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Demonstrating Semantic Priming without Using Primes

by

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ABSTRACT

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Whether priming can occur in the absence of prime identification is a long debated question. The standard priming paradigm used to explore the issue has been criticized on methodological grounds. The present study introduces a new paradigm, in which there is no prime per se, only targets. Both words in a pair were presented for every-increasing durations until one was identified. Experiments 1 through 6 demonstrated highly reliable priming when the words were presented with no delay between them and when a mask of from 33 ms to 500 ms intervened between them. However, the priming effect declined as the delay increased and was non-significant at a full second. Results from Experiment 7 showed no effect of the proportion of related words on the size of the priming effect. However, an analysis of errors indicated that partial identification may play a role in the priming effect with this paradigm.

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TABLE OF CONTENTS

I. INTRODUCTION

Standard priming paradigm 1

Problems with standard priming paradigm 2

A. Subjective vs. objective threshold measure 2

B. Problems with threshold determination 5

C. Inconsistent findings on duration of priming 7

A new paradigm 8

II. EXPERIMENTS

Experiment 1 10

Experiment 2 13

Experiment 3 15

Experiment 4 17

Experiment 5 18

Experiment 6 20

Experiment 7 28

III. GENERAL DISCUSSION 36

IV. REFERENCES 40

LIST OF TABLES

Table 1	25
Table 2	26
Table 3	32

INTRODUCTION

The notion of the content of mind being an association or chain reaction of ideas dates back at least as far as Aristotle, and was the cornerstone of the British associationist school of philosophy from Hobbes through Locke, Hume and Hartley to James Mill and John Stewart Mill. The ease of reading, say, the previous sentence compared to reading the same words in jumbled order (e.g., "Being the of the association as dates notion…")may be due, in part to the higher transitional probabilities of each word and its successors in the former case than in the latter. These higher transitional probabilities may lead to greater word-to-word priming in the sentence version.

An intriguing question for both philosophers and more recently psychologists is whether identification of a word can be primed by a word that is not itself identified. The question has given rise to a huge body of research, virtually all of which has relied on what may be referred to as the standard priming paradigm.

Standard Priming Paradigm

With this procedure, priming is explored in its simplest form. It involves the presentation of two items, typically words, in quick succession. The first is referred to, somewhat presumptively, as the *prime* and the second as the *target*. The subject's task is to respond to the target as quickly as possible. The response usually consists of either naming the word or deciding whether it is in fact a word. With the latter, or lexical-decision, task some of the trials have nonword letter strings as targets to ensure the task is meaningful. At issue is whether responses to target words are faster when they follow related compared to unrelated primes.

Problems with the Standard Priming Paradigm

Meyer and Schvaneveldt (1971) were the first to report semantic priming. Their paradigm was slightly different from the standard priming paradigm. They asked subjects to make lexical decisions to a pair of simultaneously presented letter strings. Of particular interest was the finding that when both strings of a pair were semantically related words, the response was faster and more accurate. After their study, a great deal of attention was directed toward the field of semantic priming, and the standard priming paradigm has evolved.

Of concern here is the use of this paradigm to ask whether word identification can be facilitated, or primed, by an unidentified word. In essence, two words are presented one after the other, with the first being presented so quickly that it is, or is assumed to be, unidentified. Although much evidence has been offered in support of priming under such conditions (e.g., Fowler et al., 1981; Marcel, 1983), it has not gone unchallenged (Cheesman & Merikle, 1984; Purcell et al., 1983). It is likely that the discrepancies in the findings from this paradigm result from discrepancies in procedural details, not the least of which is the presentation duration of the prime word. This needs to be long enough to allow any potential priming effect to occur but short enough to preclude its identification. The most common strategy for meeting these criteria is to establish a threshold duration for each subject ahead of the experiment proper. However, this threshold-setting strategy is inherently problematic, not least because it cannot guarantee that prime is unidentifiable.

Subjective vs. objective threshold measure. One relevant issue is the much-debated question of whether the threshold should be set according to an objective or a subjective criterion. The objective threshold is defined as the maximum exposure duration for which discrimination of the presented from nonpresented words is at chance level. The subjective threshold, which is the more commonly used, is defined as the maximum exposure duration for which the subject claims an inability to identify the presented word.

Two patterns of results have emerged. One set of results indicated that semantic priming effects occurred under objective threshold conditions (e.g., Fowler et al., 1981; Marcel, 1983). In contrast, another set of results suggested that semantic priming effects only occurred at subjective thresholds (e.g., Cheesman & Merikle, 1984).

Then there comes the question: what is the most adequate index to measure nonidentification/nondetection? Henley (1984) argued that the forced-choice procedure used by Fowler et al. (1981) and Marcel (1983) to establish an objective detection threshold was inappropriate. Cheesman and Merikle (1984, 1986) criticized some previous studies (Fowler et al., 1981; Marcel, 1983) as inadvertently establishing the subjective threshold rather than the objective threshold as they claimed. They pointed out that although Marcel (1983) tried to set up an objective threshold at the chance level in the two-choice task, his criterion for performance was less than 60%, not exactly around 50%. In that case, some detection could have happened and given rise to semantic priming. Similar evidence came from Fowler et al.'s study (1981), in which the experimenters admitted their threshold was somewhat above the objective threshold. In conclusion, Cheesman and Merikle (1984) claimed priming occurred only at subjective thresholds rather than objective thresholds, a claim that was further supported by their Experiment 2.

However, Kemp-Wheeler and Hill (1988) disagreed with Cheesman and Merikle (1984). They stated that the four-choice color identity discrimination task used by Cheesman and Merikle (1984) was inappropriate to establish valid subjective thresholds because the task may induce response bias arising from potential color preference. Kemp-Wheeler and Hill (1988) used new criteria to assess objective thresholds and they found semantic priming effects under objective thresholds. Furthermore, converging evidence of semantic priming at objective thresholds was revealed by studies using brain-imaging and neural activity assessment techniques (e.g., Dehaene et al., 1998; Ruz et al., 2003).

But Merikle et al. (2001) insisted that the objective threshold had a serious limitation. They argued although a failure in the forced-choice task indicates an absence of awareness, a correct response may not necessarily indicate a presence of awareness; in other words, a correct response may also occur without awareness. Therefore, if the threshold is set according to the more stringent and conservative objective criterion, the minimal stimulus condition may not only reduce the likelihood of perception with awareness, but also reduce the likelihood of perception without awareness. On the other hand, they suggested, subjective measure based on self-report, was a more direct and accurate indicator of the absence or presence of identification.

In general, the evidence seems to indicate that priming can occur without identification. This is the case when subjective thresholds are used (e.g., Cheesman & Merikle, 1984) and also when more stringent objective thresholds are used (e.g., Fowler et al., 1981; Marcel, 1983). However, there remain problems with the determination of these thresholds and whether they are appropriate for all experimental trials, as discussed below.

Problems with threshold determination. A second relevant issue is that in the threshold-setting phase, the prime is presented in isolation, whereas in the experiment proper it is presented in the context of a semantically related or unrelated target. Thus, it is questionable whether the threshold is appropriate for the experiment proper (Bernstein et al., 1989; Hirshman & Durante, 1992).

A related problem is a potential drift in the threshold over the course of an experiment. In this connection, Purcell et al. (1983) argued that sensory adaptation may differ between the threshold-setting and semantic priming phases of the experiment, with the result that the prime is more visible in the latter case.

