

## The Effects of Word Association and Meaning Frequency in a Cross-Modal Lexical Decision Task: Is the Priming Due to "Semantic" Activation?

YASUSHI HINO, *Chukyo University*

STEPHEN J. LUPKER, *University of Western Ontario*

CHRIS R. SEARS, *University of Calgary*

**Abstract** The effects of priming by ambiguous, auditorily presented word primes were examined. In related conditions, primes were followed by either associatively related or semantically related but associatively unrelated targets. When the targets were presented at prime offset (Experiment 1), priming effects were observed only for associatively related targets, independent of meaning frequency (i.e., whether the target was related to the dominant or subordinate meaning of the ambiguous prime). When the targets were presented after a 700 ms delay (Experiment 2), however, priming effects were observed only for targets related to the prime's dominant meaning, regardless of the nature of the prime-target relation. These results raise the strong possibility that previously reported differences in the nature of priming effects that had been ascribed to meaning frequency might actually be due to differences in associative strength. These results are discussed in terms of Fodor's (1983; 1990) "anti-semantic" modularity view.

It is a well-established finding that the speed of responding to a target word can be influenced by the nature of the preceding context. For example, when a target word is semantically associated to the prime word that precedes it (e.g., NURSE-DOCTOR, where DOCTOR is the target and NURSE is the prime), responses to the target are facilitated relative to when target and prime are unassociated (e.g., BUTTER-DOCTOR) (Meyer & Schvaneveldt, 1971; Neely, 1977; Lupker, 1984; Seidenberg, Waters, Sanders, & Langer, 1984; see Neely, 1991, for a review). This effect has come to be referred to as "semantic priming" and, as Neely (1991) has documented, the basic semantic priming paradigm has proven to be quite useful for investigating a number of issues important to cognitive psychologists. It was also the primary tool used in the present investigation.

The main focus of the present investigation was the process of lexical ambiguity resolution. That is, some words in English are ambiguous (e.g., HORN, BANK) in the

sense that they possess more than one meaning, yet readers and listeners report little difficulty understanding the intended meaning of these words. The process by which readers and listeners accomplish this has received a great deal of attention in recent years.

One technique often used in studying this process is a specific version of the semantic priming paradigm referred to as cross-modal priming. In this paradigm, an ambiguous word prime is presented auditorily and the target is presented visually. The subjects' task is to respond to the target, typically by making a lexical decision. If a target word is related to the activated meaning(s) of an ambiguous word prime, a semantic priming effect should be observed. By noting what types of prime-target relations produce semantic priming effects, this paradigm presumably enables one to gain information about the nature of the meaning retrieval process for auditorily-presented ambiguous words.

In one of the first studies of this nature, Swinney (1979) used the cross-modal priming paradigm to examine the effects of sentential context on the process of resolving lexical ambiguity. Ambiguous words (e.g., BUG) were embedded in a spoken passage and presented through headphones. A visual target was then presented either at the offset of the ambiguous word or three syllables later. The critical targets were words related to the contextually appropriate meaning of the ambiguous words (e.g., INSECT) or words related to the contextually inappropriate meaning of the ambiguous words (e.g., SPY). Swinney found a "multiple priming effect" when the targets were presented at the offset of the ambiguous word (the "offset condition"). That is, lexical decision latencies to both contextually appropriate and contextually inappropriate targets were facilitated relative to unrelated control targets. When the targets were presented three syllables after the offset of the ambiguous word prime, however, a "selective priming effect" was observed: Facilitation was found only for the targets related to the contextually appropriate meaning of the ambiguous word.

Based on these and similar results, a context-independent view of meaning retrieval/activation has been proposed (e.g., Kintsch & Mross, 1985; Onifer & Swinney, 1981; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979; Till, Mross, & Kintsch, 1988). According to this view, initial meaning activation is independent of sentential context; all of the meanings of an ambiguous word are assumed to be activated. Following this exhaustive access stage, a selection mechanism selects the meaning which is contextually appropriate, allowing its activation to be maintained while suppressing the activation of inappropriate meanings.

Not all reported results, however, have been consistent with Swinney's (1979). Tabossi, Colombo, and Job (1987), for example, using essentially the identical paradigm, reported that when the sentential context was biased toward the more common (or "dominant") meaning of an ambiguous word, a priming effect was observed only for targets which were related to the contextually congruent meaning, even at prime offset. There was no priming effect for targets which were related to the contextually incongruent and less common (or "subordinate") meaning. Thus, these results provide support for a context-dependent view, that is, the view that the initial meaning activation is affected by a prior sentential context (see also, Simpson, 1981; Simpson & Krueger, 1991; Tabossi, 1988).

In addition to the nature of the sentential context, another factor often investigated in these studies has been the ambiguous word's "meaning frequency." That is, typically, for ambiguous words such as "BANK," the various possible intended meanings are not invoked equally frequently in discourse. Rather, one of the meanings is thought of as being "dominant" because it is most often the intended meaning when the word is used (e.g., "a financial institution"), and the others are denoted as being "subordinate" (e.g., "the edge of a river"). Simpson (1981), for example, examined the effect of meaning frequency using a single ambiguous word context in which both prime and target were presented visually. In the related conditions, the ambiguous primes were paired with targets that were associatively related to either the dominant or the subordinate meaning of the prime. Subjects made lexical decisions to both prime and target with a 0 ms response-stimulus interval. Simpson (1981) reported a significant meaning frequency (dominant vs. subordinate) by relatedness (related vs. unrelated) interaction in target latencies. In particular, only responses to targets related to the prime's dominant meaning were significantly facilitated.

Simpson and Burgess (1985) expanded on Simpson's (1981) results by examining the time-course of activation of dominant and subordinate meanings. As in the Simpson (1981) study, both prime and target were visually presented and ambiguous word primes were paired with

associatively related targets which were related to either the dominant or the subordinate meaning of the prime. The interval between the onset of the prime and the onset of the target (stimulus onset asynchrony, or SOA) was also manipulated (16, 100, or 300 ms in Experiment 1; 300, 500, or 750 ms in Experiment 2) in these experiments. Subjects made lexical decisions only to the targets.

Simpson and Burgess (1985) found that responses to dominant associates were facilitated at all SOAs. In contrast, there was no facilitation for subordinate associates at the 16 ms SOA. The facilitation for subordinate associates developed as SOA increased, however, reaching nearly the same level as that for the dominant associates by 300 ms SOA. After 300 ms, the facilitation for subordinate associates declined, with no facilitation observed at the 750 ms SOA. Thus, with a single word context, both dominant and subordinate associates showed facilitation, however, the time-course of facilitation differed according to meaning frequency. Simpson and Burgess (1985) concluded that all the meanings of an ambiguous word are initially activated, with the rate of activation determined by meaning frequency. Ultimately, with no other contextual constraints, attention focusses on the dominant meaning, and the subordinate meaning is suppressed. Simpson and Krueger (1991) reported similar results using a naming task.

Needless to say, however, the literature also contains results inconsistent with the findings of Simpson and colleagues. For example, Onifer and Swinney (1981) presented targets associated to either the dominant or the subordinate meaning of ambiguous words at the offset of ambiguous, auditorily-presented word primes. The primes were contained in a spoken passage. Subjects made lexical decisions to visually presented targets. Onifer and Swinney obtained priming effects for both the dominant and the subordinate targets in this situation. That is, meaning frequency did not affect the size of the priming effect even with this very short prime-target interval.

One of the main aims of the present studies was to try to help resolve the inconsistency regarding the effects of meaning frequency, focussing specifically on the situation where the prime is an auditorily-presented single word rather than a sentence. In doing so, we first need to discuss issues surrounding the use of the priming paradigm in monitoring the time-course of semantic activation.

#### SEMANTIC VS. ASSOCIATIVE PRIMING

In most lexical ambiguity studies using a priming task, an ambiguous word prime is followed by an associative target which is related to either the dominant or the subordinate meaning of the ambiguous word prime. Priming effects are typically assumed to reflect the degree of semantic activation brought about by the ambiguous word prime. The question that must be asked, however, is whether

these priming effects are truly the result of semantic (i.e., meaning) relations.

