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Acta Psychologica xxx (2007) xxx–xxx
acta psychologica
www.elsevier.com/locate/actpsy

Word associations are formed incidentally during sentential semantic integration

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Received 9 July 2006; received in revised form 26 December 2006; accepted 4 January 2007

Abstract

Sentential context facilitates the incidental formation of word associations (e.g., Prior, A., & Bentin, S. (2003). Incidental formation of episodic associations: the importance of sentential context. *Memory and Cognition, 31(2)*, 306–316). The present study explored the mechanism of this effect. In two experiments, unrelated word pairs were embedded in coherent or semantically anomalous sentences. Anomalous sentences included either a local or a global anomaly. During an incidental study phase, participants performed a sentence categorization task. The strength of the incidental associations formed between two nouns jointly appearing in a sentence was probed by gauging their influence on subsequent paired-associate learning and cued recall in Experiment 1, and by assessing their associative priming effect in a subsequent unexpected explicit recognition test for single words in Experiment 2. In both experiments, significant associative memory was found for noun pairs studied in coherent sentences but not for those appearing in anomalous sentences, regardless of anomaly type. In a sentence rating task, global anomalies yielded less plausible sentences than local anomalies, however both types of anomalies were equally detrimental to the sentence integration process. We suggest that sentence constituents are incidentally associated during sentence processing, particularly as a result of sentence integration and the consolidation of a mental model.

PsycINFO classification: 2340; 2343

Keywords: Word association; Context; Semantic; Sentence integration; Incidental learning

1. Introduction

Association between mental events is a basic organizational principle in memory with important implications for performance. It is not surprising, therefore, that the impact of established associations on cognitive processes and the characteristics of the associative process have a long and distinguished history in cognitive

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doi:10.1016/j.actpsy.2007.01.002

research. The scope of such research was broad, ranging from behaviorist investigations of paired associate learning (e.g., Postman & Keppel, 1970) and explorations of free association patterns (e.g., Deese, 1965), up to more recent computational models that use inter-lexical associations as a basis for computing word meaning (e.g., Plaut, 1995). The impact of word associations on linguistic performance has been extensively investigated using various tasks such as priming in lexical access (Neely, 1991), sentence comprehension (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Stanovich & West, 1983) and language production (Spence & Owens, 1990). In contrast, questions regarding the processes leading to the establishment of word associations during natural language use, and the influence of linguistic context on the associative process have received less attention. Assumptions as to the nature of these associative processes are not fully articulated and remain, by and large, implicit.

During the daily use of the language, associations between words are formed incidentally, that is, without the explicit intention of the speaker to memorize a specific association. Nevertheless, much of the research concerned with the episodic formation of word associations, and their influence on lexical processing, has been conducted using intentional paired-associate learning paradigms (e.g., Dagenbach, Horst, & Carr, 1990; Durgunoglu & Neely, 1987; Goshen-Gottstein & Moscovitch, 1995a; Goshen-Gottstein & Moscovitch, 1995b; McKoon & Ratcliff, 1986; Neely & Durgunoglu, 1985; Schacter & Graf, 1986; Schacter & McGlynn, 1989; Schrijnemakers & Raaijmakers, 1997). In contrast, in the present experiments participants were incidentally exposed to words in a meaningful context while performing a semantic task involving whole-sentence comprehension. At the time of this incidental exposure they were not informed of an ensuing memory test, and thus presumably made no intentional attempt at encoding specific associative information in long term memory.

A commonly held assumption is that associative links between words reflect their co-occurrence in written and spoken language (McRae & Boisvert, 1998). Putatively, words that tend to co-occur frequently will become associated and consequently will activate each other in the lexicon (Spence & Owens, 1990). Computational models of lexical organization such as HAL (Burgess, 1998; Lund & Burgess, 1996; Lund, Burgess, & Audet, 1996) or LSA (Landauer & Dumais, 1997) formally rely on statistical co-occurrence in language as the basis for lexical associations.[1] However, the notion of co-occurrence does not fully account for the fact that the formation of associations is facilitated both by semantic relatedness (Greene & Tussing, 2001; Prior & Geffet, 2003; Smith, Theodor, & Franklin, 1983; Silberman, Miikkulainen, & Bentin, 2001, in press; Thomson & Tulving, 1970) and by context (Arnold, Bower, & Bobrow, 1972; Prior & Bentin, 2003; Schacter & McGlynn, 1989). Specifically, Prior and Bentin (2003) found that despite equal co-occurrence, incidental associations were formed more easily between nouns embedded in a sentential context than between nouns co-occurring as isolated pairs. The present study elaborates on this finding, and attempts to explore the source of the sentence facilitation effect.

The results reported by Prior and Bentin (2003), namely that sentential context facilitates the formation of an association between its constituent words when compared to context-free presentation, can be attributed to various factors. One account is that the meanings of individual words encountered in a sentential context receive more elaboration and deeper processing, and that unique relationships are established between the concepts they denote (Moscovitch & Craik, 1976; Stein, Littlefield, Bransford, & Persampieri, 1984). This account relates less to the intrinsic process of sentence comprehension and integration but hints to differences in the ways that individual words are processed, depending on whether or not they are embedded in sentential context. According to this view, words embedded in sentences are processed more elaborately, and might also recruit greater attention resources. This could lead to the elicitation of more extensive semantic activation for sentence constituents, thus increasing the probability that an association will be formed.

A second account relies on sentence comprehension theories (Carpenter, Miyake, & Just, 1995; Townsend & Bever, 2001) and suggests that associative links between constituent words might be established more efficiently during the integrative processes required for sentence comprehension. For example, according to the Construction-Integration (CI) model (Kintsch, 1998), sentence comprehension includes creating a "situation model" in which links are established among the constituent words, and between them and prior knowledge.

[1] Note that while the semantic relatedness between words in these models relies on global co-occurrence, defined as similarity of distribution throughout the corpus (and not direct co-occurrence), it has been postulated that local co-occurrence may indeed predict the degree of association, as defined above (see Prior & Geffet, 2003, for further discussion of this issue).

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Similarly, the sentence comprehension and memory theory developed using the ACT-R architecture postulates that the semantic structure of a sentence is encoded by the creation of a proposition (Anderson, Budiu, & Reder, 2001). Comprehension of the sentence then proceeds by a search of declarative memory for suitable referents. These processes might reinforce associations between constituents of the sentence by establishing links to the existing schemas or structures.

Finally, it is also possible that sentential context imposes semantic constraints on the interpretation of the constituent words (Moss & Marslen-Wilson, 1993; Onifer & Swinney, 1981; Schwanenflugel & Shoben, 1985; Swinney, 1979) leading to partial retrieval of context-dependant features from the lexicon (Barsalou, 1982). Therefore, when two words are encountered in a unifying context, there is a greater likelihood that their common features will be selectively activated as opposed to their discriminative features leading to feature alignment, feature matching, and ultimately stronger associative links (Foss & Speer, 1991). However, this account is closely linked to the specific conditions contrasted by Prior and Bentin (2003) and while it might partially explain the associative advantage conferred by sentential context, it does not speak directly to the aspects of sentence processing that we see as more central to understanding this phenomenon, which are addressed in the previous two accounts. Therefore, the present study does not directly test this account.