In some studies, subjects were asked on all or some randomly selected subset of the trials to identify the prime following their response to the target (Dark, 1988). Dark and Benson (1991) went one step further by asking their subjects to identify the prime both before and after responding to the target. But even these precautions are not without problems. First, asking subject to identify the prime ahead of target presentation could undermine any priming in the processing of the target. As Hirshman and Durante (1992, p. 256,) have put it: "The process that mediates articulation of the prime might interfere with the activation generated by the prime. Similarly, guessing processes arising after an unsuccessful prime-identification attempt could interfere with the activation generated by the prime." Also, asking for identification of the prime after the response to target could result in prime identification purely as a result of retroactive priming of the prime by the target (Briand et al., 1988; Dark & Benson, 1991), making it difficult to know whether any prime identification occurred before or after the response to target. Note, too, that any such retroactive priming would be more prevalent in the related than in the unrelated condition, which raises the possibility of a selection bias.

Hirshman and Durante (1992) sought to overcome some of the difficulties in ascertaining the appropriate prime duration threshold by interweaving the threshold-setting and priming portions in the experiment and using a pre-cuing procedure. Specifically, on a random half trials, subjects were cued to say aloud the prime word, or as much (if any) of it as they could identify, immediately after presentation of the target. On the remaining trials, they responded to only the target word. The results showed that with a prime duration of 33 ms there was semantic priming but almost no prime identification, leading Hirshman and Durante to conclude that semantic priming was not completely dependent on prime identification. This conclusion overlooks the possibility that pre-cuing could have differentially influenced processing, and identification, of the prime.

Greenwald et al. (1996, 1998) devised a regression method to analyze the role of “conscious” and “unconscious” processes in priming. The priming effect was regressed onto prime perceptibility, in which the regression intercept was treated as an indicator of the magnitude of priming associated with zero prime perceptibility. In an effort to enhance the observed effect of any semantic priming, they also limited the time allowed for responding to a narrow window. Furthermore, Greenwald and associates recruited the so-called affective priming paradigm in which words having either negative or positive affective connotations displayed as primes and targets. They found that only when the prime-target stimulus-onset asynchrony (SOA) was 100 ms or shorter was there a reliable priming effect from unidentified word.

Inconsistent findings on duration of priming. Greenwald et al.'s conclusion about the duration of priming is not consistent with other findings. With masked primes presented at what was, or was assumed to be, below identification threshold, Fowler et al. (1981) found semantic priming when the prime-target SOA was around 2000 ms but not when it was 250 ms. Similarly, Balota (1983) failed to obtain semantic priming with a 350 ms prime-target SOA, whereas Hirshman and Durante (1992) found semantic priming with a 1000 ms prime-target SOA. Balota (1983) suggested that sub-threshold primes required longer SOAs for semantic analysis. On the other hand, several researchers reported semantic priming from unreported primes at prime-target SOAs as short as 33 ms and 40 ms. Van der Heijden, Hagenaar, and Bloem (1984) explained the findings of short SOA priming in terms of rapid occurrence and rapid fading of semantic analyses. And if the picture were not confused enough, Cheesman and Merikle (1984) found similar levels of semantic priming for prime-target SOAs of 50 ms, 550 ms and 1050 ms, contrary to Balota's (1983) finding. Moreover, recent criticisms have been raised against Greenwald et al's conclusions. Researchers have questioned whether the rapid decay of the priming effect revealed by the special response window procedure and regression method has any generality (Holender & Duscherer, 2004; Snodgrass et al., 2004). In addition, it has also been argued that what they observed in the affective priming paradigm was actually caused by response competition rather than semantic priming (Holender & Duscherer, 2004). The issue of the persistence of semantic priming when primes are not identified is still a focus of discussion. Holender and Duscherer (2004) concluded that semantic priming without prime perception was not necessarily very short-lived but was paradigm dependent.

A New Paradigm

In short, researchers have been trying long and hard to clarify the relationship between prime identification and semantic priming. Although there are variations in their procedures, all have used the standard priming paradigm. This paradigm is grounded in a sharp distinction between prime and target and it requires setting a threshold for prime duration with all of its inherent problems. Clearly, what is needed is an entirely fresh approach.

The experiments proposed for my thesis adopted a new paradigm, one that resolves the problem of possible prime identification and avoids the problems associated with determining a threshold. The resolution involves abandoning the distinction between prime and target items. In essence, a pair of words is presented in alternating sequence at a fast but ever slowing rate. The task is to identify as quickly as possible either word of the pair. In this way, each word is a potential prime as well as a target. The only assumption with this procedure is that the subject will follow the instruction by reporting a word as soon as they identify it. It follows from this assumption that the other, unreported word will not have already been identified. At issue is whether identification will be faster when the two words are normatively related than when they are nominally unrelated. If so, priming by related words will have been demonstrated. Note that identification of the second word is not of interest for present purposes, for this could be mediated by the first (identified) word.

Experiments 1 through 6 tested for the existence of semantic priming in this new paradigm, varying the SOA between prime and target. Experiment 7 addressed the issue of partial identification of primes and targets and whether a criterion shift rather than a change in sensitivity could account for the priming observed in this new paradigm.

EXPERIMENTS

Experiment 1

Method

Subjects. The subjects were 20 undergraduates at Rice University. They participated to fulfill a course requirement.

Materials. The materials consisted of 192 pairs of semantically related words, selected from the University of South Florida Free Association Norms (Nelson, McEvoy & Schreiber, 1998). The average of the forward and backward associative strengths within a pair ranged from .83 to .21, with a mean of .35. Because each word of a related pair served as a forward and backward mask for the other, selection was restricted to pairs whose members consisted of the same number of letters and presentation was in a monospaced font (namely, `courier`). Word length ranged from 3 letters (e.g., ARM-LEG, DAD-MOM) to 10 (e.g., UNDERSTAND-COMPREHEND, TELEVISION-COMMERCIAL), with a mean of 4.93. There was an equal number of words at each word length.

The related word pairs were re-paired to form 192 unrelated word pairs. Re-pairing was between word pairs of same letter length. Also, re-pairing was such that the number of instances in which a given letter occupied the same position within the two words of either of two yoked pairs was the same for the related and unrelated conditions. For example, for the related yoked pairs ALLIGATOR-CROCODILE and SPAGHETTI-MEATBALLS, the number of shared letters in place is 0 (for ALLIGATOR-CROCODILE) and 1 (for the third letter, A, in SPAGHETTI-MEATBALLS) for a total of 1; and for the corresponding yoked unrelated pairs CROCODILE-SPAGHETTI and

ALLIGATOR-MEATBALLS, the total is also 1 (0 for CROCODILE-SPAGHETTI and 1 for the sixth letter of ALLIGATOR and MEATBALLS – also, by chance, an A).

Design. The independent variable was the relatedness of the words within a pair (related or unrelated), and this was varied within subjects. Counterbalancing of word pairs called for two groups of subjects, so that for one group each yoked pair of word pairs was assigned to the related condition in the first half of the trials (i.e., Trials 1-192) and to the unrelated condition for the second half (i.e., 193-384), and for the other group it was the other way around. For example, if for Group 1 *MOM-DAD, ARM-LEG, STORY-RODEO and FABLE-HORSE* were assigned to the first half and *MOM-LEG, DAD-ARM, STORY-FABLE* and *RODEO-HORSE* to the second half, then for Group 2 *MOM-LEG, DAD-ARM, STORY-FABLE* and *RODEO-HORSE* were assigned to the first half and *MOM-DAD, ARM-LEG, STORY-RODEO and FABLE-HORSE* to the second half. The order of the word pairs within each half of the trials was randomized.