For example, Fodor (1983) argues that the multiple priming effects in Swinney's (1979) studies are not "semantic" effects, but rather are "associative" effects. That is, they are simply due to the fact that certain words have been frequently linked with one another in our experience rather than because the meanings of the concepts are related. Thus, Fodor makes an important distinction between these two types of relations. He further suggests that the representations at the lexical level reflect only associative relations, with other types of relations being represented outside the lexical module. Fodor (1990) termed this position the "anti-semantic" modularity view.<sup>1</sup>

If this "anti-semantic" modularity view were correct, intra-lexical associative priming could occur quite rapidly, possibly even before the semantic representations of an ambiguous word were activated. Thus, in the offset condition of Swinney's cross-modal priming task, the multiple priming effect may be due to associative priming and not to semantic priming. If so, these effects would tell us little about the meaning activation process for ambiguous word primes.

Fodor's (1983; 1990) arguments suggest then that associative and semantic priming may be mediated by different mechanisms, and that the distinction between the two is of paramount importance in understanding results from lexical ambiguity studies. If Fodor is correct, it should be possible to obtain evidence that associative and semantic relatedness actually have qualitatively different effects in certain situations. In fact, there are a number of studies which have sought to distinguish between associative and semantic priming, and they have met with varying degrees of success.

Fischler (1977) first raised the question of whether what researchers had been calling "semantic priming effects" are truly semantically mediated. Like Fodor, Fischler noted that there was, at least, a theoretical distinction between associative and semantic relations, with semantic relations being based on the fact that two concepts had similar semantic properties whereas associative relations were based on frequency of co-occurrence of the two concepts' names. Fischler also noted that in most of the semantic priming experiments that had been reported to that point, the related pairs had been selected specifically because they were associatively related. Thus, it was unclear whether any of the previously reported "semantic priming effects" really were due to semantic relatedness.

<sup>1</sup> In theory, it is quite possible to suggest that semantic relations are also represented within the lexical module and that the role of this module is to map physical signals to semantic representations. As such, the issue of whether word associations are represented separately from semantic relations is not identical to asking whether a modularity hypothesis is viable.

Fischler sought to determine whether semantic or associative relations mediate these priming effects. Using a simultaneous lexical decision task (where two letter strings are presented simultaneously and subjects respond positively only if the two strings are both words), Fischler compared the amount of facilitation when the prime and target were associatively and semantically related (e.g., BREAD-BUTTER — we will refer to these as the "associative pairs") to when they were semantically related but associatively unrelated (e.g., GOAT-CAT, we will refer to these as "nonassociative pairs"). If the priming effects were due to semantic relatedness, priming should occur with both types of pairs. Conversely, if the priming effects were based on word association, there should be no priming for nonassociative pairs regardless of the fact that they are semantically related. Fischler found comparable amounts of priming in the two conditions. Thus, he concluded that it is the semantic relatedness between the prime and target stimuli that produces the priming in this task.

Using Fischler's stimuli, Seidenberg et al. (1984) replicated Fischler's result of equivalent priming for associative and nonassociative pairs in a sequential lexical decision task. Using a different set of stimuli, Lupker (1984) also found priming in a sequential lexical decision task with both associative and nonassociative pairs, although the effect was somewhat larger in the former case (a 47 ms effect vs. a 26 ms effect). (In Lupker's experiments, primes and targets were defined to be semantically related if they were from the same semantic category.) Thus, none of these results provides much support for Fodor's argument because they all suggest that if there is a difference between semantic and associative relatedness, it is merely a quantitative one.

A stronger argument can be made for Fodor's position by considering results in naming tasks. Lupker (1984), for example, demonstrated that categorically related, nonassociative pairs (e.g., GOAT-CAT) produce little, if any, priming in naming tasks. The results from his three naming experiments showed 6 or 7 ms priming effects, effects that, although significant in the subjects' analyses, were not significant in the items' analyses. In Lupker's (1984) fourth experiment, the effect of categorical relatedness in a naming task was examined by comparing primes and targets that were both semantically and associatively related (e.g., BREAD-BUTTER) with primes and targets that, although they were associatively related, were not at all semantically similar (e.g., CANARY-YELLOW). Results indicated that there was no extra benefit for the semantically related pairs. That is, equivalent 18 ms priming effects were observed for both types of pairs, effects that were significant in both subjects' and items' analyses.

Based on the fact that the semantic similarity of primes and targets played no role in his fourth experiment and the fact that nonassociative semantic priming effects in his

first three experiments were not significant in the items' analyses, Lupker (1984) concluded that the small priming effects in his first three experiments were not truly semantic effects. Instead, Lupker suggested that such small effects on naming latencies are best regarded either as null effects or as residual associative effects, because there was no way to guarantee that any two semantically related words would not also have at least some associative strength for at least some proportion of the subjects.<sup>2</sup>

The explanation that Lupker offered for the different results in the lexical decision and naming tasks was based on the idea that lexical decision performance reflects not only the operations of a lexical-selection process but typically also a post-selection, decision-making process, whereas performance in the naming task mainly reflects the operations of the lexical-selection process (see also Balota & Chumbley, 1984; West & Stanovich, 1982). Given that associative priming effects were observed in both lexical decision and naming tasks, Lupker argued that associative relations affect the lexical-selection stage common to both tasks. That is, word associations are implemented within the lexicon, and these links between lexical entries for associatively related words allow activation to spread, leading to a facilitation of lexical selection for those words.

On the other hand, because the nonassociative semantic priming effect was evident only in the lexical decision task, Lupker argued that this effect occurred at a stage specific to lexical decision; namely, a post-selection, decision-making stage (a stage that, in theory, could be sensitive to both associative and semantic relatedness). In particular, as suggested by Balota and Lorch (1986; see also Neely & Keefe, 1989), subjects might develop a consistency checking strategy to aid in making word-nonword decisions. That is, if subjects detect a relation between the prime and target, by definition, the target must be a word, whereas if there is no relation, the odds are that it is a nonword (only unrelated word targets cannot be classified accurately by using this strategy). Thus, a strategy of evaluating the relation between the prime and target when making lexical decisions and then using this information as a cue to the target's lexical status could speed lexical decision making. If so, the effect of association may appear during lexical selection and the effect may be augmented at the post-selection stage. Thus, the size of the associative priming effect could be larger in lexical decision than in naming, as Lupker observed.

<sup>2</sup> Nonassociative semantic priming effects in naming tasks have also been reported by other researchers (Brodeur & Lupker, 1994; Hines, Czerwinski, Sawyer, & Dwyer, 1986; Huttenlocher & Kubicek, 1983; Seidenberg et al., 1984). Although these effects were often significant in the subjects' analysis, in no instance did any of these authors report that the priming effect was significant in an items' analysis.

Lupker's (1984) naming experiments do lend support to Fodor's (1983;1990) contention that there is a qualitative difference between associative and semantic relations and that intra-lexical priming effects may be mediated solely by word association (see also Balota & Lorch, 1986; McNamara & Altarriba, 1988; Shelton & Martin, 1992 for similar discussions based on the data from mediated priming experiments). If so, one must consider the possibility that the results of previous cross-modal priming experiments involving ambiguous word primes have not necessarily reflected the "semantic" activation process. Rather, the results may have also reflected the effects of word association.

#### MEANING FREQUENCY OR ASSOCIATIVE STRENGTH?

If this argument is correct, it points up a second problem for interpreting previously reported priming effects from ambiguous primes. In particular, there is the possibility that the meaning frequency manipulations of Simpson and colleagues were confounded with the effects of associative strength. That is, it is possible that the dominant associates have greater associative strengths than the subordinate associates because dominant associates tend to be generated more frequently than subordinate associates when subjects are asked to generate an associate for each ambiguous word in a free association task. Thus, the larger priming effects for the dominant targets in some of the previous studies may actually have been due to there being greater associative strength for the dominant pairs.

To assess this possibility, the associative strength values for the word pairs used in the Simpson and Krueger (1991) study were calculated using word association norms (Cramer, 1970; Nelson, McEvoy, Walling, & Wheeler, 1980).<sup>3</sup> Given a prime, the number of subjects who generated a particular target was counted and divided by the total number of subjects who generated any target in response to that prime. Twenty-eight of the 32 ambiguous words were found in these norms. For these 28 ambiguous words, the mean associative strength values were .206 for the dominant pairs and .057 for the subordinate pairs, a difference that was highly significant,  $t(54) = 4.14, p < .001$ .

