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False memories and lexical decision: even twelve primes do not cause long-term semantic priming

René Zeelenberg [a,*], Diane Pecher [b]

[a] *Department of Psychonomics, University of Amsterdam, Roetersstraat 15, 1018 WB Amsterdam, Netherlands*
[b] *Utrecht University, Netherlands*

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Abstract

Semantic priming effects are usually obtained only if the prime is presented shortly before the target stimulus. Recent evidence obtained with the so-called false memory paradigm suggests, however, that in both explicit and implicit memory tasks semantic relations between words can result in long-lasting effects when multiple 'primes' are presented. The aim of the present study was to investigate whether these effects would generalize to lexical decision. In four experiments we showed that even as many as 12 primes do not cause long-term semantic priming. In all experiments, however, a repetition priming effect was obtained. The present results are consistent with a number of other results showing that semantic information plays a minimal role in long-term priming in visual word recognition. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

A well-known finding, often reported in the literature, is that a response to a word (e.g., *lion*) is faster and more accurate if the target word is presented in the immediate context of a related word, the prime (e.g., *tiger*), than if it is presented in the context of an unrelated word (e.g., *chair*). This *semantic priming* effect was first

* Corresponding author. Tel.: +31-20-5256644; fax: +31-20-6391656.
E-mail address: pn_zeelenberg@macmail.psy.uva.nl (R. Zeelenberg).

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obtained by Meyer and Schvaneveldt (1971) and has been replicated many times (e.g., Balota & Lorch, 1986; McNamara, 1992; Zeelenberg, Pecher, de Kok, & Raaijmakers, 1998). Another well-known finding is the *repetition priming* effect. Responses to words are faster and more accurate for recently studied words than for words that have not been studied recently (e.g., Ratcliff, Hockley, & McKoon, 1985; Scarborough, Cortese, & Scarborough, 1977; Wagenmakers, Zeelenberg, & Raaijmakers, 2000).

One remarkable difference between semantic priming and repetition priming concerns the time interval over which both effects can be obtained. The semantic priming effect has been shown to be an extremely short-lived phenomenon. In the standard semantic priming paradigm, the prime is presented immediately prior to the presentation of the target. A number of studies have shown that the priming effect is eliminated if one or more unrelated words intervene between the presentation of the prime and the target (Bentin & Feldman, 1990; Dannenbring & Briand, 1982; Kirsner, Smith, Lockhart, King, & Jain, 1984; Masson, 1995). Some studies (Joordens & Besner, 1992; McNamara, 1992) have found that priming can survive the presentation of one intervening unrelated word, but even in those cases the size of the priming effect was reduced dramatically by the presentation of an intervening word. For example, McNamara obtained a 30-ms priming effect when no words intervened between the prime and target, a 21-ms priming effect with one intervening word and no effect (i.e., a nonsignificant – 2-ms effect) with two intervening words. In contrast to semantic priming, repetition priming is obtained even when long periods of time and numerous unrelated items intervene between the first and second presentation of the target word. Several reports indicate that repetition priming can be obtained even when the first and second presentation of a word are one or more days apart (e.g., Jacoby & Dallas, 1981; Scarborough et al., 1977).

In contrast to the results mentioned above, Becker, Moscovitch, Behrmann, and Joordens (1997) recently obtained evidence for long-term semantic priming using an animacy decision task. In accordance with the results of previous studies, they obtained no long-term semantic priming, however, in a lexical decision task. Becker et al. proposed that a single mechanism underlies both repetition priming and long-term semantic priming and described a distributed connectionist type model for word recognition to account for their results. In this model, presentation of a prime causes learning of the pattern associated with that word by strengthening the connections between activated nodes. This learning speeds up later processing not only of the same word, but also of words that are *similar* to the prime because these words have a large part of their pattern in common with the prime. In this model, long-term semantic priming is due to the overlap of the semantic patterns of prime and target. Becker et al. argued that the different results in animacy decision and lexical decision are due to the different extents to which performance in both tasks relies on semantic processing. They argued that performance in animacy decision relies primarily on semantic processing whereas performance in lexical decision relies primarily on orthographic processing. Therefore, they argued that in a lexical decision task semantic similarity is not expected to result in long-term priming.

In a follow-up study, Joordens and Becker (1997) did obtain long-term semantic priming in lexical decision. More specifically, they obtained semantic priming over a lag of eight intervening stimuli. This is the only study that we are aware of that obtained semantic priming in a lexical decision task over a lag of more than two items. These results seem to conflict with the absence of long-term semantic priming generally observed in lexical decision. It should be noted, however, that the study of Joordens and Becker was specifically designed to encourage semantic processing of the stimuli. Semantic processing was promoted by including pseudohomophones as nonword stimuli (a pseudohomophone is a nonword that sounds like an existing word, for example *brane*), making the word/nonword decision more difficult. Joordens and Becker argued that the inclusion of pseudohomophones results in a higher degree of semantic processing. In other words, it turns the lexical decision task into a more semantic task, explaining the occurrence of long-term semantic priming.

