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BRIEF REPORTS

Conceptual combinations and relational contexts in free association and in priming in lexical decision and naming

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Words known to have strong associates of a particular relational type were embedded in lists of other words with relations of the same type or in lists of words with relations of a different type (e.g. *close–far* in a list of other opposite pairs or in a list of synonym pairs). In free association, the probability of a response consistent with the relational context was higher than the probability of a response inconsistent with the context. In lexical decision and naming, significant priming was obtained for related pairs of words only when their relation was consistent with the relational context of the list in which they were embedded. The priming effects were obtained when the stimulus onset asynchrony between prime and target words was short (250 msec for lexical decision and 300 msec for naming), indicating that the effects were due to automatic retrieval processes. These findings point to the importance of the particular relations between words in the retrieval of information from memory, an aspect of processing overlooked by current memory models.

Earth–sky, *man–father*, *white–snow*: These combinations of concepts are familiar to us in our real lives and in our cognitive psychology research. The concepts in each pair are highly associated to each other, and these associations are frequently thought of as fixed combinations of concepts without any attention given to the relations that hold the combinations together. However, the relations between the concepts in each pair are quite different: *earth* and *sky* are opposites on a salient dimension of meaning, *father* is a member of the category of *man*, and *white* describes *snow*. In this article, we present data to show that the different relations between concepts can be critically important to the cognitive processes that work with combinations of concepts, and we suggest that the ways in which concepts combine are more flexible than previously believed.

Early models of semantic memory (Anderson, 1976, 1983; Collins & Loftus, 1975; E. E. Smith, Shoben, & Rips, 1974) built into their representations of knowledge fixed relations among concepts. In spreading activation models, which represented knowledge in terms of networks of connections among concepts, a concept like *father* and its category *man* were hardwired together by a link between them. Stronger versus weaker associations were built into the network by placing strength values on the connecting links. In feature models, associations were lists of features—*man* and *father* were related because there was considerable overlap in their lists of features.

The first step in conceiving of the representation of knowledge as something less than "written in concrete" was the realization that associations could depend on context. Roth and Shoben (1983) showed that the most likely associate to a concept was different in different semantic contexts. The most likely animal to be ridden is a horse, whereas the most likely animal to be milked is a cow (see also McKoon & Ratcliff, 1989). Newly learned associations can also be shown to depend on context. Retrieving the information that the word *jam* was on a recently studied list of words is more likely if retrieval takes place in the same context as occurred at study (e.g., the context *traffic* vs. *strawberry*; Light & Carter-Sobell, 1970; see also Tulving & Thomson, 1973).

In this article, we present evidence that the context sensitivity of information retrieval is not limited to concepts but also applies to relations. Unlike the context effects on combinations of concepts that can be described as effects on some aspect of a concept itself (what kind of animal or what kind of jam), the context effects on relations that we investigate in this article are effects mainly external to a concept. All the different theoretical representations of knowledge that have been proposed include ways of expressing relations. Semantic network models encode relations as labels on the links between concepts. Propositional models encode relations as the lead elements of propositions. Feature models encode re-

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lations as features. But when it comes to retrieval of information from the knowledge representation system, the relations are, for the most part, ignored by the models. For example, spreading activation network models assume that activation spreads down all pathways until an intersection of activation between two concepts is found; then the pathway becomes available for evaluation. Anderson (1976, p. 154) reported a number of experiments in which the variable of interest was whether items were linked with different relations or with the same relation; he argued from the results of the experiments that the spread of activation is independent of what kind of relational label is on the links and concluded that the human system does not take advantage of the information offered by the relations among concepts in the rapid, spreading activation phase of retrieval. Similarly, retrieval of information from propositional representations is hypothesized to proceed in the same way whether it is based on relations or concepts (Kintsch, 1988).

The impetus for the studies reported in this article came out of the debate between McNamara (1992a, 1992b, 1994) and us (McKoon & Ratcliff, 1992; Ratcliff & McKoon, 1988, 1994, in press) about compound cue versus spreading activation models of retrieval. In that debate, the probabilities with which associates are produced in free association were used to determine the chains of associations that link concepts in memory and how strong the individual links are in the chains. Our question was: Does free association measure the structure of memory independent of context or is it context dependent? Some indication that free associations may be context dependent can be found in early experiments described by Woodworth (1938, chap. 30). He discusses experiments in which subjects were given an experimenter defined "set" in advance of generating associates. Specifically, the subjects were given a relationship, such as "part–whole" or "coordinate," and then, for each of a list of single words, an associate was to be produced that formed the given relationship (e.g., for an associate of *foot* to form the part–whole relation, *body* would be a possible response). The time required to generate a response decreased through the list, suggesting that the relational context affected the process of generating associates. It was concluded that this kind of result made it impossible to accept any theory of thinking based purely on the concept of association (Woodworth, 1938, p. 791).

