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Investigating the effects of multiple primes: An analysis of theoretical mechanisms

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Abstract Is the size of a semantic-priming effect a function of the strength of the semantic context? This issue was examined in four studies using a single categorically related prime as the weaker context and four categorically related primes as the stronger context. Results indicate that, independently of prime-target SOA, four primes provide a larger priming effect than a single prime in a lexical-decision task, but not in a naming task. These data provide further support for the argument that different mechanisms mediate priming in the two tasks. In particular, only the lexical-decision task appears to be susceptible to higher-level processes that can be influenced by the number of primes. Priming in a naming task appears to be driven by more automatic processes. Possible accounts of this multiple-prime advantage in lexical-decision tasks are considered.

Introduction

A key question for reading researchers is how the reading process is affected by context. A major tool for addressing this question has been the priming paradigm. The standard paradigm involves the presentation of a target stimulus (a word or a nonword) following a semantically related or unrelated prime stimulus. The typical finding is that responses to targets are faster after related primes than after unrelated primes (e. g., Meyer & Schvaneveldt, 1971; Neely, 1977; see Neely, 1991, for a review of this literature).

Since Meyer and Schvaneveldt (1971) first reported this finding, a number of models of semantic-context effects have been proposed. The most commonly cited is Collins and Loftus' (1975) spreading-activation model. In this model, semantic and lexical memories are thought of as networks consisting of nodes and links between nodes. When the prime is processed, its nodes are activated. This activation then spreads out to nodes for semantically similar concepts (e. g., concepts that are associatively related, in the same semantic category, etc.). The result is an increase in the activation levels of those nodes. If the target word is the name of one of those semantically similar concepts, access to its lexical and semantic nodes is facilitated because of their heightened activation.

Although the spreading-activation model provided much of the impetus for the present research, for future discussion a number of other models of the process will be presented. According to Becker's (1980) verification model, semantic priming is due to a prime-initiated, expectancy-generation process in which the prime presentation causes the subject to establish an "expectancy set" of words whose features are the first to be compared with the features of the target word. If a match is found, a rapid response is executed. If not, the search for a match for the target must continue, leading to a longer response time. In most circumstances, the expectancy set contains words semantically similar to the prime, thus leading to the semantic-priming effect.

In Becker's (1980) model, as in the spreading-activation model, the process responsible for the semantic-priming effect is presumed to be lexical access. Norris's (1986) plausibility-checking model attributes the effect to a slightly later stage. According to this model, a target word actually allows access to a number of lexical entries. These entries are then evaluated serially to complete word identification. The order of evaluation is determined by both frequency and context, so that contextually appropriate words are evaluated (and hence identified) sooner than contextually inappropriate words. Although this evaluation process is "post-access," it must still be completed before a word is identified. Thus, all three models suggest that semantic priming should be observed whenever a word is identified.

Models that do not require that semantic priming should occur when a word is identified have also been suggested. Most of these models hypothesize that the lexical-decision task has a post-lexical, decision component, which is a locus

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of facilitation (these models will be referred to as *post-lexical* models, although the Ratcliff and McKoon (1988) model is more properly thought of as an *alexical* model). Many versions of this type of model are now in the literature (Balota & Lorch, 1986; De Groot, 1984; Forster, 1981; Neely, 1976; 1977; Neely & Keefe, 1989; Seidenberg, Waters, Sanders, & Langer, 1984), but most are based on the idea that some sort of semantic-coherence checking or meaning integration takes place between prime and target. If prime and target are semantically coherent, a response can be made more rapidly than when they are not. This coherence-checking process, however, is typically assumed not to be involved in a naming task.

The most detailed description of a coherence-checking process is contained in the semantic-matching model of Neely and colleagues (Neely & Keefe, 1989; Neely, Keefe, & Ross, 1989). According to this model, nonwords also activate lexical units – in particular, units of visually similar words. In the typical semantic-priming task, however, these units are not units for words semantically related to the prime. As such, the result of this lexical-activation process can be used as a cue to the correct response. That is, before subjects have had time to make their response, they can determine whether any of the activated lexical units match the prime semantically. Since a semantic match would only be found on related word trials, and no match would be found on all nonword trials, the outcome of this matching process is predictive of the ultimate response on all but the unrelated word trials. When the nonword percentage is large, the matching process will quite often be useful, and hence it should be used more, as the authors appear to have demonstrated.

Finally, Ratcliff and McKoon's (1988) compound-cue model also localizes the semantic-priming effect at a higher, decision level. They suggest that when subjects are making lexical decisions, they are essentially making a familiarity judgment. When a prime and a target are presented, the familiarity judgment is based on a combination of the two stimuli. Related pairs generate a higher familiarity, yielding a faster reaction time. Thus, while the compound-cue model is quite appropriate to tasks involving a binary decision (e. g., episodic recognition), it would not be a description of priming in a naming task.

For present purposes, note that these models represent different ways of explaining the effect of an appropriate semantic context on target processing. In all cases, the models can explain the basic semantic-priming effect. In addition, as Neely (1991) has documented, each model can explain some extensions of the effect, while failing to explain others. The purpose of the present paper was to explore another extension of the effect, in order to shed more light on the explanatory power of the different models. The basic question concerns the effects of multiple primes. Specifically, as additional primes are provided, is there a concomitant increase in the size of the priming effect?

This question is actually one specific version of the more general question of whether the size of the priming effect is a function of the strength of an appropriate context. Previous studies, using single word primes and varying the strength of the context in other ways, seem to suggest that context strength is important. For example, De Groot, Thomassen, and Hudson (1982) found a larger priming effect with strong associates than with weaker associates. Lorch (1982), Lorch, Balota, and Stamm (1986), and Keefe and Neely (1990) have reported that high-dominance exemplars are named faster than low-dominance exemplars when primed by the category name. Massaro, Jones, Lipscomb, and Scholz (1978) demonstrated a similar effect in a lexical-decision task. On the other hand, some studies have failed to find such strength effects. For example, Becker (1980) found essentially equal priming effects for category primes and antonym primes in a lexical-decision task (in which the priming effect is defined as the difference between related and unrelated conditions). Similarly, Lorch et al. (1986), Den Heyer, Briand, and Smith (1985), and Neely (1977) failed to find any effects of category dominance in a lexical-decision task.

Studies using sentence primes have also produced evidence for strength effects. In a lexical-decision task, Kleiman (1980) reported that words that were acceptable sentence endings were responded to more rapidly if they were more related to the context. Perfetti and Roth (1981) reported a similar effect with grade-4 students in a naming task. Studies using predictability as the strength manipulation also tend to support the argument. Fischler and Bloom's (1979; 1980; 1985) results, using a lexical-decision task, suggest that predictability, as measured through a cloze procedure, does correlate with the size of the priming effect, at least when the sentences are not presented too rapidly. Schvanenflugel and LaCount (1988) reported similar, though smaller, differences, also using a lexical-decision task. Stanovich and West (1981; 1983; West & Stanovich, 1982), on the other hand, report larger facilitation effects for less predictable, though more difficult, words. Nonetheless, the general pattern across these studies does seem to suggest that the strength of the context is a determinant of the degree of priming observed.

