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Spreading Activation Versus Compound Cue Accounts of Priming: Mediated Priming Revisited

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Spreading activation theories and compound cue theories have both been proposed as accounts of priming phenomena. According to spreading activation theories, the amount of activation that spreads between a prime and a target should be a function of the number of mediating links between the prime and target in a semantic network and the strengths of those links. The amount of activation should determine the amount of facilitation given by a prime to a target in lexical decision. To predict the amount of facilitation, it is necessary to measure the associative links between prime and target in memory. Free-association production probability has been the variable chosen in previous research for this measurement. However, in 3 experiments, the authors show priming effects that free-association production probabilities cannot easily predict. Instead, they argue that amount of priming depends on the familiarity of the prime and target as a compound, where the compound is formed by the simultaneous presence of the prime and target in short-term memory as a test item.

An important function of memory is to provide the information necessary for an integrated understanding of the various objects that we encounter. People, words, and objects do not occur in isolation; rather, they occur in some larger context, and memory must provide the means of integrating the individual parts into the unified context. Memory processes use multiple cues to focus on some relevant subset of the vast amount of information in memory. For example, *housewives* in the context of *children* evokes a different set of information than *housewives* in the context of *careers*, or *housewives* in the context of *linoleum* (Light & Carter-Sobell, 1970; Tulving & Thomson, 1973). Currently, two classes of theories have been proposed to explain how focusing is accomplished: spreading activation theories and compound cue theories. In this article, we show that one set of published data (McNamara & Altarriba, 1988), claimed to be consistent only with spreading activation theories, can also be accommodated by compound cue theories.

Spreading activation is assumed to work within a semantic memory network. The network consists of a set of interconnected nodes, with each node representing a concept. Nodes are connected to each other if they are related by prior association (*baby–mother*), if they have been recently studied together (*baby–concrete* in the sentence *The baby hit the concrete*), or if they share semantic features. When a concept is presented to the system, activation of the node representing the concept is increased, and activation spreads through the network, temporarily increasing the activation of nearby concepts. The amount of activation given to nearby concepts is a function of the distance between them and the input concept, or the relative strengths of the links between them and the input, or both. It is this spread of activation that leads to focusing on information relevant to the input. This process also accounts for the phenomenon of priming, whereby presentation of one item—a prime—facilitates responses to a subsequent, related item—the target.

Compound cue theories have recently been proposed by Ratcliff and McKoon (1988) and Dosher and Rosedale (1989). The mechanism by which focusing is said to occur in a compound cue theory is very different from that proposed by spreading activation. There is no temporary activation of information in the long-term memory system. Instead, items presented to the system are assumed to join together in short-term memory to form a compound cue. This compound cue is assumed to have some degree of familiarity, where familiarity is determined by the strengths of associations between the compound in short-term memory and items in long-term memory. The familiarity value is assessed by direct access to a composite long-term memory or by parallel comparisons to all items in long-term memory (depending on specific global memory model implementation). In the compound cue view, focusing is accomplished by means of a matching process that matches compounds formed from items that co-occur in short-term memory against all the items in long-term memory. Priming phenomena are consistent with compound cue theories because a response to the second of two items in a compound will be facilitated by a high familiarity value for the compound. What determines the value of familiarity depends on the task. For recognition, the global memory models spell out in detail how familiarity is computed from factors involved at encoding (i.e., the probability that features

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of an item are encoded or that strength of the item is built up). In lexical decision, familiarity would be based on other factors such as preexperimental familiarity, frequency, learned associations (McKoon & Ratcliff, 1979, 1989), and semantic relatedness or association.

The compound cue mechanism can be implemented in a number of current memory models (Gillund & Shiffrin, 1984; Grossberg & Stone, 1986; Hintzman, 1986; Murdock, 1982). The key to all the implementations is a boost in the familiarity value for a compound when items in the compound are mutually associated in long-term memory. For example, in an implementation of Hintzman's or Murdock's models, associated pairs of items (for two-item compounds) are stored in a single vector or convolution of two vectors, respectively (see Ratcliff & McKoon, 1988). If a prime-target probe matches a stored pair, the value of match will be much larger than if the probe pair partly matches different pairs (e.g., if A–B is stored, then the probe A–B will have a high degree of match; the probes A–C and D–B will have much lower degrees of match). In Hintzman's model, this is because the degree of match involves a cubing operation, and in Murdock's model, a partial match (A–B with A–C) of a convolution is no better than a match between unrelated pairs. The Gillund–Shiffrin model differs from Hintzman's and Murdock's models in that the degree of match for a compound depends both on direct associations in memory between the two words in the compound and on associations between the two words and one intermediate concept (but only such two-step associations, not more than two). Multiplication of the strength of association of the words in the compound with their mutually associated concepts in memory gives the nonlinearity required to boost the match value.

Because priming phenomena have been such a major source of evidence for the spreading activation mechanism, they have provided the grounds for confrontation between spreading activation and compound cue theories. Ratcliff and McKoon (1988) summarized a number of priming effects and their explanations in terms of each class of theory. For example, they showed that both spreading activation and compound cue theories can account for automatic and strategic priming processes, empirical characteristics of the temporal onset of priming, effects of neutral primes, forward and backward priming effects, and priming of ambiguous words. More telling were comparisons between the theories' accounts of the decay function for priming effects and of the range of priming effects.

Decay of priming refers to the finding that, as other test items intervene between prime and target, the amount of facilitation on the target is reduced. According to compound cue theories, decay must occur rapidly because the effect of an earlier prime must be small and must get smaller as the prime is less likely to be included in the compound and weighted less in calculating familiarity. Thus, for the compound cue mechanism, decay is a function of items intervening between prime and target in short-term memory. Spreading activation, on the other hand, is not affected by the contents of short-term memory (but see ACT*; Anderson, 1983). Activation decays as a function of time, and the rate is a free parameter, constrained only post hoc by empirical data. Ratcliff and McKoon (1988) tested these two views of decay against each other. In their experiments, the time delay between an associated prime and target was held constant, and the variable was whether a third, unrelated item intervened between them. By the spreading activation hypothesis, the intervening item should have had no effect on the level of activation of the target, and so no effect on the amount of priming from the prime to the target. But, in fact, the intervening item did reduce the priming effect, as predicted by a compound cue mechanism in which the intervening item would "bump" the prime out of the compound in short-term memory.

The range of priming is defined as the number of concepts across which priming should occur. For example, consider a story that is made up of a number of propositions connected in a linear fashion such that each proposition is directly connected only to the proposition that occurs temporally before it and the proposition that occurs temporally after it (Ratcliff & McKoon, 1988). According to spreading activation theories, input of a concept from one of the propositions should give rise to activation spreading from the input concept through the temporal chain to concepts in the other propositions. The amount of activation at any one proposition will be a function of its distance from the input concept (see Ratcliff & McKoon, 1981, for discussion of the temporal dynamics of this process). The maximum distance at which there will still be significant amounts of activation is not determined by any intrinsic assumption of the spreading activation theories but instead is a post hoc parameter set to account for available data. In contrast, for the compound cue mechanism, the range of priming effects is completely constrained by the architectures of the models in which the mechanism is implemented. In the Gillund–Shiffrin implementation (1984), priming between two concepts can occur only if they are directly connected to each other or if they are separated by no more than one intervening concept. In implementations with Hintzman's model (1986) or with Murdock's model (1982), the two concepts must be directly connected. When Ratcliff and McKoon (1988) tested the range of priming, they found results in accord with the compound cue mechanism. Using concepts from linearly structured stories, they found a strong priming effect when the prime and target concepts were directly connected or separated by only one concept. But priming effects were at a minimum when the prime and target were separated by only four other concepts, and the priming effect was no larger for four intervening concepts than for six.

Both the decay of priming and range of priming functions provide tests that could have potentially falsified the compound cue theories. But empirical results did not falsify these theories; results were exactly as predicted by the compound cue mechanism. However, the results can also be explained by spreading activation theories as long as parameters of those theories are set to accommodate the data. Thus, although compound cue theory has been subjected to more stringent tests than spreading activation, both the compound cue and spreading activation mechanisms are still viable hypotheses.

The purpose of this article is to address another empirical test of the range of priming, a test that has been claimed to show support for spreading activation theories over compound cue theories. The finding has been labeled "mediated priming." A mediated prime–target pair is a pair of words assumed to be connected in memory not directly but only via a third concept. Priming would be said to occur for a mediated pair if the response to the target were facilitated by the prime (where priming is usually measured in lexical decision response times). Mediated priming is claimed to be problematic for (some) compound cue theories because these theories predict that facilitation will occur only when the relation between prime and target is direct, not when it is mediated. In this article, we challenge this claim by arguing that mediated primes and targets are actually directly (although weakly) related.

In previous research designed to support spreading activation theories, mediated priming effects have been predicted from free-association production probabilities. The assumption has been that the amount of facilitation given by a prime to a target can be predicted by the probability that the prime will produce the target (directly or indirectly) in free association. This assumption is explicit in the experimental work of de Groot (1983), Balota and Lorch (1986), and McNamara and Altarriba (1988). For example, if *animal* is produced as a free associate of *deer* with a high probability, then *animal* would be said to be directly associated to *deer*, and *deer* should facilitate responses to *animal*. For indirect associations, a prime is said to be connected to a target via a mediator if the mediator is produced as an associate of the prime, the target is produced as an associate of the mediator, and the target is *not* produced as an associate of the prime. *Deer* and *vegetable* would be said to be mediated if *deer* produced *animal* in free association and *animal* produced *vegetable*, but *deer* did not produce *vegetable*. By spreading activation views, the prime of a mediated pair (*deer*) should facilitate a lexical decision on the target (*vegetable*) via activation spreading among the prime, mediator, and target (although the amount of facilitation would be reduced because the prime and target are not directly connected). Reliance on free association to predict priming effects was stated explicitly by Balota and Lorch (1986): "If the mediated target does not occur across associates given either within a subject or across subjects, then it is highly unlikely that there is a direct association from the mediated prime to the mediated target" (p. 338).