Our first experiment was designed to manipulate set (which we call *relational context*) by the other free association responses in a list rather than by a specific instruction about the required relation for words that were to be generated. Subjects were given a list of stimulus words and asked to produce one free associate to each word. All the words of a list had as a high associate a word of a specific relation. For example, in an "opposite" list, all the stimulus words had a word opposite in meaning as a high associate. Some of the stimulus words in a list were fillers, and each of these had a single high associate of the relation specified for the list. Others of the stimulus words in a list were those of experimental interest. These were selected so as to have two high associates, each related in a different way. We hypothesized that list context would affect which of the two associates was produced. For instance, *animal* has the two associates *vegetable* and *dog*; the former might be more likely produced as an associate in a list for which most associates were opposites, and the latter might be more likely produced as an associate in a list for which most associates were members of the stimulus category. The data from Experiment 1 confirmed this hypothesis, showing that free association responses cannot be used to directly measure structures in memory because they are subject to context effects. This finding also motivated further experiments to examine whether relational context can affect fast automatic retrieval processes in lexical decision and naming latency paradigms.

EXPERIMENT 1
Free Association

Method

Materials. Stimuli were chosen to have at least two highly likely responses in free association. Some of the stimuli were chosen from published norms (e.g., Palermo & Jenkins, 1964; Postman & Keppel, 1970), and others were chosen by intuition. For each stimulus, one of the likely responses was associated to it by one of the relations shown in Table 1 and the other response(s) was associated to it by another of the relations shown in the table or some other relation not shown in Table 1. The relations between stimulus and response shown in Table 1 were defined as follows: two words that are opposite on some salient dimension of meaning; two words that are highly synonymous in meaning; a category word and a member of that category; a member of a category and its category word; an adjective describing a noun; a noun that typically performs some verb action; (e.g., *lion–roar*); a noun described by some adjective (e.g., *grass–green*; and two members of the same category. Examples are shown in Table 2. In addition to these

Table 1
Stimuli and Responses in Experiment 1

List	Relation	Number of Items Scored	Number of Filler Items	Response Probability for Associate in Appropriate List	Response Probability for Associate in Inappropriate List
1	Opposite	24	45	.345	.195
2	Synonym	14	13	.310	.185
3	Category–Member	11	26	.538	.262
4	Member–Category	10	08	.119	.042
5	Adjective–Noun	06	01	.609	.369
6	Noun–Verb	06	09	.269	.269
7	Noun–Adjective	10	00	.468	.346
8	2 Category–Members	18	02	.344	.253
9	Variable	34	00		

Table 2
Data From Experiments 2 and 4

	Experiment 2		Experiment 4		Experiment 2		Experiment 4
	RT	ER (%)	NL		RT	ER (%)	NL
Opposites (*close–far*)				Synonyms (*close–near*)			
Opposite list	532	2.5	468	Synonym list	532	0.8	457
Synonym list	574	2.5	463	Opposite list	565	4.2	467
Unprimed	576	3.3	475	Unprimed	586	1.6	466
Opposites (*soft–hard*)				Adjective–Noun (*soft–pillow*)			
Opposite list	512	0.8	445	Adjective–noun list	544	0.8	454
Adjective–noun list	555	3.3	458	Opposite list	542	0.0	479
Unprimed	587	4.2	469	Unprimed	524	0.8	464
Opposites (*animal–vegetable*)				Category–Member (*animal–dog*)			
Opposite list	533	2.5	454	Category–member list	535	3.3	469
Category–member list	559	0.8	474	Opposite list	533	3.3	473
Unprimed	555	5.0	481	Unprimed	567	3.3	463
2 Category–Member (*red–green*)				Member–Category (*red–color*)			
2 Category–member list	515	0.0	462	Member–category list	532	1.6	470
Member–category list	552	1.6	457	2 Category–member list	563	0.0	477
Unprimed	543	1.6	476	Unprimed	564	0.8	477

Note—RT, lexical decision response time in milliseconds; ER, lexical decision error rate; NL, naming latency in milliseconds.

stimuli that were used for the experimental design, there were also filler stimuli, each of which had one highly likely response that was related to it by one of the relations shown in Table 1.