In the present studies, we manipulated context strength in a directly quantitative way. The weaker context condition consisted of a single prime from the target's semantic category, while the stronger context condition consisted of four primes from target's category. There were three purposes for this particular manipulation. First, the spreading-activation model clearly predicts that multiple primes would produce more priming than a single prime, because more activation would spread to the target from four sources than from one. Second, presenting multiple primes seemed to be a more straightforward manipulation of context strength than category dominance or cloze percentage. That is, while dominance ratings or cloze percentage assure that the stronger prime condition is stronger on average, the size of the difference may vary substantially between subjects. At the very least, this will add to the variability. Further, if there is no effect, as in some of the studies cited above, there is no way of knowing whether the manipulation was a strong one for that particular set of subjects. On the other hand, four primes should provide a stronger context than one prime for all subjects. Finally, the presentation of multiple category-member primes has had interesting, counterintuitive effects in similar tasks. These studies will be discussed below, after a short review of earlier research on the effects of multiple primes in a lexical-decision task.

There appear to be only two published papers comparing single and multiple primes in a lexical-decision task. Schmidt (1976) used either one, three, or eight prime(s) that were highly related, moderately related, or unrelated, in terms of being in the same semantic category (e. g., scotch-rum; beer-milk; juice-house, respectively). The relevant finding was a significant difference in the size of the priming effect for one versus eight primes. This difference was only observed, however, when the primes were moderately related to the targets. Further, even this difference was compromised by an apparent speed-accuracy tradeoff. As such, Schmidt's (1976) results provide very little support for a priming advantage for multiple primes.

The other study that investigated the effects of multiple primes was reported by Klein, Briand, Smith, and Smith-Lamothe (1988). Subjects were presented with either two identical or two different primes, at an SOA of either 80 or 320 ms. (When two different primes were presented, they always consisted of a category name and an exemplar from that category). Larger priming effects were found in a lexical-decision task for two different primes (in comparison with two identical primes) at an SOA of 320 ms, supporting the conclusion that multiple primes are more effective than a single prime (hereafter referred to as a *multiple-prime advantage*). With an 80 ms SOA there was no evidence of a multiple-prime advantage.

Klein et al. (1988) interpreted their results as supporting the spreading-activation model. The effect of multiple primes is to cause activation to spread to the target's node from two prime nodes. The result is more activation in the target's node than when only one prime is used (even when it is repeated). Klein et al.'s (1986) results suggest that the multiple-prime advantage was found only at the longer SOA because 80 ms was not enough time for the activation to spread from the category prime to the exemplar target, although it was enough time for activation to spread from the exemplar prime to the exemplar target.

While Klein et al.'s (1988) results are consistent with the spreading-activation model, they would also seem to be consistent with most of the other models. For example, in both Becker's (1980) and Norris' (1986) models, the priming effect is due to a serial search facilitated by the use of semantic relatedness as a cue. Multiple primes may simply provide a better cue than a single prime, allowing the target word to be identified faster, and thus producing the multiple-prime advantage. In the post-access, coherence-checking models, a multiple-prime advantage could be due to a more extensive semantic context providing greater semantic coherence, and hence faster responding. In all cases, the SOA difference would have to be explained in terms of the second prime being less useful at short SOAs because there was insufficient time to process it fully before the target arrived.

It also seems possible that Klein et al.'s (1988) multiple-prime advantage could be explained by Ratcliff and McKoon's (1988) compound-cue model, if it could be assumed that the compound cue can contain more than two items. Ratcliff and McKoon (1988) suggest that the importance of (i. e., the weight attached to) any previous word in the compound cue is less than that of the target and that importance is a decreasing function of the ordinal distance of the word from the target word. Thus, in general, the cue functionally contains only two items, the prime and the target. (As such, in a standard lexical-decision task, the target from the previous trial would not be included in the cue). In order to account for any additional priming with multiple primes, the weights would have to be set to allow additional primes to be weighted reasonably heavily in the cue.

Allowing additional primes to have reasonable weights would seem to be a minor change in the model. However, the selection of weights that would actually allow the model to account for a multiple-prime advantage may not be a straightforward task. In particular, there would appear to be real limits to the importance that could be attached to the primes. If too much importance is attached to the primes, the importance of the target itself will be minimized. The result would be that many nonwords (together with their primes) would generate a reasonably high level of familiarity, leading to a high level of incorrect responses. Along these lines, Clark and Shiffrin (1987), in applying an early version of the compound-cue model (Gillund & Shiffrin, 1984) to data from an episodic recognition task, were able to account for slightly *lower* levels of performance with two cues than with one. Although this result does not imply that the model could not predict a multiple-prime advantage in a lexical-decision task, it does suggest that selecting the appropriate weights may not be a simple task. Nonetheless, it is at least theoretically possible that the model could account for the multiple-prime advantage reported by Klein et al. (1988).

There are also a couple of other studies suggesting that the effects of multiple categorically related cues are actually somewhat detrimental, at least in comparison with the effects of a single cue. Brown (1981) reported cumulative inhibition when subjects were presented with a series of category-first letter pairs (e. g., color-B) and asked to generate the name of a category member that began with the presented letter. That is, subjects performed more slowly on each consecutive trial with the same category. Brown (1981) also reported a similar cumulative inhibition in picture-naming latency when subjects were presented with a list of categorically related pictures.

Blaxton and Neely (1983) used a task similar to Brown's generation task and obtained a similar result. That is, subjects were slower to generate the name of a category exemplar when they had just generated four other exemplars from the same category than when they had just generated only one. More relevant to the present situation, Blaxton and Neely (1983) also reported results from an unrelated condition, in which a category exemplar was generated following the generation of one or four category exemplars from different categories. A comparison between this condition and conditions in which the same category was repeated (the related condition) indicated a significant priming effect in the one-prime condition, but not in the four-prime condition. These results were, however, restricted to the situation in which both the primes and the targets were generated. When either was simply read, the one- and four-prime conditions did not differ.

Brown's (1981) and Blaxton and Neely's (1983) results are suggestive of the notion that as multiple related primes are processed, some sort of inhibition builds up to make the processing of further category members problematic, a result that on the surface, at least, would seem to be inconsistent with the results reported by Klein et al. (1988). The purpose of Experiment 1 was to attempt to replicate the Klein et al. (1988) results, to establish that multiple primes do produce more priming than a single prime in a lexical-decision task.

There were two important methodological differences between the present studies and those of Klein et al. (1988) concerning the nature of the prime presentations. First, in the present studies the primes were presented sequentially, rather than simultaneously, to ensure that the subjects had time to read each prime (as opposed to the short SOA condition used by Klein et al., 1988). Nonetheless, the overall SOA used in the four-prime condition (420 ms) was only slightly longer than that used by Klein et al. (1988) and certainly was within the range of SOAs at which effects due to spreading activation are assumed to occur (Balota & Lorch, 1986; McNamara & Altarriba, 1988). Second, the prime in the one-prime condition was not repeated. Results reported by Cohene, Smith, and Klein (1978), Smith (1984), and Friedrich, Henik, and Tzelgov (1991), all suggest that the repetition of a prime may decrease the priming effect. Although this effect was only significant in Experiment 1 of Cohene et al. (1978), in which the prime was repeated many times, the effect was consistent across studies and ranged in size from 7 to 19 ms. Given that the size of the multiple-prime advantage that Klein et al. (1988) observed was only 21 ms, the feeling was that it would be better not to risk contaminating the one-prime condition in this fashion. The reader should note, however, that these changes in the presentation procedure did introduce a necessary confounding between the one- versus four-prime conditions and SOA. That is, the overall SOA in the one-prime condition (105 ms) was substantially shorter than that in the four-prime condition.

