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Level of discrimination for recognition judgments reduced following the recognition of semantically related words

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Abstract

Participants read lists of words and then made recognition judgments to pairs of words, each of which consisted of a prime word and a test word. At issue was the effect of a semantic relationship between the prime word and the test word on the recognition judgment to the test word. Under standard recognition conditions, semantic priming impeded correct recognition judgments to new test words and had no effect on recognition judgments to old test words. The overall effect was to reduce the level of discrimination for recognition judgments to the test word. Under conditions in which familiarity assessment would be expected to play a greater role in judgments to old test words, semantic priming facilitated those judgments. The results are explained in terms of a dual process account of recognition.

Keywords: Recognition; Memory; Priming; Semantic; Dual process

Retrieval from recognition memory is often fast and relatively effortless. The possibility therefore arises that the recognition of an item will be affected consequent to the prior recognition of other items in the same context. Sequential dependencies of this sort are most likely to occur when recognition judgments are made about related items in the same context. Such dependencies are studied with priming tasks. These tasks ask whether a recognition judgment to a *test item* is affected consequent to the presence of a relationship between that test item and a *prime item.*

Priming has been studied for two kinds of recognition judgment. In *lexical decision*, the test item is a letter string. Participants indicate whether or not the item is a legal word of the prevailing language. Thus, the question for memory is whether the test item has been encountered previously in any context. In *episodic recognition*, participants indicate whether or not the test item appeared an earlier phase of the experiment. Thus, the question for memory is whether the test item has been encountered previously in a particular context.

Priming has been extensively explored for lexical decision. Although the prime–test item relationship has in some cases been learned for the purposes of the experiment, in most cases it has been given by prior knowledge. Semantic relationships—those given by knowledge of the word meaning—have, in particular, been extensively explored. The general finding has been that, when the prime and the test item are both words, responses to the test item are facilitated when a semantic relationship links the two (McNamara & Holbrook, 2003; Neely, 1991). Although questions of discrimination are difficult to untangle in lexical decision, because of the intrinsic differences between word and non-word items, the general finding has been that semantic priming

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either increases or has no effect on the level of discrimination for lexical decisions to the test item (with the only effect in the latter case being one of bias) (Farah, 1989; Rhodes, Parkin, & Tremewan, 1993).

Priming has been less thoroughly explored for episodic recognition. Here again, semantic relationships have been most extensively explored. Johns (1985) and Lewandowsky (1986) tested memory for lists of common nouns, each of which was composed of several words from each of several semantic categories. On each trial of the experimental procedure, the participant studied a list of words and then made recognition judgments to a series of pairs of words, with each pair consisting of a prime word and a test word. Correct recognition judgments to a test word from a particular category were facilitated when the prime word came from the same as opposed to a different category. This was the case regardless of whether or not the test word was *old*—present in the list, or *new*—absent from the list. Thus, priming increased the level of discrimination for recognition judgments to the test word.

Dosher, McElree, Hood, and Rosedale (1989) tested memory for uncategorized lists of common nouns using a procedure that differed from that of Johns (1985) and Lewandowsky (1986) in that the lists were shorter and that no response was required to the prime word. On each trial of the Dosher et al. procedure, the participant studied a list of words and then responded to a series of prime word/test word pairs. For each pair, the participant read the prime word, and then made a recognition judgment to the test word. The prime word was never present in the list. When the prime and test word were semantically related, correct recognition judgments to the test word were facilitated and impeded, respectively, depending on whether the test word was old or new. Thus, priming had no effect on level of discrimination for recognition judgments to the test word.

In sum, semantic priming has been explored extensively in lexical decision, and somewhat less extensively in episodic recognition. The general finding has been that semantic priming either increases or fails to affect the level of discrimination for recognition judgments to the test item.

In the experiments reported here, we explored the effect of semantic priming in episodic recognition using a different procedure than has been used in past work. In contrast to Johns (1985) and Lewandowsky (1986), we used uncategorized rather than categorized lists. In contrast to Dosher et al. (1989), we required successive recognition judgments to the prime word and the test word. Using these procedures, we demonstrated an effect of semantic priming that differs from those that have been observed in past work. Whereas semantic priming has either increased or failed to affect the level of discrimination for recognition judgments in past work, semantic priming decreased the level of discrimination for recognition judgments in the present study. We suggest an explanation of this new priming effect in terms of a particular class of recognition model and provide support for this explanation.

General method

The following method was used in all but one of the experiments in the study. On each of a series of trials, the participant read the words in a *study list*, counted backwards briefly, and then made recognition judgments to the words in a *test list*. The test list consisted of one or more *test pairs*, where each test pair consisted of a *prime word* and a *test word.* When the test list consisted of multiple test pairs, only some of these were *crucial* to the experiment and the rest were *filler* pairs. Interest focused on the recognition judgments to the test word. Performance on these judgments was examined as a function of relatedness—that is, whether or not the prime and test word were semantically related, prime word study status—that is, whether the prime word was old or new, test word study status, and other factors.

Participants

The participants were students at the George Washington University. They received credit in a psychology course in exchange for their efforts.

Materials

The crucial test pairs for each experiment were created from a *generator set* of word triples. The first and second words of each triple were semantically related (e.g., burglar, thief). The third word had no obvious semantic relationship to the first word or second word (farmer). The crucial test pairs for a given participant were created as follows: First, the triples were assigned to the experimental conditions according to a random scheme that was unique to the participant in question. Second, a test pair was created for each triple, as follows: The first word of the triple was always the test word. If the triple was assigned to a condition in which the prime and test word were semantically related, the second word of the triple was the prime word. If the triple was assigned to a condition in which the prime and test word were not semantically related, the third word of the triple was the prime word. Finally, the test pairs were assigned to the trials of the experiment according a random scheme that was unique to the participant in question. Given the test pair or pairs that were assigned to a given trial for a given participant, the study list for that trial was created as follows:

(1) For test pairs assigned to conditions in which the prime word was old, the prime word was placed in the list. (2) For tests pairs assigned to conditions in which the test word was old, the test word was placed in the list. (3) The rest of the words in the list were then sampled without replacement from a *filler pool* of words. (4) If the test list consisted of multiple test pairs, each filler word that was placed in the list was also placed randomly as either a prime or a test word in one of the filler pairs for the trial. The rest of the words in the filler pairs were then sampled without replacement from the filler pool. (5) The words in the list were placed in a random order that was unique to the participant in question. If the test list consisted of multiple test pairs, the pairs were placed in a random order that was unique to the participant in question.

Procedure

The trials were presented on a computer monitor. The participant initiated the presentation of each trial by pressing the space bar of the computer. The study list for the trial in question was then presented, word by word, with each successive word appearing alone in the middle of the screen for a *study interval* of a certain length and being followed by an *inter-word interval* of a certain length. After the last word of the study list was presented, a message appeared at top of screen instructing the participant to count backwards silently from a randomly selected number. After 3 s, this message disappeared and a message appeared, instructing the participant to prepare for the test phase. After 1000 ms, this message disappeared and the test list was presented. The following sequence occurred with the presentation of each test pair: The prime word appeared and remained on the screen until the participant responded. The participant was instructed to respond positively to the word only if it had appeared in the current study list. She/he was instructed to press the "B" and "N" keys to indicate positive and negative responses, respectively, and to respond as quickly as possible to the word, without sacrificing accuracy. After the participant responded to the prime word it disappeared and the test word appeared in the same place, remaining on the screen until the participant responded, in the same manner as to the prime word, at which point the test word disappeared. If the response to either word in a test pair was incorrect, a message appeared to that effect after the test word disappeared from the screen. Each error message remained on the screen until the participant pressed the space bar of the computer.

Experiments 1A, 1B, and 1C sought to establish the effect of semantic priming in the present recognition task. Because their results were similar, the experiments will be presented as a group (Table 1 summarizes the attributes of all of the experiments of the study).

Experiment 1A

The task for Experiment 1A was closely modeled on the task of Lewandowsky (1986) except that the study lists were not categorized. Each study list consisted of 32 words and each test list consisted of 32 test pairs. The study and test lists consisted exclusively of common nouns. Nine of the test pairs for each trial were crucial pairs and the rest were filler pairs. Over the course of the experiment, the prime word and the test word were synonyms (burglar, thief) in half of the crucial pairs and had no obvious semantic relationship to one another (burglar, farmer) in the rest of the crucial pairs. The prime word was old in half of the crucial pairs and new in the rest of the crucial pairs. The test word was old in half of the crucial pairs and new in the rest of the crucial pairs. For the filler pairs, the prime word and test word were old and new with the same probability as for the crucial pairs. For these pairs, the prime and test word were never related, however.

The experiment was run in two waves. The first wave was run as a stand-alone experiment. The second wave was run as part of a larger experiment, across which participants performed a synonym priming task and another task, not to be reported here, that involved superficial priming (e.g., priming 'Barry' with 'Harry'). The synonym priming task and the superficial priming

Table 1
Attributes of the different experiments in the study

Experiment	Prime/test relationship	Study and test list	Judgment required	Special features
1A	Synonym	Long	Recognition	
1B	Associative	Long	Recognition	
1C	Synonym	Short	Recognition	
2	Synonym	Long	Recognition/confidence	
3	Synonym	Short	Recognition	Vary study interval
4	Synonym	Short	Recognition	Vary response interval
5	Synonym	Continuous	Recognition/recency	

task were performed in counterbalanced order, with the same results being observed for synonym priming regardless of the order of performance.

Methods

Participants

Seventy-eight and one-hundred and twenty-six participants were tested in the first and second waves of the experiment.

Design

Relatedness, Prime Word study status, and Test Word study status were manipulated in a $2 \times 2 \times 2$ design. Each session in the first wave of the experiment consisted of eight trials (and thus eight study lists). With nine crucial pairs per trial, 72 crucial pairs were presented over the course of the session. The pairs were equally distributed across conditions, with nine pairs being presented for each of the eight conditions. Each session in the second wave of the experiment consisted of five trials (and thus five study lists). With nine crucial pairs per trial, 45 crucial pairs were presented over the course of the session. The pairs were distributed across conditions as equally as possible, with five pairs being presented for three of the conditions and six pairs being presented for the rest of the conditions. The particular conditions receiving five and six iterations were determined randomly for a given participant. The design dictated that an average of 1.12 pairs of related words were present in each study list and that each test list contained an average of 4.5 related test pairs.

Materials

The materials were created as indicated in General method. The generator set for the first wave consisted of 72 common noun triples. The first and second words of each triple were synonyms. The generator set for the second wave consisted of 45 triples, with a different random sample being taken for each participant from the larger set of 72. The filler pool consisted of 792 common nouns. Because the words in the study list were randomly ordered, two related words were separated in the study list, on average, by 10.6 words.