We take this logic (or definition) one step further. If a target does not occur across associates to the prime, and it does not occur across associates of associates of the prime, then it is highly unlikely that there is a mediated association between the prime and target. And if there is no direct or mediated association, then according to spreading activation theories, there should be no facilitation from prime to target. It is critical to note that Balota and Lorch's statement is the only statement we have been able to find that provides an explicit empirical method for determining mediation. No method other than free association has been suggested for finding out whether pairs are mediated or not (except intuition).

We show that, in fact, there is facilitation for pairs of words that fulfill the conditions of no direct or mediated associations. Two conclusions can follow from this demonstration. Either spreading activation accounts of priming are wrong, or free association does not provide an infallible index of associative links in memory. If free association does not provide an infallible index, then it may be that all pairs of words that exhibit priming are actually directly connected in memory (with various degrees of strength), and contrary to previous claims, findings of mediated priming are fully consistent with compound cue theories because they are actually demonstrations of direct priming.

We took as the starting point for our experiments nonmediated prime–target pairs—pairs for which we thought the prime and target should be weakly and directly associated but for which the target would not be produced in free association either as a response to the prime or as a response to any associate of the prime. For these pairs, we used as primes words that were primes in Balota and Lorch's materials. *Deer–grain* is an example. *Grain* is not strongly associated to *deer*; *grain* is not produced as a response to *deer* in free association. But *deer* and *grain* are likely to be (weakly) directly associated because grain is something deer can eat. From the compound cue theories, we predicted that weakly and directly associated pairs of words would show small but significant priming effects. The priming effects depend on the weak direct association in long-term memory that is cued by the presence of both words of the pair in the compound formed in short-term memory. It is the simultaneity of their presence in short-term memory that gives rise to a high value of familiarity. From the reasoning used in previous tests of mediated priming (e.g., Balota & Lorch, 1986), these nonmediated pairs should not exhibit priming because free association shows no connection between the prime and target.

In the first experiment, we used pairs of two types. The pairs of the first type (previously used by McNamara & Altarriba, 1988) had mediating concepts through which activation could hypothetically spread among prime, mediator, and target; *deer–vegetable* with the mediator *animal* is an example. We label these pairs the McNamara–Altarriba pairs. Pairs of the second type, for example, *deer–grain*, did not have mediators through which activation could spread (according to free-association productions); we label these the McKoon–Ratcliff pairs. We measured the facilitation given by the prime of each pair to the target, using lexical decision as the response task. If the spread of activation is measured by free association, then according to spreading activation theories, there should be facilitation only for pairs with mediators, not for pairs without mediators. But for the compound cue theories, the existence of a mediator is irrelevant to the lexical decision response; facilitation should depend only on the familiarity of the pair of words as a compound, and if the familiarity of the two types of pairs is equal, then the amount of facilitation should be equal. (Note that by "familiarity" we mean the theoretical construct postulated by the compound cue theories, which is not necessarily the same as the empirical "familiarity" that is sometimes measured by subjects' ratings.)

Results were consistent with the compound cue view—there was facilitation for both types of pairs and about the same amount of facilitation. In the second experiment, a different and larger set of nonmediated pairs was used, and again there was significant facilitation. These first two experiments showed that facilitation effects are not predicted by free association. The goal of the third experiment was to determine whether facilitation effects might be predicted by another variable, the frequency with which the two words of a pair co-occur in natural language.

In the final section of this article, we discuss how free-association production probabilities fail to predict priming effects and what other variables might be used to predict priming effects.

Experiment 1

Experiment 1 used two sets of materials, the McNamara–Altarriba mediated pairs, previously developed by Balota and Lorch (1986) and McNamara and Altarriba (1988), and the McKoon–Ratcliff nonmediated pairs. Balota and Lorch collected free-association data in order to determine, for each pair, that the target was produced as an associate of an associate of the prime but that the target was not produced as a direct associate of the prime. Balota and Lorch showed that the primes of these pairs facilitated naming responses to the targets, and McNamara and Altarriba showed that the primes facilitated lexical decisions to the targets. Facilitation was measured against a control condition in which primes and targets were randomly re-paired to give an unrelated prime for each target. For these pairs, we expected to replicate McNamara and Altarriba's finding of a small but significant priming effect in lexical decision.

The McKoon–Ratcliff pairs were made up of a prime from a pair used by Balota and Lorch (1986) and McNamara and Altarriba (1988), and a new target. The new target was a word we thought to be weakly and directly related to the prime but not produced directly as an associate of the prime in free association nor as an associate of an associate of the prime. If spreading activation is measured by free-association responses, then spreading activation theories predict either that priming will be reduced for these pairs relative to the McNamara–Altarriba pairs, or that there will be no significant priming. Compound cue theories predict that the amount of priming will reflect the familiarity of the prime–target pairs. If the familiarity for the McKoon–Ratcliff pairs is as high as the familiarity for the McNamara–Altarriba pairs, then the amount of priming will be the same for the two kinds of pairs.

McNamara and Altarriba (1988) showed that priming in lexical decision with their pairs can be obtained only under certain experimental conditions. Their data indicated that the relation between the prime and the target of a mediated pair should not be obscured by the relations between much more highly associated primes and targets. Our goal with the McNamara–Altarriba pairs was simply to replicate the priming previously obtained by McNamara and Altarriba so that we could compare it to priming with the McKoon–Ratcliff pairs. Therefore, we replicated McNamara and Altarriba's experimental design exactly (McNamara & Altarriba, 1988, Experiment 2, mediated-only condition), and in particular, there were no highly associated primes and targets in our experiment.

In presenting Experiment 1, we first describe the results for lexical decision priming, showing that small but significant amounts of priming are found for both the McNamara–Altarriba and McKoon–Ratcliff pairs. Then we describe a number of follow-up analyses of the two sets of pairs, in which we compare them using free-association production statistics and ratings of prime–target relatedness. Among all the follow-up analyses, the only difference between the two kinds of pairs is that the McNamara–Altarriba pairs have mediating concepts. Hence, we argue that there are no confounding variables that might provide spreading activation theories with the means to discount nonmediated priming.

Method

Subjects. The subjects in the lexical decision experiment were 88 students from an introductory psychology course, participating in the experiment for credit in the course. The experiment described here, about 10 min in length, preceded another experiment of about 30 min that is not relevant to this article. One group of 44 students was tested with the McNamara–Altarriba pairs. We used the exact lists of stimuli used by McNamara and Altarriba. The second group of 44 students was tested with the McKoon–Ratcliff pairs that we generated.[1]

Materials. For the group of subjects who were tested with the McNamara–Altarriba pairs, the materials were exactly the same as those used by McNamara and Altarriba, and a complete description is given in McNamara and Altarriba (1988, Experiment 2). These materials included words of the 48 triples from Balota and Lorch (1986) and 48 nonwords.

For the group of subjects who were tested with McKoon–Ratcliff pairs, the materials included the new nonmediated pairs, filler words, and nonwords. The new pairs were constructed from the 48 triples used by McNamara and Altarriba, where each triple was made up of a prime, a mediator, and a target (e.g., *cat, mouse, cheese*). The two words in the constructed pair were the original prime (*cat*) and a new word to be used as target (*meat*). The new target was chosen to share meaning with the prime in somewhat the same way as the old target did, but we intended that there would be no direct mediator between the prime and the new target. For *cat*, for example, we could think of no highly associated mediator that would lead to *meat*, but we thought that the overlap in meaning was about the same because *meat* and *cheese* are both things that animals eat. We constructed pairs like this for 20 of the 48 triples, as follows: *lion–spots, beach–bag, deer–grain, nurse–teacher, war–noisy, eyes–taste, soap–eat, cat–meat, rough–cotton, ceiling–drapes, hard–wool, navy–gun, moon–cold, flower–root, window–roof, school–go, birthday–pudding, oyster–*

[1] Our first effort to replicate McNamara and Altarriba's (1988) findings was not successful, and so it is important to describe details of our procedure exactly and completely. When we failed to replicate, we used test lists that we constructed from the Balota and Lorch (1986) materials rather than McNamara and Altarriba's lists, the experiment was conducted in the winter and spring quarters, the experimenter was sometimes an undergraduate work-study student, and many subjects were participating in their second or third reaction-time experiment in our laboratory. When we succeeded in replicating, we used McNamara and Altarriba's lists, the experiment was conducted in the fall quarter with almost all subjects freshmen, the experimenter was a recent graduate and so older than the subjects, and all subjects were participating in their first reaction-time experiment in our laboratory. We believe that the difference between succeeding and failing to replicate was due to reduction in variance as a result of using motivated, serious subjects.

bracelet, lemon–salty, summer–rain. The filler words for the subjects who were tested with the McKoon-Ratcliff pairs were chosen from triples that were not used to form the McKoon-Ratcliff pairs, and the nonwords were chosen from those used in the McNamara and Altarriba lists.

Procedure. All test items were presented on a cathode ray tube (CRT) screen and responses were collected on the CRT keyboard. Stimulus presentation and response recording were controlled by a real-time computer system.

The experiment began with 30 word–nonword test items for practice. Then the 120 test items of the experiment proper were presented. To begin the practice items, and before the first and the 61st test items, the instruction *Press the space bar when ready* was displayed on the CRT screen. When the space bar was pressed, the test items were displayed one at a time. Each test item remained on the screen until a response key was pressed, then the test item was erased, and if the response was correct, the next test item appeared after a 100-ms pause. If the response was not correct, the word *ERROR* was displayed for 1,500 ms followed by a pause of 1,000 ms before the next test item. Subjects were instructed to press the ?/ key on the keyboard to respond "word" and the Z key to respond "nonword." They were instructed to respond as quickly and accurately as possible. This procedure is the same as that used by McNamara and Altarriba.

For the subjects with McNamara–Altarriba pairs, the test lists were those constructed by McNamara and Altarriba to have no directly related test pairs; all related pairs of words were related through a mediator and not directly (see McNamara & Altarriba, 1988, Experiment 2). A complete description of the test lists is given in McNamara and Altarriba (1988). To summarize, the lists contained 12 related pairs (e.g., *cat–cheese*), 12 control pairs (unrelated words), 24 nonword–word pairs, and 24 word–nonword pairs. The words of each pair were presented one immediately after the other in the test list, and thus the pairings were not apparent to subjects in any obvious way.