Two other methodological considerations are also worth mentioning. First, in an attempt to minimize the effects of associative relationships, only category exemplars, and not category names, were used as primes. Lupker (1984) reported that unassociated category exemplars produced a small (26 ms), but significant, priming effect in a lexical-decision task, at least when the primes and the targets were drawn from six reasonably well-structured categories. Finally, as in a few previous studies (Lupker, 1984; O'Connor & Forster, 1981; Schvaneveldt & McDonald, 1981), related nonwords were used. All the nonwords were visually similar to, and reasonably homophonic with, a real word. For each subject, half of the nonwords were similar to a member of the category of the prime(s) (the related nonwords). Although the nature of the nonwords would appear to be irrelevant to some of the theories discussed above (spreading activation, Becker's (1980) theory and Norris's (1986) theory), data from related nonwords do have implications for the post-lexical models, particularly Neely and Keefe's (1989) semantic-matching model. Discussion of the specific implications will be postponed to the General Discussion.

Experiment 1

Method

Subjects. Fifty-six subjects from the University of Western Ontario Summer subject pool received payment for participating in this experiment. All subjects were native English speakers.

Stimuli and apparatus. Twelve exemplars from 30 different categories were chosen from the Battig and Montague norms (1969). Categories and exemplars are listed in the Appendix. Eight exemplars from each category were randomly selected to serve as primes; two were randomly selected to serve as word targets; the remaining two words were altered to serve as nonword targets. Nonwords were constructed by changing one letter in each word. An attempt was made to create nonwords that were as similar in pronunciation as possible to the original words (e.g., CANOE-CANUE; WASP-WOSP).

For the four-prime condition, the 30 categories were divided into two sets of 15. Related prime-target quintuples were created by four of the primes being paired with one of the selected targets for each of 15 categories. Unrelated prime-target quintuples were created by four exemplars being taken from each of the 15 remaining categories and combining each set of four with a selected target from a different, unrelated category (i.e., target words were paired with prime words from 1 of the remaining 14 categories). Thus, in every quintuple, the four primes were always all from the same category. For the one-prime condition, the same two sets of 15 categories were used. However, categories that had been used to form related pairings in the four-prime condition were now used to form unrelated pairings, and vice versa. Related trials were formed by the selection of one of the remaining primes from each of the 15 categories and the pairing of the prime with the other word from the category that had been selected as a target. Unrelated trials were formed in the same manner, except that the target words were paired with prime words from one of the other 14 categories.

An equal number of nonword trials were randomly mixed among the word trials in both priming conditions. The organization of nonword trials was identical to the organization of word trials. The 15 categories used to form related trials in the one-prime condition with words were also used to form related trials in the four-prime condition with nonwords. Related trials in the four-prime condition were formed by taking the four primes not used in the four-prime condition on word trials and pairing them with one of the selected nonword targets from that category. The unrelated trials were formed from the other 15 categories. As on related trials, the four primes not used in the four-prime condition on word trials were used as primes. The targets were nonword targets from these 15 categories, which were then paired with four primes from one of the other 14 categories. As on word trials, the one-prime conditions were formed by switching the assignment of the two sets of 15 categories and selecting one of the primes not used on nonword trials in the four-prime condition. Note that this procedure reuses the primes in the one-prime condition – that is, every prime appearing in the one-prime condition was also part of a prime quadruple in the four-prime condition (appearing at a random position in the quadruple). However, its role, in all cases, was completely reversed. For example, if it appeared as a related prime for a word, it also appeared in the prime quadruple that served as the unrelated prime for a nonword.

Across subjects, target words were exchanged among the four trial types (related/one-prime; unrelated/one-prime; related/four-prime; unrelated/four-prime) in a between-subjects manipulation. A similar manipulation was done with the nonword targets. The result was that four groups of subjects were needed to complete the counterbalancing. All subjects saw exactly the same primes although their placement in terms of conditions varied with counterbalanced targets. The one- and four-prime conditions were run in separate blocks. Each block consisted of 8 practice trials (2 per trial type) and 60 experimental trials (15 related/word; 15 unrelated/word; 15 related/nonword; 15 unrelated/nonword). Within each block, the order of the trials was random.

Stimulus presentation and data collection were controlled by an IBM PC and stimulus arrays appeared on an Electrohome color monitor. Reaction times were measured with a software timer that timed events at 1-ms accuracy (Graves & Bradley, 1987) and RTs were measured from stimulus onset. Because the start of the ms timer was not synchronized with the start of the vertical-retrace interval of the 60-Hz monitor being used, there was an average 8-ms lag between the start of the timer and the appearance of the stimulus, with a range from 0 to 16 ms. Responses were made by pressing on one of the two outside keys of a four-key button box built for use in reaction-time experiments. The button box was interfaced to the gameport of the computer, which provided virtually delay-free polling of the buttons (Segalowitz & Graves, 1990).

Trials consisted of a small block presented in the center of the screen for 1,400 ms to serve as a fixation point, followed by a blank screen for 105 ms, followed by the sequential presentation of primes for 70 ms each and finally the target, which remained on the screen until the subject responded. A 35-ms interval of blank screen intervened between each of the prime and target presentations. Following the offset of the target there was a 1,400-ms intertrial interval. Two features distinguished the targets from the primes: (1) placement in the sequence (i.e., the second stimulus presented in the one-prime condition, the fifth stimulus presented in the four-prime condition); (2) color of the stimuli (i.e., primes were presented in green, targets in red). All stimuli were presented in upper case. Subjects were seated approximately 80 cm from the screen.

Procedure. Subjects were tested individually. Each participant was given identical lexical-decision-task instructions. They were told to look at the words that appeared in green, and to push the right-hand button if the red letter string was a word and the left-hand button if the red letter string was not a word. As we have noted, the one- and four-prime conditions were presented in separate blocks with the order of the blocks counterbalanced across subjects. Following the instructions, each subject received practice trials in either the one- or the four-prime condition. All practice trials consisted of categories not used in the experimental trials. After practice, subjects were presented with the experimental trials involving the same number of primes as the practice trials. The same routine of practice and test was followed for the other condition. Response times and errors were recorded for each trial. The entire procedure took 30–35 minutes.

Results

Word data. A trial was scored as an error if the subject pushed the wrong button, or if the response latency was longer than 1,400 ms, or if the response latency was shorter than 150 ms. This final type of error was not included in the error analysis. Mean correct reaction times (RTs) are shown in Table 1. These data were submitted to a 2 (Number of Primes: 1 vs. 4) × 2 (Relatedness: related vs. unrelated) × 2 (Order: 1 prime first vs. 4 primes first) × 4 (Groups: reflecting the counterbalancing of targets) ANOVA. Order and Groups were between-subjects factors and Number of Primes and Relatedness were within-subjects factors.

Because the stimuli (both categories and exemplars) used in the present experiment(s) were not randomly selected (in any sense of the term), separate ANOVAs based on items as a random factor were not computed. Note however, the same target items did appear in different conditions for different subjects. Thus, if items were to be considered as a random factor, error variance due to items would have contributed to the expected mean squares for the conventional Subject and Subject × Relatedness error terms. As such, the conventional *F* values, based on these error terms, would be the appropriate *F* values in any case.