Procedure. Subjects were tested individually in a single session of about 40 minutes. After being given detailed instructions and six practice trials, the subjects engaged in a series of 384 word identification trials. A simplified depiction of a trial is shown in Figure 1. The subjects began by clicking a *go* button, which caused a fixation field of 15 Xs to be displayed for 33 ms. This was followed directly by the presentation of two words, either related or unrelated, in an alternating sequence and with no break between them. Each word was presented five times with exposure duration of 16.7 ms, after which the exposure duration was increased to 33.3 ms for five more presentations, and then to 50.0 ms for five more, and so on in increment of 16.7 ms until the subjects clicked the mouse to stop the presentation. At this point the words were replaced by the fixation field and the *go* button was replaced by a *check* button. The subjects then typed their response into a response field and clicked the *check* button. If the typed response matched either word of the pair, the *check* button was replaced by the *go* button, which the subject clicked to initiate the next trial; if the response was incorrect, the alternating presentations resumed precisely where they had left off.

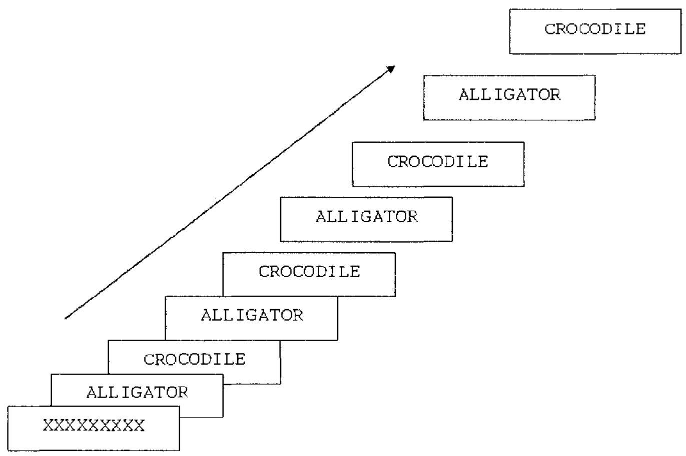


Figure 1. Gradually slowing presentation of a word pair (Experiment 1).

Results

If the identification of a word can be primed by the contiguous presentation of a related word, then the exposure time at which identification occurred should have been shorter in the related than in the unrelated condition. This prediction was upheld by all 20 subjects. The mean exposure duration at which identification occurred was 51.2 ms in the related condition and 55.8 ms in the unrelated condition, $t\ (19) = 5.87, p < .0001$. It is therefore concluded that identification of a word can be primed by the contiguous occurrence of a related word even when the latter is itself unidentified.

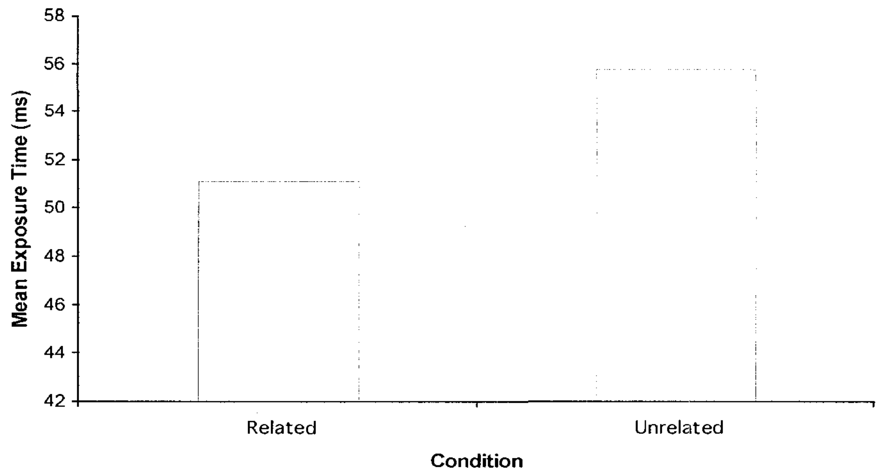


Figure 2. Mean exposure time for identification in the related and unrelated condition (Experiment 1).

Experiment 2

The purpose of Experiment 2 was to see whether the priming observed in Experiment 1 would survive the interpolation of a patterned mask between the individual word presentations. If the priming was but fleeting, it might dissipate between word presentations, in which case the exposure time necessary for word identification would be no shorter in the related than in the unrelated condition.

Method

Subjects. Twenty-four Rice University undergraduates served as subjects.

Materials and design. These were as for Experiment 1.

Procedure. The procedure was also as for Experiment 1, except that a 33-ms mask was inserted between word presentations. The mask was identical to the fixation field except that the number of Xs matched the number of letters in the ensuing words. A simplified depiction of a trial is given in Figure 3. The masks and words followed one another directly.

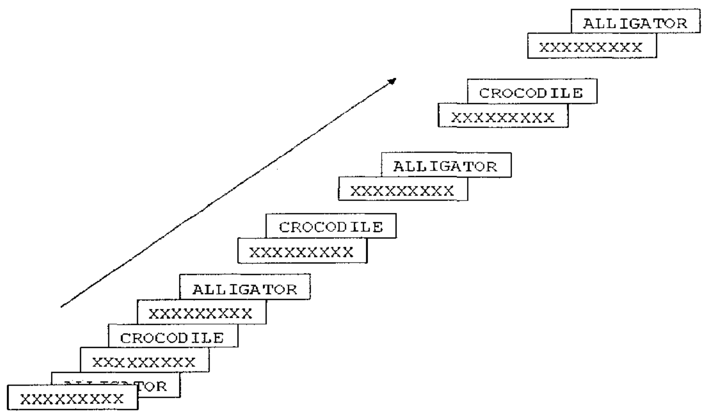


Figure 3. Presentation of a word pair (Experiment 2).

Results

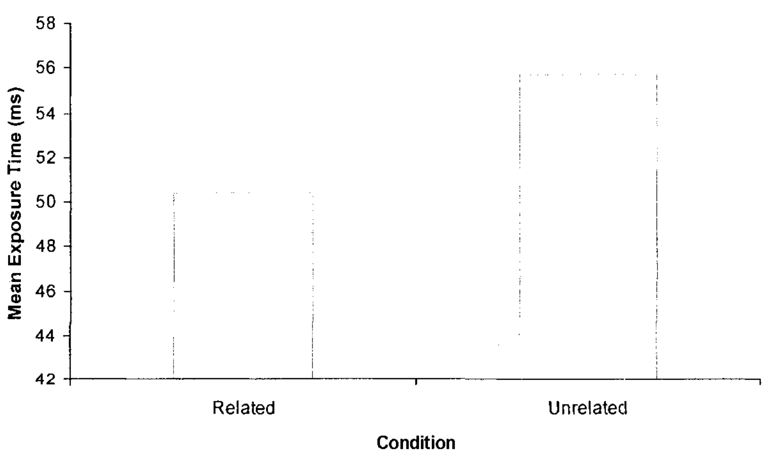


Figure 4. Mean exposure time for identification in the related and unrelated condition at 33-ms mask duration (Experiment 2).

The results were very similar to those of Experiment 1. In particular, there was a convincing priming effect, with identification occurring at exposure times that were shorter in the related than in the unrelated condition for all 24 subjects. The mean exposure duration at identification was 50.4 ms in the related condition and 55.7 ms in the unrelated condition, $t(23) = 4.16, p < .001$. It is therefore concluded that the priming potential of an unidentified masked word can persist for at least 33 ms.