The test lists for the McKoon–Ratcliff pairs were constructed in the following way: The first 60 test items comprised 5 experimental targets immediately preceded in the test list by their related words (e.g., *cat–meat*), 5 targets immediately preceded by a control word (e.g., *sky–meat*), 10 filler words followed directly by nonwords, and 10 filler words preceded directly by nonwords. These 30 pairs were placed in the test positions in random order. The second 60 test items were arranged in the same manner.

Design. Assignment to the two groups, one receiving McNamara–Altarriba pairs and one McKoon–Ratcliff pairs, was random according to arrival time at the lab, except that the number of subjects in each group was kept approximately equal. For the group of subjects who received McKoon–Ratcliff pairs, there were two experimental conditions: The target was preceded in the test list either by its related prime or by a control word. The control word was a prime for some other target. The experimental conditions were crossed with sets of pairs (10 per set) and groups of subjects. For the groups of subjects who received the McNamara–Altarriba pairs, the design was somewhat more complicated (see McNamara and Altarriba, 1988) but could be treated in the same way as for the McKoon–Ratcliff pairs, with each target preceded by its related prime or a control word (the control word was a prime for some other target).

Results

Means were calculated for each subject and each item, and means of these means are shown in Table 1. Analyses of variance were performed on these means, with both subjects and items as the random variables, and $p < .05$ was used throughout. One of the McKoon–Ratcliff pairs was deleted from the analyses for reasons given in the Materials Analyses section. However, the pattern of results (and the significance of the effects) did not change whether or not this item was included.

Table 1
Response Times (RTs in Milliseconds) and Error Rates (ER in Percentages) for Targets From Experiment 1

	Mediated pairs		Nonmediated pairs	
Condition	RT	ER	RT	ER
Related	570	3	562	2
Control	584	5	575	6
Word filler	575	2	574	2
Nonword filler	702	13	707	9

As can be seen in the table, the amount of facilitation given by a related word to its target is 13 ms with the McKoon–Ratcliff nonmediated pairs and 14 ms with the McNamara–Altarriba mediated pairs, in both cases remarkably close to the 14 ms of facilitation obtained by McNamara and Altarriba (1988, Experiment 2, mediated-only). Analyses of variance showed the amount of facilitation significant, $F_1(1, 86) = 5.3$ with subjects as the random variable, and F_2 $(1, 38) = 4.1$ with items as the random variable. The *F*s for the main effect of the two groups of subjects (one group for the McNamara–Altarriba pairs and one for the McKoon–Ratcliff pairs) and the *F*s for the interaction of the two variables were less than 1. The standard error of the response time means was 4.3 ms. For error rates, all *F*s were less than 1. These analyses included only the 20 of the McNamara–Altarriba pairs that had the same prime as the McKoon–Ratcliff pairs.

Materials analyses. The results of Experiment 1 suggest that an associated prime can facilitate the lexical decision on a target when, by looking at free-association production probabilities, it appears that the two words are neither strongly directly associated nor associated through a mediator. As previously argued, it is difficult to account for this result with standard spreading activation models if we assume that priming is predicted by free-association production probabilities. Free association is the only method of determining connections between concepts that has been offered as a predictor variable with which to account for priming effects with spreading activation. Without free association, it is not clear how spreading activation theories can predict when facilitation should and should not occur. However, several questions can be raised about the McKoon–Ratcliff pairs of words that were generated for Experiment 1. In this section, we address these questions.

First, it might be the case that the prime and target for the McKoon–Ratcliff pairs were more strongly associated than the prime and target for the mediated pairs, or that, despite our intentions, there actually were mediators for the McKoon–Ratcliff pairs. To rule out these possibilities, we asked subjects to generate free associations to the primes, using the same procedure that was originally used by Balota and Lorch (1986) for the mediated triples.

Two questionnaires were constructed, one for the prime word (e.g., *cat*) of 10 of the McKoon–Ratcliff pairs used in

Experiment 1 and one for the prime word of the other 10 pairs. Ninety subjects were each given one of the questionnaires and asked to write down eight associates for each prime, and in addition, they were asked to try not to generate the associates from their own responses but rather to generate associates from the prime words directly. On the questionnaires, each prime was presented on one line, eight blank lines followed, then the next prime and eight blank lines, and so on.

The responses on the questionnaires were scored in four ways. For the original McNamara–Altarriba mediated triples, we searched for the mediators and the targets, and for the McKoon–Ratcliff pairs, we searched for the targets and any possible mediators. For example, for the prime *lion*, we searched for *tiger, stripes, spots*, and any possible mediator between *lion* and *spots*, such as *leopard*.

For the McNamara–Altarriba mediated triples, the mediator should be given frequently (Balota & Lorch, 1986), and this is what we found. Out of 900 possible chances (10 primes per subject for 90 subjects), the mediator was given as a response 402 times (45%). For these triples, Balota and Lorch found that targets were never given as responses to the primes. However, in our questionnaires, 1 of 45 subjects gave *cheese* in response to *cat*, 3 gave *carpet* in response to *ceiling*, 2 gave *necklace* in response to *oyster*, and 2 gave *sweet* in response to *lemon*; this amounts to 0.8%.

For the 20 McKoon–Ratcliff pairs, 1 of 45 subjects gave the target as a response to the prime for each of four primes (*lemon, flower, moon*, and *war*). This pattern of a few targets generated as associates closely matches the pattern for the McNamara–Altarriba targets. However, for one of our pairs (*navy–gun*), the target was given by 6 of 45 subjects. This item was the one eliminated from analyses of the response time data.

In searching the responses to the primes for the McKoon–Ratcliff pairs, we looked for responses that could have been possible mediators between a prime and its target (e.g., a mediator between *deer* and *grain*). We found only one such response, *leopard* as a mediator between *lion* and *spots*, given by only one subject. We also tabulated the data to obtain the four most frequently given responses for each prime word (after first eliminating responses that were the targets or the mediators for the mediated targets). Questionnaires were constructed with the four responses for each of 10 of the primes (40 words in all). Twenty subjects were asked to give four associates to each of these 40 words. Of the 3,200 responses ($20 \times 4 \times 40 = 3{,}200$), only two were the McKoon–Ratcliff targets for the original prime word. It appears, therefore, that free association does not produce any mediators between the McKoon–Ratcliff prime and target that could account for significant priming effects.

Another possible problem with the McKoon–Ratcliff pairs might be that the McKoon–Ratcliff target was a high associate of the McNamara–Altarriba target. In other words, for the prime *cat* with the mediated target *cheese, meat* might be an associate of *cheese*. If this were the case, then the reason for the facilitation of responses to *meat* might be activation spreading through the original mediator and the original McNamara–Altarriba target to the McKoon–Ratcliff target. To check this possibility, we used another set of questionnaires with the McNamara–Altarriba target as the word to which associates were given, and we counted the number of times the McKoon–Ratcliff target was given as an associate. For 19 subjects who each generated four associates to the McNamara–Altarriba target, only 4% of the time was the McKoon–Ratcliff target given. Elimination of the five items that accounted for most of the generated McKoon–Ratcliff targets from the analyses of the lexical decision priming data still showed significant amounts of facilitation for the McKoon–Ratcliff as well as for the McNamara–Altarriba pairs (and no interaction between amount of facilitation and type of pair).

Another way to compare the McKoon–Ratcliff prime–target pairs to the McNamara–Altarriba prime–target pairs is to ask subjects to rate "how related" are the two words of a pair. It is possible that empirical relatedness ratings might reflect the theoretical construct of familiarity used in compound cue theories. Thus, it is possible that relatedness ratings might predict the amount of facilitation on target responses. To check this possibility, we constructed another set of questionnaires with pairs of words for subjects to rate (on a scale of 1 to 7, with 7 being *most highly related*). There were two questionnaires, each with 10 of the McKoon–Ratcliff pairs, 10 of the McNamara–Altarriba pairs, 15 pairs of highly associated words such as *thin–fat* (taken from the highly associated pairs used by McKoon & Ratcliff, 1979), and 15 pairs of words for which there was no obvious relation (e.g., *games–round*). Twenty subjects were tested with each of the questionnaires. The mean rating for the McKoon–Ratcliff pairs was 3.16; for the McNamara–Altarriba pairs, 2.61; for the high associates, 3.5; and for the unrelated words, 1.1. Analysis of variance showed the difference between ratings on the McKoon–Ratcliff pairs and the McNamara–Altarriba pairs marginally significant, $F_2(1, 19) = 3.7$, but the difference was due to only four of the pairs. Eliminating these pairs from the analysis led to means of 2.69 for the McKoon–Ratcliff pairs and 2.65 for the McNamara–Altarriba pairs, and to an F_2 value less than 1. Eliminating these four pairs from the analyses of the lexical decision response times did not change the pattern of results; the amount of facilitation for the McKoon–Ratcliff pairs was still 14 ms, and the effect was still (marginally) significant. We also calculated the correlation between the mean rating for each word pair and the mean amount of facilitation for that pair from Experiment 1. For the McKoon–Ratcliff pairs, we found $r = -.14$, and for the McNamara–Altarriba pairs, $r = -.044$, both nonsignificant.

The relatedness ratings show that the lexical decision results for the McNamara–Altarriba and McKoon–Ratcliff pairs cannot be explained as due, in some way, to differences in relatedness for the two kinds of pairs. Other conclusions that might be drawn about the ratings are more tenuous. Within the groups of items, the ratings did not correlate with lexical decision response times. But this would probably not be true in general; larger differences in ratings (which might be obtained by including strong direct associates in the experiment) would certainly lead to positive correlations between ratings and response times. It is also not possible to draw a general conclusion about the relation between relatedness ratings and the theoretical construct of familiarity that is part of the compound cue theories. Familiarity is hypothesized to drive the processes involved in fast, automatic decisions like lexical decisions. Relatedness ratings are not fast and automatic but based on slower assessments, and so they probably do not reflect exactly the same information that enters into lexical decisions (see Ratcliff & McKoon, 1982, 1989).

