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Incidental formation of episodic associations: The importance of sentential context

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The influence of relevant semantic context on the incidental formation of episodic associations between words was probed in two experiments. In Experiment 1, we examined the influence of associations formed incidentally between unrelated words presented either in isolation or embedded in a sentential context on subsequent explicit paired-associate learning tested by cued recall. The results of Experiment 1 showed that the cued-recall rate of words studied in sentential context was higher than that of words co-occurring in isolated pairs. A subsequent single-items recognition test showed equal item memory for words studied in sentences than for words studied in isolated pairs, suggesting that the sentential context effect in cued recall indeed reflected stronger associations between paired words rather than better memory for single words. In Experiment 2, we ruled out memory for the entire sentence as an alternative explanation for the results of Experiment 1. We suggest two possible mechanisms to account for this advantage: First, pairs embedded in a sentence undergo semantic elaboration that might lead to the incidental formation of an association between them. Second, words embedded in a sentence enjoy the conjoint activation of compatible semantic features, a fact that may also facilitate the formation of an episodic association between them. The implications of these results for computational models using word representations based on co-occurrence data are discussed.

Most models of lexical structure postulate an intricate network of associations linking words to one another. Some aspects of these associations are manifested directly in tasks of free association, in which subjects are requested to utter the first word that comes to mind on viewing a cue word. Such associations are thought to reflect the associative structure of the lexicon and/or that of the conceptual network (de Groot, 1990; Nelson, McEvoy, & Dennis, 2000). The psychological reality of the associative links is also revealed in studies of word recognition, in which (episodic) association as well as semantic relatedness between words significantly facilitates performance (McRae & Boisvert, 1998; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995). Importantly, there is evidence that even newly formed episodic associations can lead to significant facilitation in word processing (Dagenbach, Horst, & Carr, 1990; McKoon & Ratcliff, 1986; Schrijnemakers & Raaijmakers, 1997; but see Durgunoglu & Neely, 1987). Indeed, episodic association between target and prime may modulate the semantic relatedness effect (Chiarello, Burgess, Richards, & Pollock, 1990) or might even constitute a necessary (and sufficient) condition for priming to occur (Shelton & Martin, 1992).

Whereas modern psycholinguistic research has focused extensively on the role of association in lexical processing, the processes leading to the incidental formation of word associations (which is frequent in extra-experimental circumstances) have been investigated to a lesser degree. Commonly held theories ascribe the formation of such associations to the co-occurrence of words throughout the lifespan (e.g., Spence & Owens, 1990). That is, words that tend to co-occur frequently in a language will become associated and, consequently, will activate each other in the lexicon. Many of these theories rely on early research carried out in the behaviorist framework. Behavioristic paradigms, however, diverged from the circumstances governing the natural formation of word associations in two important respects. First, many (if not most) associations formed outside the experimental setting result from incidental binding rather than from the intentional encoding used in most studies (e.g., Rimm & Biggs, 1967). Second, the subject matter in many of the early studies consisted of meaningless pseudowords or, at best, single words presented out of context (e.g., Berry & Cole, 1973), as opposed to the

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contextually embedded, meaningful words normally encountered in natural language processing. Hence, without disregard for the importance of the earlier studies to our understanding of human learning mechanisms, the artificiality of studying meaningless material out of context raises the question of whether their outcomes can be extended to account for the natural formation of associations between words.

A second line of previous associative learning research focused on finding evidence for episodic associations in implicit memory measures, particularly priming. In much of this work (e.g., Dagenbach et al., 1990; Durgunoglu & Neely, 1987; McKoon & Ratcliff, 1986; Schacter & Graf, 1986; Schrijnemakers & Raaijmakers, 1997), the question of whether one constituent of a newly formed pair facilitates the processing of the other constituent was investigated. Other researchers (Goshen-Gottstein & Moscovitch, 1995a; Reingold & Goshen-Gottstein, 1996) looked into facilitated processing of intact over recombined pairs. Both paradigms, however, relied on intentional encoding of the associative information: The pairs of words to be associated were always marked at study, even when they were embedded in a sentential context (Schacter & Graf, 1986; Schacter & McGlynn, 1989), and subjects were informed that in later stages of the experiment their memory for the pairs would be tested. Indeed, one experiment in which pairs of words were not intentionally studied but simply repeated in a lexical decision task failed to demonstrate episodic associative priming (Schrijnemakers & Raaijmakers, 1997). These studies, then, do not provide information as to the associative processing taking place incidentally, during the natural course of language comprehension.

The issue of intentionality discussed above is especially relevant in combination with the question of context. In order to simulate natural conditions as much as possible, word pairs should not only be associated incidentally but must also be embedded contextually. The main reason for assuming that simple episodic factors alone might not account for the natural formation of associations is that the co-occurrence of words in natural language use is in no way arbitrary. In using language, speakers select their words carefully, with the conscious intent of conveying a meaningful message. Any co-occurrence in natural language is framed contextually in sentences and discourse. It is, therefore, conceivable that contextual factors influence the association process. Perhaps, in natural language use, words become associated by virtue of appearing in a unified, meaningful context (rather than by simple co-occurrence), which relates them to each other. The interrelation of words (or concepts) in context is worth processing because, in addition to its obvious relevance to message comprehension, the joint appearance of words reflects, at least to some extent, the nature of the world around us.