A recent study by McDermott (1997), however, suggests that long-term semantic priming might be obtained even in tasks that are usually assumed to rely primarily on the processing of orthographic or perceptual information. McDermott investigated long-term priming in word stem completion and word fragment completion and used a procedure analogous to the false memory paradigm (Deese, 1959; Roediger & McDermott, 1995). In this paradigm, a study list (e.g., *garage*, *drive*, *transportation*, *crash*, *chauffeur*, *freeway*, *parking*, *wheel*, *bus*, *jeep*, *race*, *taxi*) consisting of words that are all related to a critical item, the lure (e.g., *car*), is presented and subsequently memory is tested. In explicit memory paradigms such as free recall and recognition, this procedure leads to a high percentage of false memories (i.e., a high percentage of intrusions of the critical lure in free recall and a high percentage of false alarms in recognition). McDermott showed that this procedure also affects performance in implicit memory tasks. Of particular interest for the present study are the results obtained in word stem completion and word fragment completion. In these tasks subjects are given a word stem (e.g., co_) or a word fragment (e.g., _o_d) that they have to complete with the first word that comes to mind (e.g., *cold*). For the critical lures McDermott obtained a marginally significant priming effect in word stem completion and a significant priming effect in word fragment completion. These results contrast not only with the previous studies that failed to obtain long-term priming in lexical decision, but also with studies that failed to obtain long-term semantic priming in word fragment completion (Lombardi, 1997; Roediger & Challis, 1992).

Two factors may be responsible for McDermott's (1997) success in obtaining long-term priming. First, in the McDermott study as many as 10 related primes were presented for each target word. In contrast, all but one of the studies that failed to obtain long-term semantic priming have presented only *one* related prime for each target. The only study (Becker et al., 1997) that presented more than one prime also failed to obtain significant long-term semantic priming. However, there was a 10-ms effect in the expected direction and although Becker et al. presented five related primes for each target, this is still considerably less than the 10 primes presented in the McDermott study. A second possibly important factor is that in the McDermott study the primes were probably processed more deeply than in previous studies that failed to obtain long-term semantic priming in lexical decision. All published studies on long-term semantic priming in lexical decision have presented *both* the prime and the target in a lexical decision task. Because response times in lexical decision are usually quite fast (i.e., in the order of 500–600 ms) it is likely that subjects do not fully access the semantic information of a word and hence not much semantic information may be stored in memory (see Becker et al., for a similar argument). McDermott, however, presented the primes for 5 s each during the study phase and subjects were instructed to study them carefully because they would later be asked questions about the words.

The results of McDermott (1997) are of interest not only because they contrast with the absence of long-term priming in many studies but also because they challenge several views of long-term priming. One such view is proposed by Schacter (1994). Schacter argued that priming is mediated by a Perceptual Representation System (PRS). The PRS exists of three subsystems: the visual-word-form system, the auditory-word-form system and the structural-description system. Although the subsystems process different kinds of information, they are assumed to share common features and principles of operation. For example, the three subsystems support unconscious contributions to performance (i.e., implicit memory phenomena) and operate at a level that does *not* involve access to the meaning of words. In this view, long-term priming in visual priming tasks such as word fragment completion depends on the storage of *perceptual* (and not semantic) information. Therefore, the PRS account of long-term priming predicts that prior study of semantically related words should not affect the visual encoding of the target stimulus, and hence no long-term semantic priming should be obtained. Other researchers have also argued that long-term priming in visual word recognition does not depend on semantic processes. For example, Bowers (1999, 2000) argues that long-term priming depends on the strengthening of *orthographic* codes. In fact, the absence of long-term semantic priming is one of the arguments used by Bowers (1999) for an orthographic basis of long-term priming.

It may, however, be premature to take the results of McDermott (1997) as strong evidence against the view that long-term priming in visual word recognition depends on perceptual or orthographic processes. Several researchers have argued that performance in word stem and word fragment completion may be contaminated by explicit retrieval strategies (e.g., Reingold & Goshen-Gottstein, 1996; Toth, Reingold, & Jacoby, 1994). Responses in word stem and fragment completion are usually quite slow. In the McDermott study, subjects were allowed up to 20 s for responding, leaving plenty of time for explicit retrieval. Especially in word fragment completion, which is a difficult task, subjects might try to think back to the study phase in order to come up with a correct completion for the word fragment. If the results were indeed due to such a contamination by explicit retrieval strategies, then the data do not provide evidence against theories that attribute priming in visual word recognition to the strengthening of perceptual or orthographic codes.