Naming latency. With the original McNamara–Altarriba pairs used by Balota and Lorch (1986) and McNamara and Altarriba (1988), facilitation was obtained between prime and target in both lexical decision and naming latency. Therefore, we checked whether the McKoon–Ratcliff pairs also showed facilitation in naming latency.

In this experiment, words were presented in pairs. Subjects were instructed to read the first word of the pair and then pronounce aloud the second word of the pair. The first word was displayed for 250 ms on a CRT screen and then erased from the screen, and the second word was displayed until the subject pronounced it. The subject then pressed a key to indicate whether the pronunciation had been correct. Then, after a 1,000-ms pause, the first word of the next pair was presented.

There were 15 pairs for practice. Then the 20 McKoon–Ratcliff targets with their primes plus 40 filler targets and primes were presented in random order. The McKoon–Ratcliff targets were presented either with their related primes or with a prime for some other target. Half of the words used as filler primes and targets were words used in the original McNamara–Altarriba pairs, and half were words known to have slow naming latencies from previous data (they were chosen from the 10% slowest from a corpus of about 3,000 words). Half of each kind of filler were primes and half were targets. No word was used more than once in the experiment. The subjects were 36 undergraduates from the same population as in Experiment 1.

The results showed that the McKoon–Ratcliff primes did facilitate naming latency for their targets, by 12 ms (515 ms vs. 527 ms). This difference was significant with subjects as the random variable, $F_1(1, 35) = 9.1$, and with items as the random variable, $F_2(1, 18) = 7.5$, with a standard error of 3.0 ms.

Considerable discussion of priming effects has involved the naming task. However, the compound cue models do not address priming phenomena in naming because of the differences in processing. In the view of these models, naming requires retrieval of a specific test item from one of a large number of verbal items in order for a response to be given, whereas lexical decision requires deciding the degree of familiarity of a test item. Empirically, priming in naming latency has been found for the McNamara–Altarriba pairs (Balota & Lorch, 1986), and the data presented here show that priming can also be found for the McKoon–Ratcliff pairs and that it is of about the same magnitude (Balota & Lorch found an effect of 16 ms). Thus, we have addressed the empirical issue, but theoretical interpretation must wait for a comprehensive model of naming and lexical representation (see Ratcliff & McKoon, 1992a, for further discussion on this point).

Discussion

The result of Experiment 1 is straightforward. The amount of facilitation given by a prime to its target did not depend on the existence in free-association productions of a mediating concept to relate the prime to the target. For prime–target pairs with mediators (as defined by free-association production probabilities), there was 14 ms of facilitation; for prime–target pairs without such mediators, there was 13 ms of facilitation. In previous tests of priming by spreading activation theorists, the amount of facilitation has been said to be predictable from free-association responses: The amount of facilitation should be greater when there is a mediating concept between prime and target than when there is not. For the prime–target pairs in Experiment 1, the probability that a mediator would be given in free association for the McNamara–Altarriba pairs was .45, whereas it was only .008 for the McKoon–Ratcliff pairs. If priming is to be predicted from free association, this large difference should be reflected in the amount of facilitation in the lexical decision task, but it was not.

If free-association production probabilities cannot in general be used to predict priming effects, then they are almost certainly not a direct reflection of associative links in memory. If this is the case, then there is no basis on which to claim that the primes and targets of mediated pairs are not directly connected to each other. It may be that they *are* directly connected, but by links that are not used in free association. If they are directly connected, then finding priming for them is fully consistent with compound cue theories. Thus, the phenomenon of mediated priming is not evidence against these theories.

Experiment 2

The goal of the second experiment was to extend the generality of the nonmediated priming result to a new and larger set of prime–target pairs. The McKoon–Ratcliff targets used in Experiment 1 were generated by intuition, and it was desirable to find pairs that we ourselves had not constructed. In addition, we extended generality by using a slightly different procedure. Instead of requiring a lexical decision response to both primes and targets, as was done in Experiment 1 and in McNamara and Altarriba's Experiment 2, the procedure in our Experiment 2 followed McNamara and Altarriba's Experiment 1 in requiring a response only to the target. The prime was presented 200 ms in advance of the target, and subjects were asked to read it but to make no response to it.

New nonmediated priming pairs were obtained from the words of sentences used by Duffy, Henderson, and Morris (1989). Their sentences (originally used by Stanovich & West, 1981) contained a subject noun and an object noun that were weakly associated. Examples include *climber–summit*, *gardener–trowel*, and *skier–avalanche*. We hypothesized that these words were weakly and directly associated, so that there would be significant priming between them when they were presented as prime and target.

Duffy et al. (1989) did not test for priming between the words in these pairs. However, they did test for priming with whole sentences, including articles and verbs. The prime in their experiments was a phrase made up of the words of a sentence up to the final object noun; these words included the subject noun, a verb, articles, and sometimes an auxiliary verb. The final object noun was presented as a target. In one condition, the sentence formed by the priming phrase and the target object had relatively high familiarity, for example, *The climber reached the – summit.* In a second condition, the sentence formed by the priming phrase and the target object had relatively less familiarity, for example, *The climber watched the – summit.* As Duffy et al. point out, responses to the target noun should be inhibited in the second condition relative to the first, and this is the result they obtained. However, there is no way to determine from this result what would happen if the subject noun alone were presented as the prime (*climber* alone instead of *The climber watched the*). With only the two words, subject noun and object noun as prime and target, they would both certainly be in short-term memory and enter the compound with which memory was probed. But with a whole sentence, it is less certain that the subject noun and object noun would both be part of the compound. In addition, even if the whole sentence does form the compound, we have no a priori way of determining the relative familiarities of the subject–object compound (*climber–summit*) and the phrase–object compound (*The climber watched the summit*). Duffy et al. do provide another condition for comparison, a phrase prime that used a different subject word (e.g., *The people watched the* for the target *summit*). But there is still no way to use this condition to determine priming for the subject–object pair. Again, this is because there is no way to determine the relative familiarities of the different compounds. The familiarities of the two phrase–object compounds (*The climber watched the summit* and *The people watched the summit*) may not be significantly different. In summary, there are no data from Duffy et al.'s experiments upon which to base our prediction that there would be priming for the subject–object pairs from their sentences. Our prediction was based on our intuition that the pairs had some familiarity greater than the familiarity of randomly paired words.

If the subject–object pairs do have familiarity greater than that of randomly paired words, then compound cue theories predict a significant priming effect between the subject as prime and the object as target. The prediction from spreading activation theory depends on whether there is a mediator such that activation can spread among prime, mediator, and target. The only way suggested to determine the existence of such a mediator has been free association. If free-association responses map memory, and if they do not produce a mediator, then either there should be no facilitation from prime to target, or at least the amount of facilitation should be reduced relative to pairs for which there are such mediators (such as the McNamara–Altarriba pairs in our Experiment 1).

Method

Materials. The 44 word pairs were chosen from the sentences used by Duffy et al. (1989). The cue word of each pair was the subject of one of the sentences used by Duffy et al., and the target word was the object of the sentence. Some examples are *wine–decanter, mortician–cadaver, politician–constituency,* and *accountant–ledger.* The complete set of sentences is given in Duffy et al. There were also a pool of 480 words used as fillers and a pool of 600 nonwords.

Procedure. The test items were presented on a CRT screen, and responses were collected on the CRT's keyboard. Test items were presented as prime–target pairs. Each pair was preceded by a warning signal (a row of pluses) displayed for 400 ms; then, on the next line, the prime was displayed for 200 ms; and then, on the next line, the target was displayed. The target remained on the screen until a response key was pressed (?/ for "word," Z for "nonword"). If the response was correct, the warning signal for the next item was displayed after a pause of 700 ms. If the response was an error, the word *ERROR* was displayed for 1,500 ms before a blank interval of 1,000 ms followed by the next warning signal.

The experiment began with 15 practice test items. After that, the items were divided into four blocks. Each block began with an instruction to press the space bar on the keyboard to initiate the block. Each block included 5 or 6 of the experimental targets with their related primes, 6 or 5 of the experimental targets with unrelated primes, 40 pairs for which the prime and target were unrelated words, and 40 pairs for which the prime was a word and the target was a nonword. These pairs were arranged in random order, except that the experimental targets could not occur in the first four positions in the block. Assignment of items to blocks was also random. No word or nonword was presented more than once in the experiment.

Design and subjects. The experimental targets were presented either with their related primes or with unrelated primes. The unrelated primes were the related primes for other targets. This variable was crossed with two sets of items (22 per set) and two sets of subjects. There were 38 subjects, participating in the experiment for credit in an introductory psychology course.

Results

Means were calculated for each subject and each item in each condition. The main result was that responses to targets were faster with a related prime than with an unrelated prime, 643 ms (11% errors) versus 667 ms (12% errors), $F_1(1, 37) = 5.3$ and $F_2(1, 43) = 9.9$. The standard error of the response time means was 7 ms. There were no significant differences in error rates. Mean response time on filler words was 587 ms (5% errors), and mean response time on nonwords was 698 ms (10% errors). Responses to the experimental targets were slower and less accurate than responses to the fillers, we assume because the targets occur with lower frequency in the language.

We checked free associations and relatedness ratings for these pairs of words as we did for the pairs used in Experiment 1. Twenty-five subjects rated how related the 44 pairs were; the correlation between the ratings and facilitation was $r = -.135$. Thirty-nine subjects were each given 22 of the cues and asked to generate eight free associates to each one. Only 0.3% of the time did subjects give a target word as a response, less than for the McKoon–Ratcliff pairs and McNamara–Altarriba pairs used in Experiment 1. (In tabulating the data, we counted synonyms of targets as well as actual targets.) We searched the responses to each prime for words that could serve as mediators—words to which the target might be produced as a free associate—but there were almost no possible mediators. This finding is easiest to document with examples. For the primes of the first five pairs, the three most frequently given free associates were as follows: for the prime *wine–red, white, glass*; for the prime *mortician—death, coffin, black;* for the prime *politician—campaign, corrupt, speech*; for the prime *accountant—money, taxes, numbers*; for the prime *general—army, war, stars.* The targets for these five primes were *decanter, cadaver, constituency, ledger,* and *strategy.* None of the associates given to the primes seems likely to give a target in free association, and therefore none seems likely to serve as a mediator.