The point should be made, of course, that using association norms to calculate associative strength is not without its problems. In particular, in creating these norms, subjects are typically required to give a single response. Thus, if the prime is ambiguous, and there are two almost equally strong responses, one for each meaning, the slightly stronger one may be consistently given as

<sup>3</sup> Because the materials used by Simpson and Burgess (1985) were not reported in their article, we, instead, calculated the associative strength values for Simpson and Krueger's (1991) materials which were listed in the Appendix of their article.

a first response by most of the subjects. Two results would follow. First, that prime would be classified as one having a clearly dominant meaning (due to the fact that the meaning dominance measure is based on the norms) and, thus, would be a prime candidate for use in experiments of the sort discussed here. Second, one would observe a large calculated difference in associative strengths between the dominant and subordinate associates, in spite of the fact that the two associates are almost equally strong. In other words, this measure may overestimate the associative strength difference between the dominant and subordinate associates because it may overestimate the strength of the dominant associates and underestimate the strength of the subordinate associates.

The main implication of this argument is that measuring associative strength based solely on the norms is not without its potential problems. As we note below, to try to remedy this potential problem, we also used a second measure of associative strength. The most important point, however, is that because Simpson and colleagues did not attempt to equate the associative strengths between the dominant and subordinate associates, there is the possibility that, in Simpson and colleagues' materials, meaning frequency was confounded with associative strength. Consequently, it is possible that the meaning frequency by relatedness interaction obtained by Simpson and colleagues was actually due to a difference in associative strength between the dominant and subordinate pairs.

In Experiment 1, we attempted to separate priming effects from ambiguous word primes into semantic and associative components by using two different types of target words. Semantically related ("nonassociative") targets were paired with ambiguous word primes to evaluate the "pure semantic" component of the priming effects. Semantically and associatively related ("associative") targets were used to estimate the combined effects of semantic and associative relatedness. Further, we attempted to equate associative strengths for the dominant and subordinate prime-target pairs (for both associative and nonassociative pairs) in two ways. The first involved using the norms and calculating associative strength in the standard way. In addition, we collected associative strength ratings for our materials. A separate group of subjects was asked to rate the likelihood that they would think of the second word when they saw the first word of each prime-target pair using a seven-point scale from "Very Unlikely" (1) to "Very Likely" (7). This measure, undoubtedly, has its flaws as well (e.g., subjects may not be able to completely prevent semantic relations from coloring their judgments). Nonetheless, by selecting dominant and subordinate pairs that are similar on both measures of associative strength, we were able to achieve better control over this factor than had ever been achieved previously.

The paradigm was a cross-modal priming paradigm with a single word prime. Targets were presented at prime offset (0 ms interstimulus interval — ISI). Subjects made lexical decisions to the targets. The lexical decision task was used because previous research (Fischler, 1977; Lupker, 1984; Seidenberg et al., 1984) suggests that this task would be sensitive not only to associative priming but also to the "pure semantic" component of priming. Thus, any priming effects in the nonassociative condition at this short ISI would be evidence of early semantic activation. In particular, a meaning frequency effect for the nonassociative pairs would be clear evidence for Simpson and colleagues' claim that semantic information about the dominant meaning is available before semantic information about the subordinate meaning. With respect to the associative pairs, as Fodor has argued, associative relations appear to be more primary than semantic relations. Thus, there should be clear evidence of priming for associative prime-target pairs. The questions are, (1) will the priming effects be larger for the associative pairs than for the nonassociative pairs?, and (2) will there be a meaning frequency by relatedness interaction in either condition?

### Experiment 1

#### METHOD

##### *Subjects*

Forty-eight undergraduate students from the University of Western Ontario participated in this experiment for course credit. All were native English speakers and had normal or corrected-to-normal vision.

##### *Stimuli*

Seventy-two ambiguous words (the potential primes) were initially selected from Nelson et al. (1980) and Cramer (1970). Each ambiguous word was paired with two associates and four semantically related nonassociates. For the associates, one was related to the dominant meaning of the prime and one was related to the subordinate meaning. The associative strengths were calculated based on the association norms (Cramer, 1970; Nelson et al., 1980) and closely matched between the dominant and the subordinate associates. Two nonassociates were related to the dominant meaning of the prime and the other two nonassociates were related to the subordinate meaning. These nonassociates were selected based on the first author's intuition, and none of these words appeared in the word association norms (Cramer, 1970; Nelson et al., 1980). Finally, another 24 ambiguous words were selected from Nelson et al. and were paired with unrelated words.

To select the actual word pairs for use in the experiment, associative strength rating values were obtained between each ambiguous word prime and its six potential

targets. To accomplish this, six stimulus lists were created. Each list contained 72 related pairs involving the 72 ambiguous word primes and one of their potential targets (24 were associative pairs and 48 were nonassociative pairs) as well as the 24 unrelated pairs. Each word appeared only once in a list. The 96 word pairs were randomly ordered and listed in a questionnaire. To get ratings for every pair, six different questionnaires were created. Each word pair in the questionnaire was accompanied by a seven-point scale from "Very Unlikely" (1) to "Very Likely" (7). Subjects were instructed to rate the likelihood that they would think of the second word when they saw the first word of each word pair. Rating data from a total of 192 subjects were obtained, with 32 subjects assigned to each of the six questionnaires.

Ultimately, 24 ambiguous words were selected together with their two associative targets and two of their semantically-related, nonassociative targets. One associative target and one nonassociative target were related to the dominant meaning and the other targets were related to the subordinate meaning of the prime. The mean word frequency (Kucera & Francis, 1967) of these 24 ambiguous word primes was 96.75, and the mean word length was 4.38. The dominant and the subordinate meaning frequencies for the ambiguous words were calculated based on the association norms. The dominant meaning frequency (0.817) was significantly higher than the subordinate meaning frequency (0.138),  $t(46) = 35.87, p < .001$ .

The main factor driving the selection of these 24 primes, of course, was that the dominant and subordinate pairs were equated on associative strength. According to the norms, the mean associative strengths for dominant (0.065) and subordinate associates (0.065) were virtually identical,  $t(46) = .03$ . To compare the associative strength values for these pairs based on the subject ratings, the ratings for the selected targets were submitted to a 2 (Meaning Frequency: Dominant vs. Subordinate)  $\times$  2 (Type of Relation: Associative vs. Nonassociative) analysis of variance. There were significant main effects of Meaning Frequency,  $F(1, 92) = 11.60, MS_e = .832, p < .01$ , and Type of Relation,  $F(1, 92) = 59.55, MS_e = .832, p < .001$ , as well as a significant interaction between these two factors,  $F(1, 92) = 9.55, MS_e = .832, p < .01$ . Planned t-tests indicated that the mean associative strength rating for the dominant associates (5.20) was significantly higher than that for the subordinate associates (3.99),  $t(46) = 4.43, p < .001$ , whereas there was no significant difference between the mean associative strength ratings for the dominant (3.19) and subordinate (3.13) nonassociates,  $t(46) = .23$ .

The results of this analysis suggest that even though the associative strengths, calculated based on word association norms, had been very closely matched between the dominant and subordinate associates, our manipulation of

the associative strengths for the associative pairs was not perfect. That is, although we equated the associative strengths between the dominant and subordinate associates based on the norms, the associative strength rating values were a bit greater for the dominant associates than for the subordinate associates. Nonetheless, three points need to be noted. First, this difference is now better controlled than in previous studies. Second, there is clearly no difference in associative strength ratings between the dominant and subordinate meanings for the nonassociative pairs on either measure. Thus, the contrast for the nonassociative pairs should provide a pure evaluation of the effect of meaning frequency on the retrieval of semantic information. Finally, for the associative targets, the difference that was observed is in the opposite direction from that which we were concerned about. That is, the concern was that using the norms could lead to an underestimation of the strength of the subordinate associates and an overestimation of the strength of the dominant associates. Thus, when the values based on the norms were equated, the subordinate associates would actually be stronger associates than the dominant associates. Our ratings tell us that, if anything, the reverse was true.

In addition, the associative strength ratings for the dominant and subordinate nonassociates were compared with those for the 24 unrelated pairs. The mean associative strength ratings for the dominant (3.19) and subordinate (3.13) nonassociates were both significantly higher than that for unrelated pairs (1.49),  $t(46) = 9.69, p < .001$  for dominant nonassociates;  $t(46) = 8.25, p < .001$  for subordinate nonassociates. These results seem to suggest either that there are still weak associative relations between ambiguous word primes and their nonassociative targets or that the semantic relation between these primes and targets colored the ratings slightly. If it is the former, and if there is some evidence of priming for the nonassociative pairs, as there was in Lupker (1984), it will not be entirely clear as to whether the effect was due to semantic relatedness or to these weak associative relations. These issues will be considered in the Discussion section of this experiment.

Finally, the word frequency, word length, and orthographic neighborhood size for the selected targets were also submitted to a 2 (Meaning Frequency)  $\times$  2 (Type of Relation) analysis of variance. There were no significant effects in these analyses, all  $F_s < 1.7$ .