In the present study, we explored the role of semantic integration in the incidental formation of lexical associations during sentence comprehension while trying to compare study conditions that were more similar. We compared the strength of the associations formed between the constituents of semantically coherent sentences with that of associations formed between constituents of semantically anomalous sentences, which could not be fully integrated. In semantically anomalous sentences the local analysis is disrupted, and the initial meaning extracted during that process does not enable the reader to construct a coherent conceptual structure, or to assign the appropriate thematic roles and functional categories (Ferretti, McRae, & Hatherell, 2001). Furthermore, as suggested by Townsend and Bever (2001), the attempt to re-analyze the whole-sentence meaning under such circumstances fails as well, so that no coherent output can be generated and, in effect, the sentence cannot be comprehended and integrated.

The present design allowed us to contrast the first account offered above, namely the level-of-elaboration or resource allocation account, with the second account, namely the sentence integration account. According to the former, stronger associations are formed between words embedded in sentences because during sentence comprehension greater cognitive resources are allocated to the elaboration of constituent words than when they are presented in isolation. Importantly, semantically anomalous words might be even more extensively elaborated than semantically congruent words (and hence, better recalled) during the unsuccessful attempt to integrate them into the pre-set context. Indirect support for this hypothesis is evidenced by larger cortical activity elicited by semantically incongruent words in sentences (cf. the N400 effect, Kutas & Hillyard, 1980; for similar results using stimuli of the same type to those used in the present study, see Prior & Bentin, 2006). Additional evidence are findings of enhanced free recall for words appearing in semantically bizarre sentences, at least if such sentences are not a majority in the list (McDaniel & Einstein, 1986; Worthen & Marshall, 1996). Therefore, if indeed the critical factors leading to the formation of associations during sentence comprehension were the depth of processing and the amount of resources invested in processing the constituent words, the processing of an anomalous sentence should lead to the establishment of associations that are at least as strong as (or stronger than) those formed during the processing of a coherent sentence. We refer to this possibility as the *Elaborative Processing* account.

The second possibility is that rather than being a question of elaboration or resources, the factor leading to the formation of strong associations between words in sentences is the sentence integration process required for forming a coherent conceptual structure, as described in the second account above. If this were so, we would predict the formation of stronger associations during the processing of semantically coherent, as opposed to semantically anomalous, sentences. We refer to this possibility as the *Integrative* account.

To further test the *Integrative* account, we created two classes of anomalous sentences, arguably different in their detrimental effect on integration and comprehension (see Table 1 for examples). The first class included sentences with local meaning violations, which do not pertain to the relations between major sentence parts and thematic roles (subject/agent and object/patient). In the second class of anomalous sentences, these same relations were indeed interrupted, leading to a global meaning violation. It is conceivable that the violations of the second class, due to their interruption of the basic argument structure of the sentence, would lead to a

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Table 1
Examples of normal and semantically anomalous sentences used in Experiment 1 for the noun pair Shoe-Fly

Anomaly Type	Sentence	Sentence in Hebrew word order
Coherent	The brown shoe hit the tired fly	The shoe brown hit the fly tired
Adjective1 (A1)	The *curly* shoe hit the tired fly	The shoe *curly* hit the fly tired
Verb (V)	The brown shoe *heard* the tired fly	The shoe brown *heard* the fly tired
Noun (N)	The brown shoe pleased the tired *fly*	The shoe brown pleased the *fly* tired
Adjective2 (A2)	The brown shoe hit the *square* fly	The shoe brown hit the fly *square*

The word creating the anomaly is italicised.

greater difficulty in integration. Therefore, according to the *Integrative* account, while both types of anomalies should lead to weaker associations than in semantically coherent sentences, the associations formed between the constituents of sentences from the latter, global, violation class should be even weaker than those formed between the constituents of sentences of the former, local, violation class. Further strengthening this prediction, previous work has demonstrated differential effects of these anomaly types on the N400 ERP component, which is sensitive to sentential integration (Prior & Bentin, 2006).

In this paper, we present two experiments investigating this issue. In Experiment 1 we compared the effect of incidentally studying word pairs embedded in coherent and anomalous sentences on cued recall performance, using a design similar to that used in Prior and Bentin (2003). Experiment 2 probed the same question using the same materials but a different design. In particular, Experiment 2 did not include an explicit study phase nor did it include an overt measure of associative memory. Rather, the strength of incidental associations formed while processing coherent and anomalous sentences was probed implicitly, by exploring associative facilitation in a single word recognition test.

2. Experiment 1

The present experiment is a direct continuation of the work reported in Prior and Bentin (2003), in which we compared the strength of associations formed between words embedded in sentential context with the strength of associations formed between words presented context-free. We replicated the method used in our previous work, and incorporated both incidental and explicit study phases in the experiment. Thus, during an incidental learning phase, each pair of nouns was repeated four times embedded either in coherent sentences, or in anomalous sentences. Participants were engaged in a sentence categorization task during the incidental study phase. During this phase, the critical items were not marked in any way. In order to enable a cued recall memory task, we had to identify to the participants the pairs of interest. To this end, the incidental study phase was followed by an explicit paired-associate study phase. Thus, the incidental associations formed during the incidental learning stage were probed by assessing their influence on the subsequent explicit paired-associate learning, which was tested by cued recall. Since in this procedure all pairs are equally studied explicitly, any advantage we find in cued recall for pairs incidentally encountered in coherent sentences over those incidentally encountered in anomalous sentences could only be explained by reference to the incidental learning manipulation.

In the present experiment, we included a single-word recognition task and a cued sentence memory test, in addition to the cued recall measure of associative memory. However, none of the items were repeated in the different memory tasks. The purpose of the single-word recognition test was to ensure that any advantage found in cued-recall is not the result of enhanced encoding and memory of single items, either the cue or the target (or both). Both relational processing and item-specific encoding processes have been demonstrated to influence memory performance (Hunt & Einstein, 1981; Hunt & McDaniel, 1993), and cued recall performance is thought to benefit from both encoding strategies (Hunt & Einstein, 1981). The cued sentence memory test was included in order to ensure that any cued-recall advantage found for pairs initially studied in coherent as opposed to anomalous sentences is not a result of memory for the entire sentence but is rather an indication of associations formed between the sentence-embedded nouns. This may also be conceptualized as probing the difference between the episodic trace of the noun pair and the source memory of the sentence frame in which it was embedded.

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Therefore, the outline of the experiment was (1) incidental study, (2) explicit study, (3/4) a single word recognition test and a cued recall memory test (the order of which was counterbalanced across participants) and finally (5) a cued sentence memory test. Across participants, different items were presented in each of the memory tasks, and for each participant none of the items were repeated in the different memory tasks.

