-way interaction, we analyzed the related and unrelated pairs separately. For the related pairs, the Pair Type × Study Modality was not significant, $F(1, 38) = 0.20$, $MSE = 50{,}665$, $p > .5$. For unrelated pairs, however, this interaction achieved significance, $F(1, 38) = 4.87$, $MSE = 37{,}493$, $p < .05$. Thus, for related pairs, crossing modalities did not attenuate the association-specific repetition effect. Indeed, for these pairs, the association-specific effect was nonsignificantly enhanced when modalities were crossed. For unrelated pairs, however, crossing modalities did attenuate the association-specific effect.

Semantic Priming

As in Experiments 1 and 2, a semantic priming effect was observed, with faster processing of related pairs than of unrelated pairs. However, this effect was observed for unstudied, control pairs only in the visual study condition but not in the auditory study condition. We found this result difficult to interpret because modality of study should not affect control pairs that were never presented at study.

A Comparison of the Repetition Effects Across the Different Tasks

To facilitate integration of the data over the three experiments, we computed item-specific and association-specific modality effects for the recognition task and the two implicit tasks by subtracting the priming effect for the auditory study condition from that of the visual study condition. These data are presented in Table 6.

The speeded-recognition task (Experiment 3) produced several function dissociations with the two implicit tasks. First, crossing modality enhanced (nonsignificantly) the inhibitory association-specific effect for unrelated pairs in the relatedness judgment task but attenuated this effect in the recognition task.[2] Second, crossing modality attenuated the association-specific effect for related pairs in the relatedness judgment task but enhanced (albeit not significantly) the effect in the recognition task. Third, crossing modality attenuated (nonsignificantly) the item-specific effect for unrelated pairs in the relatedness judgment task while enhancing the effect for recognition. Finally, crossing modality attenuated the item-specific effect for related pairs, both for the lexical-decision task and the relatedness judgment task, while it enhanced this effect for recognition.

Together, these functional dissociations cast doubt on the possibility that the association-specific and item-specific repetition effects for related and unrelated pairs in the relatedness judgment task, and for association-specific memory for related pairs on the lexical-decision task, were due solely to explicit recognition (but see Bowers & Schacter, 1990; Jacoby, Toth, & Yonelinas, 1993; Neely, 1989, for several criticisms and limitations of the functional dissociation methodology).

Although the item-specific and association-specific repetition effects in lexical decision and recognition of unrelated pairs operated in the same direction, there are good reasons, backed by evidence, to believe that conscious recollective processes were, nevertheless, not involved in obtaining the priming effects. First, although the recognition task was designed to be as similar as possible to the implicit tasks in terms of materials, format, and general procedure; mean RTs for recognition, at 1,200 ms, were more than 400 ms longer than mean RTs in either of the implicit tests. If participants were using recognition processes to aid implicit test performance, their RTs in the implicit tasks should have been much slower (but see Neely, 1989, note 6).[3] Second, Goshen-

Table 6
Summary Table: Priming Effects for Reaction Times (RTs; in Milliseconds) and Percentage of Error Rates (ER) in the Three Tasks for the Visual and Auditory Study Conditions

	Effect type			
	Association specific		Item specific	
Task	RT	ER	RT	ER
	Related			
Lexical decision				
Visual	−17	−1	+51	+1
Auditory	−16	+1	+23	−1
Modality effect	−1[b]	−2	+28[a]	+2
Relatedness judgment				
Visual	+49	−1	+57	0
Auditory	+7	+1	+10	0
Modality effect	+42[a]	−2	+47[a]	0
Episodic recognition				
Visual	+276	+29	+137	−25
Auditory	+320	+28	+256	−19
Modality effect	−44[b]	+1	−119[b]	−6
	Unrelated			
Lexical decision				
Visual	+58	−1	+62	0
Auditory	+9	+2	+103	−2
Modality effect	+49[a]	−3	−41[b]	+2
Relatedness judgment				
Visual	−13	−7	+50	−2
Auditory	−47	−8	+44	+1
Modality effect	+34[c]	+1	+6[a]	−3
Episodic recognition				
Visual	+369	+15	+39	−6
Auditory	+179	+16	+177	−14
Modality effect	+190[a]	−1	−138[b]	+8

Note. The modality effect was computed by subtracting the priming effect for the auditory study condition from that of the visual study condition.
[a]Crossing modalities attenuated the effect. [b]Crossing modalities did not attenuate the effect. [c]Because the repetition effect in the visual modality was inhibitory for unrelated pairs in this task, the +34-ms modality effect describes an enhanced inhibitory effect rather than attenuation of the original effect.