Experiment 3

A large body of prior research has explored the influence of prime-target delay on the priming effect by manipulating prime-target SOA. But these prior studies did not come to the same conclusion. Fowler et al. (1981) only observed priming effect from masked stimuli presented under the identification threshold with a prime-target SOA of 2000 ms, but not with an SOA of 250 ms. Balota (1983) had a similar result in his study. In contrast, Cheesman and Merikle (1984) used 50 ms, 550 ms and 1050 ms prime-target SOA, and they got priming effects at all three intervals with an unvaried magnitude of the priming effect. Furthermore, Greenwald et al. (1996) found a reliable priming effect from unidentified stimuli only when the prime-target SOA was 100 ms or less.

Given the mixed results, the purpose of Experiment 3 was to explore further the persistence of the priming effect observed in Experiments 1 and 2. In Experiment 2, the effect was found to survive a masked interval of 33 ms. Experiment 3 seeks to replicate this finding and to determine whether the effect will remain when the masked interval is extended to 50 and 67 ms.

Method

Subjects. The subjects were 48 Rice University undergraduates.

Materials and design. The experiment was structured according to a 2 (related and unrelated condition) by 3 (33-, 50- and 67-ms mask durations) within-subjects factorial design. The materials were as in Experiments 1 and 2. The design was also as before except that each yoked pair of word pairs was assigned to one of three mask duration conditions. Each of two groups of subjects were split into three subgroups, so allowing each yoked pair of word pairs to be assigned equally often to not only the related and unrelated conditions but also to each of the three mask durations within the related and unrelated conditions. The order of the resulting six conditions was randomized within each half of the trials.

Procedure. The procedure was as for Experiment 2 except that the duration of the mask between the words of a pair varied unpredictably from one trial to the next.

Results

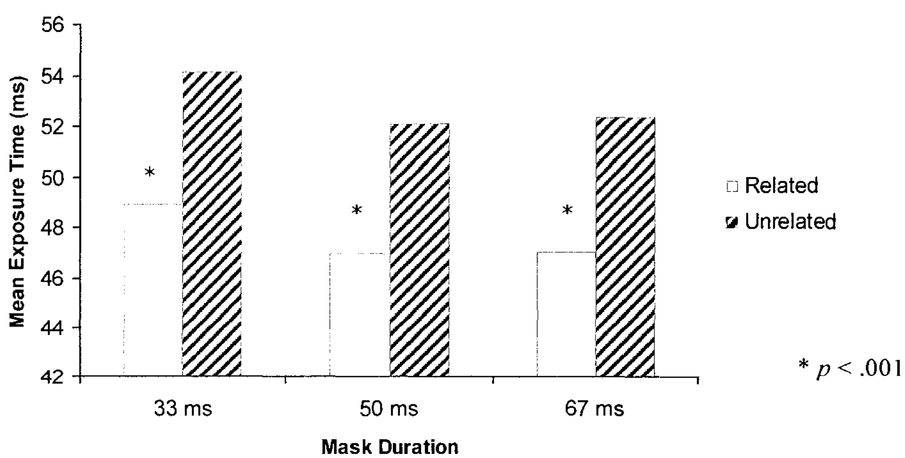


Figure 5. Mean exposure time for identification in the related and unrelated condition at each of the three mask durations (Experiment 3).

At issue was whether the priming observed in Experiment 2 with a between-word masked interval of 33 ms would also occur when this interval was extended to 50 ms and 67 ms. As can be seen in Figure 5, it did.

For the 33-ms mask condition, the finding closely replicated those of Experiment 2, with a mean identification exposure time of 49.0 ms in the related condition and 54.1 ms in the unrelated condition, $t\ (47) = 8.93, p < .001$. With the 50-ms masks, these means were 47.0 ms and 52.2 ms respectively, $t\ (47) = 7.49, p < .001$. And with the 67 ms masks, they were 47.0 and 52.4 ms respectively, $t\ (47) = 8.59, p < .001$. There was no discernible difference in the size of the priming effects among the three mask duration conditions, $F\ (2, 94) = 0.09$, $p = .92$. Clearly, priming by an unidentified word can endure for at least 67 ms.

Experiment 4

Experiment 4 was designed to check for priming with an inter-word interval longer than in the previous experiments.

Method

The method was identical to that of Experiment 3 except that the mask durations were increased to 67 ms, 133 ms and 200 ms. Forty-eight Rice University undergraduates were tested.

Results

As shown in Figure 6, a convincing priming effect occurred with all three mask durations. The findings with the 67-ms mask duration closely replicated those of Experiment 3, with a mean identification exposure time of 47.2 ms in the related condition and 53.0 ms in the unrelated condition, t (47) = 8.92 , $p < .001$. For the 133 ms condition, the mean related and unrelated identification times were 46.7 ms and 51.8 ms, respectively, t (47) = 6.40, $p < .001$; and for the 200 ms condition, they were 49.4 ms and 53.9 ms, respectively, t (47) = 6.05, $p < .001$. There was no clear evidence that the magnitude of priming effect varied with mask duration, F (2, 94) = 1.68, $p = .19$.

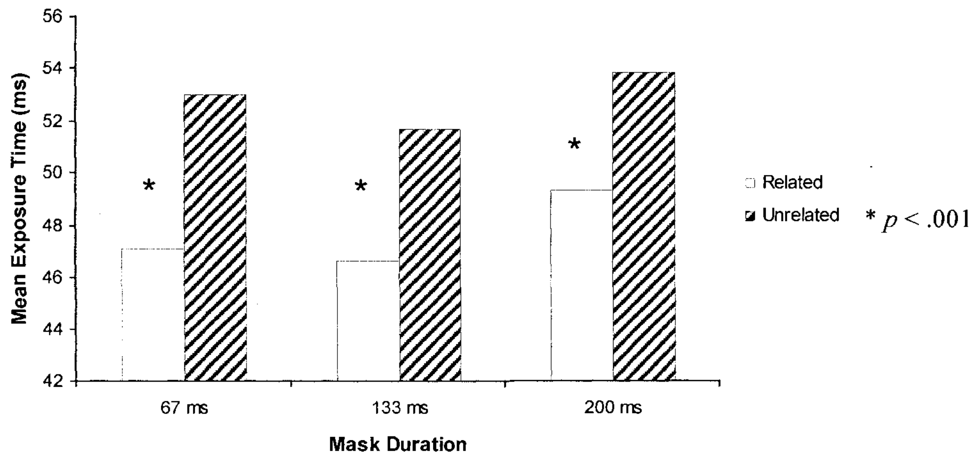


Figure 6. Mean exposure time for identification under each mask duration (Experiment 4).

Experiment 5

In this experiment the mask durations were increased to 200 and 500 ms.

Method

Subjects. The subjects were 28 Rice University undergraduates.

Materials and design. The design was essentially the same as for Experiments 2 to 4, except that there were just two mask durations, namely 200 ms and 500 ms and, because of the resultant lengthening of the trial durations, the number of trials was reduced by half. In effect, the subjects performed just the first half of what their counterparts performed in the previous three experiments. Thus, any given word was presented once within either the related or the unrelated condition (rather than being presented in the one condition in the first half of the experiment and in the other condition in the second half).

As before, counterbalancing of words across relatedness conditions called for two groups of subjects. Also as before, for any given group each word pair was assigned to the same related condition as its corresponding yoked pair. For example, the yoked pairs MOM-DAD and ARM-LEG were both in the related condition for Group 1 and in the unrelated condition for Group 2. An attempt was made to equate the mean of the forward and backward associative strengths of those yoked pair of pairs that for a given group were assigned to the related condition with that for those assigned to the unrelated condition. To this end, the 96 yoked pairs of pairs were ranked according to the mean within-pair forward and backward associative strengths, and the pair of yoked pairs with the highest mean (viz., EAST-WEST and LESS-MORE) was assigned to Group 1, the next two pairs of yoked pairs to Group 2, the next two to Group 1, and so on down to the pair of yoked pairs with the weakest mean association strength (viz., GRAPH-CHART and GREAT-SUPER), which was assigned to Group 1.