2.1. Method

2.1.1. Participants

The participants were 48 undergraduate students from the Hebrew University who participated for course credit or payment. All were native Hebrew speakers with normal, or corrected to normal, vision. The participants signed an informed consent approved by the Hebrew University IRB.

2.1.2. Materials and design

The critical items were 84 pairs of concrete nouns (Appendix A). The words of each pair were semantically unrelated and non-associated (as verified by the Hebrew Word Association Norms, Rubinstein, Henik, Anaki, Faran, & Drori, 2005). For each critical word pair, 10 different sentences using both of the words were constructed (see Table 1 for examples). All sentences were simple active transitive sentences in Hebrew, adhering to the normative SVO (subject–verb–object) word order. Both nouns in the sentence were modified by adjectives, leading to the following structure: noun (subject)–adjective–verb–noun (object)–adjective, plus necessary determiners. (Hebrew adjectives normally follow the noun they are modifying.) The first word of the critical pair was the noun placed in the subject position and the second word was the noun filling the (direct or indirect) object position. Of the 10 sentences including a critical pair, two sentences were semantically coherent and the remaining eight were semantically anomalous. The two semantically coherent sentences were different from each other, and none of the words used in these sentences were repeated (except for the critical pair, of course). Four types of semantic anomaly were introduced, all created by violating selectional restrictions at specific points in the sentence, but retaining grammaticality. Thus, the specific word in the sentence creating the violation could have been one of the following: the first adjective (A1), the verb (V), the noun (object of the sentence) (N) or the second adjective (A2) (see Table 1). In both the verb and the noun conditions, the selectional restrictions of the verb were violated but in different manners, that became apparent at different points in time during the linear processing of the sentence. In the verb violation, the sentence had an incongruent agent, so that the anomaly became apparent upon processing of the verb. In the case of the noun violation the sentence included an anomalous patient/goal, so that the anomaly became apparent upon processing of the object noun.

In the case of adjective anomalies the transitive relations remained plausible, while in the verb and noun anomalies the meaningful relation between the subject and the object was breached. The semantically anomalous sentences were created by varying a single word in the semantically coherent sentence, and thus rendering it implausible. Since each participant read different pairs in the coherent and anomalous conditions, none of the sentences were repeated within an experimental list.

Note that in Hebrew adjectives normally follow the noun they are modifying, so that in the case of the Adjective 2 anomaly the noun appears before the adjective in the sentence, and, therefore, the adjective is the word causing the violation. Similarly, in the Adjective1 anomaly, the subject noun precedes the adjective, so that once again the adjective is the word causing the violation.

Eight study lists were assembled, each including all 84 critical pairs in different sentences.[2] Within each list, half of the pairs appeared in semantically coherent sentences, while the remaining pairs appeared in only one of the four possible semantically anomalous conditions. Each pair appeared in two different sentences (belonging to the same condition, either anomalous or coherent), and each of these sentences was presented twice during the study phase of the experiment. The repetition was introduced in order to improve the incidental memory performance on the subsequent test, by exposing participants to each pair 4 times. This structure resulted in a total of $84 * 4 = 336$ sentences per list. Each list was presented to six participants. Thus, while the effect of coherent vs. anomalous sentences was examined within participant, anomaly type was manipulated between

[2] A complete set of the Hebrew sentences used can be found in the supplementary materials.

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participants. A third of the items from each condition were later probed in each of the three memory tasks, so a minimum of 42 pairs per condition had to be presented to allow for sufficient items in each memory task. Including more than two conditions would have made the study list too long, and would have overloaded the participants' memory. Across participants each pair appeared equally in all experimental conditions.

For the single word recognition task, in which a third of the studied pairs were presented (28), an additional 56 concrete nouns were added to the list, for a 1:1 ratio of new to old items.

2.1.3. Procedure

The experiment consisted of an incidental study phase, an explicit study phase and three memory tests. The experimental design was implemented using E-prime (Psychological Software Tools, Inc.). In the incidental study phase, participants performed a semantic judgment on sentences. They were told to determine whether the sentence described an active event (e.g. the brown shoe hit the tired fly) or rather a steady state of affairs (e.g. the shiny key was behind the old fork). Each trial began with a fixation point presented at the center of the screen for 170–230 ms, in order to avoid a monotonic rhythm of the trials. The entire sentence was then presented on the screen for 3 s, and never exceeded one line of text. The sentence was followed by one of two possible probe questions ("Action?" or "State?"), which remained on the screen until a "yes" or "no" response was recorded, by button. The subsequent trial started after a 100 ms blank screen. Probe questions varied randomly from trial to trial; therefore, even when a sentence was repeated, repeating a previous decision during incidental learning might have led to an incorrect reply (repeating a "yes" response to a specific sentence when the question presented was "Action?" would lead to an error in a subsequent presentation of the same sentence followed by the question "State?"). Hence, the task performed by the participants encouraged semantic processing of the sentences and called for their integration. The 336 sentences were randomly ordered for each participant and divided into four blocks. Breaks were introduced between the blocks.

In the *explicit learning phase*, each of the 84 noun pairs was presented in a separate trial. The fact that these items had appeared in the previous part of the experiment was not explicitly mentioned, though probably it was noticed by the participants. In each trial the two nouns were presented simultaneously side-by-side for 2 s, with an inter-trial interval of 100 ms. Participants were instructed to memorize the pairs and informed that their memory for the pairs would be tested shortly. The pairs were presented in random order. Once again, since the explicit learning phase was identical for all pairs, any differences found in cued recall performance could only be attributed to the study context manipulation (coherent vs. anomalous sentences) implemented in the previous, incidental, study phase.

The *test phase* consisted of three memory tests, each of which included a third of the studied items. None of the items were repeated in or across the different memory tests for any given participant. In the cued-recall test the "first noun" of a pair was presented on the screen and the participant was instructed to write down its pair mate on an answer sheet. The cue nouns appeared in random order. The first noun was defined as the noun appearing on the right side in the explicit study list. Because Hebrew is read right-to-left, the first noun was the noun that had occupied the subject position in the sentences. The word appeared and remained on the screen until the participant pushed a button in order to initiate the following trial. In the single word recognition test, single words were presented on the screen, and the participants were instructed to discriminate by button press words that had appeared in the explicit study list and words that were not encountered previously. All the old words belonged to the critical pairs. The order of these two memory tests was counterbalanced across participants.

The final stage of the experiment was the sentence memory test, in which again a cue word appeared on the computer screen, and participants were instructed to recall the sentence in which the word had appeared in the first, incidental, study phase and write it down on an answer sheet. The cue word was again always the first word of the pair. The cue remained on the screen until the participants initiated the next trial by button press. The sentence memory test was always the third memory test, since it refers participants back to the incidental study phase, and we did not want this to occur prior to the recognition and cued-recall test so as to minimize the possibility that performance in these tasks would rely on sentence memory as opposed to the associations formed.