To this end, the goal of the present study was to investigate the associative influence of a sentence—that is, to ask to what degree an incidental association is formed between individual words processed naturally in sentential context and to compare such associations with those formed between words presented in isolated pairs. In both conditions, the participants were engaged in a semantic categorization task during an incidental-learning phase. To ensure that learning would be incidental, it was necessary that the words forming the pair would not identified as such during sentence processing and that the participants would not be aware that their memory would be probed at a later stage of the experiment (of which, indeed, they were not informed). Consequently, we could not administer an explicit memory test for the word associations, since the participants were not aware of the pairing. One way to circumvent this problem would be to explore the implicit effect of incidental learning on subsequent explicit learning of new associations.[1] Previous research showed that explicit associative learning is facilitated by previously existing associations between the words in a pair (Balch & Shapiro, 1971). Therefore, if participants find it easier to explicitly associate a pair of words that were earlier embedded in a sentence than a pair that appeared context free, this facilitation might reflect the formation of a stronger incidental association between the former pair by virtue of its being processed within the context of a sentence. Thus, following the incidental-learning phase, word pairs were presented for explicit associative learning, and memory was then tested explicitly.

EXPERIMENT 1

In this experiment, we directly assessed the probability that associations would be incidentally formed between unrelated and unassociated noun pairs that were either embedded in sentences or presented without additional context. During an incidental-learning phase, each pair of nouns was repeated five times either embedded in a sentence or in isolation, and the participants were instructed to perform a semantic categorization task. The incidental associations formed at this stage were probed by an assessment of their influence on subsequent explicit paired-associate learning, as tested by cued recall.

Using a similar design, in a previous study (Prior & Bentin, 2003) we found better cued recall for pairs initially presented in a sentence context (58.5%) than for pairs presented in isolation (26.0%). Since all the pairs were learned equally during a subsequent explicit learning phase, any advantage in cued recall for the pairs initially encountered in sentences over those initially encountered in the isolated-pairs condition could be explained only by the incidental-learning manipulation. A possible explanation is that associations are formed during the incidental-learning phase, and that the associations formed between words embedded in sentential context are stronger than those formed between words in isolated pairs.

However, an advantage to cued recall might also be the result of enhanced encoding and memory of single items—either the cue or the target (or both). Hence, it might not rely on the formation of an association between the two. Both relational processing and item-specific encoding processes have been demonstrated to influence memory performance (Hunt & Einstein, 1981; Hunt & McDaniel, 1993). These processes are seen as complementary, each contributing independently to successful retrieval on a variety of memory tasks. Specifically, measures of cued recall, among others, are thought to benefit from both encoding strategies (Hunt & Einstein, 1981).

In our previous study, we did not control for the possibility that the enhanced cued-recall performance following the incidental associative learning of words in sentences, in comparison with performance when they were presented as isolated pairs, was the result of better item memory rather than of stronger associations. To control for this, a recognition task of single words designed to probe item memory was also included in the present experiment, following explicit learning of the word pairs. Half of the items were presented in each memory test.

Method

Participants. The participants were 48 undergraduate students from the Hebrew University who participated in the experiment for course credit or payment. All were native speakers of Hebrew with normal or corrected-to-normal vision.

Stimuli. The critical items were 72 pairs of concrete nouns (see Appendix A). The words of each pair were neither associated nor semantically related, as was ascertained by association norms in Hebrew and independent judgments of the two authors. Each word pair was embedded in a meaningful Hebrew sentence in which the words of the pair were separated by two or three content words (for examples, see Appendix B). The sentences ranged in length from five to nine content words (average length was 6.88 words). Four additional sentences, each containing either the name of a flower or the name of a piece of jewelry, were created as well. The 72 critical pairs were divided randomly into three lists of 24 pairs each.

Design. The experiment consisted of three phases: incidental learning, explicit learning, and test. In the incidental-learning phase, there were three conditions: sentential context (SENT), isolated pairs (PAIR), and new (i.e., word pairs not learned incidentally—NEW). All the participants performed in two blocked incidental-learning conditions: one contextual and one with isolated pairs.[2] Only one list of 24 pairs appeared in each block, and each pair was repeated five times (in random order); the remaining list of 24 pairs was not presented, forming the NEW condition. In addition, to allow for semantic categorization that was used as the orientation task (see below), four target sentences and four target pairs were added to each incidental-learning list, which was also repeated randomly five times. Two of the target sentences (or pairs) included the name of a flower and the other two, the name of a piece of jewelry. Hence, each incidental-learning block included a total of 140 trials (24 relevant sentences + 4 target sentences, repeated 5 times). The order of the two incidental-learning blocks was counterbalanced across participants. The stimulus lists were rotated so that across participants all pairs appeared equally often in all three conditions.

In the explicit-associative-learning phase, all 72 pairs were presented; 24 pairs had not been previously encountered, 24 pairs had been incidentally learned as isolated pairs, and 24 pairs had been incidentally learned while embedded in sentences. The test phase immediately followed. At test, each participant completed two memory tests: a recognition test for single words and a cued-recall test of associative learning of pairs. Half of the pairs in each incidental-learning condition were presented in the cued-recall test. The remaining pairs were presented in the recognition test as separate words, for a total of 72 words (36 pairs, 12 from each condition). In addition, 72 nouns that had not been previously studied were added, so that the ratio of old and new items in the recognition list was 1:1.The order of presentation in the recognition memory test was pseudorandom, with the restriction that the nouns in a pair would never be presented contiguously. The order of the memory tests was counterbalanced across participants, and the lists were rotated, so that each pair studied in each of the incidental-learning conditions (SENT, PAIR, and NEW) appeared equally often in both memory tests.

