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Effects of Semantic and Associative Relatedness on Automatic Priming

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Models of automatic priming of word identification can be divided into those based on associative relations (e.g., spreading activation) and others based on semantic similarity (e.g., distributed models). In three experiments, associative relatedness was manipulated by presenting asymmetrically associated word pairs in both their forward and backward directions. Priming was comparable in both directions for semantically related pairs. Furthermore, priming was not obtained in either direction when pairs were associated but not semantically similar. The absence of inhibition, practice, and nonword ratio effects suggested that priming was not the result of nonsemantic, controlled processes. These results indicate that semantic similarity, and not associative relatedness, is both necessary and sufficient to produce automatic priming. © 1998 Academic Press

The facilitative effect that a prime word has on the subsequent pronunciation or identification of a related target word was initially described both as an ‘‘effect of association’’ (Meyer and Schvaneveldt, 1971) and as a ‘‘semantic facilitation effect’’ (Neely, 1977). The discussion of whether this priming effect is in fact associative or semantic has since become the subject of some controversy (Shelton & Martin, 1992; McRae & Boisvert, 1996). One motivation for resolving the question of the nature of the priming effect is that this effect has often been used to elucidate fundamental principles about the structure and processes of semantic memory. Specifically, the underlying nature of the priming effect has implications for the plausibility of distributed models of semantic memory.

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Associative relatedness is a normative description of the probability that one word will call to mind a second word (e.g., Postman & Keppel, 1970). Associative relations are assumed to reflect word use rather than word meaning (e.g., ‘‘needle–thread,’’ ‘‘spider–web’’). The source of these associations might be temporal contiguity in verbal or written language (Plaut, 1995) or co-occurrence within propositions (McNamara, 1992). On the other hand, semantic relatedness reflects the similarity in meaning or the overlap in featural descriptions of two words (e.g., ‘‘whale–dolphin,’’ ‘‘duck–chicken’’). Although the degree of associative relatedness and semantic relatedness between two words often vary together, it is possible for words to be either highly associated yet semantically dissimilar (e.g., ‘‘coat–rack’’) or weakly associated yet semantically similar (e.g., ‘‘radish–beets’’).

Theoretical accounts of priming tend to be based on either associative relatedness or semantic similarity. Associative relatedness underlies two very different theories of priming: *spreading activation* (Collins & Loftus, 1975) and *compound-cue* retrieval theory (Ratcliff & McKoon, 1988). Initial explanations of priming described facilitation of word recognition as the result of increased activation of a target word following the passive spread of activa-

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tion from the prime word node to other nodes linked in an associative network (Meyer & Schvaneveldt, 1971). This theory was largely unchallenged until Ratcliff and McKoon (1988) suggested that facilitative priming effects are the result of an associative match between prime and target in long-term memory. Like spreading activation, this compound-cue retrieval theory of priming predicts that priming depends on associative relations between the prime and the target, although the two models differ in their description of the processes which lead to facilitation. In contrast, theories of *distributed memory* focus on semantic similarity, an implicit feature of the overlap in featural representations or patterns of activation. Distributed models of word retrieval produce facilitation effects as a result of a decrease in the amount of time required to make a shift in semantic space between similar words (Kawamoto, 1988; Masson, 1991, 1995). In stark contrast to other models of priming, the dependence of the priming effect on semantic similarity is critical to distributed models of semantic memory.

These three models of priming—spreading activation, compound-cue, and distributed memory—all describe facilitation as the result of a passive, automatic process that reflects the organization of semantic memory. However, priming can also result from nonsemantic factors including grammatical class (Goodman, McClelland, & Gibbs, 1981), expectancies (Neely, 1977), and episodic memory (Ratcliff & McKoon, 1988). Evidence of nonsemantic facilitation has led to the formulation of a two-process theory of priming: a fast process that occurs automatically, without intention or conscious awareness, and a slower, limited-capacity process requiring conscious attention (Posner & Snyder, 1975). Unlike automatic processes, controlled processes such as expectancy-based generation (Posner & Snyder, 1975) and postlexical matching (Neely, 1991) do not necessarily reflect features of semantic organization or processing. Therefore, conclusions about semantic memory structures should be limited to priming phenomena that are the result of primarily automatic processes.

Several methods are known to minimize controlled influences on priming or to diagnose the relative degree of controlled processing. Sufficient resources (e.g., time, attention) and incentives (e.g., cost–benefit ratio) are required for the use of controlled mechanisms. A short stimulus-onset asynchrony (SOA, Neely, 1977), a low proportion of related primes (Tweedy, Lapinski, & Schvaneveldt, 1977), a pronunciation task instead of a lexical decision task (West & Stanovich, 1982), and a continuous presentation instead of a pairwise presentation (Shelton & Martin, 1992) are all experimental manipulations that decrease facilitation by diminishing the participant's ability or incentive to use controlled mechanisms. In contrast, these manipulations have no effect on facilitation resulting from automatic processes that are not under the participant's control. Furthermore, the ''cost'' of using a limited-capacity attentional mechanism, called *inhibition,* can be measured as the difference in latency to read or to classify a target item when it is preceded by an unrelated prime word relative to a neutral prime item (e.g., a row of x's, the word ''blank''). As there is no such cost attached to an automatic process, the amount of inhibition should reflect only the degree of controlled processing in the task (Neely, 1977). Thus, it is possible to identify and manipulate that part of the priming effect which reflects automatic semantic processing.

An understanding of the nature of priming under automatic conditions will help distinguish between models of semantic knowledge that are based on associative relatedness (e.g., Collins & Loftus, 1975) and others that rely solely on implicit semantic similarity (e.g., Masson, 1995). The most straightforward way to distinguish between the effects of semantic and associative relatedness is to vary these characteristics orthogonally across items in the stimulus set and to compare the resulting priming magnitudes. Several studies have attempted to control for semantic similarity while varying degree of associative relatedness, with conflicting results (Fischler, 1977; Shelton & Martin, 1992). Fischler (1977) reported priming for pairs that were semantically related, based on the sharing of a number of semantic features, but that were not normatively associated. Although the word pairs may have been associated via another word or words (mediated priming; e.g., Balota & Lorch, 1986), Fischler quantified this ''mutual relatedness'' factor and found it to be quite small. Furthermore, Seidenberg, Waters, Sanders, and Langer (1984) reported priming on both lexical decision and pronunciation tasks using Fischler's stimuli, whereas mediated priming effects typically are not found with lexical decision tasks (Balota & Lorch, 1986). These studies demonstrate that under some conditions it is possible to obtain reliable priming in the absence of associative relatedness; however, the nature of the mechanisms underlying this effect are not clear.