One-third of the studied items (28 pairs) appeared in each of the memory tests, half of which were incidentally studied in coherent sentences and the remainder of which were incidentally studied in anomalous

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Table 2
Mean percent of accuracy (SEM) in cued recall and sentence memory for pairs incidentally studied in coherent and anomalous sentences[a]

		Anomaly type group			
		Adjective 1	Verb	Noun	Adjective 2
Cued recall	Coherent	32% (7)	35% (7)	27% (7)	34% (7)
	Anomalous	22% (6)	35% (6)	15% (5)	30% (6)
	Difference	10%	0%	12%	4%
Sentence memory	Coherent	20% (3)	15% (4)	11% (4)	19% (4)
	Anomalous	15% (4)	14% (3)	11% (3)	14% (3)
	Difference	5%	1%	0%	5%

[a] Note that within each anomaly-type group, each pair of nouns was embedded in both coherent and anomalous sentences across participants.

sentences. The memory lists were counterbalanced, so that across participants each studied pair appeared equally in all three memory tests.

2.2. Results

The first step we performed in analyzing the data were to examine the participants' performance on the single word recognition task. On average, participants correctly recognized 67.4% of the words from coherent sentences and 66.5% of the words from anomalous sentences. Similarly, in the item analysis 66% and 64.8% of the participants recognized words that had appeared in coherent sentences as opposed to semantically anomalous sentences, respectively. These differences were not statistically significant in either a subject or an items paired t-test comparison ($t_1(47) < 1$; $t_2(167) < 1$). The power of the test for detecting a 5% difference in performance at the 0.05 confidence level was 0.7 for the subject analysis and 1 for the item analysis. An effect size of 5% was chosen because this was the magnitude of the average effects found for the cued recall and sentence memory tests (see Table 2). Thus, we felt confident that the null result in single item recognition is not due to a lack of power.

Participants' cued recall and sentence memory performance was examined next. Because anomaly type was a between-participants factor, in effect there were four distinct groups of 12 participants, each exposed to anomalous sentences of a different type. The participants' performance for coherent and anomalous sentences is presented in Table 2 broken down by anomaly type. Note, however, that the groups differed only in regards to the anomalous sentences they were exposed to, and there were no differences in the coherent sentences presented to each group.

In order to allow a comparison between sentence memory and cued recall performance, all scores were transformed to reflect percent of successful recall. Sentence memory performance was coded as follows: Each content word correctly recalled received 1 point, for a maximum score of 4 per sentence (the first content word in the sentence, the subject, was always given as the cue). The number of points was summed per participant and divided by 112, the total score for perfect performance across all items (4 points × 28 sentences). For the cued recall performance, the number of correctly recalled items was summed and divided by 28, the total number of pairs. Thus, each participant had a percent correct score for each of the memory tests (sentence memory and cued recall) for each of the incidental study conditions (coherent and anomalous).

The Sentence Memory performance was analyzed with a two-way (2×4) ANOVA with one within subject factors: Study Condition (coherent, anomalous), and one between-subjects factor: Anomaly Type Group (Adj1, Noun, Verb, Adj2). In the items analysis, only the within-item factor of Study Condition was included.[3] Both analyses showed a significant main effect of Study Condition ($F_1(1,44) = 4.4$, MSE $= 0.01$, $p < 0.05$; $F_2(1,83) = 4.1$, MSE $= 4.7$, $p < 0.05$), demonstrating better memory for coherent as opposed to anomalous

[3] Since the design was entirely within item there were only two observations per cell of anomaly type, and so data were collapsed across anomaly type.

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sentences. On the other hand, the main effect of Anomaly Type in the subject analysis was not significant ($F(3,44) < 1$), nor was the two-way interaction ($p > 0.3$).

As discussed at greater length in Section 2.3, performance in the cued recall task can be attributed, at least partially, to re-instatement of the sentential context as a strategy for response activation. In the present analysis, however, we wished to explore the unique contribution of associative encoding during sentence comprehension to cued recall performance, beyond any effects that might be a result of sentence re-instatement. We thus performed a repeated-measures ANCOVA on cued recall performance, with one within-participant factor of Study Condition and one between-participant factor of Anomaly Type in the participant analysis, and a single within-item factor of Study Condition in the items analysis. In both cases, we entered the difference score for the sentence memory performance (the score for coherent sentences minus the score for anomalous sentences) as a covariate.[4] The mean of this difference score was 2.7%, with a standard error of 1.3% for the participant analysis, and 2.1% with a standard error of 1% for the item analysis. In both cases the distribution was found to significantly differ from zero ($t_1(47) = 2.1$, $p < 0.05$; $t_2(83) = 2.0$, $p < 0.05$). In addition, tests for skewness and kurtosis showed that neither was significantly different from zero, suggesting that both sentence memory difference scores were normally distributed.

For both the participant and the item analyses, we found a significant effect of Study Condition on cued recall performance ($F_1(1,43) = 4.8$, MSE = 0.02, $p < 0.05$; $F_2(1,82) = 4.8$, MSE = 0.1, $p < 0.05$). These results demonstrate that even after partialling out the contribution of sentence memory reinstatement during cued recall to the observed variance in cued recall performance (as assessed by performance on the sentence memory test), there remains a significant advantage in cued recall for pairs encountered in coherent sentences over those encountered in anomalous sentences. In the participant analysis, the main effect of Anomaly Type was not significant ($F < 1$), as was the case in the sentence memory results, nor was the two-way interaction significant ($F(3,43) = 1.4$, MSE = 0.02, $p > 0.2$).

2.3. Discussion

The goal of Experiment 1 was to reach a better understanding of the cued recall advantage reported in Prior and Bentin (2003) for pairs embedded in sentential context over pairs incidentally studied context-free. To this end, we replicated the general design of the previous experiments, but manipulated the incidental learning conditions and compared noun pairs incidentally studied in either semantically coherent or semantically anomalous sentences. The results show enhanced cued recall performance for pairs embedded in coherent sentences over those incidentally studied in anomalous sentences, suggesting that stronger associations were incidentally formed in the former case.

The present data also showed that coherent sentences were better recalled than were anomalous sentences, as evidenced by the significant effect of Study Condition on sentence memory performance (for similar findings see e.g., Craik & Tulving, 1975) and might account for part of the coherence effect on cued recall. Importantly, such an account does not imply that stronger lexical associations were formed between the constituents of coherent sentences during sentence integration. Rather, it suggests that the coherence advantage found in cued recall performance is a result of more reliable memory traces being formed at study for coherent sentences as a whole. Then, during the performance of the cued recall task, coherent sentences were easier to reinstate than anomalous sentences, leading to the observed pattern of results. However, while sentence reinstatement might have played some role in cued recall performance, this could not be the sole account because a significant main effect of Study Condition on cued recall was found even after the variance resulting from differences in sentence memory was factored out. Hence, pairs studied incidentally in coherent sentences were better recalled than those incidentally studied in anomalous sentences, above and beyond any differences found in memory for the sentences as a whole.