Eight lists of stimuli were constructed such that each list established one of the relational contexts shown in Table 1. In each list, all of the stimuli had likely responses that fit the list context. For example, for all of the stimuli in List 1, an opposite was a likely response; for all of the stimuli in List 3 (all names of categories), a member of their category was a likely response. The stimuli with two highly likely responses were each placed in two of the lists, one list matching the relation of one of the responses and the other list matching the relation of the other response. For example, the stimulus *animal* was placed in the opposite list (List 1) and in the category–member list (List 3), because two likely responses are *vegetable* and *dog*. Another example is *appear*; it was placed in the opposite list (for the response *disappear*) and in the synonym list (for the response *see*). For some of the stimuli, the second likely response did not correspond to any of the relations listed in Table 1; these stimuli were placed in the ninth list together, and this list had no definable overall relational context. Five of the stimuli had three or four likely responses, and they were placed in the appropriate number of lists (three or four). Most of the lists also included filler stimuli to help establish the list's relational context. The number of stimuli used in the experimental design is shown in Table 1 in the column labeled the "Number of Items Scored." The number of filler stimuli for each list is also shown in Table 1. For some of the relational contexts, we could not find good filler stimuli (e.g., noun–adjective). Therefore, the context of the list was probably not established for the first few items in the list, so scoring these items probably somewhat reduced the observed relational context effect.

Procedure, Subjects, and Design. The nine lists were printed as nine booklets, and either 25 or 26 subjects were tested with each booklet. Each stimulus word was printed beside a blank line. The order of the stimuli was random except that if there were filler items in the booklet, more of them were placed at the beginning of the booklet. The subjects were instructed to write one response only for each stimulus and to write the first response that came to mind, proceeding through the booklet as quickly as possible. No word appeared in a booklet more than once. In all of the experiments reported here, the subjects were students participating for credit in an introductory psychology course.

Results

For each item, the probabilities were calculated that a response of one kind of relation would be given in the relationally appropriate list and that a response of the same kind of relation would be given in a relationally inappropriate list. For example, for *animal*, the probability that an opposite (*vegetable*) was given as a response was calculated for the opposite list (List 1) and for the category– member list (List 3). Similarly, the probability that a member of the category *animal* (e.g., dog) was given as a response was calculated for the category–member list and the opposite list. Any response word of the scored category was counted into the calculation of probability (for example, all kinds of animals were counted as members of the *animal* category). The means of these probabilities are shown in Table 1.

The data show a relational context effect. For every kind of relation except noun–verb, the probability of giving a response of a particular relational association was larger if the responses to the other items in the list reflected the same relational association. For example, opposite responses were given with probability .345 in the opposite list, but they were given with only probability .195 in other kinds of lists. Across the 133 stimuli that were scored, 81% of them showed a relational context effect, an effect significant by sign test ($z = 7.20$).

EXPERIMENTS 2 AND 3
Lexical Decision

Because current models of retrieval from memory place little emphasis on the involvement of the particular relations between words in retrieval processes, there has been little empirical research on this issue. What work has been done has involved slow decision processes, likely to involve conscious processing. Neely's (1977) original investigation of relations in semantic memory found that subjects required considerable time to switch to the relation defined by instructions as correct. Other experimenters have found significant effects of the proportions of different kinds of pairs of words in a list, but only when the stimulus onset asynchrony (SOA) between the first and the second word of a pair was quite long (e.g.,1,000 msec; Becker, 1980; den Heyer, Briand, & Smith, 1985; Neely, Keefe, & Ross, 1989; see Neely, 1991, for a review).