Shelton and Martin (1992) suggested that Fischler's priming for semantically related but unassociated word pairs reflected controlled processing. Shelton and Martin manipulated and assessed the impact of controlled processing on a lexical decision task, as described above, and failed to detect reliable priming with unassociated word pairs. Taken at face value, this finding supports priming theories based on associative relatedness. However, a closer examination of their stimuli reveals an important confound in their experiments: the unassociated word pairs (e.g., ''dirt–cement,'' ''bird–fish,'' ''duck–cow'') seem to have far fewer semantic features in common than do the associated word pairs (e.g., ''hill–mountain,'' ''blanket–sheet,'' ''road–street''). In other words, the authors did not adequately equate semantic similarity in their two lists of stimuli. Therefore, an alternative explanation for their results is that priming depends on the degree of semantic similarity between the words; this interpretation would be consistent with semantic memory models based on semantic relatedness.

The methodological challenge is to construct stimulus sets which are perfectly matched in terms of semantic similarity or featural overlap, but which differ in degree of associative relatedness. The difficulty in this design is the natural confound between these variables in language. An alternative solution to the same problem is to use a single set of stimuli in which the degree of associative relatedness varies *within* each word pair due to an asymmetric association between the words. Priming of asymmetrically associated word pairs has been studied in a variant of priming called *backward priming*[1]. Backward priming is the facilitation of a target by a prime word that is asymmetrically associated with the target, such that the target word (e.g., flea) calls to mind the prime word (e.g., dog), but not vice versa. While a pair of words can be asymmetrically associated, the degree of semantic similarity between the two concepts is symmetrical[2]. The use of asymmetrically associated word pairs provides a good opportunity to explore the effects of associative and semantic relatedness on priming, because strength of association can be manipulated within each word pair, while semantic relatedness is held constant. For this reason, the backward priming paradigm can distinguish models of semantic memory based on associative relatedness from those based on semantic similarity.

According to spreading activation, automatic priming should be limited to the direction of links in the associative network, and

[1] This use of the term backward priming is distinct from studies of the facilitative effect on a target by a subsequently presented ''prime'' which demonstrate a temporal overlap of word processing (Kiger & Glass, 1983).

[2] Tversky (1977) argued for a featural contrast model of similarity to account for his finding of asymmetrical ratings which belie the view of similarity as a function of distance in representational space. He showed that the salience of particular items, and consequently the similarity relations between them, can be manipulated via the context of presentation (such as grouping effects) or by manipulations in the salience of typicality of the stimuli themselves. With regard to the current study, however, there were neither context effects (as shown in Experiment 2) nor systematic variations in typicality. Furthermore, Tversky's findings relate to the task of producing an explicit similarity judgment, which may be affected by processes beyond the underlying similarity of the representations themselves.

therefore, to the forward direction of association. In other words, associative models of priming predict an asymmetric priming effect that mirrors the asymmetry in association. However, in distributed models without explicit associative links, symmetrical priming is expected for asymmetrically associated word pairs presented in either direction, because the mechanism for priming depends on the featural overlap (i.e., semantic similarity) between the two words and not on the strength of either forward or backward associations.

Several studies have reported reliable backward priming, although the mechanisms underlying the effect have not been clear. Seidenberg et al. (1984) found backward priming with a lexical decision task (500 ms SOA) but not with a pronunciation task. This study was unique in its use of word pairs that had no overlap of semantic features; most of these pairs were compound words or idiomatic two-word phrases separated into their constituent parts (e.g., ''high–way,'' ''coat–rack''). Thus, priming for these semantically unrelated words depended entirely on associative relatedness. Using the same stimuli, Shelton & Martin (1992) obtained backward priming under controlled conditions but not under automatic conditions. These studies implicate controlled processes as the mechanism underlying backward priming.

However, several findings are inconsistent with the interpretation of backward priming as a controlled priming phenomenon. First, Koriat (1981) found an increase in forward priming, but not backward priming, across experimental blocks (lexical decision task, 650 ms SOA). If backward priming were the result of controlled processing, an increase in the effectiveness of a strategy with practice should cause an increase in priming over blocks. Second, using auditory primes preceding visual targets, Peterson and Simpson (1989) found backward priming on a pronunciation task with a short interstimulus interval (ISI; 100 ms) but not with a long ISI (300 ms). Although the total SOA when auditory primes are used is necessarily longer than the range that typically characterizes automatic priming, the ability to utilize controlled processes should increase as the interval between the prime and target increases (Neely, 1977); backward priming with a short ISI is certainly suggestive of automatic processing. Thus, it appears that backward priming may not be solely the result of controlled processing, as initially argued. It may also be relevant that neither Seidenberg et al. (1984) nor Shelton and Martin (1992) used word pairs that were semantically related, while both Koriat and Peterson and Simpson did.

In the present study, forward and backward priming effects were measured using word pairs that shared semantic features, but were asymmetrically associated according to word association norms. The conditions of priming were designed to be primarily automatic, with the use of a low proportion of related primes and a short SOA with a lexical decision task (Experiments 1 and 2) and a pronunciation task (Experiment 3). Additionally, the automatic nature of task was verified in three ways. First, the effects of controlled processing were assessed by measuring inhibition of unrelated primes relative to neutral primes. Second, changes over the course of the experiment attributable to increases in controlled processing with practice were assessed by comparing priming effects over six experimental blocks. Third, the effects of a manipulation of controlled processing, the nonword ratio, were assessed in Experiment 2. In Experiment 3, priming for semantically similar words was compared directly to priming for the semantically dissimilar words used by Seidenberg et al. (1984). Evidence of comparable backward and forward priming only for semantically similar words would favor models of semantic memory based on semantic relatedness.

EXPERIMENT 1

In Experiment 1, forward and backward priming effects were measured for word pairs that were asymmetrically associated and, like those used by Koriat (1981), were semantically related. A lexical decision task with a short SOA (250 ms) and a low proportion of related primes (33%) was used to minimize potential influences of controlled priming. Additionally, both facilitation and inhibition were measured in relation to a neutral prime, so that the relative effects of controlled processing, if any, could be assessed by the magnitude of inhibition.

Methods

Stimuli. Word association norms were collected for 160 words, from 80 pairs of semantically related words. Each participant (N = 200) received a subset of 18 unrelated words, and was asked to write the first four words that came to mind for each item. Responses were scored as follows: if the target word (i.e., the related word in the pair) was written first, the score was 4, if the target word was written second, the score was 3, if the target word was written third, the score was 2, and if the target word was written fourth, the score was 1. If the target word was not given as a response, the score was 0. Median association scores across participants were computed for each item.