The aim of the present study was to determine if long-term semantic priming can be obtained under conditions that reduce or eliminate the possibility of contamination by explicit retrieval attempts. Therefore, a lexical decision task was used in the present study. Because response times in lexical decision are very fast, it is unlikely that an explicit retrieval strategy will be effective. A finding of long-term semantic priming in the present study would be problematic for theories that attribute long-term priming in lexical decision to the storage of perceptual or orthographic information. [1]

2. Overview of Experiments 1, 2 and 3

Initially we expected to obtain long-term semantic priming and therefore set out to run a series of experiments to determine the conditions under which long-term semantic priming can be obtained. In the standard false memory paradigm, the list items or primes are presented in a blocked design. Thus, for example, first all list items are presented that are related to the critical lure or target *car*. Then all list items are presented that are related to the critical lure *spider*, etc. Subjects are instructed to study the words for a later memory test. It is possible that this type of instruction leads to a strategy whereby subjects try to improve their memory performance by actively thinking of a cue that might help later retrieval. For lists that are used in false memory paradigms it is very likely that this cue is the nonpresented critical lure, because this is the item around which all list items are 'centered'. Studies have shown that, in free recall and episodic recognition, the false memory effect is larger after blocked presentation than after random presentation (Toglia, Neuschatz, & Goodwin, 1999; Tussing & Greene, 1997). We therefore wanted to investigate whether the blocked presentation procedure used by McDermott (1997) was a crucial factor in finding long-term semantic priming. In Experiment 1 we investigated whether we could replicate the results of McDermott in a lexical decision task using a *random* presentation order of the list items during study. In Experiment 2 the list items were presented in a blocked presentation order but instead of an intentional learning task we used an *incidental* learning task. Subjects were instructed to perform a pleasantness rating task on all list items, and no mention of a memory test was made. To anticipate our results, in both Experiments 1 and 2 we obtained no indication of a long-term semantic priming effect. In Experiment 3 we used a procedure very similar to that of McDermott (1997) in order to maximize our changes of obtaining evidence for long-term semantic priming. With this procedure McDermott obtained priming in a word fragment completion task. During study, we presented the list items or primes in a blocked design and gave intentional learning instructions.

[1] In the present study, we are primarily concerned with long-term semantic priming in tasks that are usually assumed to rely on the processing of orthographic or perceptual information. Therefore, regular pronounceable nonwords were used in the present study. Also, unless otherwise noted, when discussing the lexical decision task we refer to the standard procedure in which regular pronounceable nonwords are used (i.e., no specific attempt is made to include pseudohomophones as nonwords).

3. Experiment 1

3.1. Method

3.1.1. Subjects

Thirty-four students of the University of Amsterdam participated for course credit. All subjects were native speakers of Dutch.

3.1.2. Stimulus materials and design

The experiment consisted of a study phase during which 18 lists consisting of 12 words each were presented for study and a test phase in which a lexical decision task was given. The question of interest was whether lexical decisions would be facilitated for words *related* to the words presented during the study phase. In order to compare the results for the critical lures to those of actually presented words we also included words from the study list in the lexical decision test. For these words a repetition priming effect was expected.

Word lists used by Stadler, Roediger, and McDermott (1999) were translated into Dutch. Some words were replaced by a new word to make the list more suitable for a Dutch subject population (e.g., on the list for the critical lure *flag*, the list items *stars* and *stripes* were replaced). Each list was centered around one critical lure. For example, for the critical lure (or target) *car* the list items (or primes) consisted of the following words: *garage*, *drive*, *transportation*, *crash*, *chauffeur*, *freeway*, *parking, wheel*, *bus*, *jeep*, *race*, *taxi*. There were 36 lists of 12 list items each. The study lists were split in two sets (i.e., set A and set B) of 18 lists for counterbalancing purposes. Half of the subjects studied the lists from set A and the other half studied the lists from set B, so that across subjects each stimulus was presented equally often in the studied and nonstudied condition.

For the lexical decision test a set of 72 words and 72 nonwords was created. The words consisted of the 36 critical lures belonging to the study lists and 36 list items (one from each list). Thus, during lexical decision half of the critical lures belonged to lists that were studied and the other half belonged to lists that were not studied. Similarly, half of the list items were from studied lists and the other half were from nonstudied lists. Frequency counts for the critical lures and list items were obtained from the CELEX norms (Baayen, Piepenbrock, & van Rijn, 1993). For the critical lures the mean frequency of occurrence per million was 137 (S.D. = 209). For the list items the mean frequency of occurrence per million was 135 (S.D. = 206).