The free association responses obtained in Experiment 1 could also be the result of conscious processes. The subjects might have noticed that the stimulus words of a list had mostly words of a particular relation as responses, and so might have adopted a strategy of making their responses conform. To examine context effects on fast automatic components of retrieval (as in ACT*, Anderson, 1983; the global memory models, Gillund & Shiffrin, 1984, Hintzman, 1988, and Murdock, 1982; the context-integration model, Kintsch, 1988; the compound cue model, Ratliff & McKoon, 1988), Experiment 2 used a lexical decision priming procedure. The prime word of a pair (e.g., *animal*) was presented for only 250 msec. Then, the target word of the pair (e.g., *vegetable*) was immediately presented for a lexical decision. With only 250 msec between prime and target, and with fast responses to the target, retrieval processes can be labeled "automatic" in the Posner and Snyder (1975) sense of automatic (see also Neely, 1977; Ratcliff & McKoon, 1981), and they are the processes modeled by current retrieval theories. List context was manipulated by testing a prime–target pair either in a list in which almost all the other pairs had the same relation as itself or in a list in which almost all the others had some other relation. For example, analogously to Experiment 1, *animal–vegetable* was tested either in a list of mostly other opposite pairs or in a list of mostly category–member pairs. The goal of Experiment 2 was to show differential priming as a function of list context. Experiment 3 checked that the differences in priming obtained in Experiment 2 were indeed due to the context of a list as a whole and not merely to the immediate context of one pair to the next within a list.

Method

Materials. Four sets of 12 triples each were constructed; examples are shown in Table 2. Each triple was made up of a prime and two targets. The two targets were highly associated to the prime in that they were frequently given as responses to the prime in Experiment 1. In the first set of triples, the three words of a triple were a prime, a target with opposite meaning from the prime, and a target with about the same meaning as the prime. In the second set, the prime was an adjective, one target was an opposite of the prime, and the other target was a noun that the adjective could describe. In the third set, one target was an opposite of the prime and the other was a member of the category of the prime. In the fourth set, one target was a member of the same category as the prime and the other target was a category of which the prime was a member. The two members of the same category were words often contrasted as opposites (e.g., *sweet* and *sour*). All four sets of triples are given in the Appendix.

There were also sets of filler pairs of words: 60 opposite pairs, 20 synonym pairs, 20 adjective–noun pairs, 20 category name–category member pairs (e.g., *cereal–oatmeal*), 20 pairs of words from the same category (e.g., *walnuts–pecans*), and 20 category member–category name pairs (e.g., *silk–fabric*). The two words of a pair were highly associated in that the second word was frequently given in response to the first in Experiment 1. There were also a pool of 1,557 single filler words to be used as primes for nonwords and a pool of 657 nonwords.

Procedure. Stimuli were presented on the screen of a PC computer, and responses were collected from keys on the computer's keyboard. The experiment began with a list of 12 prime–target pairs presented for practice at using the response keys (for the pairs in this list in which both prime and target were words, the two words were opposites of each other). Then, there were eight lists for the experiment proper, each list containing 40 pairs. Each list began with an instruction displayed on the PC screen to "press the space bar" to begin the list. For each pair, the prime was displayed for 250 msec, then the screen was erased and the target was immediately displayed one line below where the prime had been displayed. The target remained on the screen until the subject pressed a response key, the ?/ key for "word" and the Z key for "nonword." After the response, the screen was erased, there was a 250 msec pause, and then the prime of the next pair was displayed. The subjects were instructed to respond as quickly and accurately as possible.

Design and Subjects. In Experiment 2, prime–target pairs were tested either in a list context of pairs with the same relation as themselves or in a list context of pairs of some other relation (or in an "unprimed" condition, see below). For each of the four sets of triples, there were two possible list contexts, representing the relations between the prime and its two possible targets. For example, across four of the conditions of the experiment, the prime *close* was tested with the target *far* in a relationally appropriate opposite list and in a relationally inappropriate synonym list, and it was tested with the target *near* in a relationally appropriate synonym list and in a relationally inappropriate opposite list.

For each triple in each of the four sets, there was a total of six conditions. Each of the two targets for a prime could appear either in the list for which the relation matched (e.g., an opposite prime–target pair in an opposite list context) or in the list for which the relation did not match (e.g., an opposite pair in a synonym context), or each of the targets could appear in the "unprimed" condition—that is, with a prime from some other triple (chosen randomly). For half of the subjects, an unprimed target appeared in one of the two possible list contexts for its triple; for the other half of the subjects, it appeared in the other list context. The six conditions for each triple were crossed in a Latin square design with groups of triples (two triples per group, with each of the four sets of triples having six groups) and groups of subjects (10 per group). There were 60 subjects in Experiment 2.