For each pair, median scores for each word of the pair were compared. Items were classified as asymmetrical either if the median rating for one of the two words in the pair was 0 or if the difference between the two scores was greater than 1.5. Items were classified as symmetrical if the difference between the two scores was less than 1.5. Eight items were eliminated because both scores were very low (i.e., unassociated in both directions). Of the remaining 72 word pairs, 36 were classified as asymmetrical (e.g., ‘‘path–road,’’ ‘‘bar–drink,’’ ‘‘engine–car’’) and 36 were classified as symmetrical (e.g., ‘‘robber–thief,’’ ‘‘spider–web,’’ ‘‘leg–arm’’). The median association score was 1.78 for the symmetrical items. For the asymmetrical items, the median association score was 1.63 in the forward direction and 0.35 in the backward direction, $t(35) = 8.82$, $p < .001$. A complete list of the word pairs used in this experiment is given in Appendix A.

Participants. Twenty-four undergraduates from Stanford University participated in the experiment for credit in an introductory psychology class. Participants were tested individually. One participant was eliminated and replaced for performing below chance on the lexical decision task. No participants who participated in the collection of normative data described above were included in this or the following experiments.

Materials. From each of the 72 base pairs of words (described above), 12 test pairs were constructed. Six test pairs were in the forward direction and six in the backward direction. For symmetrical items, one direction was randomly designated as the forward direction in each pair for purposes of counterbalancing presentation order and conducting factorial analyses. In each direction, three of the six test pairs had word targets and three had nonword targets. Nonword targets were constructed by changing one or two consonants in the target word to form a pronounceable nonword. Each target word was preceded by either a related, an unrelated, or a neutral prime. The string ‘‘blank’’ was used as the neutral prime. Unrelated primes were selected by randomly recombining the primes with unrelated targets. An example of the 12 test pairs constructed from a single base pair is shown in Table 1.

In each test block, participants saw one of the test pairs from each base pair, totaling 72 trials per block. Each block contained equal numbers of each of the 12 types of pairs. For a given base pair, test pairs were presented for each prime type (related, neutral, unrelated) and target type (word, nonword); however, each item was presented in only one direction (forward or backward) for a given participant. Thus, although target items were repeated, the pairing of the related prime with the target was not repeated in the reverse direction. In total, participants saw each base pair six times, three times with the word target and three times with the corresponding nonword target. Twelve versions of the experiment were created in order to counterbalance prime type, target type, and direction of presentation between participants.

Procedure. Instructions and stimuli were presented on a Macintosh IIci computer using

TABLE 1

Example of Stimuli in Each of the 12 Possible Test Conditions in Experiments 1–2 for the Base Pair ‘‘bar–drink’’

	Direction			
	Forward		Backward	
Prime	Word	Nonword	Word	Nonword
Related	bar–drink	bar–prink	drink–bar	drink–dar
Neutral	blank–drink	blank–prink	blank–bar	blank–dar
Unrelated	table–drink	table–prink	house–bar	house–dar

a Hypercard program to display the stimuli and collect the reaction times. Each trial was initiated with a central fixation point for 500 ms. The prime word was presented slightly above-center for 150 ms, followed by a blank ISI of 100 ms. The target string was presented centrally until the participant made a response. Participants indicated a response by pressing a key on the keyboard labeled ‘‘word’’ or ‘‘nonword.’’ The ‘‘word’’ key was always pressed with the participant’s dominant hand. Trials were advanced by pressing the space bar. The experimental session began with a practice block of eight trials, using words that did not appear elsewhere in the experiment, followed by the six test blocks.

Results

Median lexical decision latency in the first three blocks and the last three blocks was computed for each type of test pair with a word-target, after eliminating any trials on which the participant made an incorrect response (fewer than 2% of trials in all conditions). Median latency, averaged across participants, is shown in Table 2.

Lexical decision latency was analyzed in a repeated measures analysis of variance of prime type (related, neutral, unrelated), symmetry (symmetrical, asymmetrical), direction (forward, backward), and block (first three, last three). Prime type had a significant effect on decision latency, main effect, $F(2,46) = 14.36$, $p < .01$. Latencies decreased across blocks, main effect, $F(1,23) = 7.92$, $p < .01$, although priming effects were comparable between the first three blocks ($M = 26$ ms) and last three blocks ($M = 31$ ms), interaction $p > .80$. No higher order interactions were significant. Specifically, there was no interaction between the prime type and direction of presentation. In the critical comparison of asymmetric pairs, facilitation in the forward direction ($M = 20$ ms) did not differ from facilitation in the backward direction ($M = 28$ ms), $p > .60$.

Pairwise comparisons with a Bonferroni-corrected alpha rate of .017 were used to evaluate the relative effects on facilitation and inhibition in the overall priming effect. Lexical decisions were made faster to targets preceded by related primes ($M = 500$ ms) than neutral primes ($M = 525$ ms), indicating a significant facilitation effect, $t(23) = 4.07$, $p < .001$. However, latencies for targets preceded by neutral primes were not faster than those preceded by unrelated primes ($M = 528$ ms), $p > .50$.

TABLE 2

Mean (Standard Deviation) Lexical Decision Latency across Subjects ($n = 24$) for Each Type of Stimulus Pair in Experiment 1

	Prime type		
Direction	Related	Neutral	Unrelated
Asymmetrical			
Forward	498 (91)	518 (119)	522 (95)
Backward	506 (93)	534 (100)	523 (97)
Symmetrical	498 (98)	523 (90)	535 (102)

To preclude the possibility that the effects we observed were the result of item repetition, the data from only the first presentation of each item were also analyzed as described above. The results from the analysis of first presentation items alone replicated the findings reported above: a significant priming effect was obtained, $F(2,46) = 4.32$, $p < .05$, that did not interact with the direction of presentation, $p > .70$. Decision latencies were faster for targets preceded by related primes ($M = 529$ ms) than by neutral primes ($M = 554$ ms), $t(23) = 2.60$, $p < .017$, but latencies for targets preceded by neutral primes were not faster than those preceded by unrelated primes ($M = 555$ ms), $p > .90$.

An additional analysis was performed in which items, instead of subjects, were treated as a random variable. The median decision latency across subjects was computed for each item in each presentation condition. Data were analyzed in a mixed analysis of variance, with symmetry as a between-items factor and prime type and direction as within-items factors. In this analysis, as in the previous analyses, there was a significant effect of prime type, $F(2,140) = 12.91$, $p < .001$, that did not interact with direction of presentation or with symmetry, p's $> .90$. Thus, the symmetrical priming effect reported here is generalizable both across subjects and across items.