These experimental word quintets (two associative and two nonassociative targets for an ambiguous word prime) are listed in the Appendix. The statistical characteristics of these word quintets are given in Table 1.

Each subject was presented with only associative or nonassociative targets. Each prime was presented only once per subject. To counterbalance properly, the 24

TABLE 1  
Mean Meaning Frequency (MF), Associative Strength (AS), Associative Strength Rating (Rating), Target Word Frequency (Freq), Target Word Length (Len), and Orthographic Neighborhood Size (N) in Each Condition.

Target Type	MF	AS	Rating	Freq	Len	N
Associative / Dominant	0.817	0.065	5.20	58.75	5.58	4.33
Associative / Subordinate	0.138	0.065	3.99	51.75	5.17	6.29
Nonassociative / Dominant	0.817	—	3.19	45.88	5.58	4.21
Nonassociative / Subordinate	0.138	—	3.13	46.29	5.92	3.79

experimental primes were arbitrarily divided into four sets of size six. All primes within a set were presented with the same type of target (i.e., dominant-related, dominant-unrelated, subordinate-related, or subordinate-unrelated). Thus, the unrelated pairings were created by reassigning primes and targets within a set. As such, counterbalancing the experimental targets required four different groups of subjects for the associative targets and four different groups of subjects for the nonassociative targets.

In addition to the 24 experimental pairs, each subject was presented with 72 filler word pairs and 96 word prime-nonword target pairs. Half of the filler word pairs were related pairs (18 associatively related and 18 semantically related but associatively unrelated pairs), and the other half were unrelated pairs. The nonwords were all pronounceable and were created by replacing one letter from real words. Subjects were assigned to one of the eight groups according to their order of the arrival for the experiment. Six subjects were assigned to each group.

#### Apparatus and Procedure

The 192 prime words were randomly ordered and recorded onto the right channel of a cassette tape by a female speaker. At the offset of each prime, a sound signal was recorded on the left channel of the cassette tape. The left channel of a stereo tape recorder (Sony FM/AM Stereo Cassette-Corder CFS-900) was connected to a microcomputer (AMI 386 Mark II) through a programmable timer board with I/O channels (London R & D Three Channel Timer Board). The right channel of the tape recorder was connected to a pair of stereo headphones.

Subjects wore the headphones and sat in front of a video monitor (CMS-3436, Multiscan Monitor) at a distance of approximately 50 cm. At the start of each trial, a fixation point appeared at the center of the video monitor. A prime was then presented binaurally through the headphones. At the offset of the prime, the microcomputer received a signal from the tape recorder and a target stimulus was presented just above the fixation point on

TABLE 2  
Mean Free Recall and Mean Recovery Across Tests as a Function of Word Type in Experiment 2

Word Type	Test			Recovery	
	1	2	3	1-2	2-3
Remember	.34 (.15)	.36 (.15)	.36 (.17)	.05 (.05)	.02 (.03)
Forget	.25 (.09)	.29 (.10)	.29 (.10)	.07 (.06)	.02 (.03)

Note. Standard deviations are shown in parentheses.

the video monitor. Subjects were asked to make a word-nonword decision to the target as quickly and as accurately as possible by pressing either the "Word" or "Nonword" button of a response-box interfaced to the microcomputer. The subjects were instructed to pay attention to the words presented through the headphones because these words might help them in responding to the targets. The "word" response was made using the subject's dominant hand and the "nonword" response was made using the subject's nondominant hand. The subject's response terminated the presentation of the target stimulus and the fixation point. Lexical decision latencies were measured from the onset of the target stimulus to the subject's button press, and the accuracy and latency of each response were automatically recorded by the microcomputer. The intertrial interval was 3 seconds.

The order of the prime presentation was randomized but was the same for all subjects. Twelve practice trials were given prior to the 192 experimental trials. During the practice trials, subjects were provided with latency and accuracy feedback after each trial. No feedback was given during the experimental trials. Breaks were given after every 48 experimental trials.

#### RESULTS

Because the lexical decision latencies for the correct responses to the experimental stimuli were all more than 250 ms but less than 1400 ms, no data points from the experimental trials were regarded as outliers. The mean lexical decision latencies for the correct responses and the mean error rates (based on the experimental trials) were calculated across subjects and items separately. The mean lexical decision latencies and error rates averaged over subjects are presented in Table 2.

Subject and item means of lexical decision latencies and error rates (based on the experimental trials) were submitted to separate 2 (Type of Relation)  $\times$  2 (Meaning Frequency)  $\times$  2 (Relatedness) analyses of variance. For the subjects' ( $F_i$ ) analyses, Meaning Frequency and Relatedness were within-subject factors, and Type of Relation was a between-subject factor. For the items' ( $F_j$ ) analyses, Type

TABLE 2  
Mean Lexical Decision Latencies (ms) and Error Proportions in Experiment 1.

Relatedness	Type of Relation							
	Associative				Nonassociative			
	Dominant		Subordinate		Dominant		Subordinate	
	M	SD	M	SD	M	SD	M	SD
Related	531 (.014)	66.3 (.05)	548 (.056)	56.2 (.09)	583 (.035)	72.6 (.08)	600 (.035)	72.0 (.08)
Unrelated	558 (.042)	60.2 (.09)	569 (.076)	81.0 (.10)	582 (.056)	68.3 (.08)	586 (.014)	76.3 (.05)
RT difference	+27		+21		-1		-14	

Notes. Error proportions are in parentheses. The mean lexical decision latency and error rate for the nonwords were 649 ms and .069, respectively.

of Relation and Meaning Frequency were between-item factors, and Relatedness was a within-item factor.

In the analyses of lexical decision latencies, the main effect of Type of Relation was significant in both the subjects' and the items' analyses ( $F_s(1, 46) = 5.17$ ,  $MS_e = 12418.87$ ,  $p < .05$ ;  $F_i(1, 92) = 7.61$ ,  $MS_e = 8371.44$ ,  $p < .01$ ). Responses to associative targets were 36 ms faster than responses to nonassociative targets. The main effect of Meaning Frequency was marginally significant in the subjects' analysis ( $F_s(1, 46) = 3.75$ ,  $MS_e = 1930.03$ ,  $p < .06$ ), although not in the items' analysis ( $F_i(1, 92) = 1.07$ ,  $MS_e = 8371.44$ ). The main effect of Relatedness was not significant in either analysis ( $F_s(1, 46) = 1.52$ ,  $MS_e = 2181.01$ ;  $F_i(1, 92) = 1.17$ ,  $MS_e = 2946.09$ ).

The interaction between Type of Relation and Relatedness was significant in the subjects' analysis ( $F_s(1, 46) = 5.32$ ,  $MS_e = 2181.01$ ,  $p < .05$ ) and marginally significant in the items' analysis ( $F_i(1, 92) = 3.69$ ,  $MS_e = 2946.09$ ,  $p < .06$ ). This interaction reflected the fact that priming effects were only observed for the associative pairs. That is, for associative pairs, a simple main effects analysis showed that the 24 ms priming effect was significant,  $t(23) = 3.34$ ,  $p < .01$ , whereas for the nonassociative pairs, the 8 ms difference between the related and unrelated conditions, in fact, went in the wrong direction,  $t(23) = .64$ . No other interactions were significant, all  $F_s < 1$ .

In the analysis of error rates, the only significant effect was the interaction between Type of Relation and Meaning Frequency,  $F_s(1, 46) = 6.85$ ,  $MS_e = .0061$ ,  $p < .025$ , which was marginally significant in the items' analysis,  $F_i(1, 92) = 2.94$ ,  $MS_e = .0142$ ,  $p < .10$ . This significant interaction appeared to be due to the fact that more errors were made to subordinate associates than to dominant associates, whereas more errors were made to dominant nonassociates than to subordinate nonassociates. It is not

clear why this particular interaction between Type of Relation and Meaning Frequency was observed. Nonetheless, because it does not involve the Relatedness factor, it should not affect the interpretation of the lexical decision latency data.

#### DISCUSSION

The major finding of Experiment 1 was that priming effects were only observed for the associatively related pairs — semantically related, nonassociative pairs did not exhibit any priming. This result suggests that the priming effects observed at prime offset in single word prime cross-modal lexical decision tasks are due to word association, and not to semantic relatedness. This result is consistent with Fodor's (1983; 1990) argument that associative relations are more primary than semantic relations in that associative information is activated earlier. Thus, priming effects from ambiguous word primes at prime offset tend to be associatively rather than semantically mediated.