Each of the eight lists instantiated a context for one prime–target relation (see Table 2). Three lists established an opposite context, one list a synonym context, one list a member–category context, one list a category–member context, one list a context of two members of the same category, and one list an adjective–noun context. The eight lists were presented in random order. The 40 pairs of each list were made up of 20 filler pairs that established the list context (e.g., the filler primes and targets were all opposites of each other), 6 pairs for the experimental design (2 pairs that matched the list context, 2 pairs that did not match the context, and 2 unprimed pairs), and 14 pairs for which the prime was a word and the target was a nonword. The 2 pairs that matched the list context were presented in List Positions 9 and 29, the 2 pairs that did not match the context were presented in Positions 12 and 32, and the 2 unprimed pairs were presented in Positions 20 and 40. Each of these 6 pairs was immediately preceded in the list by a filler pair of words (for which the relation between prime and target always matched the list context). The remaining pairs were positioned randomly in the list, with a new randomization chosen for each second subject. No prime or target was presented more than once.

The design of Experiment 3 was the same as that of Experiment 2, except that when each prime–target pair appeared in a list context of a relation different from itself, it was preceded by one filler pair of the same relation as itself. So, although the list context as a whole did not match the prime–target pair, the context of the immediately preceding pair did match. There were 36 subjects in Experiment 3.

Results

Mean response times and error rates were calculated for each subject and each target in each condition; for Experiment 2, these are shown in Table 2. Filler word response times averaged 536 msec (2.6% errors), and nonword response times averaged 641 msec (11.3% errors). There were no significant differences in error rates among any of the experimental conditions shown in Table 2. There was also no significant change in response times for filler words as a function of the test positions around the critical target positions (fillers around targets in Positions 9, 12, 20, 29, 32, and 40, *F*s < 0.00), indicating that any differences among target response times in the different experimental conditions were not due to position in the test list.

As can be seen in Table 2, for most of the kinds of relations, there was a list context effect: response times were speeded when a pair was tested in a list context of other pairs of the same relation as itself relative to a list context of pairs of a different relation. For example, opposites in an opposite list had faster response times than did opposites in a synonym list. The standard deviation of the means in the table is 15 msec, and this variability is apparent across the eight sets of means in the table.

For statistical analyses, we combined all the different prime–target relations together; the mean response time for pairs tested in the same list context as themselves was 529 msec, the mean for pairs tested in a different list context was 556 msec, and the mean for unprimed items was 563 msec. These means were significantly different from each other [$F(2,118) = 10.6$], with a standard error of 5 msec. A planned test showed that the same list context mean was different from the different list context mean [$F(1,118) = 12.6$]. There was little difference between the different list context mean and the unprimed mean, indicating that there was neither significant priming nor significant inhibition with a mismatching relational context.

Experiment 3 was the same as Experiment 2, except that when each prime–target pair appeared in a list context of a relation different from itself, it was preceded by a filler pair of the same relation as itself. In general, the data of Experiment 3 showed the same effects as did those of Experiment 2. The overall mean response time for pairs tested in the same list context as themselves was 550 msec, the mean for pairs tested in a different context was 586 msec, and the mean for unprimed pairs was 585 msec. These means were significantly different from each other [$F(2,70) = 4.6$], with a standard error of 10 msec. This result indicates that the list context effect on response times is attributable to the list context as a whole, not to the relationship for a single pair preceding the target pair (i.e., not to a compound of the preceding relation with the currently tested relation). Correct responses on positive filler items averaged 578 msec (2.4% errors), and correct responses on negative filler items averaged 695 msec (10.3% errors).

Discussion

The results of Experiments 2 and 3 show that the priming effect for a pair of associated words is influenced by relational context: If the relation between the prime and target is the same as the relation between other primes and targets in the list, priming is obtained. If the relation is not the same, the priming effect is diminished to insignificance. Because the SOA between prime and target was short, the observed priming effects are assumed to be the result of automatic retrieval processes. The conclusion, therefore, is that automatic retrieval is affected by relational context. How this effect might be understood in terms of current retrieval models is considered in the General Discussion.

The effect is reminiscent of other "set" effects on lexical decision processes. For example, Smith and colleagues found that priming between close associates is reduced when only shallow processing is required (e.g., letter search, M. C. Smith, 1979; M. C. Smith, Theodor, & Franklin, 1983) or when some test items are difficult to see relative to others (M. C. Smith, Besner, & Miyoshi, 1994). Dagenbach, Carr, and Wilhelmsen (1989) found that priming was affected by what the task was in an experiment that preceded the lexical decision experiment in which priming was measured. Snow and Neely (1987) found that priming was decreased by the inclusion into the experiment of large numbers of pairs for which the prime and target were identical words. With these set effects, all prime–target pairs were affected, whatever their conceptual meanings or relational combinations. In contrast, the context effect observed in the experiments reported here is intrinsically bound up with meanings and the meaningful relations between words. Whether these two kinds of set effects will eventually be found to have the same or different loci in the processes of word recognition and lexical decision is an open question.