Procedure

The procedure was as indicated in General method with the following refinements. (1) The study interval was 1600 ms and the inter-word interval was 400 ms. (2) During the test phase, a message appeared on the screen announcing the appearance of each test pair. After 2000 ms, this message disappeared and the prime word from the next test pair was presented.

Results

Interest centered on responses to the test word.[1] Two sets of analyses were conducted, one that conditionalized on correct responses to the prime word (that is, considered only the data from trials on which the response to the prime word was correct), and one that did not. As the two analyses produced essentially the same results, only the conditionalized analysis will be reported. This will be the case for all experiments in the study. Each participant contributed 16 data points to the analysis. These data points recorded the mean time for correct responses to the test word and the accuracy of responses to the test word in the eight experimental conditions. As was the case throughout the study, the data for a given participant were not included in the analysis if the participant was missing any of the data points. This happened either when all of the participant's responses to the prime word were incorrect in a condition (so that no test-word data were available for that condition) or when all of the participant's responses to the test word were incorrect (so that no response-time data were available for that condition). The final sample for the analysis consisted of 150 participants (68 in the first wave and 82 in the second wave). Separate analyses were conducted for responses to old and new test words. In addition, analyses were conducted collapsing across the two sets of responses. All statistical tests were conducted against a significance criterion of .05. Table 2 presents the response-time data for the present experiment and the rest of the experiments in the study. Fig. 1 presents the accuracy data for the present experiment.

Test Word Old

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,149) = 1.07$, $MSE = 25{,}606$]. Response time was longer when the prime word was old [$F(1,149) = 5.70$, $MSE = 21{,}059$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,149) < 1$]. Similar results were observed for the two waves of participants. Response time did not differ in the two waves [$F(1,148) < 1$]. The effect of Relatedness [$F(1,148) = 2.26$, $MSE = 25{,}606$] and the interaction of the effects of Relatedness and Prime Word [$F(1,148) = 4.43$, $MSE = 19{,}899$] did not differ in the two waves. However, the effect of Prime Word was greater in the first wave of participants [$F(1,148) = 5.29$, $MSE = 21{,}059$].

[1] In this and the other experiments of the study, the overall level of performance for the prime word closely resembled the overall level of performance for the test word, with response times and error rates being, respectively, slightly longer, and slightly higher, for the prime word than for the test word.

Table 2
Experiments 1A–4: Mean time for correct responses to test word

Experiment		Test word							
		Old				New			
		Related		Unrelated		Related		Unrelated	
		Prime word							
		Old	New	Old	New	Old	New	Old	New
1A		717 (16)	696 (17)	734 (17)	702 (14)	785 (18)	793 (18)	753 (17)	768 (14)
1B		693 (33)	718 (41)	722 (40)	689 (23)	764 (27)	756 (34)	754 (26)	798 (52)
1C		793 (31)	743 (24)	805 (33)	735 (15)	860 (26)	865 (32)	795 (21)	801 (26)
2		148 (10)		147 (11)		182 (21)		150 (9)	
3		Short study interval				837 (28)	853 (42)	786 (40)	785 (30)
		680 (32)	693 (32)	731 (38)	698 (28)				
		Long study interval							
		702 (39)	649 (20)	700 (24)	707 (28)				
4 (Response interval)	Short	237 (13)	235 (13)	260 (20)	244 (13)	277 (16)	322 (26)	255 (14)	288 (18)
	Long	159 (13)	146 (9)	195 (22)	145 (12)	182 (26)	167 (18)	179 (21)	155 (10)

Note. Standard errors are given in parentheses.

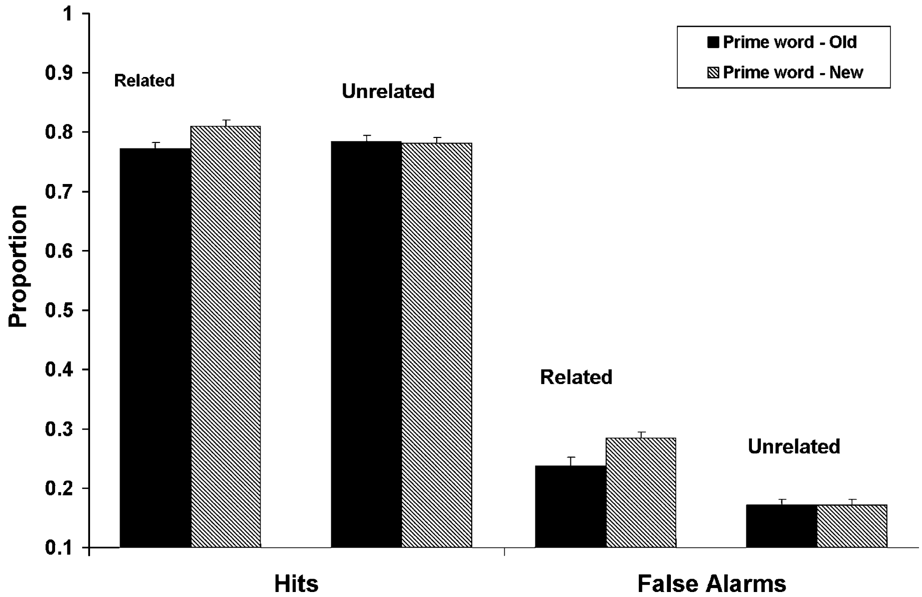

Fig. 1. Experiment 1A: Accuracy of responses to the test word as a function of whether or not the prime and test word were related, whether the prime word was old or new, and whether the test word was old or new.

Hit rate did not vary as a function of whether or not the prime and test word were related [$F(1,149) < 1$] or whether the prime word was old or new [$F(1,149) = 1.84$, $MSE = .029$]. The effects of Relatedness and Prime Word did not interact in the hit-rate data [$F(1,149) = 2.32$, $MSE = .031$]. Similar results were observed for the two waves of participants. Hit rate did not differ in the two waves [$F(1,148) = 3.30$, $MSE = .077$]. The effects of Relatedness [$F(1,148) < 1$] and Prime Word [$F(1,148) = 1.20$, $MSE = .029$] and the interaction of the effects of Relatedness and Prime Word [$F(1,148) < 1$] did not differ in the two waves.

Test Word New

Response time was longer when the prime and test word were related than when they were unrelated [$F(1,149) = 5.50$, $MSE = 20{,}298$]. Response time did not vary as a function of whether the prime word was old or new [$F(1,149) < 1$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1, 149) < 1$]. Similar results were observed for the two waves of participants. Response time did not differ in the two waves [$F(1, 148) < 1$]. The effects of Relatedness [$F(1, 148) = 1.07$, $MSE = 20{,}278$] and Prime Word [$F(1, 148) < 1$] and the interaction of the effects of Relatedness and Prime Word [$F(1, 148) = 3.50$, $MSE = 24{,}309$] did not differ in the two waves.

False-alarm rate was higher when the prime and test word were related than when they were unrelated [$F(1, 149) = 40.89$, $MSE = .028$]. False-alarm rate did not vary as a function of whether the prime word was old or new [$F(1, 149) = 2.22$, $MSE = .040$]. The effects of Relatedness and Prime Word did not interact in the false-alarm-rate data [$F(1, 149) = 2.48$, $MSE = .030$]. Similar results were observed for the two waves of participants. False-alarm rate did not differ in the two waves [$F(1, 148) = 1.05$, $MSE = .073$]. The effects of Relatedness [$F(1, 148) = 1.67$, $MSE = .028$] and Prime Word [$F(1, 148) < 1$] and the interaction of the effects of Relatedness and Prime Word [$F(1, 148) < 1$] did not differ in the two waves.

Overall

Performance to positive and negative test words can only be aggregated in terms of a model of the recognition process (MacMillan & Creelman, 1991). We use the equal-variance Gaussian signal detection model for this purpose. In doing so, we do not intend to embrace this model as an account of our results. In fact, the account that we later suggest for our results is more complex than this. However, given that some version of the signal detection model plays a role in most accounts of the recognition process, we believe that a summary view obtained in terms of the equal-variance Gaussian version of that model should be useful regardless of what particular account is ultimately accepted for our results. Accordingly, estimates of d' were calculated for each of the four conditions that resulted when the data were collapsed across the Test Word variable (estimates of c were not calculated because the interpretive challenges associated with such were deemed greater than the potential insight that they might provide (Neely & Tse, 2007)). In calculating the estimates of d', hit and false alarm rates of 1.0 and 0.0 were assigned z-score values of 3.09 and -3.09, respectively.

The d' estimates for this as well as the rest of the experiments in the study are summarized in Table 3. As the Table shows, d' was lower when the prime and test word were related than when they were unrelated, [$F(1, 149) = 12.34$, $MSE = 2.46$] and d' did not vary as a function of whether prime word was old or new [$F(1, 149) < 1$]. The effects of Relatedness and Prime Word did not interact in the d' data [$F(1, 149) < 1$]. Although the two waves of participants differed in mean d', with the mean for the second wave being higher than that for the first wave, [$F(1, 148) = 14.28$, $MSE = 6.21$] the effects of Relatedness [$F(1, 148) < 1$] and Prime Word [$F(1, 148) < 1$] and the interaction of the effects of Relatedness and Prime Word [$F(1, 148) = 1.57$, $MSE = 1.83$] did not differ across the two waves (mean response-time was also computed for each of the four conditions that resulted when the data were collapsed across the Test Word variable. This measure showed no significant effects in the present experiment, or in any of the experiments of the study. Nothing more will be said about it).

Discussion

Synonym priming impeded correct recognition judgments to new test words. The effect appeared in the response-time and the accuracy data. Synonym priming had no effect on recognition judgments to old test words. A power analysis was conducted to assess the probability

Table 3
Experiments 1A–C, 3–5: Results of signal detection analyses of accuracy data

Experiment		d'			
		Related		Unrelated	
		Prime word		Prime word	
		Old	New	Old	New
1A		2.58 (.16)	2.49 (.14)	3.02 (.14)	2.97 (.16)
1B		1.87 (.26)	1.93 (.25)	2.79 (.29)	2.68 (.27)
1C		2.28 (.17)	2.29 (.15)	3.52 (.21)	2.85 (.17)
3 (Study interval)	Short	2.72 (.22)	2.22 (.21)	2.97 (.25)	2.78 (23)
	Long	3.06 (.22)	2.51 (.22)	3.80 (.22)	3.42 (.23)
4 (Response interval)	Short	1.85 (.26)	1.67 (.25)	2.18 (.24)	1.58 (.24)
	Long	2.53 (.23)	2.53 (.24)	3.39 (.25)	3.20 (.21)
5		1.288 (.10)		1.620 (.14)	

Note. Standard errors are given in parentheses.

that a priming effect would have been detected for old test words, had such an effect been present. As was the case with all of the power analyses for this study, the size of the hypothetical priming effect was estimated from the priming effect that was observed for new test words. The analysis showed that such an effect would have been detected with probability .99. The overall effect of synonym priming was to reduce the level of discrimination for recognition judgments to the test word. In an additional result, correct recognition judgments to old test words were slower when the prime word was old than when the prime word was new. This result will be discussed further later.