Discussion

Reliable priming was found both for symmetrically associated word pairs and for asymmetrically associated word pairs in both the forward and backward direction. There was no indication of asymmetry in the priming of asymmetrically associated word pairs; the magnitude of priming for pairs presented in the backward direction was as great as that for pairs presented in the forward direction. In order to evaluate the claim that backward priming effects reflect controlled processing (Seidenberg et al., 1984), despite the short SOA and low proportion of related primes used in this experiment, two specific effects were examined. First, the ‘‘cost’’ of controlled processing was measured by the difference between latencies to targets preceded by unrelated primes relative to neutral primes. There was no inhibition effect in the present experiment. Second, because the magnitude of controlled processing should increase throughout the experiment, as participants recognize the utility of a strategy, interactions between priming effects and block effects were examined. Although latencies decreased overall throughout the experiment, presumably the result of a repetition priming phenomenon that has been shown to be independent of semantic priming effects (den Heyer, Goring, & Dannenbring, 1985), priming effects were comparable between blocks of the experiment.

Despite the lack of inhibition and block effects in this experiment, there may be doubts raised about each of these indices of automatic priming. First, there may be some question as to the ‘‘neutrality’’ of the neutral prime ‘‘blank.’’ Several studies (de Groot, Thomassen, & Hudson, 1982; den Heyer et al., 1985, Jonides & Mack, 1984) reported that response times to targets preceded by a row of X’s are longer than those preceded by the word ‘‘blank.’’ For this reason, the word ‘‘blank’’ was chosen in the present experiment in order to maximize the potential differences between the neutral and unrelated conditions. However, the uncertainty about the use of ‘‘blank’’ as a neutral prime does raise the possibility that inhibition effects can not be relied upon to accurately reflect the impact of controlled processing. Second, although the interaction between priming effects and block effects did not approach statistical significance, there was a slight increase (5 ms) in the priming magnitude over blocks. In order to confirm the presence of backward priming under automatic conditions, the next experiment was designed to replicate the current results and to assess the effects of manipulating a variable that impacts the degree of controlled processing, the nonword ratio.

EXPERIMENT 2

Controlled processing is a generic term for any type of mechanism that is under the participant’s strategic control. These strategies can be distinguished according to whether they occur before the target word appears (i.e., prelexical) or after the target word appears (i.e., postlexical). For example, Posner and Snyder's two-process model of semantic priming describes an expectancy-based priming mechanism that is invoked prior to the appearance of the target. When an expectancy-based strategy is used, participants generate a set of expected targets after reading the prime word. If the target is among that set, as would happen commonly with associated word pairs, the reading or decision time is facilitated relative to a neutral priming condition. If the target is not among that set, as would happen with unrelated word pairs, the reading or decision time is inhibited relative to a neutral priming condition.

The use of this expectancy-based strategy should increase in situations where the participant is more likely to benefit from the use of such a strategy than to be slowed by the strategy. Such an effect has been found when the proportion of related primes is varied between participants in a semantic priming experiment: The magnitude of semantic priming increases as a function of the proportion of related primes (Tweedy et al., 1977). This relatedness proportion effect is eliminated when the SOA between prime and target is shorter than 250 ms (den Heyer, Briand, & Dannenbring, 1983; Neely & Keefe, 1989; Stolz & Neely, 1995). Presumably, when there is not enough time to generate a set of expected targets, an expectancy-based strategy cannot be used even when the proportion of related primes is high enough to warrant its use.

Other strategies may be used by participants after the target word appears and the meaning is partially available, but before the participant is able to make a response. For example, a postlexical ''semantic matching'' strategy (Keefe & Neely, 1990; Neely, Keefe, & Ross, 1989; Neely, 1991) enables participants to bias their response based on the relation between the prime and target. If the pair is related, the participant is biased to decide that the target is a word, thereby facilitating decisions to word-targets preceded by related primes. If the pair is unrelated, the participant is biased to decide that the target is a nonword, thereby inhibiting decisions to word-targets preceded by unrelated primes.

Two differences are important when considering the relative influence of prelexical and postlexical strategies in the present experiments. First, when a short SOA is used, prelexical strategies are minimized because they require time before the presentation of the target to allow for the generation of the expectancy set; however, postlexical strategies do not depend on sufficient time between prime and target because the mechanism is invoked after the target is presented. Therefore, although tasks which use a short SOA between prime and target have been traditionally described as automatic tasks, the possibility of postlexical strategic mechanisms exists even under these conditions.

Second, prelexical strategies, in particular, expectancy-based priming mechanisms, are effective only when the participant can generate the target word in response to the prime word with a high probability of success. This is precisely the explanation given for the relatedness proportion effect. In conditions of backward priming, using stimuli that have been constructed so that participants do not generate the target word in response to the prime word, expectancy-based priming should not be effective in facilitating lexical decisions. However, postlexical strategies, such as the semantic matching process, occur after the participant has some awareness of both the prime and the target. The direction of the association may become irrelevant after the meaning of the target has become available. For this reason, this semantic matching process has been used to explain the existence of backward priming effects on lexical decision tasks (Neely et al., 1989; Seidenberg et al., 1984).

Just as the proportion of related primes has been shown to influence the likelihood of the use of expectancy-based priming mechanisms, Neely et al. (1989) identified a variable that influences the likelihood of the use of the semantic matching process, the nonword ratio. The relatedness proportion is defined as the probability that a word target will be related to the prime. The nonword ratio, on the other hand, is defined as the probability that an unrelated prime will be followed by a nonword target. (For nonword targets, an unrelated prime is not strongly related to any words which are graphemically similar to the target nonword.) These two factors are typically confounded in any manipulation of the proportion of related word pairs. Neely et al. systematically varied the nonword ratio while holding the relatedness proportion constant and vice versa. Results of these manipulations indicated that while the relatedness proportion specifically affects the use of prelexical strategies, the nonword ratio affects the use of postlexical strategies.

In the present experiment, because the most likely source of controlled processing, if any, is a postlexical semantic matching process, the nonword ratio was manipulated so the effects of postlexical strategies could be assessed. If postlexical strategic processes are responsible for the backward priming effect, then priming in this experiment should increase as a function of the nonword ratio. If, however, there is no effect of nonword ratio on the magnitude of priming, then any evidence of backward priming is not likely to be the result of a strategic processing, but of automatic processing. As in Experiment 1, inhibition and block effects will also be used to assess the possible influence of controlled processing. Again, the priming magnitudes for asymmetrically associated word pairs presented in either the forward or backward direction were compared.

Methods

Participants. Thirty-six undergraduates from Stanford University participated in the experiment for credit in an introductory psychology class. Participants were randomly assigned to one of three test conditions and were tested individually.