[2] It is possible, though unlikely, that the association-specific dissociation for the unrelated pairs was caused by a confound of response type (no in relatedness judgment and yes in recognition); similarly, the item-specific dissociations were caused by a confound of response type and response hand to control pairs in recognition (no) versus the implicit tests (yes). Analysis of the effects of modality on the implicit and explicit tasks may nevertheless be informative if it is assumed that modality of study affects only the decision–response and selection–response execution processes in the different tasks but not the speed of accessing the stored memory representation.

[3] One reviewer suggested an alternate interpretation for the differences in RT in lexical decision and recognition. This interpretation suggests that performance on both implicit and explicit tests is mediated by episodic information, except that in lexical decision it operates at an unconscious level, whereas in recognition, at a conscious level. According to this interpretation, unconscious episodic information is made available rapidly so that it can influence performance on implicit tests of memory such as the lexical-decision task. Gaining conscious access to this information requires more time and accounts for the longer RTs in recognition than in lexical decision. Although we concede such an interpretation is possible, there are a number of reasons to believe that it is unlikely to be correct. (a) There is no evidence to support the idea of a common source of information on the two tests, except crossing modalities affects performance in the same direction for the two tests. (b) The increased amount of time necessary to gain conscious access to that information may lengthen the overall RTs in recognition in comparison to lexical decision. However, there is no reason to believe it should also increase the magnitude of the priming effect. It could just as easily be argued that if it is the same information that is being accessed, the priming effect should remain constant across tests. (c) In a recent study (Goshen-Gottstein & Moscovitch, 1995), we have found that levels of processing and format specificity affect associative priming differently from recognition of unrelated pairs.

Gottstein and Moscovitch (1995) have recently obtained association-specific dissociations between the unrelated pairs in the lexical-decision task and a recognition task by using a level-of-processing manipulation and a manipulation of test format (sequential vs. simultaneous). These variables had opposite effects on recognition and on priming. Third, normal association-specific priming for unrelated pairs, but severely impaired recognition, was obtained in the large majority of amnesic patients, as well as in patients with unilateral left or right temporal lobectomy, that were tested.

General Discussion

The experiments presented in this article demonstrated that association-specific repetition priming effects could be obtained both for newly formed pairs and for pairs with preexperimentally existing associations. The implicit nature of the repetition effects was established by comparing performance on the implicit tasks to that on the explicit speeded-recognition task (for a detailed description of the differences found, see Experiment 3). The dissociations we found provided evidence that conscious recollective processes did not likely mediate implicit test performance on the simultaneous lexical-decision task (for further evidence see Goshen-Gottstein & Moscovitch, 1995). We now describe the conditions we believe are necessary for obtaining association-specific repetition priming.

The Conditions Necessary for Obtaining Association-Specific Priming for Unrelated Pairs

To date, the evidence of associative repetition priming for unrelated word pairs when using the lexical-decision task has been equivocal (Carroll & Kirsner, 1982; Dagenbach et al., 1990; Durgunoglu & Neely, 1987; McKoon & Ratcliff, 1979, 1986; Neely & Durgunoglu, 1985; Smith et al., 1989). A number of factors may account for our success in demonstrating association-specific repetition effects for unrelated pairs obtained in our study. One possibility is that ours is the only study in which the first member of the target pair appeared twice on the test list: once as a member of an intact pair and once in a recombined pair. The constraints imposed on the materials yielded too few items to support a single appearance of each. However, using the simultaneous lexical-decision task, we have recently obtained association-specific priming for unrelated pairs with a procedure in which every item was seen only once during test (Goshen-Gottstein & Moscovitch, 1995).

Theoretically more interesting factors, therefore, probably account for the positive results obtained in our study. To date, the only test that has reliably produced associative repetition priming for unrelated word pairs was the stem completion task (Graf & Schacter, 1985, 1987, 1989; Schacter & Graf, 1986a, 1989). Whereas in stem completion studies, test targets were simultaneously presented with their primes, in previous lexical-decision studies, test presentation was sequential, with the prime appearing before the target.