[4] Please note that in this analysis the dependent variable is performance on the cued-recall memory test, while the independent variable is the study condition. Sentence memory performance was correlated with the dependent variable of cued recall performance (thus necessitating the ANCOVA analysis), but was not correlated with the independent variable, and therefore meets the conditions of the statistical test (Tabachnick & Fidell, 2001, chap. 8).

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This conclusion is further strengthened by our previous study in which we compared associations formed between a pair of sentence-embedded nouns presented either in a single sentence repeated five times, or embedded in five different sentences that were presented once each, and found no differences in cued recall (Prior & Bentin, 2003). Since memory for sentences should have been better in the first case, the absence of cued-recall differences following these two conditions indicates again that lexical associations are formed during sentence comprehension and cued recall performance does not depend upon sentence reinstatement at test. Moreover, in the present study as well, each noun pair was embedded in two different sentences, reducing even further the probability of sentence reinstatement at test, since there was not a unique sentence to be reinstated per pair, but rather two distinct possibilities. Thus, in concert with our previous study, the results of Experiment 1 provide evidence for the incidental formation of lexical association during sentence comprehension.

However, since in the present experiment the explicit paired-associate study phase followed the incidental exposure to coherent and anomalous sentences, there is still a possibility that participants were strategically using the information gained in the incidental study phase, particularly in the semantically coherent sentences, to enhance their encoding of materials presented in the explicit study phase. Although this scenario seems unlikely given the finding of significant cued recall advantage beyond sentence memory effects, the design of the present experiment does not allow us to rule it out completely. This issue is taken up in Experiment 2, which eliminated the explicit paired-associate study phase altogether.

Although these data support the *Integration* account for the sentential context effect, a second prediction arising from this account was not borne out. We hypothesized that the adjective anomalies would interrupt the integration of the sentence to a lesser degree than would the verb and noun anomalies (see Prior & Bentin, 2006 for related findings). The current results, nonetheless, showed no significant differences in the cued recall or sentence memory rates for the different semantic anomaly types. Indeed, we found evidence that only weak incidental associations were formed during the processing of sentences, including either local or broader anomaly types.

In Experiment 2, we sought to elaborate on the findings of Experiment 1 in two important ways: First, we collected plausibility ratings of sentences including the different anomaly types in order to validate our hypothesis regarding the differences among them in the degree of semantic interruption they cause. Second, and more importantly, we implemented a design that included neither explicit study of associations nor an overt associative memory test, reducing the possibility that the results would reflect strategic memory processes unique to the laboratory setting.

3. Experiment 2

The present experiment sought to emulate and investigate, as much as possible under laboratory conditions, the natural processes leading to the formation of associative links between words. Thus, Experiment 2 included only an incidental study phase for sentences including embedded noun pairs, and eliminated the explicit paired-associate study that was included in Experiment 1.

Further, we tested associative memory using a task that is less prone to strategic influences. Previous research on associative memory usually probed the strength of associations using cued recall tests, priming in semantic or lexical decision tasks (Schrijnemakers & Raaijmakers, 1997) or different variants of primed recognition (Carroll & Kirsner, 1982; Neely & Durgunoglu, 1985). In most of these studies, associated and unassociated words were presented in pairs at test. Therefore, while informative, these procedures did not mask the associative nature of the memory test, and consequently might have induced strategic associative retrieval efforts. This is true for the cued recall measure implemented in Experiment 1 as well. In an attempt to reduce the strategic impact, Experiment 2 introduced a single word recognition method to test associations implicitly. Serial recognition of single words conceals to some extent the paired structure of the recognition list, and thus diminishes the participants' awareness of the fact that the test probes memory for associations (McKoon & Ratcliff, 1979; Ratcliff & McKoon, 1981). In this design, the comparison of interest is between the recognition rates for targets following a putatively associated prime and targets following an unassociated item. Any advantage found in the former case is evidence for an association existing between the prime and the target.

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Table 3
Mean plausibility ratings (SEM) for sentences used in Experiments 1 and 2[a]

Sentence type	Rating
Coherent	6.36 (.09)
Adjective1	3.37 (.21)
Adjective2	3.69 (.24)
Verb	2.08 (.18)
Noun	2.24 (.25)

[a] Ratings were between 1 (makes no sense) and 7 (perfectly coherent).

3.1. Method

3.1.1. Participants

The participants were 64 undergraduate students from the Hebrew University who participated in the experiment for course credit or payment. None of them had participated in Experiment 1. All were native Hebrew speakers with normal, or corrected to normal, vision.

3.1.2. Materials and design

The study materials were identical to those described for Experiment 1. In order to validate our hypothesis regarding the differential integration burden posed by the local and global anomaly types, we collected plausibility ratings for the four types of anomalous sentences as well as for coherent sentences. Since the total number of sentences in our experiments was 840, the task of collecting ratings for each and every sentence was unrealistic. We therefore randomly sampled 24 sentences from each anomaly type condition (A1, Verb, Noun and A2 anomalies) as well as 24 coherent sentences, for a total of 120 sentences. These sentences were then randomized twice, and each version of the resulting questionnaire was presented to 16 participants. The Participants were native speakers of Hebrew, who did not participate in any of the other experiments presented in this paper, and received course credit or payment. Participants rated how much the meaning of each sentence made sense on a scale of 1 (makes no sense) to 7 (makes perfect sense).[5] As can be seen in Table 3, the ratings show that the different types of sentences differed, as expected, on their plausibility ratings.

The ratings were analyzed using a one-way ANOVA over items, where the mean rating of the participants for each sentence was calculated. The main effect of anomaly-type was significant ($F(4,115) = 71.1$, $\mathrm{MSE} = 1.0$, $p < 0.001$). Post hoc tests demonstrated that coherent sentences were rated as being significantly more plausible than sentences sampled from all other anomaly types ($p < 0.001$). Further, sentences with adjective anomalies were rated as being significantly more plausible than sentences with noun and verb anomalies ($t(94) = 6.1$, $p < 0.001$). Finally, sentences belonging to the two adjective anomaly types did not differ significantly from each other, and neither did sentences including noun and verb anomalies (both $F < 1$). Thus, the plausibility ratings provide robust support for our initial hypothesis regarding the different levels of anomaly induced by adjectives, on the one hand, and by nouns and verbs, on the other hand (see also Prior & Bentin, 2006, for similar findings).

The study phase of Experiment 2 was identical in all respects to the incidental study phase of Experiment 1.

The test phase of Experiment 2 consisted of a single-word recognition test. In addition to the 168 studied nouns (84 pairs), 168 unstudied concrete nouns were used as new items in this test. Although from the participants' perspective the recognition test comprised a list of single words, from the experimenter's point of view it included a series of word pairs. For each such pair, the subject noun was defined "prime" and the object noun in the sentence was defined "target". For each study condition (semantically coherent and semantically anomalous), studied pairs were presented in one of four test conditions (with 14 pairs per condition): Intact, Recombined, New-Target and Prime-New. The remaining 112 new items were randomly divided into 56 New–New pairs.

[5] The questionnaires included an additional 120 sentences being normed for a different study.