More specifically, the fact that previous studies have reported nonassociative semantic priming effects (Fischler, 1977; Lupker, 1984; Seidenberg et al., 1984) does indicate that the prime-target lexical decision task should be sensitive to "pure" semantic relations. The lack of an effect in Experiment 1 must therefore imply that semantic information from the ambiguous word prime was simply not available soon enough to influence processing of semantically related targets. That is, the process of accessing semantic representations appears to require a certain amount of time, and this process is, apparently, not yet sufficiently far along to produce priming when the target is presented at prime offset.

The second important finding from Experiment 1 was that for the associative pairs, the degree of priming was not affected by meaning frequency. That is, the magni-



tudes of the priming effects for the dominant (27 ms effect) and the subordinate pairs (21 ms) were quite similar. As noted, Onifer and Swinney (1981) also failed to observe a meaning frequency effect for targets presented at prime offset in a cross-modal lexical decision task. Together, these results seem to suggest that, contrary to Simpson and colleagues' claim (e.g., Simpson & Burgess, 1985; Simpson & Krueger, 1991), the magnitude of priming effects is not modulated by meaning frequency when the target is presented at prime offset.

Note also that the present results appear to alleviate any concerns that may have arisen about the difference in associative strength ratings for the dominant and subordinate associates. That is, even though these two types of targets had been equated on associative strength based on the norms, the mean associative strength rating for the dominant associates (5.20) was slightly larger than that for the subordinate associates (3.99). Thus, if we had observed a meaning frequency by relatedness interaction for the associates, it would be ambiguous whether meaning frequency does matter for associates or whether this effect might have been due to a failure to fully equate dominant and subordinate associates on associative strength. Because the sizes of the priming effects for the dominant and subordinate associates were very similar in spite of the fact that there was this small difference in the associative strength ratings indicates that this potential ambiguity should not be a concern.

Before fully accepting these conclusions, however, two additional issues need to be resolved. First, as noted, the semantic pairs were selected from the set of words not appearing in the association norms mainly on the basis of the intuitions of the first author (as in Fischler, 1977). Thus, at this point, we have no clear evidence that these pairs are sufficiently semantically related that they would produce a semantic priming effect in any circumstance. Second, although we calculated meaning frequency in a fairly standard way, there is no clear evidence that we had a strong meaning frequency manipulation and, hence, any potential for observing a meaning frequency by relatedness interaction. These are the two issues to be investigated in Experiment 2.

### Experiment 2

If our materials truly are problematic in these ways, we would not expect to observe either a priming effect for nonassociative pairs or a meaning frequency by relatedness interaction for either associative or nonassociative pairs, even under optimal circumstances. On the other hand, if the lack of these effects in Experiment 1 was due to the fact that sufficient semantic activation had not yet been generated by prime offset, based on previous results (e.g., Onifer & Swinney, 1981; Simpson, 1981; Simpson &

Burgess, 1985; Swinney, 1979), both effects should emerge with an increased ISI. That is, sufficiently delaying the target presentation should produce both nonassociative semantic priming and a meaning frequency by relatedness interaction, with dominant targets exhibiting more facilitation than subordinate targets. Accordingly, in Experiment 2, the prime-target ISI was set to 700 ms to test these predictions.

### METHOD

#### *Subjects*

Forty-eight undergraduate students from the University of Western Ontario participated in this experiment for course credit. All were native English speakers and had normal or corrected-to-normal vision. None had participated in Experiment 1.

#### *Stimuli*

The stimuli were the same as those in Experiment 1.

#### *Apparatus and Procedure*

The apparatus and procedure were identical to those of Experiment 1, except that the ISI between the prime and the target was 700 ms.

### RESULTS

Lexical decision latencies less than 250 ms or greater than 1400 ms were considered as errors and excluded from the RT analyses. A total of 7 data points from the experimental trials (0.61%) were excluded in this fashion. The mean lexical decision latencies for correct responses and the mean error rates were calculated across subjects and items separately. The mean lexical decision latencies and error rates (based on the experimental trials) averaged over subjects are presented in Table 3.

As in Experiment 1, subject and item means of lexical decision latencies and error rates (based on the experimental trials) were submitted to separate 2 (Type of Relation)  $\times$  2 (Meaning Frequency)  $\times$  2 (Relatedness) analyses of variance.

In the analysis of lexical decision latencies, the main effect of Relatedness was significant in both the subjects' and the items' analyses ( $F_s(1, 46) = 6.31, MS_e = 1681.14, p < .025; F_i(1, 92) = 4.25, MS_e = 4734.12, p < .05$ ). Lexical decision latencies were 15 ms faster for related targets than for unrelated targets. The main effect of Meaning Frequency was marginally significant in the subjects' analysis ( $F_s(1, 46) = 3.76, MS_e = 2538.42, p < .06$ ) but not in the items' analysis ( $F_i(1, 92) = .91, MS_e = 10038.30$ ). In addition, the interaction between Meaning Frequency and Relatedness was significant both in the subjects' and the items' analyses ( $F_s(1, 46) = 15.78, MS_e = 3257.96, p < .001; F_i(1, 92) = 8.43, MS_e = 4734.12, p < .01$ ). This interaction

TABLE 3  
Mean Lexical Decision Latencies (ms) and Error Proportions in Experiment 2.

Relatedness	Type of Relation							
	Associative				Nonassociative			
	Dominant		Subordinate		Dominant		Subordinate	
	M	SD	M	SD	M	SD	M	SD
Related	553 (.014)	79.7 (.05)	599 (.028)	99.9 (.09)	553 (.021)	78.5 (.07)	600 (.056)	105.5 (.09)
Unrelated	598 (.042)	98.7 (.07)	580 (.042)	87.3 (.07)	603 (.028)	93.5 (.06)	584 (.063)	80.8 (.10)
RT difference	+45		-19		+50		-16	

Notes. Error proportions in parentheses. The mean lexical decision latency and error rate for the nonwords was 676 ms and .066, respectively.

reflects the fact that a priming effect was only observed for the dominant targets. That is, for the dominant targets, a simple main effects analysis showed that the 47 ms priming effect was significant,  $t(47) = 5.87$ ,  $p < .01$ , whereas for the subordinate targets, the 18 ms difference between the related and unrelated conditions, in fact, went in the wrong direction,  $t(47) = 1.53$ ,  $p > .10$ . No other effects were significant, all  $F_s < 1$ .

In the analysis of error rates, the main effect of Meaning Frequency was marginally significant in the subjects' analysis,  $F_1(1, 46) = 3.31$ ,  $MS_e = .0063$ ,  $p < .08$ , but not in the items' analysis,  $F_1(1, 92) = 2.19$ ,  $MS_e = .0095$ . No other effects were significant, all  $F_s < 1.6$ .

#### DISCUSSION

In contrast to the results of Experiment 1, associative and nonassociative pairs behaved identically. In particular, priming effects were only observed for dominant pairs, regardless of the nature of the prime-target relation. Thus, both a nonassociative semantic priming effect and a meaning frequency by relatedness interaction were observed with a 700 ms ISI. These results seem to suggest that the priming effects at this ISI are primarily due to semantic relatedness and that meaning frequency has started to play an important role.

What should also be pointed out is that because a nonassociative semantic priming effect and a meaning frequency by relatedness interaction were observed with the 700 ms ISI using the identical materials as in Experiment 1, the lack of these effects in Experiment 1 cannot be attributed to problems with our materials. Rather, based on the fact that identical size priming effects were observed for the dominant associative and dominant nonassociative prime-target pairs, our dominant nonassociative pairs do appear to have a reasonable amount of semantic strength.

As well, the meaning frequency by relatedness interaction clearly indicates that our pairs represent a reasonably strong meaning frequency manipulation.

In drawing conclusions from these results, it is important to first consider whether it would be at all possible to explain them solely in terms of either associative relatedness or semantic relatedness. One could conjecture, for example, that the dominant nonassociative pairs simply involve weak associative relations and that they produced a priming effect only at the longer ISI simply because it may take longer for weak associations to produce a sizable priming effect.

The reason that this type of account would not be successful is that it could not explain the results for the subordinate associative pairs. For these pairs, although there was a significant priming effect in Experiment 1, there was none in Experiment 2. Since the significant priming effect in Experiment 1 suggests that these pairs involve strong associative relations, one would have expected them to have produced a priming effect in Experiment 2 if the priming effects were simply due to word association.