EXPERIMENT 4
Naming Latency

It is often suggested that making a lexical decision differs from simply naming a word in that only lexical decisions are subject to context effects (see Balota & Lorch, 1986; Seidenberg, Waters, Sanders, & Langer, 1984). The idea is that naming does not require the binary decision that lexical decision does, and it is only a binary decision that subjects would attempt to facilitate with context information (see McNamara & Altarriba, 1988, and Neely & Keefe, 1989, for discussion of this issue). However, these considerations, to the extent that they are valid, may apply only to slower conscious retrieval processes (see Neely, 1991). If the relational context effect obtained in Experiments 2 and 3 is the result of fast automatic processing, then it should appear in naming latencies as well as in lexical decision response times.

Method

Experiment 4 differed from Experiment 2 in that subjects were asked to name a target word aloud instead of making a lexical decision response. Test lists were constructed exactly as for Experiment 2 except that all prime–nonword pairs were deleted. The timing of presentation of test items was as follows: a test pair was presented with the prime displayed for 300 msec, the target was then displayed until a response (naming the target aloud), and then there was a 1-sec pause before the next prime. Response times were measured with a voice key, and an experimenter sat behind each subject to record incorrect responses. There were 18 subjects.

Results

Error responses, responses longer than 650 msec (about 2 standard deviations above the overall mean), and responses faster than 300 msec were eliminated from the analyses; altogether, this was about 5% of the data. As with the lexical decision experiments, the data showed a list context effect (see Table 2). For pairs tested in a list context of the same relation as themselves, mean response time was 458 msec. For pairs tested in a different list context, the mean was 467 msec. For unprimed pairs, the mean was 471 msec. The means were significantly different from each other [$F(2,34) = 7.3$], with a standard error of 2.8 msec. The same list context mean was shown to be different from the different context mean by planned test [$F(1,34) = 4.5$].

GENERAL DISCUSSION

The data presented in this article are novel and puzzling for most current views of memory and retrieval processes. The main result is that relational context affected lexical decisions and naming responses—tasks that have been argued to reflect automatic processing. When the relation between the prime and target of a test pair matched the list context of relations, then the response to the target was facilitated relative to an unprimed condition. When the relation between the prime and target did not match the list context, there was no significant facilitation. In some way, information about the relation between primes and targets in a list entered into the decision process. The issue is whether current classes of models can be modified to deal with this finding.

Spreading Activation Models

In recent implementations of these models, concepts in memory are represented in a network of nodes, where links between nodes represent relationships. There is no mechanism to have particular kinds of relations influence the spreading activation process (although the relational labels are available for later processing after a pathway has been retrieved). It might be possible to generalize these models by changing relations from labels on links to nodes in the network. *Animal* and *vegetable* would be nodes, and the relation "opposite" would also be a node connecting them. This would result in thousands of opposite nodes connecting all the opposite concepts in memory. Alternatively, there could be only one opposite node for the whole of memory, and every word that was part of an opposite pair would be connected to it. Whichever scheme, there would have to be something to show that *man–woman* and *red–green* were opposites, but not *man–green*. To account for the data from the experiments reported here, activation would be put into either the single opposite node if there was only one or all the opposite nodes for all the opposite pairs; this would give opposite pairs more activation than pairs of words connected by other relations and so lead to a priming effect relative to unrelated words. There would also have to be inhibition of activation for pairs of words that were related but not opposites so that they showed no priming relative to unrelated words. Most difficult would be coming up with some mechanism for suppressing activation when the prime and target of a test pair were related to each other and both had opposites but they were not opposites of each other (e.g., *boy–uncle*). We would expect these pairs not to show priming in an opposite list context. Perhaps the only feasible solution would be the use of higher order units that encoded the whole constellations of components including both words and relationships. But any such model would be quite different from the current semantic network models.