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In the Intact condition, both the prime and the target in each "pair" were "old", and had appeared in the same sentence during study; in the Recombined condition, the prime and the target in each pair were "old" as well, but the pairs were shuffled so that a target was preceded by a prime that had been paired at study with a different target (from the same study condition). In the New-Target condition, old targets were preceded by new words. In the Prime-New condition old primes were followed by new words. In the New–New condition, two unstudied words were presented sequentially (see Table 4). The New-Target, Prime-New and New–New conditions were included as fillers, to achieve a 50% ratio of old/new words in the test list, and to ensure that the status of a target could not be easily predicted by the status of the prime. To further control for spurious priming effects, in the Recombined condition a prime did not appear among the three words preceding its episodically associated target. Pairs were rotated, so that across participants each target occurred equally in all test conditions though each participant saw each target only once. Hence, the final test list included 56 old-old pairs (Intact and Recombined, for both normal and anomalous study conditions), 56 mixed pairs (Prime-New and New-Target, again for both study conditions), and 56 New–New pairs.

3.1.3. Procedure

Experiment 2 consisted of an incidental study phase and a test phase. The study phase of Experiment 2 was an exact replication of the incidental study phase described in Experiment 1.

During the test phase, a single word appeared on the computer screen in each trial, and participants determined whether or not it had appeared in the first part of the experiment. Each word was presented in isolation at fixation and remained exposed until the participant responded; a new trial started 100 ms after a response was given. Speed and accuracy were equally stressed in the recognition test. Participants were not informed of the "paired" structure of the list, and responded identically to both primes and targets. Note that for each given pair in the Intact and Recombined conditions, both the prime and the target could be either correctly recognized as "old" or mistakenly designated as "new". The length of the experiment was circa 50 min.

3.2. Results

Mean accuracy rates and reaction times were computed separately per participant, per condition, after excluding trials deviating by more than 2 SD from the participant's mean in each condition. Less than 4% of the data were discarded. The complete pattern of accuracy rates is presented in Table 5 (for old, studied targets) and in Table 6 (for new, unstudied targets).

We analyzed the raw subject accuracy rates for primes and targets using a three-way repeated measures ANOVA, with these factors: Study Condition (coherent, anomalous); Test Condition (intact, recombined) and

Table 4
Examples of pairs in the Intact, Recombined and Unstudied test conditions

Study	Test: Prime-Target				
	Intact	Recomb.	New-Target	Prime-New	New–New
The brown **shoe** hit the tired **fly**	Shoe – Fly	Pen – Fly	Ring – Fly	Shoe – Lamp	Cake – Broom
The shiny **key** was behind the old **fork**	Key – Fork	Shoe – Fork	Book – Fork	Key – Tree	Door – Shirt
The plastic **pen** fell under the low **table**	Pen – Table	Key – Table	Dog – Table	Pen – Hand	Mouse – Fan

Table 5
Mean accuracy rates (SEM) for primes and OLD targets, by test condition

Test condition	Incidental study condition			
	Coherent sentences		Anomalous sentences	
	Prime	Target	Prime	Target
Intact	59% (2.5)	56% (2.7)	61% (2.6)	56% (2.8)
Recombined	62% (2.7)	51% (2.8)	60% (2.6)	56% (2.4)
New Prime–Old Target	81% (2.2)	53% (2.4)	82% (1.9)	49% (2.5)

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Table 6
Mean accuracy rates (SEM) for primes and NEW targets, by test condition

Test condition	Accuracy	
	Prime	Target
Old Prime–New Target	62% (2.2)	78% (2.1)
New Prime–New Target	83% (1.7)	85% (1.6)

Table 7
Conditional accuracy rates (SEM) for old targets following correctly recognized primes

Test condition	Incidental study condition	
	Coherent	Anomalous
Intact	67% (2.9)	61% (3.2)
Recombined	56% (3.2)	59% (3.3)
Associative priming	11%	2%

Word Role (prime, target). The main effect of Word Role was significant ($F(1,63) = 17.4$, MSE = 71, $p < 0.001$), indicating better recognition performance for primes over targets. Particularly, the main effect of Study Condition was not significant ($F < 1$), showing no difference between the recognition performances for single words that had been studied in coherent as opposed to anomalous sentences. This comparison is analogous to the analysis performed on the results of the single-word recognition test used in Experiment 1, and replicates the previous null effect. The only other significant finding was the three-way interaction ($F(1,63) = 7.5$, MSE = 15.4, $p < 0.01$), driven by the fact that for pairs studied in coherent sentences targets were identified more accurately in the intact test condition while primes were more accurately identified in the recombined test condition, but no differences in prime and target accuracy are evident for pairs studied in anomalous sentences. However, there seems to be no theoretical reason for assuming differential performance on primes in the intact as opposed to the recombined condition, since when participants were responding to the prime they had no way of knowing the identity of the subsequent target. We will therefore not attempt to further analyze this interaction.[6]

In light of the main effect of word role and our specific interest in possible associative facilitation on target performance, we calculated the conditional accuracy rates of target following correctly recognized primes for each experimental condition separately (Table 7).[7]

These results showed that when they were studied in coherent sentences, targets following correctly recognized primes were better recognized in the intact than in the recombined test condition. By contrast, no such effect is evident for targets studied in semantically anomalous sentences. These data were analyzed using a three-way mixed model ANOVA with one between participants factor of Anomaly Type (A1, V, N, and A2) and two within participant factors: Study Condition (coherent, anomalous) and Test Condition (intact, recombined). We found a significant main effect of Test Condition ($F(1,60) = 6.5$, MSE = 0.2, $p < 0.05$), demonstrating that targets were recognized more accurately in the intact than in the recombined Test Condition. Importantly, this effect was qualified by a significant two-way interaction between Study Condition and Test Condition ($F(1,60) = 5.1$, MSE = 0.1, $p < 0.05$), showing that indeed associative facilitation between prime and target was limited to those noun pairs studied in the context of a coherent sentence. The remaining main effects and interactions were not significant (all $F < 1$). Note specifically the lack of a significant three-way interaction between Study Condition, Test Condition and Anomaly Type, indicating that this pattern of associative facilitation

[6] Because items were not rotated between prime and target status, this might simply be an effect of item properties, reflecting the fact that prime words might have been easier to remember. Importantly, the targets themselves were rotated between conditions across participants, and thus the analyses of target performance are not similarly confounded.

[7] We also examined the performance on all targets, regardless of prime performance, and the conditional accuracy rates for targets following unrecognized primes. In both cases, we did not find a significant coherence advantage, as there were no differences in the performance on targets studied in coherent and anomalous sentences.