Experiment 1B

Experiment 1B sought to show that the priming effect of Experiment 1A occurs as a function of semantic relationships other than the synonym relationship. Specifically, the experiment sought to show that the priming effect occurs as a function of associative relationships. The experiment followed Experiment 1A in all respects except that the crucial relationship between the prime and test word was associative (e.g., doctor–nurse).

Methods

Participants

Thirty-seven participants were tested in the experiment.

Materials

The generator set consisted of 72 triples, with the words in each triple being either common nouns or verbs. The first and second words of each triple were associatively related; on average, the first word of each triple had a Postman and Keppel (1970) production frequency of 140 with the second word as stem. The third word had no obvious associative relationship to the first and second words. The filler pool consisted of 792 common nouns and verbs. In other respects, the method was as for Experiment 1A.

Results

The final sample for the analysis consisted of 33 participants. The response time and accuracy results for this sample are summarized in Table 2 and Fig. 2, respectively.

Test Word Old

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,32) < 1$] or as a function of whether the prime word was old or new [$F(1,32) < 1$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,32) = 1.13$, $MSE = 23{,}946$]. Hit rate did not vary as a function of whether or not the prime and test word were related [$F(1,32) = 1.07$, $MSE = .036$] or as a function of whether the prime word was old or new [$F(1,32) = 1.20$, $MSE = .03$]. The effects of Relatedness and Prime Word did not interact in the hit-rate data [$F(1,32) = 1.08$, $MSE = .03$].

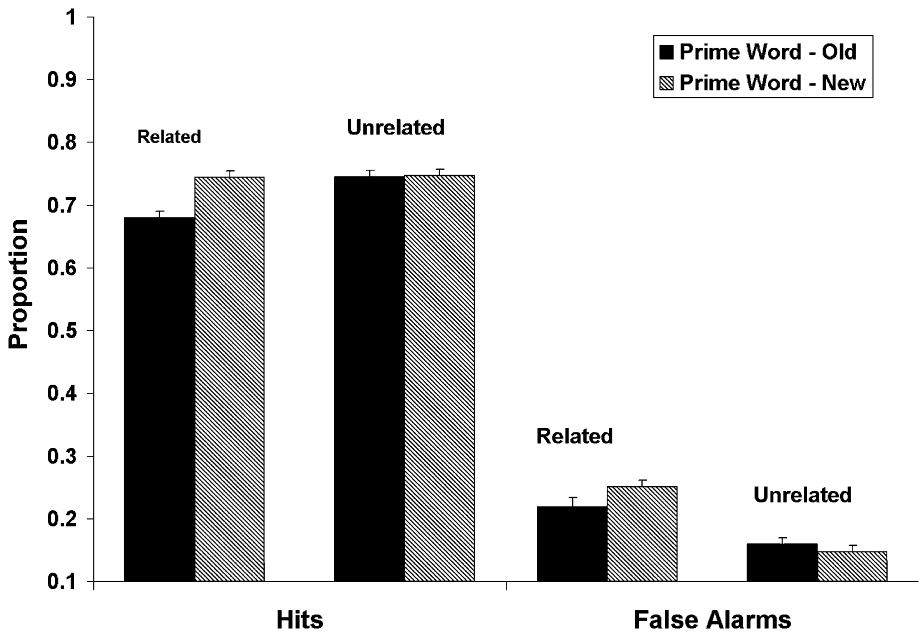

Fig. 2. Experiment 1B: Accuracy of responses to the test word as a function of whether or not the prime and test word were related, whether the prime word was old or new, and whether the test word was old or new.

Test Word New

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,32) < 1$] or as a function of whether the prime word was old or new [$F(1,32) < 1$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,32) < 1$]. False-alarm rate was higher when the prime and test word were related than when they were unrelated [$F(1,32) = 15.44$, $MSE = .014$]. False-alarm rate did not vary as a function of whether the prime word was old or new [$F(1,32) < 1$]. The effects of Relatedness and Prime Word did not interact in the false-alarm-rate data [$F(1,32) < 1$].

Overall

As Table 3 shows, d' was lower when the prime and test word were related than when they were unrelated [$F(1,32) = 10.02$, $MSE = 2.29$] and d' did not vary as a function of whether the prime word was old or new [$F(1,32) < 1$]. The effects of Relatedness and Prime Word did not interact in the d' data [$F(1,32) < 1$].

Discussion

The general pattern was the same as in Experiment 1A. Associative priming impeded correct recognition judgments to new test words. The effect appeared in the accuracy data. Associative priming had no effect on recognition judgments to old test words. The overall effect of associative priming was to reduce the level of discrimination for recognition judgments to the test word. A power analysis showed that a priming effect would have been detected in the accuracy data for old test words with probability .80, had such an effect been present.

Experiment 1C

Experiment 1C sought to replicate the crucial results of Experiments 1A and 1B using shorter lists such as were used by Dosher et al. (1989). The task for the experiment was modeled on the task of Dosher et al. except that a recognition judgment was required to the prime word. Each of the 72 trials involved the presentation of a study list consisting of 12 words and a test list consisting of a single test pair. The study and test lists consisted exclusively of common nouns. Over the course of the experiment, the prime word and the test word were synonyms (burglar, thief) on half of the trials and had no obvious semantic relationship to one another (burglar, farmer) on the rest of the trials. The prime word was old on half of the trials and new on the rest of the trials. The test word was old on half of the trials and new on the rest of the trials.

Methods

Participants

Seventy-five participants were tested in the experiment.

Design

Relatedness, Prime Word, and Test Word were manipulated in a $2 \times 2 \times 2$ design. The trials were distributed equally across conditions, with nine trials being assigned to each of the eight conditions. The design dictated that a single pair of related words was present in one eighth of the study lists and that the words in half of the test pairs were related.

Materials

The materials were constructed as indicated in General method using the same generator set and filler pool as were used in Experiment 1A. A pair of related words in a study list were separated, on average, by four words.

Procedure

The procedure was as indicated in General method with the following refinements. (1) The study interval was 1000. (2) The inter-word interval was 0 ms. (3) During the test phase, a message appeared on the screen announcing the appearance of the test pair. After 2000 ms, this message disappeared and the prime word for the test pair appeared.

Results and discussion

The final sample for the analysis consisted of 74 participants. The response time and accuracy results for this sample are summarized in Table 2 and Fig. 3, respectively.

Test Word Old

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,73) < 1$]. Response time was longer when the prime word was old [$F(1,73) = 6.68$, $MSE = 40{,}296$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,73) < 1$]. Hit rate did not vary as a function of whether or not the prime and test word were related [$F(1,73) = 1.22$, $MSE = .016$] or as a function of whether the prime word was old or new [$F(1,73) < 1$]. The effects of Relatedness and Prime Word did not interact in the hit-rate data [$F(1,73) < 1$.

Test Word New

Response time was longer when the prime and test word were related than when they were unrelated [$F(1,73) = 14.73$, $MSE = 20{,}842$]. Response time did not vary as a function of whether the prime word was old or new [$F(1,73) < 1$]. The effects of Relatedness and Prime Word did not interact in the response-time data

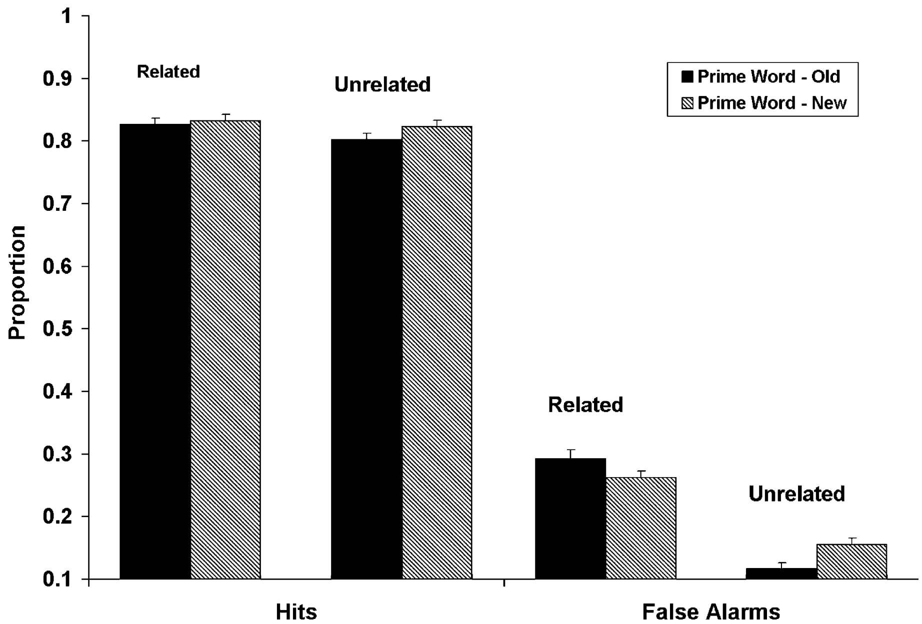

Fig. 3. Experiment 1C: Accuracy of responses to the test word as a function of whether or not the prime and test word were related, whether the prime word was old or new, and whether the test word was old or new.

[$F(1,73) < 1$]. False-alarm rate was higher when the prime and test word were related than when they were unrelated [$F(1,73) = 60.46$, $MSE = .024$]. False-alarm rate did not vary as a function of whether the prime word was old or new [$F(1,73) < 1$]. The effects of Relatedness and Prime Word interacted in the false-alarm-rate data [$F(1,73) = 5.64$, $MSE = .015$] with the effect of Relatedness being greater when the prime word was old.

Overall

As Table 3 shows, d' was lower when the prime and test word were related than when they were unrelated [$F(1,73) = 42.26$, $MSE = 1.41$] and d' did not vary as a function of whether the prime word was old or new [$F(1,73) = 3.38$, $MSE = 2.30$]. The effects of Relatedness and Prime Word interacted in the d' data [$F(1,73) = 5.69$, $MSE = 1.48$], with the effect of Relatedness being greater when the prime word was old.