Task and Procedure. The participants were tested individually. The task in both incidental-learning conditions was identical: In each trial, following the presentation of the stimulus (word pair or sentence), one of two question words was presented: "Flower?" or "Jewelry?" In the PAIR condition, the participants were instructed to determine whether one of the words of the pair belonged to the category probed. In the SENT condition, they were instructed to determine whether a noun belonging to the probed category had appeared in the sentence. The participants used a buttonpress to record their decisions. Since the category probe appeared only after the presentation of the entire sentence or pair and was chosen randomly in each trial, the participants were not encouraged to remember the answer rather than read the entire display. Furthermore, since the probe questions varied from trial to trial, referencing back to a previous decision during incidental learning might have led to an incorrect reply.

Pair trials commenced with a fixation point followed by the pair of words, which were displayed side by side for 500 msec. The pair was then replaced by the question word, which remained on the screen until the participant replied. SENT trials were identical in all parameters except display duration, which was determined by the number of content words in the sentence—250 msec per word (as for pairs). Thus, sentence display time ranged from 1,250 msec (for five-word sentences) to 2,250 msec (for nine-word sentences).

Each incidental-learning block was preceded by five practice trials, to ensure that the participants fully understood the task. In both blocks, speed and accuracy were equally stressed. A break was introduced between the SENT and PAIR blocks, and the participants were given a chance to rest before continuing.

In the explicit-learning phase, all 72 noun pairs were presented once in separate trials. In each trial, the two nouns were presented simultaneously side by side for 2 sec, with an intertrial interval of 500 msec. At this time, the participants were instructed to memorize the pairings and informed that they would be tested on them. The pairs were presented in random order.

The test phase consisted of two memory tests. In the cued-recall test, the first noun of each pair was presented on the screen, and the participants were instructed to respond by uttering the noun with which it was paired. The nouns appeared in random order. The first noun was defined as the noun appearing on the right side in the explicit-learning list.[3] The word appeared and remained on the screen until the participants named its paired noun or said they couldn't remember. An experimenter recorded the participants' answers. In the recognition test, single words were presented on the screen, and the participants were asked to discriminate, by buttonpress, between words that had appeared in the explicit-learning list and words that had not been encountered previously.

Results

Performance on the incidental task (identification of flowers and jewelry) was highly accurate and was almost identical in the two incidental-learning conditions (95.2% and 95.7% accuracy in the contextual and isolated-pairs conditions, respectively). Thus, any findings of Experiment 1 cannot be attributed to orientation-task difficulty.

The results of Experiment 1 are presented in Figure 1. As could be expected, memory was better overall in the recognition test than in the cued-recall test. Each memory test was analyzed separately. For the analysis of the results of the recognition test, a d' measure of discriminability (between old and new items) was calculated for each participant in each study condition (NEW, PAIR, and SENT). For these purposes, the list of filler items was randomly divided into three lists, and, thus, each d' was calculated in relation to a unique filler list, in order to reduce dependencies between the measures. The average d' scores across participants in each study condition are presented in Table 1.

The statistical reliability of the differences between the d' scores across incidental-learning conditions was analyzed with a one-way within-subjects analysis of variance (ANOVA). This analysis showed a significant main effect [$F(2,92) = 24.93, p < .001$]. This effect was further examined by planned contrasts. A significant difference was found between the NEW condition and both incidental-learning conditions [$F(1,46) = 66.55, p < .001$], indicating that the participants were better able to correctly recognize words as old if they had been learned incidentally in both conditions than if they had been presented only in the explicit-learning condition. Importantly, no significant difference was found between the participants' ability to identify words appearing in the PAIR condition as opposed to those appearing in the SENT condition [$F(1,46) = 1.77, p = .19$; the power of this comparison was .99, based on the effect size of the difference found between these two conditions in the cued-recall task].

The same ANOVA was used to examine the pattern of differences in cued-recall performance (percentage of correctly recalled pairs), which showed a significant main effect of the incidental-learning condition [$F(1,47) = 23.03, p < .001$]. Planned contrasts revealed that, in contrast with the case of recognition-memory performance, the difference between the NEW condition (20%) and the PAIR condition (24%) was not significant [$F(1,47) = 2.49, p = .12$], whereas cued-recall performance was better for pairs appearing in the SENT condition (38%) than in the PAIR condition [$F(1,47) = 20.67, p < .001$].

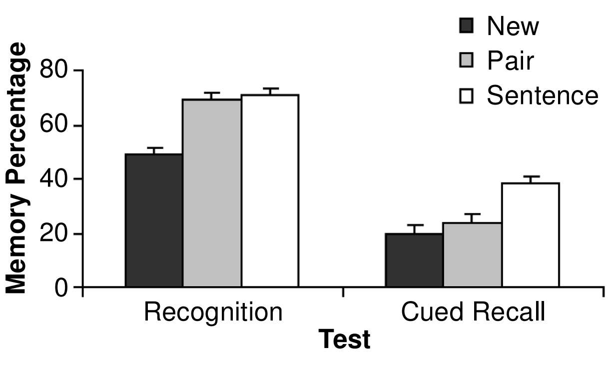

Figure 1. Results of Experiment 1. Percentage of correct recognition and cued recall (mean and standard error) for words associated explicitly following no incidental learning (new), following incidental learning with five repetitions as an isolated pair (pair), and following incidental learning when the words were embedded in a sentence repeated five times (sentence).