Nonwords were pronounceable letter strings (but *not* pseudohomophones) that were created by changing one letter from an existing Dutch word that was not one of the list items or critical lures. A practice set of five words and five nonwords was created for use during the practice lexical decision trials. No word or nonword appeared twice during the experiment, except for the 18 list items that were presented during both the study phase and in the lexical decision test.

3.1.3. Procedure

During the study, the words were presented in a random order. Subjects were instructed to study the words for a later (unspecified) memory test. Each word was presented on the center of a computer screen for 2000 ms, followed by a blank screen of 500 ms. The next word was presented immediately after the blank screen. The critical lures were, of course, never presented during study. After a series of 12 items, subjects could take a short rest and continue by pressing the space bar to start presentation of the next 12 items.

The study phase was immediately followed by the lexical decision task. Words and nonwords were presented one at a time on the same computer screen used during the study. Each trial started with the presentation of a fixation mark (* * * * *) for 500 ms. The fixation mark was followed immediately by the target stimulus that remained on the screen until the subject had made a lexical decision by pressing one of two buttons with the right (for word response) or left (for nonword response) index finger. If the subject made an error, the word 'FOUT' (error) was presented for 1000 ms. The next trial started 1000 ms after the response or feedback.

The lexical decision task consisted of two 'blocks' of 72 stimuli each. The first block consisted of the 36 critical lures (18 from studied lists and 18 from nonstudied lists) and 36 nonwords. The second block consisted of the 36 list items and the other 36 nonwords. The transition from the first block to the second block was not indicated to the subjects. The critical lures and list items were presented in separate blocks to prevent that on some occasions the list item (e.g., *drive*) was presented immediately prior to the critical lure (e.g., *car*) from the same list. Thus, by presenting critical lures and list items in separate blocks we prevented that a possible semantic priming effect could be due to the prime being presented at a short lag rather than at a long lag. The presentation of the words and nonwords within the two blocks was randomized for each subject. Subjects were instructed to respond as accurately and as quickly as possible.

3.2. Results

Reaction times faster than 300 ms and slower than 1200 ms were excluded from the analyses. Trimming resulted in removal of 0.47% of the reaction times. The same outlier criterion was used in all subsequent experiments. The mean reaction times and error percentages are shown in Table 1. For the critical lures, lexical decisions were slightly *slower* if the corresponding list had been studied than if the list had not been studied. However, the effect was not significant, $t(33) = 1.55,\ p > 0.10$. Thus, there was no evidence of long-term semantic priming. For the list items, lexical decisions were faster if the item had been presented on the study list than if it had not been presented, $t(33) = 2.67,\ p < 0.01$, indicating that we obtained a significant repetition priming effect. An analysis on the error data showed no significant difference between critical lures corresponding to studied and nonstudied lists. However, the effect for list items was significant, $t(33) = 2.44$, $p < 0.05$. Thus a repetition priming effect was evident in both response latency and error rate whereas neither measure showed evidence for long-term semantic priming.

Table 1
Mean lexical decision times (in ms) and percent errors in Experiments 1–4

	Critical lures		List items	
	RT	PE	RT	PE
Experiment 1: *intentional study, random presentation*				
Studied list	543	3.6	544	3.1
Nonstudied list	533	4.4	565	6.5
Priming	−10	0.8	21	3.4
Experiment 2: *incidental study, blocked presentation*				
Studied list	571	3.4	594	3.8
Nonstudied list	573	4.2	612	4.2
Priming	2	0.8	18	0.4
Experiment 3: *intentional study, blocked presentation*				
Studied list	559	3.4	572	3.2
Nonstudied list	565	3.2	587	5.3
Priming	6	−0.2	15	2.1
Experiment 4: *intentional study, blocked presentation*				
Studied list	543	3.6	555	5.3
Nonstudied list	545	5.6	579	8.7
Priming	2	2.0	24	3.4

Note. Priming for critical lures indicates long-term semantic priming. Priming for list items indicates long-term repetition priming. In Experiments 1–3, Dutch stimuli were used and a Dutch subject population was tested. In Experiment 4, English stimuli were used and an American subject population was tested.

4. Experiment 2

4.1. Method

4.1.1. Subjects

Thirty-four students of the University of Amsterdam participated for course credit. All subjects were native speakers of Dutch.

4.1.2. Stimulus materials and procedure

The same sets of stimuli were used as in Experiment 1. The procedure was also similar to that of Experiment 1 with two exceptions. First, during study the items were presented in a blocked order so that all items of a list were grouped together. Thus, for example, first all items from the *car* list were presented (but not the word car itself), and then all items from the *spider* list were presented, and so on. The order of the lists was randomized for each subject. The order of words within a list was fixed, with the stronger associates at the start of the list. Second, subjects were not instructed to study the words, but were instructed to rate the pleasantness of each word on a scale from 1 to 5. Words were presented for 2000 ms on the computer screen, and subjects entered their rating on the keyboard (the word was presented for a fixed duration of 2000 ms, regardless of whether or not subjects entered their rating before the 2000 ms elapsed). As in Experiment 1, there was again a 500 ms blank screen between trials. However, when the subject had not typed a rating after this 500 ms, the screen remained blank until a response was typed.