Discussion

The nonmediated pairs of Experiment 2 showed a priming effect just as the nonmediated pairs of Experiment 1 did. Experiment 2 used a larger and different set of pairs than Experiment 1, and a slightly different procedure, and so provides generality for nonmediated priming.

The primes and targets in Experiment 2 were the subjects and objects of sentences used by Duffy et al. (1989). The result that these pairs show priming suggests a new interpretation of Duffy et al.'s data. They argued that a subject did not prime its related object, and they based this argument on their finding that a phrase prime containing the subject did not prime the object, relative to a neutral control condition. However, from the compound cue point of view, the absence of a priming effect with a phrase does not necessarily predict the absence of priming with a single word. A phrase prime is not the same as a single word prime, even if the phrase prime adds only what could be seen as "neutral" information to the single word. In the example *The climber watched the summit,* the addition of the seemingly neutral information *The . . . watched the* to the subject *climber* may change the familiarity of the resulting compound. Whereas *climber–summit* may have enough familiarity to give priming relative to a neutral control, a climber watching a summit may not. The effect of neutral information on priming has been documented before. O'Seaghdha (1989) placed function words between primes and their highly associated targets. If the function words were syntactically well formed, then priming effects were larger than if the function words were not syntactically well formed (e.g., *author of this book* vs. *author the and book*). In both cases, the function words were neutral information, but the form of the neutral information significantly affected priming.

Experiment 3

For Experiments 1 and 2, the pairs for which association was weak and direct were chosen on the basis of intuition. The pair *accountant–ledger* sounded good to us in a way that *wine–ledger* did not. There was no independent measure of the familiarity of the pairs. Priming was clearly not predicted by free-association production probabilities.

The purpose of Experiment 3 was to examine an alternative measure of weak association. In the compound cue theories, priming depends on familiarity, as defined in the global memory models. If the notion of familiarity is taken literally, then what is needed is a measure of the frequency with which the subjects in our experiments have encountered or processed a compound in past experience. Of course, there is no such measure, but what is available as the beginning of an approximation is a measure of frequency of occurrence in large samples of written language.

Church and Hanks (1989) have developed a measure they label an *association ratio,* defined for two words x and y as the mutual information (unidirectional) between the two words, $\log_2 [P(x, y)/P(x)P(y)]$. For a sample of language, this ratio compares the probability of observing the words x and y together (joint probability) with the probability of observing each of the words independently. If the two words are likely to co-occur in the sample, then their joint probability will be larger than the product of their independent probabilities, and the value of the ratio will be larger than 1. The probabilities are estimated from samples of the Associated Press (AP) newswire (several million words). The independent probabilities for x and y are estimated by counting the number of times x and y occur in the sample and normalizing by the number of words in the sample. The joint probability of x and y is estimated by counting the number of times that x is followed by y in a window of w consecutive words. If the value of the association ratio for a pair of words is larger than 1, then the words co-occur more often than would be expected by chance. Whether they co-occur significantly more often can be estimated with a t statistic (Church & Hanks, 1989).

For Experiment 3, we chose target words that we know to have highly associated primes (from published norms). For each target, we chose two additional prime words that co-occurred in a six-word window more often than would be expected by chance. The association ratios were based on statistics from a corpus of 6 million words from the AP newswire. We used word pairs for which the association ratio had a high t value and pairs for which the ratio had a low t value. It should be stressed that the corpus on which the t values were based was not large enough to make us confident about the relative sizes of the t values. To provide reliability and generality, it would be necessary to compute the t values from other corpora and for much larger corpus sizes. However, we thought it useful to include both the high and low t values to determine whether there was a priming effect for both or only for the high t-value pairs, and to leave reliability of the split into high and low t values until larger corpora become available.

For each target word used in the experiment, there were four different priming conditions. One prime was a word from which the target would be produced in free association with a high probability. For example, the target *baby* is produced in response to the prime *child* with a high probability (according to free-association norms). The second and third primes for a target were the words that formed pairs with either high or low t values. For the target *baby,* the association ratio for the pair *hospital–baby* had a high t value, and the association ratio for the pair *room–baby* had a low t value. The fourth prime for a target was unrelated to the target; it was a randomly chosen low t value prime for some other target.

The high and low t value primes were chosen so that they would be unlikely to elicit their targets or mediators to their targets in free association. However, the probability of production in free association could not be kept as low as for the nonmediated pairs that were used in Experiments 1 and 2. This was because there were three constraints on the pairs that had to be simultaneously met. First, the targets had to be words for which a highly related associate prime was available from free-association production norms. Second, the targets had to be words that occurred frequently enough in the AP newswire corpus to provide meaningful association ratios. Third, the targets had to have primes that had significant *t* values (and that gave the targets with low probability in free association). For the 40 targets that met these constraints, the probability that the high *t* value primes elicited the targets in free association was .04 (up from .004 for the nonmediated pairs in Experiment 1), and the probability that the high *t* value primes elicited mediators was estimated to be .12 (up from .0025 in Experiment 1).

Method

Materials. Forty target words were chosen such that each had three prime words. For one prime, the target was highly related, as measured by free-association data (from standard norms). For the second and third primes, the target co-occurred more often than would be expected by chance within a window of six words in the AP newswire corpus. For the second prime, the *t* statistic averaged 6.56, and for the third prime, it averaged 1.73. There were primes for which the *t* value was higher, but we did not use primes or synonyms of primes that were associated to the targets in the free-association norms. The 40 sets of words are given in the Appendix. It should be noted, first, that the high and low *t* value primes reflect their origin in the AP newswire corpus, and second, that these primes represent several kinds of associations with their targets. In addition to the primes and targets, there were a pool of 309 words to be used as fillers and a pool of 600 nonwords.

Procedure. Stimuli were presented on a CRT screen, and responses were collected on the CRT's keyboard. The test items included highly associated prime–target pairs. Previous research (McNamara & Altarriba, 1988) suggests that including such pairs in the experiment may lead subjects to adopt strategies that result in the absence of priming for weakly associated pairs. However, McNamara and Altarriba suggested that these strategies can be avoided if responses are required to both the prime and the target. Hence, we used this procedure (similar to the procedure used in Experiment 1). Lexical decision responses were made to both prime and target test items. Test items were presented one at a time, with each item displayed until a response key was pressed. If the response was correct, the next item was displayed after a 100-ms blank interval. If the response was not correct, the word *ERROR* was displayed for 1,500 ms, followed by a 1,000-ms blank interval before the next test item.

The test list was divided into a practice list of 30 items, followed by 10 sublists of 36 items. Each sublist was made up of 4 target words, each preceded in the list by the prime word appropriate to its experimental condition, 16 filler words, and 12 nonwords. Except that the experimental targets could not occur in the first four test positions, the test items were randomly ordered. No test item occurred in the experiment more than once.

Design. There were four experimental conditions. The target word was preceded in the test list by the prime highly related in free-association norms, by the prime related by a high value of the *t* statistic, by the prime related by a low value of the *t* statistic, or by an unrelated word. The unrelated primes were chosen from the low *t*-value primes for other targets. The four conditions were combined with four sets of items and four groups of subjects in a Latin square design. There were 52 subjects serving in the experiment for credit in an introductory psychology course.

Results

Means were calculated for each subject and each item in each condition. Over the four conditions, there were significant differences in the response time means, $F_1(3, 153) = 6.5$ and $F_2(3, 117) = 7.5$, with a standard error of 7.5 ms. The fastest response times occurred with the prime highly related by free-association norms, 500 ms (0.8% errors), and the slowest times with the unrelated prime, 549 ms (1% errors). As predicted, the prime related by a high value of the *t* statistic speeded responses to a mean of 528 ms (2% errors). This mean was significantly different from the unrelated mean, $F_1(1, 153) = 3.9$ and $F_2(1, 117) = 4.3$. The prime related by the low value of the *t* statistic speeded responses somewhat, 532 ms (1% errors), but not significantly so, $F_1(1, 153) = 2.6$ and $F_2(1, 117) = 2.8$. For filler words, the response time mean was 571 ms (2% errors), and for nonwords, 712 ms (8% errors).

As in the preceding experiments, we collected ratings of the relatedness of the prime and target words. The mean of the ratings for the low *t* statistic prime with the target was 3.9, the mean for the high *t*-statistic prime with the target was 4.9, and the mean for the free-association prime was 5.9 (calculated over 64 subjects, who each rated all of the 40 targets, one third with each of the three primes). The correlation between amount of facilitation of response times and relatedness rating was .26 for the low *t*-statistic primes, and −.11 for the high *t*-statistic primes. Free-association responses (four responses for each prime word) were collected from 12 subjects for 35 of the 40 items used in the experiment. The probabilities with which targets and mediators to targets were produced were given in the introduction section.

Discussion

Experiment 3 shows that co-occurrence statistics calculated from large corpora have potential applicability as predictors of priming effects. While the corpus we used was relatively small, we anticipate the availability of larger corpora and further research with them. Meanwhile, we point to co-occurrence statistics as variables that fit naturally with the compound cue theory point of view.

General Discussion

We have previously claimed that compound cue theories of priming can explain at least as much data as spreading activation theories and that therefore compound cue theories provide an important alternative view (Ratcliff & McKoon, 1988; Dosher & Rosedale, 1989). Compound cue theories can explain the many kinds of priming effects outlined in this article. They also inherit all the properties of the global memory models on which they are based and so are embodied in a framework that can account for a range of other kinds of data such as recognition, recall, frequency judgments, categorization, and so on.

Mediated Priming?

Recently, the compound cue approach has been criticized for its inability to account for mediated priming (McNamara & Altarriba, 1988). In this article, we argue that what has been called mediated priming for a prime and target is instead priming resulting from weak *direct* associations between prime and target—priming that is fully consistent with compound cue theories.