Results

Figure 7 summarizes the results. For the 200-ms mask durations, the mean identification exposure time was 54.7 ms in the related condition and 61.4 ms in the unrelated condition, $t\ (27) = 4.76$, $p < .001$. For 500-ms durations, they were 49.1 ms and 50.7 ms, respectively, $t\ (27) = 1.87$, $p = .073$. The interaction between mask duration and relatedness was significant, $F(1, 27) = 23.89, p < .001$, reflecting a reduction in priming as mask duration was extended from 200 ms to 500 ms.

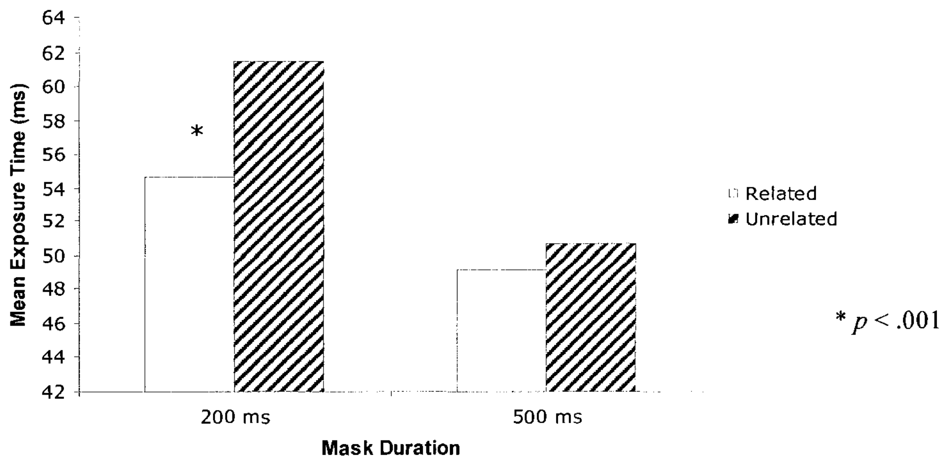


Figure 7. Mean exposure time for identification at each mask duration (Experiment 5).

Experiment 6

Given that in Experiment 5 the priming effect was substantially reduced with a 500-ms mask duration, Experiment 6 was designed to determine whether it would dissipate entirely with yet longer mask durations. There were, in fact, three mask durations: 500 ms, 750 ms, and 1000 ms.

Method

Subjects. The subjects were 42 Rice University undergraduates.

Materials and design. The design was essentially the same as for Experiments 2 to 4, but with mask durations of 500 ms, 750 ms and 1000 ms. Because of the resultant lengthening of the trial durations, the number of trials was reduced to a quarter of the number used in Experiment 2 to 4: just 96 word pairs in total. The counterbalancing of word pairs called for 6 groups of subjects. The selection and manipulation of the 96 word pairs was as for Experiment 5.

Results

The results are summarized in Figure 8. For the 500-ms mask duration, the mean identification exposure time was 53.9 ms in the related condition and 59.2 ms in the unrelated condition, $t\,(47) = 5.02$, $p < .001$. However, in Experiment 5, for the same 500-ms mask duration, there was no significant priming effect. The different results may be due to different contexts in the two experiments in terms of the other mask durations that subjects were exposed to. Further analyses could compare the 500 ms duration condition for subjects who did that first in the two experiments. For the 750-ms condition, they were 51.5 ms and 54.5 ms, respectively, $t\,(41) = 2.91$, $p = .006$. And for the 1000 ms condition, they were 50.2 ms and 51.9 ms, respectively, $t\,(41) = 1.90$, $p = .064$. The steady decline in the magnitude of priming effect as mask duration increased was captured in the interaction between mask duration and relatedness, $F\,(2, 82) = 3.57$, $p = .033$. Although this experiment failed to convincingly demonstrate a complete elimination of priming, it confirms the suggestion in Experiment 5 that it does decline as the delay between prime and target is increased, and it further suggests that it is a very low level when the delay is extended to a full second.

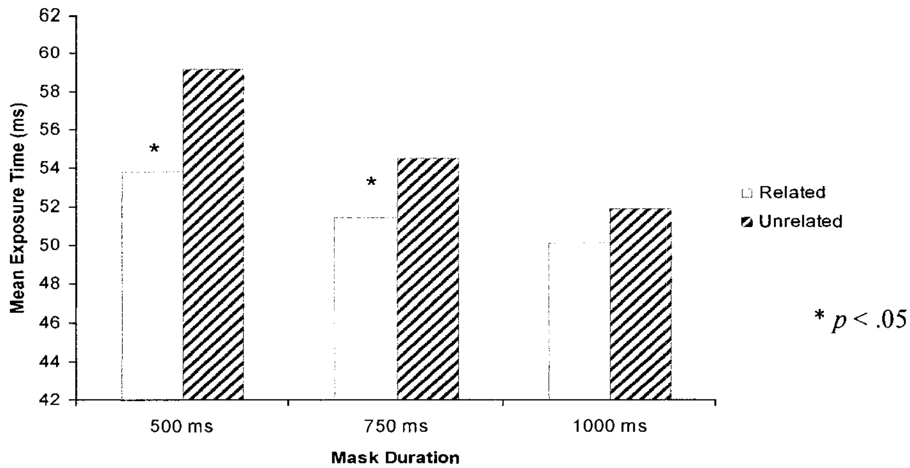


Figure 8. Mean exposure time for identification at each mask duration (Experiment 6).

Item based analyses: Investigating the effect of word length and frequency on the size of the priming effect. The evidence of semantic priming in Experiment 1 to 6 was revealed by analyses based on subjects. Further analysis was conducted based on items (word pairs) in order to assess the effects of word length and frequency on the size of priming effects. As will be discussed more thoroughly in Experiment 7, it is possible that subjects partially identify items and adjust their criterion for reporting an item depending on whether the item is occurring in a related or unrelated pair. If partial identification is at work, then one might expect reconstruction of an item from partial information to be easier for higher frequency or longer items. Length could help because longer words have fewer neighbors (e.g., Weekes, 1997). That is, main effects of the items on identification time per se should show an advantage for high frequency items and longer items. In terms of the priming effect, however, given that identification would be expected to be harder for low frequency or shorter words, the existence of a semantic context might be particularly helpful for reconstructing such words. Thus, the size of the priming effects might show reverse effects of these variables.

For a yoked pair of pairs, for example, DAD-MOM, ARM-LEG, DAD-ARM, MOM-LEG, the mean exposure time of the response word under related and unrelated condition was computed across subjects, respectively. The priming effect for a yoked pair was computed by subtracting the mean exposure time of the response word in the related condition from that in the unrelated condition. Note that the response words in the related condition and unrelated condition may not be the same. Frequency was also averaged for each yoked pair.

A regression model was constructed to examine whether word length and word frequency predicted the size of the priming effect. Multiple regression analysis was only conducted for the first five experiments, because in Experiment 6, only a portion of the word pairs were used. With just word length and word frequency in the model, the variance in the priming effect could not be explained collectively by the independent variables and only two of the regression coefficients were significant for any experiment (see Table 1). Even the direction of the effects of frequency and length effects varied across experiment and SOA. In another regression model, the interaction term of word length and word frequency was computed (word length and word frequency were first translated into deviation-score form and then made up to form the interaction term) and then added into the model together with word length and word frequency as independent variables (see Table 2). Although the interaction term was significant in three cases (three SOAs across three different experiments), there was no consistent evidence across five experiments to show a convincing relationship between the priming effect, and word length, word frequency, and their interaction. (Where the interaction was significant, the co-efficient was negative indicating the slope of the regression line between priming and word length was greater for low frequency words from that for high frequency words.)