Discussion

The important patterns in the data of Experiments 1A and 1B were replicated. A power analysis showed that a priming effect would have been detected in the accuracy data for old test words with probability .99, had such an effect been present. In an additional result, correct recognition judgments to old test words were slower when the prime word was old than when the prime word was new. A similar result was observed in Experiment 1A. These results will be discussed later. In a further additional result, the effect of synonym priming was greater when the prime word was old. This result will also be discussed later.

In order to clarify the interpretation of the results of Experiments 1A, 1B, and 1C, the data from these experiments were combined in a single analysis.

Test Word Old

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,254) < 1$]. Response time was longer when the prime word was old than when it was new [$F(1,254) = 5.86$, $MSE = 27{,}494$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,254) = 1.52$, $MSE = 24{,}696$]. Although mean response time differed across the three experiments, [$F(2,254) = 4.23$, $MSE = 84{,}101$] the effects of Relatedness [$F(2,254) < 1$] and Prime Word [$F(2,254) = 1.65$, $MSE = 27{,}494$] and the interaction of the effects of Relatedness and Prime Word [$F(2,254) < 1$] did not.

Hit rate did not vary as a function of whether or not the prime and test word were related [$F(1,254) < 1$] or as a function of whether the prime word was old or new [$F(1,254) = 2.62$, $MSE = .03$]. The effects of Relatedness and Prime Word did not interact in the hit-rate data [$F(1,254) = 1.40$, $MSE = .028$]. Although hit rate differed across the three experiments, [$F(2,254) = 5.76$, $MSE = .068$] the effects of Relatedness [$F(2,254) = 1.13$, $MSE = .027$] and Prime Word [$F(2,254) < 1$] and the interaction of the effects of Relatedness and Prime Word [$F(2,254) < 1$] did not.

Test Word New

Response time was longer when the prime and test word were related than when they were unrelated [$F(1,254) = 5.59$, $MSE = 21{,}143$]. Response time did not vary as a function of whether the prime word was old or new [$F(1,254) < 1$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,254) < 1$]. Mean response time differed across the three experiments, [$F(2,254) = 3.53$, $MSE = 97{,}923$] as did the effect of Relatedness [$F(2,254) = 3.65$, $MSE = 21{,}143$], with response time in Experiment 1C but not Experiments 1A and 1B being longer when the prime and test word were related than when they were unrelated. The effect of Prime Word [$F(2,254) < 1$] and the interaction of the effects of Relatedness and Prime Word [$F(2,254) < 1$] did not differ across the experiments.

False alarm rate was higher when the prime and test word were related than when they were unrelated [$F(1,254) = 76.33$, $MSE = .025$]. False alarm rate did not vary as a function of whether the prime word was old or new [$F(1,254) < 1$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,254) < 1$]. Neither the false alarm rate [$F(2,254) < 1$] nor the effect of Relatedness [$F(2,254) = 2.96$, $MSE = .025$] nor the effect of and Prime Word [$F(2,254) < 1$] differed across the experiments. However, the interaction of the effects of Relatedness and Prime Word did differ across the experiments [$F(2,254) = 3.56$, $MSE = .024$]. Whereas these variables interacted in the data from Experiment 1C, as was described earlier, they did not interact in the data from Experiments 1A and 1B.

Overall

Finally, d' was lower when the prime and test word were related than when they were unrelated [$F(1,254) = 44.66$, $MSE = 2.14$] and d' did not vary as a function and whether the prime word was old or new [$F(1,254) = 1.64$, $MSE = 2.13$]. The effects of Relatedness and Prime Word did not interact in the d' data [$F(1,254) = 1.47$, $MSE = 2.06$]. Neither mean d' [$F(2,254) = 1.95$, $MSE = 5.70$] nor the effects of Relatedness [$F(2,254) = 2.56$, $MSE = 2.14$] or Prime Word [$F(2,254) < 1$] nor the interaction of the effects of Relatedness and Prime Word [$F(2,254) = 1.57$, $MSE = 2.06$] differed across the three experiments.

In general, the three experiments produced the same pattern of results, with the effect of semantic priming in the response-time data for old test words being stronger in the short-list task of Experiment 1C than in the longer list task of Experiments 1A and 1B.

Experiment 2

Experiment 2 sought to further clarify the priming effect of Experiments 1A, 1B, and 1C. Under the assumption that performance in the tasks for those experiments reflected an equal variance Gaussian signal detection process, the results of these experiments imply that semantic priming reduces the level of discrimination for recognition judgments. Experiment 2 sought to confirm this conclusion, while relaxing the requirement that the distributions in the signal detection process be of equal variance. Participants again performed a recognition task, as in the earlier experiments. In addition to making recognition judgments to the prime word and the test word, participants rated the confidence of their response to the test word. ROC analyses were carried out to assess the level of discrimination in the recognition process.

The experiment was built upon the framework of Experiment 1A. In addition to the incorporation of the rating task, the following changes were made with respect to the earlier experiment: (1) Whereas Experiment 1A manipulated the study status of the prime word, Experiment 2 allowed the study status of the prime word to vary randomly. This change was made because sufficient data points would not have been available to calculate distinct ROC curves as a function of the two levels of prime word study status as well as the two levels of relatedness. (2) Whereas responses to the test word were temporally uncontrolled in Experiment 1A, responses to the test word were controlled with a response signal procedure in Experiment 2. The object of this change was to concentrate the priming effect in the error-rate data.

Methods

Participants

Sixty-six participants were tested in the experiment.

Design

Relatedness and Test Word were manipulated in a 2×2 design. Each session consisted of eight trials. Each of the eight study lists consisted of 32 words and each of the eight test lists consisted of 32 test pairs. Twenty-one of the test pairs for each trial were crucial pairs. Thus, 168 crucial pairs were presented over the course of the session. The pairs were distributed equally across conditions, with 42 pairs being presented for each of the four conditions. The design dictated that an average of 2.62 pairs of related words were present in each study list and that each test list contained an average of 10.5 related test pairs.

Materials

The materials were created as indicated in General method. The generator set consisted of 168 common noun triples of the sort used in Experiment 1A. The filler pool consisted of 572 common nouns. For each test pair, the prime word was placed in the study list with probability .5. A pair of related words in a study list were separated, on average, by 10.6 words.

Procedure

The procedure was as indicated in General method with the following refinements. (1) The study interval was 1600 ms and the inter-word interval was 400 ms. (2) During the test phase, a message appeared on the screen announcing the appearance of each test pair. After 2000 ms, this message disappeared and the prime word of the next test pair appeared. (3) A row of asterisks appeared at the bottom of the screen 800 ms after the test word appeared. (4) The participant was instructed to make her/his response to the test word coincident with the appearance of the asterisks. (5) If the participant made her/his response to the test word before the response signal appeared, or 250 after it appeared, a message appeared, immediately after the response to the test word, indicating that the response was either too fast or too slow. This message remained on the screen for 2000 ms. The temporal parameters of the response signal procedure were set, on the basis of the results of Experiment 1A, so as to provide participants with adequate time for accurate responding. (6) After the participant responded to the test word, a message appeared asking the participant to indicate his/her confidence in that response. If the participant's response to the test word was positive, he/she was asked to evaluate that response on a four point scale: (a) Pretty sure, (b) Somewhat sure, (c) Somewhat unsure, (d) Pretty unsure. If the participant's response to the test word was negative, he/she was asked to evaluate that response on a five point scale: (a) Pretty sure, (b) Somewhat sure, (c) Somewhat unsure, (d) Pretty unsure, (e) Completely unsure. (Different scales were used for positive and negative responses in the interest of obtaining four independent ROC points for negative as well as positive responses. This was important for analyses not to be reported here).

Results

The final sample for the analysis consisted of 66 participants. The response time and accuracy results for this sample are summarized in Table 2 and Fig. 4, respectively.

Test Word Old

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,65) < 1$]. Hit rate did not vary as a function of whether or not the prime and test word were related [$F(1,65) < 1$].

Test Word New

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,65) = 1.99$, $MSE = 17{,}188$]. False-alarm rate was higher when the prime and test word were related than when they were unrelated [$F(1,65) = 16.86$, $MSE = .008$].

With the data from each of the four experimental conditions, a proportion was computed for each of the nine response categories to reflect the relative number of responses that fell either into this category or into a more positive category. Taking the proportions computed for the Test Word Old and Test Word New conditions as probabilities of hits and false alarms, respectively, z-transformed ROC curves were plotted for the Related and Unrelated conditions. The curves

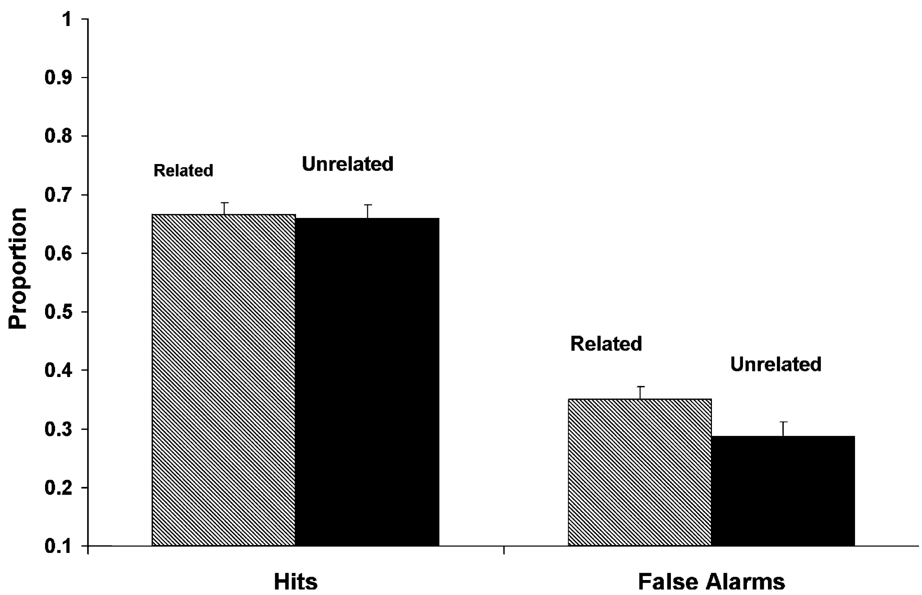

Fig. 4. Experiment 2: Accuracy of responses to the test word as a function of whether or not the prime and test word were related and whether the test word was old or new.

are shown in Fig. 5. For both conditions, least squares regression analyses revealed significant linear (Related: .824, $t(8) = 42.65$, $SE = .019$; Unrelated: .762, $t(8) = 79.36$, $SE = .01$) and quadratic (Related: $-.042$, $t(8) = 5.22$, $SE = .008$; Unrelated: $-.03$, $t(8) = 7.13$, $SE = .004$) components in the function relating hits to false alarms. The slopes of both functions were less than 1, a common finding in studies of recognition memory (Ratcliff, McKoon, & Tindall, 1994; Ratcliff, Sheu, & Gronlund, 1992). Significant linear (Related: 1.055, $t(8) = 24.44$, $SE = .043$; Unrelated: 1.17, $t(8) = 32.23$, $SE = .036$) and quadratic (Related: .095, $t(8) = 7.21$, $SE = .013$; Unrelated: .08, $t(8) = 7.14$, $SE = .011$) components were also present in the functions relating false alarms to hits.