The crux of the argument is how to decide whether a prime and target are directly related or related only through a mediator. Previous investigations of mediated priming have depended on free-association production probabilities to determine that a particular prime and target are not related directly but that they are related through a mediator. However, Experiments 1 and 2 indicate that free association does not adequately explain priming. In Experiment 1, for example, production probabilities differed dramatically from the mediated pairs used by McNamara and Altarriba (1988) to the new, nonmediated pairs that we generated. The probability of a mediator appearing in free association was .45 for the McNamara–Altarriba pairs, whereas it was estimated to be only .008 for the McKoon–Ratcliff pairs. But the facilitation in response time was almost identical for the two sets of pairs (13 ms and 14 ms).

If free-association production probabilities cannot by used to distinguish whether a prime and target are directly related or related only through a mediator, then one possibility is to simply abandon free association as a predictor variable for priming. This course of action carries with it two important consequences. First, it leaves compound cue theories free of criticism based on mediated priming; mediated priming can be said to be priming between directly related weak associates. Second, abandoning free association would mean that spreading activation theories lose the only way they have had to predict priming effects from network distance. In previous studies, the only variable that has been used to distinguish direct from mediated priming has been free-association production probabilities. Without free association, spreading activation theories will need to find some new (noncircular) way of predicting priming.

In contrast, compound cue theories do not need free association as a predictor of priming. In fact, from the point of view of these theories, free association would not necessarily correspond exactly to priming because the cue to the memory system is different in the two cases. The cue in priming includes both the prime and target, whereas the cue in free association does not include the target. Instead of free association, compound cue theories find a natural predictor variable in co-occurrence statistics. Although the co-occurrence statistics used in Experiment 3 were based on only a small corpus and the results of the experiment are somewhat tentative, we expect that this approach will be a fruitful one in the future. Compound cue theories can also make use of semantic relationships among words. Fischler (1977) selected pairs of words for which the target was never given as a free-association response to the prime and for which there was very low probability that the same words were given in response to both the prime and target. Fischler found that the amount of priming for these pairs was as large as the amount of priming for pairs that were strongly directly associated according to free-association production probabilities. Semantic relatedness correlated positively with the size of the priming effect, but free-association production probabilities correlated negatively with priming (see also the replication by Seidenberg, Waters, Sanders, & Langer, 1984). Although recent work (McKoon & Ratcliff, 1992; Shelton & Martin, 1992) suggests the need for more research into semantic priming effects,[2] semantic relatedness and co-occurrence statistics are variables consistent with compound cue theories as predictors of priming effects. In sum, abandoning free association as a variable to predict priming is not problematic for compound cue theories but has serious consequences for spreading activation theories.

One response that spreading activation theorists can make is to try to salvage free association. McNamara (1992) attempts to do exactly this by finding potential mediators for the McKoon–Ratcliff pairs and validating them with free-association production probabilities. However, as will be detailed subsequently, these new mediators have different characteristics from the original mediators for the McNamara–Altarriba pairs. Unlike the mediators for the McNamara–Altarriba pairs, the new mediators are not among the highest-probability associates produced from their primes.

To generate the new mediators for the McKoon–Ratcliff pairs, McNamara (1992) thought up potential mediators himself and then tested these potential mediators in free association. For example, consider the McKoon–Ratcliff pair *flower–root*. In the free-association data collected for Experiment 1, subjects did not give any responses to *flower* that in turn would lead to *root*. But McNamara thought that *plant* would be a potential mediator. To show that it was, he collected free-association responses to all three words, the prime, the potential mediator, and the target. He found that the probability that *plant* was produced in response to the prime *flower* was very low (.08), consistent with the free-association data from Experiment 1. But he also found that the probabilities with which the prime and target were produced from the mediator were high (both *flower* and *root* were frequently given as responses to *plant*). Using his method, McNamara (1992, Appendix C) was able to find pathways (connected links for which the free-association production probabilities were larger than zero) among prime, target, and one or more mediators for all but one of the McKoon–Ratcliff pairs.

There are two problems with the use of these production probabilities to predict priming. The first concerns how the probabilities should be measured, and the second concerns how they should be averaged across items. When McNamara (1992) examined his potential new mediators for the McKoon–Ratcliff pairs, he calculated the probability that a me-

[2] Shelton and Martin (1992) failed to find priming in lexical decision for a set of semantically related word pairs (e.g., *spider–ant*). However, using the same set of pairs, McKoon and Ratcliff (1992) did find a significant priming effect. Experiments that attempt to resolve this discrepancy in results are currently in progress.

diator was given in response to the prime by counting responses from all output positions, that is, from all the responses that subjects produced during 1 min. The probabilities reported for Experiment 1 were also based on all eight responses that subjects produced. However, according to earlier work in free association, a better measure is the first-production probability, that is, the probability that a word is produced as the first response to its prime (Keppel & Strand, 1970; Postman, 1970). The earlier researchers were attempting to measure strength of association, and they argued that (instructions to the contrary) responses later in the sequence are likely to be generated not just from the prime but from the prime plus the additional context of the other responses, in chains or other sorts of combinations of prime plus responses (see also Cramer, 1968). In the data from Experiment 1, one subject in response to *beach* produced *sand, water, ball, swimming*, and *umbrellas*, things that might be encountered at the beach, followed by *California, ocean, sea*. This example indicates that later responses may not be independent of earlier responses and that the later responses can be contaminated by earlier responses. Thus, following the earlier work, we would claim that first-production probabilities, not production probabilities calculated over all output positions, should be used in comparing different sets of items and in efforts to model free association and priming processes.

Figure 1 provides examples of differences between the old mediators for the McNamara–Altarriba pairs and the new mediators found by McNamara for the McKoon–Ratcliff pairs. The data are based on the free-association responses collected for Experiment 1, for which subjects were asked to generate eight free associates for each prime. First, the McKoon–Ratcliff pairs were divided into two sets. The first set is made up of the McKoon–Ratcliff pairs for which McNamara found one new mediator for a two-step chain (e.g., for the McKoon–Ratcliff pair *flower–root*, he found the mediator *plant* to give the chain *flower–plant–root*). The second set is composed of pairs for which he found two new mediators for a three-step chain (e.g., for the pair *deer–grain*, he found the chain *deer–animal–farm–grain*).

Figure 1 gives the probabilities with which mediators were given as responses to the primes. For example, for the prime *flower*, the figure shows probabilities of production for the new mediator *plant* that would hypothetically mediate between *flower* and the McKoon–Ratcliff target *root*. For the three-step chains, the figure shows probabilities for the first mediator in the chain. The figure also shows probabilities of production for the old mediators that would hypothetically mediate between the prime and the McNamara–Altarriba target (e.g., *flower–rose–thorn*). In each of these cases, two measures of production probability are given. One is based only on responses that were the first produced to the prime, and the other is based on all eight responses that were produced. For example, for the prime *flower*, the response *plant* might never be produced as any subject's first response, and so its probability of first production would be zero. But *plant* still might be produced quite frequently in later positions in subjects' lists of responses.

Figure 1 shows that the old and new mediators can differ on both measures. Consider first the two-step items. The old

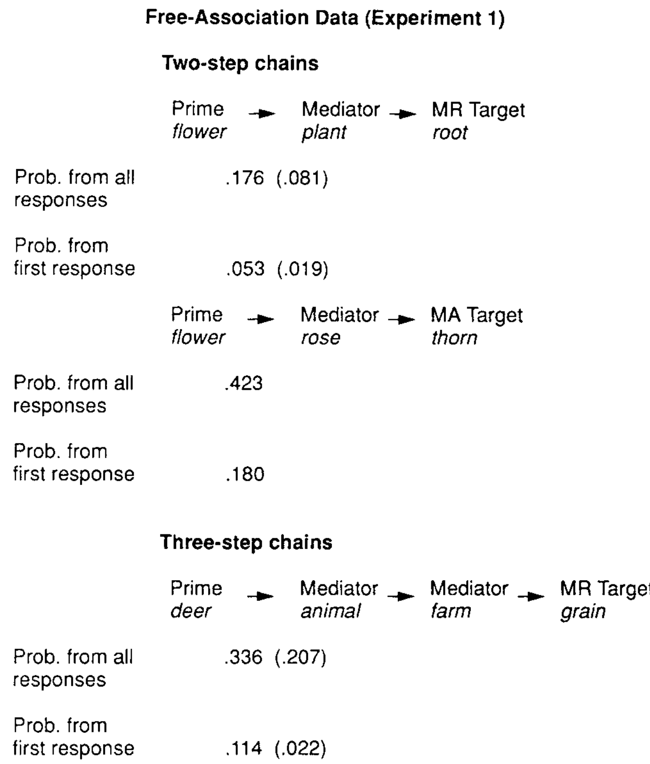

Figure 1. Probabilities of free-association responses to primes for the two-step McKoon–Ratcliff (MR) pairs (top panel); the McNamara-Altarriba (MA; 1988) pairs (middle panel); and the three-step MR pairs (bottom panel). (The numbers in parentheses are the probabilities for pairs that did not include a MA mediator.)

mediators for the McNamara–Altarriba pairs appear among all responses with a high probability (.423), whereas the new mediators for the McKoon–Ratcliff pairs appear among all responses with a lower probability (.176). The probabilities of the mediators being produced as first responses show a greater difference: .180 versus .053. For the three-step items, the differences are not as large. Calculated over all responses, the probabilities are .423 versus .336; and over first productions only, .180 versus .114. For some of the items, the first mediator in the chain constructed by McNamara for the McKoon–Ratcliff pairs was the same word as the mediator for the old McNamara–Altarriba pairs. If we consider only those new McKoon–Ratcliff mediators that were not the same as for the McNamara–Altarriba pairs, then the differences between the new McKoon–Ratcliff mediators and the old McNamara–Altarriba mediators are much larger: .423 versus .081 and .207, and .180 versus .019 and .022.