Materials. The test items were identical to those used in Experiment 1, with 72 test items in each of six blocks. In addition, 24 filler items were added to each test block in order to manipulate the nonword ratio. In Experiment 1, each block contained 24 unrelated primes, 12 of which were followed by nonword targets, resulting in a nonword ratio of 0.50. Filler items were added to each block to create nonword ratios of 0.25, 0.50, and 0.75 in the present experiment. In the low nonword ratio (0.25) condition, 24 unrelated primes followed by word targets were added to each block, for a total of 12 nonword targets out of 48 unrelated pairs. In the medium (0.50) condition, 12 unrelated primes followed by word targets and 12 unrelated primes followed by nonword targets were added to each block, for a total of 24 nonword targets out of a total of 48 unrelated pairs. In the high (0.75) condition, 24 unrelated primes followed by nonword targets were added to each block, for a total of 36 nonword targets out of a total of 48 unrelated pairs.

As in Experiment 1, prime type and target type were counterbalanced within participants. Prime type, target type, and direction of presentation were counterbalanced between participants. Nonword ratio was the only variable manipulated between participants in the experiment.

Procedure. The procedure was identical to the procedure described for Experiment 1.

Results

Median lexical decision latency in the first three blocks and the last three blocks was computed for each type of test pair with a word target, after eliminating any trials on which the participant made an incorrect response (fewer than 2% of trials in all conditions). Median latency, averaged across participants, is shown in Table 3.

Lexical decision latency was analyzed in a mixed analysis of variance with nonword ratio (low, medium, high) as a between-participants factor and prime type (related, neutral, unrelated), symmetry (symmetrical, asymmetrical), direction (forward, backward), and block (first three, last three) as within-participants factors. Prime type had a significant effect on decision latency, main effect, $F(2,66) = 17.39$, $p < .01$. Latencies decreased across blocks, main effect, $F(1,33) = 37.27$, $p < .01$,

TABLE 3

Mean (Standard Deviation) Lexical Decision Latency across Subjects ($n = 36$) for Each Type of Stimulus Pair in Experiment 2

Direction	Prime type: Related	Neutral	Unrelated
Asymmetrical			
Forward	464 (98)	482 (95)	489 (101)
Backward	495 (95)	513 (99)	512 (112)
Symmetrical	474 (97)	495 (101)	497 (93)

although priming effects were comparable in Block 1 ($M = 23$ ms) and Block 2 ($M = 20$ ms). Decision latencies in the backward direction were longer than those in the forward direction, main effect, $F(1,33) = 39.15$, $p < .01$; however, direction did not interact with the priming effect. No higher order interactions were significant. Specifically, the interaction between prime type, symmetry, and direction did not approach significance ($p > .60$). In the critical comparison of asymmetric pairs, facilitation in the forward direction ($M = 17$ ms) did not differ from facilitation in the backward direction ($M = 18$ ms), $p > .90$.

Pairwise comparisons were used, with a Bonferroni-corrected alpha rate of .017, to evaluate the relative effects on facilitation and inhibition in the overall priming effect. Lexical decisions were made faster to targets preceded by related primes ($M = 477$ ms) than neutral primes ($M = 496$ ms), indicating a significant facilitation effect, $t\,(35) = 4.85$, $p < .001$. However, latencies for targets preceded by neutral primes were not faster than those preceded by unrelated primes ($M = 498$ ms), $p > .60$.

Facilitation was comparable for low ($M = 20$ ms), medium ($M = 18$ ms), and high ($M = 20$ ms) levels of nonword ratio. No interactions between the priming effect and nonword ratio approached significance (p's $> .40$). There was reliable facilitation, p's $< .05$, and no inhibition, p's $> .10$, at all three nonword ratios. Priming was also comparable across blocks of the experiment, with reliable facilitation, p's $< .01$, and no inhibition, p's $> .50$, in each block.

Discussion

As in Experiment 1, the magnitude of priming of asymmetrically associated word pairs presented in the backward direction did not differ from that of pairs presented in the forward direction. Furthermore, the magnitude of priming did not increase across blocks of the experiment, nor did it increase as a function of the probability that an unrelated prime was followed by a nonword target (i.e., the nonword ratio). Across all blocks and nonword ratio conditions, reliable facilitation was found, but inhibition was not found. The absence of inhibition effects, block interactions, and nonword ratio interactions provide convergent evidence that controlled mechanisms, including postlexical semantic matching processes, did not contribute to the symmetrical backward priming effect found in this experiment.

Experiments 1 and 2 demonstrated that under automatic conditions, the degree of associative relatedness (i.e., the direction of presentation of asymmetrically associated word pairs) does not affect the degree of priming. All of the stimuli used in these experiments were semantically related. Thus, it appears that semantic relatedness is *sufficient* to produce priming under automatic conditions, as evidenced by the reliable backward priming effect. However, these experiments did not address whether semantic relatedness is *necessary* to produce automatic priming, as priming was not examined for words that had a nonsemantic (i.e., associative) relation only. In the next experiment, the role of semantic relatedness in priming was further examined.

EXPERIMENT 3

If automatic priming reflects only semantic similarity, and not associative relatedness, two predictions can be made. First, there should be equivalent priming for associated and unassociated pairs that are not semantically related. Second, there should be no priming for either associated or unassociated pairs that are not semantically related. The previous experiments addressed the first prediction: Under automatic conditions, equivalent priming was observed for both associated (forward direction) and unassociated (backward direction) pairs that were semantically related. Experiment 3 tested the second prediction by measuring priming in both directions of association for semantically unrelated words.

Seidenberg et al. (1984) measured priming for word pairs that had associative but not semantic relations (e.g., ''coat–rack''). They found both forward and backward priming on a lexical decision task with these stimuli; however, controlled processes likely contributed to the priming effect under their task conditions (SOA = 500 ms). Under automatic task conditions, Shelton & Martin (1992) used the same stimuli and failed to find priming for pairs presented in either the forward or the backward direction. One possible explanation for their failure to obtain priming in that experiment is that the stimuli did not have any semantic similarity, which may be necessary for priming under automatic conditions. This possibility was examined in the current experiment.

In Experiment 3, priming was measured for two types of stimuli: semantically related words (used in Experiments 1 and 2) and semantically unrelated words (used by Seidenberg et al., 1984 and Shelton & Martin, 1992). Both sets of stimuli comprised word pairs that were asymmetrically associated, and priming was measured for pairs presented in both the forward (associated) and backward (unassociated) direction. Thus, in this experiment measures of priming were obtained for pairs that were (1) semantically unrelated and associatively unrelated; (2) semantically related and associatively unrelated; (3) semantically unrelated and associatively related; (4) semantically related and associatively related.