Table 1 Mean correct RTs (and error rates) for word and nonword trials in Experiment 1

	Word Trials	
	1 Prime	4 Primes
Related	612 (6.7)	628 (4.8)
Unrelated	626 (6.7)	675 (10.4)
Priming Effect	+14 (0.0)	+47 (+5.6)
	Nonword Trials	
	1 Prime	4 Primes
Related	730 (14.2)	772 (16.4)
Unrelated	732 (16.2)	776 (13.8)
Priming Effect	+2 (+2.0)	+4 (–2.6)

There were significant main effects of Number of Primes, $F(1,48) = 11.84$, $MS_e = 5008$, $p < .01$, and Relatedness, $F(1,48) = 29.60$, $MS_e = 1722$, $p < .001$, indicating that subjects were faster in the one-prime condition and in the related condition. More importantly, there was a significant interaction of Number of Primes with Relatedness, $F(1,48) = 7.02$, $MS_e = 2240$, $p < .05$. This interaction was due to there being a larger (priming) effect in the four-prime condition (47 ms) than in the one-prime condition (14 ms). The priming effect in the one-prime condition was only marginally significant, $t(48) = 1.47, p < .08$, one-tailed. The only other significant effect was the Number of Primes by Relatedness by Groups interaction, $F(3,48) = 10.12$, $MS_e = 2240$, $p < .001$. This interaction indicates that the Number of Primes by Relatedness interaction did vary as a function of the counterbalancing procedure. That is, the use of different words in the different conditions for the four different groups produced different patterns in this interaction. Given that the different sets of words were not matched on any relevant variables, interactions of this sort neither are surprising nor do they compromise any of the other effects.

The mean error rates are also shown in Table 1. These data were submitted to the same ANOVA as the RT data. As with the RT data, the Relatedness effect, $F(1,48) = 10.42$, $MS_e = .946$, $p < .01$, and the interaction of Number of Primes with Relatedness, $F(1,48) = 8.04$, $MS_e = 1.226$, $p < .01$, were significant, although the Number of Primes effect was not ($F < 1.00$). The interaction was due to there being a priming effect in the four-prime condition, but not in the one-prime condition. Also significant was the interaction of Relatedness with Groups, $F(3,48) = 5.59$, $MS_e = .946$, $p < .01$, and, as in the RT data, the Number of Primes by Relatedness by Groups interaction $F(3,48) = 6.53$, $MS_e = 1.226$, $p < .001$. As we have argued previously, any interactions involving Groups can be attributed to the counterbalancing procedure (i.e., the use of different words in different conditions for the different groups).

Nonword Data. As with word trials, mean correct RTs and percentage errors were submitted to individual ANOVAs, with analogous factors. These data are also shown in Table 1.

For the RT data, only the Number of Primes main effect was significant, $F(1,48) = 18.73$, $MS_e = 5537$, $p < .001$, indicating that responses were faster in the one-prime condition than in the four-prime condition.

For the error data, only two interactions involving Groups, Number of Primes with Groups, $F(3,48) = 4.85$, $MS_e = 1.600$, $p < .01$, and Number of Primes with Relatedness with Groups, $F(3,48) = 4.82$, $MS_e = 2.269$, $p < .01$, were significant. Again, these interactions can most likely be attributed to the counterbalancing procedure.

Finally, in all the present experiments we examined error RTs to check the possibility that subjects may have traded-off accuracy for speed on some proportion of the trials. There were no signs of such a trade-off.

Discussion

Experiment 1 was an attempt to compare the effects of one versus four primes in a lexical-decision task. Previous research (Klein et al., 1988) suggested that multiple primes provide more facilitation than a single prime, at least in certain situations. The present experiment (both RT and error data) provides further support for this conclusion and extends the scope of this effect to the situation in which the multiple-prime condition consists of four sequentially presented primes from the target's semantic category. As we have noted, this result is compatible with most, if not all, of the current models.

Four additional issues about these results should be mentioned. First, there was a main effect of the number of primes. Subjects were slower overall in the four- than in the one-prime condition. There are a number of possible explanations for this effect. It is possible, for example, that more resources are needed to process four primes than one prime, leaving fewer for target processing. What is more important, however, is the question of whether this effect has any implications for the Number of Primes by Relatedness interaction. For example, would it be possible to argue that the multiple-prime advantage was in some way due to the longer overall RTs in the four-prime condition? Although this argument cannot be completely ruled out, it seems somewhat unlikely. As demonstrated in subsequent experiments and elsewhere (Brodeur, 1989), an overall longer RT in the four-prime condition does not inevitably result in a larger priming effect.

A second issue concerns the priming effect in the one-prime condition. This effect (14 ms) was somewhat small and only marginally significant. There was no reason, however, that any larger effect should have been expected. To begin with, an attempt was made not to use pairs that seemed to have any associative relationship. Lupker (1984) used this same criterion in selecting stimulus pairs and reported only a 26-ms priming effect. Those stimuli, however, were all drawn from 6 reasonably well-structured categories (i.e., animals, body parts, vehicles, clothing, kitchen utensils, and furniture). To create sufficient stimuli for the present experiment, the number of categories was increased to 30. It seems unlikely that categories such as, for example, male and female names, or weather, or toys, are at all well structured, and so it is not clear how well the concepts of prime and target are linked in memory. If the links are weaker the priming effect should be even smaller than that reported by Lupker (1984). Thus, an effect of approximately 14 ms does not seem at all unusual.

The third issue concerns the fact that although the primes from the one-prime condition were used in the four-prime condition, these primes were not always in the final prime position in the four-prime presentations. (The position of the single prime in four-prime trials was assigned randomly. It was in positions one, two, three, and four, 10, 12, 18, and 20 times, respectively). Thus, one could argue that the multiple-prime advantage was an artifact resulting from the prime that immediately preceded the target in the four-prime condition being in some way a better prime than the single prime in the one-prime conditon.

Although this argument cannot be rejected out of hand, it seems unlikely. First, because a prime from the one-prime condition was in the last position ⅓ of the time (20 of the 60 four-prime sequences), the larger priming effect in the four-prime condition would have to be due to the remaining ⅔ of the trials. Assuming that the primes from the one-prime condition produce an approximately 14-ms priming effect when used in the final position in four-prime sequences, the implication is that the other trials must have produced a 63-ms priming effect in order to produce an overall 47-ms effect. Given that the prime that did appear in the final position was selected randomly and that there appeared to be no associative relationships between primes and target and that even well-structured categories do not produce very large priming effects (Lupker, 1984), a 63-ms priming effect on the remaining ⅔ of the trials seems to be virtually impossible. Second, as will be reported below, these same stimuli do not always produce a multiple-prime advantage. If this advantage were due simply to having better primes in the fourth position in the four-prime condition, the effect should emerge whenever these stimuli are used.

A final issue is that, as has been noted, there was a confound between number of primes and the SOA between first prime and the target. Thus, one could argue that the multiple-prime advantage was actually an effect of SOA. It is possible, for example, that at the one-prime SOA (105 ms) there was insufficient time for activation to spread fully, thus yielding a diminished priming effect. A number of points argue against this proposal, however. First, the size of the effect in the one-prime condition is what would be expected on the basis of the nature of the primes and targets used (Lupker, 1984). Second, Klein et al.'s (1988) data suggest that priming from exemplar primes to exemplar targets (as used in the present studies) is nearly fully developed by 80-ms SOA. Finally, as will be shown in Experiment 3, the multiple-prime advantage also arises when a substantially longer SOA for the one-prime condition is used.