Table 1
d' Scores of Recognition and Standard Errors of the Means in Experiment 1

	NEW		PAIR		SENT-R	
	d'	*SE*	d'	*SE*	d'	*SE*
Recognition	1.565	0.09	2.091	0.11	2.225	0.09

Discussion

The similarity in recognition memory for materials studied in the two incidental conditions (SENT and PAIR) suggests that the cued-recall differences observed in Experiment 1 (which replicates the study of Prior & Bentin, 2003) can hardly be ascribed to enhanced item memory for words appearing in the contextual versus the isolated-pairs condition. Furthermore, since the co-occurrence rate of pairs was equated across both SENT and PAIR incidental-learning conditions (all noun pairs were repeated five times), the higher level of associative learning that apparently occurred in the contextual condition in comparison with the isolated-pairs condition cannot be explained only by simple episodic/mnemonic factors. This conclusion is further supported by the fact that, whereas pairing was conspicuous outside the sentence context (the words were adjacent and isolated), it was less evident in the context of the sentence. Indeed, the critical nouns in each sentence were not adjacent, but were separated by two or three other content words. Hence, it is clear that the sentential context was indeed a critical factor determining the difference in cued-recall performance between the SENT and the PAIR incidental-learning conditions.

Furthermore, although repeated exposure to the word pairs appearing in the PAIR incidental-learning condition improved the participants' ability to recognize single words as well as they did in the SENT condition, apparently, it did not create meaningful links between the words of the pair. Indeed, as was indexed by the equal cued-recall performance for the NEW and PAIR conditions, the only links that were formed between the words in the PAIR condition were those formed intentionally in the explicit-learning test. Hence, sentential context might be essential for the formation of new associations between words.

However, a competing account does exist, which is based on the fact that sentences are easier to retrieve than unrelated words. Thus, although item memory for words in the SENT condition was not better than that for words in the PAIR condition, during the cued-recall test subjects might use the cue to retrieve the whole sentence, and the sentence to retrieve the target item. This account is congruent with the proposal that recall is a function of the accessibility of to-be-remembered items (Tulving & Pearlstone, 1966) and with findings that recognition levels of items are higher when the cue is a sentence rather than a single word (Craik, 1973). Furthermore, it was found that retrieval of words is facilitated not only by a deeper level of processing, but also by the uniqueness of the cue–target association (Moscovitch & Craik, 1976).

Experiment 2 was designed to examine to what extent memory for the entire sentence might be the mechanism leading to the results of Experiment 1.

EXPERIMENT 2

Experiment 1 demonstrated that associative learning is facilitated by previous incidental exposure to word pairs presented in sentential context, but only to a lesser degree (if at all) by their context-free incidental exposure. In the present experiment, we manipulated factors influencing memory for the entire sentence to explore the role of sentential context. To this end, we modified the incidental-learning procedure by creating a condition in which the probability that entire sentences would be remembered was reduced. Once again, a semantic categorization task was used during the incidental-learning phase. Two forms of sentential context were compared within subjects. In the first, each noun pair was repeated during the incidental-learning phase in five different sentences (SENT-D condition). In the second (as in Experiment 1), each noun pair was embedded in a single sentence, which was then repeated in its entirety five times during incidental learning (SENT-R condition). The probability of the participants' remembering the sentence as a whole is expected to be higher in the latter condition than in the former. (In the SENT-R condition, each sentence is repeated five times, whereas in the SENT-D condition, each sentence is presented only once.) As in Experiment 1, an additional condition of no incidental learning (previously termed NEW) was included in this experiment as well.

In addition to differing in the expected strength of the memory trace for the entire sentence, the SENT-R and SENT-D incidental-learning conditions are distinguished by the saliency of the word pairs themselves. In the SENT-R condition, the entire sentence is repeated, and the words of the pair are not marked in any manner. In the SENT-D condition, the same pair of words is repeated on a background of five different sentences. Thus, they might capture the participants' attention and become salient, and so be better recalled in the later stages of the experiment.

Each of the two factors should have a different influence on cued-recall performance. According to the sentence-memory account, memory performance, and especially cued recall, should be better in the SENT-R than in the SENT-D condition. The saliency account predicts the opposite pattern: improved performance for the SENT-D over the SENT-R condition.

The account relying on the incidental formation of associations (during performance of the orienting task) would not predict a significant advantage for either SENT-R or SENT-D, since in both conditions word pairs are embedded in meaningful contexts and are processed in the framework of a sentence.

Method

Participants. The participants were 30 undergraduate students from the Hebrew University who participated in the experiment for course credit or payment. All were native speakers of Hebrew with normal or corrected-to-normal vision. None of the participants had taken part in Experiment 1.

Stimuli. The critical items were 72 noun pairs (see Appendix C) largely different from those used in Experiment 1. This variation served to determine whether the findings of Experiment 1 were not specific to the words used. The words of each pair were neither associated nor semantically related. Each noun pair was embedded in five different meaningful Hebrew sentences of five to nine content words each, with an average of 7.03 content words. In each sentence, the two critical nouns were separated by two or three content words. The 72 critical pairs were divided randomly into three lists of 24 pairs each.

Design. Like Experiment 1, this experiment consisted of three phases: incidental learning, explicit learning, and test. The incidental-learning conditions were SENT-R and SENT-D, and all the participants performed in both conditions. In the SENT-D condition, the participants were presented with 24 noun pairs, each repeated in five different meaningful sentences. In the SENT-R condition, the participants were presented with 24 noun pairs, each embedded in a single meaningful sentence repeated five times. Thus, each participant was exposed to a total of 240 trials (24*5 in SENT-R + 24*5 in SENT-D). The sentences were presented in random order, in two mixed blocks of 120 sentences each. The stimulus lists were rotated between conditions across participants, so that each noun pair was presented equally often in the SENT-R and in the SENT-D conditions. The sentences were also rotated, so that each sentence appeared in both the SENT-R and the SENT-D condition across participants.