To find out whether the level of discrimination differed in the Related and Unrelated conditions, *z*-transformed ROC curves were plotted for each participant. A slope was then fit to each curve, using maximum likelihood estimation. Because the slopes of the *z*-transformed ROC curves were generally less than 1, sensitivity was measured in terms of d_a (MacMillan & Creelman, 1991). Across participants, d_a was lower in the Related (.931) than the Unrelated (1.089) condition, $F(1, 65) = 4.27$, $MSE = .193$.

Discussion

These results reinforce the results of Experiments 1A–C.Under the assumption that performance in the tasks for those experiments reflected an equal variance Gaussian signal detection process, the results of the experiments imply that semantic priming reduces the level of discrimination for recognition judgments. The results of the present experiment confirm this conclusion, while relaxing the requirement that the distributions in the signal detection process be of equal variance. Notice that the present results are consistent with the results of the previous experiments in that semantic priming exerted a greater effect on the false alarm rate than on the hit rate (see Fig. 5).

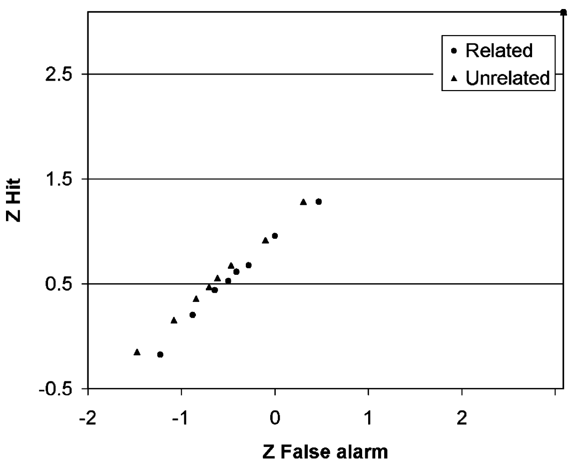

Fig. 5. Experiment 2: *z*-ROC curves for trials on which a relationship was present and absent between the prime and the test word.

The effect of semantic priming in the present recognition task differs from the effects that have been observed in previous studies of recognition memory. In previous studies of episodic recognition, the general finding has been that semantic priming either facilitates correct recognition judgments to old and new test words (Johns, 1985; Lewandowsky, 1986), or facilitates and impedes correct recognition judgments to old and new test words, respectively (Dosher et al., 1989). In previous studies of recognition, more generally construed, the general finding has been that semantic priming either increases or fails to affect the level of discrimination for recognition judgments to the test item (Dosher et al., 1989; Farah, 1989; Johns, 1985; Lewandowsky, 1986; Rhodes et al., 1993). Thus, the present results suggest an enlarged view of the effects of semantic priming on recognition judgments.

Granting its novelty, can we provide an account of the present priming effect? Such an account presumes a model of recognition and a mechanism of priming. Two sorts of recognition model are generally distinguished. In *global matching* models, making a recognition judgment involves a single process in which the degree of overlap is assessed between the test item and the items in memory (Clark & Gronlund, 1996). In *dual process* models, making a recognition judgment can potentially involve two different processes. First, it can involve *familiarity assessment* with regard to the test item. Second, it can involve an attempt to *recollect* the prior experience of the item (Norman & O'Reilly, 2003; Yonelinas, 1994).

Two sorts of recognition priming mechanism have been considered in past work. In *compound cueing* accounts, a recognition judgment to a test item is influenced by the informational context in which the item occurs (Dosher & Rosedale, 1989; Ratcliff & McKoon, 1988). Such accounts are generally stated in terms of global matching models of recognition. For example, one influential account proposes that, when a test item is presented for recognition judgment in the context of a prime item, the degree of overlap with the items in memory is assessed concurrently for the prime and test item. In general, the degree of overlap is greater when the prime and test item are related than when they are not. This principle holds regardless of whether the prime–test item relationship is given by the current context (i.e., learned for the purposes of the experiment) or by longer-term knowledge (Ratcliff & McKoon, 1988).

Spreading activation accounts of priming typically assume that knowledge is mentally represented in terms of a semantic network, the nodes and links of which record knowledge elements and relationships among those elements. A cognitive operation with respect to a test item is assumed to be facilitated to the extent that the mental representation for the item is activated. And, to the extent that the representation for a knowledge element is activated, activation is assumed to spread to the representations for elements that are recorded nearby in the network (McNamara, 1992a, 1992b). Because they apply to a broader range of cognitive operations than recognition judgments, spreading activation accounts are not generally tied as explicitly as compound cue accounts to models of recognition memory. However, the activation frameworks in which spreading activation accounts are stated typically provide dual process explanations of recognition memory (Anderson, 1983; Anderson & Lebiere, 1998; Reder et al., 2000).

It is not clear how a global matching account would explain the present results. To explain the priming effect that was observed for new test words, such an account would presumably hold that the degree of overlap for the test word was greater when the prime and test word were related than when they were unrelated. The account would presumably hold that, because the degree of overlap was greater when the two words were related, correct negative recognition responses were impeded. Having explained the priming effect for new test words in this way, it is not clear how a global matching account would then explain the absence of a priming effect for old test words. If the degree of overlap for a new test word increases with the presence of a prime–test word relationship, then the degree of overlap for an old test word should similarly increase. Thus, if correct negative responses are impeded when a prime–test word relationship is present, then correct positive responses should be facilitated when such a relationship is present. A global matching account might be able to avoid making the latter prediction by distinguishing prime–test word relationships that are given by the current context from longer term prime–test word relationships. It is not clear how this distinction would be made, however. Therefore, although a global matching account of the present results is no doubt possible, we will focus our energies on developing a dual process account.

One such account runs as follows: When the prime and test word were related, processing the prime word increased the likelihood of a positive familiarity assessment to the test word. The likelihood increase impeded correct recognition judgments to new test words. Recognition judgments to old test words were not affected because familiarity assessment had only minimal impact in this case, being overshadowed by recollection. Thus, semantic priming impeded correct recognition judgments to new test words and had no effect on recognition judgments to old test words. This account can be formulated in terms of spreading activation, but does not have to be formulated in such terms. In one possible formulation, the increase in the likelihood of a positive familiarity assessment reflected an increase in the familiarity level of the test word, mediated by a process of spreading activation. In another possible formulation, the likelihood increase reflected a decrease in the criterion for positive familiarity assessment.

This Potentiated Familiarity Hypothesis resembles a dual process account that has previously been offered for the word frequency mirror effect (Joordens & Hockley, 2000; Reder et al., 2000). The latter account seeks to explain the fact that decreases in word frequency facilitate correct recognition judgments to both old and new test words. The account runs as follows: Recognition judgments to old test words reflect primarily recollection. The likelihood that an old test word will be recollected increases as the word's frequency deceases. As a consequence, decreases in word frequency facilitate correct recognition judgments to old test words. Recognition judgments to new test words reflect primarily familiarity assessment. The likelihood that a new test word will receive a positive familiarity assessment decreases as the word's frequency decreases. As a consequence, decreases in word frequency facilitate correct recognition judgments to new test words.

Experiments 3, 4, and 5 sought support for the Potentiated Familiarity Hypothesis as an explanation of the present priming effect. The experiments sought to do this by confirming predictions of the hypothesis concerning the effect of semantic priming on recognition judgments to old test words. The hypothesis predicts that, under conditions in which familiarity assessment has substantial impact on judgments to such test words, semantic priming should facilitate correct judgments to such test words. This follows because processing the prime word should increase the likelihood of a positive familiarity assessment to the test word.

Given this prediction, we can gather support for the Potentiated Familiarity Hypothesis by (1) arranging conditions under which familiarity assessment is likely to have substantial impact on recognition judgments to old test words and (2) demonstrating that, under these conditions, semantic priming facilitates correct recognition judgments to such test words. Experiment 3 sought to do this by manipulating events during the study phase of the recognition procedure. Experiments 4 and 5 sought to do this by manipulating events during the test phase of the procedure.

Experiment 3

Experiment 3 manipulated events during the study phase of the recognition procedure to arrange conditions under which familiarity assessment would be likely to have substantial impact on recognition judgments to old test words. The object was to show that, under these conditions, synonym priming facilitated correct recognition judgments to such test words. The experiment assumed that familiarity assessment would be likely to have substantial impact on recognition judgments to old test words if such test words were weakly encoded during the study phase. The experiment assumed that test words would be have a high likelihood of being weakly encoded during the study phase if they were presented only briefly. Joordens and Hockley (2000) made similar assumptions in an experiment conducted to support their dual process account of the word frequency mirror effect, which was outlined above.

The experiment used the same task as Experiment 1C. Each of the 72 trials involved the presentation of a study list consisting of 12 words and a test list consisting of a single test pair. On half of the trials, the prime and test word were synonyms; on the rest of the trials, the two words had no obvious semantic relationship to one another. On half of the trials, the prime word was old; on the rest of the trials, it was new. On one third of the trials, the test word was old and the study interval was short; on one third of the trials, the test word was old and the study interval was long; on one third of the trials, the test word was new.

The trials on which the test word was old and the study interval was long and the trials on which the test word was new essentially reproduced the manipulations of Experiments 1A, 1C, and 2. On the basis of the results of these experiments, it was expected that synonym priming would not affect recognition judgments to the test word on the former trials and that synonym priming would impede correct recognition judgments to the test word on the latter trials. The object was to show that synonym priming facilitated correct recognition judgments to the test word on trials in which the test word was old and the study interval was short.

Methods

Participants

Sixty-five participants were tested in the experiment.

Design

Relatedness (Related, Unrelated), Prime Word (Old, New), and Test Word (Old–Short, Old–Long, New) were manipulated within participants, in a $2 \times 2 \times 3$ design. The trials were distributed equally across conditions, with six trials being assigned to each of the 12 conditions. The design dictated that a single pair of related words was present in one sixth of the study lists and that the words in half of the test pairs were related.