Experiment 2

The results of Experiment 1 validate earlier claims (Klein et al., 1988) that multiple primes provide more facilitation than a single prime does. The next questions concern the mechanism and the locus for the effect. As we have noted, three of the models, the spreading activation model, Becker's verification model and Norris's plausibility-checking model share a key assumption. They all assume that the process that is facilitated is the word-identification process. Thus, all would predict that the pattern of priming observed in Experiment 1 should emerge whenever a word must be identified. This prediction was evaluated in Experiment 2, in which the target task was changed from lexical decision to naming.

Method

Subjects. Thirty-two subjects were recruited from the University of Western Ontario subject pool. All participants received either course credit or payment for their participation. All subjects were native English speakers.

Stimuli and apparatus. The stimuli used in Experiment 2 were identical to those used in Experiment 1, except that word targets replaced their homophonic nonword targets. Vocal responses were registered by means of a SHURE (Model 575S) microphone connected to a Lafayette Instruments (Model 18010) voice-activated relay.

Procedure. The procedure was identical to that of Experiment 1, except that subjects were required to name the target rather than to make a lexical decision.

Results

A trial was scored as an error if the subject stuttered or mispronounced the target, if the response latency was longer than 1,100 ms, if the response latency was shorter than 150 ms, or if the subject spoke too softly to trigger the voice key. These final two types of errors were not included in the error analysis. The mean correct RTs are shown in Table 2. These data were submitted to a 2 (Number of Primes: 1 vs. 4) × 2 (Relatedness: related vs. unrelated) × 2 (Order: 1-prime first vs. 4-prime first) × 4 (Groups: reflecting the counterbalancing of targets) ANOVA. Order and Groups were between-subjects factors and Number of Primes and Relatedness were within-subjects factors.

The only significant main effect was the Relatedness effect, $F(1,24) = 13.41$, $MS_e = 171$, $p < .01$. Targets following related primes were named faster than targets following unrelated primes. Although there was a slightly larger priming effect in the four-prime condition, the interaction of Number of Primes with Relatedness, $F(1,24) = 2.46$, $MS_e = 167$, $p > .10$, was not significant. Also significant were the interaction of Relatedness with Groups, $F(3,24) = 3.60$, $MS_e = 171$, $p < .05$, and the Number of Primes by Relatedness by Groups interaction, $F(3,24) = 12.32$, $MS_e = 167$, $p < .001$. These effects were similar to those in Experiment 1 and appear to be due to the counterbalancing procedure.

Table 2 Mean correct RTs (and error rates) in Experiment 2

	1 Prime	4 Primes
Related	490 (1.0)	492 (0.4)
Unrelated	495 (1.7)	504 (1.7)
Priming Effect	+5 (+0.7)	+12 (+1.3)

Mean error rates are also shown in Table 2. These data were submitted to the same ANOVA as the RT data. No effects reached significance (all *ps* $> .05$).

Discussion

Although the priming effect in the four-prime condition was numerically larger than the priming effect in the one-prime condition, the results of Experiment 2 stand in fairly stark contrast to those of Experiment 1. In particular, the size of the priming effect in the four-prime condition was substantially smaller in Experiment 2. This result is not particularly surprising, because priming effects are typically larger in lexical decision than in naming (Lorch, Balota, & Stamm, 1986; Lupker, 1984; Seidenberg et al., 1984), a difference that does not appear to be due simply to the absence of nonwords in the naming task (Keefe & Neely, 1990; West & Stanovich, 1982). What is more relevant to the present issue, however, is that these data (both RT and error data) provide fairly little evidence that four primes are better than one in a naming task.

The spreading-activation model, Becker's (1980) verification model and Norris's (1980) plausibility-checking model all localize priming effects in the word-identification process. In the spreading-activation model and in Becker's verification model, the process that is facilitated is lexical access. In Norris's (1980) model, the process that is facilitated is that of selecting a winner from among the candidate set. In all instances, the models predict that facilitation effects observed in lexical decision should be observed in other tasks requiring word identification. The difference between Experiments 1 and 2 (specifically, the reduction of the priming effect in the four-prime condition) would suggest that the multiple-prime advantage observed in Experiment 1 could not be accounted for in terms of these models.

The finding that some priming effects can be obtained in lexical-decision tasks, but not in naming tasks, has led to the proposal that the lexical-decision task is more susceptible to post-lexical influences than the naming task is (Balota & Chumbley, 1984; 1985; De Groot, 1984; Forster, 1981; Lupker, 1984; Seidenberg et al., 1984; West & Stanovich, 1982), leading further to the post-lexical accounts of semantic priming discussed earlier. These accounts are not necessarily alternative accounts, but rather are proposals of additional loci that produce priming in lexical decision. The present data support the idea of an additional locus for priming effects in lexical-decision tasks while suggesting that (a) the component of priming due to the word-identification process is fairly small; and (b) the multiple-prime advantage observed in Experiment 1 has a post-lexical locus. This argument was evaluated further in Experiments 3 and 4.

Experiments 3 and 4

The results of Experiment 2 provide little support for Klein et al.'s (1988) proposal that a summation of spreading activation is responsible for a multiple-prime advantage. One possible counterargument, however, would be that on a reasonably large percentage of the trials, the target words used in Experiment 2 were named primarily via assembly processes, and essentially without lexical involvement (Baluch & Besner, 1991; Coltheart, 1978; Paap & Noel, 1991). If so, the effects due to normal, lexically-based word-identification processes and, hence, the sizes of the priming effects would be expected to be smaller overall in Experiment 2, as was observed.

It would probably be impossible to reject this alternative explanation completely on the basis of the present data. However, if words in Experiment 2 had been named primarily via assembly processes, there should have been little evidence of frequency effects. Such was clearly not the case. The correlation between RT and frequency was significant in both the one- and the four-prime conditions, $r = -.23$, $t(118) = -2.60$, $p < .01$; $r = -.27$, $t(118) = -3.07$, $p < .01$, respectively. These results do not, of course, prove that lexical access was accomplished on every trial in Experiment 2, but they do indicate that there was at least a reasonable amount of lexical involvement in both conditions. Thus, if the multiple-prime advantage observed in Experiment 1 (and reported by Klein et al., 1988), were a result of spreading activation processes producing heightened lexical activation, one would have expected to find a multiple-prime advantage in Experiment 2 as well.

The proposal that the multiple-prime advantage is instead due to a post-lexical process was examined directly in Experiments 3 and 4. First of all, if the advantage were due to spreading activation, SOA should be important. That is, spreading activation is assumed to be a fast-acting process with a reasonably rapid decay rate (Neely, 1977). Thus, if the SOA were sufficiently long, whatever activation a word's lexical node would have received from spreading activation would be gone, leaving only activation due to attentional processes. If, however, the multiple-prime advantage were due to a process other than spreading activation, within reasonable limits, SOA should not matter. Experiment 3, which was identical to Experiment 1, except that a longer SOA was used, provides an examination of this issue.