The probabilities for the old mediators for the McNamara–Altarriba pairs and the new mediators for the McKoon–Ratcliff pairs in Figure 1 show quite different patterns. However, this is not the only problem in comparing the two kinds of mediators. There is also a problem with averaging. Suppose that for some of the two-step chains, the production probabilities were from prime to mediator, .1, and from mediator to target, .8; and that for other two-step chains, the probabilities were the opposite: .8 and .1. Then the average prime-to-mediator probability would be .45, the same as the average mediator-to-target probability. This kind of averaging produces a potential problem for most spreading activation models. The amount of priming from prime to target will be predicted to be much larger if the prediction is based on averages than if it is based on the component probabilities from which the averages were calculated. For example, in the first case, using the components, .1 of the activation from the prime would be passed to the mediator and .8 of that would be passed to the target, that is, .08 would be passed to the target. But using the averages, .45 times .45 would be passed to the target, that is, .20, over twice as much as if the components were used. Inspection of the McKoon–Ratcliff pairs in McNamara (1992, Appendix C) shows that 15 out of 18 cases have one probability in the chain twice as large as another, and 13 out of 18 have one probability three times as large as another. In contrast, for the McNamara–Altarriba pairs, the prime-to-mediator probabilities include few very small values: the probability for most of the items is about the same as the average shown in Figure 1.

The analysis shown in Figure 1 is incomplete; it shows data only for free associations from the prime word to the mediators, not associations back to the primes or from the mediators to and from other mediators or the targets. Nevertheless, the mediators proposed by McNamara (1992) to link the McKoon–Ratcliff primes to their targets clearly pattern differently than the mediators proposed to link the McNamara–Altarriba pairs to their targets. The averages are different, as shown in Figure 1, and these averages are based on different distributions of probabilities across items. McNamara argues that these differences are not important when all the production probabilities for all the links among prime, mediators, and target are placed into a model such as ACT*; even given the differences, ACT* could predict equivalent amounts of priming for the two sets of pairs. However, the modeling has not yet been done, and so this remains an open question (see Ratcliff & McKoon, 1992a).

In summary, the ability of spreading activation models to use free-association production probabilities to explain the priming effects obtained in Experiment 1 appears to us to be an open question. Free-association production probabilities, as they have been defined in previous research, cannot predict the equality of priming for the McKoon–Ratcliff and the McNamara–Altarriba pairs. The new mediators suggested by McNamara (1992) may work, but a specific model such as ACT* has not been tested against the data. Moreover, questions remain about which measure of production probability is most appropriate for modeling, and how probabilities should be averaged across items.

So far, we have considered whether spreading activation models could be made consistent with both the priming and free-association data of Experiment 1. At this point, it seems reasonable to ask whether compound cue models can predict priming effects directly from free-association data. But is it reasonable?

Compound cue models, as we have mentioned, are intended to describe the processes by which cues focus on subsets of information in memory. The whole point of considering the prime and target as a compound is to focus on exactly those associations that make the appearance of the prime and target together in short-term memory more or less familiar. These might not be the same associations that come into focus when the prime is presented alone, in the context of a free-association experiment (Ratcliff & McKoon, 1992b). And if they are not the same associations, then predicting effects of one set of associations (based on the prime–target compound) from a different set of associations (based on a prime–free-association-context compound) will likely fail.

McNamara (1992) shows such a failure. He uses the compound cue theory as implemented in SAM (Gillund & Shiffrin, 1984; Ratcliff & McKoon, 1988). To apply SAM to the free-association production and priming data, connection strengths are set to produce familiarity values that fit the priming data. But once these strengths are set, McNamara shows that they are not consistent with free-association data. That is, if they are set strong enough to give the right amount of priming, then they also predict much higher probabilities of free-association production than are actually obtained in data. Thus, SAM cannot jointly accommodate priming effects and free-association production probabilities. But unlike ACT*, it is not necessarily desirable for SAM to do this; in SAM, different contexts (free association vs. prime–target pairs) may focus on different associations in memory.

Failure of models to predict both free association and priming should not be surprising. There are a number of norms that give frequencies of first-associate production (e.g., Postman & Keppel, 1970). These norms show that sometimes the first associate is given by as many as 70% of the subjects and the second most likely associate by only 4%, and other associates are even less likely. If priming effects were linearly related to production probability, then the priming effect for the most frequent associate would be 15–20 times that of the priming effect for the next most frequent. What would be surprising would be if only the most frequent associate ever gave priming, or if the priming effect for that associate were 20 times larger than for the next most frequent associate.

One clear conclusion to be drawn from this discussion is that there is currently no good account of the relation between free association and priming effects. The conclusion to be drawn about priming theories is less clear. If spreading activation theories can no longer depend on free association to predict priming effects, then these theories will have to find new predictor variables (or rely on intuition). Compound cue theories, on the other hand, already have other predictor variables (co-occurrence statistics, semantic relationships), but these variables are not yet well understood.

Lag Effects

Priming in lexical decision is usually studied when the target is presented immediately after the prime. But priming can also occur when the prime and target are separated in the test list by an unrelated item (Joordens & Besner, 1992; McNamara, 1992; Ratcliff, Hockley, & McKoon, 1985; Ratcliff & McKoon, 1978). This result implies that the compound with which memory is accessed might sometimes contain three test items, not just two. In the discussion that follows, we label the three items preprime, prime, and target, where they are respectively the first, second, and third items presented in a successive triple (embedded in a long sequence of single-item trials).

It should be noted that priming from the preprime item is problematic for ACT*. In ACT*, activation arises from information that is currently being presented to the system. For ACT* to predict priming from preprime to target (as in the sequence *hammer-vase-nail*), both the prime and preprime items would have to be sources of activation. Given the parameters of lag experiments, the preprime would have to stay active for about 1,000–1,300 ms (depending on assumptions about when the prime starts to decay as a source of activation and when the decision process begins on the target). However, assuming that the preprime is active for this amount of time is problematic in light of other data. Ratcliff and McKoon (1988, Experiment 2) examined target–prime–target sequences (e.g., *dog-floor-cat*) and found that if the intervening prime was a word, then priming from the previous target to the current target was eliminated. If the previous target had been active for 1,000–1,300 ms, then priming should not have been eliminated. So, while keeping a preprime item active for 1,000–1,300 ms may allow ACT* to predict some lag effects, it leads to problems with other lag effects.

For compound cue models, if the compound contains three test items, then the relative amounts of priming for all the possible combinations of three items should be predictable. Consider, for example, the preprime, prime, and target sequence *hammer-vase-nail.* If the compound contains all three of these items, then the familiarity of *hammer-nail* should facilitate responses to *nail*, but the facilitation would be less than if the sequence were *vase-hammer-nail.* The reduction in amount of facilitation would come from placing less weight on the preprime than on the prime and less weight on the prime than on the target in the calculation of familiarity. There would also be facilitation for the target *vase* in the sequence *hammer-nail-vase* because of the association of *hammer* and *nail*, but the facilitation would be even smaller, again because of lower weights on the preprime and prime than on the target. Contrary to this last prediction, McNamara (1992) did not find facilitation for a target when the preprime and prime were related to each other but not to the target, and he uses this finding to argue against compound cue theory.

The problem with McNamara's (1992) argument is that it depends on the relative weights of the preprime, prime, and target. If the weights of the preprime and prime combined equal the weight of the target, and the weight on the preprime is greater than half of the prime weight, then McNamara is right—the amount of priming on the target should be large enough to observe empirically. But these are unreasonable assumptions. If the preprime and prime weights combined equal the weight of the target, then if the two items preceding the target are nonwords, the error rate on the target word would be 50%. More reasonably, the preprime and prime combined should be given less than half the total weight, and similarly, the preprime should have less than half the weight of the prime. Under these assumptions, the predicted amount of facilitation is too small to detect empirically.

Table 2 shows familiarity values calculated from the SAM model for preprime, prime, target triples for different values of weights and strengths of associations. In the table, U stands for a word unrelated to any other word in its triple, and R stands for words related to each other. For example, the triple *hammer-vase-nail* is represented as RUR. For the calculations, we assumed that the strength connecting a word presented as a cue to its own image in memory (e.g., *nail* to *nail*) was high and also that the strength connecting a word to a related image (e.g., *nail* to *hammer*) was high; these values were both set to 1.0 in the first column of Table 2. All other strengths were set to the same lower value (e.g., .2 in Column 1; see Ratcliff & McKoon, 1988, Table 1).

Consider the familiarity values in the first column of the table, where the target is given a little more weight than the prime and preprime combined (.6 vs. .3 vs. .1). When the prime is related to the target (URR), the value of familiarity for the target is much larger than when neither the prime nor the preprime is related to it (UUU); the familiarity values are 3.86 versus 3.45, an increment in familiarity due to priming of 0.41. However, in the condition which McNamara claimed a problem for compound cue theories, in which the preprime and prime are related to each other but not to the target (RRU), there is only a small amount of facilitation, 3.50 versus 3.45, an increment of only 0.05. This predicted amount of priming in familiarity for the RRU condition is only about 13% of the amount for the URR condition, and it would not be observable empirically (assuming roughly linear mapping from familiarity to reaction time). If URR gave 30 ms of priming, then RRU would give about 4 ms, which would be too small to observe empirically. At the same time, the facilitation for the RUR condition is about 30% of the UUU condition, which is detectable (though this is less facilitation than was obtained empirically by McNamara, 1992). In contrast, using McNamara's weights (.2, .3, and .5, so that half

Table 2
Familiarity of Various Preprime, Prime, and Target Relations

	Weights				
Triple	.1, .3, .6[a]	.14, .29, .57[a]	.14, .29, .57[b]	.2, .3, .5[a]	.1, .2, .7[a]
UUU	3.45	3.41	26.77	3.34	3.58
RRU	3.50	3.47	26.93	3.44	3.61
RUR	3.57	3.56	27.14	3.53	3.73
URR	3.86	3.77	27.60	3.64	3.90

Note. U = words unrelated to any other word in its triple; R = words related to each other.
[a] Strengths = 1 and .2. [b] Strengths = 5 and .2.

the total weight is on the preprime and prime; see column 4), priming in the RRU condition is 30% of priming in the URR condition, an amount of priming that would be observable empirically.