In Experiments 1 and 2, priming was assessed using a lexical decision task. Although by all indications the priming effect in those experiments was the result of automatic processing, the lexical decision task may be more susceptible to the effects of controlled processing than a pronunciation task, either because participants are more likely to engage such mechanisms or because the mechanisms are more effective (Seidenberg et al., 1984; West & Stanovich, 1982). For this reason, a pronunciation task, rather than a lexical decision task, was used in the current experiment.

If automatic priming reflects an effect of associative relatedness, priming should be observed for both semantically related and semantically unrelated pairs in the forward direction (associated) but not for semantically related or semantically unrelated pairs in the backward direction (unassociated). However, if automatic semantic priming reflects an effect of semantic relatedness, priming should be observed for semantically related pairs in both the forward and backward directions but not for semantically unrelated pairs in either the forward or backward direction. This experiment, therefore, provided a direct test of both of the predictions made by models of priming based solely on semantic similarity.

Methods

Participants. Thirty-four undergraduates from Stanford University and the University of Pennsylvania participated in the experiment for credit in an introductory psychology class or for monetary compensation. Participants were tested individually.

Materials. Three sets of word pairs were used in this experiment: 18 word pairs were asymmetrically associated and semantically unrelated (Seidenberg et al., 1984), 18 word pairs were asymmetrically associated and semantically related (a subset of the items used in Experiments 1 and 2), and 18 word pairs were symmetrically associated (a subset of the items used in Experiments 1 and 2) and semantically related. The complete list of stimuli used in this experiment is given in Appendix B. Prime type was counterbalanced within participants, so that participants saw each target word three times, once per block. Prime type and direction of presentation were counterbalanced between participants.

Procedure. Instructions and stimuli were presented on a Macintosh IIci computer using

TABLE 4

Mean (Standard Deviation) Naming Latency across Subjects ($n = 34$) for Each Type of Stimulus Pair in Experiment 3 and Mean Priming Effect (PE, unrelated–related)

Direction	Prime type: Related	Neutral	Unrelated	PE
Dissimilar				
Forward	506 (71)	504 (70)	509 (74)	2
Backward	513 (70)	505 (63)	511 (68)	−2
Similar				
Forward	510 (69)	514 (68)	521 (67)	12
Backward	526 (72)	536 (70)	539 (74)	12
Symmetrical	500 (59)	512 (64)	511 (65)	11

PsychLab software to display the stimuli and collect the reaction times. Each trial was initiated with a central fixation point for 500 ms. The prime word was presented centrally for 150 ms, followed by a blank ISI of 50 ms. The target word was presented centrally until the participant made a response. Participants read the word into a microphone, which triggered a voice-activated relay (Lafayette Instrument) to the computer. The experimental session began with a practice block of six trials, using words that did not appear elsewhere in the experiment, followed by three test blocks.

Results

Median naming latency was computed for each type of test pair, after eliminating any trials on which the participant made an incorrect response or on which there was a microphone error. Due to the smaller number of items in this experiment, medians were not computed separately for each block. Median latency, averaged across participants, is shown in Table 4.

Naming latency for asymmetrically associated items was analyzed in a repeated measures analysis of variance of prime type (related, neutral, unrelated), stimulus type (semantically related or semantically unrelated), and direction (forward, backward). Prime type had a significant effect on decision latency, main effect, $F(2,66) = 3.51$, $p < .05$. However, the effect of prime type varied as a function of stimulus type, interaction, $F(2,66) = 4.52$, $p < .05$. The two-way interaction between prime type and direction did not approach statistical significance ($p > .90$). The three-way interaction was not statistically significant.

Three pairwise comparisons (with a Bonferroni-corrected alpha rate of .017) were used to evaluate the interaction between stimulus type and prime type; for each stimulus type, response times were averaged over forward and backward directions. For semantically unrelated pairs, target words were named no faster following related primes ($M = 509$ ms) than following unrelated primes ($M = 510$ ms), $p = .91$. However, for semantically related pairs, target words were named significantly faster following related primes ($M = 518$ ms) than following unrelated primes ($M = 530$ ms), $t\,(33) = 2.97$, $p < .01$. Likewise, for symmetrical pairs, target words were named faster following related primes ($M = 500$ ms) than following unrelated primes ($M = 511$ ms), $t\,(33) = 3.39$, $p < .01$.

To confirm the generalizability of these results across items, an item analysis was performed in which median naming latencies for asymmetrically associated items were computed for each item across subjects. These data were subjected to a mixed analysis of variance, treating items as a random variable, with stimulus type as a between-items factor and prime type and direction of presentation as within-items factors. This item analysis yielded the same pattern of results as the within-subjects analysis. There was a significant main effect of prime type, $F(2,68) = 3.44$, $p < .05$ and an interaction between prime type and stimulus type, $F(2,68) = 4.39$, $p < .01$.

Discussion

As in Experiments 1 and 2, the magnitude of priming for asymmetrically associated items was not affected by the direction of presentation. For semantically related pairs, reliable priming was found in both the forward and backward presentation direction (*M* priming effect = 12 ms). This replicates the earlier finding that semantic relatedness is sufficient for automatic priming. Additionally, priming was not found for semantically unrelated pairs in either the forward or backward presentation direction (*M* priming effect = 0 ms). These findings confirm that semantic relatedness is both necessary and sufficient to produce priming under automatic conditions.

In Experiment 3, priming was measured on a pronunciation task. Priming effects on pronunciation tasks tend to be much smaller than those reported on lexical decision tasks (e.g., Seidenberg et al., 1984 reported priming magnitudes of 7–8 ms on a pronunciation task and 20–27 ms on a lexical decision task). Consistent with this pattern, the magnitude of priming found in this experiment was considerably smaller, although still reliable, than the magnitude of priming on the lexical decision task used in Experiments 1 and 2.

The magnitude of priming depended on the degree of semantic relatedness between the words (interaction with stimulus type) but not on the associative relatedness between the words (no interaction with presentation direction). These results support the argument that automatic semantic priming is the result only of semantic similarity and not of strength of association.

GENERAL DISCUSSION

The three experiments described here demonstrate that semantic relatedness is both necessary and sufficient to produce priming under automatic task conditions. First, the elimination of controlled mechanisms was established by using a short SOA, a low proportion of related primes (Experiments 1–3), and (in Experiment 3) a naming task, and was verified with the absence of inhibition effects and block interactions (Experiments 1) and the failure to find an effect of nonword ratio on priming (Experiment 2). Second, under these automatic conditions, the magnitude of priming observed for asymmetrically associated items was equivalent for items presented in either the forward or backward direction (Experiments 1–3). Third, priming in both presentation directions was reliable when the word pairs were semantically related, but not when the word pairs were semantically unrelated (Experiment 3). The magnitude of priming depended on the degree of semantic relatedness but not on the degree of associative relatedness.