Compound Cue Models

These models were developed from the global memory models to account for priming effects in lexical decision and recognition (and Masson, 1995, has applied a compound-cue-like mechanism to naming, an issue also discussed by Ratcliff & McKoon, 1994). Memory is assumed to represent the strengths between words as cues to memory and their images in memory. Retrieval is a match process by which cues to memory are matched against all items in memory, and an overall value of familiarity is calculated; if the value is above some criterion, a positive response is indicated, and if it is below the criterion, a negative response is indicated. For priming, the cue to memory is assumed to be a multiplicative compound of the prime word (or, sometimes, more than one prime word, depending on experimental procedures), the target word, and the context in which they are tested (see Dosher & Rosedale, 1989; Ratcliff & McKoon, 1988). Compound cue models have not been applied to complex representational issues. However, it is useful here to show how a model with limited representational capabilities might attempt to deal with relational context effects. First, every word that has a strongly associated relation to another word would have to have a high value of strength for that relational context; *animal* and *vegetable* would both have high values of "opposite context" strength. However, relational context strengths plus pairwise associations would not be enough, because of the problem pointed out above; even though the words of a pair such as *boy–uncle* are both opposites of some other word and they are related to each other, no priming would be expected between them in an opposite context. What is needed is for the pair of words to share the same correct context: essentially triples are required (e.g., *boy–opposite–girl*). Dosher and Rosedale (1989) have investigated newly learned triples and argued that a slightly modified version of TODAM (Murdock, 1982) can successfully account for their processing. However, an additional problem is that, to account for the data presented here, the appropriate relation must be induced by list context, and the compound cue models have no obvious way to implement this.

The data presented in this article challenge existing models of semantic representation and process. Previous work has shown that the retrieval of information about the combination of a pair of words is determined not just by the words of the combination but also by the semantic context in which the combination is presented. We have shown that the retrieved information is also controlled by the relational context in which the combination is presented. The models that are commonly used to explain priming effects must now explain relational context effects, and this is complicated because triple associations, not just pairwise associations, are needed. In sum, the models must address the "set" effects that were so important to early research on thinking (Woodworth, 1938).

REFERENCES

Anderson, J. R. (1976). *Language, memory, and thought*. Hillsdale, NJ: Erlbaum.

Anderson, J. R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.

Balota, D. A., & Lorch, R. F. (1986). Depth of automatic spreading activation: Mediated priming effects in pronunciation but not in lexical decision. *Journal of Experimental Psychology: Learning, Memory, & Cognition,* **12**, 336-345.

Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory & Cognition*, **8**, 493-512.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, **82**, 407-428.

Dagenbach, D., Carr, T. H., & Wilhelmsen, A. (1989). Task-induced strategies and near-threshold priming: Conscious influences on unconscious perception. *Journal of Memory & Language*, **28**, 412-443.

den Heyer, K., Briand, K., & Smith, L. (1985). Automatic and strategic effects in semantic priming: An examination of Becker's verification model. *Memory & Cognition*, **13**, 228-232.

Dosher, B. A., & Rosedale, G. (1989). Integrated retrieval cues as a mechanism for priming in retrieval from memory. *Journal of Experimental Psychology: General*, **118**, 191-211.

Gillund, G., & Shiffrin, R. M. (1984). A retrieval model for both recognition and recall. *Psychological Review*, **91**, 1-67.

Hintzman, D. (1988). Judgments of frequency and recognition memory in a multiple-trace memory model. *Psychological Review*, **95**, 528-551.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. *Psychological Review*, **95**, 163-182.

Light, L. L., & Carter-Sobell, L. (1970). Effects of changed semantic context on recognition memory. *Journal of Verbal Learning & Verbal Behavior*, **9**, 1-11.

Masson, M. E. J. (1995). A distributed memory model of semantic priming. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **21**, 3-23.

McKoon, G., & Ratcliff, R. (1989). Semantic association and elaborative inference. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **15**, 326-338.

McKoon, G., & Ratcliff, R. (1992). Spreading activation versus compound cue accounts of priming: Mediated priming revisited. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **18**, 1155-1172.

McNamara, T. P. (1992a). Priming and constraints it places on theories of memory and retrieval. *Psychological Review*, **99**, 650-662.

McNamara, T. P. (1992b). Theories of priming: I. Associative distance and lag. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **18**, 1173-1190.

McNamara, T. P. (1994). Priming and theories of memory: A reply to Ratcliff and McKoon. *Psychological Review*, **101**, 185-187.

McNamara, T. P., & Altarriba, J. (1988). Depth of spreading activation revisited: Semantic mediated priming occurs in lexical decisions. *Journal of Memory & Language*, **27**, 545-559.

Murdock, B. B. (1982). A theory for the storage and retrieval of item and associative information. *Psychological Review*, **89**, 609-626.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, **106**, 226-254.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264-336). Hillsdale, NJ: Erlbaum.