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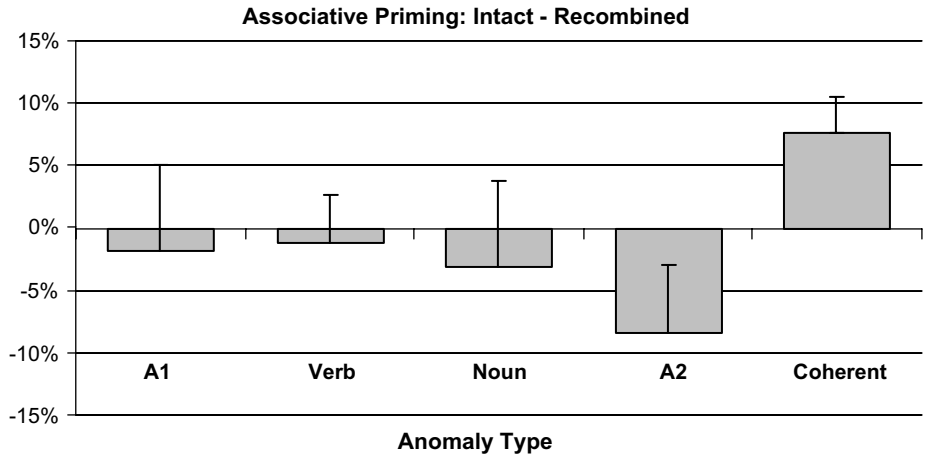

Fig. 1. Mean associative priming effect (Intact – Recombined) in conditional accuracy rates for targets, presented by Anomaly Type.

only for pairs studied in coherent sentences was similar across all types of anomalous sentences introduced in the experiment (see Fig. 1).

The RT data were analyzed in order to rule out the possibility of a speed/accuracy tradeoff. Mean RT was calculated for all accurate target trials, pooled across correctly recognized and unrecognized primes in each condition (Table 8). We performed a three-way mixed model ANOVA, and although none of the main effects were found to be significant ($F < 1$ for Study Condition, Test Condition and Anomaly Type), the interaction between Study Condition and Test Condition approached significance ($F(1,57) = 3.9$, MSE = 528,986, $p = 0.053$), hinting that the pattern of response latencies follows the same direction of facilitation found for accuracy rates (a 130 ms advantage as opposed to 10 ms, for pairs studied in coherent and anomalous sentences, respectively). Thus, in the RT data as well we found some evidence of greater associative facilitation for pairs studied in coherent sentences over pairs studied in anomalous sentences.

3.3. Discussion

Possibly indicating the incidental formation of associative connections during sentence processing, targets were better recognized when they were preceded by primes with which they had been jointly presented in the sentence, than when they were preceded by words studied in different sentences. The conditional accuracy rates for targets following correctly recognized primes show clear associative facilitation in recognizing targets in the intact over the recombined condition. This effect was evident, however, only when the studied sentential context was coherent. Words incidentally studied in semantically anomalous sentences did not facilitate the recognition of each other when they were seen in immediate sequence at test. The sentential context facilitation did not result from improved single item memory, as shown by the non significant comparison of single word recognition accuracy across study conditions, nor was it a result of a speed/accuracy tradeoff, as shown by the RT analysis.

Thus, implementing a completely incidental design at study and at test, we replicated the results of Experiment 1. Namely, we found evidence that reliable associations were incidentally formed between constituents of

Table 8
Mean RT (SEM) in milliseconds for correctly recognized targets

Test condition	Incidental study condition	
	Coherent	Anomalous
Intact	1180 (79)	1239 (84)
Recombined	1310 (104)	1229 (83)
Associative Priming	130	−10

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semantically coherent sentences, but not between constituents of semantically anomalous sentences. Unlike the cued recall test used in Experiment 1 and in our previous demonstration of a sentential context associative effect (Prior & Bentin, 2003), the single-item recognition procedure used in the present experiment reduced the participants' awareness of our interest in associative processes and their inclination to invest strategic efforts directed at associative encoding or retrieval. This implicit design tapped the incidental formation of associations, allowing us a high level of confidence in the ecological validity of our results.

However, this pattern of associative facilitation was only found on trials where the prime was correctly recognized, and not when all trials or trials that included unrecognized primes were examined.[7] Theoretically, this finding was not expected and we do not believe that the associative facilitation is inherently dependant on conscious recollection of the prime word as indeed associative priming is considered by many to be an automatic process (Pecher, Zeelenberg, & Raaijmakers, 2002). We offer two tentative suggestions regarding this finding.

First, we are cautious in interpreting the performance on targets following unrecognized primes since our sample of such trials is relatively small and the data are unstable (across study and test conditions, participants correctly recognized on average of 8.46 primes out of 14 trials, and failed to recognize the remaining 5.54 primes). Second, and more importantly, in the present design the participants made decisions regarding both the prime and the target words. By definition, when a prime went unrecognized, the participant made an erroneous judgment on the prime trial, and this fact might have implications for the decision made on the following target trial even though the participants were not explicitly alerted to the paired structure of the list. Thus, there is a fundamental difference between target trials following identified and unidentified primes – in the first case, a correct decision for the target entails repetition of a "yes" response, while in the second case a correct decision for the target would entail a "yes" response following a previous erroneous "no" response. It is possible that this confound in the design is responsible for the difference emerging in the associative facilitation patterns. Further investigation of this question using automatic priming paradigms and shorter prime displays without an overt response is warranted.

Finally, as in Experiment 1, we found no significant effects of Anomaly Type on the formation of associations, despite having collected data regarding the differential impact of the local as opposed to global Anomaly Types on rated sentence plausibility. We therefore conclude that these differences do not influence the formation of associations, as reflected both in the cued recall performance of Experiment 1 and in the patterns of associative facilitation in the single word recognition task in the present experiment. This issue will be taken up at greater length in Section 4.

4. General discussion

The purpose of the present study was to investigate the mechanism by which sentential context facilitates the incidental formation of associations between its constituent words. In two experiments we found that associations were formed more efficiently between the constituents of semantically coherent, but not semantically anomalous, sentences. Experiment 1 used a cued recall measure of associative memory, and Experiment 2 implemented an implicit measure of associative priming in a single word recognition task.

Therefore, between the two alternative accounts for the sentential context benefit presented in the introduction, the *Elaborative Processing* account and the *Integration* account, the results of both experiments unequivocally lend support to the latter. In spite of the conceivably more extensive processing and resources that might have been required by anomalous sentences (in an effort to integrate their meaning), associative links were not formed among their constituent words. Notably, this was evident even if the aberrant word was one of the two nouns, between which the association was tested.

The positive influence of sentential coherence on the formation of associations between sentence constituents is in line with similar results that have been reported previously using cued-recall measures of memory. Besson, Kutas, and Van Petten (1992) showed higher cued-recall for the final words of coherent as opposed to anomalous sentences.

Thus, it stands to reason that lexical associations between sentence constituents are formed during a relatively late stage of processing, when the incoming word sequence is structured to a mental model, and related to existing knowledge (e.g., Anderson et al., 2001; Carpenter et al., 1995; Kintsch, 1998; Townsend & Bever, 2001). Hence, the present data shed additional light on aspects of associative processes that have been

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somewhat neglected in previous associative memory studies (e.g., Neely & Durgunoglu, 1985; Schacter & Graf, 1986), and in the details of models relying on lexical co-occurrence patterns (e.g., Lund & Burgess, 1996). Moreover, in line with our previous work (Prior & Bentin, 2003) these data demonstrate that statistical counts of co-occurrence are not the sole mechanism leading to association, since in our studies co-occurrence was equated in the incidental learning conditions. Apparently, there are deeper issues of meaning and context at work.