4.2. Results

Trimming resulted in removal of 0.21% of the reaction times. The mean reaction times and error percentages are shown in Table 1. For the critical lures, lexical decisions were not affected by whether or not the list that it was related to was studied, $t(33) = 0.29,\ p > 0.25$. For the list items, lexical decisions were faster if the item had been presented on the study list than if it had not been presented, $t(33) = 3.75$, $p < 0.001$. There were no significant effects for the error data. Thus, again we obtained evidence for repetition priming but not for long-term semantic priming.

5. Experiment 3

5.1. Method

5.1.1. Subjects

Thirty-eight students of the University of Amsterdam participated for course credit. All subjects were native speakers of Dutch.

5.1.2. Stimulus materials and procedure

The same sets of stimuli were used as in Experiments 1 and 2. The procedure was similar to that of Experiment 2, except that subjects were asked to study the items for a later (unspecified) memory test. The present procedure was very much like that of McDermott's (1997) study that showed long-term semantic priming in word fragment completion.

5.2. Results

Trimming resulted in removal of 0.23% of the reaction times. The mean reaction times and error percentages are shown in Table 1. For the critical lures, lexical decisions were not affected by whether or not the list that it was related to was studied, $t(37) = 0.98,\ p > 0.25$. For the list items, lexical decisions were faster if the item had been presented on the study list than if it had not been presented, $t(37) = 2.31,\ p < 0.05$. There were no significant effects for the error data. These results replicate those of Experiments 1 and 2 as we again obtained no evidence for long-term semantic priming.

5.3. Discussion of Experiments 1, 2 and 3

For the critical lures, we obtained no effect of whether the related list was studied or not studied. For list items, however, we consistently obtained an effect, indicating a reliable repetition priming effect. Thus, the results so far do not show any evidence for long-term semantic priming. McDermott (1997) observed priming effects for critical lures about half the size of the priming effects for actually studied words. In our Experiment 3, in which we used a procedure most similar to that of McDermott, the effect for critical lures was not significant but numerically it was almost half the size of the effect for the list items. Therefore, we wanted to do another experiment. In Experiment 4 we used the same procedure as in Experiment 3, except that the study phase was divided in two, with each study phase followed by a lexical decision task. This was done in order to decrease the amount of time between study and test and make the experiment even more similar to that of McDermott. We used a new set of materials and a different subject population. The stimulus set consisted of the lists that were used by McDermott and that had elicited 'false' implicit memories in her experiment. In addition, we used lists used by Stadler et al. (1999) and lists used by McEvoy, Nelson, and Komatsu (1999). All these lists have elicited high false memory rates in explicit memory tests.

6. Experiment 4

6.1. Method

6.1.1. Subjects

Thirty-eight volunteers at Emory University participated for a monetary fee. All subjects were native speakers of English.

6.1.2. Stimulus materials

The stimuli consisted of 32 lists of 10 words each. Of these lists, 16 were identical to those used by McDermott (1997, Experiment 4). The other 16 lists consisted of 8 lists that were taken from Stadler et al. (1999) and 8 lists that were taken from McEvoy et al. (1999). These 16 lists were chosen because previous studies showed that they elicit high false recognition rates for the nonpresented critical lures. No word appeared more than once in the complete stimulus set. The stimuli were divided into two sets of 16 lists for counterbalancing purposes.

For the lexical decision task a list was created that consisted of the 32 lures and 32 list items (i.e., one list item and one critical lure from each list). All these items were presented for lexical decision. For each subject, half the items were from studied lists, the other half were from nonstudied lists. The condition of an item was counterbalanced across subjects. Frequency counts for the critical lures and list items were obtained from the CELEX norms (Baayen et al., 1993). For the critical lures the mean frequency of occurrence per million was 143 (S.D. = 201). For the list items the mean frequency of occurrence per million was 67 (S.D. = 91).

In addition to the word lists there were two sets of 32 nonwords each. The nonwords were derived from existing words by changing one or two letters. All nonwords were orthographically legal and pronounceable.