Neely, J. H., & Keefe, D. E. (1989). Semantic context effects on visual word processing: A hybrid prospective/retrospective processing theory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 24, pp. 207-248). New York: Academic Press.

Neely, J. H., Keefe, D. E., & Ross, K. L. (1989). Semantic priming in the lexical decision task: roles of prospective prime-generated expectancies and retrospective semantic matching. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **15**, 1003-1019.

Palermo, D. S., & Jenkins, J. J. (1964). *Word association norms: Grade school through college*. Minneapolis: University of Minnesota Press.

Posner, M. I., & Snyder, C. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium* (pp. 55-85). Hillsdale, NJ: Erlbaum.

Postman, L., & Keppel, G. (1970). *Norms of word association*. New York: Academic Press.

Ratcliff, R., & McKoon, G. (1981). Automatic and strategic priming in recognition. *Journal of Verbal Learning & Verbal Behavior*, **20**, 204-215.

Ratcliff, R., & McKoon, G. (1988). A retrieval theory of priming in memory. *Psychological Review*, **95**, 385-408.

Ratcliff, R., & McKoon, G. (1994). Retrieving information from memory: Spreading activation theories versus compound cue theories. *Psychological Review*, **101**, 177-184.

Ratcliff, R., & McKoon, G. (in press). Sequential effects in lexical decision: Tests of compound cue retrieval theory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*.

Roth, E. M., & Shoben, E. J. (1983). The effect of context on the structure of categories. *Cognitive Psychology*, **15**, 346-378.

Seidenberg, M. S., Waters, G. S., Sanders, M., & Langer, P. (1984). Pre- and postlexical loci of contextual effects on word recognition. *Memory & Cognition*, **12**, 315-328.

Smith, E. E., Shoben, E. J., & Rips, L. J. (1974). Structure and process in semantic memory: A featural model for semantic decisions. *Psychological Review*, **81**, 214-241.

Smith, M. C. (1979). Contextual facilitation in a letter search task depends on how the prime is processed. *Journal of Experimental Psychology: Human Perception & Performance*, **5**, 239-251.

Smith, M. C., Besner, D., & Miyoshi, H. (1994). New limits to automaticity: Context modulates semantic priming. *Journal of Experimental Psychology: Human Perception & Performance*, **20**, 104-115.

Smith, M. C., Theodor, L., & Franklin, P. E. (1983). The relationship between contextual facilitation and depth of processing. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **9**, 697-712.

Snow, N., & Neely, J. H. (1987, November). *Reduction of semantic priming from inclusion of physically or nominally related prime-target pairs*. Paper presented at the meeting of the Psychonomic Society, Seattle.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, **80**, 352-373.

Woodworth, R. S. (1938). *Experimental psychology*. New York: Holt.

APPENDIX
Experimental Stimuli

Opposites	Synonyms	Opposites	Adjectives
appear–disappear	appear–see	beautiful–ugly	beautiful–girl
kind–mean	kind–nice	cold–hot	cold–snow
close–far	close–near	door–window	door–knob
large–small	large–big	dark–light	dark–night
sickness–health	sickness–illness	loud–soft	loud–noise
numbers–letters	numbers–digits	soft–hard	soft–pillow
joy–sorrow	joy–happiness	sour–sweet	sour–lemon
mountain–valley	mountain–hill	sweet–sour	sweet–candy
earth–sky	earth–ground	white–black	white–snow
broad–narrow	broad–wide	deep–shallow	deep–sea
quick–slow	quick–fast	heavy–light	heavy–weight
bitter–sweet	bitter–sour	blue–red	blue–sky

Opposites	Member of Category	2 Members of Category	Member of Category
fruit–vegetable	fruit–apple	sweet–sour	sweet–taste
flower–weed	flower–rose	table–chair	table–furniture
animal–mineral	animal–dog	apple–orange	apple–fruit
man–woman	man–father	red–green	red–color
liquid–solid	liquid–water	snake–lizard	snake–reptile
meat–vegetable	meat–beef	cabbage–lettuce	cabbage–vegetable
boat–plane	boat–yacht	square–round	square–shape
drink–eat	drink–water	lion–tiger	lion–animal
fish–fowl	fish–trout	hammer–saw	hammer–tool
soldier–sailor	soldier–captain	cake–pie	cake–dessert
food–drink	food–bread	car–truck	car–vehicle
doctor–nurse	doctor–surgeon	salt–pepper	salt–seasoning

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