Another difference between stem completion and some of the lexical-decision studies concerns encoding instructions. Elaborative encoding was necessary for obtaining associative repetition effects on the stem completion test (Graf & Schacter, 1985). In many lexical-decision studies, encoding at study was shallow or unspecified.

By borrowing the positive features of the stem completion task, we devised a lexical-decision task that produced reliable associative repetition priming effects. In our task, word pairs were simultaneously presented and decisions were made about both members of the pair. Also, participants studied items under elaborative encoding instructions.

A recently completed study (Goshen-Gottstein & Moscovitch, 1995) underscores the importance of the simultaneous presentation for obtaining reliable associative repetition priming effects. By switching from simultaneous to sequential (SOA = 350 ms) presentation at test, the associative repetition effect was eliminated. By contrast, this manipulation had no effect on an explicit memory version of this test. These results indicate that to achieve associative repetition priming, the information that was associated at study, including the format of presentation, must be made available to participants at the time of test. When sequential presentation was used at test, the quality of the associative information was reduced. This procedure, used in almost all lexical-decision studies on associative repetition priming, seems perversely designed to emphasize item information at the expense of associative information. Our procedure restored the balance and lead to robust and reliable associative repetition effects.

A related interpretation for the success of our procedure is derived from the encoding specificity principle (Tulving, 1983). This principle, formulated to deal with explicit recall and recognition, states that memory performance benefits when study and test conditions are made to resemble each other. Perhaps this principle is equally applicable to implicit memory performance. Because items were simultaneously presented at study, presenting them simultaneously at test may have contributed to the effect. Similarly, this principle may explain why crossing modality between study and test attenuated the associative repetition effect. Not only had modality changed but the format of presentation was also altered from sequential auditory input at study to simultaneous visual presentation at test.

Alternatively, it may be that perceptual contiguity of both members of the pair is critical for obtaining associative repetition effects in the visual modality. According to this perceptual contiguity hypothesis, only simultaneous presentation can lead to associative repetition effects. Sequential presentation, even if it is maintained across study and test, should not be effective.

Newly Formed Associations: Modality Specificity

Having obtained reliable and replicable associative repetition effects, we addressed the question of whether these effects were perceptual or conceptual. To do so, we crossed modality of presentation between study and test. Our findings were consistent with the idea that the perceptual or conceptual component of the representation would be emphasized, depending on the tasks that were used and the type of word pairs. For unrelated pairs, the new associations that were formed during study were probably both perceptual and conceptual. Therefore, when the task used was lexical decision (Experiment 1), a test that focuses on low-level perceptual or lexical features, it was the perceptual component of the priming that was picked up, and changing modality eliminated the effect.

However, when the semantic relatedness judgment task was used (Experiment 2), then the conceptual component of the association was emphasized, and changing modality did not influence the effect. As for related pairs, because new conceptual links were probably not formed at study, the repetition priming effect was primarily carried by the perceptual component produced by the gestalt of seeing the related words alongside each other, presumably for the first time.

The perceptual effects that were observed on the lexical-decision task for unrelated items replicate those of Schacter and Graf (1989), who also found cross-modal attenuation when stem completion was used. Together these results suggest that associative repetition effects for both item and associative information are dependent, at least in part, on the formation of perceptual records in perceptual representation systems (PRS) or in perceptual input modules (Moscovitch, 1992a; Schacter, 1992). Reactivation of semantic records (Kirsner & Dunn, 1985; Moscovitch, 1992a) may also be involved as suggested by our finding that associative repetition priming of unrelated pairs in the semantic relatedness task was not affected by changes in modality.

An alternate model to the systems approach is that of transfer-appropriate processing (TAP). Processing theories (cf. Blaxton, 1989; Jacoby, 1983; Roediger & Blaxton, 1987; Roediger, Weldon, & Challis, 1989) claim that memory is revealed to the extent that processing operations at study overlap with those at test (i.e., TAP; Morris, Bransford, & Franks, 1977). Memory tests can be classified into those that are primarily *conceptually driven,* in the sense that performance relies on the recapitulation of elaborate semantic processes that were applied during encoding, and those that are *data driven,* whereby performance relies on the match between the sensory perceptual analysis applied to the stimuli during study and test. Within this framework, test performance can rely on different retrieval processes and therefore benefit from different types of processing at study.