Materials

The materials were constructed as indicated in General method using the same generator set and filler pool as were used in Experiment 1A. A pair of related nouns in a study list were separated, on average, by four words.

Procedure

The procedure was as indicated in General method with the following refinements. (1) When the test word was present in the list, its study interval was 400 ms in the Old-Short condition and 1600 ms in the Old-Long condition. The study interval for the rest of the words of the list, including the prime word, when it was present in the list, was either 400 or 1600 ms, with equal likelihood. The inter-word interval was always 400 ms. (2) During the test phase, a message appeared on the screen announcing the appearance of the test pair. After 2000 ms, this message disappeared and the prime word for the test pair appeared.

Results

The final sample for the analyses consisted of 58 participants. The response time and accuracy results for this sample are summarized in Table 2 and Fig. 6, respectively. We discuss, first, the results for the conditions that reproduced the manipulations of earlier experiments and, then, the results for the crucial manipulation.

Test Word Old—Study Interval Long

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,57) = 2.03$, $MSE = 22{,}160$] or as a function of whether the prime word was old or new [$F(1,57) = 1.29$, $MSE = 23{,}556$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,57) = 2.53$, $MSE = 21{,}211$]. Hit rate did not vary as a function of whether or not the prime and test word were related [$F(1,57) < 1$] or as a function of whether the prime word was old or new [$F(1,57) < 1$]. The effects of Relatedness and Prime Word did not interact in the hit-rate data [$F(1,57) < 1$].

Test Word New

Response time was longer when the prime and test word were related than when they were unrelated [$F(1,57) = 7.15$, $MSE = 29{,}134$]. Response time did not vary as a function of whether the prime word was old or new [$F(1,57) < 1$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,57) < 1$]. False-alarm rate was higher when the prime and test word were related than when they were unrelated [$F(1,57) = 23.80$, $MSE = .042$]. False-alarm rate did not vary as a function of whether the prime word was old or new [$F(1,57) < 1$]. The effects of Relatedness and Prime Word did not interact in the false-alarm-rate data [$F(1,57) < 1$].

Test Word Old—Study Interval Short

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,57) = 2.97$, $MSE = 15{,}157$]. Note, however, that response time

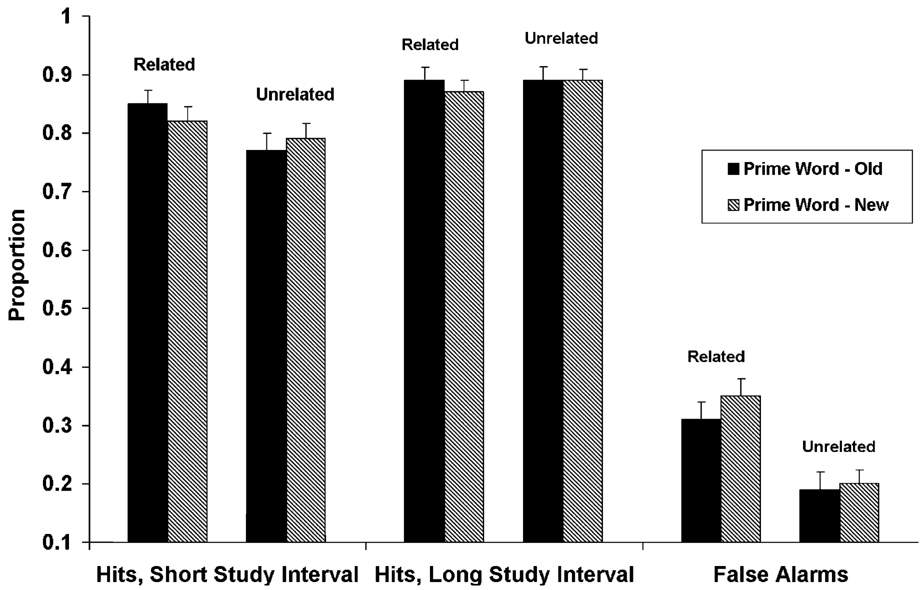

Fig. 6. Experiment 3: Accuracy of responses to the test word as a function of whether or not the prime and test word were related, whether the prime word was old or new, whether the test word was old or new, and, for the case in which the test word was old, the study interval.

trended shorter when the two words were related than when they were unrelated. Response time did not vary as a function of whether the prime word was old or new [$F(1,57) < 1$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,57) = 1.25$, $MSE = 24{,}524$]. Hit rate was higher when the prime and test word were related than when they were unrelated [$F(1,57) = 6.86$, $MSE = .027$]. Hit rate did not vary as a function of whether the prime word was old or new [$F(1,57) < 1$]. The effects of Relatedness and Prime Word did not interact in the hit-rate data [$F(1,57) = 1.66$, $MSE = .031$].

Overall

Separate analyses were done pairing the data for the Test Word Old-Short Study Interval and Test Word Old-Long Study Interval trials with the data for the Test Word New trials. *Test Word Old-Study Interval Long + Test Word New*: In this analysis, d' was lower when the prime and test word were related (2.79) than when they were unrelated (3.61) [$F(1,57) = 14.78$, $MSE = 2.67$] (see Table 3) and d' did not vary as a function of whether the prime word was old or new [$F(1,57) = 4.33$, $MSE = 2.96$]. The effects of Relatedness and Prime Word did not interact in the d' data [$F(1,57) < 1$].

Test Word Old-Study Interval Short + Test Word New. In this analysis, d' did not vary as a function of whether or not the prime and test word were related [$F(1,57) = 3.54$, $MSE = 2.72$] or as a function of whether the prime word was old or new [$F(1,57) = 2.16$, $MSE = 3.18$]. The effects of Relatedness and Prime Word did not interact in the d' data [$F(1,57) < 1$].

Discussion

Synonym priming impeded correct recognition judgments to the test word when the test word was new. The effect was present in the response-time and the accuracy data. Synonym priming did not affect recognition judgments to the test word when the test word was old and the study interval was long. The overall effect of synonym priming in these two conditions was to reduce the level of discrimination in recognition judgments to the test word. These results replicate the results of Experiments 1A, 1C, and 2. More important, when the test word was old and the study interval was short, the experiment confirmed the predictions of the Potentiated Familiarity Hypothesis; synonym priming facilitated correct recognition judgments to the test word. The effect was present in the accuracy data and the response-time data hinted in that direction. This is what would have been expected under the hypothesis if the familiarity assessment process had exerted substantial impact on this subset of the trials. Given that the short study interval was used for the express purpose of increasing the involvement of familiarity assessment on this subset of trials, these results support the hypothesis.

Experiment 4

Experiment 4 sought to achieve the same basic result as Experiment 3 by manipulating events in the test rather than the study phase of the recognition procedure. As in Experiment 3, the object was to arrange conditions under which familiarity assessment would be likely to have substantial impact on recognition judgments to old test words. The object was to show that, under these conditions, synonym priming facilitated correct recognition judgments to such test words. The experiment assumed that familiarity assessment would be likely to have substantial impact on recognition judgments to old test words if little time was available for the judgments. Again, similar assumptions have been made in previous work (Joordens & Hockley, 2000). The experiment sought to control the amount of time available for the recognition judgments with a response signal procedure.

The experiment used the same task as Experiment 1C. Each of the 80 trials involved the presentation of a study list consisting of 12 words and a test list consisting of a single test pair. On half of the trials, the prime and test word were synonyms; on the rest of the trials, the two words had no obvious semantic relationship to one another. On half of the trials, the prime word was old; on the rest of the trials, it was new. On half of the trials, the test word was old; on the rest of the trials, it was new. Responses to the test word were controlled with a response signal procedure. On half of the trials, the interval between presentation of the test word and the response signal was short; on the rest of the trials, the interval was long.

The trials in which the response interval was long and the test word was, respectively, old and new, essentially reproduced the manipulations of Experiments 1A, 1C, and 2. On the basis of the results of these experiments, it was expected that synonym priming would not affect recognition judgments to the test word in the former case and that synonym priming would impede correct recognition judgments to the test word in the latter case. The object was to show that synonym priming facilitated correct recognition judgments to the test word on the trials in which the response interval was short and the test word was old. It was assumed that the results for the trials in which the response interval was short and the test word was new would resemble the results for the trials in which the response interval was long and the test word was new.

Methods

Participants

Eighty-two participants were tested in the experiment.

Design

Relatedness (Related, Unrelated), Prime Word (Old, New), and Test Word (Old, New), and Response Interval (Short, Long) were manipulated within participants in a $2 \times 2 \times 2 \times 2$ design. Each session consisted of 80 trials. The trials were distributed equally across conditions, with five trials being assigned to each of the sixteen conditions. The design dictated that a single pair of related words was present in one eighth of the study lists and that the words in half of the test pairs were related.

Materials

The materials were created as indicated in General method. The generator set resembled the generator set for Experiment 1A except that it consisted of 80 common-noun triples. The filler pool consisted of 880 common nouns. A pair of related nouns in a study list were separated, on average, by four words.

Procedure

The procedure was as indicated in General method with the following refinements. (1) The study interval was 1600 ms and the inter-word interval was 400 ms. (2) During the test phase, a message appeared on the screen announcing the appearance of the test pair. After 2000 ms, this message disappeared and the prime word from the test pair appeared. (3) A row of asterisks appeared at the bottom of the screen either 300 (Short condition) or 1800 (Long condition) ms after the test word appeared. The participant was instructed to make her/his response to the test word coincident with the appearance of the asterisks. (4) If the participant made her/his response to the test word before the response signal appeared, or 250 after it appeared, a message appeared, immediately after the response to the test word, indicating that the response was either too fast or too slow. This message remained on the screen for 2000 ms. (5) The experiment was broken into two parts, with the interval between the appearance of the test word and the response signal being 300 ms in one part and 1800 ms in the other part. The order of the two parts was counterbalanced across participants.

Results

The final sample for the analysis consisted of 80 participants. The response time and accuracy results for this sample are summarized in Table 2 and Fig. 7, respectively.

Test Word Old/Response Interval Long

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,79) = 1.77$, $MSE = 14{,}553$]. Response time was longer when the prime word was old than when it was new [$F(1,79) = 6.44$, $MSE = 12{,}533$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,79) = 1.76$, $MSE = 15{,}509$]. Hit rate did not vary as a function of whether or not the prime and test word were related [$F(1,79) < 1$] or as a function of whether the prime word was old or new [$F(1,79) < 1$]. The effects of Relatedness and Prime Word did not interact in the hit-rate data [$F(1,79) < 1$].