Procedure. The participants were tested individually. The orienting task used in the incidental-learning phase was similar to that used in Experiment 1. Each sentence was followed by a probe word, which was one of the five following category names: "Fruit?", "Flower?", "Vehicle?", "Clothing?", and "Toy?" The participants were asked to determine whether an object belonging to the probed category had appeared in the previous sentence and to signal their choice by a buttonpress ("yes" or "no"). Probes requiring a positive answer occurred on 13.8% of the trials, equally distributed between conditions. Again, the participants were discouraged from referring back to previous decisions, since each probe question appeared only once for each sentence.

Each incidental-learning trial began with a fixation point displayed for 170–230 msec, in order to avoid a monotonic rhythm of trials. The entire sentence was then presented on the screen at once and never exceeded one line of text. Each sentence was presented for 2,500 msec. The sentence was followed by the probe word, which remained on the screen until a response was recorded, and the display was terminated on response.

The explicit-learning and test phases were identical to those described in Experiment 1.

Results

Once again, performance on the incidental task was highly accurate and was almost identical in the two incidental-learning conditions (93.9% and 94.5% accuracy in the SENT-R and SENT-D conditions, respectively).

Across participants and stimulus lists, cued-recall and recognition performance in both sentential incidental conditions was considerably better than performance in the NEW condition (word pairs learned only explicitly), as might be expected. Furthermore, recognition performance was better than cued-recall performance across the board. However, no big differences were found in either memory test between the two sentential incidental (SENT-R and SENT-D) conditions (Table 2).

As in Experiment 1, the statistical reliability of this pattern was examined by an analysis of the performance on each memory test separately. For the recognition test, a one-way ANOVA revealed a significant effect of the incidental-learning condition [$F(2,58) = 45.9, p < .0001$], and planned contrasts showed no difference between the two incidental-learning conditions ($F < 1.0$) but a significant advantage for both sentential context conditions over the NEW condition [$F(1,29) = 78.4, p < .0001$]. The analysis of the cued-recall data revealed a similar pattern: a significant main effect of incidental learning [$F(2,58) = 51.1, p < .0001$], which planned contrasts revealed to arise from a reliable difference between the NEW incidental-learning condition and both sentential conditions [$F(1,29) = 72, p < .0001$]. Once again, the difference between the SENT-R and the SENT-D conditions was not significant [$F(1,29) = 1.4, p = .24$; the power of this comparison was .97, based on 1/3 the effect size of the difference found between the NEW condition and both sentential conditions in the cued-recall task].

Discussion

The pattern of results described above supports neither the saliency account nor the sentence-memory account. Recall that, whereas in the SENT-D incidental-learning condition the two critical nouns were embedded in five different sentences, in the SENT-R condition the entire sentence was repeated along with the relevant embedded word pair. This design should have reduced the ability to recall entire sentences in the SENT-D condition relative to the SENT-R condition (because in the former the participants were exposed to 120 different sentences, each seen once, as opposed to 24 sentences, each repeated five times in the latter), but augmented the saliency of the critical pairs in the former relative to the latter, because each noun pair was repeated, each time on a different background.

Contrary to the word-pair saliency account, we found no advantage in cued-recall performance in the SENT-D condition. Contrary to the sentence-memory account, no advantage was found in cued recall of pairs appearing in the SENT-R condition. This outcome indicates that, at the very least, simply remembering the whole sentence during cued recall cannot explain, or even provide a major account for, the advantage found in Experiment 1 of associating noun pairs encountered in a sentential context relative to nouns pairs seen in isolation.[4]

Hence, the results of Experiment 2 do not lend support to two of the three accounts detailed in the introduction: the saliency account and the sentence-memory account. What remains is the third suggested account—that the mere presence of sentential context initiates an associative process that links the words of the sentence together. This process conceivably facilitates the formation of episodic associations during the explicit-learning phase. It remains to be determined, however, what it is in sentential context processing that has this influence on the ability to form and remember an association. This issue shall be addressed below.

Table 2
Percentage of Correct Recognition and Cued Recall and Standard Errors of the Means in Experiment 2

	SENT-R		SENT-D		NEW	
	%	*SE*	%	*SE*	%	*SE*
Recognition	69.16	2.9	69.16	3.6	41.53	3.6
Cued Recall	48.6	4.5	52.50	4.2	13.6	3.6

GENERAL DISCUSSION

The experiments presented above suggest that the incidental formation of an association between previously unassociated words is affected by the context of presentation. They demonstrate that repeated processing of words in sentential context is more effective in facilitating their association than simple repeated co-occurrence of words. Several alternative explanations of these results were explored and ruled out.

In Experiment 1, we established the basic phenomena described above. Pairing of words previously seen embedded in sentential context was more easily learned and better recalled than pairing of words previously presented in isolation. We further dissociated between the effect of context during incidental learning on two explicit measures of memory: cued recall and recognition. Incidental learning in sentential context improved performance in the cued-recall condition relative to that in the isolated-pairs condition. However, the difference between cued recall following the isolated-pairs condition and cued recall for pairs studied only in the explicit-learning phase was not significant. In contrast, recognition of single words was equal following both incidental-learning conditions. Both led to recognition performance superior to that achieved for single words that were studied only in the explicit paired-associate learning phase. Taken together, these results indicate that, whereas both incidental-learning conditions led to superior item memory in comparison with memory for new word pairs, incidental associations were reliably formed only between the word pairs presented in sentential context.