Similarly, an account based solely on semantic relatedness would also run into problems. That is, if one assumed that the semantic strengths of the dominant nonassociative pairs were less than those for the dominant associative pairs and that weaker relations need longer ISIs to show priming, one could account for the increased priming effects for the dominant nonassociative pairs in Experiment 2. What would be unexplained, however, is why the priming for the subordinate associative pairs disappeared in Experiment 2. What would also be difficult to explain would be why there was no priming for the subordinate nonassociative pairs in Experiment 2 since these pairs also appear to be semantically related.

In order to examine the issue of semantic strength in more depth, we obtained semantic strength ratings for our materials, both for the related pairs and for their respective unrelated control pairs. Given each word pair, subjects were asked to judge the extent to which the two words are related in meaning using a seven-point scale from "Unrelated" (0) to "Very Related" (6). They were also instructed not to base their judgments on how easily and quickly one word comes to mind when reading the other (i.e., to try not to rate the associative strength of the pairs).<sup>4</sup>

For both associative and nonassociative pairs, the ratings were significantly greater for the related pairs (5.06 for the dominant associative pairs, 4.26 for the subordinate associative pairs, 3.93 for the dominant nonassociative pairs, and 3.82 for the subordinate nonassociative pairs) than for their unrelated control pairs (1.18, .95, .88, and .77 for the respective unrelated control pairs),  $F(1, 92) = 656.68$ ,  $MS_e = .81$ ,  $p < .001$ . Thus, the rating data suggest that even our subordinate nonassociative pairs do have significant semantic strength. Note also that although the dominant associative pairs received higher semantic strength ratings than the other related pairs, the ratings were quite similar for the other three types of pairs. In fact, significant differences were not detected across these three types of pairs,  $F(2, 69) = 1.16$ ,  $MS_e = 1.09$ ,  $p > .10$ . This fact, coupled with the fact that the pattern of priming changed in a predictable way across the two experiments clearly indicates that our results cannot be attributed to the differences in the strengths of semantic relatedness. Rather, it is more likely that the priming effects in Experiment 1 were mainly due to word association and that, in Experiment 2, the priming effects were driven by semantic relatedness interacting with meaning frequency.

The entire set of results then is consistent with our conclusions that the lack of a nonassociative semantic priming effect and the lack of a meaning frequency effect in Experiment 1 were due to semantic information not yet being available at prime offset. That is, the process of accessing semantic representations seems to require a

certain amount of time and this process does not appear to have been sufficiently far along when the target was presented at prime offset. Thus, the semantic information relating to the ambiguous word prime was not available to influence target processing at that point.

An interesting aspect of the Experiment 2 results is that the magnitudes of the priming effects were the same for the dominantly-related associative targets (45 ms) and the dominantly-related nonassociative targets (50 ms). Consistent with this result, Fischler (1977) and Seidenberg et al. (1984) reported that the magnitudes of the priming effects for associative pairs and nonassociative pairs in lexical decision tasks were also quite similar. On the other hand, Lupker (1984) observed a larger priming effect for associative pairs (47 ms) than for nonassociative pairs (26 ms) in his lexical decision experiments. As noted, Lupker suggested that associative priming effects occurred at the lexical-selection stage, and were further augmented at the decision-making stage due to the semantic relatedness. If Lupker's argument were correct, an obvious question might be why were the priming effects not greater for associative pairs than for nonassociative pairs. What should also be noted, of course, is that if Lupker's analysis truly were applicable here, one also would have expected a significant priming effect for subordinate associative pairs in Experiment 2 because there was a significant priming effect for those pairs in Experiment 1.

There would appear to be two possible explanations for the equivalent priming effects for the dominant meaning pairs, either the lexical activation that leads to associative priming effects decayed (or was suppressed) during the 700 ms ISI, or the relatively smaller associative priming effect during lexical selection was simply obscured by the greater contribution of the post-selection, semantic effects at the decision-making level (see also Balota & Lorch, 1986; McNamara & Altarriba, 1988 for similar discussions concerning the lack of mediated priming in lexical decision tasks). Given the lack of an associative priming effect for the subordinate associative pairs in Experiment 2 and the fact that, based on the results of Experiment 1, associative priming effects actually do seem to be of reasonable size, the first explanation seems to be the more likely one. Thus, the implication is that the priming effects in Experiment 2 appear to have been purely semantic and, presumably, occurred purely at the decision-making level.

Finally, the general conclusion that the results of Experiments 1 and 2 allow us to draw is that priming effects seem to be altered qualitatively as well as quantitatively by manipulations of the interval between the ambiguous word prime and target. The priming effects that were observed when targets were presented at prime offset (Experiment 1) were primarily due to word association. With a 700 ms delay (Experiment 2), however,

<sup>4</sup> One of four associative sets and one of four nonassociative sets used in Experiments 1 and 2 were appropriately combined and four stimulus lists were created, each of which consisted of 6 dominant associative pairs, 6 subordinate associative pairs, 6 dominant nonassociative pairs, 6 subordinate nonassociative pairs and their respective 24 unrelated control pairs. In each stimulus list, ambiguous word primes appeared twice, once with a related target and once with an unrelated target, whereas targets appeared only once. In addition to the 48 pairs, each stimulus list also involved 40 filler pairs, in which twenty unambiguous words were paired once with semantically related associative targets and once with unrelated targets. Four versions of questionnaires were created by randomly ordering each of the four stimulus lists. Semantic strength ratings were then obtained from a total of 100 subjects, with 25 subjects assigned to each of four questionnaires.

priming effects appear to be essentially entirely semantically based. These results suggest that the priming effects in cross-modal lexical decision tasks do not necessarily reflect the time-course of "semantic" activation for the ambiguous word prime. Rather, consistent with Fodor's (1983; 1990) arguments, priming effects may be observed at prime offset because word association affects the lexical-selection process at a very early point in processing. The effects of semantic factors such as semantic relatedness and meaning frequency only become evident when there is some delay between prime and target.

### General Discussion

The cross-modal priming paradigm has been used by many researchers to investigate the process of lexical ambiguity resolution. The priming effects in this paradigm have traditionally been interpreted as being due to the semantic relation between the prime and target. That is, hearing the prime causes meaning information to be retrieved automatically, and then, when the target is related to the retrieved meaning(s) of the prime, responding to the target is facilitated.

There have, however, been some challenges to this interpretation of cross-modal priming effects. Fodor (1983; 1990), in particular, has argued that many ostensible "semantic" priming effects are, in fact, effects of association. In Fodor's conception of the lexicon, lexical units are connected via associative links. These are links that are built up as a result of the co-occurrence of words and, thus, may have little to do with semantics. Semantic information is stored externally to the lexicon and, thus, would be activated at some point after associative information had been activated. If these conjectures are correct they raise the possibility that the priming effects observed at prime offset in a cross-modal priming task may also have very little to do with semantic relations.

In fact, Fodor's description of our mental architecture does gain some support from a number of results in the literature (e.g., Balota & Lorch, 1986; Lupker, 1984; McNamara & Altarriba, 1988; Shelton & Martin, 1992). Thus, the present research was an attempt to determine the relative contributions of "semantic" activation and word association to the priming effects in the cross-modal lexical decision task with ambiguous word primes. To address this issue, our related pairs involved two types of prime-target relations: an ambiguous word prime was paired with either an associative target or a semantically related, nonassociative target. In any circumstance where priming is due only to word association, only associative pairs should exhibit priming. On the other hand, in circumstances where priming is also due to semantic relatedness, then semantically related, nonassociative pairs should also exhibit a priming effect.

In Experiment 1, the targets were presented at the offset of the ambiguous word primes. Priming was observed for associative pairs, but there was no priming for nonassociative pairs. This result suggests that the priming was due to word association and not to semantic relatedness. Because the lexical decision task should be sensitive to "pure semantic" relatedness as well as to associative relations, the lack of a nonassociative priming effect indicates that the semantic activation for the ambiguous word prime was only minimally established when the subjects were responding to the target. Thus, there would appear to be a difference in the speed at which word association and semantic information become available. This conclusion is consistent with Fodor's suggestion that word association may be implemented and accessed within the lexicon, whereas semantic information, which is stored outside the lexicon, is only activated subsequently.

In Experiment 2, the targets were presented after an ISI of 700 ms. If the activation of semantic information simply takes a bit more time, then one would expect that semantically related, nonassociative pairs would show some evidence of priming at an ISI of 700 ms. In fact, this is precisely what was observed (for targets related to the dominant meaning of the prime). Together, these results suggest that priming effects at prime offset in the cross-modal priming task are due to word association, and that priming due to semantic relatedness only arises when a bit more time is available for prime processing.