TAP theory would predict that when modality specificity is observed, shallow encoding should be sufficient to produce repetition priming. This theory would argue that modality specificity indicates that performance relies on the match between the sensory perceptual analysis applied to the stimuli during study and test. Similarly, that shallow encoding is sufficient to produce associative priming shows that semantic analysis of study items is unnecessary and that perceptual analysis alone can extract the relevant task information. Several reports, however, suggest that associative repetition priming can be obtained with elaborative semantic encoding but not with encoding of shallow surface features (Graf & Schacter, 1985; Schacter & Graf, 1986a).

To resolve this discrepancy, Schacter and Graf (1989; Schacter & McGlynn, 1989) have suggested that elaborative encoding is necessary for unitization of the items. Another possibility is that stem completion is not a sufficiently sensitive test to detect associative priming under shallow conditions. It is possible that another test might show associative priming where stem completion failed. Indeed, we have recently completed a study using our modified lexical-decision task in which we obtained associative repetition priming, even under shallow encoding conditions (Goshen-Gottstein & Moscovitch, 1995). In this study, we required participants to compare at encoding the number of vowels in one member of the pair with the other. Comparing the items may be critical for producing the effect because shallow processing of each item independently seems to be ineffective (Carroll & Kirsner, 1982). This finding, together with the modality-specific effect observed in Experiment 1, strengthens the prediction derived from the TAP theory.

Although we believe that the cross-modal attenuation observed in the lexical-decision task supports a perceptual locus for the effect (supported by either systems approach or TAP theory), there are alternative interpretations of this finding. One interpretation is that visual input may lead to the formation of a "stronger" implicit memory trace than does auditory input. Accordingly, cross-modal attenuation is not caused by differences in study and test modalities but rather by the stronger trace left by the visual input. Only a factorial design, that also includes visual study and auditory testing (Bassili, Smith, & MacLeod, 1989), can rule out this possibility.

A second alternative interpretation is that cross-modal attenuation is caused by a shift in temporal parameters from visual–simultaneous presentation at study to auditory–sequential presentation at test. Some have even suggested that different meanings may be activated by the visual–simultaneous and auditory–sequential presentation of words (Seidenberg & McClelland, 1989; for a similar idea, see also Light & Carter-Sobell, 1970).

Although theoretically possible, the claim that different meanings of a word are activated by visual and auditory presentation needs stronger experimental support than is currently available (Humphreys, 1976, 1978; Humphreys & Bain, 1984). Moreover, such a change-of-meaning interpretation cannot be confined to understanding cross-modal attenuation for word associations and would therefore also have to be proposed for explaining cross-modal attenuation effects for single items.

With regard to the simpler claim that modality was confounded with temporal parameters, we agree that at present our experiments cannot distinguish between the two interpretations. At bottom, however, both the temporal and perceptual interpretations point to the same broad conclusion; that is, that associative repetition priming effects are sensitive to alterations in certain perceptual or sensory attributes of the stimuli between study and test.

Preexisting Associations

Association-specific repetition priming for unrelated items can be either perceptual or conceptual, depending on whether it is assessed by tests of lexical decision or semantic relatedness. For related pairs, we found associative repetition priming effects only in a relatedness judgment task. Clearly, a decision as to whether items are related or not cannot be based on presemantic information derived from a purely perceptual system. Such a decision requires an analysis of the semantic properties of the items to determine whether they are related. Yet the finding that associative priming for related pairs is modality specific indicates that perceptual factors were also involved.

Viewed this way, these results are not only problematic for PRS or input module interpretations but also for TAP theory. According to the TAP theory, the relatedness judgment task should constitute a primarily conceptually driven process. Such a process should not be modality specific.

A two-stage model, proposed in the *Discussion* section of Experiment 2, provides a possible solution to this problem. According to this model, the conceptually loaded semantic relatedness task is influenced by earlier perceptual factors. Indeed, we suggested that for related pairs, and for unrelated pairs under certain conditions, the locus of the associative repetition effect is perceptual. The benefit gained from reactivating perceptual records (according to systems or components theories) or recapitulating perceptual processes (according to TAP theory) is retained by later, conceptual processing stages. Whereas this benefit is revealed for unrelated items in the lexical-decision task, it takes a semantic relatedness task to expose this effect for related items.