6.1.3. Procedure

The study lists were presented in two study blocks of 8 lists each. Presentation was identical to that in Experiment 3, except that each list consisted of 10 items (instead of 12). After 8 study lists, 32 words (i.e., 8 critical lures and 8 list items from 8 studied lists, and 8 lures and 8 list items from 8 nonstudied lists) and 32 nonwords were presented in the lexical decision task. In contrast to Experiments 1, 2 and 3, in which first all critical lures were presented and then the list items, the presentation order of critical lures and list items was completely random. This was done to make the procedure as similar as possible to that of the McDermott (1997) study. A different random order was used for each subject.

The lexical decision task was followed by a recognition task. During the recognition test 3 items from each of the 8 presented lists and 3 items from each of the 8 nonpresented lists were presented. After the recognition task this whole cycle of study task, lexical decision test, and recognition test was repeated for the remaining 16 lists. Again, 8 lists were presented and the remaining 8 lists were not presented. Data from the recognition test were not analyzed.

6.2. Results

Trimming resulted in removal of 0.39% of the reaction times. The mean reaction times and error percentages are shown in Table 1. For the critical lures, there was again no effect of whether or not the list that the lure was related to was studied, $t(37) = 0.34$, $p > 0.25$. For the list items, lexical decisions were faster if the item had been presented during study than if it had not been presented, $t(37) = 3.64$, $p < 0.001$. For the error data there was no significant difference between the critical lures from studied and nonstudied lists $t(37) = 1.60$, $p > 0.10$. The effect for list items, however, was significant, $t(37) = 2.52$, $p < 0.05$. Thus, again we obtained evidence for repetition priming but no indication of long-term semantic priming.

7. General discussion

In the present series of experiments we found no evidence for long-term semantic priming. The absence of long-term priming is consistent with a large number of studies that show that semantic priming in lexical decision is an extremely short-lived phenomenon (Becker et al., 1997; Bentin & Feldman, 1990; Dannenbring & Briand, 1982; Joordens & Besner, 1992; Masson, 1995; McNamara, 1992). The present study differs from these previous studies in two important ways. First, in the present study the primes were presented for 2 s during the study phase. In other studies, not only the targets but also the primes were presented in a lexical task and hence the presentation time (i.e., study time) of the prime was typically about 500–600 ms (i.e., the time needed to make a lexical decision). The presentation time used in the present study likely resulted in a deeper encoding of the prime than in previous studies. Second, instead of presenting only one semantically related prime, as is common in the large majority of semantic priming studies, we presented as many as 12 related primes in the present study. Thus, our manipulation was much stronger than that used in previous studies investigating long-term priming in lexical decision. Nonetheless, we still did not obtain evidence for long-term semantic priming. Although we failed to obtain evidence for long-term priming in four experiments, we do not argue that long-term priming effects will be absent in lexical decision under all circumstances. Joordens and Becker (1997) obtained evidence for long-term semantic priming when pseudohomophones were included. They argued that under these circumstances subjects are more likely to engage in semantic processing of the stimuli. Thus, it might be that long-term semantic priming would be observed with the present materials if the lexical decision task were set up in a manner that encouraged semantic processing.

To address possible concerns about the power to detect an effect, we combined the data from all four experiments. Averaged over the four experiments there was a 0 ms long-term priming effect for the critical lures. Thus, the combined data from Experiments 1–4 show no indication of long-term semantic priming. The averaged effect for list items amounted to 19 ms. A t-test indicated that this repetition priming effect was highly significant, $t(143) = 6.00,\ p < 0.0001$. We performed a power analysis to investigate the power of the experiments to detect a long-term semantic priming effect. When calculating the power one needs to estimate the size of the effect, several studies using the false memory paradigm in explicit memory tasks such as free recall and recognition have found that the veridical memory effect (i.e., memory for presented list items) and false memory effect (i.e., memory for nonpresented critical lures) are about equally large. These studies would suggest that a reasonable way to estimate the size of the long-term semantic priming effect in the present study would be to take the size of the repetition priming effect. Using G*Power (Buchner, Faul, & Erdfelder, 1997), we found that the power to detect a long-term semantic priming effect of 19 ms was 1.00 (two-tailed). It should be noted, however, that McDermott (1997) observed that in word fragment completion the size of the long-term semantic priming effect was about half the size of the repetition priming effect. One could argue that this is a more realistic estimate of the long-term semantic priming effect in the present study. Using this more conservative estimate of the size of the long-term semantic priming effect (i.e., 10 ms) the power to detect an effect was still 0.89 (two-tailed). Therefore, the lack of a long-term semantic priming effect in the present experiments is not likely due to a lack of power.