The other important variable examined in the present research was meaning frequency. Whereas meaning frequency interacted with relatedness when the targets were presented after a 700 ms delay (Experiment 2), with a 0 ms delay (Experiment 1), the magnitude of the relatedness effects were nearly identical for dominant and subordinate associative pairs. Thus, these results were inconsistent with other studies which have reported a meaning frequency by relatedness interaction at short prime-target intervals (e.g., Simpson & Burgess, 1985; Simpson & Krueger, 1991; Tabossi et al., 1987). Most notable is Simpson and Burgess' (1985) report of a meaning frequency by relatedness interaction in a visual prime-target lexical decision task with a prime-target SOA of less than 300 ms.

The point to keep in mind here is that the associative strengths for dominant and subordinate pairs were not equated in any of the previous studies that we are aware of (and in the Simpson and Krueger (1991) study, associative strengths clearly seemed to be higher for the dominant pairs). Thus, our hypothesis is that the previously reported meaning frequency by relatedness interactions in short prime-target interval conditions are due to a confound between meaning frequency and associative strength.

## THEORETICAL IMPLICATIONS CONCERNING TIME-COURSE

As noted, many investigators (e.g., Kintsch & Mross, 1985; Onifer & Swinney, 1981; Seidenberg et al., 1982; Simpson, 1981; Simpson & Krueger, 1991; Swinney, 1979; Till, Mross, & Kintsch, 1988; Tabossi, 1988; Tabossi et al., 1987) have assumed that the cross-modal priming paradigm allows one to observe the time-course of "semantic" activation brought about by the ambiguous word prime. Based on our results, this assumption appears to be incorrect. That is, our results suggest that, over time, the nature of the priming effect itself changes, from associative to semantic. Thus, inferences regarding the time-course of semantic activation cannot be solely based on manipulations of prime-target intervals.

What then can one say about the nature of the time course of semantic activation? To try to measure pure semantic activation, we used semantically related, nonassociative prime-target pairs in our studies. As noted, although there was no evidence of a priming effect for these pairs when the target was presented at prime offset, with a 700 ms delay, a priming effect was observed for the dominant targets. This pattern of results suggests either that semantic activation occurs only for the dominant meaning of an ambiguous word or that whatever semantic activation occurs for the subordinate meaning of an ambiguous word has already disappeared by 700 ms.

Based on results reported by Simpson and Burgess (1985), the latter is probably correct. That is, Simpson and Burgess reported that targets related to the subordinate meaning of the prime do not produce priming effects at a very short SOA, but do produce priming at 300 ms SOA (although not at 750 ms SOA). Because these pairs showed no priming at Simpson and Burgess's shortest SOA, it seems likely that they had very little associative strength. Thus, the effect they demonstrated at the 300 ms SOA is probably semantic. The fact that this effect does not exist at around 700 ms SOA (in both Simpson and Burgess's experiment and the present Experiment 2) implies that Simpson and Burgess's conclusion is probably correct. The semantic activation for subordinate targets, although not available immediately, arises reasonably quickly, but then typically has a short life span.

What about semantic activation for dominant targets? Simpson and colleagues (Simpson & Burgess, 1985; Simpson & Krueger, 1991) have also concluded that the initial semantic activation of an ambiguous word is determined by meaning frequency when an ambiguous word is not accompanied by biasing context. That is, based on their finding of a meaning frequency by relatedness interaction in their shortest SOA condition, they argue that although both dominant and subordinate meanings are activated automatically, the speed of activation is faster for the dominant meaning. Our results and analysis described above, however, suggest that Simpson

and colleagues' data do not provide strong support for this claim.

To summarize, first, our results suggest that manipulations of prime-target intervals do not simply reflect the time-course of semantic activation. Rather, the nature of the priming effect changes from associative to semantic. Consequently, some portion of the priming effects at short ISIs in Simpson and colleagues' studies was probably due to effects of word association, effects that would have to be teased out to be able to make firm claims about the effects of semantic relations.

Second, Simpson and colleagues' meaning frequency manipulation seems to be confounded with the differences in associative strength between the dominant and subordinate pairs. Thus, the meaning frequency by relatedness interactions which they found in their shortest SOA condition may very well have been due to the differences in associative strength between the dominant and subordinate pairs. Obviously, for Simpson and colleagues to substantiate their claim about the relative rates of availability of semantic information for dominant and subordinate meanings, they would need to establish their time course differences as truly being due to semantic rather than associative relations.

## THE DISTINCTION BETWEEN ASSOCIATIVE AND SEMANTIC PRIMING

The present studies are just two of a number of studies suggesting that it is important to distinguish between associative and semantic priming. What should be noted, however, is that Simpson and Krueger's (1991) results seem to provide some evidence against this suggestion. Based on the results of our Experiment 1, we argued that short ISI priming effects in cross-modal priming tasks are mainly due to word association. As such, Simpson and Krueger's meaning frequency by relatedness interaction at the short ISI with unbiased context may very well have been due to differential associative strengths. The point, however, is that if the priming in short ISI conditions is due *only* to word association, one would predict that there would be an identical pattern with biasing context. Yet, when the context was biased toward the subordinate meaning of the ambiguous word prime in Simpson and Krueger's experiments, the pattern changed. In this condition, priming was observed only for the subordinate targets, with no priming for the dominant targets even at their shortest ISI. Thus, when an ambiguous word is accompanied by biasing context, that context may create semantic/thematic effects even with very short ISIs between the final word in the context sentence (the prime) and the target.

One must, however, be a bit cautious in interpreting Simpson and Krueger's (1991) data because their ISI manipulation was somewhat imprecise due to the fact that

target presentation was controlled by an experimenter pressing a button simultaneously with the subject beginning to pronounce the last word in the context sentence. Thus, there is some possibility that even their shortest ISI condition involved a not insubstantial delay in target presentation. If so, Simpson and Krueger's semantic/thematic effects would also not be particularly problematic for either our general argument or Fodor's "anti-semantic" position.

What may be a bit of a problem for a strict anti-semantic position would be the results reported recently by Moss, Ostrin, Tyler, and Marslen-Wilson (1995). McNamara and Altarriba (1988) and Shelton and Martin (1992) have suggested that a single item lexical decision task is sensitive to automatic components of priming but is insensitive to strategic components based on the fact that, in single item lexical decision tasks, associative and mediated priming effects were observed but nonassociative semantic and backward priming effects (e.g., Koriat, 1981; Seidenberg et al., 1984) were not. These results allowed Shelton and Martin to argue, in agreement with Fodor, that automatic priming seems to be solely due to associative relations. Moss et al., however, have recently found a significant nonassociative semantic priming effect for word pairs holding instrument relations such as "BROOM-FLOOR" in a single item lexical decision task, although priming was not observed for category coordinates or script relations. These results suggest that automatic priming may be due to some other types of relations in addition to associative relations. Thus, although these data do not necessarily argue against a modular account, per se, they do suggest that the lexical module may code at least some types of semantic relations.

There is a growing interest in the issue of whether semantic factors affect the lexical-selection process. Balota, Ferraro, and Connor (1991), in a review of semantic effects in isolated word recognition studies, have argued that semantic variables do influence the speed of lexical selection. More recently, however, Hino and Lupker (1996), in an examination of the effects of polysemy (number of meanings) on word recognition, have argued that semantic effects of the sort that Balota et al. have cataloged are not necessarily due to the lexical-selection process, but could instead be due to task-specific processes. Thus, it is still an open question whether semantic variables influence the lexical-selection process. In any case, although there is little doubt that the debate will continue for some time to come, the importance of the original research question has not diminished. An adequate understanding of the language processing system can only come about through a better understanding of how knowledge is implemented in that system.

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Correspondence should be addressed to Yasushi Hino, Department of Psychology, Chukyo University, 101-2 Yagotohonmachi, Showaku, Nagoya, Aichi, 466, Japan (e-mail: hino@scs.chukyo-u.ac.jp).