In Experiment 2, we discredited a major alternative explanation of the results of Experiment 1—namely, that of whole-sentence memory. In addition, the design of the experiment allowed us to discount word-pair saliency as an important associating factor. We found no difference between the two sentential incidental-learning conditions (SENT-R and SENT-D) in either memory measure (recognition and cued recall). Thus, better retrieval of the entire sentence was discounted as the sole mechanism accounting for the superior cued-recall performance in the contextual condition of Experiment 2, since no difference was found between the performance in the SENT-R (which should have led to better sentence-memory) and SENT-D conditions. Also, the memory for pairs embedded in different sentences (the SENT-D condition) could not simply be a result of their putative saliency gained by their appearing together in several distinct contexts. The converging pattern of the results of this study conforms to the account assigning the facilitation of explicit associative learning in the second phase of the experiments to the formation of incidental associations between nouns repeatedly paired, and contextually presented, in the first phase. How can sentential context facilitate the formation of incidental associations between the constituent words of the sentence?

Presentation within a sentence differs from the context-free presentation of a word pair in many respects: A sentence has a meaning distinct from that of the individual words comprising it, and it has a syntactic structure that is lacking in single words, to name just two of the most prominent. Doubtless, these aspects, as well as others, influence the manner in which words embedded in a sentence are processed.[5] A claim could be made that reading a sentence requires deeper processing of its constituent words than does reading a pair of nouns (even when the same task—semantic category verification—is performed in both instances). Therefore, a simple levels-of-processing explanation (Craik & Lockhart, 1972), extended over associative learning, could apparently account for our results. Indeed, Goshen-Gottstein and Moscovitch (1995b) found a significant effect of levels of processing at intentional learning on subsequent performance of an explicit associative recognition task. However, if this were the mechanism operating in the present work, we would expect to find significant differences between the contextual and the isolated-pairs incidental-learning conditions on the single-item recognition task as well, and we found no such effect. Therefore, we should also take into account relational processes operating in sentence processing which do not apply to the processing of isolated word pairs.

Context affords the human learner a framework for association. A sentential context provides a framework for integrating the words into a single, meaningful unit, and—for example, during this integration process—perhaps also for forming a comprehensive mental image. The integration of the meaning of a sentence is a result of relating the words comprising the sentence to each other. The syntax of a sentence provides a blueprint of how the parts relate to each other, and the verb specifies these relations further. In order for a sentence to be understood, the meaning of its constituent words must be elaborated, and it is well established that items elaborated at encoding are better recalled at test (Craik & Tulving, 1975; Eysenck, 1979; Jacoby & Craik, 1979). However, simple elaboration of item meaning could not account for the results presented here, because we found no difference in item recognition between the contextual and the isolated-pairs incidental conditions. But elaboration can take different forms leading to different results. In early memory research, authors considered elaboration as a process by which the semantic analysis of the word spreads over possible connotations, semantic associates, and so forth (e.g., Craik & Tulving, 1975). Another form of elaboration has been put forth, however. The outcome of this elaborative process is the establishment of unique relationships among concepts in addition to, or rather than, the mere increase of the distinctive character of elements involved in those relationships (Moscovitch & Craik, 1976; Stein, Littlefield, Bransford, & Persampieri, 1984). Whereas the former form of elaboration can be applied to individual words, the latter is probably more characteristic of words appearing in a larger, integrative context, such as a sentence. This is because the sentence definitely establishes a meaningful relationship among its constituent words.[6] The present data suggest that the latter form of elaboration is more conducive to the establishment of associations between words than is the former.

The effect of elaboration has been demonstrated primarily in explicit tests of memory, but also in implicit tests (see, e.g., Bentin, Moscovitch, & Nirhod, 1998; for reviews, see Brown & Mitchell, 1994; Challis & Brodbeck, 1992; Roediger & McDermott, 1993; Schacter & McGlynn, 1989).[7] As was described in the introduction, the present results extend these findings over incidental association formation. The present cued-recall memory test required accessing an association between items rather than single items. That is, we tested the influence of elaborative processing induced by a sentence context on associating items rather than simply storing the individual items in memory or retrieving them. Most importantly, in the present study we examined the degree to which the elaborative effort contributed to the incidental formation of associations between items without this being the intention of the participants and without any awareness of the pairing on their part. Hence, we tested, in fact, the implicit effects of elaborative processing on subsequent explicit attempts to establish new associations between words.

A sentence might facilitate association formation in another way. Semantic elaboration in context might facilitate associative learning of words—for example, by selectively activating only their compatible features. In support of feature selectivity while meanings are activated, Johnson-Laird, Gibbs, and de Mowbray (1978) found that semantic processing of a word does not imply that all of its semantic elements are necessarily activated. Further support for this hypothesis can be found in Barsalou's (1982) distinction between the core meaning of a concept and its context-dependent properties. The core meaning is context independent and always activated, whereas the context-dependent properties are activated only when appropriate. In addition, it has been demonstrated that context poses constraints on the interpretation of a word and on the semantic information retrieved from the lexicon upon its recognition (Moss & Marslen-Wilson, 1993; Onifer & Swinney, 1981; Swinney, 1979). Hence, when two words are encountered in a unifying context, it is likely that their common features will be activated more than their discriminative features. By contrast, if pairs were presented in isolation, primarily their context-independent features were (or remained) activated, and, consequently, it is possible that during explicit associative learning the words were more distinct.

Therefore, sentential context may have benefited cued recall by priming the formation of the episodic association during the explicit-learning phase. Hinting at the importance of semantic contextual factors in the formation of associations between words, recent research in our laboratory has demonstrated that episodic associations between initially unassociated category coordinates are (incidentally) formed more readily than are those between unrelated word pairs (Silberman, Miikkulainen, & Bentin, 2001; see also Smith, Theodor, & Franklin, 1983). Assuming that category coordinates have more semantic features in common than random, unrelated word pairs do, this finding attests to the importance of feature similarity in incidental association formation. Similar evidence was reported in children (Guttentag, 1995). In addition, the latter study showed that explicit instruction to elaborate on the relation between the words of the pair further facilitated the formation of associations between semantically related words (see also Hunt & Einstein, 1981).