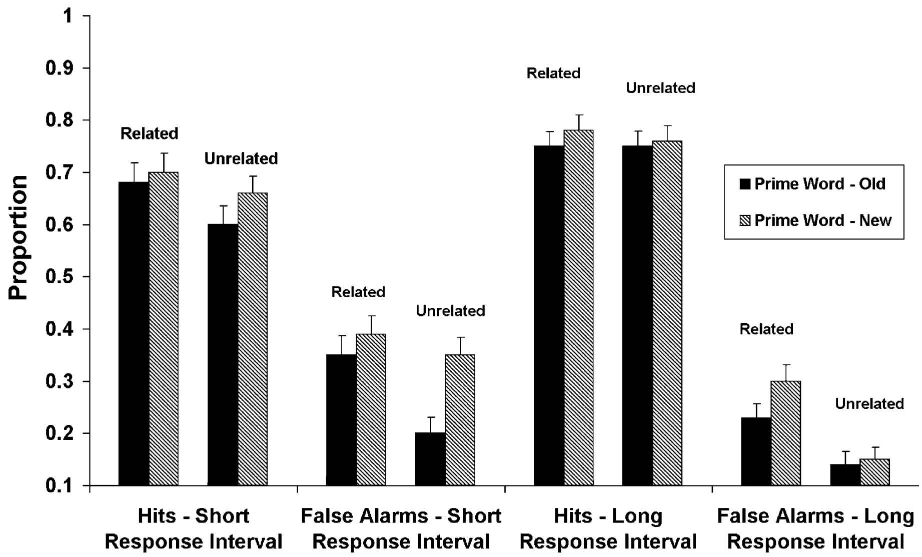

Fig. 7. Experiment 4: Accuracy of responses to the test word as a function of whether or not the prime and test word were related, whether the prime word was old or new, whether the test word was old or new, and the response interval.

Test Word New/Response Interval Long

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,79) < 1$] or as a function of whether the prime word was old or new [$F(1,79) = 1.05$, $MSE = 28{,}024$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,79) < 1$]. False-alarm rate was higher when the prime and test word were related than when they were unrelated [$F(1,79) = 28.58$, $MSE = .041$]. False-alarm rate did not vary as a function of whether the prime word was old or new [$F(1,79) = 2.46$, $MSE = .048$]. The effects of Relatedness and Prime Word did not interact in the false-alarm rate data [$F(1,79) = 1.24$, $MSE = .044$].

Test Word Old/Response Interval Short

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,79) = 1.60$, $MSE = 12{,}584$] or whether the prime word was old or new [$F(1,79) < 1$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,79) < 1$]. Hit rate was higher when the prime and test word were related than when they were unrelated [$F(1,79) = 5.35$, $MSE = .055$]. Hit rate did not vary as a function of whether the prime word was old or new [$F(1,79) < 1$]. The effects of Relatedness and Prime Word did not interact in the hit-rate data [$F(1,79) < 1$].

Test Word New/Response Interval Short

Response time did not vary as a function of whether or not the prime and test word were related [$F(1,79) = 3.18$, $MSE = 18{,}820$]. Note, however, that response time trended longer when the two words were related. Response time was longer when the prime word was new than when it was old [$F(1,79) = 4.79$, $MSE = 25{,}196$]. The effects of Relatedness and Prime Word did not interact in the response-time data [$F(1,79) < 1$]. False-alarm rate was higher when the prime and test word were related than when they were unrelated [$F(1,79) = 13.10$, $MSE = .056$]. False-alarm rate was higher when the prime word was new than when it was old [$F(1,79) = 5.62$, $MSE = .119$]. The effects of Relatedness and Prime Word interacted in the false-alarm-rate data [$F(1,79) = 7.32$, $MSE = .036$]. The effect of Relatedness was greater when the prime word was old than when the prime word was new.

Overall

Separate analyses were done pairing the data for the Test Word Old and Test Word New trials at the two levels of Response Interval. *Test Word Old + Test Word New/Response Interval Long*: In this analysis, d' was lower when the prime and test word were related than when they were unrelated [$F(1,79) = 13.14$, $MSE = 3.56$] and d' did not vary as a function of whether the prime word was old or new [$F(1,79) < 1$]. The effects of Relatedness and Prime Word did not interact in the d' data [$F(1,79) < 1$] (see Table 3).

Test Word Old + Test Word New/Response Interval Short: In this analysis, d' did not vary as a function of whether or not the prime and test word were related [$F(1,79) < 1$] or as a function of whether the prime word was old or new [$F(1,79) = 2.92$, $MSE = 4.48$]. The effects of Relatedness and Prime Word did not interact in the d' data [$F(1,79) < 1$].

Discussion

Synonym priming did not affect recognition judgments to the test word on the trials in which the test word was old and the response interval was long.

Synonym priming impeded correct recognition judgments to the test word on the trials in which the test word was new and the response interval was long. The effect was present in the accuracy data. The overall effect of synonym priming was to reduce the level of discrimination for recognition judgments to the test word. These results replicate the results of Experiments 1A, 1C, and 2. More important, on the trials in which the test word was old and the response interval was short, the experiment confirmed the predictions of the Potentiated Familiarity Hypothesis; synonym priming facilitated correct recognition judgments to the test word. The effect was present in the accuracy data. This is what would have been expected under the hypothesis if the familiarity assessment process had exerted substantial impact on this subset of the trials. Given that the short response interval was used for the express purpose of increasing the involvement of the familiarity assessment process on this subset of trials, these results support the hypothesis. As expected, the results for trials on which the test word was new and the response interval was short resembled the results for the trials on which the test word was new and the response interval was long.

Other, less important results were observed. First, when the response interval was short, correct recognition judgments to new test words were slower and less accurate when the prime word was new than when the prime word was old. Second, when the response interval was long, correct recognition judgments to old test words were slower when the prime word was old than when the prime word was new. These two results are probably related to results observed in Experiments 1A and 1C. In these experiments, correct recognition judgments to old test words were slower when the prime word was old than when the prime word was new. The general pattern in all of these results is that a recognition judgment to a test word of a certain study status (old or new) is impeded if it follows a recognition judgment to a prime word of the same study status. Dopkins, Sargent, and Ngo (submitted for publication) have observed a similar pattern in a slightly different task. Because the pattern appears only intermittently in the present study, it will not be discussed further here.

In a further result, when the response interval was short and the test word was new, the effects of Relatedness and Prime Word interacted: the difference between the related and unrelated conditions was greater when the prime word was old than when it was new. A similar interaction was observed in Experiment 1C. What was the basis of this interaction? It is worth noting at this point a complicating feature of the general experimental design for the present study. Consider the subset of trials in which the test word was new. In the Prime Word New condition, the Related condition differed from the Unrelated condition in a single respect: the test word was related to the prime word in the former but not the latter condition. In the Prime Word Old condition, the Related condition differed from the Unrelated condition in the same respect and also in another respect: the test word was related to a word in the list (that is, the prime word) in the former but not the latter condition. Thus, performance in the Prime Word New condition provided a pure reflection of the effect of a *test word–prime word* relationship. From the fact that performance was worse in the Related than in the Unrelated condition, we can infer that recognition judgments to new test words were impeded when such a relationship was present. Performance in the Prime Word Old condition, however, reflected the effect of a *test word–list word* relationship as well as the effect of a *test word–prime word* relationship. Past work suggests that correct recognition judgments to new test words may be impeded when a relationship of the former sort is present (Greene & Klein, 2004; Greene & Tussing, 2001; Neely & Balota, 1981). Thus, the interaction that was observed here and in Experiment 1C may reflect the fact that correct judgments to new test words were impeded by a *test word–prime word* relationship in the Prime Word New condition and by a *test word–list word* relationship as well as a *test word–prime word* relationship in the Prime Word Old condition The fact that this interaction was observed only intermittently in the present study suggests that the effect of a *test word–list word* relationship was generally small.

Experiment 5

Experiment 5 sought to achieve the same objective as Experiments 3 and 4 by slightly different means. Rather than adjusting the parameters of the recognition task, as those previous experiments had done, this experiment altered the basic structure of the task. On each of the 600 trials in the experiment, a single target word was presented and the participant indicated whether or not that word had appeared on one of the previous ten trials. Seventy-two of the trials played the role of experimental trials in the framework of the previous experiments. The following was the case with respect to each of these trials: The target word for the immediately preceding trial and the target word for the current trial played the role of the prime word and the test word, respectively, in the framework of the previous experiments. The two words were either synonyms or were linked by no semantic relationship. On positive trials, the word that played the role of the test word had appeared as the target word 3, 5, or 8 trials previously. On negative trials, the word that played the role of the test word had appeared as the target word 30 or 90 trials previously or had not appeared previously in the experiment.

The rationale for the experiment was as follows: The fact that the target word for a given trial has appeared at some point in the course of the experiment will not be sufficient to justify a positive response to it. Such a response will have to be justified in terms of a shifting subset of the words that appear over the course of the experiment. Recollection will not be useful in justifying a positive response because the different versions of this shifting subset will not be distinguished by any obvious contextual features. Rather, a positive response will have to be justified on the basis of familiarity assessment. If the task is performed in this way, familiarity assessment will have substantial impact on positive trials. The object of the experiment was to show that synonym priming facilitated correct recognition judgments on those trials.

Methods

Participants

Sixty participants were tested in the experiment.

Design

Relatedness (Related, Unrelated), Test Word (Positive, Negative), and Test Word Recency (Low, Medium, High) were manipulated within participants, in a $2 \times 2 \times 3$ design. Within the Test Word Positive condition, the target word had appeared 3, 5, and 8 trials previously in the High, Medium, and Low Recency conditions, respectively. Within the Test Word Negative condition, the target word had appeared 30 and 90 trials previously in the High and Medium Recency conditions and had not appeared previously in the Low Recency condition. Six of the 72 experimental trials were devoted to each of the 12 conditions.