#### References

- Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance*, 10, 340-357.
- Balota, D. A., Ferraro, R. F., & Connor, L. T. (1991). On the early influence of meaning in word recognition: A review of the literature. In P. J. Schwanenflugel (Ed.), *The psychology of word meanings* (pp. 187-221). Hillsdale, NJ: Erlbaum.
- Balota, D. A., & Lorch, R. F. (1986). Depth of automatic spreading activation: Mediated priming effects in pronunciation but not in lexical decision. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 12, 336-345.
- Brodeur, D. A., & Lupker, S. J. (1994). Investigating the effects of multiple primes: An analysis of theoretical mechanisms. *Psychological Research/Psychologische Forschung*, 57, 1-14.
- Cramer, P. A. (1970). Study of homographs. In L. Postman & G. Keppel (Eds.), *Norms of word association* (pp. 361-382). New York: Academic Press.
- Fischler, I. (1977). Semantic facilitation without association in a lexical decision task. *Memory & Cognition*, 5, 335-339.
- Fodor, J. A. (1983). *Modularity of mind: An essay on faculty psychology*. Cambridge, MA: MIT Press.
- Fodor, J. A. (1990). *On the modularity of parsing: A review*. Unpublished manuscript.
- Hines, D., Czerwinski, M., Sawyer, P. K., & Dwyer, M. (1986). Automatic semantic priming: Effect of category exemplar level and word association level. *Journal of Experimental Psychology: Human Perception and Performance*, 12, 370-379.
- Hino, Y., & Lupker, S. J. (1996). The effects of polysemy in lexical decision and naming: An alternative to lexical access accounts. *Journal of Experimental Psychology: Human Perception and Performance*, 22, 1331-1356.
- Huttenlocher, J., & Kubicek, L. F. (1983). The source of relatedness effects on naming latency. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 9, 486-495.
- Kintsch, W., & Mross, E. F. (1985). Context effects in word identification. *Journal of Memory and Language*, 24, 336-349.
- Koriat, A. (1981). Semantic facilitation in lexical decision as a function of prime-target association. *Memory & Cognition*, 9, 587-598.
- Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.

- Lupker, S. J. (1984). Semantic priming without association: A second look. *Journal of Verbal Learning and Verbal Behavior*, 23, 709-733.
- McNamara, T. P., & Altarriba, J. (1988). Depth of spreading activation revisited: Semantic mediated priming occurs in lexical decisions. *Journal of Memory and Language*, 27, 545-559.
- Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, 90, 227-234.
- Moss, H. E., Ostrin, R. K., Tyler, L. K., & Marslen-Wilson, W. D. (1995). Accessing different types of lexical semantic information: Evidence from priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21, 863-883.
- Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 106, 226-254.
- Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.) *Basic processes in reading: Visual word recognition* (pp. 264-336). Hillsdale, NJ: Erlbaum.
- Neely, J. H., & Keefe, D. E. (1989). Semantic context effects on visual word processing: A hybrid prospective/retrospective processing theory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory*, Vol. 24 (pp. 207-248). New York: Academic Press.
- Nelson, D. L., McEvoy, C. L., Walling, J. R., & Wheeler, J. W. (1980). The University of South Florida homograph norms. *Behavior Research Methods & Instrumentation*, 12, 16-37.
- Onifer, W., & Swinney, D. A. (1981). Accessing lexical ambiguities during sentence comprehension: Effects of frequency of meaning and contextual bias. *Memory & Cognition*, 9, 225-236.
- Seidenberg, M. S., Tanenhaus, M. K., Leiman, J. M., & Bienkowski, M. (1982). Automatic access of meanings of ambiguous words in context: Some limitations of knowledge-based processing. *Cognitive Psychology*, 14, 489-537.
- Seidenberg, M. S., Waters, G. S., Sanders, M., & Langer, P. (1984). Pre- and postlexical loci of contextual effects on word recognition. *Memory & Cognition*, 12, 315-328.
- Shelton, J. R., & Martin, R. C. (1992). How semantic is automatic semantic priming? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 1191-1210.
- Simpson, G. B. (1981). Meaning dominance and semantic context in the processing of lexical ambiguity. *Journal of Verbal Learning and Verbal Behavior*, 20, 120-136.
- Simpson, G. B., & Burgess, C. (1985). Activation and selection processes in the recognition of ambiguous words. *Journal of Experimental Psychology: Human Perception and Performance*, 11, 28-39.
- Simpson, G. B., & Krueger, M. A. (1991). Selective access of homograph meanings in sentence context. *Journal of Memory and Language*, 30, 627-643.
- Swinney, D. A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, 18, 645-659.
- Tabossi, P. (1988). Accessing lexical ambiguity in different types of sentential contexts. *Journal of Memory and Language*, 27, 324-340.
- Tabossi, P., Colombo, L., & Job, R. (1987). Accessing lexical ambiguity: Effects of context and dominance. *Psychological Research*, 49, 161-167.
- Till, R. E., Mross, E. F., & Kintsch, W. (1988). Time course of priming for associate and inference words in a discourse context. *Memory & Cognition*, 16, 283-298.
- West, R. F., & Stanovich, K. E. (1982). Source of inhibition in experiments on the effect of sentence context on word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 8, 358-399.

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**Appendix**  
Experimental Word Quintets Used in Experiments 1 and 2

Ambiguous Word Prime	Associative Target		Nonassociative Target	
	Dominant	Subordinate	Dominant	Subordinate
frisk	touch	cat	doubt	movement
digit	calculator	finger	degree	appendage
ruler	twelve	king	map	govern
bug	beetle	bother	snake	defect
jam	bread	stuck	syrup	congestion
mint	candy	coins	cake	bank
scrap	waste	fight	fragment	feud
diamond	stone	baseball	mineral	catcher
calf	mother	ankle	fawn	arm
port	boats	wine	beach	alcohol
habit	smoke	nun	frequent	dress
meal	dinner	corn	tea	flour
net	basketball	worth	fabric	total
coat	pocket	cover	shoe	wax
plain	simple	flat	unique	horizon
bay	ocean	hound	geography	cry
scale	measure	fish	statistics	skin
plant	oak	factory	grass	manufacture
note	card	music	ink	piano
bill	check	duck	nickel	wing
rest	sit	remainder	refresh	extra
court	judge	yard	police	volleyball
case	lawyer	brief	tale	carry
state	texas	condition	local	manner

## Sommaire

Le paradigme d'amorçage intermodal a été utilisé par un certain nombre de chercheurs pour étudier le processus de résolution de l'ambiguïté lexicale. Dans ce paradigme, les effets d'amorçage ont habituellement été interprétés comme étant le temps d'absorption de l'activation "sémantique" découlant de mots-amorces ambigus. Toutefois, cette interprétation, basée sur l'idée que ces effets d'amorçage pourraient être produits non seulement par l'activation sémantique mais également par l'association du mot, représente certaines difficultés. Au cours des présentes expériences, lors de décisions intermodales comportant des mots amorcés ambigus, nous avons tenté d'étudier l'apport relatif de l'activation sémantique et de

l'association du mot aux effets d'amorçage. Pour étudier la question, les mots-amorces ambigus présentés verbalement étaient suivis soit par des cibles reliées par association ou par la sémantique, mais non reliées par association dans les conditions reliées. De plus, nous avons tenté d'égaliser les forces associatives pour ce qui est des cibles à relation dominante et à relation subordonnée.

Lorsque les cibles étaient présentées avec un amorçage décalé (expérience 1), les effets d'amorçage ne pouvaient être observés que pour les cibles reliées par association, indépendamment de la fréquence de la signification (selon que la cible était reliée à la signification dominante ou subordonnée de l'amorce ambiguë). Toutefois, lorsque les



cibles étaient présentées après un délai de 700 ms (expérience 2), les effets d'amorçage ont été observés seulement dans le cas des cibles reliées à la signification dominante de l'amorce, quelle que soit la nature de la relation entre l'amorce et la cible.

Ces résultats suggèrent que les effets d'amorçage sont causés par l'association au mot. L'activation sémantique du mot-amorce ambigu ne semble pas suffisamment développée pour influencer, à ce moment précis, le traitement des cibles reliées par la sémantique. Cependant, un délai de 700 ms donne le temps à l'activation sémantique de prendre forme, tandis que l'activation reliée à l'association au mot semble décroître (ou être supprimée), de façon à ce que, lors du délai de 700 ms, les effets d'amorçage soient

dirigés essentiellement par la relation sémantique. Donc, contrairement aux interprétations précédentes, ces résultats suggèrent que la nature associative des effets d'amorçage devient, avec le temps, sémantique. Ces résultats démontrent également qu'il est fort probable que les différences de format constatées auparavant dans les effets d'amorçage entre les cibles reliées à la dominante et les cibles reliées à la subordonnée, dans des intervalles courts entre l'amorce et la cible, soient attribuables aux différences de fréquence de la signification, mais plutôt à une confusion entre la fréquence de la signification et la force associative des paires dominantes et subordonnées. Ces résultats sont examinés selon le point de vue de la modularité "anti-sémantique" de Fodor (1983, 1990).