The relative influences of associative and semantic relatedness were examined in earlier studies through methods which allowed for important confounds between these two factors to remain. The failure of Shelton and Martin (1992) to find automatic priming for word pairs without associative relatedness could, instead, reflect the low degree of semantic similarity between words in that condition. Indeed, the semantic distance, calculated with the Hyperspace Analogue to Language (HAL) model (Lund, Burgess, & Atchley, 1995), was greater for the unassociated than the associated word pairs used by Shelton & Martin. McRae and Boisvert (1996) measured semantic priming using both Shelton and Martin's unassociated word pairs and a new set of unassociated word pairs with a high degree of featural overlap (e.g., ''moose–caribou,'' ''bus–subway,'' and ''mat–carpet''). Reliable priming was obtained with unassociated word pairs that shared common semantic features but not with the stimuli used by Shelton and Martin. Although their finding is consistent with the assertion that priming depends on semantic relatedness, one might raise the same objection regarding confounds between semantic and associative relatedness in their stimulus sets.

The use of asymmetrically associated word pairs allows the strength of associative relatedness to be manipulated within a given item by varying the direction of presentation, while varying semantic relatedness orthogonally in a repeated-measures design. The observation of priming for asymmetrically associated word pairs presented in a backward direction in this study is not new; several previous studies have reported reliable backward priming effects (Koriat, 1981; Peterson & Simpson, 1989; Seidenberg et al., 1984; Shelton & Martin, 1992). However, the finding of backward priming has received two quite different interpretations.

Seidenberg et al. (1984) explained backward priming as the result of a postlexical strategic mechanisms. It was hypothesized that forward priming was the result of automatic spreading activation but that backward priming, which could not be explained by traditional spreading activation models, must instead be the result of controlled mechanisms. Koriat (1981) explained backward priming as the result of a reverbatory spread of excitation from the target back to the prime, an automatic process. Facilitation from forward associations, Koriat argued, was the result of strategic, prelexical processes. Although these two accounts provide opposite interpretations of backward and forward priming effects, they both predict that under conditions in which strategic processing is reduced or eliminated, priming effects for asymmetrically associated pairs would be asymmetrical. That is, under purely automatic conditions, Seidenberg's model would predict an absence of backward priming and Koriat's model would predict an absence of forward priming.

In the current study, the priming effects for asymmetrically associated word pairs were symmetrical. That is, under automatic conditions reliable priming was obtained and was equivalent in both a forward and a backward direction. This finding of symmetrical priming of asymmetrically associated word pairs under automatic task conditions is problematic for the accounts of backward priming offered by both Koriat (1981) and Seidenberg (1984).

In fact, the finding of automatic, symmetrical priming of asymmetrically associated word pairs is problematic for most traditional accounts of semantic priming. Neely (1991) described a priming theory including three mechanisms: automatic spreading activation and prelexical and postlexical strategic mechanisms. In the current experiment, postlexical processes seem an unlikely explanation of the semantic priming effect because there was no inhibition, no increase in priming over blocks, and no effect of the nonword ratio on the magnitude of priming. Prelexical processes also seem an unlikely explanation of the semantic priming effect for these reasons and for the additional reason that the time between the prime and the target was too short for prelexical mechanisms to be invoked (SOA = 250 ms). The lack of any effects traditionally associated with controlled semantic priming converge on the elimination of strategic mechanisms as an explanation of the priming effect in this study, leaving spreading activation as the remaining candidate mechanism according to this account. However, spreading activation in an associative network would predict asymmetrical priming effects between words that are asymmetrically associated, and not symmetrical priming effects as observed in all three experiments.

An alternative theory of priming, the compound-cue retrieval theory (Ratcliff & McKoon, 1988) describes facilitation as the result of a match between the prime-target combination with a long-term memory of that lexical pairing. While this theory might accommodate the symmetry of priming effects with presentation order reversals (e.g., if the memory trace was not sensitive to the order of the words), it fails to explain the strong effect of semantic similarity on the magnitude of priming. One would need to posit that the semantically related pairs (e.g.,''brandy–wine,'' ''lizard–snake'') had a stronger match in long-term memory that the semantically unrelated compound words (e.g., ''high–way,'' ''fire–truck''). As this seems unlikely, the compound-cue theory also fails to account for these data.

Spreading activation and compound-cue models both predict that priming depends on an associative relation between the prime and the target. According to spreading activation, this relation is represented explicitly as a link between word nodes in an associative network. Compound-cue models point to the joint representation in long-term memory of associated words. Unlike both spreading activation and compound-cue models of priming, distributed memory models do not define relations between words in terms of explicit, lexical associations.

Distributed models account for semantic priming phenomena in terms of a connectionist or brain-style approach. The meaning of a word is represented by a pattern of activation across a set of processing units corresponding to semantic features or attributes.[3] It is useful to think of the representation in spatial terms as a location in a multidimensional semantic space. The state of activation of the system at a particular time is a point in this space, and similar meanings map to nearby points. Information processing occurs through a process of constraint satisfaction whereby the system settles on a stable interpretation, an attractor in the space. The amount of processing required is determined by the distance that must be traversed between, for example, an initial state representing the interpretation of a prime and a stable state representing the interpretation of a target. Thus, distributed models account for facilitation in terms of feature overlap or proximity in semantic space between prime and target. If the meanings are similar, then many of the unit activations will begin at or near their target values and the processing requirements are few.

It has already been shown that distributed models can successfully account for a number of priming findings (e.g., Kawamoto, 1988; Masson, 1991, 1995). However, in assessing the validity of the distributed model account, it is vital to test the most basic and disputed assumption: that automatic priming is a matter of commonality of meaning rather than commonality of occurrence.[4] This assumption makes two strong predictions. First, automatic priming should occur when word pairs are semantically related, regardless of the degree of associative relatedness. This finding was obtained in all three of the current experiments, as well as earlier studies varying associative relatedness (Fischler, 1977) and presentation direction (Koriat, 1981; Peterson & Simpson, 1989). Failures to obtain this effect may be due to confounds between associative and semantic relatedness (Shelton & Martin, 1992) and influences of controlled processing (Seidenberg et al., 1984).