Table 1: Raw Regression Coefficients (With Standardized Regression Coefficients in Parentheses) From Multiple Regression Analyses on Priming Effect (Without Interaction Term)

	Predictor	Coefficient	Std. Error	t	p
Experiment 1	Word length	.967(.115)	.902	1.072	.287
	LogFre.	-2.476(-.114)	2.323	-1.066	.289
	Overall model			F (2,93) = 1.65	.197
Experiment 2	Word length	1.063(.148)	.751	1.415	.160
(33 ms)	LogFre.	-3.728(-.201)	1.934	-1.927	.057
	Overall model			F (2,93) = 4.09	.020*
Experiment 3	Word length	-1.088(-.152)	.766	-1.420	.159
(33 ms)	LogFre.	-2.753(-.150)	1.973	-1.396	.166
	Overall model			F (2,93) = 1.52	.225
(50 ms)	Word length	.329(.045)	.794	.415	.679
	LogFre.	.326(.017)	2.045	.159	.874
	Overall model			F (2,93) = .09	.917
(67 ms)	Word length	-.015(-.002)	.842	-.018	.986
	LogFre.	-2.143(-.107)	2.169	-.988	.362
	Overall model			F (2,93) = .53	.588
Experiment 4	Word length	.236(.029)	.873	.270	.788
(67 ms)	LogFre.	-2.553(-.123)	2.247	-1.136	.259
	Overall model			F (2,93) = .86	.427
(133 ms)	Word length	2.221(.232)	1.017	2.185	.031*
	LogFre.	1.585(.064)	2.618	.605	.546
	Overall model			F (2,93) = 2.39	.097
(200 ms)	Word length	-.220(-.021)	1.144	-.193	.848
	LogFre.	-.934(-.035)	2.947	-.317	.752
	Overall model			F (2,93) = .06	.946
Experiment 5	Word length	.377(.028)	1.466	.257	.798
(200 ms)	LogFre.	-4.545(.130)	3.776	-1.204	.232
	Overall model			F (2,93) = .94	.393
(500 ms)	Word length	1.424(.140)	1.101	1.293	.199
	LogFre.	.713(.027)	2.836	.251	.802
	Overall model			F (2,93) = .85	.432

* $p < .05$

Table 2: Raw Regression Coefficients (With Standardized Regression Coefficients in Parentheses) From Multiple Regression Analyses on Priming Effect (With Interaction Term)

	Predictor	Coefficient	Std. Error	t	p
Experiment 1	Word length	.718(.085)	.913	.787	.433
	LogFre.	-2.594(-.120)	2.311	-1.123	.265
	Interaction	-1.882(-.150)	1.297	-1.451	.150
	Overall model			F (3,92) = 1.82	.150
Experiment 2	Word length	.802(.112)	.755	1.062	.291
(33 ms)	LogFre.	-3.852(-.208)	1.911	-2.015	.047*
	Interaction	-1.977(-.184)	1.072	-1.843	.069
	Overall model			F (3,92) = 3.93	.011*
Experiment 3	Word length	-1.450(-.203)	.758	-1.914	.059
(33 ms)	LogFre.	-2.926(-.159)	1.918	-1.525	.131
	Interaction	-2.746(-.258)	1.076	-2.552	.012*
	Overall model			F (3,92) = 3.24	.026*
(50 ms)	Word length	-.001(.000)	.792	-.003	.998
	LogFre.	.168(.009)	2.004	.084	.993
	Interaction	-2.510(-.231)	1.125	-2.232	.028*
	Overall model			F (3,92) = 1.72	.168
(67 ms)	Word length	-.049(-.006)	.862	-.057	.955
	LogFre.	-2.159(-.108)	2.181	-.990	.325
	Interaction	-.257(-.022)	1.224	-.210	.834
	Overall model			F (3,92) = .37	.777
Experiment 4	Word length	-.156(.-.019)	.866	-.180	.857
(67 ms)	LogFre.	-2.739(-.132)	2.193	-1.249	.215
	Interaction	-2.968(-.246)	1.230	-2.412	.018*
	Overall model			F (3,92) = 2.54	.061
(133 ms)	Word length	1.866(.195)	1.022	1.827	.071
	LogFre.	1.416(.058)	2.586	.548	.585
	Interaction	-2.689(-.188)	1.451	-1.853	.067
	Overall model			F (3,92) = 2.78	.046*
(200 ms)	Word length	-.211(-.020)	1.171	-.180	.857
	LogFre.	-.930(-.034)	2.965	-.314	.755
	Interaction	.069(.004)	1.664	.042	.967
	Overall model			F (3,92) = .04	.946
Experiment 5	Word length	.198(.015)	1.497	.132	.895
(200 ms)	LogFre.	-4.630(-.132)	3.791	-1.221	.225
	Interaction	-1.358(-.067)	2.127	-.638	.525
	Overall model			F (3,92) = .76	.519
(500 ms)	Word length	1.148(.113)	1.117	1.028	.307
	LogFre.	.582(.022)	2.827	.206	.837
	Interaction	-2.087(-.137)	1.586	-1.316	.191
	Overall model			F (3,92) = 1.15	.335

* $p < .05$

Discussion of Experiments 1-6

In Experiment 1 to 6, a new semantic priming paradigm was introduced and used to explore semantic priming without prime identification. These experiments demonstrated that the priming effect is not necessarily short-lived, but does have a clear tendency to decline as the delay between prime and target is increased.

With the new paradigm, identification is defined as subjects' overt response and obviously it is a subjective measure. According to this operational definition, we could conclude, based on the results of the six experiments, that the identification of a word is faster in the context of a related word than in the context of an unrelated word even when identification of the context word is ruled out. More accurately, we can rule out the possibility of the "full identification" of context words, but it is still likely that subjects may identify some letters of the unreported word, which may help them identify the identified words. In other words, since identification is also a subjective measure, it can be affected by response criterion. To look at this issue in further detail, Experiment 7 was designed to see whether the proportion of related trials would affect the size of priming effects, which would suggest an influence of strategic factors on priming (Neely, 1991; Bodner & Masson, 2003).

Experiment 7

In the present paradigm, priming may have happened because of partial identification of the prime. That is, subjects may have identified some letters of the prime, which made them guess that a particular word was present, but not with enough confidence to report the prime as recognized. For example, they may have recognized "A--IG-T--R", which led them to guess that the word "alligator" had been presented. However, their confidence may not have been high enough for them to give this as a response. When the subsequent word of a related pair was presented (i.e., CROCODILE), they may have again not fully identified all the letters but only partially identified the letters (e.g., "CRO--DI-E), which led them to guess "crocodile." If this degree of identification of "crocodile" had been in the context of a preceding unrelated word, they may have not been confident enough to produce this response. However, when in the context of a preceding related word, their partial confidence for the priming word led them to be more confident about the identification of the subsequent word. That is, the subject might reason that since they were fairly confident the preceding word was "alligator," they are now more confident that the subsequent word is "crocodile" and are willing to produce it as a response. They would have been less confident that the word was "crocodile" if the preceding word had been partially identified as some unrelated word like "spaghetti".