If the multiple-prime advantage reappears in Experiment 3, it will provide additional support for the argument that the multiple-prime advantage was due to a process other than spreading activation. It would not, however, clearly argue for a post-lexical explanation of those particular results. That is, the longer SOA would certainly allow the subjects the time necessary to attend to lexical nodes of expected targets. The result could be a facilitation of their word-identification process, as described, for example, in the models of Becker (1980) or Norris (1986). Further, as was noted previously, this process may be more effective with four primes than with one prime, producing a multiple-prime advantage.

In order to get converging evidence on these issues, Experiment 4 was a replication of Experiment 2, with the same long SOAs as those used in Experiment 3. If the multiple-prime advantage emerges in Experiment 3 and is due to word-identification processes, the same effects should emerge in Experiment 4.

Method (Experiment 3)

Subjects. Thirty-two subjects from the University of Western Ontario Summer subject pool received payment for participating in this experiment. All subjects were native English speakers.

Stimuli, apparatus, and procedure. The only difference between Experiments 3 and 1 was that in Experiment 3 the primes were all exposed for 700 ms and the interstimulus interval between primes (in the four-prime condition) and between primes and targets was also 700 ms.

Results

Word data. Error criteria were the same as in Experiment 1. The RT data were submitted to a 2 (Number of Primes: 1 vs. 4) × 2 (Relatedness; related vs. unrelated) × 2 (Order: 1 prime first vs. 4 primes first) ANOVA. Order was a between-subjects factor and Number of Primes and Relatedness were within-subjects factors. Unfortunately, the coding for the Groups factor was lost for these subjects, and so this factor was not included in any of the analyses in Experiment 3. The effect is to lump the variance (and the degrees of freedom) due to Groups and its interactions into the analogous error terms. Given that some of these effects tended to be significant in other experiments, the most likely result is that the ANOVA in Experiment 3 was slightly less powerful than in Experiments 1 and 2. The mean correct RTs are shown Table 3.

There was a significant main effect of Number of Primes, $F(1,30) = 6.12$, $MS_e = 10128$, $p < .05$, indicating that subjects were slower overall in responding to a target preceded by four primes than to a target preceded by one prime. There was also a significant Relatedness effect, $F(1,30) = 15.51$, $MS_e = 4264$, $p < .001$, indicating that subjects responded faster to targets following related primes than to targets following unrelated primes. Most importantly, there was a significant interaction of Number of Primes with Relatedness, $F(1,30) = 11.65$, $MS_e = 2052$, $p < .01$. This interaction was due to there being a much larger priming effect in the four-prime condition (73 ms) than in the one-prime condi-

Table 3 Mean correct RTs (and error rates) for word and nonword trials in Experiment 3

	Word Trials	
	1 Prime	4 Primes
Related	674 (5.6)	690 (8.3)
Unrelated	692 (7.3)	763 (14.0)
Priming Effect	+18 (+1.7)	+73 (+5.7)
	Nonword Trials	
	1 Prime	4 Primes
Related	749 (11.5)	773 (23.5)
Unrelated	756 (10.6)	782 (22.3)
Priming Effect	+7 (–0.9)	+9 (–1.2)

tion (18 ms). The Relatedness effect in the one-prime condition was again only marginal, $t(30) = 1.57$, $p < .07$, one-tailed.

Mean error rates are also shown in Table 3. These data were submitted to the same ANOVA as the RT data. As with the RT data, both the Number of Primes effect, $F(1,30) = 7.77$, $MS_e = 2.035$, $p < .01$, and the Relatedness effect, $F(1,30) = 8.50$, $MS_e = 1.127$, $p < .01$, were significant, indicating that subjects made fewer errors in the one-prime condition and to related targets. The interaction of these two factors was only marginal, $F(1,30) = 3.47$, $MS_e = .812$, $p < .10$. The only other significant effect was the interaction of Relatedness with Order, $F(1,30) = 4.33$, $MS_e = 1.127$, $p < .05$. This effect was due to subjects who received the four-prime condition first showing a larger overall advantage for the related condition.

Nonword data. Mean correct RTs and percentage of errors were submitted to the same ANOVAs as the word data. These data are also shown in Table 3.

For the RT data, none of the main effects nor interactions was significant. For the error data, the only significant effect was the Number of Primes main effect, $F(1,30) = 36.73$, $MS_e = 2.765$, $p < .001$, indicating that fewer errors were made in the one-prime condition.

Method (Experiment 4)

Subjects. Thirty-two subjects were recruited from the University of Western Ontario subject pool. All participants received either course credit or payment for their participation. All subjects were native English speakers.

Stimuli, apparatus, and procedure. The only difference between Experiment 4 and 2 was that in Experiment 4 the primes were all exposed for 700 ms and the interstimulus interval between primes (in the 4-prime condition) and between primes and targets was also 700 ms.

Results

The error criteria were the same as in Experiment 2. The mean correct RTs are shown in Table 4. These data were submitted to the same ANOVA as in Experiment 2.

Table 4 Mean correct RTs (and error rates) in Experiment 4

	1 Prime	4 Primes
Related	460 (2.6)	468 (2.1)
Unrelated	466 (2.3)	477 (2.1)
Priming Effect	+6 (–0.3)	+9 (0.0)

There were significant main effects of both Number of Primes, $F(1,24) = 5.96$, $MS_e = 482$, $p < .05$, and Relatedness, $F(1,24) = 11.48$, $MS_e = 164$, $p < .01$. As before, these effects are due to more rapid responding in the one-prime condition and to related targets. There was, however, no interaction of Number of Primes with Relatedness ($F < 1.00$).

Also significant was the interaction of Number of Primes with Order, $F(1,24) = 11.38$, $MS_e = 482$, $p < .01$, and that of Groups with Relatedness, $F(3,24) = 4.13$, $MS_e = 164$, $p < .05$. As in the previous experiments, the latter interaction is attributable to the counterbalancing procedure. The former interaction is due to subjects being faster in the prime condition that they received second.

The mean error rates are also shown in Table 4. These data were submitted to the same ANOVA as the RT data. The only effect that reached significance was the interaction of Number of Primes with Groups, $F(3,24) = 3.76$, $MS_e = .701$, $p < .05$.

Discussion

The results of Experiments 3 and 4 are quite clear. Changing the SOA from a very brief one to a very long one mattered very little. There was still a clear multiple-prime advantage in the lexical-decision task, with little evidence of such an effect in the naming task. In fact, the sizes of the priming effects in the short- and long-SOA experiments were quite comparable. The only possible exception was the priming effect in the four-prime condition in the lexical-decision task, which was slightly larger with the longer SOA.

The results of these experiments provide further support for the arguments advanced earlier. The SOA used in these experiments should be sufficient to rule out any interpretations in terms of spreading activation. Thus, the multiple-prime advantage observed in Experiment 3 must have another source. The lack of a multiple-prime advantage in Experiment 4 suggests that this effect in Experiment 3 is not due to a facilitation of the word-identification process that arises when the subjects have sufficient time to prepare for the target. Thus, the pattern of the data across all four experiments supports the claims that: (a) the component of semantic priming due to the word-identification process is fairly small and (b) the multiple-prime advantage has a post-lexical locus.

It should be noted that the second of these claims is based mainly on an acceptance of the null hypothesis in Experiments 2 and 4. Furthermore, in both experiments there was slightly more priming in the four-prime condition than in the one-prime condition. Thus, it is not impossible that with a more powerful analysis a significant multiple-prime advantage might be observed in a naming task. Nonetheless, as the present results indicate, any multiple-prime advantage observed in a naming task would be likely to be much smaller in magnitude than that observed in an analogous lexical-decision task. If so, the second claim might have to be amended slightly to read: the locus of the multiple-prime advantage in lexical-decision tasks is primarily (although perhaps not completely) post-lexical.