Materials

The stimulus materials were generated from the same set of common-noun triples as was used in Experiment 1A. The materials for a given participant were created as follows: (1) A subset of 72 trials was selected from the set of 600 trials in the experiment. The trials in the subset were selected according to a random scheme that was unique to the participant in question, with the constraints that (a) the subset included the last trial in the experiment, and (b) successive trials in the subset were separated by from 5 to 12 trials. (2) The 72 common-noun triples were assigned to the 72 trials in the subset according to a random scheme that was unique to the participant in question. (3) The triples were assigned to experimental conditions according to a random scheme that was unique to the participant in question. (4) The first word in each triple was used as the target word for the trial to which the triple was assigned. This word played the role of the test word in the framework of the previous experiments. Depending on whether the triple was assigned to the Positive or Negative level of the Test Word variable, and whether the triple was assigned to the High, Medium, or Low level of the Test Word Recency variable, the same word appeared as the target word 3, 5, 8, 30, or 90 trials previously or did not appear elsewhere in the experiment. If the triple was assigned to the Related level of the Relationship variable, the second word of the triple was used as the target word on the trial immediately preceding the trial to which the triple was assigned. If the triple was assigned to the Unrelated level of the Relationship variable, the third word of the triple was used as the target word on the trial immediately preceding the trial to which the triple was assigned. Thus, the second or third word of the triple played the role of the prime word in the framework of the previous experiments. The word that was used as the target word on the trial preceding the one to which the triple was assigned was also used as the target word on a previous trial, where the number of trials intervening between the two appearances of the word was drawn from a uniform distribution whose minimum and maximum values were, respectively, 6 and 45. As a consequence of this design, a pair of related words were separated in the test series, on average, by 26.1 words. The target words for the rest of the trials were drawn from the same filler pool as was used in Experiment 1A. The target word for each of these filler trials had either appeared roughly 3, 5, 8, 30, or 90 trials previously, or had not appeared previously in the experiment, with each of these six situations being equally probable.

Procedure

At the beginning of each trial, a target word was presented. After 1000 ms, the computer accepted the response for that trial. Participants were instructed to press the "B" key if the target word had appeared in one of the previous 10 trials and to press the "N" key if the target word had appeared less recently than in one of the previous 10 trials, or had not appeared at all. If the response to the target word was incorrect, a message appeared to that effect after the target word disappeared from the screen. This message remained on the screen until the participant pressed the space bar of the computer.

Results

Response-time data were not collected, so the accuracy data were crucial. Data points were missing for none of the participants. Thus, the final sample consisted of 60 participants. The results for this sample are summarized in Fig. 8.

Test Word Positive

Hit rate was higher when the target words that played the role of the prime and test word were related than when they were unrelated [$F(1, 59) = 4.54$, $MSE = .038$]. Hit rate increased with recency of the target word that played the role of the test word

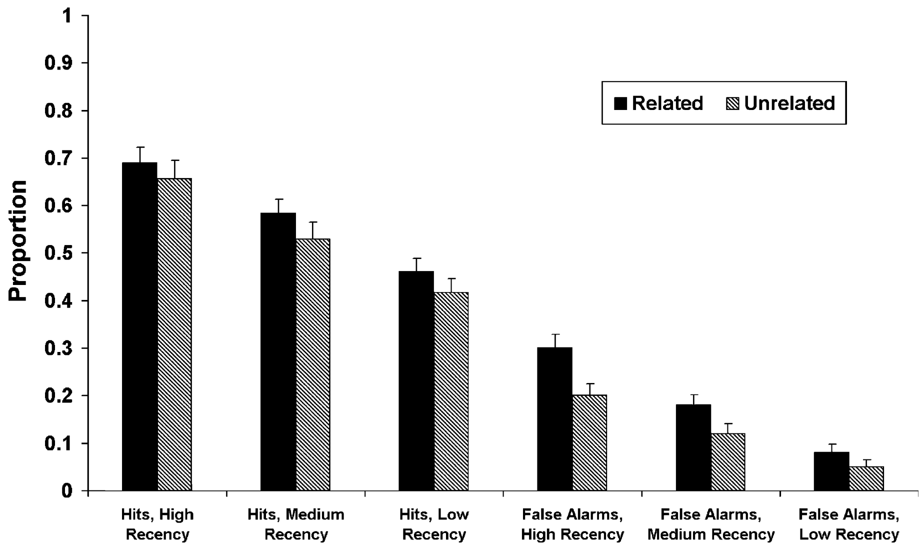

Fig. 8. Experiment 5: Accuracy of responses to the target word that played the role of the test word as a function of whether or not the target words that played the role of the prime and test word were related, the recency of the target word that played the role of the test word, and whether or not target word that played the role of the test word had appeared within the previous 10 trials.

[$F(1,59) = 67.71$, $MSE = .051$]. The effects of Relatedness and Recency did not interact in the hit-rate data [$F(2,118) < 1$].

Test Word Negative

False-alarm rate was higher when the target words that played the role of the prime and test word were related than when they were unrelated [$F(1,59) = 13.62$, $MSE = .025$]. False-alarm rate decreased with recency of the target word that played the role of the test word [$F(1,59) = 89.05$, $MSE = .024$]. The effects of Relatedness and Recency did not interact in the false-alarm-rate data [$F(2,118) = 1.48$, $MSE = .021$].

Overall

Because no obvious framework was available for matching Positive and Negative test words as a function of recency, performance was collapsed across levels of recency. The resulting analysis showed that d' was lower for the Related then the Unrelated condition [$F(1,59) = 6.34$, $MSE = .52$] (see Table 3).

Discussion

As predicted, synonym priming facilitated correct recognition judgments on positive trials. These results support the Potentiated Familiarity Hypothesis.

General discussion

The present series of experiments explored the effect of semantic priming in episodic recognition. When sufficient processing time was allowed during the study and the test phase of the recognition task, semantic priming impeded correct recognition judgments to new test words but had no effect on recognition judgments to old test words. The overall effect of priming was to reduce the level of discrimination in the recognition judgment to the test word. Across six experiments, the priming effect was reliably present in the accuracy data and sometimes present as well in the response-time data. As has been noted, this priming effect differs from the effects that have been observed in previous studies of recognition memory.

The Potentiated Familiarity Hypothesis was proposed as an account of the present priming effect. The hypothesis starts from the assumption that episodic recognition involves processes of familiarity assessment and recollection. The hypothesis holds that processing a related prime word in the present recognition task increased the likelihood that the test word would be classified as familiar. This likelihood increase impeded correct recognition judgments to new test words and would have facilitated correct judgments to old test words except that familiarity assessment had only minimal impact on these judgments, being overshadowed by recollection.

To gather support for the Potentiated Familiarity Hypothesis, the study sought to arrange conditions in which familiarity assessment would be expected to have substantial impact on judgments to old test words. The hypothesis predicted that, under these conditions, semantic priming should facilitate correct judgments to such test words. Over the course of the study, three different methods were used to increase the impact of familiarity assessment on judgments to old test words. Experiment 3 manipulated the amount of time for which the test words were presented during the study phase. Experiment 4 manipulated the amount of time that was available for the recognition judgment during the test phase. Experiment 5 changed the recognition task so that recollection was of little use in performing it. In all three cases, the predictions of the Potentiated Familiarity Hypothesis were confirmed.

In sum, the Potentiated Familiarity Hypothesis can explain the effects of semantic priming in the present recognition task and the dual process framework is crucial to the explanation. In contrast, it is not clear how these effects could be accommodated within the global matching framework. As has been noted, that framework faces the challenge of accounting for the semantic priming effect that was observed here under standard recognition conditions. The framework faces the further challenge of accounting for the semantic priming effect that was observed here when special steps were taken to increase the impact of familiarity assessment on judgments to old test words.

Granting the viability of the proposed account of the present results, can we reconcile the results of the present and previous explorations of semantic priming in episodic recognition? Consider, first, the results of Johns (1985) and Lewandowsky (1986), who found that semantic priming facilitated correct recognition judgments to old and new test words. The most important difference between Johns and Lewandowsky, on one hand, and the present study, on the other hand, probably lies in the stimulus materials. Each of the lists of Johns and Lewandowsky contained multiple words from each of several semantic categories. In contrast, a word in a list for the present study was related to at most one other list word. Thus, more studied words were related to each test word in the experiments of Johns and Lewandowsky than in the present experiments. This difference in stimulus materials may have affected recognition judgments through several mechanisms. Previous work has shown that recognition performance varies in complex ways as a function of the number of studied words that are related to each test word (Neely & Tse, 2007). In addition, the difference in stimulus materials may have encouraged a strategy in which (1) the prime word cued retrieval of the subset of words from the category to which the prime word belonged, with the prime word then being compared to the members of that subset, and with the outcome of the recognition judgment depending on whether or not the comparison produced a match, and (2) a similar strategy was subsequently used in the recognition judgment to the test word. If such a strategy was used, then, when the prime and test word came from the same category, the judgment to the test word would have been facilitated, regardless of whether the test word was old or new, because the appropriate subset would have already been present in working memory when the test word was presented.

Consider, next, the results of Dosher et al. (1989), who found that semantic priming facilitated and impeded correct recognition judgments to old and new test words, respectively. We may be able to account for these results, and their divergence from the present results, on the basis of the fact that, in contrast to the present study, Dosher et al., did not require a recognition judgment to the prime word. Consider the following as an account of the results of Dosher et al.: Two things happened when the prime word was presented. (1) An attempt was made to retrieve a related word from the list (this attempt was possible because no recognition judgment was required to the prime word); (2) an increase occurred in the likelihood of positive familiarity assessment for words related to the prime word. Thus, when the prime and test word were related, processing the prime word had different effects on the recognition response to the test word, depending on whether the test word was old or new. In the former case, a correct response was facilitated because the prime word cued retrieval of the test word from the list. In the latter case, a correct response was impeded because processing the prime word increased the likelihood of positive familiarity assessment for words related to the prime word. The end result, then, was that semantic priming facilitated and impeded correct recognition judgments to old and new test words, respectively. It is consistent with this account that Dosher (1991), using the same procedures as Dosher et al. (1989), but with categorized lists, found that semantic priming facilitated correct recognition judgments to old and new test words. With categorized lists, the prime word could have been used to retrieve the entire set of words from the corresponding category, and a strategy such as was proposed for Johns (1985) and Lewandowsky (1986) could have been used.

Finally, we should note that the present priming effect has some relationship to a previously reported phenomenon. Jacoby and Whitehouse (1989) presented a prime stimulus and a test word in sequence, requiring a recognition judgment to the test word but not the prime stimulus. When the prime stimulus was presented briefly enough that participants were unaware of it, the false alarm rate was greater and the hit rate was sometimes smaller when the prime stimulus and test word matched than when they did not. When the prime stimulus was presented for a longer interval, so that participants were aware of it, the false alarm rate was sometimes smaller and the hit rate was consistently smaller when the prime stimulus and test word matched than when the prime stimulus was a non-matching word. The Jacoby and Whitehouse phenomenon resembles the present priming effect but differs from it (a) in the results that are observed for hit rates, (b) in the differing results that are observed as a function of awareness of the prime stimulus, and (c) in that the matching prime stimulus is identical to rather then similar to the test word.

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