At the moment, we can only speculate as to why different tasks are needed to produce an effect that is perceptual in both cases. One possibility is that in the lexical-decision task, the automatic semantic priming caused by the preexperimental history of the related items may have masked or interfered with the facilitation caused by a recent repetition (Monsell, 1985; but see den Heyer, Goring, & Dannenberg, 1985). Making the semantic decision explicit in the relatedness task may have prevented or inhibited automatic semantic priming and allowed the perceptual influences to be felt.

Although both the systems approach and the TAP framework may rely on this two-stage model to accommodate the modality specificity observed in the semantic relatedness task, the finding that crossing modality did not attenuate the association-specific effect for related pairs on the recognition task (Experiment 3) may be irreconcilable with a TAP account. The systems framework predicts this dissociation, in that the relatedness judgment task is presumed to tap an implicit memory system, whereas the speeded-recognition task is presumed to tap an explicit memory system. According to the TAP theory, however, both semantic relatedness and speeded recognition are primarily conceptual tasks and should therefore be influenced by similar variables. That they do not poses a problem for proponents of the TAP framework.

An interactive activation model that includes orthographic, phonological, and semantic variables might also account for the contribution of semantic and perceptual information on associative repetition priming (Seidenberg & McClelland, 1989). The appeal of an interactive activation model is that it would reject the notion of autonomous processing for orthographic (e.g., visual word form system, Peterson et al., 1989; Warrington & Shallice, 1980) and phonological (e.g., auditory word form system, Ellis & Young, 1988; Schacter, 1992; Schacter et al., 1993) variables, with meaning exerting little or no influence.

Such an interactive model may have the potential for explaining repetition priming effects in which perceptual and conceptual processes interact. It has yet to be determined, however, how successful this type of model can be at accounting for the variety of studies in the normal and neuropsychological literature that indicate that perceptual repetition priming effects are not influenced by conceptual factors (Moscovitch, 1992a, 1992b; Moscovitch & Umilta, 1990, 1991; Schacter, 1992; Tulving & Schacter, 1990). On the other hand, the theoretical framework that is based on PRS or perceptual input modules, as well as the TAP framework, has been highly successful both in accounting for most of the evidence on repetition priming and in guiding programs of research on this topic. To surpass them, interactive models will have to be implemented and be shown capable of accounting for the observed dissociations in both normal and brain-damaged subjects.

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Appendix

Forty-Four Preexisting Association Arrays Used in Experiments 1–3

	Array member					Array member			
Array	A1	A2	A3	A4	Array	A1	A2	A3	A4
1	bible	story	church	religion	23	earth	planet	orbit	moon
2	queen	crown	honey	bee	24	vegetable	garden	grass	green
3	nail	hit	ring	finger	25	book	cover	memory	study
4	rough	rider	mean	tough	26	sea	ocean	pepper	salt
5	white	bread	slush	snow	27	train	travel	swift	fast
6	flower	smell	woman	pretty	28	peace	corps	library	quiet
7	sour	lemon	strawberry	cream	29	mouse	trap	dog	cat
8	sheep	lamb	mutton	wool	30	still	yet	black	night
9	leg	arm	hand	foot	31	music	note	noise	sound
10	round	square	play	ball	32	hold	grasp	screw	tight
11	cigarette	butt	smoke	cancer	33	steal	rob	cop	thief
12	whistle	sound	go	stop	34	hill	climb	high	mountain
13	butter	milk	cheese	yellow	35	floor	ceiling	candle	wax
14	window	door	lamp	light	36	judge	court	order	law
15	fun	laugh	drunk	happy	37	apple	red	fruit	tree
16	shoot	kill	soldier	gun	38	eat	food	whiskey	drink
17	road	street	wheel	drive	39	toe	heel	lace	shoe
18	bug	beetle	fly	spider	40	lettuce	cabbage	ketchup	tomato
19	hair	long	ache	head	41	war	fight	corpse	death
20	arm	chair	orchestra	band	42	sleep	bed	wish	dream
21	rug	carpet	insect	bug	43	lake	river	sky	blue
22	star	sky	smart	bright	44	town	country	pea	small

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