If subjects are using such a reasoning process, then one might expect the degree of priming to be affected by relatedness proportion. That is, the higher the proportion, the more likely it will be that subjects will notice that related pairs exist in the stimulus set and use this process of relating the current word to their partial identification of the prior word. One might also expect that the degree of priming would be related to factors that would influence the likelihood that identification of some letters would lead to successful reconstruction of the word – such as word frequency and length, as discussed previously. Also, one might see in the errors that subjects produce, evidence of reconstructing words from identification of some subset of the letters.

In Experiment 7, relatedness proportion was varied across two different groups of subjects to see whether it would lead to variation in the size of priming effect. In this new paradigm, although there is no prime, per se, relatedness proportion may still substantially influence the identification process and thus have an effect on priming. If a criterion shift is at work, greater priming would be expected in the high than low relatedness proportion condition.

Method

Subjects. The subjects were 30 Rice University students.

Materials and design. The relatedness proportion was manipulated between subjects with the relatedness manipulated within subjects. The inserted mask duration was 50 ms.

The between-subject design of related proportion called for two groups of subjects: one for 25% RP condition and the other for 75% RP condition. Each of two groups of subjects was split into three subgroups. For the 25% RP condition, the three subgroups processed the same 192 unrelated pairs but different one-third portion of the 192 related pairs. The same effort, as it was in Experiment 5, was made to roughly equate the average associative strength among three portions. For the 75% RP condition, the three subgroups processed the same 192 related pairs but different one-third portion of the 192 unrelated pairs, with each portion consisting of corresponding pairs of the related pairs for each subgroup under the 25% RP condition.

Results

Priming data. The results are summarized in Figure 9. For the 25% RP condition, the mean identification exposure time was 51.3 ms for related pairs and 57.2 ms for unrelated pairs, $t\ (14) = 10.13, p < .001$. For the 75% RP condition, the mean identification exposure time was 49.9 ms for related pairs and 56.9 ms for unrelated pairs, $t\ (14) = 6.64, p < .001$. The interaction between relatedness proportion and relatedness was not significant $F\ (1, 28) = .92, p = .345$, indicating that relatedness proportion did not influence the magnitude of semantic priming effect.

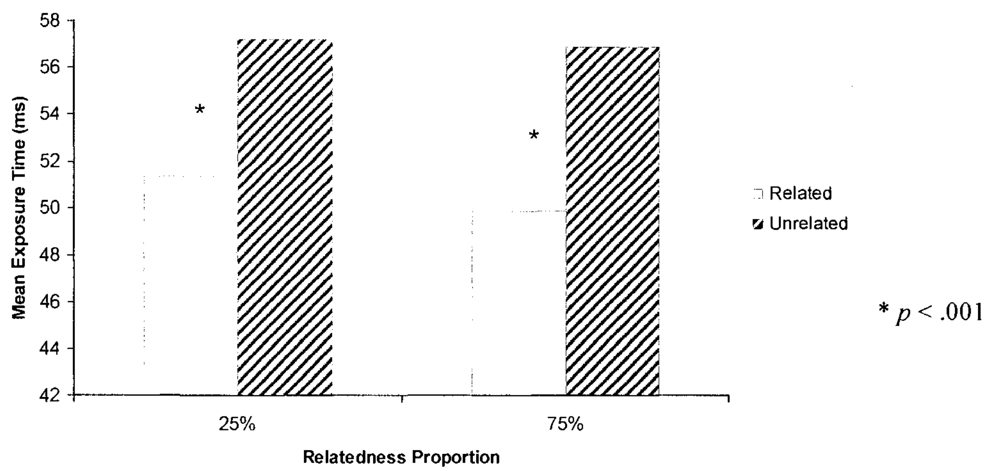
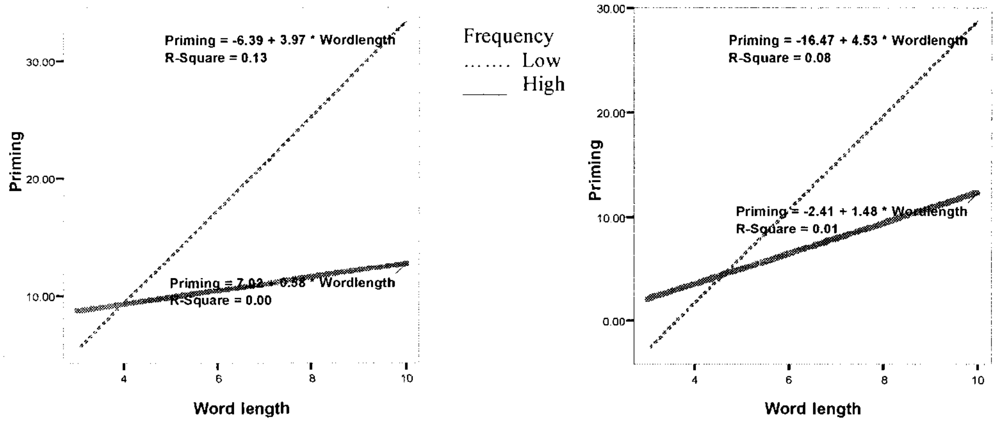


Figure 9. Mean exposure time for identification at each relatedness proportion condition (Experiment 7).

Multiple regression. As before, two regression models were constructed to explore the relation among the priming effect and word length and word frequency. In the first model, without the interaction term of word length and word frequency, for the 25%

RP condition, variance in the priming effect could be explained collectively by the two independent variables, $F(2, 93) = 4.15$, $p = .019$, but neither of the coefficients was significant (see Table 3); for the 75% RP condition, the priming effect was not well explained by the two predictors, $F(2, 93) = 2.00$, $p = .142$, but the coefficient of word length was marginally significant. After the interaction term was entered in the second model, the overall model was significant under the 25% RP condition, with a negative relation between priming and the interaction, but under the 75% RP condition, neither the overall model nor any of the coefficients were significant. As in Experiments 1-5, when the interaction was significant, it received a negative weight. When simply splitting the data into two halves according to the frequency-low vs. high, and constructing regression models between priming and word length for each frequency condition, the interaction was further depicted (Figure 10). Under the 25% RP condition, the slope of the regression line was greater for low frequency words than that for high frequency words. In other word, for low frequency words, the longer they were, the bigger priming effect they produced; but for high frequency words, there was not such a strong relation between word length and priming effect. The coefficient of the three-way interaction (word length * word frequency * RP) was not significant, $p = .703$, providing evidence that the effect of the interaction between word length and word frequency on the size of priming did not differ between the two RP conditions.



25% RP 75% RP

Figure 10. Interaction between word length and word frequency at each RP condition (Experiment 7).

Table 3: Raw Regression Coefficients (With Standardized Regression Coefficients in Parentheses) From Multiple Regression Analyses on Priming Effect in Experiment 7

	Predictor	Coefficient	Std. Error	t	p
Model without interaction					
	Word length	1.927(.185)	1.086	1.775	079
(25% RP)	LogFre.	-4.505(-.168)	2.796	-1.611	.110
	Overall model		F (2,93) = 4.15		.019*
	Word length	3.226(.209)	1.647	1.958	053
(75% RP)	LogFre.	.965(.024)	4.243	.227	.821
	Overall model		F (2,93) = 2.00		.142
Model with interaction					
	Word length	1.439(.138)	1.078	1.336	.185
(25% RP)	LogFre.	-4.737(-.177)	2.728	-1.736	.086
	Interaction	-3.690(-.238)	1.531	-2.410	.018*
	Overall model		F (3,92) = 4.85		.004*
	Word length	2.923(.189)	1.678	1.742	.085
(75% RP)	LogFre.	.821(.021)	4.248	.193	.842
	Interaction	-2.297(-.100)	2.383	-.964	.338
	Overall model		F (3,92) = 1.64		.186

* $p < .05$

Error response. Error responses were recorded for each subject. Two graduate students independently rated the errors and categorized them into three types: orthographic errors, semantic errors and other errors. Orthographic errors were words reconstructed of letter parts from either one of the presented stimuli or both of them, for example, for the presented pair BLACK-BRIDE, the error response BLADE was considered as an orthographic error. Semantic errors were the responses semantically related to either of the presented words, for example, FAIL was treated as a semantic error for the pair WILD-PASS; more specifically, there were some errors which were semantically related to one presented word and orthographically similar to the other presented word, for example, RIGHT as an error response for the pair TIGHT-WRONG. All other errors were put into the third category. The agreement on categorization between the two coders was not 100%, but very few disagreements.