Our results contrast with those obtained by McDermott (1997). She found long-term semantic priming in word fragment completion (i.e., a higher percent target completions for critical lures corresponding to studied lists than for critical lures corresponding to nonstudied lists). Word stem completion, word fragment completion, lexical decision and perceptual identification are usually categorized as perceptual implicit memory tasks and therefore one would expect to find parallel effects in these tasks (Blaxton, 1989; Roediger, 1990; Roediger & McDermott, 1993). However, as we noted in Section 1, it is possible that performance in word fragment completion is contaminated by explicit retrieval attempts. In the present study, the influence of explicit retrieval strategies was minimized by using a lexical decision task. Although our experiments do not provide direct evidence that the results obtained by McDermott (1997) were due to explicit retrieval attempts, the absence of long-term priming in lexical decision is consistent with this hypothesis.

As we mentioned in the Section 1, the absence of long-term *semantic* priming in lexical decision contrasts with the finding of long-term *repetition* priming in many studies. In the present study, we also obtained robust long-term repetition priming effects. An important difference between semantic priming and repetition priming is that in the repetition priming paradigm the target word *itself* is presented previously (i.e., the prime and target are identical) whereas in the semantic priming paradigm a word related to the target is presented previously (i.e., the prime is semantically related to the target). However, this difference by itself does not explain the absence of long-term semantic priming. There is some indication that long-term priming effects can be obtained for target words that are orthographically *similar* but not identical to the prime words. Rueckl (1990) investigated the influence of orthographic similarity priming in perceptual identification. Thus, during study the words *lane* and *fame* were presented and during test the word *lame* was presented. Rueckl obtained priming not only for words (e.g., *lane* and *fame*) that had been presented themselves during study but also for words (e.g., *lame*) that were orthographically similar to the words presented during study (but see, Ratcliff & McKoon, 1997).

Also note that it is *not* the case that semantic relations between words in general have only a short-lasting effect. Becker et al. (1997) obtained long-term semantic priming in animacy decision. Notice the correspondence between long-term semantic priming and orthographic similarity priming. In both cases the prime and target are similar to each other but in the long-term semantic priming paradigm, the similarity is at the semantic level instead of the orthographic level. It might seem that the finding of long-term priming in animacy decision conflicts with the results of the present study and the absence of long-term priming in lexical decision in general. However, as we explained in Section 1, the theory of Becker et al. attributes these different results to the different processing demands in both tasks. Whereas in animacy decision the meaning of a stimulus must be accessed in order to perform the task, this is not the case in lexical decision and therefore semantic similarity plays a much more important role in animacy decision.

The absence of long-term semantic priming in lexical decision is consistent with the view that long-term priming in visual word recognition tasks is primarily due to the strengthening of perceptual or orthographic codes. Several other results reported in the literature also indicate that long-term priming takes place primarily at a level lower than that of semantic representations. It has been demonstrated that priming effects are eliminated or reduced when surface characteristics of words are changed, for example by study-to-test changes in modality of presentation (e.g., Bowers & Michita, 1998; Jacoby & Dallas, 1981) or language (i.e., study of the Spanish word *casa* does not result in a long-term priming effect for its English translation equivalent *house*, Kirsner, Brown, Abrol, Chadna, & Sharma, 1980; Kirsner et al., 1984; Scarborough, Gerard, & Cortese, 1984). The absence of an effect of a levels-of-processing manipulation on priming in perceptual identification (e.g., Jacoby & Dallas, 1981) also points to the minimal role of meaning in long-term priming. All these results show that overlap in perceptual or orthographic features and not semantic features between the prime and target is crucial in obtaining long-term priming in visual word recognition.

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References

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). The CELEX lexical database (CD-ROM), Linguistic Data Consortium. Philadelphia, PA: University of Pennsylvania.

Balota, D. A., & Lorch, R. F. (1986). Depth of automatic spreading activation: mediated priming effects in pronunciation but not in lexical decision. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *12*, 336–345.

Becker, S., Moscovitch, M., Behrmann, M., & Joordens, S. (1997). Long-term semantic priming: a computational account and empirical evidence. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 1059–1082.

Bentin, S., & Feldman, L. B. (1990). The contribution of morphological and semantic relatedness to repetition priming at short and long lags: evidence from Hebrew. *Quarterly Journal of Experimental Psychology*, *42A*, 693–711.

Blaxton, T. A. (1989). Investigating dissociations among memory measures: support for a transfer appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*, 657–668.

Bowers, J. S. (1999). Priming is not all bias: commentary on Ratcliff and McKoon (1997). *Psychological Review*, *106*, 582–596.

Bowers, J. S. (2000). In defense of abstractionist theories of repetition priming and word identification. *Psychonomic Bulletin and Review*, *7*, 83–99.

Bowers, J. S., & Michita, Y. (1998). An investigation into the structure and acquisition of orthographic knowledge: evidence from cross-script Kanji–Hiragana priming. *Psychonomic Bulletin and Review*, *5*, 259–264.