Finally, in one of the very few studies that tested the formation of associations between words embedded in sentential contexts, Arnold, Bower, and Bobrow (1972) demonstrated that semantic compatibility of the sentence constituents facilitates the formation of episodic associations between them (even if some of these constituents are pseudowords assigned meanings during the experimental session). Similarly, Schacter and McGlynn (1989, Experiment 4) found that the cued recall of word pairs embedded in a sentence frame is better than that of pairs processed in a shallow manner (with intentional study instructions).

Taken together, the reviewed studies point to the importance of semantic (sentential) context in association formation. The context may enhance the compatible features of the words embedded in it and, thus, facilitate the formation of associations among them. It may also serve as a means of elaboration on the relations between two items, resulting in enhanced memory for associations. The present design does not allow us to distinguish between the account based on elaboration theory and that based on partial activation of semantic features, which, incidentally, are in no way mutually exclusive. Perhaps, forming a meaningful relationship and reducing the arbitrariness of an association are accomplished through an alignment of the semantic features of the two concepts, which is achieved when they are presented in a joint context. Future research should address this issue.

On a different note, the work presented in this paper may have interesting implications for computational linguistics. Lately, with the flourish of computational models in language research, recognition of the importance of associations is on the rise. Many of these models (Burgess, 1998; Landauer & Dumais, 1997; McDonald & Lowe, 1998) use representations of words based on co-occurrence patterns in large corpora of text to investigate various psycholinguistic phenomena. These representations capture both the direct co-occurrence between a pair of words and their distributional similarity—that is, the degree of overlap in the co-occurrence patterns of each of the original words with all other words in the corpus. Distributional similarity is thought to correspond to semantic relatedness (Miller & Charles, 1991), whereas direct or local co-occurrence is thought by some to correspond to episodic associations (Plaut, 1995).

The Hyperspace Analogue to Language (HAL) is a model representing word meanings by lexical co-occurrence data (Burgess, 1998; Lund & Burgess, 1996). HAL representations are built by sliding a window of 10 words across the textual basis and recording all co-occurrences of words within that window. Simulations conducted on HAL representations have failed to replicate some of the priming effects found with human subjects. Specifically, Lund and his colleagues (Lund, Burgess, & Atchley, 1995; Lund, Burgess, & Audet, 1996) failed to produce associative priming and the associative boost (Moss et al., 1995) with HAL simulations while replicating robust semantic priming effects. Lund et al. (1996) conclude that “most associative information is not carried by temporal word sequence in language . . . . The notion that associativity can be characterized by temporal association in language receives little or no support” (p. 603). Thus, the proposition that lexical associations reflect local co-occurrence is not corroborated by the HAL data.

McDonald and Lowe (1998) presented a model that replicates the semantic and associative priming results of Moss et. al (1995). Their simulation revealed a significant associative boost, such that associated pairs had higher rates of local than of global co-occurrence. The divergence from the HAL results is explained by the setting of the window parameters of both models. HAL uses a window of ±10 words, whereas McDonald and Lowe used a window of only ±3 words. Under these conditions, highly associated words were found to have a higher probability of directly co-occurring with each other, above and beyond their distributional similarity.

The co-occurrence data of McDonald and Lowe’s (1998) model, with a ±3-word sliding window, are closer in nature to the association process found in the present experiments. It is reasonable to assume that a narrower window reduces the weight given in the model to the co-occurrence of words appearing in adjacent sentences and phrases, and increases the weight of co-occurrence within the same sentence or phrase. Therefore, according to this model, associated pairs have a higher probability of occurring within the same sentence. This corresponds with our results—namely, that the formation of an association between words is facilitated if they appear in the same sentence. One can suppose that relational processing occurs mostly, if not exclusively, between the content words within a sentence. In most cases, elaborations aimed at reducing the arbitrariness of relations between words operate only within a sentence. Thus, the finding of the model that associated pairs tend to co-occur directly with each other is once again reminiscent of our results, which indicate that relational processing enhances association formation.

The present findings should perhaps be incorporated into future computational models. One possible consequence would be to stress the role of co-occurrences within sentences in constructing lexical representations.

This could be a means of computationally simulating the cognitive processes of elaboration, selective feature activation, and relational processing operating in sentence comprehension, which have proven to have a significant influence on association formation.

In conclusion, more than simple co-occurrence, joint appearance of two nouns in a meaningful sentence leads to the formation of an incidental association between them, even if the words are processed for meaning in both cases. The active mechanism mediating this effect may be matching of activated semantic features, distinct elaboration of the relations holding between the words, or both. This demonstrates the influence of integrative processes on the formation of associations. Together, these two effects point to the distinct influence of presentation context on association formation, a fact that should be accounted for in computational models that rely on co-occurrence data for the construction of lexical semantic representations and for the simulation of lexical associations.

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NOTES

1. The use of a free-association test would have been a natural solution; however, in a previous study (Silberman, Miikkulainen, & Bentin, 2001) we found that, although incidental learning might be evident in free-association tests, these effects are small and require numerous repetitions of a small number of pairs.

2. A block design was used in order to minimize the use of word-screening strategies that would characterize monitoring of noun pairs during sentence reading.

3. Note that in the explicit-learning phase the location of each noun on the screen preserved the order in which they appeared in both the contextual and the isolated-pairs incidental-learning conditions. Because Hebrew is written from right to left, the first noun was, in fact, the one presented on the right.