For 25% RP condition, the mean number of total error responses was 34.5, and for 75% RP condition, the mean was 25.6, t (28) = 1.67, p = .107. The mean number of semantic errors was 1.20 and 1.27 for the 25% and 75% RP condition respectively, t (28) = .132, p = .896. The mean number of orthographic errors was 26.4 and 15.8 for the 25% and 75% RP conditions, respectively, t (28) = 2.523, p = .018. After computing the proportion of orthographic errors in each relatedness condition, a main effect of relatedness was obtained, F (1, 28) = 8.77, p = .006, with more errors in the unrelated condition. In this analysis, the main effect of RP was marginally significant, F (1, 28) = 3.60, p = .068; however, the effect of relatedness did not differ between the two RP conditions F (1, 28) = .91, p = .347.

Discussion

In Experiment 7, there were several pieces of evidence arguing against a criterion shift as the source of the priming effect in this paradigm. First, the size of priming effect did not vary as a function of RP. Second, very few semantic errors were made, which provides some evidence that subjects' identification criterion did not shift when RP was manipulated. Third, according to the results of multiple regression, there was little strong evidence that length, frequency, or their interaction had an effect on the size of the priming effect. It should be noted that for a given yoked pair, for example "MOM, DAD, ARM, LEG", the numbers of the data point collected for related condition and unrelated condition were different, with more data for the unrelated pairs in the 25% condition and more data for the related pairs in the 75% condition. Thus, there may have been some noise in the data that impeded the detection of effects. However, similar analyses in Experiments 1-5 where this problem did not exist also failed to reveal consistent effects of these variables.

On the other hand, there was one piece of evidence suggesting that differences in guessing between the related and unrelated conditions may have played a role in the priming effect. Many of the errors were orthographic errors, strongly implying the use of partial identification. Moreover, there were more orthographic errors in the unrelated than related condition, indicating that subjects did rely on the relatedness of the pairs to some degree to help them narrow down the possible candidates and make a faster response in the related condition. The very few semantic errors most likely resulted because for many unrelated word pairs it was difficult to come up with a guess that was semantically related to the other member of the pair and also included the identified letters. If an experiment were designed such that many unrelated pairs allowed for this possibility (e.g., pairs like "tight-wrong"), then substantially greater semantic errors might occur and the effect might be modulated by relatedness proportion.

GENERAL DISCUSSION

In the series of seven experiments, a new semantic priming paradigm was introduced in which there was no prime/target distinction, therefore overcoming the problems with threshold-setting procedure in the standard paradigm. For example, in the threshold-setting phase of the standard paradigm, it has been found that subjects' tendency to report a prime could vary across trials and between subjects (Bengson & Hutchison, 2007). Therefore, the demonstrated priming effect without prime identification may actually arise from some of the identified prime trials or by a subset of the subjects. In comparison, the new paradigm was designed in such a way that priming effect could be explored by each subject individually and by each trial as well, unlike the standard paradigm in which the same threshold applies for all the subjects and all the trials (although some studies measure individual threshold but still apply the same threshold to all the trials for a given subject). The new design is superior to the standard semantic priming paradigm by not using primes, which easily gets rid the problems associated with threshold procedures.

The question of the persistence of the semantic priming effect without prime identification was revisited using the new paradigm. Although semantic priming was not totally eliminated when the delay between two words was extended to 1 sec, it did decrease as delay increased. This result is not really in line with the claims of supporters of either side based on prior studies, in which one side claimed semantic priming without prime identification was short-lived (e.g., Van der Heijden et al., 1984; Greenwald et al., 1996), whereas the other claimed it only happened when the delay was long enough (Fowler et al., 1981; Balota, 1983). Rather, it provided evidence for Holender and

Duscherer's (2004) suggestion that priming is not necessarily short-lived but is paradigm dependent. More specific, with present paradigm, because each word was presented repeatedly for a given duration, it may have an influence on the persistence of the priming effect. Further analysis could be conducted to look into this issue.

One potential problem with the new paradigm may arise from the identification task itself. Since the identification was defined by subjects' overt response, it did not take into account the underlying processes which may be influenced by subjects' response criterion (e.g., Bengson & Hutchison, 2007). In Experiment 7, RP was manipulated between subjects to detect the influence of potential criterion changes on priming effect. Previous studies have shown that response criteria may affect identification and semantic priming. For example, Bengson and Hutchison (2007) used the standard masked semantic priming paradigm and an exclusion task in which subjects were instructed to complete a word stem with a word not related to the presented prime to examine the role of response criterion. They varied the response criteria by asking subjects to report the prime if they saw it, or give their best guess, or report any information they saw and their confidence level. They found semantic priming, suggested by exclusion failures, was eliminated under more liberal prime-report conditions. However, in Experiment 7, the manipulation of RP did not affect semantic priming by mediating subjects' response criterion (e.g., confidence level).

However the result of multiple regression and error response analyses did cast light on the existence of partial identification and response criterion changes. Although the multiple regression did not give strong and consistent evidence of the relationship among the priming effect and word length, word frequency, and their interaction, there were some findings indicating a role for these factors. The interaction between word length and word frequency, suggested that word length was a strong predictor for the priming effect for low frequency words, but not for high frequency words.

The analysis of error responses in Experiment 7 gave further evidence of the role of partial identification. Firstly, most errors were orthographic errors, resulting from reconstruction from either or both words. Therefore, identification of the unreported word cannot be ruled out. There was, likely at least, partial identification. Secondly, more orthographic errors were made in the unrelated condition, thus indicating an influence of relatedness on subjects' response criterion.

Other studies have also shown priming from partial identification (Abrams & Greenwald, 2000; Kouider & Dupoux, 2004). Kouider and Dupoux (2004) used the Stroop priming paradigm to show that priming requires at least partial identification. However, this conclusion was challenged by Abrams and Grinspan (2007) who argued that these findings could not be generalized to other situations in which semantic priming is found. Further studies are needed to take a careful examination of this issue.

To summarize, the development of this new paradigm solved the context problem of the standard priming paradigm, by getting rid of the distinction between prime and target. In addition, by using the new paradigm, this study showed that the semantic priming could be long-lived and may be dependant on which paradigm is used. Moreover, it provided some evidence for priming from partial identification.

With this new paradigm, for future studies, more liberal operational definitions of "identification" could be explicitly instructed, for example, by asking subjects to report either word when they first have some sense of the word or report either word only when they are 100% sure and then the priming effect could be compared between those conditions. Even with the definition applied in Experiment 1-7, we could ask subjects to rate their confidence level when they report a word. These manipulations may give some hints to aid understanding of the role of partial identification. Moreover, a different set of word pairs could be used, consisting of target pairs and fillers instead of all target pairs as it was in Experiment 7; the masked duration in Experiment 7 could be varied as well, to further explore RP effect.

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