Second, automatic priming should *not* occur when word pairs are not semantically related, regardless of the degree of associative relatedness. In addition to the evidence provided in Experiment 3, this effect has also been found in studies varying degree of semantic similarity (McRae & Boisvert, 1996; Shelton & Martin, 1991). Additionally, priming during a concurrent letter search task, which should eliminate controlled influences by dividing attention, is present for associated and semantically related pairs, but is absent for associated but semantically unrelated pairs (Maxfield & Chiarello, 1996). Instances of priming in the absence of semantic relatedness (Seidenberg et al., 1984) are most likely the result of controlled mechanisms. Taken together, previous and current findings present strong evidence for a semantic, rather than associative, basis for automatic priming.

The experiments described in this paper provided a test of predictions based on the assumptions of a distributed memory model. This is not to say that other models might not provide an equally suitable account of these data. For example, one of the earliest explanations of the semantic priming effect, based on ‘‘semantic distance,’’ would also predict a semantic basis for automatic priming (Rips, Shoben, & Smith, 1973). In fact, these data lend support to any model based on semantic,

[3] Becker, Moscovitch, Behrmann, and Joordens (1997) describe a rather different connectionist model of word recognition, in which priming effects are the result of incremental learning. However, while this model captures a variety of long-term priming effects, Becker et al. observed that such a model is unlikely to explain short-term priming effects. Instead, the authors suggest that long-term and short-term priming may be the result of separate mechanisms that reflect long-term weight changes and short-term activation effects, respectively.

[4] Plaut (1995) presented a distributed model meant to account for both semantic and associative priming by manipulating the frequency with which one word follows another during the training of an attractor network. However, the underlying assumption that temporal co-occurrence grounds word associativity was challenged by Lund, Burgess, and Audet (1996).

as opposed to associative, similarity. However, as similarity-based priming effects have been considered a potential weakness of distributed semantic memory models, the current study provides a clear test of that aspect of these models. Furthermore, this point provides a useful way to discriminate between distributed models and localist associative network models. Toward this end, we can say that these data are inconsistent with the latter and that they are consistent with a class of models organized on the basis of semantic similarity, including distributed models of semantic memory.

Semantic relatedness has been used in this paper to describe any relation between two words that is based on their meaning and not simply their usage. The relations between the word pairs in the present experiment include category coexemplars (e.g., ''lizard–snake''), category superordinates (e.g., ''bird–eagle''), functional (e.g., ''scissors–cut''), part–whole (e.g., ''stem–flower''), and thematic (e.g., ''usher–movie''). To some extent, all of these relationships can be considered either functional or conceptual. Distributed memory models predict that priming would result from any set of shared features between two concepts. For example, two concepts that were functionally distinct but that were perceptually very similar (e.g., ''ball–cherry,'' ''banjo–tennis racket'') would have some shared semantic features that should result in priming.

This counterintuitive prediction was verified with word pairs that shared perceptual semantic features, based on the physical properties of the object such as shape or size (Flores d'Arcais, Schreuder, & Glazenborg, 1985; Schreuder, Flores d'Arcais, & Glazenborg, 1984). Because the perceptually related words were not associated either by co-occurrence in language or even by conceptual relatedness, this finding offers additional support for models of priming based on semantic similarity. Additionally, whereas priming for perceptual relations was greatest on fast tasks (naming, speeded lexical decision), priming for conceptual relations was found on slower tasks (lexical decision, slow naming). This suggests possible differences in the time course of activation of perceptual and conceptual features, which could result from differences in the degree of intercorrelations between different type of features, a possibility which could be explored in future models.

The results of these experiments can only be extended to priming under primarily automatic conditions. Processes based on associative relatedness, including strategic mechanisms and compound-cue retrieval, may operate under task conditions favoring controlled processing. Many findings showing an effect of associative relatedness on priming may reflect these strategic processes. For example, Seidenberg et al. (1984) reported forward and backward priming under strategic conditions, using stimuli that were not semantically related but that were asymmetrically associated. These were the same stimuli that did not produce reliable priming in either direction under automatic conditions in the current study (Experiment 3) or in previous studies (Shelton & Martin, 1992). Differences between priming observed in the current study and priming observed in previous studies of backward priming are most likely due to differences in the extent to which strategic mechanisms were used by participants in these experiments.

The current findings suggest that semantic relatedness, and not associative relatedness, is both necessary and sufficient to produce priming under automatic conditions. Neither controlled processes nor hypothesized mechanisms of priming based on associative relatedness (e.g., spreading activation, compound cue retrieval) can account for the absence of associative priming effects. However, these data are provided a clear interpretation by models of word representation based on semantic similarity, such as distributed memory models. Thus it appears that the name initially given to this phenomenon was not a misnomer: semantic priming is truly semantic.

APPENDIX A

Stimuli Used in Experiments 1 and 2

Assymmetrically Associated Pairs

light–lamp	iron–steel
road–path	cream–lotion
knife–sword	car–engine
wool–sheep	see–appear
coffee–tea	water–ocean
city–town	wine–brandy
cut–scissors	salt–pepper
drink–bar	bread–mold
bird–eagle	smoke–tobacco
candy–mint	snow–sleet
flower–stem	track–train
ship–crew	deep–shallow
brush–comb	house–cottage
sleep–dream	king–crown
hand–fingers	dirt–mud
moon–crater	silver–gold
snake–lizard	foot–inch
dog–flea	movie–usher

Symmetrically Associated Pairs

lose–find	sweet–sour
mad–anger	food–eat
sickness–health	sell–buy
tire–rubber	shoe–boot
gun–shoot	grass–green
crowd–people	die–live
cat–mouse	man–woman
clown–circus	now–then
stream–river	church–priest
over–under	fork–spoon
tub–bath	tiger–lion
rug–carpet	leaf–rake
hump–camel	pound–ounce
needle–thread	long–short
sky–blue	robber–thief
web–spider	leg–arm
law–justice	nail–hammer
nurse–doctor	skip–jump

APPENDIX B

Stimuli Used in Experiment 3

Asymetrically Associated/Semantically Unrelated Pairs

fruit–fly	lip–stick
crack–down	space–ship
high–way	coat–rack
bus–boy	eye–ball
hatch–back	fire–truck
bed–pan	soft–core
foot–note	stage–hand
head–line	book–worm
bell–hop	score–board

Asymmetrically Associated/Semantically Related Pairs

bar–drink	cottage–house
crater–moon	steel–iron
tobacco–smoke	lamp–light
crown–king	stem–flower
appear–see	engine–car
mint–candy	usher–movie
eagle–bird	brandy–wine
flea–dog	lizard–snake
sleet–snow	scissors–cut

Symmetrically Associated/Semantically Related Pairs

mad–anger	web–spider
sickness–health	nurse–doctor
crowd–people	fork–spoon
cat–mouse	tiger–lion
stream–river	leg–arm
needle–thread	gun–shoot
sweet–sour	clown–circus
robber–thief	rug–carpet
over–under	nail–hammer

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