4. The absence of the entire-sentence-memory effect on recognition was not predicted. This might suggest that the previously reported advantage of item memory for words studied in sentences relative to memory for isolated words does not hold for incidental learning. Note that such a conclusion is also supported by the results of Experiment 1. However, this aspect of the data is not the focus of the present study and, obviously, requires further investigation.

5. In fact, sentential syntactic structure may facilitate even memory for pseudowords (see, e.g., Epstein, 1969).

6. Anecdotal evidence supporting this claim can be found in the tendency of several participants to relate to the contextual sentences as "stories," even though they were only one line long. Apparently, the participants felt they were gaining significant information from these sentences.

7. Note, however, that the major issue discussed in these reviews was the influence of levels of processing on implicit and explicit tests of memory, without a clear distinction between levels of processing and elaborative processing.

APPENDIX A
Word Pairs Used in Experiment 1

Actress–Party	Coat–Fence	Laborer–Stork
Airplane–Cake	Cook (F)–Necklace	Lamp–Guava
Aunt–Key	Crane–Chocolate	Model–Comb
Baby–Kitchen	Dancer (F)–Pencil	Monkey–Jar
Bag–Water	Doctor (F)–Motorcycle	Mountain–Worm
Bank–Television	Driver–Salad	Movie–Beetle
Bear–Flu	Eggplant–Sink	Newspaper–Door
Bee–Apple	Elephant–Foot	Passover–Pool
Bird–Coin	Fork–Lemon	Path–Box
Book–Plant	Gambler (F)–Ship	Police–Play
Bread–Notebook	Gardner–Dog	President–Tie
Bridge–Ice-cream	Hammer–Pea	Reporter–Virus
Car–Dress	Horse–Window	Restaurant–Mouse
Cat–Fire	House–Sabbath	Revolver–Table
Carpet–Milk	Instructor (F)–Grapefruit	Ring–Handkerchief
Cigarette–Cards	Judge (F)–Sweater	Robber–Shoes
Clerk–Bed	Kettle–Grandfather	Rooster–Ball
Clown–Camera	Knife–Mirror	Scissors–Towel

(*Continued on next page*)

APPENDIX A (Continued)

Singer (F)–Stopper	Storm–School	Tourist (F)–Watermelon
Soldier–Egg	Student–Balloon	Train–Sun
Spoon–Piano	Teacher–Letter	Waiter–Socks
Sportsman–Store	Telephone–Road	Watch–Bucket
Spy–Wine	Test–Computer	Wedding–Pizza
Steward–Tomato	Toad–Peanuts	Writer–River

Note—In the experiment, the words were presented in Hebrew; the words presented here are their English equivalents. Names of occupations in Hebrew are marked for gender. Here, the names of occupations presented in the feminine form are marked by (F). All of the items are single words in Hebrew.

APPENDIX B
Examples of Hebrew Sentences Used in Experiments 1 and 2 (in English Translation)

1. The *actress decided not to go to the *party, because she had to study her lines.
2. Before boarding the *plane, Irit had a slice of *cake.
3. *Aunt Shoshana looked for the *key in the drawer, but couldn't find it.
4. There was a hole in the *bag, so all the *water dripped out of it.
5. In the local *bank, a *television was set out in the lobby.
6. Research indicates that the *bear has a natural immunity to the *flu.
7. Ravit slapped the *bee away, and continued eating her *apple.
8. The veterinarian determined that the *bird died because it had swallowed a *coin.
9. The *book said that the *plant should be watered twice a week.
10. You shouldn't place the fresh *bread on your *notebook, it might get dirty.

*Words belonging to the subsequently studied pairs. Note, however, that during incidental presentation they were not marked, and the participants in that condition could not distinguish them as components of the test pairs.

APPENDIX C
Word Pairs Used in Experiment 2

Armchair–Paper clip	Glasses–Zipper	Refrigerator–Bell
Article–Verandah	Grapefruit–Camera	Restaurant–Mouse
Baby–Kitchen	Hammer–Pea	Revolver–Table
Bank–Television	Horse–Window	Rooster–Ball
Bathtub–Wine	House–Sabbath	Rubber band–Belt
Bear–Flu	Judge (F)–Envelope	Scissors–Towel
Bee–Apple	Kettle–Grandfather	Ship–Virus
Bird–Coin	Key–Salad	Shop–Swimming Pool
Book–Plant	Lamp–Guava	Skillet–Cassette
Bread–Notebook	Lane–Box	Skirt–Bag
Bridge–Ice-cream	Letter–Egg	Socks–Knapsack
Car–Dress	Mirror–Ointment	Spider–Raft
Carpet–Milk	Monkey–Jar	Spoon–Piano
Cat–Fire	Motorcycle–River	Storm–School
Cigarette–Cards	Mountain–Worm	Student–Balloon
Clown–Pillow	Movie–Beetle	Telephone–Road
Coat–Fence	Newspaper–Door	Tent–Tombstone
Comb–Bed	Parachute–Chimney	Ticket–Pencil Case
Doctor–Tomato	Pencil–Stopper	Toad–Peanuts
Doll–Tractor	Picture–Map	Tourist (F)–Watermelon
Eggplant–Sink	Pipe–Kite	Train–Sun
Engine (of a train)–Purse	Plane–Cake	Tree–Vase
Exam–Computer	Police–Play	Watch–Bucket
Fan–Mosquito	President–Tie	Wedding–Pizza

Note—The words presented here are English equivalents of the original Hebrew words. The names of occupations presented in the feminine form are marked by (F). All of the items are single words in Hebrew.

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