Buchner, A., Faul, F., & Erdfelder, E. (1997). G*Power: a priori, post-hoc, and compromise power analyses for the Macintosh (Version 2.1.2) [Computer program]. Trier, Germany: University of Trier.

Dannenbring, G. L., & Briand, K. (1982). Semantic priming and the word repetition effect in a lexical decision task. *Canadian Journal of Psychology*, *36*, 435–444.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology*, *58*, 17–22.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, *110*, 306–340.

Joordens, S., & Becker, S. (1997). The long and short of semantic priming effects in lexical decision. *Journal of Experimental Psychology: Learning Memory, and Cognition*, *23*, 1083–1105.

Joordens, S., & Besner, D. (1992). Priming effects that span an intervening unrelated word: implications for models of memory representation and retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*, 483–491.

Kirsner, K., Brown, H. L., Abrol, S., Chadna, N. N., & Sharma, N. K. (1980). Bilingualism and lexical representation. *Quarterly Journal of Experimental Psychology*, *32*, 585–594.

Kirsner, K., Smith, M. C., Lockhart, R. S., King, M. L., & Jain, M. (1984). The bilingual lexicon: language-specific units in an integrated network. *Journal of Verbal Learning and Verbal Behaviour*, *23*, 519–539.

Lombardi, W. J. (1997). Associative priming in word fragment completion: a dissociation between explicit and implicit retrieval processes. *Memory*, *6*, 673–702.

Masson, M. E. J. (1995). A distributed memory model of semantic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 3–23.

McDermott, K. B. (1997). Priming on perceptual implicit memory tests can be achieved through presentation of associates. *Psychonomic Bulletin and Review*, *4*, 582–586.

McEvoy, C. L., Nelson, D. L., & Komatsu, T. (1999). What is the connection between true and false memories? The differential roles of interitem associations in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*, 1177–1194.

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, *90*, 227–234.

McNamara, T. P. (1992). Theories of priming: I. Associative distance and lag. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*, 1173–1190.

Ratcliff, R., Hockley, W., & McKoon, G. (1985). Components of activation: repetition and priming effects in lexical decision and recognition. *Journal of Experimental Psychology: General*, *114*, 435–450.

Ratcliff, R., & McKoon, G. (1997). A counter model for implicit priming in perceptual word identification. *Psychological Review*, *104*, 319–343.

Reingold, E. M., & Goshen-Gottstein, Y. (1996). Separating consciously controlled and automatic influences in memory for new associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 397–406.

Roediger, H. L. (1990). Implicit memory: retention without remembering. *American Psychologist*, *45*, 1043–1056.

Roediger, H. L., & Challis, B. H. (1992). Effects of exact repetition and conceptual repetition on free recall and primed word-fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*, 3–14.

Roediger, H. L., & McDermott, K. B. (1993). Implicit memory in normal human subjects. In F. Boller, & J. Grafman (Eds.), *Handbook of neuropsychology* (Vol. 8) (pp. 63–131). Amsterdam: Elsevier.

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 803–814.

Rueckl, J. G. (1990). Similarity effects in word and pseudo word priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*, 374–391.

Scarborough, D. L., Cortese, C., & Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance*, *3*, 1–17.

Scarborough, D. L., Gerard, L., & Cortese, C. (1984). Independence of lexical access in bilingual word recognition. *Journal of Verbal Learning and Verbal Behavior*, *23*, 84–89.

Schacter, D. L. (1994). Priming and multiple memory systems: perceptual mechanisms of implicit memory. In D. L. Schacter, & E. Tulving (Eds.), *Memory systems 1994* (pp. 233–268). Cambridge, MA: MIT Press.

Stadler, M. A., Roediger, H. L., & McDermott, K. B. (1999). Norms for word lists that create false memories. *Memory and Cognition*, *27*, 494–500.

Toglia, M. P., Neuschatz, J. S., & Goodwin, K. A. (1999). Recall accuracy and illusory memories: when more is less. *Memory*, *7*, 233–256.

Toth, J. P., Reingold, E. M., & Jacoby, L. L. (1994). Toward a redefinition of implicit memory: process dissociations following elaborative processes and self-generation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*, 290–303.

Tussing, A. A., & Greene, R. L. (1997). False recognition of associates: how robust is the effect? *Psychonomic Bulletin and Review*, *4*, 572–576.

Wagenmakers, E. M., Zeelenberg, R., & Raaijmakers, J. G. W. (2000). Testing the counter model for perceptual identification: effects of repetition priming and word frequency. *Psychonomic Bulletin and Review*, *7*, 662–667.

Zeelenberg, R., Pecher, D., de Kok, D., & Raaijmakers, J. G. W. (1998). Inhibition from nonword primes in lexical decision reexamined: The critical influence of instructions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*, 1068–1079.