Theories of sentence comprehension (Anderson et al., 2001; Carpenter et al., 1995; Kintsch, 1998; Townsend & Bever, 2001) postulate that the processing of an incoming sentence involves a search of declarative memory for suitable referents for each word encountered. After an initial proposition is constructed, sentence comprehension includes creating a "situation model" in which links are established among the constituent words, and between them and prior knowledge (see also Johnson-Laird, 1983). These processes might reinforce associations between constituents of the sentence both by binding them in the same meaningful semantic structure, and by establishing links to existing schemas or structures (Traxler, Foss, Seely, Kaup, & Morris, 2000). Along with such theories, the results of the present study indicate that word associations are probably formed during the later stages of sentence comprehension, and might be a subsidiary result of the meaningful links building up the mental model representation of the sentence. Conceivably, if the incoming information does not match the existing knowledge and schemas, as was the case in our anomalous sentences, an adequate mental model cannot be constructed, and associative processes break down. It is implied in this account that semantic anomaly inhibits the ability to integrate the words into a meaningful scheme and, consequently, impedes the formation of associations between sentence constituents.

The plausibility rating described in Experiment 2 demonstrated that, as we assumed, participants rated sentences including a local anomaly induced by violating selectional restrictions of modifiers (adjectives) to be more plausible than sentences including a global anomaly induced by violating selectional restrictions at the predicate (verb) or object (noun) of the sentence. This finding is in agreement with the sentence comprehension literature, and with the manner in which thematic roles are computed and integrated during sentence comprehension (Carlson & Tananhaus, 1988; Ferretti et al., 2001; Frazier & Rayner, 1982; Frazier & Clifton, 1996). Whereas verb and noun anomalies interrupt the basic argument structure and the main proposition of the sentence, the scope of the adjective anomalies is rather more limited (also see Prior & Bentin, 2006, for related ERP findings). Nevertheless, in both experiments, we found that local anomalies resulted in a lack of association formation to the same extent that global anomalies did. This pattern did not conform to our assumption that global anomalies should interfere more than local anomalies with associative learning.

A possible account for this unpredicted pattern is that even the milder, local anomalies introduced in this study were severe enough to cause a breakdown in the processes of mental model construction and associative binding of sentence constituents. Therefore, although local anomalies were rated as significantly more plausible than global anomalies, with an average of 3.53 as opposed to 2.16, both these values are fairly low on a scale of 1–7, since the incoming information in all cases was incommensurate with existing semantic structures. It is possible that these values are low enough to result in a floor effect for associative memory. Along these lines, the Plausibility Analysis Model (Connell & Keane, 2003, 2004) assigns a central role to the fit of the incoming information with prior knowledge in determining sentence plausibility. Given that we see this factor as important in successfully creating a mental model and associating sentence constituents as well, we can understand why low plausibility ratings would lead to a lack of associations. Perhaps a study using anomalous sentences that are rated as more highly plausible, or even examining a range of coherent sentences that vary in their rated plausibility, might be able to demonstrate differential effects on the incidental formation of associations.

The significant associative learning in coherent sentences and the uniform absence of such learning across semantic anomaly types suggest that the sentence integration process is, indeed, crucial for the incidental formation of new associations. In conclusion, we suggest that the incidental formation of associations among sentence constituents is facilitated only by comprehension and full integration of the entire sentence. These associations are, most likely, formed at the stage where the whole sentence is integrated, during the construction of a mental model (Kintsch, 1998). At this stage links are established between the incoming information and existing schemas and world knowledge (Anderson et al., 2001). A breakdown in the process of generating an output meaning of the sentence (Townsend & Bever, 2001) interferes with the process of association formation. In addition to demonstrating once again the importance of the semantic context in the formation of new associations, the present result advances our understanding of the forces exerting their influence on the

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structure of the lexicon and the conceptual network. Moreover, this study constitutes a step on the way to reaching a well-articulated formulation of the incidental processes leading to the formation of associations during natural language use.

Acknowledgements

This research was funded by the German-Israeli Science Foundation Grant #567, by NICHD Grant 01994 to S. Bentin through Haskins Laboratories, New Haven, Connecticut and by a doctoral research stipend to Anat Prior from the Israeli Foundation Trustees. We thank Ayelet Landau for helpful comments and discussions, and Gadi Leshman and Ella Ben-Tov for skilful research assistance. Requests for reprints should be sent to S. Bentin, Department of Psychology, Hebrew University, Jerusalem, 91905, Israel.

Appendix A.
Noun pairs used in experiments 1 and 2

The pairs presented are the English translations of the 84 Hebrew word pairs. In Hebrew all items were single words.

First word	Second word	First word	Second word
Doll	Comb	Guitar	Carpet
Balloon	Refrigerator	Grocery store	Perfume
Baby	Engine	Snail	Lake
Clerk	Pan	Aunt	Coin
Tent	Lemon	Carpenter	Cake
Cow	Pear	Colander	Glasses
Elephant	Puddle	Television	Star
Letter	Wine	Pole	Apartment
Bear	Kite	Glue	Barrel
Suitcase	Tie	Ax	Airplane
Spider	Spoon	Window	Torch
Moon	Crate	Scale	Curtain
Trunk	Tower	Butterfly	Paintbrush
Newspaper	Ointment	Bird	Bell
Bat (animal)	Crane	Sprinkler	Tub
Peach	Milk	Cat	Faucet
Beetle	Pencil	Avocado	Album
Mosquito	Jar	Grapes	Scarecrow
Trumpet	Towel	Toy	Handkerchief
Bucket	Sock	Ladle	Gorilla
String	Sink	Trophy	Leaf
Chair	Chalk	Camel	Feather
Poison	Dough	Chicken	Camera
Bench	Fan	Umbrella	Taxicab
Bead	Plant	Bed	Oil
Tractor	Ship	Bowl	Office
Lamp	Shears	Thumb	Coral
Gun	Buoy	Wig	Iron
Knife	Tank	Eagle	Sandwich
Policeman	Butcher shop	Pocket knife	Shutter
Ice-cream	Bottle	Bat (instrument)	Dessert
Pad	Ladder	Lock	Dress

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Appendix (*continued*)

First word	Second word	First word	Second word
Bee	Stand	Pocket	Ball
Piano	Bridge	Telephone	Pliers
Forest	Clown	Screw	Shirt
Grandson	Juice	Patch	Bag
Orange	Valley	Sword	Bathtub
Diary	Broom	Doctor	Coat
Paper	Hanger	Button	Worm
Notebook	Kettle	Dwarf	Pillow
Door	Hammer	Boot	Lighter
Mouse	Cigarette	Ruler	Knapsack

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.actpsy.2007.01.002.

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