Further examples are given in the other columns of Table 2. With the weights in the second column of Table 2, the target gets twice the weight of the prime, which gets twice the weight of the preprime. In the fifth column, the target is weighted most heavily, showing priming in the RUR condition but little chance of detecting priming in the RRU condition. Again, it would be difficult to observe any priming in RRU with these values of weights (facilitation between 10% and 15% of URR), but priming of RUR would be observable (facilitation of about 50% of URR). The third column shows that results are similar if much higher strength values are used. In sum, Table 2 shows that if the preprime and prime combined have as much weight (or more) than the target, there should be an observable priming effect for RRU triples, but if the target has only half the weight or less, the effect will be too small to be observed.

McNamara (1992) also considers a second kind of triple, in which the preprime can be a nonword. He argues that compound cue theories cannot account for the effects of a nonword preprime, whereas spreading activation theories can. To understand this argument, it is important to understand what the two classes of theory predict, and why.

Consider a preprime, prime, target sequence in which the preprime can be either a nonword or a word completely unrelated to the prime or target. For spreading activation theories, activation will not spread from a nonword to the prime or target, and activation from a completely unrelated word will not spread to the prime or target. Therefore, responses to the target will not be affected by whether the preprime is a nonword or an unrelated word.

But the data show otherwise; a nonword preprime slows response times to the target (it slows response times equally for targets related to their primes and targets unrelated to their primes). This finding would seem to contradict the spreading activation prediction, but McNamara argues that the slow-down comes from some other processes than spreading activation. He labels these processes "sequential effects," as they have previously been called in the literature (Falmagne, 1965; Laming, 1968; Remington, 1969), and requires that they be explained in the standard way, by whatever reaction time model is appended to spreading activation models.

Compound cue theories could give two different accounts for the effects of nonword preprimes. The first is the same as for spreading activation theories. Sequential effects could be attributed to an appended reaction time model in which nonwords slow responses by changing response criteria. The second is more interesting and comprehensive. We have suggested (Ratcliff & McKoon, 1988) that sequential effects are not due to some separate process but are instead the result of compounding. So a nonword preprime will slow responses to a target because the familiarity value for a compound that includes a nonword will be low—lower than for a compound that includes an unrelated word preprime. This follows from the assumption that associations between nonwords and words are lower than associations between unrelated words. How much lower is a theoretical question and will depend on the weight given to the preprime compared with those for the prime and target. It may be that the difference in the priming effect for word and nonword preprime will be predicted to be small while at the same time an overall slowdown is predicted.

A nonword preprime will reduce the size of the priming effect for a related prime and target, because the values of prime–target familiarity are multiplied with the values of all combinations of preprime with prime and target, and these values are smaller for a nonword preprime than for a word preprime. However, how much the size of the priming effect is reduced depends on the relative weights given the preprime, prime, and target. It may be that the reduction in priming effect is small and unobservable compared to how much the nonword preprime slows responses overall. Moreover, the smaller priming effect will be measured against the slower overall baseline due to the nonword prime. A smaller priming effect against a slower baseline may appear to be the same size in milliseconds as a larger priming effect against a faster baseline. For example, a 30-ms priming effect on a baseline of 500 ms may, given current reaction time models (see Ratcliff, 1978), be equivalent to a 50-ms priming effect on a baseline of 700 ms. Unfortunately, there are currently no data to show exactly what these baseline effects might be for priming in lexical decision.

The assumption that compounding rather than an appended reaction time model accounts for sequential effects in reaction time has a precedent in the reaction time literature. This notion of compounding is similar to the linear model proposed for sequential effects in choice reaction time (e.g., Laming, 1973, Secs. 11.6–11.7). In the linear model, the subjective probability of a particular event is a continuous variable and depends on the previous sequence of stimuli; reaction time depends on this subjective probability. This assumption is similar to the notion that the compound cue tested at any point is a weighted average of prior items. In choice reaction time, it is clear from empirical data that there is a rapid decay of the influence of earlier items. For example, Laming (1968, Figure 8.11) shows that the effect of prior items in a sequence is roughly exponentially decaying as a function of position back in the sequence and that the effect has roughly dissipated by a lag of 2. Thus, the linear model is consistent with the lag effects observed in lexical decision priming studies.

In summary, the effects of a nonword preprime do not allow a clear discrimination between the compound cue and spreading activation models. To test compound cue models for these effects, we would need a model of how baseline changes affect the amount of priming. For spreading activation models, the appeal to sequential process would need some theoretical support from a specific reaction time model.

Conclusion

1. Whether the small priming effects obtained for weakly associated pairs such as *deer–vegetable* are problematic for spreading activation or compound cue theories turns on the issue of how these priming effects are to be predicted. We

have shown that they cannot be easily predicted from free-association production probabilities by any current model. Spreading activation theorists need to demonstrate how free association and priming effects can be jointly modeled, or they will need to find a new predictor variable that makes sense in the context of their theories. Compound cue theorists need more research to further document co-occurrence statistics and semantic relationships as predictor variables in the context of their theories.

2. Compound cue theories can accommodate priming effects over triples of three sequentially presented words, but their success in doing so depends on the weights given to the preprime, prime, and target in the calculation of familiarity for the response to the target. With the reasonable assumption that words are given significantly less and less weight as they increase in the distance with which they precede the target, SAM (Gillund & Shiffrin, 1984) can account for data presented by McNamara (1992).

3. When the preprime that precedes a prime and target is a nonword, responses to the target slow down (McNamara, 1992). Both spreading activation and compound cue theories can account for this finding. Spreading activation theories attribute the slow-down to sequential effects in whatever reaction time model would be appended to the spreading activation memory retrieval model (McNamara, 1992). Compound cue theories could use the same appended reaction time model explanation, or they could assume that the non-word, with its very low familiarity value, was combined with the prime and target.

Spreading activation was first proposed as a general retrieval mechanism by which the memory system could focus on a contextually relevant subset of all the information in memory and by which long pathways of connected information could be retrieved. The activation of items input to the system and items connected to them is intended to provide a focusing process, giving information that can be evaluated by subsequent decision processes or recycled to generate activation of additional information for recall processes. This spread of activation over distance from input information is the primary function of spreading activation. If spreading activation does not serve this function, then its utility is substantially diminished. Both the data reported here and earlier data (Balota & Lorch, 1986; de Groot, 1983; Ratcliff & McKoon, 1988) indicate that activation does not spread over any significant distance.

In contrast, compound cue theories use information in short-term memory to focus on appropriate subsets of information in long-term memory. The information in short-term memory is assumed to form a compound with which long-term memory is probed. The familiarity of the compound determines recognition decisions, and the compound is also used to generate retrieved information for recall tasks. Distance between concepts in memory is represented by the strengths of their mutual associations. In lexical decision, large priming effects reflect a high degree of familiarity of a compound (e.g., *baby–child*), and smaller priming effects reflect lower degrees of familiarity (e.g., *hospital–child*). The presence or absence of mediating concepts is irrelevant for the compound cue theories, because only directly associated pairs (or pairs with one mutually associated item in the Gillund–Shiffrin implementation, 1984) will produce an increment to familiarity in the models.

The compound cue theories and the results of the experiments reported in this article suggest that there are large numbers of weak direct associations in memory. The ubiquity of these associations is consistent with the way we were able to measure them in Experiment 3. Many pairs of words must co-occur more often than would be expected by chance, and identifying them is a matter of finding large enough and diverse enough databases. Experiment 3 provides the beginning of such an effort, using only a relatively small database from a relatively restricted source (the AP newswire). But even with this restricted database, over 300 words co-occur with words like *war* and *school* more often than would be expected by chance.

The compound cue view emphasizes that a word is understood in the context in which it is encountered (i.e., the information that co-occurs with it in short-term memory). In computational linguistics, this view has been summarized by the theme, "You shall know a word by the company it keeps" (Firth, 1957; cited by Church & Hanks, 1989). Hanks (1987) has pointed out that we can understand *bank* by its context *river, swim, boat* or *money, account, savings*. Similarly, we can know *housewife* by the different contexts *linoleum, baby*, or *career*. It should not be surprising that our long-term knowledge contains all of these different associations or that, in context, they are all familiar.

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(Appendix follows on next page)

Appendix
Materials Used in Experiment 3

Highly related free-association prime, high *t*-value prime, low *t*-value prime: target.

1. child, hospital, room: baby
2. children, young, father: kids
3. blade, kitchen, putty: knife
4. blue, night, fireworks: sky
5. brain, heat, radio: wave
6. ceiling, convention, manufacturer: floor
7. city, residents, flames: town
8. doctor, army, public: nurse
9. earth, earthquake, stake: ground
10. grow, power, growers: plant
11. foot, textile, workman: shoe
12. arm, left, amputation: leg
13. bake, piece, candles: cake
14. boy, death, love: girl
15. cars, fire, sound: trucks
16. country, newspapers, conscience: nation
17. crust, apple, cream: pie
18. memory, doubt, image: mind
19. green, acres, plane: grass
20. finger, cash, guard: hand
21. heal, bullet, blood: wound
22. house, vacation, morning: home
23. man, police, affair: woman
24. numbers, calls, protest: letters
25. play, war, season: games
26. priest, separation, mainstream: church
27. lamp, sales, glass: light
28. bed, hours, days: sleep
29. stomach, emergency, flowers: food
30. ocean, air, holes: water
31. door, bedroom, rain: window
32. justice, state, welfare: law
33. leaf, family, branch: tree
34. moon, movie, female: stars
35. music, theme, show: song
36. people, cheering, candidate: crowd
37. porthole, passenger, transport: ship
38. sickness, public, package: health
39. soldier, officer, protest: army
40. tobacco, black, passenger: smoke

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The Publications and Communications Board of the American Psychological Association announces the appointment of Thomas H. Carr, PhD, Michigan State University, as editor of the *Journal of Experimental Psychology: Human Perception and Performance* for a 6-year term beginning in 1994. As of December 15, 1992, manuscripts should be directed to

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