General discussion

There is little disagreement that context aids the reading process. The major question, however, is how it exerts its influence. A number of models have been proposed to account for the effects of context on word processing. Most, if not all, are based on mechanisms that allow context to have a quantitative, rather than a qualitative, effect. Thus, a stronger context can be a better context. Most, although not all, previous data have been consistent with this proposal. In the present set of experiments, we have evaluated the specific hypothesis that four semantically related primes would provide more priming than a single prime. The results suggest that this proposal is correct, but only in a lexical-decision task.

The implication is that this particular context-strength manipulation is affecting a post-lexical, decision process. That is, models such as the spreading-activation model, Becker's (1980) verification model, or Norris's (1986) plausibility-checking model cannot explain the difference between the naming and the lexical-decision tasks, even though one or more of them may be able to explain how the word-identification process can be primed. The present data do not, of course, prove that the same post-lexical mechanism is responsible for the multiple-prime advantage in both Experiments 1 and 3 (or, as will be discussed later, in Klein et al.'s (1988) study). Nonetheless, on the basis of the similarity of results and the principle of theoretical economy, at present there seems to be no strong reason to assume that there are separate mechanisms at work in Experiments 1 and 3. The present discussion will then focus on the two types of model that postulate post-lexical mechanisms for priming effects, the coherence-checking models, in particular, Neely and Keefe's (1989) semantic-matching model, and the compound-cue model of Ratcliff and McKoon (1988), on the assumption that a single mechanism is responsible for the multiple-prime advantage in both Experiments 1 and 3.

According to Neely and Keefe (1989), subjects engage in a post-identification, coherence-checking process in order to help in making a lexical decision. The reason is that although nonwords allow lexical access for similarly spelled words, those words are typically not related to the prime. Rather, a semantic match is only found on trials with related words, while a nonmatch is found on both unrelated word trials and nonword trials. The existence of a match is a-priori evidence that the target is a word, while the existence of a nonmatch biases the subjects toward a nonword response.

The usefulness of this coherence-checking strategy would seem to depend on two things, the proportion of nonwords in the experiment and the proportion of word trials that contain related targets. As either proportion increases, there is a concomitant increase in the validity of the information the coherence check provides. Thus, as either proportion increases, there should be evidence for an increased use of this particular strategy. Neely et al. (1989) have, in fact, demonstrated that the nonword proportion does seem to affect the use of this strategy, although the proportion of related words does not. Nonetheless, it does not do the model great harm to assume that the use of this strategy is mainly dependent on the nonword proportion.

The aspect of the present studies that would appear to give this model problems is the related nonword results. Given the sensitivity of this strategy to nonwords, the inclusion of related nonwords in the present studies should have discouraged subjects from adopting a strategy of this sort. That is, because these nonwords differ from their homophonic words at only one letter position, they should have been similar enough visually to activate the words' lexical entries. Thus, on related nonword trials, a semantic match would be created, reducing the effectiveness of this strategy to zero. Alternatively, if subjects still adopted the strategy, they would pay with long reaction times (or higher error rates) on the related nonwords trials. There is no evidence in the nonword data of either Experiments 1 or 3 to suggest that reaction times were longer (or error rates higher) for related nonwords. Thus, the nonword data would appear to pose a problem for this model.

One, admittedly post-hoc, way to explain these null results might be to argue that although the related nonwords did bias the subjects toward a word response (thus slowing nonword RT), this effect was counteracted by a second, facilitative, effect. In particular, the evaluation of the lexical status of a nonword such as CANUE might also be facilitated by a related prime because the prime may make it apparent that there is a particular lexical entry (i.e., that for CANOE) against which the letter string should be checked. If this check is done first, its negative outcome may induce subjects to terminate the lexical search more rapidly (thus facilitating nonword RT). The net result would be no overall effect of related nonwords, as was observed both in the present studies and in previous research (Lupker, 1984; Schvaneveldt & McDonald, 1981).

Evaluation of the compound-cue model is a bit more difficult because, at present, it can be instantiated in a number of ways. As was suggested earlier, it seems possible that if one can assume that more than one prime can be integrated into the cue, a set of parameter values could be selected that would allow the model to account for a multiple-prime advantage. The obvious follow-up question would concern its ability to handle the nonword data.

In the model, nonwords generate familiarity values in the same way that words do, through the strength of the relationships between the item and all the images in memory. This familiarity value would then be inversely related to the speed of the rejection of the nonword. Nonwords that are more wordlike should generate a higher familiarity value, and thus would be harder to reject, as is typically reported (Coltheart, Davelaar, Jonasson, & Besner, 1977; Shulman & Davison, 1977; Shulman, Hornak, & Sanders, 1978). The model could also allow an account of the pseudohomophone effect in which nonwords that are pronounced like words are harder to reject than orthographically regular nonwords (Davelaar, Coltheart, Besner, & Jonasson, 1978; Rubenstein, Lewis, & Rubenstein, 1971). The assumption would simply have to be made that the item-to-image strengths (which determine the familiarity values) are based partially on the phonological codes of the item and partially on the orthographic codes of the item. (If the strength values were totally based on the phonological codes, subjects could never respond negatively to pseudohomophones.) Thus, because there is strength between the phonological code of the word *cow* and images in memory, there is also some strength between the phonological code for the pseudohomophone *kow* and those same images in memory. The result is a higher familiarity value for *kow* than for a nonword such as *slint*, and hence a longer reaction time.

Unfortunately, this line of reasoning leads to the prediction that the related nonwords used here should be harder to reject than unrelated nonwords, for essentially the same reason that there is a priming effect for the word stimuli. That is, when a related prime or primes are involved, the item-to-image strengths that exist for related nonwords are combined with analogous high item-to-image strengths for the prime, creating higher familiarity values. Thus, this model would also appear to predict that RTs to related nonwords should be longer than to unrelated nonwords. As we have noted, there was no evidence for this effect either in the present studies or in previous research. Following Davelaar et al. (1978), it could be argued that because all the nonwords in our experiments were pseudohomophones, subjects based their lexical decisions, and hence their familiarity judgments, totally on orthographic codes. Unfortunately, this change would not help much, because the orthographic code for *kow* should still yield a higher familiarity value when combined with a prime such as *pig* than when combined with a prime such as *leg*. Thus, the lack of any effect in the nonword data would appear to pose a problem for this model. It appears, then, that the issue of how one rejects a nonword in a lexical-decision task is one that future versions of both this model and the semantic-matching model will have to deal with.

One additional issue is that although the four-prime condition provided more priming than the one-prime condition in both Experiments 1 and 3, the four-prime related condition never actually produced faster RTs than the one-prime related condition. Instead, the four-prime unrelated condition produced substantially longer RTs than the one-prime unrelated condition. This result raises the possibility that the multiple-prime advantage is, at least partly, the result of inhibitory processes rather than a pure facilitation effect.

This conclusion is, in fact, quite consistent with both of the post-lexical models under consideration. In terms of the Neely and Keefe (1989) model, the ultimate priming effect is a combination of both facilitative and inhibitory processes. That is, the coherence-checking process creates a bias toward either a word response (producing facilitation when prime and target match) or a nonword response (producing inhibition when prime and target do not match). Although these biases could be assumed to be symmetric, there is no a-priori reason to do so, and thus either effect could be dominating. In the four-prime condition, the context created by four related primes may be so strong that the biases (in either or both directions) would be substantially increased. The result would be a multiple-prime advantage that would be partly facilitation and partly inhibition.

In terms of the compound-cue model, the inclusion of extra primes in the cue may actually be a nonproductive strategy for subjects. As we have noted, Clark and Shiffrin's (1987) fit of an earlier version of the model to data from an episodic recognition task suggests that the model predicts lower performance with two cues than with one cue. The reason is that the second cue steals some of the weight from the target. Thus, overall slower RTs in the four-prime condition may be a natural prediction of the compound-cue model. It follows, then, that the penalty for stealing weight from the target would be somewhat less when the added cues are related than when they are unrelated, producing the multiple-prime advantage.

As for this issue of facilitation versus inhibition, it is worth noting that Klein et al.'s (1988) results did show a slightly different pattern. In their study, the multiple-prime advantage seemed to be mainly due to increased facilitation on related trials. Thus, the argument could be made that the multiple-prime advantage in their study was actually due to a different mechanism than that at work here. While this argument cannot be rejected out of hand, it does beg the question of why the mechanism supposedly responsible for their effect was not active in the present studies. It is possible, of course, that the difference between simultaneous and sequential presentations of multiple primes will turn out to be a crucial one. This is obviously an issue for future research.

Finally, although both Neely and Keefe's (1989) semantic-matching model and Ratcliff and McKoon's (1988) compound-cue model provide a reasonable account of the multiple-prime advantage in the lexical-decision task, neither can account for the priming in naming tasks. The present data are consistent with the argument that semantic relationships provide small priming effects in naming – effects that are very likely due to word-identification processes. Neely and Keefe (1989) do, however, suggest that semantic-matching is only one of several loci of semantic-priming effects. Their complete theory includes spreading activation and expectancy processes that act to prime word identification, thus allowing an explanation of priming in naming tasks. On the other hand, the compound-cue model explicitly does not attempt to account for priming in naming tasks. Thus, although this model has enjoyed substantial success in explaining many priming phenomena (see Neely, 1991), it will need to be expanded by the addition of either new assumptions or a second process in order to account for data like those from Experiments 2 and 4. This should not necessarily be seen as a negative aspect of the model, however. As Neely's (1991) review makes clear, the effects of context are much more complicated than early, single-mechanism models such as spreading activation have suggested. The present data would seem to provide one more demonstration of exactly that point.

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Appendix

Categories and exemplars used in the present experiments (the top four in each category are the targets)

MONEY	*WEATHER*	*BIRD*
ruble	rain	crow
penny	tornado	swallow
dime (dyme)	clouds (klouds)	eagle (eegle)
nickel (niccel)	blizzard (blizzurd)	pigeon (pigion)
dollar	snow	robin
shilling	thunder	sparrow
franc	wind	hawk
quarter	hurricane	bluejay
pounds	hail	cardinal
yen	sleet	bluebird
pesos	sunshine	canary
pence	lightning	dove

TOY	*VEGETABLE*	*INSECT*
yoyo	corn	ant
wagon	celery	cricket
puzzle (puszle)	carrot (carrut)	fly (fli)
jacks (jaces)	lettuce (lettuse)	wasp (wosp)
doll	pea	bee
marbles	bean	beetle
ball	potato	flea
teddybear	tomato	mosquito
balloon	spinach	roach
game	broccoli	spider
crayon	cabbage	grasshopper
rattle	onion	butterfly

DISEASE	*TREE*	*FEMALE NAME*
leukemia	oak	Cathy
polio	pine	Diane
cancer (canser)	maple (meple)	Anne (Enne)
malaria (malarea)	spruce (spruse)	Betty (Betdy)
measles	elm	Sarah
smallpox	cedar	Lynn
typhoid	birch	Mary
tuberculosis	dogwood	Sue
arthritis	redwood	Jane
mumps	willow	Carol
syphilis	fir	Nancy
diabetes	poplar	Sally

MALE NAME	*OCCUPATION*	*CHEMICAL ELEMENT*
Bob	janitor	sodium
Joe	professor	silver
Mike (Myke)	doctor (docter)	sulfur (sulfer)
Dave (Dafe)	lawyer (lawyar)	iron (irun)
John	engineer	nitrogen
Bruce	psychologist	helium
George	farmer	oxygen
Tom	dentist	hydrogen
Bill	salesman	gold
Jim	fireman	potassium
Steve	pharmacist	carbon
Jeff	mailman	chlorine

SPORT	*BODYPART*	*MUSICAL INSTRUMENT*
soccer	knee	violin
hockey	foot	saxophone
tennis (tennes)	head (haad)	trumpet (trompet)
golf (golv)	skull (skoll)	trombone (trumbone)
football	brain	piano
swimming	nose	guitar
baseball	eye	drum
basketball	finger	clarinet
badminton	hand	flute
bowling	thumb	cello
wrestling	leg	banjo
volleyball	arm	tuba

KITCHEN UTENSIL	*FURNITURE*	*ANIMAL*
pan	bed	cat
kettle	sofa	moose
bowl (buwl)	lamp (lemp)	cow (kow)
pot (bot)	chair (chaer)	lion (liun)
blender	desk	tiger

plate
fork
ladle
spoon
eggbeater
spatula
toaster

stool
picture
cabinet
table
dresser
television
bookcase

pig
camel
squirrel
dog
elephant
fox
horse

orchid
dandelion
marigold

uncle
daughter
husband

champagne
vermouth
kahlua

VEHICLE

car
boat
jeep (jeip)
tractor (tracter)
airplane
truck
train
canoe
bicycle
motorcycle
bus
helicopter

CLOTHING

dress
boot
vest (vust)
pants (pantz)
mitten
hat
shoe
skirt
glove
scarf
overalls
sock

FISH

bass
flounder
shark (chark)
tuna (tona)
trout
salmon
perch
catfish
cod
herring
swordfish
minnow

SHIP

tanker
rowboat
raft (ravt)
canoe (canue)
sailboat
ferry
destroyer
submarine
yacht
steamship
barge
schooner

FRUIT

apple
pineapple
peach (peech)
lime (lyme)
pear
grape
banana
plum
cherry
lemon
orange
apricot

WEAPON

rifle
club
gun (gon)
whip (whep)
bayonet
bomb
sword
grenade
knife
axe
spear
cannon

FLOWER

lilac
pansy
lily (lili)
daisy (daesy)
rose
tulip
carnation
violet
daffodil

RELATIVE

son
mother
aunt (aent)
niece (neece)
father
cousin
sister
brother
nephew

ALCOHOLIC BEVERAGE

vodka
wine
beer (beir)
scotch (skotch)
gin
whiskey
rum
bourbon
brandy

CRIME

assault
arson
murder (merder)
larceny (larseny)
treason
robbery
rape
kidnapping
perjury
extortion
fraud
forgery

CARPENTER'S TOOL

level
drill
nails (naels)
wrench (wranch)
hammer
saw
chisel
screwdriver
plane
pliers
sawhorse
sandpaper

KIND OF CLOTH

silk
wool
linen (linun)
satin (saten)
cotton
flannel
nylon
dacron
rayon
velvet
taffeta
denim